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NASA Advanced Air Mobility (AAM) Project
National Campaign
Development of Airspace Operations, Infrastructure and Data

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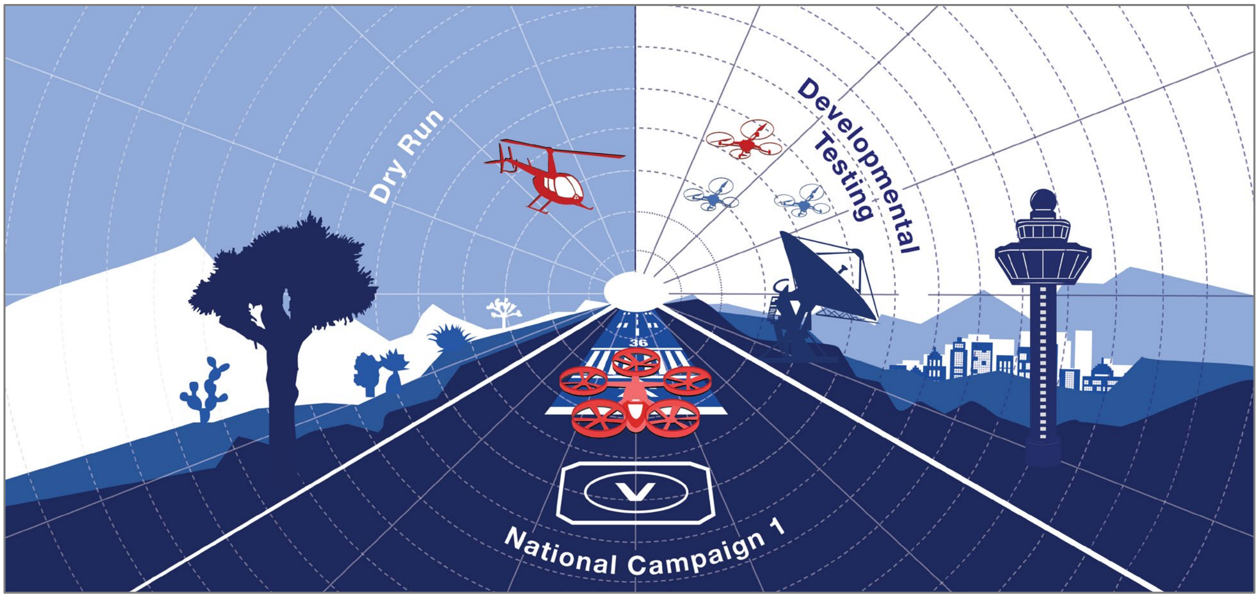

Executive Summary

The National Aeronautics and Space Administration Advanced Air Mobility National Campaign embarked upon a series of flight tests to design and develop a system of systems capability to deploy flight test infrastructure in various locations around the country with industry partners. Dry Run and Development Testing flight events enabled the campaign to iteratively develop and refine necessary infrastructure for data collection, storage, and result generation; evaluate foundational processes and identify baseline results for vehicle maneuvers and evaluations; identify key enabling range infrastructure and assets; optimize airspace routes and develop candidate procedures, sequence research priorities; and organize various reporting and engagement mechanisms to further research for the advanced air mobility of the future.

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1 INTRODUCTION

1.1 Project Background

The National Aeronautics and Space Administration (NASA) Aeronautics Research Mission Directorate (ARMD) Advanced Air Mobility (AAM) National Campaign (NC) is a 10-year series of flight activities intended to help mature the readiness level of industry with regard to vehicle performance, safety assurance, airspace interoperability and noise. The National Campaign progresses through scenarios that increase in complexity to exercise advanced technologies and verify readiness for operational use by standardized testing in partnership with the Federal Aviation Administration (FAA). NASA believes this AAM ecosystem-wide strategy can serve as a tool for the entire community to increase the collective maturity across government, industry, and academia together.

The National Campaign challenges government, industry and other community participants to address foundational problems related to AAM readiness and robustness for AAM operations; as well as address key safety and integration barriers across the AAM ecosystem while emphasizing critical operational challenges such as commercial viability and public confidence in AAM operations around populated areas. The NC infrastructure is being developed with the intent to assist NASA partners to demonstrate the design readiness, robustness, and interoperability of their vehicles, airspace concepts and technologies in an integrated airspace environment. The demonstrations from the NC will also help inform the means and methods of compliance development with the FAA, standards development, airspace management system requirements, and desired future airspace services. The NASA NC Operational View-1 is shown in Figure 1.1.

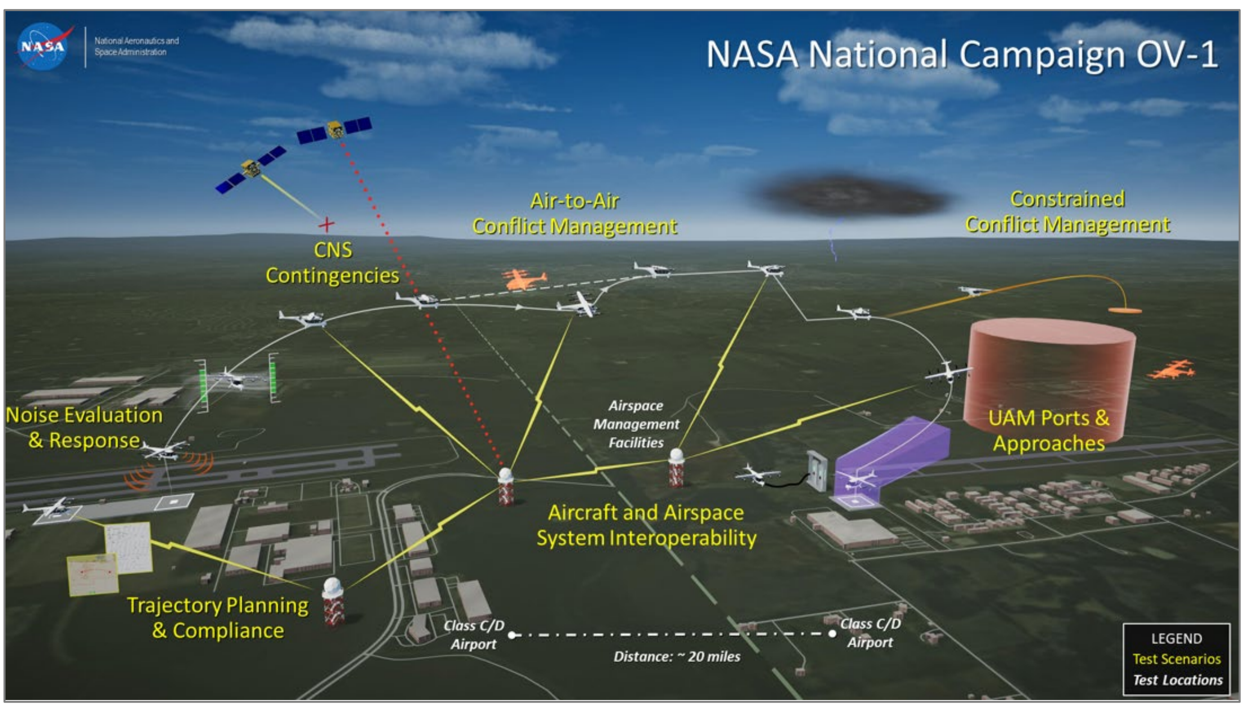


Figure 1.1. National Campaign Operational View-1.

1.2 Project Goal and Objectives

National Campaign activities focus on operational safety with an integrated set of scenarios to assess the following objectives found in Table 1.2:

Table 1.2. National Campaign Goals and Objectives.

National Campaign Goal
Ensure AAM safety and accelerate scalability through integrated demonstration of candidate operational concepts and scenarios.
National Campaign Objectives
1. **Accelerate Certification and Approval** Identify and address gaps in aircraft certification flight test requirements, landing surface requirements, and aircraft operating flight requirements for highly automated aircraft. 2. **Develop Flight Procedure Guidelines** Develop preliminary guideline for flight procedures and related airspace design criteria. 3. **Evaluate Communication, Navigation, and Surveillance Trade-Space** Assess vertiport services and capabilities, strategic/tactical collision avoidance, data links for communication, command and control, vehicle-to-vehicle and vehicle-to-infrastructure (V2V/V2I) ground-based surveillance capabilities, navigation performance, weather, ground operations, and AAM service such as conformance monitoring. 4. **Demonstrate an Airspace Management Architecture** Demonstrate an increasingly capable and integrated airspace system architecture. 5. **Characterize Community Concerns** Identify noise levels, promote public acceptance, identify infrastructure challenges, and collaborate with local communities to support informed policies.

A flight test series was executed at the NASA Armstrong Flight Research Center (AFRC) (Edwards, California) in conjunction with Edwards Air Force Base between 2020 and 2021 as the National Campaign Dry Run to advance campaign research for Advanced Air Mobility. The National Campaign developed a Flight Test Infrastructure (FTI) as the foundation for an advanced air mobility ecosystem to enable execution of NC objectives. The mobile FTI was then applied in an Acoustics Flight Test during Developmental Testing at an outside range (Objective 5). The NC team tested and developed routes and Urban Air Mobility (UAM) scenarios commensurate with expected operations and contingencies. The NC team tested vehicle performance and evaluated UAM vehicle certification test techniques (Objective 1) and developed and applied novel initial terminal procedures requiring further research (Objective 2).

1.3 Project Series Overview

The National Campaign team progressed through a sequenced series of incremental preparation to develop a flight test infrastructure, techniques, and processes for project flight events. The intent of the early series was to build capabilities prior to 2022 National Campaign-1 flight test events and research with industry partners. The series was divided into the following phases, also shown in Table 1.3.

Dry Run: Enable and ensure an effective, safe, mobile flight test infrastructure. Ensure connectivity and data capture in coordination with the AFRC Mission Control Center (MCC). Develop routes and area infrastructure such as heliports and a representative vertiport and test a vehicle within the airspace construct. Run flight test events with a surrogate vehicle for performance capabilities, handling qualities, UAM Task Elements and to develop certification testing techniques.

Developmental Testing: Develop acoustic array and run acoustic tests for an AAM prototype vehicle with the AAM subproject Revolutionary Vertical Lift Technology (RVLT). Characterize AAM prototype flight.

National Campaign-1: Develop flight test plans and flight events with AAM industry partners with progressively complex research for technology integration and operational impacts.

Table 1.3. National Campaign Test Series Overview.

National Campaign Test Series			
Test Series	**Test Type**	**Flight Event**	**Dates**
Dry Run	Connectivity	ATI Connectivity Test	09.30.20-10.01.20
	Verification	Mobile Operating Facility V&V Test	08.22.21
	Familiarization Flights	Build 1 Flight Test	12.02.20-12.03.20
		Build 2 Flight Test	03.01.21-03.12.21
		Build 2 Follow-on Flight Tests	11.08.21-11.10.21 12.06.21-12.10.21
Developmental Testing	Acoustics Flight	RVLT Acoustics Flight Test with Joby Aviation, Inc. (Santa Cruz, California)	08.30.21-09.03.21 09.08.21-09.09.21

The following events are discussed in this section: *Dry Run Connectivity Test for Airspace Testing & Integration, Dry Run Build 1 Flight Test, Dry Run Build 2 Flight Test, Dry Run Mobile Operations Facility (MOF) Verification & Validation (V&V) Testing, Developmental Testing* and *Dry Run Build 2 Follow-On Flight Test.*

Figure 1.4. National Campaign Dry Run OH-58C helicopter at AFRC.

<u>Dry Run Connectivity Test for Airspace Testing & Integration</u>

09.03.20 - 10.01.20

The National Aeronautics and Space Administration conducted a preliminary Dry Run Connectivity test event in the early autumn of 2020, with sorties on September 30 and October 1. As a precursor to all future flight events, Airspace Testing and Integration (ATI) teams ran connectivity tests to ensure data and information could flow as planned and expected. The primary motivation of the Connectivity Test was to verify NC data collection, distribution, and storage systems. A NASA TG-14 aircraft (AMT-200 Super Ximango) (Aeromot, Rio Grande do Sul, Brazil) performed sorties along predefined routes to assess network connectivity.

<u>Dry Run Connectivity Test for Airspace Testing & Integration Key Objectives</u>

- ATI/ADS-B (Automatic Dependent Surveillance-Broadcast) Connectivity Check for verification of ADS-B broadcast acquisition, dissemination, and storage.
- Dry Run Route Pilot Familiarization: An important objective that did not relate directly to the data collection, this objective was associated with the need to allow the pilot to gain familiarity with NC scenarios at AFRC.
- Ensure video of entire flight is possible. Given test instrumentation requirements for NC flights, a key objective of the test was to assess video surveillance capabilities, with primary focus on the ability to obtain video surveillance of the north base runway.
- Post-flight data handling. Acquiring post-flight digital assets will be a key part of all upcoming NC flight tests. As such, the collective teams on the NC project used the connectivity test to vet the post-flight data transfer mechanism.

<u>Dry Run Build 1 Flight Test</u>

12.02.20 - 12.03.20

To familiarize teams and crew with NC AAM surrogate OH-58C helicopter flight as well as validate infrastructure and processes, NASA conducted a flight event that exercised planning into realized flights and data for two days: December 2 and 3, 2020. The Build 1 Familiarization test commenced with 1 sortie on each day with the AAM surrogate Bell OH-58C helicopter (Bell Textron Inc., Fort Worth, Texas). Additional Range infrastructure, including the heliport and the vertiport were added to the Airspace Operations routes flown during an ATI Connectivity test activity. The ATI System included updates to correct deficiencies discovered previously. Familiarization Flights provided an opportunity for organizational cooperation between the NC stakeholders: AFRC, the NASA Ames Research Center (ARC) (Moffett Field, California), the FAA, and the UAM surrogate helicopter contractor Flight Research Inc (FRI) (Mojave, California). The activity enabled the team members to conduct aircrew and maintenance operations: helicopter operations for AFRC, and AFRC Flight Operations for FRI and the FAA. Additionally, instrumentation systems shakedown, data management, and data reduction processes between FRI, AFRC, and ARC, were evaluated.

<u>Dry Run Build 1 Flight Test Key Objectives</u>

- Aircrew and Operations familiarization. The Non-NASA aircrew from FRI and the FAA received a Range/Local area orientation. The FAA Pilot and the Flight Test Engineer (FTE) were able to become familiar with the FRI test aircraft: the Bell OH-58C helicopter.
- NASA Team experience with normal helicopter operations.
- Basic familiarization for team roles, responsibilities, and communication, including control room operations, ground support team operations, and familiarization with operations under coronavirus disease (COVID) restrictions.
- Additional ATI System checkout for risk reduction.

- Connectivity and functionality of data collection, and post-flight data processing and archiving in preparation for Build 2 preparation, including the Flight Inspection Airborne Processor Application (FIAPA) system and FRI instrumentation.

Dry Run Build 1 Flight Test Overview

Aircrew and Operations Familiarization
Team Roles, Responsibilities and Communication
COVID Restrictions
ATI System Checkout for Risk Reduction
Data Connectivity, Management, and Data Reduction Processes
Flight Characterization Techniques
Route Design Test

Dry Run Build 2 Flight Test

03.01.21 - 03.12.21

The National Aeronautics and Space Administration conducted the Advanced Air Mobility National Campaign Build 2 Flight Test event in March of 2021. Enhanced development of systems, processes, and testing techniques were implemented as a larger system of systems to include routes, heliports and vertiports, weather, video, Pulse Light Approach Slope Indicator (PLASI) lighting, and an on-vehicle high-fidelity space positioning instrumentation pallet (a global positioning system, GPS, Pallet) was called into action for flight tests. Flight Test Infrastructure was further refined to verify that the data pipeline, data collection, distribution, and storage mechanisms worked as specified, as well as to test the UAM / electric Vertical Take-Off and Landing (eVTOL) airspace system in a real-world environment.

Dry Run Build 2 Flight Test Overview

AAM Flight Characteristic Test Maneuvers
UAM Task Elements
UAM Handling Qualities
Airborne Data for Air Traffic Management Research
AAM Test Range Construct
Route Design Optimization
Infrastructure / Terminal Approaches and Departures
FAA Flight Inspection Approach Procedures
Aeronautical Radio, Incorporated (Annapolis, Maryland) (ARINC) 424 Coding Applications
Passenger Comfort for Turn Procedures

Dry Run Build 2 Flight Test Primary Objectives

Demonstrate maneuvers from key AAM Flight Characteristic tests
Develop data products from key AAM Flight Characteristic tests
Prove initial concepts for AAM operational approaches and departures
Demonstrate "Task Elements" expected to form building blocks of AAM mission profiles
Identify and refine Handling Qualities Task Elements used to determine vehicle suitability for AAM mission

Dry Run Build 2 Flight Test Additional Objectives

Provide airborne data to support Air Traffic Management research
Validate the layout of a representative AAM Test Range construct
Capture Infrastructure / Terminal base line data
Evaluate FAA Flight Inspection Approach Procedures appropriate for AAM Operations

Validate and refine airspace assumptions for UAM (AAM/UAM Maturity Level [UML] 1-2)
Reduce risk for deployment of NASA furnished equipment that will support subsequent AAM flight test activities at external ranges
Exercise NASA Airworthiness process for subsequent AAM participant vehicles
Collect Time/Space/Position and video data to support communication of AAM goals, conclusions, and concepts

Dry Run Build 2 Flight Test Activities

Performance, Trim, Stability and Control flight test maneuvers vehicle characteristics
Ground and flight tasks for AAM Mission
Heliports and Vertiports AAM Task Elements
Flight demonstrations with contingency management procedures
Airspace System Functional Checks
Fly-Ability evaluations for research AAM Approaches
Departures and Enroute Procedures
Approach, Departure, and Route Flight Checks
Preflight planning
Ground operations
Flight operations Air Traffic Management
Contingencies
Integrated Scenario Testing

Dry Run Build 2 Flight Test Activities Vehicle Characteristics

Vehicle Characteristics evaluations utilized existing or modified aircraft certification flight test techniques to validate select AAM participant Stability & Control (S&C), Trim, and Performance characteristics. The purpose was to demonstrate a limited set of foundational vehicle characteristics, utilizing traditional civil rotorcraft flight test techniques, intended to show compliance to FAA Subpart B airworthiness certification requirements. The intent was to capture data and create data products to be used for comparison purposes to future AAM vehicles, as well as to proposed alternative civil means of compliance that may be better suited for AAM vehicles. Vehicle Flight Characteristics testing was intended to support the collection of foundational data with an eye toward understanding the necessary foundational flight characteristics (Flight Control System/trim, stability, control, and performance) that will enable an AAM vehicle to support condensed instrument meteorological conditions (IMC) approaches in the urban environment. Low-speed controllability in the wind environments expected in urban settings was a particular area of emphasis.

Dry Run Build 2 Flight Test with FAA Flight Inspection Airborne Processor Application

The FAA used a procedure validation tool called the FIAPA, which is contained in a carry-on system consisting of a tablet, survey-quality global navigation satellite systems (GNSS) receiver, and GPS patch antenna. The FIAPA validated spatial data contained in the procedures and allowed flyability evaluation independent of helicopter avionics. By ingesting FAA AirNav and ARINC 424 data, the FIAPA performed data quality checks and provided lateral and vertical deviations (North, East, and “Up errors”) in a pilot flight display (PFD) format. Additionally, the FIAPA logged flight data for replay or analysis. Flight inspection data included: National Marine Electronics Association (NMEA)-0183 standard messages, Range, Vertical Angle, “Height MSL” (mean sea level), Horizontal root mean square (RMS) Error, Vertical RMS Error, Latitude and Longitude and GPS Status. The FIAPA is compatible with different GNSS receivers. For Build 2 Trimble software (Trimble Inc., Sunnyvale, California) was used to adapt portable sensors and process data collected post-flight. The FIAPA ingested real-time flight data from inside the aircraft, which was processed and analyzed post-flight.

The FIAPA testing relied on accurate positioning of the helicopter at the surveyed landing zone (LZ) locations included as part of the FTI Range Infrastructure, but otherwise collected data concurrently with other dedicated testing.

Dry Run MOF V&V Testing

08.11.21

The MOF was verified using a TG-14 aircraft flying prescribed routes:

Dry Run MOF V&V Testing Overview

Flight Test Infrastructure Subsystem Verification and End-to-End System Tests
Software Automation
Integration Testing via ATI V&V Test Process

Developmental Testing

08.30.21 - 09.03.21 and 09.08.21 - 09.09.21

Joby Aviation, Inc. (Santa Cruz, California) Acoustics Test

A flight test demonstration commenced to characterize an AAM prototype vehicle and record acoustic array test data with the AAM subproject RVLT at an external range.

Dry Run Build 2 Follow-On Flight Test

11.08.21 - 11.10.21 and 12.06.21 - 12.10.21

The National Aeronautics and Space Administration conducted the AAM NC Follow-on Flight Test (FOFT) event over three days in November and four days in December of 2021. A key objective was to exercise and mature AAM NC technology and processes while identifying operational lessons related to the ecosystem NASA will provide to partners in future flight tests during the NC-1 series. Additionally, data services initiated automated reporting and analysis of post-flight test data artifacts. The OH-58C helicopter performed ten missions along predefined routes to capture key flight test data regarding vehicle performance characteristics and UAM Task Elements (UTEs). Additional data points for specific maneuvers were gathered and wind limit tests were extended:

Dry Run Build 2 Follow-On Flight Test Overview

Dynamic Interface Urban Wind Implications
Novel AAM Approach Procedures
Additional ADS-B Instrumentation
Event Marking Processes
Simulated Pinnacle Landings
Hover Power Margins
Refined Approach Characteristics
Passenger Comfort for Approach Procedures

National Campaign-1

2022 - 2024

Joby Aviation, Inc.; Wisk; Reliable Robotics; North Texas Cohort; and AURA

X-4, Integrated Automation Systems and Automated Flight Contingency Management

The National Campaign team is developing National Campaign-1 flight test plans for flight test events with various industry partners and various combinations of collaboration across industry partners across varied fields of AAM specialization. Flight demonstrations with vehicle, airspace, and infrastructure partners will illustrate capabilities across a subset of NC scenarios for initial manned and unmanned operational use cases to explore AAM challenges and path to operations as seen in Figure 1.5. The NC-1 includes developing new interfaces to Air Navigation Service Provider (ANSP) in a UML1 to UML2 environment. Simultaneously, simulated flight event development will occur through ATM-X X4 activities in preparation for vehicle-coupled flights. with potential Provider of Services for UAM (PSU) candidates in NC-2.

Figure 1.5. Future Airspace Concept.

<u>National Campaign-1 Engagements</u>

The following engagements occurred with NC-1: *Mobile Vertipad System, Integrated Automated Systems and Automated Flight Contingency Management* and *X4 Simulated Flights.*

<u>Mobile Vertipad System</u>

To demonstrate scaled operational capabilities in urban environments, deployment of a Mobile Vertipad System (MVS) will research augmenting site survey, weather, lighting, and GPS corrections associated with point-in-space operations for AAM procedures.

<u>Integrated Automated Systems and Automated Flight Contingency Management</u>

Sequential Integration of Automated Systems (IAS) activities will integrate and test different NASA automation technologies from partner projects including interactions between the vehicle, infrastructure, and airspace to enable more complex operations. The IAS-1 activity will leverage an existing rotorcraft platform as a surrogate testbed to evaluate NASA automation algorithms.

<u>X4 Simulated Flights</u>

Simulation events with airspace partners will build on functionality established in X3 by AAM subproject ATM-X, focusing on Provider of Services for UAM (PSU) capabilities needed to support AAM operations.

1.4 Dry Run Objectives

The Dry Run flight test series was separated into three flight events: Build 1, Build 2, and Build 2 FOFTs. Table 1.6 provides an overview of the primary objective success criteria achieved through Dry Run:

Table 1.6. Dry Run Test Objectives.

National Campaign Dry Run Test Objectives				
DRPO	Success Criteria	Build 1	Build 2	FOFT
1. Demonstrate Integrated Aircraft and Test Infrastructure	Min Success: Conduct dry run testing using UAM representative vehicle with existing AFRC assets and exercise NC ADS-B Receiver connection to airspace test infrastructure.	X		
	Full Success: Conduct the dry run testing with the MOF, ground support equipment (GSE), weather systems, airspace test infrastructure systems, data collection and management systems, and instrumentation payload in the configurations identified for deployment to a remote minimalistic range such as Fort Hunter Liggett		X	X
2. Demonstrate Deployable Integrated Test Infrastructure	Min Success: Demonstrate deployable integrated test infrastructure including at least a minimal MOF capabilities and airspace test infrastructure (with a non-UAM representative vehicle if necessary) prior to deploying to an external test site		X	
	Full Success: Successfully demonstrate a UAM representative vehicle with the deployable MOF including electrical power, ground crew communication (may use EDW LMR), MOF intercom, VHF communications with the vehicle, broadband internet, receive ADS-B data in the correct format, DGPS capability, airspace test infrastructure systems interfaces, real-time weather data handling, site agnostic telephones.		X	X
3. Demonstrate Connectivity and Functionality between Range Assets and Airspace Network	Min Success: Demonstrate connectivity using NC ADS-B data to Provider of Services (PSU) for UAM network, and ADS-B surveillance data to the airspace test infrastructure data pipeline. Data must be managed and archived according to data management and handling plans and systems identified for DT.	X	X	
	Full Success: Successfully demonstrate all the ATI functions necessary for supporting scenarios 1-3. Verify the data flow between the MOF and PSU Network including: ADS-B surveillance data to PSU Network; weather data to PSU Network (either real-time or post-flight); and scenario coordination data/communications between the PSU Network, MOF. All of this data must be managed and archived according to the data management and handling plans and systems identified for DT.			X
4. Demonstrate operations, procedures, and processes	Min Success: Demonstrate airworthiness process and end-to-end flight test procedures and data handling between minimal range assets (existing AFRC control room and surveillance, ATI interface, UHF/VHF, and weather) and the Provider of Services for UAM (PSU) network	X	X	
	Full Success: Demonstrate flight test roles and responsibilities, operational timelines, end-to-end flight procedures including data handling, and coordination procedures between the MOF and the PSU Network for non-acoustics testing.			X
5. Collect, Manage and Store Data	Min Success: Collect ADS-B data from any vehicle to be able to send to the Provider of Services for UAM (PSU) operator and network. Collect instrumentation data from the vehicle for the FAA to characterize vehicle performance, stability, and control (data specifics defined in the helicopter requirements).	X		
	Full Success: Fly scenarios 1 - 3 at least three times and conduct a minimum set of performance, stability, and control test points (data specifics to be defined in the flight test plan. Assess the DGPS/INS data quality for acoustics data reduction, post-flight conformance validation for ATI, and FAA data analytics for vehicle characterization. Collect audio and video data		X	
6. Demonstrate data handling, storage, sharing processes and hardware	Min Success: Demonstrate management of structured and unstructured data and identify any lessons learned for future test activities.		X	
	Full Success: Demonstrate data sharing with appropriate data governance procedures successfully with all of the Dry Run participants (ARC, AFRC, and the FAA). Ensure data quality and persistence are implemented through the data pipeline.			X
7. Collection and distribution of weather data	Min Success: Collect weather data (surface conditions and low-altitude winds) for conducting post-flight data analysis and making real-time flight calls	X	X	
	Full Success: Demonstrate the collection of weather data and its automatic real-time distribution to a MOF display.			X
8. Evaluate route design techniques between Area A site to the X-33 site	Min Success: Fly at least five unique routes, with at least one route between Area A and the X-33 site, and one route that utilizes one takeoff/landing pads within area A	X		
	Full Success: Fly the five routes in a variety of wind conditions from light to moderate and with prevailing directions spanning at least 45 degrees. Fly one route utilizing two takeoff/landing pads within area A. The tested routes must also exercise all of the identified contingency routes.		X	
9. Evaluate terminal area operations and procedures	Min Success: Evaluate a range of UAM approach patterns with an UAM representative vehicle into at least 3 different heliports or vertiports. Visual approaches with adequate visual references (may require a visual guidance system) are sufficient. Vehicle characteristic testing will be extracted from scenario flight tests.	X		

	Full Success: Evaluate UAM approach patterns with a UAM representative vehicle into at least 3 different heliports or vertiports, including at least one heliport or vertiport at the X-33 site. A RNAV capability in the cockpit is required to evaluate the FAA coded approach and landing procedures. An FMS that can integrate coded approach and landing procedures. Additional vehicle characteristic tests to be conducted as stand-alone flight tests. Video data collection in the terminal area of at least 3 flights of scenario 3.		X	
10. Evaluate scenarios 1-3	Min Success: Fly each of the scenarios 1-3 three times each in order to collect data for post-flight analysis.		X	
	Full Success: Fly each of the scenarios 1-3 more than three times each in a variety of wind conditions and across all routes and contingencies outlined in the scenarios.		X	

The Dry Run flight test series was separated into two additional data pipeline tests: Dry Run Connectivity Test and Mobile Operating Facility V&V Test. Through this work, the NC developed a foundation for testing future Airspace Management Architecture (Objective 4) as seen in Table 1.7.

Table 1.7. Airspace Testing and Integration Dry Run Test Objectives.

National Campaign Airspace Testing and Integration Dry Run Test Objectives				
TEST NAME	DESCRIPTION	REQUIRED COORDINATION	PASS CRITERIA	P/F
Build 2 Flight Test BASIC DATA CONNECTIVITY (03.05.21-03.20.21)	This procedure tests the connectivity between the pingStation and SURFER, SURFER and UDC, UDC and the Data Pipeline, Data Pipeline to Grafana via Amazon Kinesis Data Stream, and UDC to iUTM: 1. Start Kinesis Stream client 2. Plug ATI laptop into network and receive DHCP IP address 3. Configure pingStation to use laptop IP address to send UDP packets 4. Start SURFER application on UDP port 30000 5. Observe packets sent from pingStation to SURFER application 6. Verify that UDP packets received by SURFER are forwarded to UDC 7. Verify that the data is parsed and populates both the MCC and AOL Grafana dashboards correctly via the Amazon Kinesis stream 8. Use iUTM app and Grafana to see ADS-B visualization	• pingStation to SURFER • SURFER to UDC • UDC to the Data Pipeline • Data Pipeline to Grafana • UDC to iUTM	The pingStation must send raw UDP packets data to SURFER SURFER must secure the UDP packets and send to UDC UDC must receive the data and push it to the Data Pipeline The pingStation must broadcast the correct ICAO address to xTM Client Data Pipeline must collect the data and send it to Grafana via the Amazon Kinesis stream UDC must push real-time data to iUTM	P
Build 2 Flight Test xTM CLIENT to NPSU (03.05.21-03.20.21)	This test will be an initial test of a subset of capabilities from the xTM Client v5. The test will verify the xTM Client can receive telemetry for position messages: 1. Confirm the ICAO address that the pingStation will broadcast to input in “tail number” field. 2. Import the designated trajectory JSON file and edit operational plan to be populated with correct information. 3. Submit operation plan to NPSU 4. Verify xTM Client receives incoming NPSU message, showing state change from “Proposed” to “Accepted”. 5. Announce operation is “Active”, showing state change from “accepted” to “activated” 6. Announce the end of the operation by notifying NPSU that the operation is “Ended” 7. Verify xTM Client receives operation plan state change message from “Active” to “Ended”	• pingStation to SURFER • SURFER to xTM Client v5 (local AFRC network) • xTM Client to NPSU	The pingStation must broadcast the correct ICAO address to xTM Client NPSU must accept the operation and show state change xTM Client must announce activate the operation and show state change End the operation	P

1.5 Responsible Organizations for Dry Run

The following organizations provided support to Dry Run acitivities:

The NC Team: Members from AFRC and ARC, and the airspace Principal Investigator (PI) and supporting members co-located with the FAA at the Mike Monroney Aeronautical Center (Oklahoma City, Oklahoma).

The FAA: UAM vehicle PI, certification pilot, candidate Flight Inspection software, ARINC coding and supporting staff at the Mike Monroney Aeronautical Center (Oklahoma City, Oklahoma).

Flight Research Incorporated: UAM surrogate helicopter, pilot-in-command, maintenance staff, and data system technicians of Mojave, California.

1.6 Working Groups

Several NASA Dry Run working groups were used to enable development of the plan to execute Dry Run test activities: *Systems Engineering Working Group, Flight Test Operations Working Group, Flight Test Planning Working Group, Range-ATI Integration Bi-Weekly Working Group* and *Systems Safety Working Group.*

Systems Engineering Working Group: was used to define the FTI life cycle, as well as to refine, decompose, and manage System requirements derived from the NC Objectives and Concept of Operations (CONOPS). Products included the NC Systems Engineering Master Plan (SEMP), the Range Systems Requirements Document (SRD), and the FTI V&V Test Plan.

Flight Test Operations Working Group: was used to develop CONOPS for the FTI. The many products of this working group included:

- Flight Test Operations Document (FTOD)
- Control Room Plan
- Field Operations Guide
- Mandatory Mission Requirements and Go/No-Go Requirements
- Build 1 Familiarization, Build 2, Build 2 Follow-on Flight Test (CST)
- Aircrew Qualifications Document
- Instrumentation Operations Procedures
- Day of Flight Procedures

Flight Test Planning Working Group: was used to develop the UAM Surrogate Helicopter Test Plan used for Build 2.

Range-ATI Integration Bi-Weekly Working Group: was used to manage the interface between the FTI Range developed at AFRC and the ATI developed at ARC. Products included the NC Development Test Interface Description Document.

Systems Safety Working Group: was used to identify, track, and control the human safety and damage / loss of asset / mission hazard management efforts of the project. Products included the NC Systems Safety Plan, the NC Software Assurance Plan, Dry Run Hazards, and the associated Hazard Assessment Matrices.

The NC collaborated with subject matter experts (SMEs) across industry, FAA Lines of Business and Staff Offices, and across NASA Centers with related Advanced Air Mobility subprojects to realize full potential for planning, integration, and outcomes through two groups: *Scenario Technical Working Group* and *National Campaign Working Group*.

Scenario Technical Working Group: The NC team initiated the Scenario Technical Working Group (STWG) with the FAA from 2018-2019. Experts from the NASA NC and the FAA developed flight test scenarios and associated data for future campaign events. The set of discrete "Scenarios" are designed to enable the vehicle to fly a segment of an imagined UAM mission in a relevant live or virtual airspace environment. These Scenarios are designed to obtain critical insights into potential UAM systems with a focus on enabling future FAA equipment certification and operational approvals. The scenarios are designed to test various vehicle and airspace tasks within an assumed UAM concept of operations. Scenarios 1-4 were exercised for NC Dry Run and Developmental Testing flight events:

National Campaign Working Group

The NASA - FAA National Campaign Working Group (NCWG) was established in 2020. The FAA leadership appointed Focal leads from each Line of Business and Staff Office across the agency to verify campaign activities. Focals provide insight into current standards from which to *anchor* partner engagement activities and begin work to *evolve* toward the AAM future state. Collaboration to develop requirements that can assist each FAA service with informative data for AAM planning is garnered through appointed representatives. Data toward assumptions, technological gaps, and supportive data for FAA priorities help the agency keep pace with industry development.

NCWG Objectives

- Develop and utilize an agreed-upon platform to share data from various FAA and NASA data sources.
- Provide FTI to support connectivity between vehicle, range, and airspace service providers.
- Work collaboratively with the FAA Flight Program Office (AJF) for implementation of FIAPA software to support integration of emerging aerospace technology
- Facilitate regularly scheduled Scenarios Technical Working Group meetings.
- Measure FAA data requirements during the NC Series
- Work with FAA on agreed-upon data models and data management plan
- Provide FAA access to recorded data throughout the NC Series
- Develop the statement of work for the Helicopter Dry Run Test with input from the FAA.
- Provide a test bed and ground infrastructure for UAM Vertiport evaluation, certification, and registration research required for National Airspace System (NAS) integration.
- Develop flight test plan for the NC Helicopter Dry Run.
- Provide FAA FIAPA FTE, FAA Vehicle Performance FTE, FAA-certified test pilot
- Develop a joint NC Flight Test Report for each NC Series of demonstration tests

UAM Task Elements as Means of Compliance with the FAA

The NC developed a set of UAM Task Elements based on the US Army ADS-33E "Mission Task Elements" principles. The tests were designed to evaluate discrete flight tasks, under varied environmental conditions, with specified performance parameters, for purposes of evaluating handling qualities. These task elements were designed to highlight or uncover vehicle deficiencies relating to the UAM mission. The NC Dry Run UAM Surrogate Helicopter testing endeavored to investigate developmental UAM Task Elements being considered by the FAA as means of compliance to airworthiness certification requirements for UAM vehicles. "Desired" and "Adequate" performance, the test course, and other specifications will be modified for future test activities as a result of these results. General flying and handling qualities comments were captured in written notes and flight debriefs, but exhaustive Cooper-Harper ratings were not used for all OH-58C UAM Surrogate Helicopter tests. Handling qualities tests like these are expected to be a part of future certification flight tests of UAM vehicles that make use of an integrated system of complex, highly augmented, feedback control fly-by-wire flight control systems coupled with new and novel inceptor strategies, and flight guidance systems.

Vehicle Characteristics Tests for Vertical Motion Simulator with NASA

The results of Vehicle Characteristics tests will be utilized in an effort to draw conclusions as to the efficacy of the UAM Task Element as a candidate civil airworthiness certification task. Evaluations utilized existing or modified aircraft certification flight test techniques to validate select UAM participant S&C, Trim and Performance characteristics. The purpose was to demonstrate a limited set of foundational vehicle characteristics, utilizing traditional civil rotorcraft flight test techniques, intended to show compliance to FAA Subpart B airworthiness certification requirements. The intent was to capture data and create data products to be used for comparison purposes to future UAM vehicles, as well as to proposed alternative civil means of compliance that may be better suited for UAM vehicles. The results also provide supporting data for parallel, simulator-based, research (e.g., Collaborative FAA / NASA ARC Handling Quality Task Element (HQTE) research utilizing the Vertical Motion Simulator) that is applying these candidate UAM Task Elements in simulator tests of various different UAM Vehicle design approaches. The details of these tests will evolve as UAM vehicles achieve a design maturity appropriate for flight evaluation. The UAM Helicopter testing was limited to investigation of the empirical data. It is expected that UAM Task Elements, and future evolutions in test techniques, will form the foundation to support Handling Qualities evaluations for future UAM participant vehicles once UAM flight control systems, flight guidance algorithms, and performance parameters have been refined.

AAM Subproject Integration

The NC project events and findings will inform related subprojects within Advanced Air Mobility. As the first subproject to launch, the NC flight events hold the potential to both characterize initial development and then ultimately validate research and development found within other subprojects when applied through integrated flight events. Simulation and range flight events within the NC project series can further the required research and test viability of constructs across technology, operations, vehicle design, and safety.

The following projects support research for AAM: *National Campaign, Automated Flight Contingency Management, High-Density Vertiplex, Integrated Automation Systems* and *ATM-X*.

Figure 1.8. NASA Advanced Air Mobility Subprojects and Future Integrations.

2 FLIGHT TEST INFRASTRUCTURE INTEGRATION

The NC team developed a mobile test site infrastructure that is both conducive to the early NC series and scalable for NC-1 flight test events to occur in different locations around the United States (U.S.). Flight test infrastructure was developmental, utilizing sequential, methodical processes. Standard FAA procedures and policies were applied to prepare for surrogate AAM flights from landing surfaces to airspace constructs and procedure design. The physical range environment was carefully planned and scrutinized for safety. The data infrastructure frominstruments, systems, and data pipelines to storage and outcomes were also critical stages of the NC FTI.

The following topics are discussed in the this section: *Landing Surfaces Activation* and *Heliport Airspace Construction.*

2.1 Landing Surfaces Activation

The physical range constructs such as landing surfaces were first to be conceived for the Flight Test Infrastructure. One of the National Campaign research initiatives is to address the gap of services to streamline vertiport landing locations. In particular, the registration, certification, and publication of new landing surfaces identified exclusively for AAM operations is a new frontier. Considerations include compensation-for-hire operations, which would fall under the "general" or "commercial" category, and private-use vertiports relying on instrumentation for the private use of vehicles operating in and out the urban environment. The National Campaign has addressed such concerns by exploring how to conduct the required Landing Surface Survey, FAA Form 7480-1 "Notice for Construction, Alteration, and Deactivation of Airports," and FAA Form 5010 Airport Master Record, Letter of Determination, Activation Letter, National Airspace System Public Records publication and charting for AAM operations.

Experimental Airport-Heliports-Vertiport:

Three airports were utilized for NC coding procedures in order to enable an aircraft dispatcher or operator to file a flight plan to and from a particular landing location, even though several are only a few thousand feet apart for the NC Dry Run series. The first airport was populated as XEDW at North Base, Edwards Air Force Base, Edwards, California. The second airport, XVPT, utilized a rectangular portion of the North Base taxiway at AFRC. Airport XVPT functioned as a vertiport with a short takeoff and landing runway bound together by two heliports or vertiports. The third airport created was named XX33, commemorating the old X-33 shuttle takeoff site. As seen in Figure 2.1, three XEDW landing locations were constructed and named 01H, 02H and 03H. Airport XVPT had four registered landing surfaces: 04H, 05H as well as Runway 01 (RWY) and Runway 19 (RWY). The XX33 airport had one helipad associated with the airport identifier named 06H as seen in the corner of the Figure 2.1. The nontraditional naming convention was used for simplification for the aircrew (common convention would require a duplicate 01H helipad at the farther location). For NC purposes, each airport identifier points to landing surfaces 01H to 06H for convenience and ease during communication for the duration of the flight tests. Each helipad was designed around specific criteria against either vertical obstructions, such as Building 4833, an airspace constraint such as the KEDW runway centerline, or usable length such as an elongated path at XVPT.

National Campaign Experimental Airport-Heliports-Vertiports

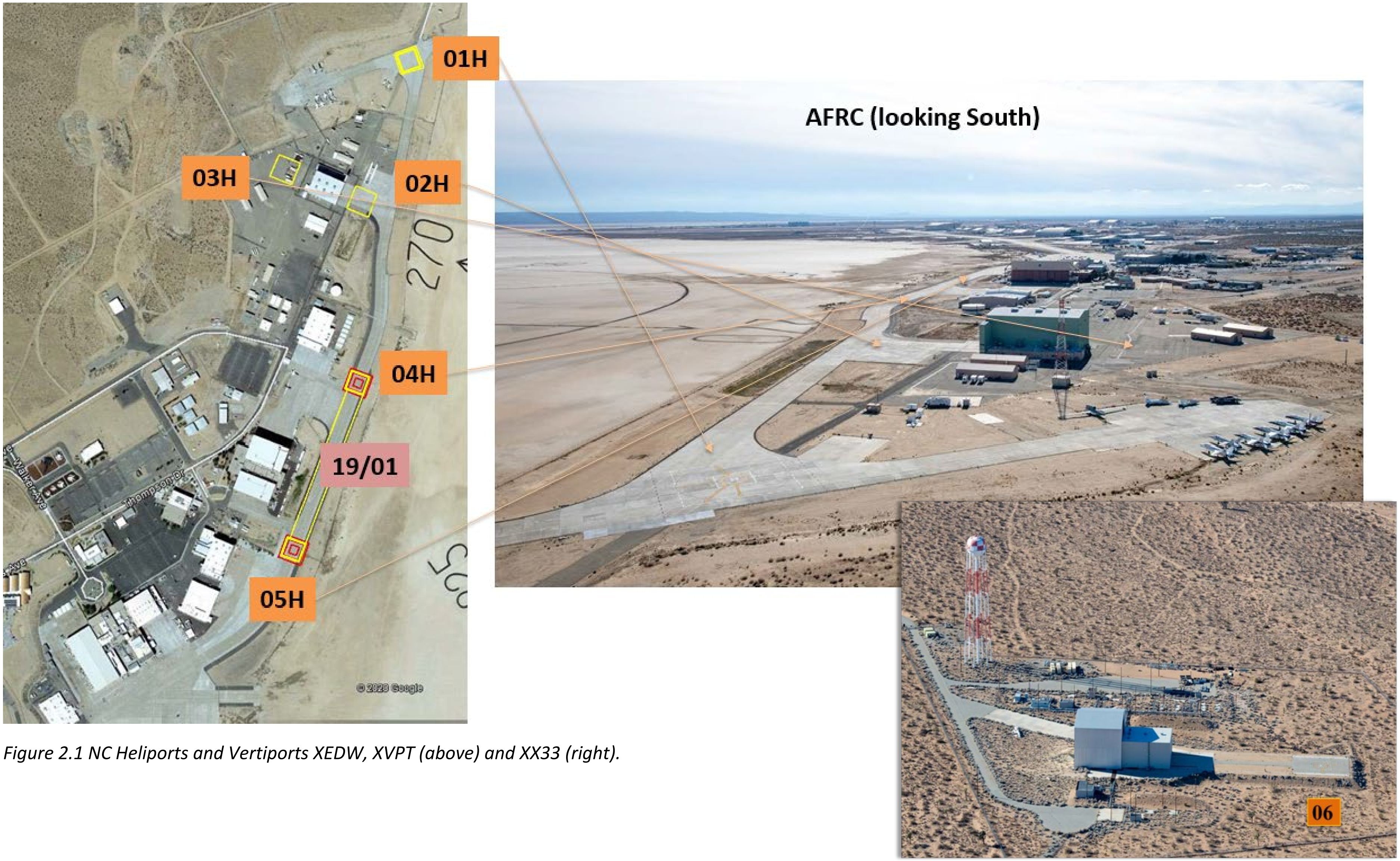
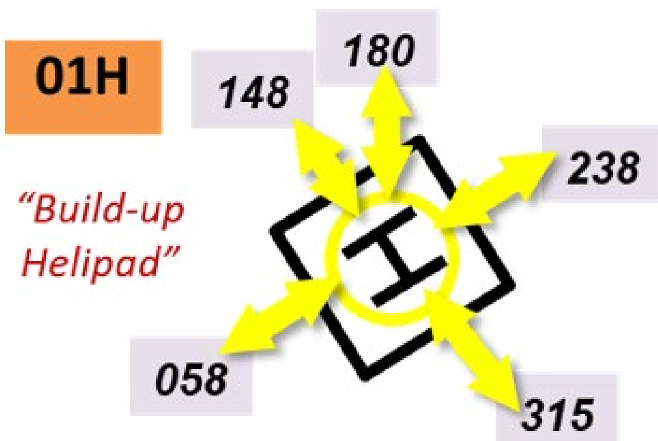


Figure 2.1 NC Heliports and Vertiports XEDW, XVPT (above) and XX33 (right).

XEDW Helipad 01H

AFRC Helipad 01H - XEDW

- Located at north end of NASA Ramp
- **N34 57.33 W117 52.54 (WGS 84)**
- TLOF Elevation 2271ft
- TLOF Dimensions 40ft x 40ft
- FATO Dimensions 120ft x 120ft
- 01H is a load bearing FATO



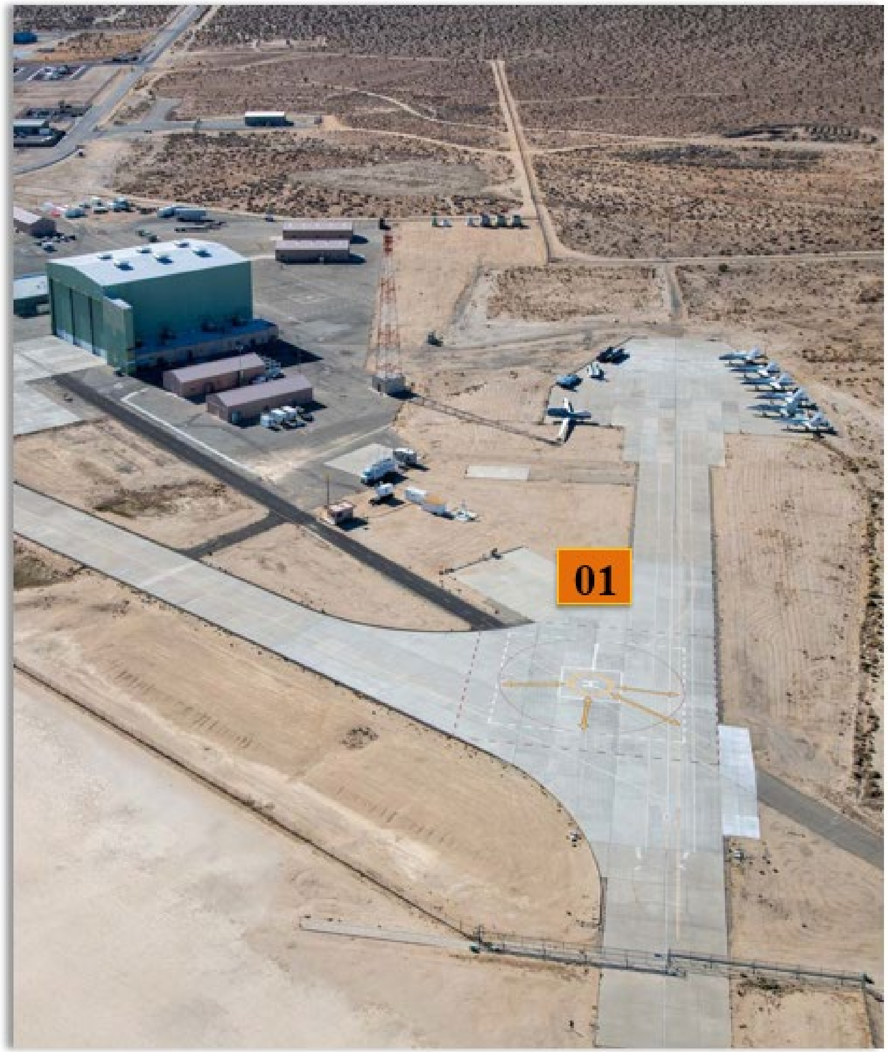


Figure 2.2. National Campaign Helipad 01H.

XEDW Helipad 02H

AFRC Helipad 02H - XEDW

- Located at east side of B4833 (NASA)
- **N34 57.25 W117 52.57 (WGS 84)**
- TLOF Elevation 2274ft
- TLOF Dimensions 40ft x 40ft
- FATO Dimensions 120ft x 120ft
- 02H is a load bearing FATO

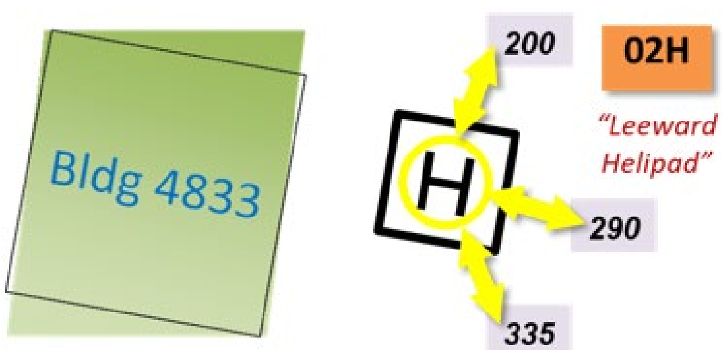


Figure 2.3. National Campaign Helipad 02H.

XEDW Helipad 03H

AFRC HELIPAD 03H - XEDW

- Located at west side of B4833 (NASA)
- **N34 57.26 W117 53.03 (WGS 84)**
- TLOF Elevation 2274ft
- TLOF Dimensions 40ft x 40ft
- FATO Dimensions 120ft x 120ft
- 03H is a non-load bearing FATO

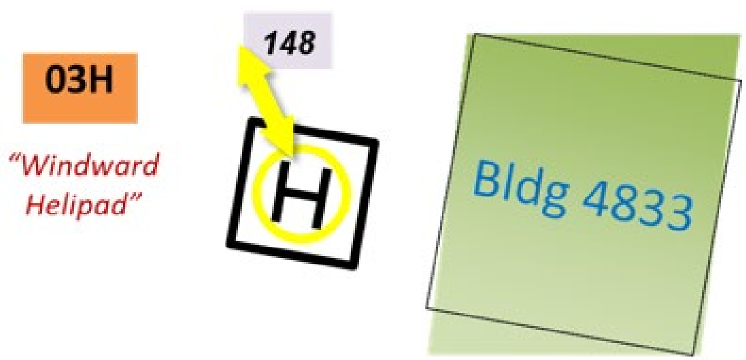


Figure 2.4. National Campaign Helipad 03H.

XVPT Helipad 04H

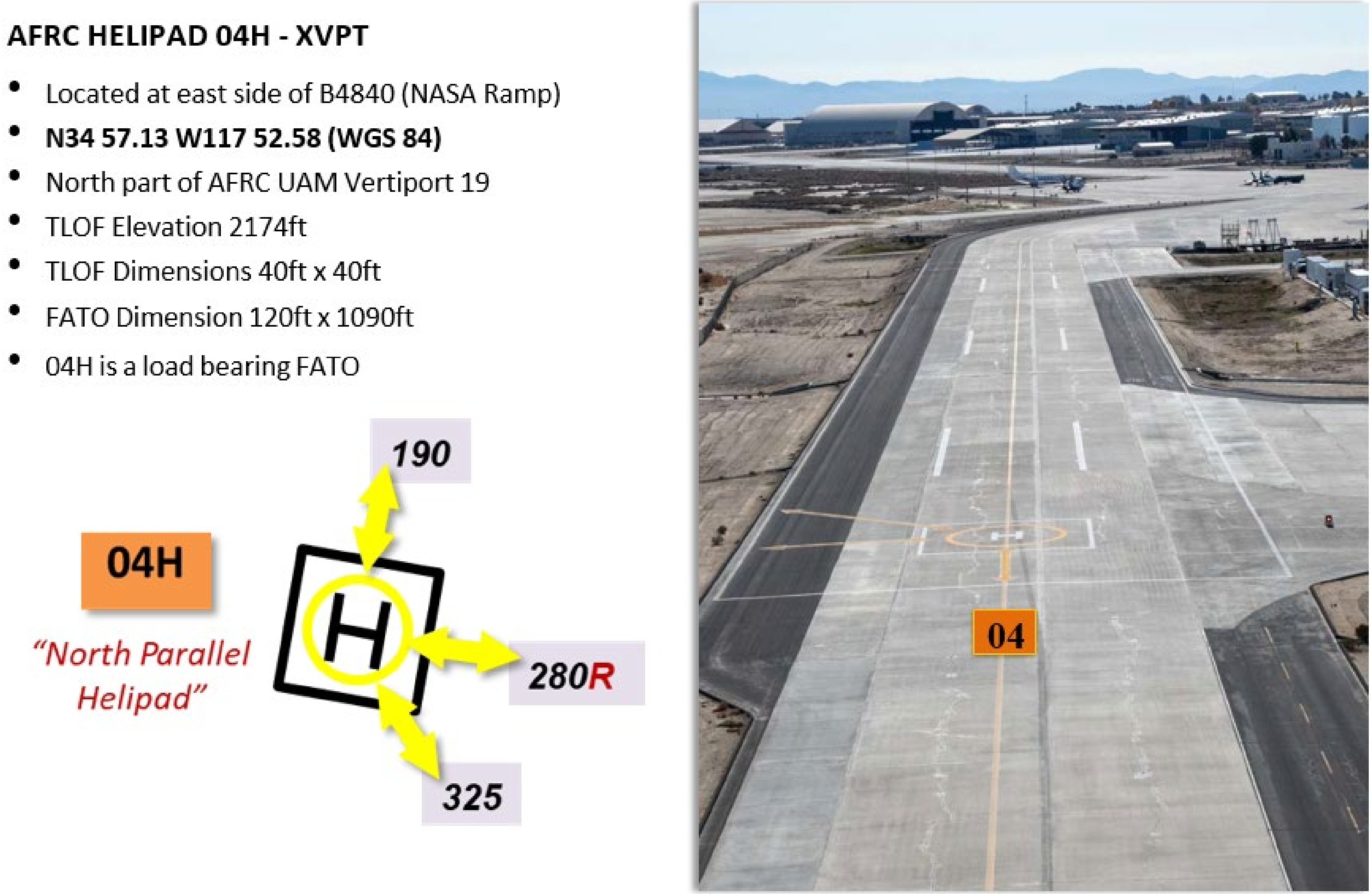


Figure 2.5. National Campaign Helipad 04H.

XVPT Helipad 05H

AFRC HELIPAD 05H - XVPT

- Located at east side of B4840 (NASA Ramp)
- **N34 57.04 W117 53.02 (WGS 84)**
- South part of AFRC UAM Vertiport RWY 01
- TLOF Elevation 2171ft
- TLOF Dimensions 40ft x 40ft
- FATO Dimension 120ft x 1090ft
- 05H is a load bearing FATO

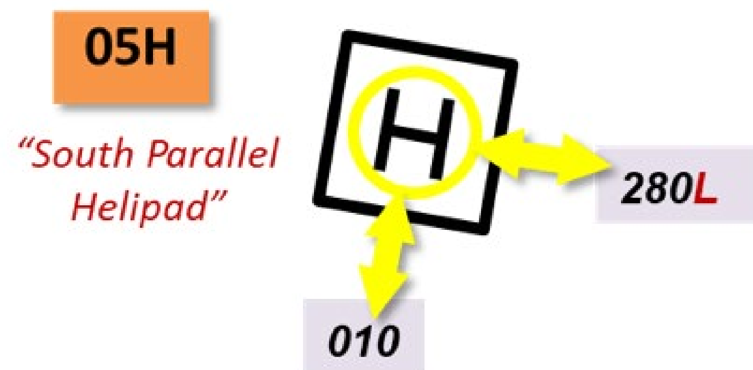


Figure 2.6. National Campaign Helipad 05H.

XX33 Helipad 06H

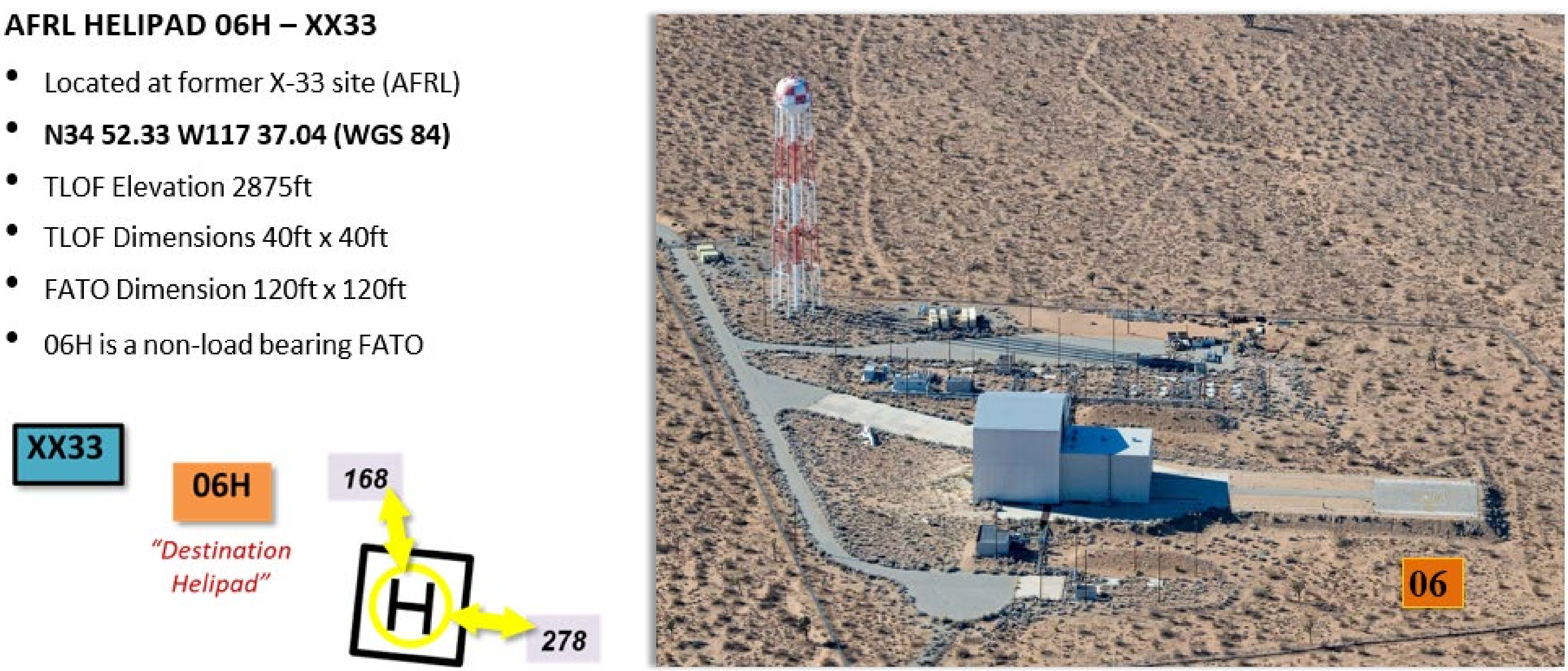


Figure 2.7. National Campaign Helipad 06H.

XVPT Runway 19/01

AFRC Vertiport RWY 19/01 - XVPT

- Located at east side of B4840 (NASA Ramp)
- Elevation 2172ft
- Dimensions 120ft x 1090ft

Figure 2.8. National Campaign Runway.

Landing Surface Infrastructure Analysis

To baseline the infrastructure of vertiports, a conventional survey was ordered and constructed to define a high-precision latitude and longitude, ellipsoidal height against the World Geodetic System 84 (WGS84) for the center and outer edges of each landing surface. The conventional survey served as a measurement against equipment such as a handheld GPS system and two-dimensional digital textiles covering a three-dimensional surface such as Google Earth, Terminal Area Route Generation Evaluation and Traffic Simulation (TARGETS), and Garmin (Garmin Ltd., Olathe, Kansas). The spatial data integrity test was conducted at XEDW on the center point of 01H. The purpose of the test was to use each available method for comparative analysis. On-demand mobility may requisition a gap for a "point-and-click" dynamic flight plan in which a potential dispatch operator could utilize a three-dimensional digital textile service such as Google Earth to identify the current location and point-and-click for the intended location. As many of the use cases are not on airports, AAM would not have a high-precision survey to back up any request that may be utilizing instrumentation for takeoff and landing operations. As such, the NC team used a point-and-click method to identify the very center of the same 01H helipad in each of these digital platforms and reported on the vertical and the lateral deviations of every system against the conventional survey results (see Figure 2.9).

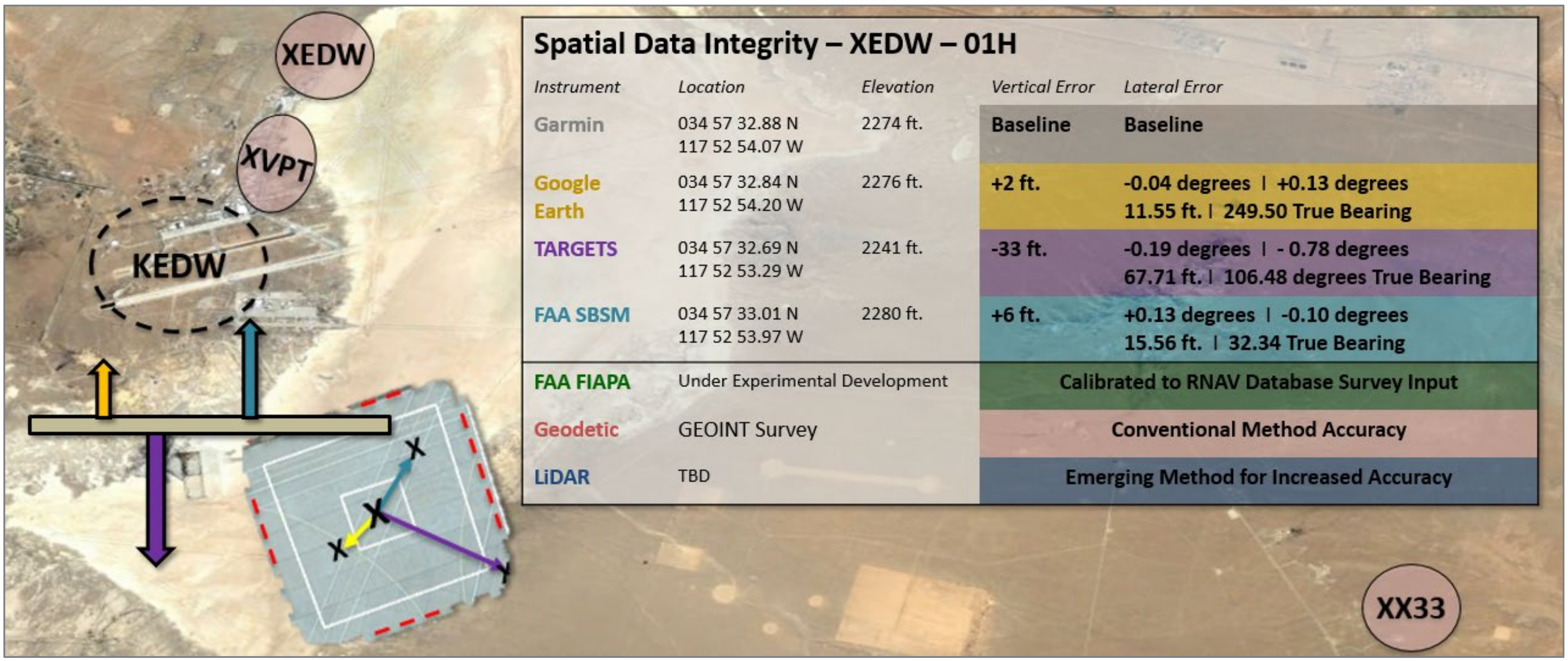


Figure 2.9. Spatial Data Analysis Results for XEDW 01H.

Landing Surface Survey Results

Another portion of the survey was used to populate the high-precision lateral and vertical information of each landing location selected in order to populate the information in the FAA area navigation AIRNAV database. The process enables the flight test to "file" a flight plan to and from a particular location. The following information was used to create experimental landing surfaces that would follow the process of uploading the baseline information to generate a file for a UAM vertiport. The process was executed up to the point of charting and publication, but because the airports were given an experimental "X" identifier, they are not to be part of the FAA official charting and publication cycle. Instead, the experimental landing surfaces remain in the background for future NC test series needs. The AIRNAV Database, Landing Surface table, Geodetic Site table, and Boundary Survey table used to generate the vertiport, vertiport boundaries as well as path point files for the test routes coding are shown in Figures 2.10 through 2.14 . All geodesic site survey results are found in Annex 6.2.

AIRNAV Database

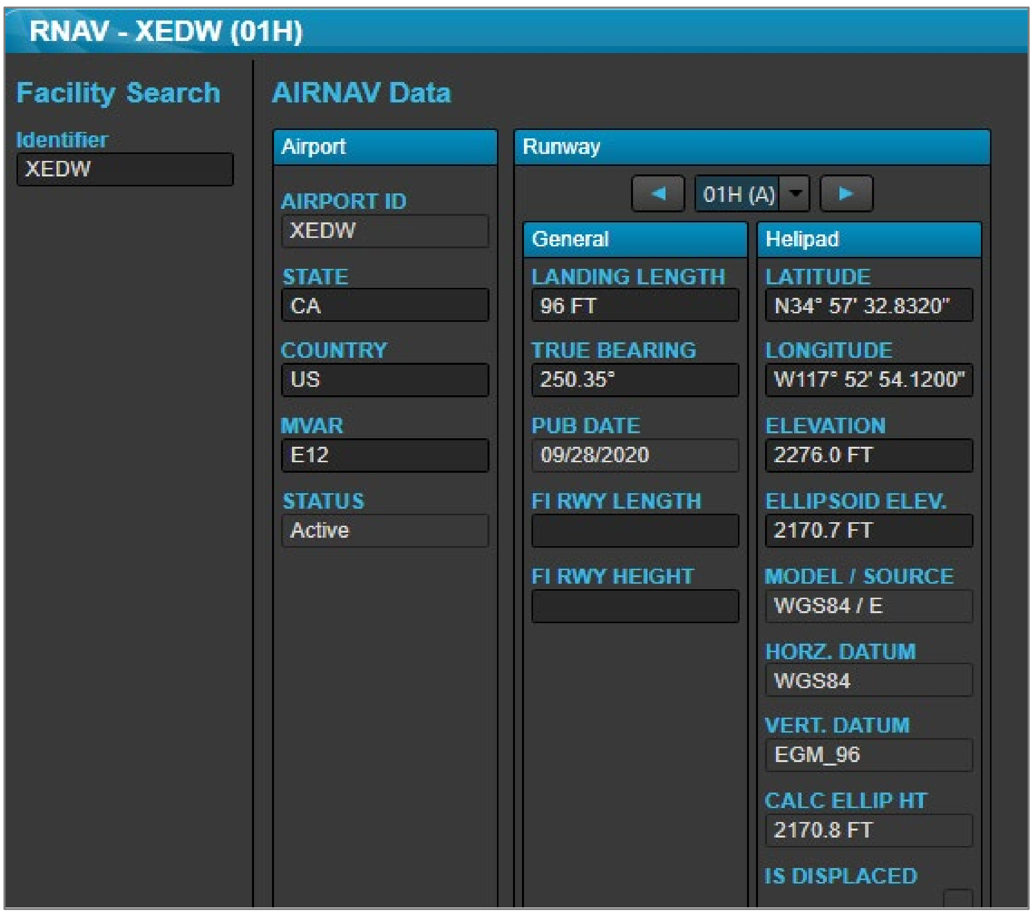


Figure 2.10. Area Navigation (AIRNAV) Database Experimental Landing Surface XEDW 01H.

Landing Surface Results

Table 2.11. Survey Results for NC Experimental Landing Surfaces.

Landing Surface Results				
STATION CODE	STATION DESCRIPTION	WGS 84 LONGITUDE (DMS)	WGS 84 ELLIPSOID HEIGHT (METERS)	WGS 84 LATITUDE (DMS)
140N-BV1	Temporary control station located on the North Base portion of EAFB, marked with a U.S. Coast & Geodetic Survey disk stamped N1140 1961	34 59 09.89396 N	117 51 44.55716 W	661.816
BV1-ARP	Ashtech antenna located atop Building 4800 at Armstrong Flight Research Center, on EAFB	34 57 00.14445 N	117 53 13.82413 W	678.224
GW18-BV1	Temporary control station located on the PIRA of EAFB, marked with a USGS disk stamped GWM 18 2449 1937	34 52 17.75511 N	117 38 55.13414 W	867.084
KEDWA 2020-BV1	Temporary control station located atop Building 4221 on North Base of EAFB	34 59 40.95197 N	117 52 24.43652 W	680.942
LZR1-BV1	Temporary control station located on the AFRL area of EAFB, marked with a DMA disk stamped LAZAR 1 1984 GSS	34 55 16.37317 N	117 42 44.17505 W	870.549
_MSB-BV1	Temporary control station located on the flight line area ofEAFB, marked with a NEC disk stamped MASTER SOUTH BASE 12-55	34 55 18.62567 N	117 52 41.77888 W	665.512

Geodetic Site Survey

GEODETIC SITE INFORMATION					
LOCATION (INSTALLATION / CITY, STATE / COUNTRY) **Edwards AFB, CA/USA**			DATUM **WGS 84**		
POINT	LATITUDE (deg min sec)	LONGITUDE (deg min sec)	ELLIPSOID HEIGHT OF POINT (meters)	HEIGHT OF POINT ABOVE GROUND (meters)	ELLIPSOID HEIGHT AT GROUND (meters)
NAS9-BV1	**N 34 56 53.05428**	**W 117 53 44.98178**	**682.983**	**0.15**	**N/A**

DESCRIPTION

Station NASA 9-BV1 (NAS9-BV1) is located in the NASA Neil A. Armstrong Flight Research Center on Edwards AFB, California.

To reach the station from the intersection of Rosamond Boulevard and North Base Road proceed south on Rosamond Boulevard for 2.4 miles to a stop sign at Lilly Avenue. Turn left onto Lilly Avenue and go 0.15 mile east to a railroad track and a dirt road about 15 meters east of track. Turn right onto the dirt road andgo 0.1 mile south to the station.

The station is a U.S. Army Corps of Engineers brass disk set in the top of a 0.1meter square concrete monument projecting 0.15 meter above the ground, stamped NASA-9 1969 LA DIST. It is 27 meters east of the railroad track centerline and 8meters west of the southwestern most of two manholes.

PHOTO/SKETCH

PREPARED BY	DATE PREPARED	CHECKED BY	DATE CHECKED
N. Rosa	**October 2020**	**M. Baumann**	**February 2021**

Figure 2.12. Geodesic Survey For National Campaign Experimental Landing surface at NAS9-BV1.

Boundary Survey

Table 2.13. Boundary Survey Results for National Campaign Experimental Landing Surfaces.

Station Code	Station Description	WGS 84 Latitude (DMS)				WGS 84 Longitude (DMS)				WGS 84 Ellipsoid Ht. (m)	WGS 84 X (meters)	WGS 84 Y (meters)	WGS 84 Z (meters)
Building 4833 West Helipad													
4833W-CENTER	Top of drill hole	34	57	25.93715	N	117	53	02.82502	W	662.068	-2447717.936	-4626035.050	3634356.137
4833W-FATO-1	Top of drill hole	34	57	26.24986	N	117	53	01.87866	W	661.766	-2447694.013	-4626041.180	3634363.862
4833W-FATO-2	Top of grade	34	57	26.71614	N	117	53	03.20501	W	662.168	-2447720.063	-4626018.455	3634375.871
4833W-FATO-3	Top of drill hole	34	57	25.62366	N	117	53	03.77270	W	662.366	-2447741.893	-4626028.913	3634348.389
4833W-FATO-4	Top of drill hole	34	57	25.15927	N	117	53	02.44554	W	661.865	-2447715.771	-4626051.547	3634336.371
4833W-FATO-PE-21	Top of asphalt	34	57	26.71018	N	117	53	03.18582	W	662.214	-2447719.699	-4626018.808	3634375.747
4833W-FATO-PE-23	Top of asphalt	34	57	26.69821	N	117	53	03.21325	W	662.238	-2447720.423	-4626018.687	3634375.458
4833W-SA-1	Top of drill hole	34	57	26.35325	N	117	53	01.56336	W	661.780	-2447686.093	-4626043.318	3634366.482
4833W-SA-2	Top of grade	34	57	26.97114	N	117	53	03.33142	W	662.171	-2447720.793	-4626012.976	3634382.313
4833W-SA-3	Top of drill hole	34	57	25.51941	N	117	53	04.08723	W	662.465	-2447749.846	-4626026.879	3634345.812
4833W-SA-4	Top of drill hole	34	57	24.89917	N	117	53	02.31692	W	661.793	-2447715.007	-4626057.082	3634329.761
4833W-SA-PE-21	Top of asphalt	34	57	26.82970	N	117	53	02.91625	W	662.132	-2447712.635	-4626020.082	3634378.719
4833W-SA-PE-23	Top of asphalt	34	57	26.54665	N	117	53	03.55426	W	662.301	-2447729.346	-4626017.052	3634371.666
4833W-TLOF-1	Top of drill hole	34	57	26.04249	N	117	53	02.50858	W	661.989	-2447709.938	-4626037.103	3634358.752
4833W-TLOF-2	Top of drill hole	34	57	26.19655	N	117	53	02.95170	W	662.123	-2447718.656	-4626029.538	3634362.721
4833W-TLOF-3	Top of drill hole	34	57	25.83297	N	117	53	03.14058	W	662.118	-2447725.893	-4626032.967	3634353.534
4833W-TLOF-4	Top of drill hole	34	57	25.67798	N	117	53	02.69661	W	661.989	-2447717.166	-4626040.562	3634349.545
Building 4833 East Helipad													
4833E-CENTER	Top of drill hole	34	57	24.65553	N	117	52	57.52063	W	661.647	-2447609.392	-4626117.694	3634323.523
4833E-FATO-1	Top of drill hole	34	57	24.96747	N	117	52	56.57538	W	661.420	-2447585.529	-4626123.877	3634331.272
4833E-FATO-2	Top of drill hole	34	57	25.43558	N	117	52	57.89959	W	661.605	-2447611.434	-4626100.991	3634343.202
4833E-FATO-3	Top of drill hole	34	57	24.34353	N	117	52	58.46710	W	661.801	-2447633.255	-4626111.444	3634315.730
4833E-FATO-4	Top of concrete	34	57	23.87689	N	117	52	57.14023	W	661.563	-2447607.259	-4626134.300	3634303.806
4833E-SA-1	Top of drill hole	34	57	25.07189	N	117	52	56.25892	W	661.352	-2447577.544	-4626125.954	3634333.871
4833E-SA-2	Top of drill hole	34	57	25.69533	N	117	52	58.02552	W	661.499	-2447612.072	-4626095.366	3634349.702
4833E-SA-3	Top of drill hole	34	57	24.23976	N	117	52	58.78238	W	661.803	-2447641.184	-4626109.324	3634313.110
4833E-SA-4	Top of drill hole	34	57	23.61623	N	117	52	57.01337	W	661.443	-2447606.520	-4626139.788	3634297.154
4833E-TLOF-1	Top of drill hole	34	57	24.75952	N	117	52	57.20525	W	661.560	-2447601.427	-4626119.750	3634326.099
4833E-TLOF-2	Top of drill hole	34	57	24.91577	N	117	52	57.64708	W	661.650	-2447610.081	-4626112.134	3634330.098
4833E-TLOF-3	Top of drill hole	34	57	24.55167	N	117	52	57.83614	W	661.742	-2447617.363	-4626115.640	3634320.953
4833E-TLOF-4	Top of drill hole	34	57	24.39523	N	117	52	57.39429	W	661.681	-2447608.721	-4626123.281	3634316.967
X-33 Helipad													
X33-CENTER	Top of drill hole	34	52	33.18394	N	117	37	04.15386	W	874.204	-2428665.555	-4642091.592	3627079.073
X33-FATO-1	Top of concrete	34	52	33.55351	N	117	37	03.37880	W	874.212	-2428645.096	-4642094.953	3627088.422
X33-FATO-2	Top of concrete	34	52	33.87926	N	117	37	04.45283	W	874.220	-2428666.609	-4642077.226	3627096.663
X33-FATO-3	Top of concrete	34	52	32.81343	N	117	37	04.92935	W	874.220	-2428686.041	-4642088.258	3627069.713
X33-FATO-4	Top of concrete	34	52	32.48746	N	117	37	03.85476	W	874.214	-2428664.517	-4642105.997	3627061.468
X33-TLOF-1	Top of drill hole	34	52	33.30676	N	117	37	03.83069	W	874.229	-2428657.288	-4642093.498	3627082.193
X33-TLOF-2	Top of drill hole	34	52	33.45081	N	117	37	04.30240	W	874.223	-2428666.725	-4642085.690	3627085.832
X33-TLOF-3	Top of drill hole	34	52	33.06103	N	117	37	04.47760	W	874.214	-2428673.849	-4642089.707	3627075.971
X33-TLOF-4	Top of drill hole	34	52	32.91689	N	117	37	04.00424	W	874.228	-2428664.379	-4642097.542	3627072.334

Landing Surface Activation Process

A sequential process exists to activate a landing site, to include registration via five forms and an approval process for each which result in population within the landing site database ahead of authorized operations. The NC team engaged in the process to register the experimental landing sites for the Dry Run seriesas seen in Figure 2.14 with the following steps within the process: *Notice of Construction Form 7480-1, Notice of Construction, Airport Master Record Form 5010, Activation Letter* and *e-NASR*.

Notice of Construction Form 7480-1: The first form addressed is the Notice of Construction Form 7480-1. Section C for the Purpose of Notification within the form pertains to the construction or establishment of a landing surface. The NC team selected the "Other" box outside the operating parameters of a heliport.

Notice of Construction: After a Notice of Construction has been populated, signed, and approved, a Letter of Determination must be granted from a local Flight Standards District Office in which an aeronautical study is performed that will determine if the use of the heliport landing surface will adversely affect the safe and efficient use of airspace by aircraft following any conditions or requirements maintained as directed by the letter of determination.

Airport Master Record Form 5010: The next form in the landing surface registration chain is the Airport Master Record Form 5010. The form covers the ownership, operation, location, and obstruction data associated with the landing surface. The NC team noted in the process that the "based" aircraft does not have a use case for an unmanned or highly automated vertical performing takeoff and landing aircraft. Lift-plus-cruise or powered-lift vehicle designations are also not options within the form.

Activation Letter: Once the Master Record has been determined, the next step is to acquire an Activation Letter to provide an International Civil Aviation Organization (ICAO) identifier in accordance with regulations for a public or private-use facility. The naming convention that is in use today may not be sufficient for a "K" or four-letter identifier to delineate a private landing surface as opposed to a public one for a UAM or highly automated operation.

e-NASR: For the final step, the NC compiled all of the vertical activation information into the National Airspace System Resource (eNASR) with the absolute minimal information that meets all helipad criteria. The eNASR registration establishes type of landing surface, pavement control number (PCN), width and length of the landing surface, ownership, operations, and any additional relevant information in accordance with local jurisdictional criteria. Information registered within the database includes calculated magnetic variation, publication date, latitude and longitude geodetic datum, and ellipsoidal heights in feet, and surveyed thresholds required by the FAA for landing surface accuracy with a takeoff or approach procedure.

Landing Surface Activation Process

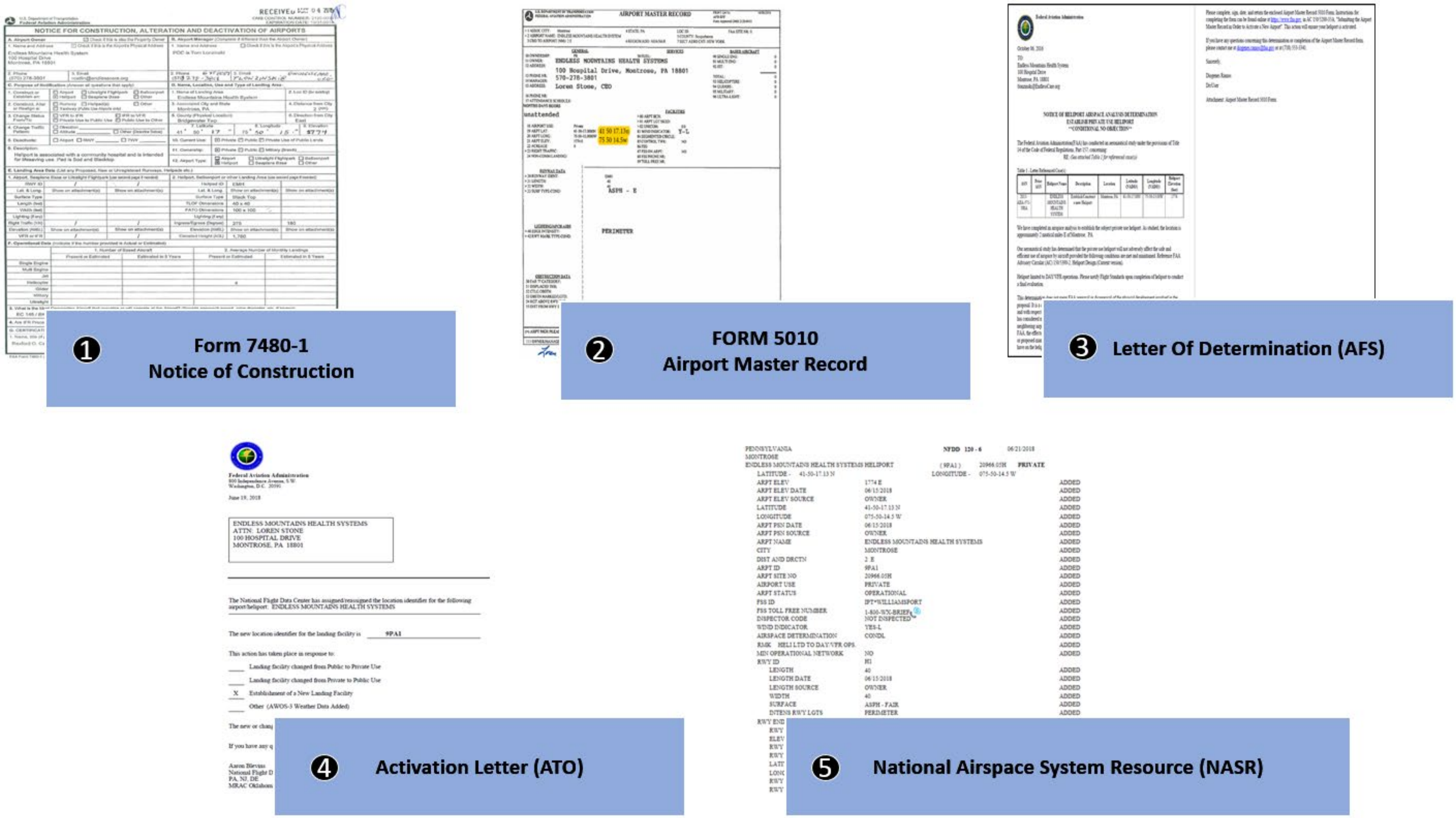
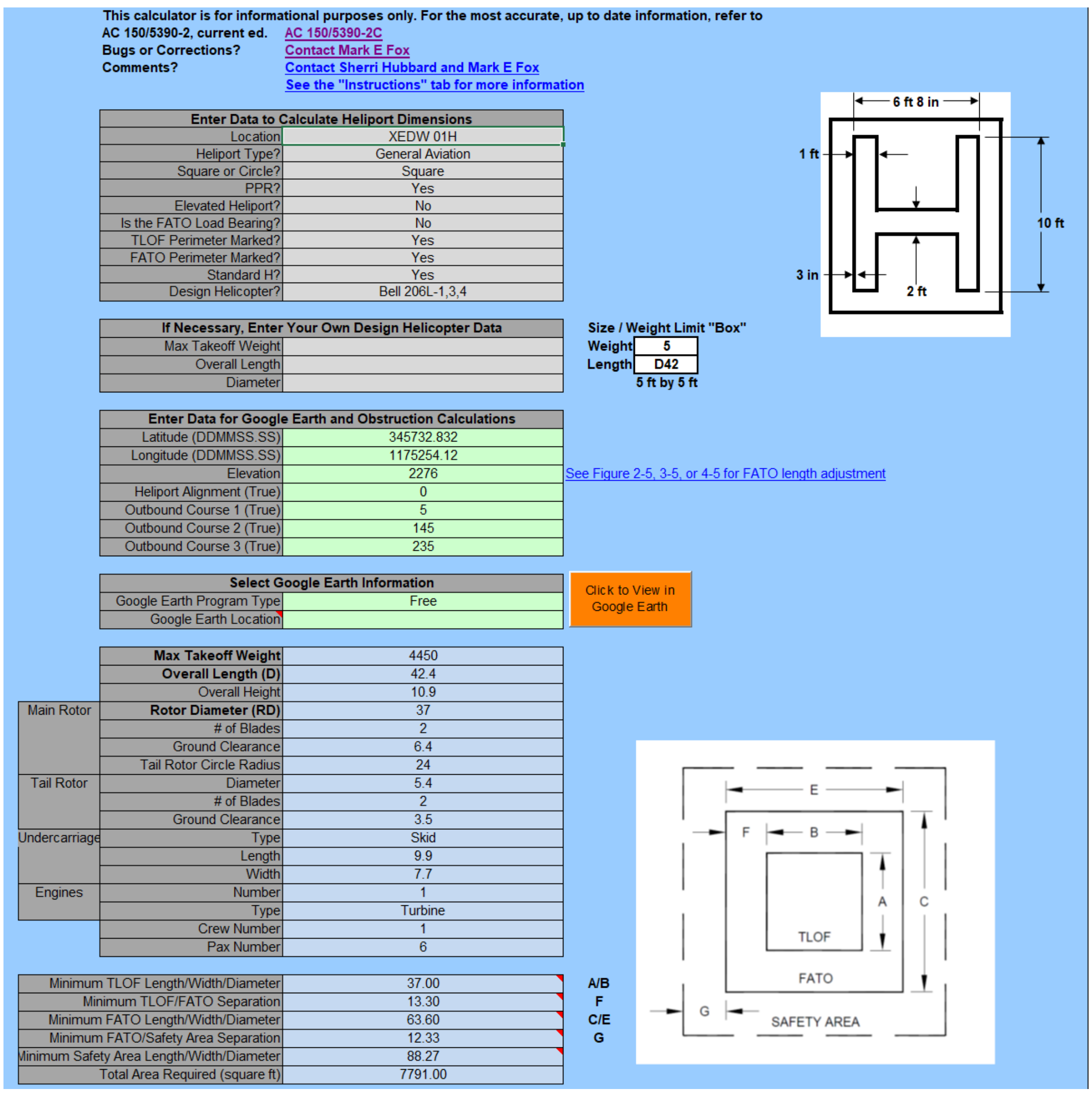


Figure 2.14. Federal Aviation Administration Landing Surface Activation Process.

2.2 Helipad Airspace Construction

The following topics are discussed in the this section: *Helipad Evaluation* and *Helipad Approach Construction*.

<u>Helipad Evaluation</u>: A remote heliport evaluation tool was used in the evaluation of the experimental vertiports at XEDW, XVPT, and XX33. The tool used in Figure 2.15 was developed by the Flight Standards branch AFS-400 at the FAA. The tool allows the evaluator to map the helicopter dimensions against the Advisory Circular 150/5390-2C recommendation for safe helicopter operations. The tool allows the evaluator to answer questions about the final approach and takeoff area and its load bearing, marking, and standard helicopter descriptions. The evaluator is responsible for inputting the latitude and longitude of the center of the helipad using a survey-grade field elevation in MSL. Three courses are available to the evaluator for outbound departure use, the NC evaluated 360 degrees from the helipad center point for omnidirectional approach and departure operations. The tool also helps the evaluator determine the minimum touch-down and lift-off (TLOF) area length and width diameter based on the intended aircrafts specific controlling dimensions.


This calculator is for informational purposes only. For the most accurate, up to date information, refer to
AC 150/5390-2, current ed. AC 150/5390-2C
Bugs or Corrections? Contact Mark E Fox
Comments? Contact Sherri Hubbard and Mark E Fox
See the "Instructions" tab for more information

Enter Data to Calculate Heliport Dimensions	
Location	XEDW 01H
Heliport Type?	General Aviation
Square or Circle?	Square
PPR?	Yes
Elevated Heliport?	No
Is the FATO Load Bearing?	No
TLOF Perimeter Marked?	Yes
FATO Perimeter Marked?	Yes
Standard H?	Yes
Design Helicopter?	Bell 206L-1,3,4

If Necessary, Enter Your Own Design Helicopter Data	
Max Takeoff Weight	
Overall Length	
Diameter	

Size / Weight Limit "Box"

Weight	5
Length	D42

5 ft by 5 ft

Enter Data for Google Earth and Obstruction Calculations	
Latitude (DDMMSS.SS)	345732.832
Longitude (DDMMSS.SS)	1175254.12
Elevation	2276
Heliport Alignment (True)	0
Outbound Course 1 (True)	5
Outbound Course 2 (True)	145
Outbound Course 3 (True)	235

See Figure 2-5, 3-5, or 4-5 for FATO length adjustment

Select Google Earth Information	
Google Earth Program Type	Free
Google Earth Location	

Click to View in Google Earth

	Max Takeoff Weight	4450
	Overall Length (D)	42.4
	Overall Height	10.9
Main Rotor	**Rotor Diameter (RD)**	37
	# of Blades	2
	Ground Clearance	6.4
	Tail Rotor Circle Radius	24
Tail Rotor	Diameter	5.4
	# of Blades	2
	Ground Clearance	3.5
Undercarriage	Type	Skid
	Length	9.9
	Width	7.7
Engines	Number	1
	Type	Turbine
	Crew Number	1
	Pax Number	6

Minimum TLOF Length/Width/Diameter	37.00	A/B
Minimum TLOF/FATO Separation	13.30	F
Minimum FATO Length/Width/Diameter	63.60	C/E
Minimum FATO/Safety Area Separation	12.33	G
Minimum Safety Area Length/Width/Diameter	88.27	
Total Area Required (square ft)	7791.00	

Figure 2.15. XEDW 01H Evaluation Worksheet.

<u>XEDW 01H Helipad Evaluation</u>: The NC team evaluated the surrogate aircraft with conventional criteria that are based on the diameter of the rotor system as well as the length of the fuselage for a traditional helicopter and the controlling dimension of a candidate UAM vehicle that might have wings in lift-plus-cruise configuration or multirotor in a quadrotor configuration. Based on the evaluation the 26.2-foot radius of the quadrotor remained within the conventional TLOF as highlighted in the green box in figure 2.15, but the 47.72-foot wingspan of the lift-plus-cruise model could not remain within the TLOF helipad/vertiport highlighted in red in Figure 2.16.

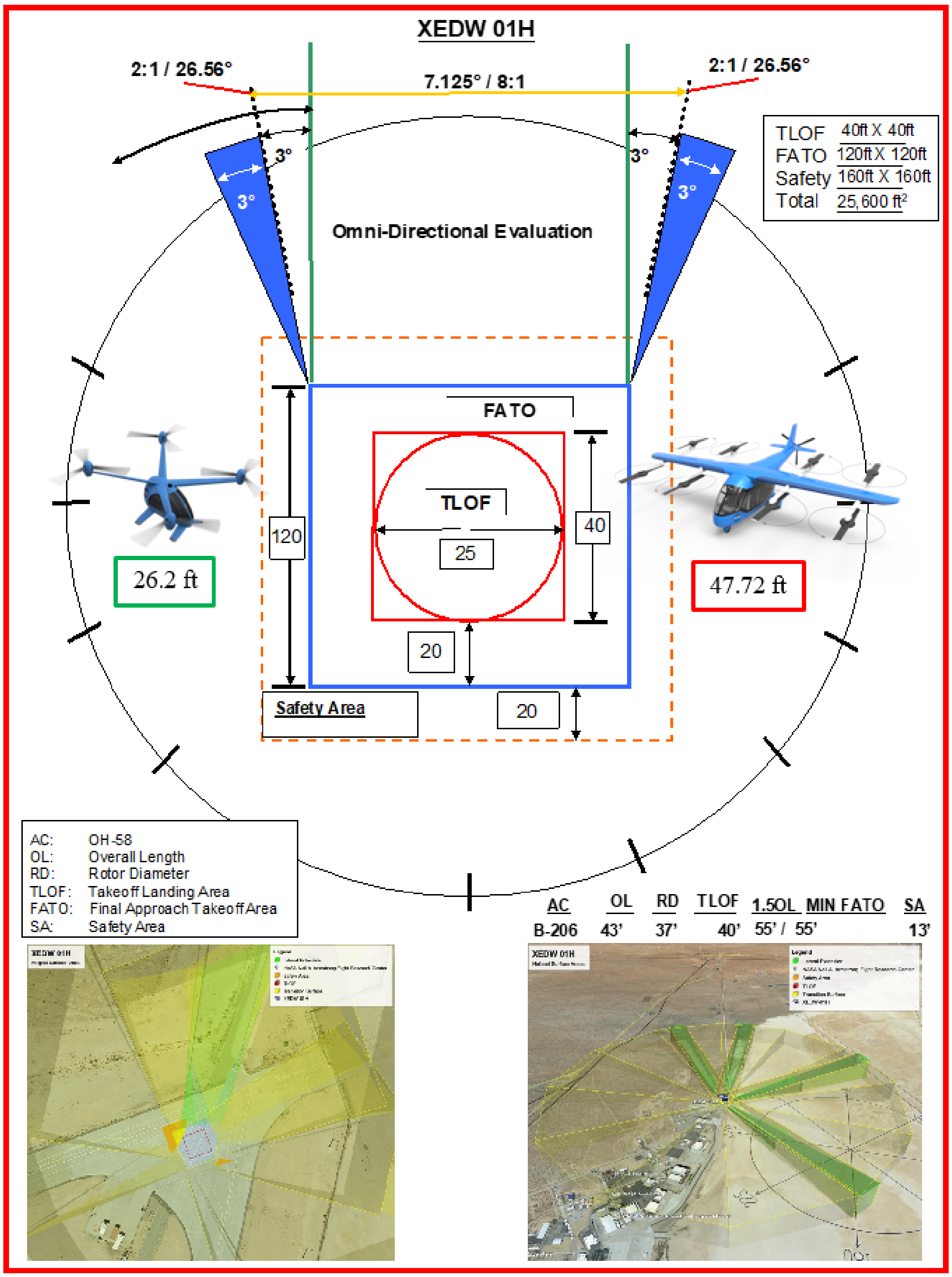


Figure 2.16. XEDW 01H Helipad Evaluation.

Helipad Approach Construction: The omnidirectional assessment of a vertiport is based on the rotor diameter of the aircraft (in this case, the OH-58C helicopter). Considerations for loadbearing and vertical obstructions were taken into account, ensuring the TLOF, Final Approach and Takeoff (FATO) Area, and Safety Area (SA) were free and clear for the NC test to proceed as seen in Figure 2.17.

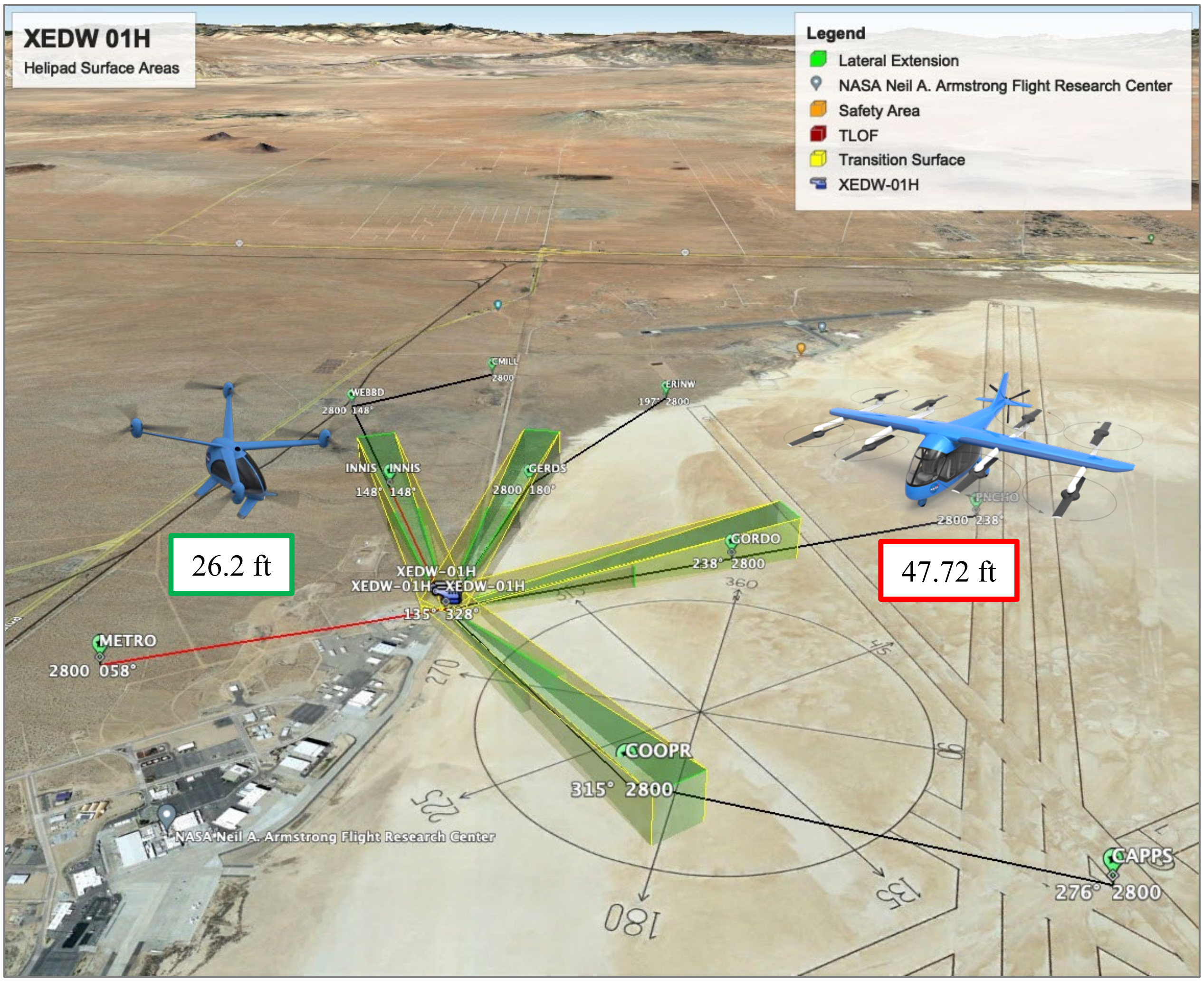


Figure 2.17. XEDW 01H Primary and Secondary Worksheet.

Once the avenues of approach at XEDW 01H were established, Localizer Performance with Vertical Guidance (LPV) splays were built. Figure 2.18 shows a primary area of evaluation (green) and secondary areas (yellow). The primary splay (green) used from each final approach fix inbound was evaluated at an 8:1 slope which equals 7.125 degrees. The secondary area (yellow) was set for a 2:1 slope which equals 26.56 degrees. The rise over run slope of 8:1 is an evaluation of 8 units that were laterally reversed on the inbound course to 1 unit vertically, creating a stair-step or minimum obstacle clearance slope. Per criteria, a penetration in the secondary area is allowed for approach, but on one side only. All final approach fixes were cleared through conventional criteria before the procedures were built and the test conducted.

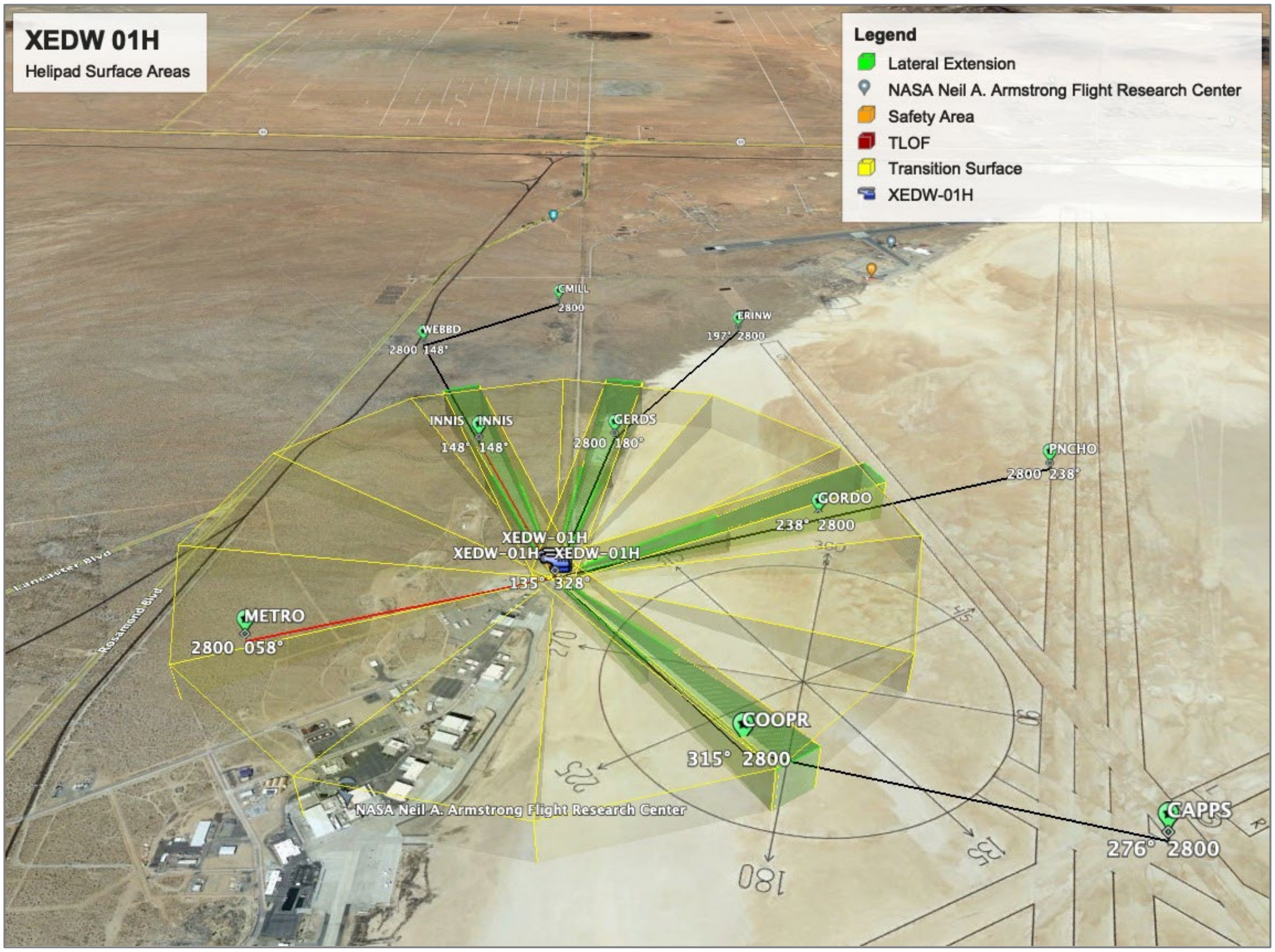


Figure 2.18. XEDW 01H Omnidirectional 8:1/7.125 Degree Assessment.

As part of the experiment, a 360-degree evaluation was conducted using the FAA heliport evaluation tool. The assessment was set at the 9-degree radius and an 8:1 slope was erected around the XEDW 01H center reference point. As depicted in figure 2.18, the omnidirectional assessment was overlaid within the pre-established avenues of approach in green. The purpose of this test was to enable dynamic evaluations given a radius, landing dimension, and required obstacle clearance slope. This process was completed for each and every landing surface for the NC flight tests.

National Campaign experimental landing surfaces XEDW 02H, XEDW 03H, XVPT 04H, XVPT 05H, XVPT RUNWAY 01/19 and XX33 06H are found in Annex 6.3.

2.3 Related Work: Precision For Landing Surfaces

New technology for landing surface evaluations within confined airspace of the future exemplified the striving toward precision approaches. Collaboration with FAA-provided related work for the NC Flight Test Infrastructure.

Emerging Lidar Survey Method

03.08.21-03.11.21

The NC partnered with the FAA Flight Program Office (AJF) and Technical Operations (AJW) groups from March 8-11, 2021, at Marina Municipal Airport (KOAR) (Marina, California) to conduct experimental Light Detection and Ranging (LiDAR) surveys to inform the development of novel UAM approach procedures for National Campaign research. The test marked the first of four planned airport surveys utilizing the LiDAR and Photogrammetry serveries. The FAA contract, awarded in October 2020, investigated the feasibility of using LiDAR to expedite the precision approach surveys and controlling obstacle capture which will increase the precision of landing surfaces, terrain, and vertical obstructions from the current 1A (3 feet) tolerance to 2-centimeter precision. The NC team provided the radius and diameter for the proposed descending /decelerating approaches at KOAR, which were then turned into survey traps for small Unmanned Aircraft System (sUAS) flights. The FAA will continue to test three additional airports in the NAS using LiDAR services to augment the traditional Instrument Landing Systems (ILS) and other current precision approach survey methods. The survey marked the first step toward increasing the accuracy of spatial data, which is an essential need for UAM operations and will help enable the execution of precise approach and departure procedures while maintaining safety.

Figure 2.19. LiDAR High-Precision Survey Study.

<u>Terrain/Obstacle 3D Surveys</u>

At least two terrain/obstacle 3D surveys were conducted to provide 3D point-cloud data for mapping and instrument procedure development. The partner contractor researched and documented operational approach framework approaches including inspection requirements for the terrain/obstacle survey. The task demonstrated the benefits of LiDAR and photogrammetry for various FAA use-cases.

Figure 2.20. Aerial View Of LiDAR Survey Research Areas.

<u>Survey/Facility #1</u>: The contractor conducted one survey using LiDAR as the primary sensor to acquire a point-cloud data set area of approximately 4 square nautical miles. The survey area was the final approach segment of an instrument approach procedure to a fixed-wing airport. Representative dimensions for the 4 square nautical miles were a trapezoid with dimensions:
a = .6 nautical miles; b = 2 nautical miles; and h = 3 nautical miles. The point-cloud resolution contained at least 1 point per square meter and also included sufficient resolution to represent protruding narrow obstacles such as towers, power lines, and treetops.

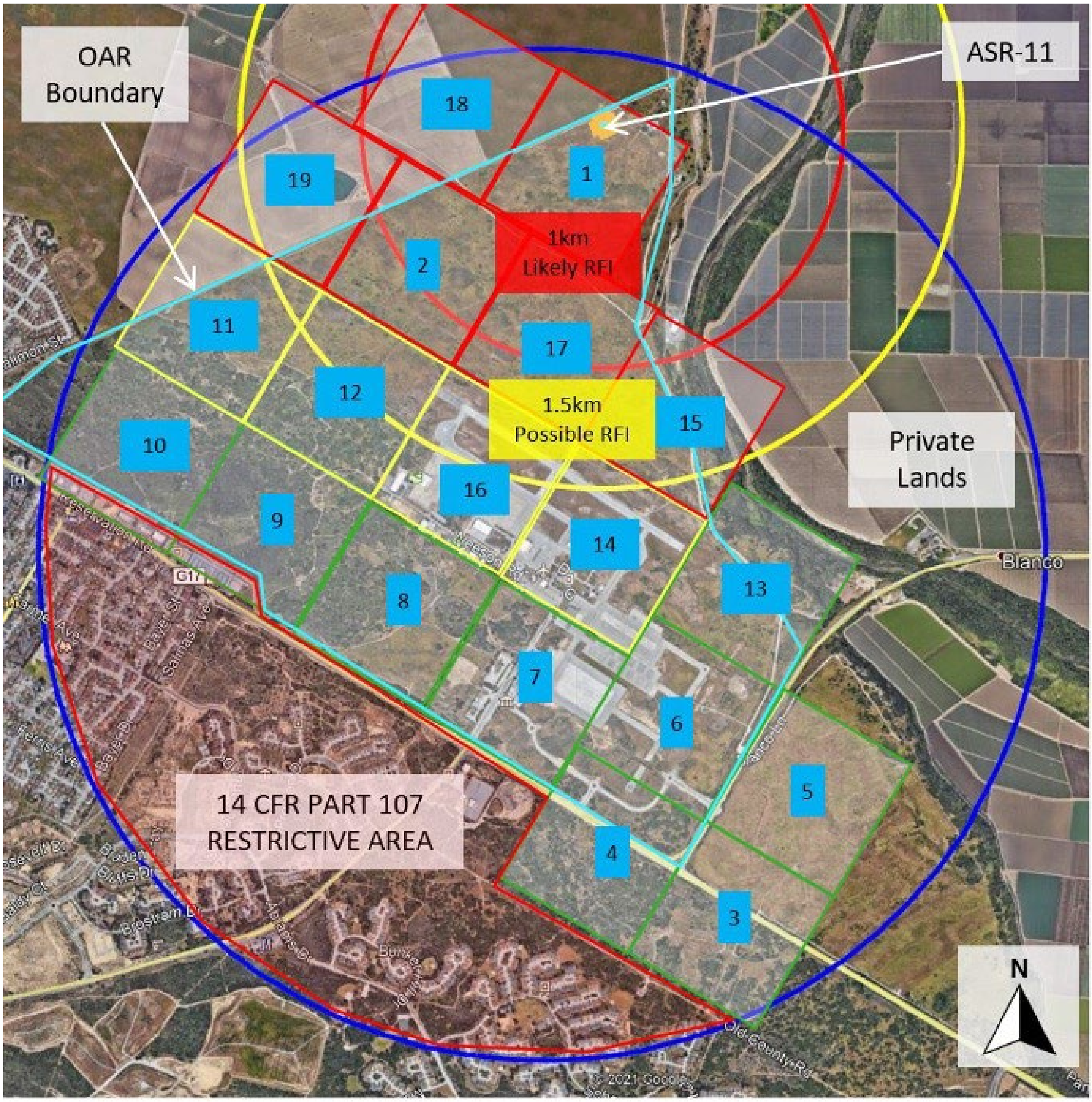


Figure 2.21. Lidar Survey KOAR ASR-11 Radio Frequency Interference (RFI).

<u>Survey/Facility #2</u>: The contractor conducted one survey using photogrammetry as the primary sensor to acquire a point-cloud data set for 4 nm^2. The survey area is a representative of an AAM environment with buildings, vertiports, and varying obstacles with representative dimensions for the 4 nm^2 area. The point-cloud resolution contained at least 1 point per m^2 and also included sufficient resolution to define terrain and obstacles in the immediate vicinity of the vertiport. The survey demonstrated the expected capabilities of photogrammetry to detect narrow obstacles such as towers, power lines, and treetops with respect to Vertical Takeoff and Landing (VTOL) aircraft procedure development.

2.4 Flight Test Infrastructure

In addition to landing surface processes and preparation for safe operations, was developing processes for range assets and instrumentation to enable accurate flight tests with valuable data.

The following topics are discussed in the this section: *Ground Range Assets, Data Systems and Processes* and *Flight Test Data Instrumentation.*

Ground Range Assets:

The NC team developed the necessary ground range instrumentation to enable guidance and atmospheric data Dry Run flight tests: *PLASI Approach Lighting System* and *Mission Control Center Portable Weather Stations.*

PLASI Approach Lighting System

Portable Pulse Light Approach Slope Indicators (PLASIs) provide visual guidance to support simulated IMC approaches to UAM Helipads and UAM Vertiports (all approaches will be flown in visual meteorological conditions) and will be positioned to support varying approach headings. Three PLASIs were procured for the NC Dry Run Flight Test to support the flight test sequence for each research sortie. The PLASIs have been modified to enable research objectives for UAM approach glidepath angle (GPA) guidance from 6 to 12 degrees, in 0.5-degree increments. The PLASI is a ground-installed, self-contained device which, visually provides vertical glide path information which includes: “Above glidepath,” “On glidepath,” “Slightly Below glidepath,” and “Below glidepath” indications. The effective width of the beam was at least 10 degrees and the minimum range (day or night) was at least 2 miles at AFRC. The PLASI shall be located adjacent (left or right) and aligned with the UAM approach path 10 feet outside of the 60-foot radial FATO (70-foot radial distance from the center of the TLOF or intended Landing Spot). The beam angle will be set to the test glidepath angle. This location assures Approach and Departure (obstacle clearance) surfaces specified in the FAA Heliport and Vertiport Design Advisory Circular. With this placement, the PLASI provides vertical guidance on UAM approaches down to 125+/-40 feet above ground level (AGL).

PLASI Guidance for UAM Approaches

Simulated Research AAM instrument approaches were flown in Dry Run in Visual Meteorological Conditions (VMC), at varying GPAs, and under various environmental conditions, in a simulated “urban environment” (9 degrees +/- 2 degrees GPA). Landing zones in proximity of structures, obstacles, and winds representative of the urban environment were evaluated. Pilot cueing was provided by a visual approach aid PLASI and/or via verbal guidance callouts sourced from the FIAPA research Course Deviation Indicator (CDI) and/or other external visual aids. Flight characteristics were measured across a range of GPAs and approach headings under varying wind conditions.

PLASI Instrumentation

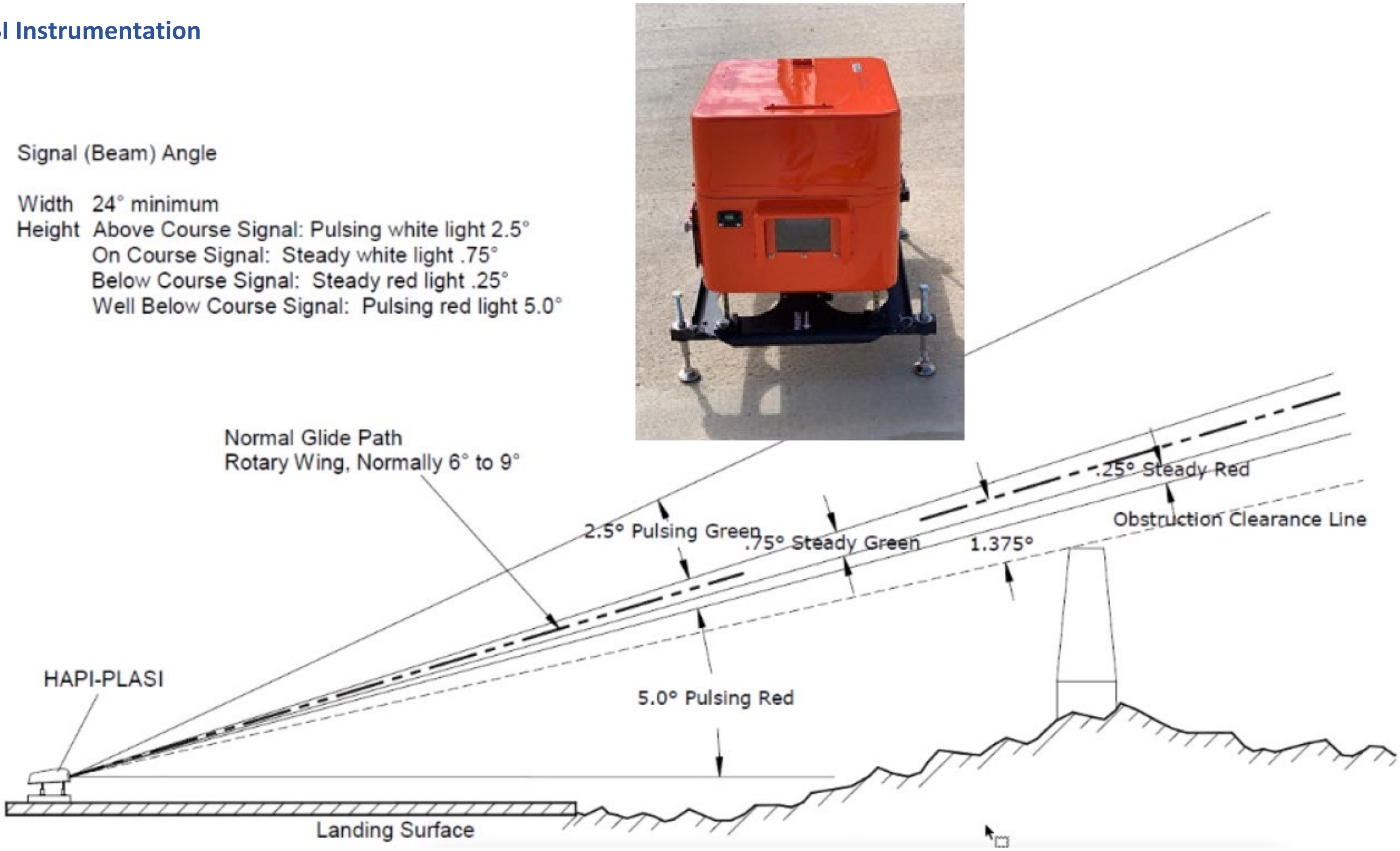


Figure 2.22. PLASI Light Frequency Indications.

Mission Control Center Portable Weather Stations

The AFRC weather team operates a fleet of surface weather station suites that are customizable to project requirements. The systems measure weather conditions near ground level with the capability to retain and relay measurements at customizable intervals.

Measurement of Surface Weather Conditions

Surface sensors measure temperature, humidity, pressure, wind speed, wind direction, solar radiation, GPS location and time synchronization. The unit includes mounting hardware and cabling (1 set per station). Sensors are required to collect measurements at a minimum of 1-second intervals for post-processed data and at 1 minute to 2 minute intervals for real-time data.

Weather Stations Internal System Data Collection

Data loggers with mounting hardware and cabling (1 set per station) within the internal data systems are required to (1) collect measurements at a minimum of 1-second intervals for post-processed data and at 1-2-minute intervals for real-time data; and (2) store measurements for a minimum of 24 hours.

Weather Stations Equipment Specifications

Weather Stations are powered with a 20W solar panel, charge regulator, 24Ah/12V battery, mounting hardware and cabling (1 set per station). The set up and stabilization of weather sensors utilizes a tripod with leg fasteners (1 set per station); and 25-pound sandbags (at least 5 per station). Weather stations can be communicated with via laptop computer, using software compatible with each data logger, Wi-Fi hotspots, and cabling (1 set per field meteorologist), cellular modems, antennas, mounting hardware, and cabling (1 set per station). Communication with the mission controller is by way of handheld land mobile radio (LMR), post-processed with data distributed via laptop computer, software (with USB drive). Weather stations are transported via customized government vehicle designed to carry portable weather stations.

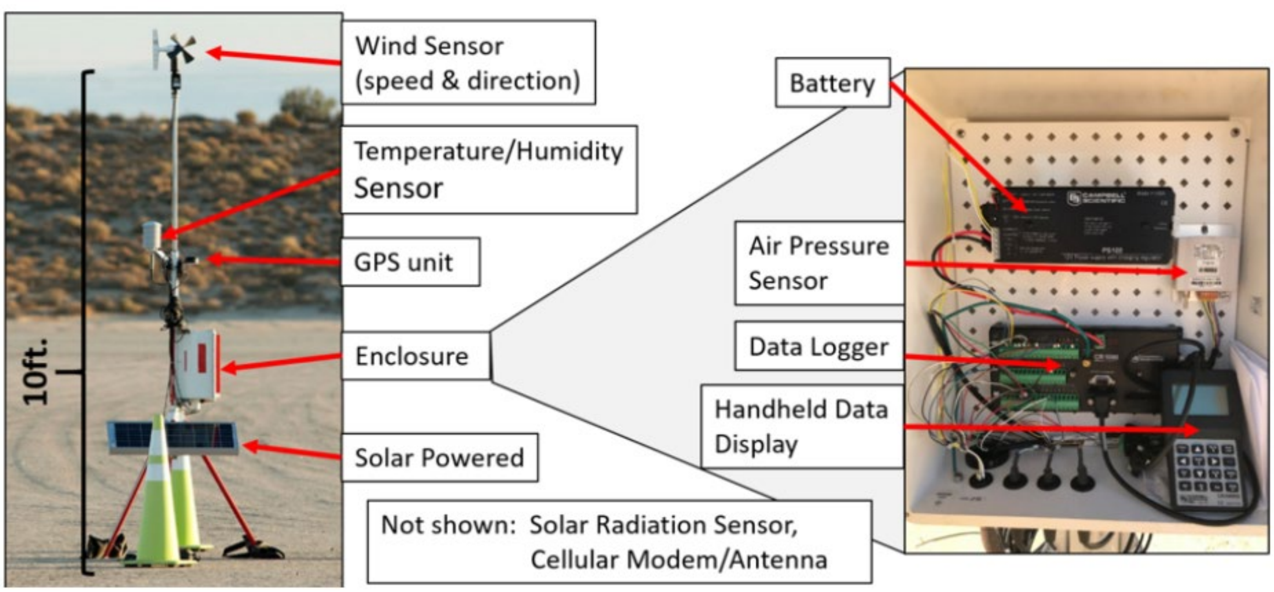


Figure 2.23. Mission Control Center Portable Weather Station Instruments.

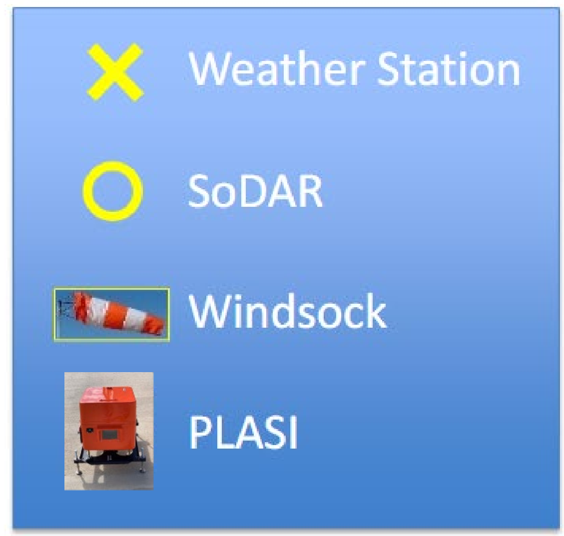
Flight Test Infrastructure Ground Assets:

Ground Support Equipment Layout@ Northern Helipad XX33

Figure 2.24. National Campaign Ground Equipment XX33.

Calculated downwash is about 32 knots 25ft below the aircraft, dissipating to 50% roughly 2 rotorspans (70ft) from the vehicle and virtually 0% 4 rotorspans (140ft) away.

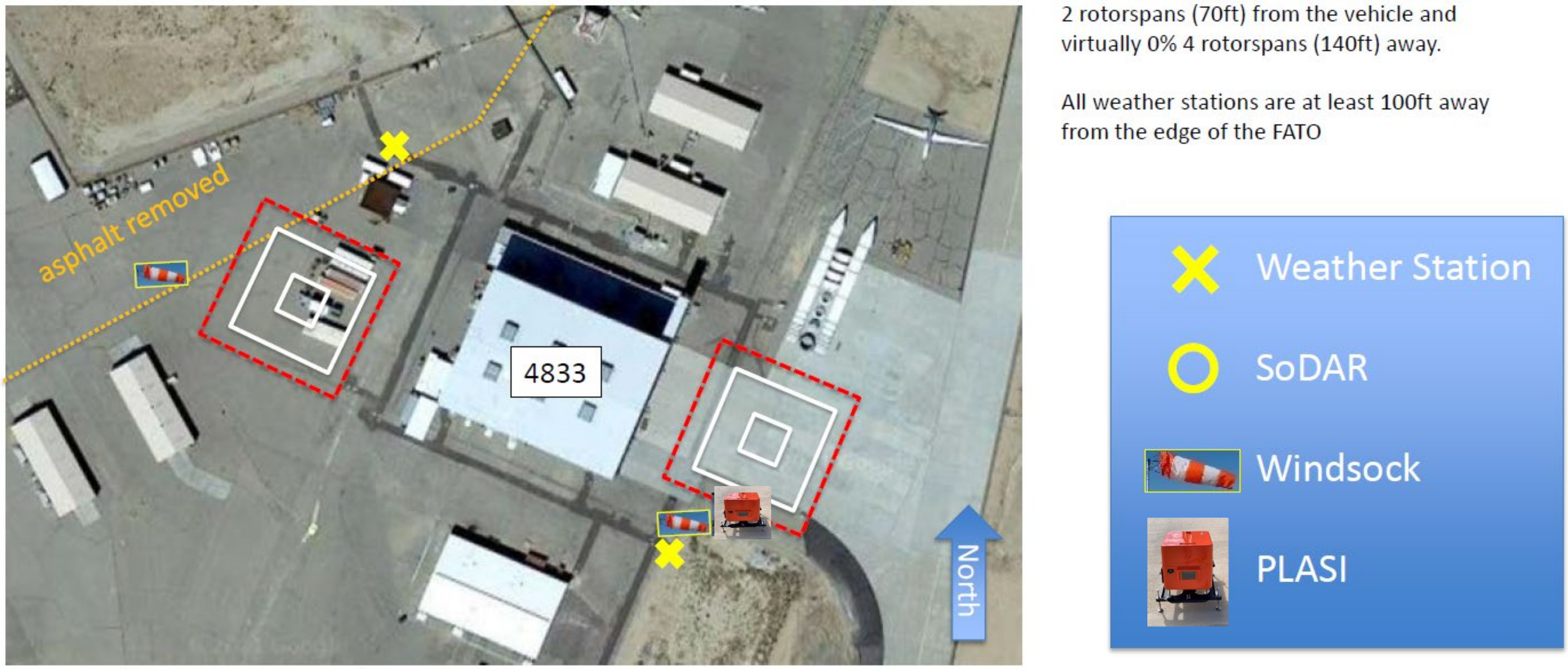
All weather stations are at least 100ft away from the edge of the FATO



Ground Support Equipment Layout @ Bldg. 4833 XEDW

Calculated downwash is about 32 knots 25ft below the aircraft, dissipating to 50% roughly 2 rotorspans (70ft) from the vehicle and virtually 0% 4 rotorspans (140ft) away.

All weather stations are at least 100ft away from the edge of the FATO



03H (West side of 4833) will not be used but the GSE remains in place

Figure 2.25. National Campaign Ground Equipment XEDW.

Ground Support Equipment Layout:

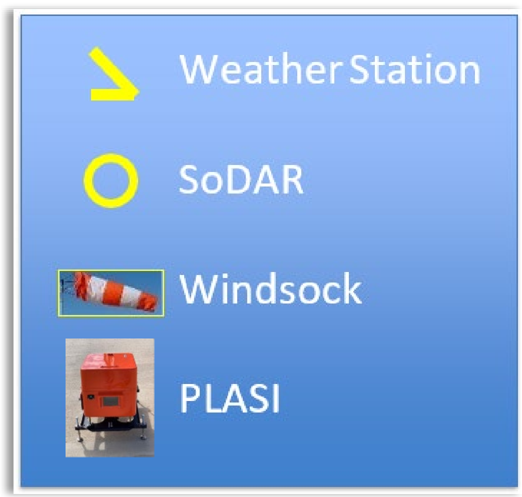
Runway 19-01 XVPT

Figure 2.26. National Campaign Ground Equipment XVPT.

Calculated downwash is about 32 knots 25 feet below the aircraft, dissipating to roughly 50%

2 rotor spans (70 ft.) from the vehicle and virtually 0% 4 rotor spans (140 feet) away

All weather stations are at least 100 feet away from the edge of the FATO



Mission Control Center Mobile Mini-SODAR

The AFRC weather team operates a fleet of Sonic Detection and Ranging (SODAR) units, including one mobile unit that was deployed for the NC Dry Run and Developmental Testing activities. The SODAR units measure low-altitude winds using sound pulses that reflect off of density variations in the atmosphere.

Measurement of Wind Conditions Aloft

SODAR unit mounted on accompanying trailer. The system is required to: (1) provide wind speed and direction; and (2) aloft be placed in an appropriate location on the test range per vendor specifications. Placement of the SODAR must be at least the same horizontal distance as its maximum vertical measurement distance from noise and echo sources in order to receive valid wind measurements. Data resolutions for the unit used are 2-minute wind speed and direction between 20 and 250 meters above ground level every 5 minutes.

Equipment Specifications

SODAR has 2 100W solar panels, charge regulator, 3 - 245Ah/12V batteries, mounting hardware, cabling, enclosures for the battery and charge regulator. Data are post-processed via laptop computer, software, formatted USB drive. SODAR is transported via a government vehicle customized to tow the SODAR trailer.

Figure 2.27. National Campaign SoDAR Unit.

Data Systems and Processes:

Airspace, Range, and Vehicle Systems are all within the FTI system-of-systems. Both real-time and post-flight interfaces are managed by ATI data services to record, deliver, store, and manage NC flight event data. Three software processes were utilized to collect real-time data during flight test events.

The following topics are discussed in the this section: *Data Systems, Software Processes, Graphical User Interfaces* and *Flight Test Visualizations*.

<u>Data Systems</u>

Data enter through the FTI system via the cloud and other networks for real-time visualization and long-term storage in a secure data repository. The general flow of data below is as follows and shown in Figure 2.28: from the upper left in the vehicle subsystem (purple), down to the range assets on the bottom (green), and to the right through a cloud network (blue). The NC team requires both real-time and post-ops requirements in support of FTI, as indicated by the red and orange ovals. Two-way communication existed between range assets and airspace assets.

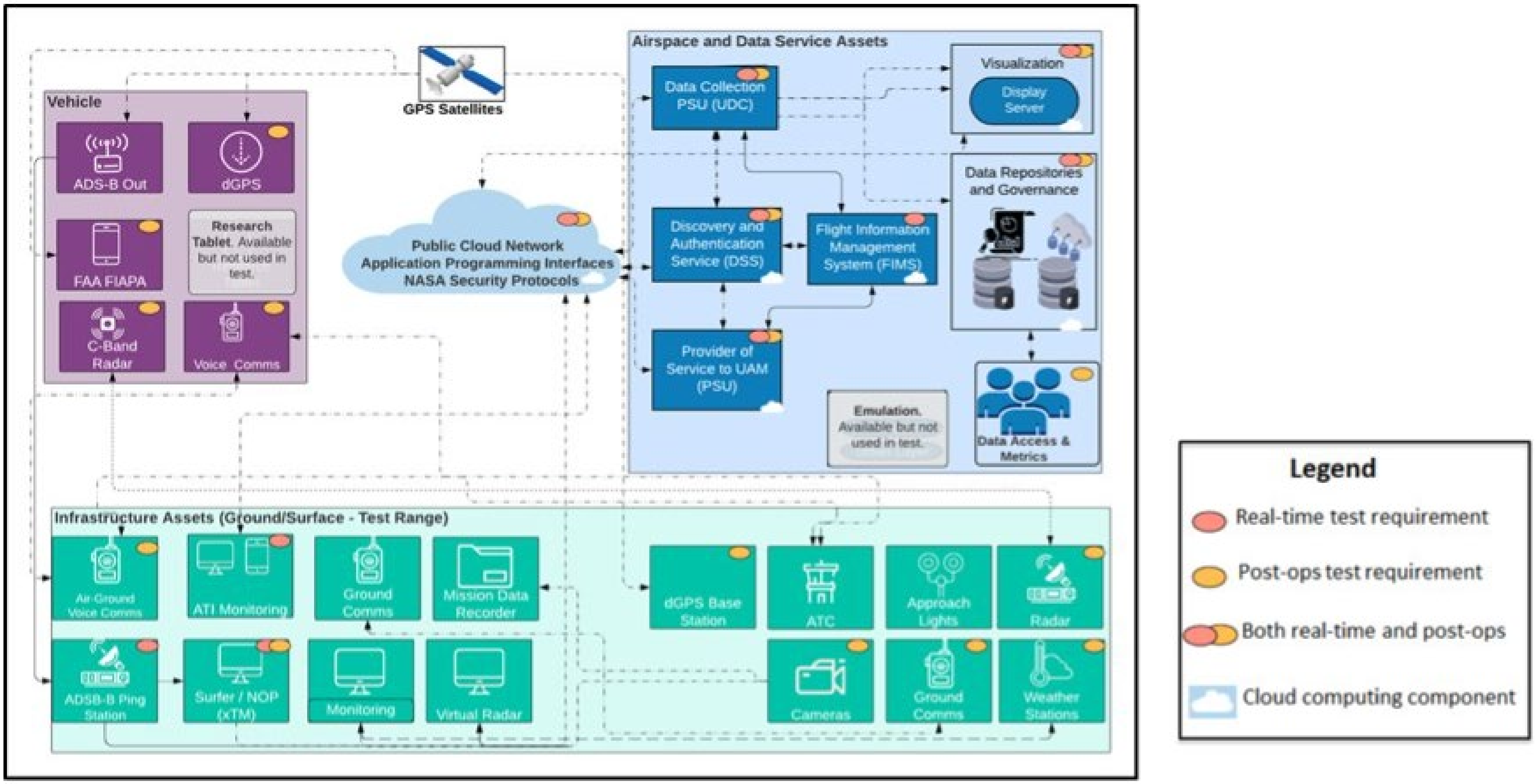


Figure 2.28. Flight Test Infrastructure Interface Diagram.

Software Processes

Airspace, Range, and Vehicle Systems are all within the FTI system-of-systems. Both real-time and post-flight interfaces are managed by ATI data services to record, deliver, store, and manage NC flight event data.

Three software processes were utilized to collect real-time data during flight test events*: Simple UDP Receiver Filter Extractor Router (SURFER), Universal Data Collector (UDC)* and *XTM Client.*

SURFER

One working requirement of the UAM CONOPS (as well as the Unmanned Traffic Management, or UTM, CONOPS), is continuous position reporting during an operation of the aircraft from the operator to the PSU (or UAM Service Supplier provider (USS)). The position reports allow the service supplier to perform conformance monitoring ensuring that the aircraft is conforming to the active Operation Intent. The current working requirement calls for these position reports every one second (1 Hz). The SURFER supports instrumentation like ADS-B. Figure 2.29 illustrates the network configuration utilized for ADS-B data collection. The network configuration involved the ADS-B receiver, a network switch on the AFRC network and the IP address of the ATI 2 laptop in the form of user datagram protocol (UDP) packets which were forwarded to the UDC. Messages persist in SURFER on the ATI 2 laptop.

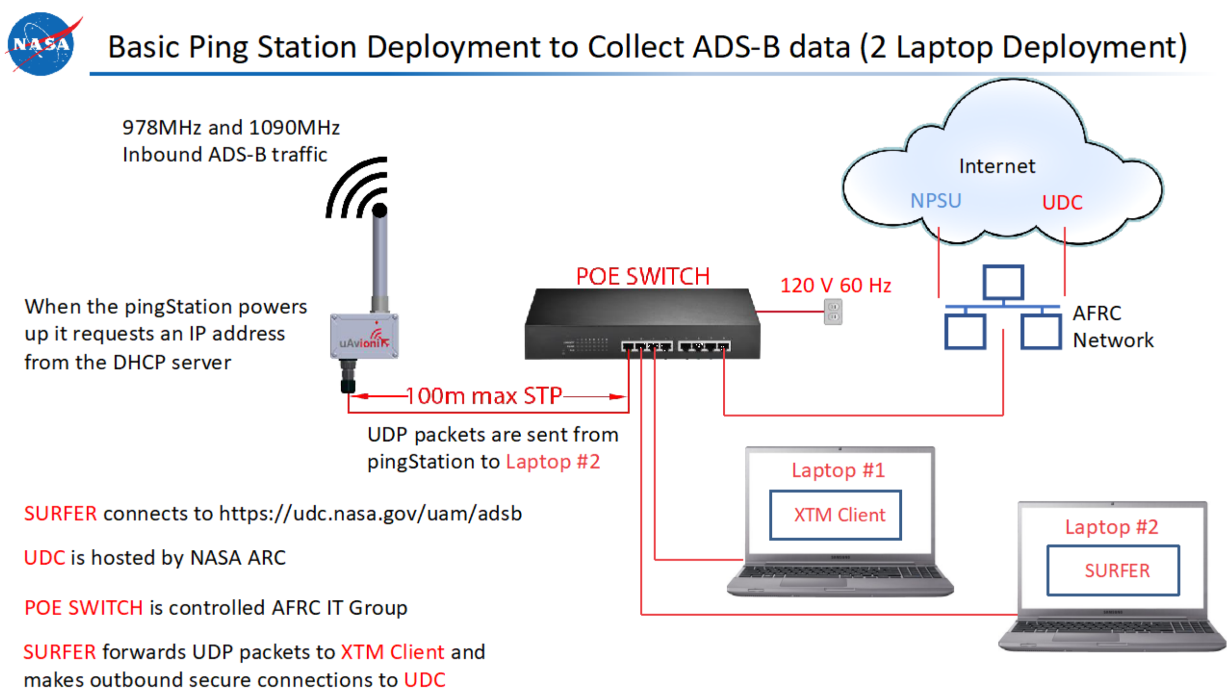


Figure 2.29. PingStation Configuration via SURFER.

UDC (Universal Data Collector)

The UDC enables real-time logging of information received from multiple partners that is relevant to UAM operations, such as messages, positions, surveillance, and airspace volume reservations. If the UDC is registered in a grid cell that a partner USS is using, then it will collect operational data exchanged between any USS within the network in a "listen-only" way.

Real-time ADS-B data were propagated to multiple display clients for live visualizations (e.g.; iUTM; Google Earth; or the Grafana open-source application). For the purpose of the Dry Run Connectivity Test, the pingStation pushed raw UDP packets to SURFER, a secure client, which then forwarded secured UDP packets to the UDC. The UDC then forwarded the ADS-B data to the Data Pipeline which was used by the Grafana dashboard. All data sent to the UDC are persisted on ARC Airspace Operations Lab (AOL) servers.

XTM Client

The Experimental Traffic Management (xTM) Client application is a Web-based User Interface (UI) serving as the gateway between the operator and the NASA Provider of Services for UAM (NPSU). The Client enables the vehicle operator to submit operations to the NPSU and receive as well as display information about the status of the proposed operation. For the purposes of the Dry Run Connectivity Testing, the xTM Client leveraged the NASA PSU (NPSU) to exchange operations, messages, and positions. All data collected from the xTM Client were stored locally on the ATI 1 laptop.

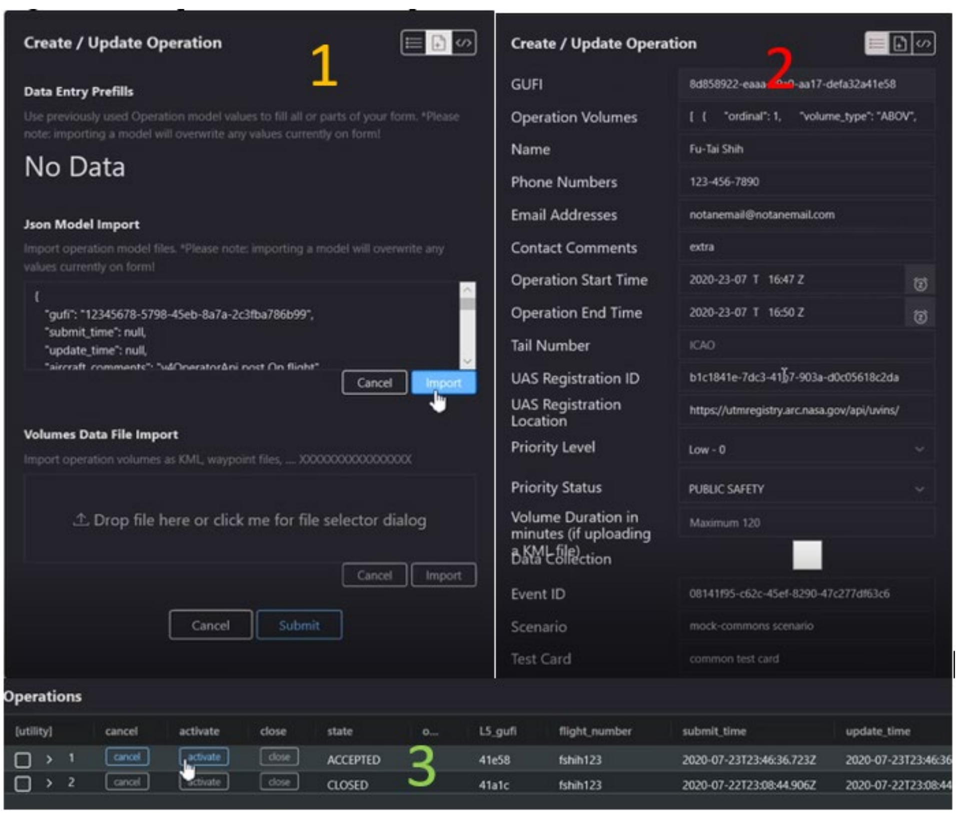


Figure 2.30. xTM Client.

Graphical User Interfaces

Two graphical user interface (GUI) components were developed for the NC Dry Run: *Event Marker GUI* and *Flight Test Monitor GUI.*

Event Marker GUI

The NC team developed a SURFER and Flight Event Marker system graphical user interface (GUI). The interface was used to monitor the connectivity and throughput of ADS-B data through the real-time ADS-B network and to enter events as dictated by the OH-58C helicopter crew. The event marker provides valuable metadata to the NC data systems and repositories for useful post-flight retrieval and analysis.

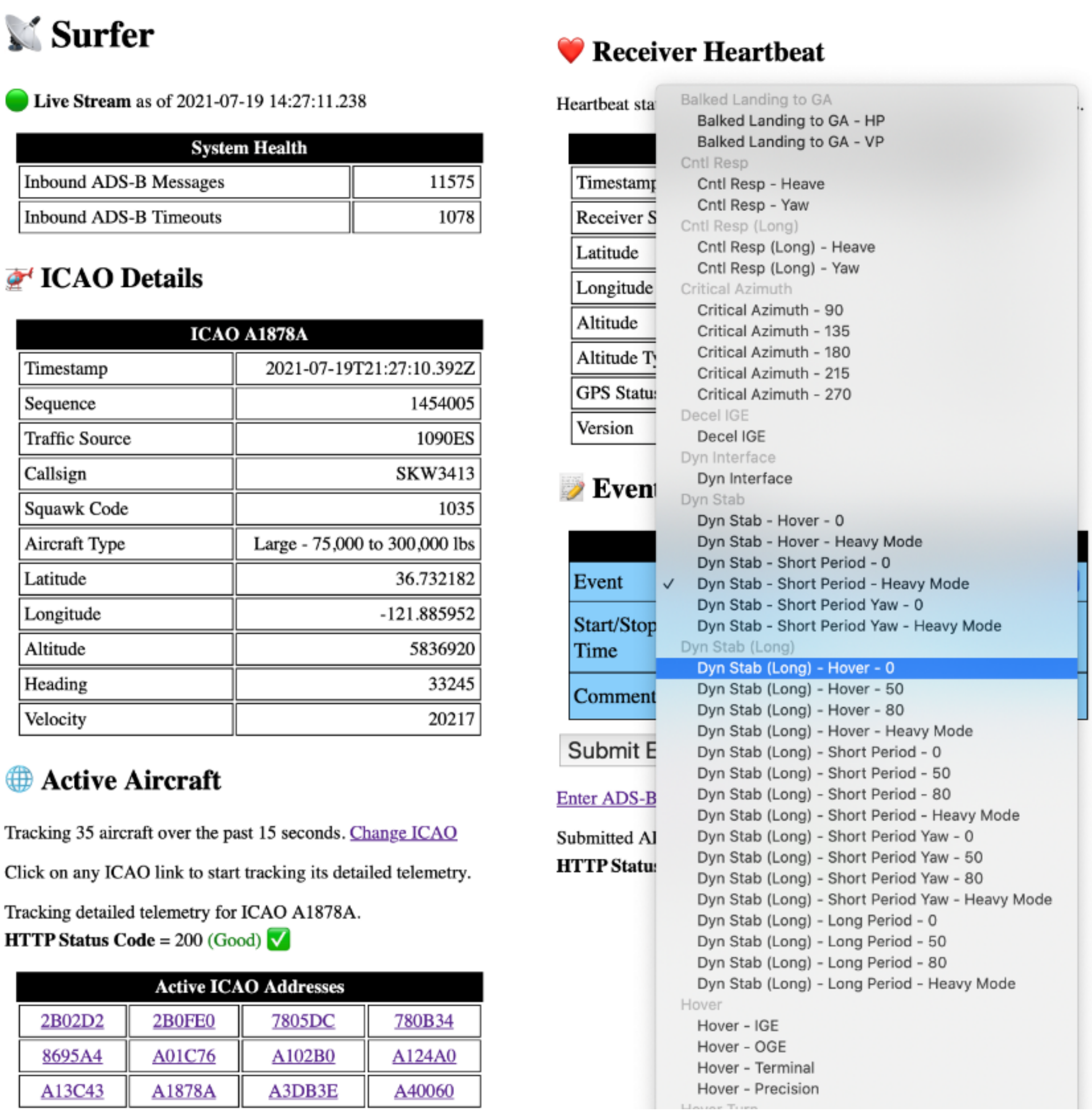


Figure 2.31. SURFER and Build 2 Follow-On Flight Test Event Marker.

Flight Test Monitor GUI

The FTI GUIs were used by ATI personnel during flight tests, including the monitors that were available. The ATI personnel were allocated test-related duties to oversee and monitor the conduct of each test from the range.

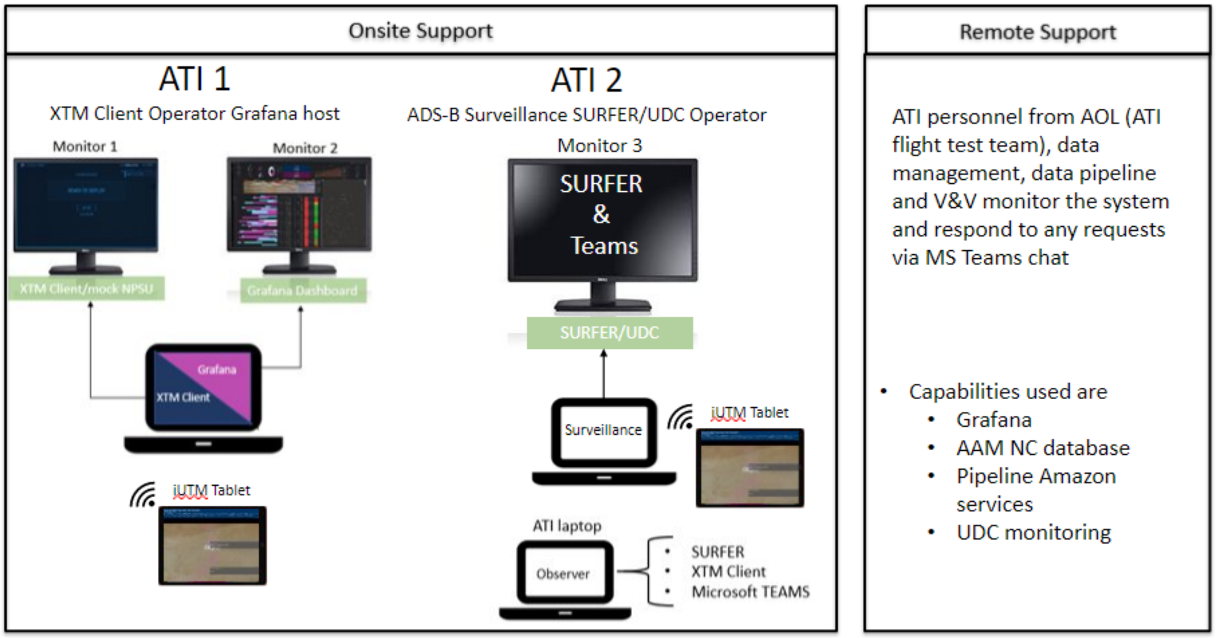


Figure 2.32. Overview of onsite and offsite support and GUI resources.

Flight Test Visualization

The ADS-B data from the OH-58C helicopter that was received by surveillance tools such as the uAvionix pingStation, SURFER, and the UDC were forwarded through the Data Pipeline to data visualization software. Two data visualization tools were used: the Grafana dashboard and the NASA-developed Insight UAS Traffic Management (iUTM) application. Data visualization tools allowed researchers to visually track the flight in real time from remote locations. The Grafana open-source application and iUTM served researchers real-time data visualizations both in the MCC and in the Airspace Operations Lab (AOL). The following Flight Test Visualizations were utitlized: *Grafana Dashboard* and *IUTM*.

Grafana Dashboard

The Grafana dashboard is built on a Web-based, open-source platform and is used to create visualization displays for either real-time or historical operational data, 3D displays, or position reports (Figure 2.33). As incoming operational data collected by the UDC are shared through the data pipeline, they appear on the Grafana dashboard in the form of 2D or 3D maps. The dashboards are non-interactive for the front-end user because the framework segregates the data-source layer which manages all data exchanges and back-end operations from the visualization layer.

Figure 2.33. Grafana 3D Visualization Display for Real-Time Tracking.

iUTM

iUTM is a NASA-developed tool used for tracking and displaying multiple aircraft operations simultaneously. The tool hosts an interactive user interface which displays aircraft information such as vehicle type, speed, altitude, and current vehicle location. Real-time data from the UDC are used to provide the underlying data that are displayed in the iUTM user interface.

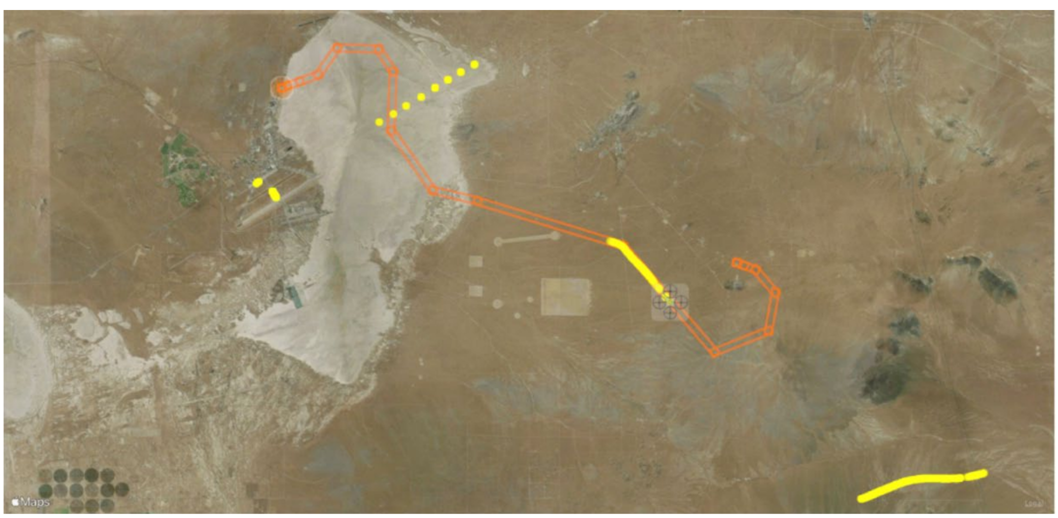


Figure 2.34. iUTM User Display.

Flight Test Data Services:

The following topics are discussed in the this section: *Data Repositories, Timestamp Synchronization, Fusion and Modeling: Integrated Data Product, Aerograph* and *Data Governance.*

Post-Flight Data Transfer

National Campaign representatives having appropriate NASA credentials transferred data generated by Vehicle and Range domains to an access-controlled Box cloud-storage location. Due to the high volume of post-flight data, each point of contact (POC) was provided with a metadata Comma Separated File

(CSV) file template along with instructions to populate the metadata file associated with each data file. The ATI developers then downloaded this source, raw data, and executed automated scripts to ingest the data and metadata information into the appropriate NC data repositories.

Data Repositories

Several different software resources comprise the AAM NC data repository. The repository consists of Amazon Web Service (AWS) Simple Storage Structure (S3) subsystems (also known as "S3 buckets"); AWS Relational Data Store (RDS) instances; and other NASA internal databases which include state-of-the-art database technologies such as graph and time series databases.

Timestamp Synchronization

Data ingested from disparate data sources that were recorded independently require synchronization to support meaningful output and findings from data. This challenge was addressed by documenting data source availability (real-time versus post-flight), clock synchronization source, and data output format from data source SMEs. Airspace domain data were recorded in Coordinated Universal Time (UTC), and utilized clocks synchronized via Network Time Protocol (NTP). Real-time data were transmitted through the NC ATI system at a granularity within 100 milliseconds. Each post-flight data source was synchronized with the GPS time scale maintained by GPS satellites and provided by atomic clocks in the GPS ground control stations. The GPS times were also normalized to the UTC time stamp standard by Extract, Transform, and Load (ETL) Data adapters when UTC was not available in the raw output. The ETL Data adapters factored in the time difference between GPS and UTC while transforming data records prior to being uploaded to databases. The UTC-GPS offset was tracked and applied. The NC ATI system accepted, preserved, and stored data at the highest level of precision available from the native source.

Time Syncronization Process

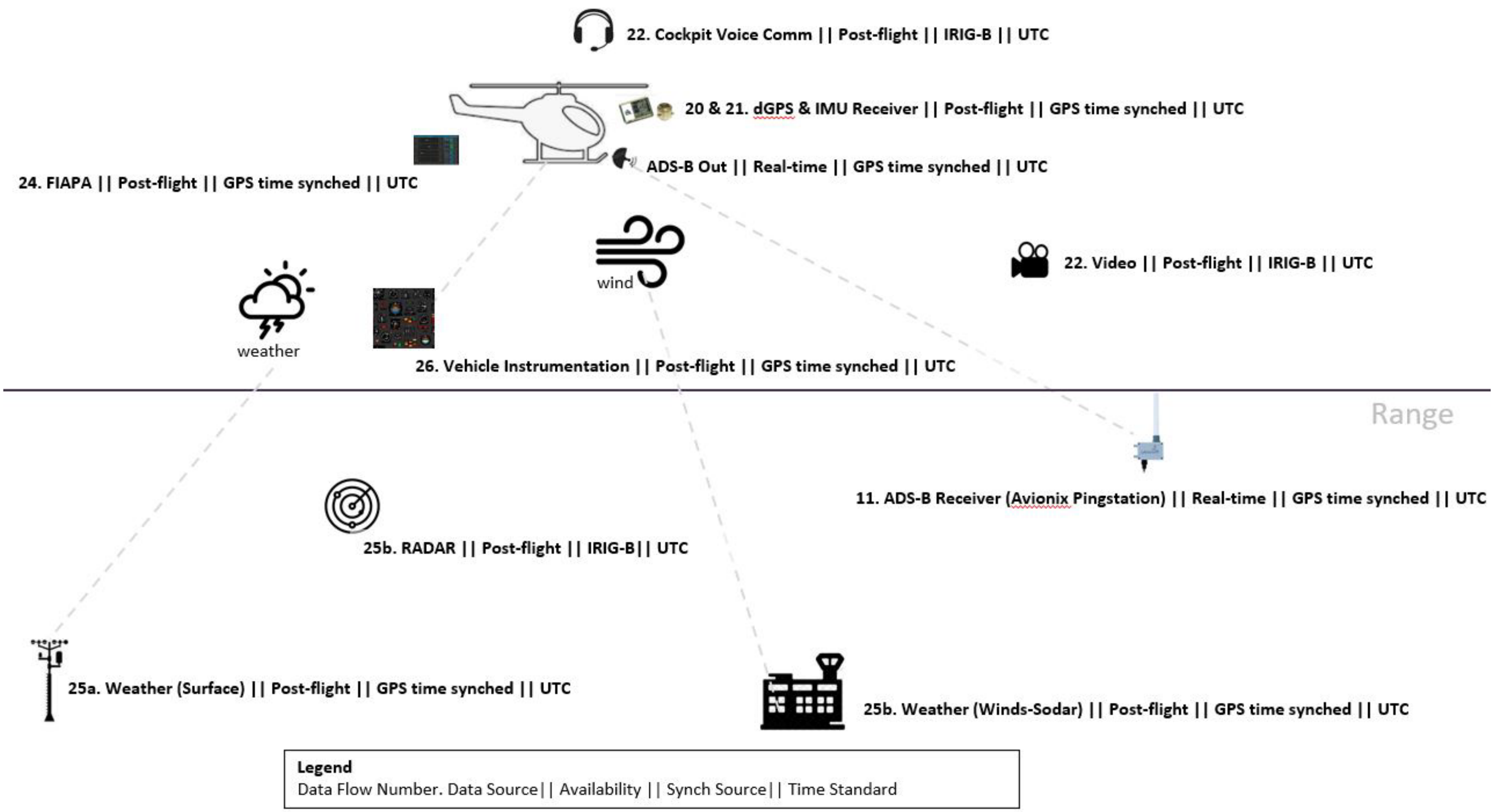


Figure 2.35. Time Synchronization across National Campaign Data Sources.

Fusion and Modeling: Integrated Data Product

Data across various disparate instruments and data rates require processing, cleaning, and synching. The AAM Integrated Data Product (IDP) is a combined dataset that provides a holistic view of an individual flight event sortie. The IDP currently integrates Interactive Authoring and Display Software (IADS), differential global positioning system (DGPS), SODAR, ADS-B Surveillance Broadcast Services Monitor (SBSM), ADS-B pingStation, and Surface Weather data using the IADS timestamp as the base frequency of record (which is approximately 40 Hz or 40 records per second). Other data sources, which report at lower frequencies are left-merged onto IADS using their respective timestamp columns as merge keys and using a "back-filled" value merge, such that the last reported value is duplicated to fill the higher-frequency IADS data. Each IDP file represents one sortie.

To reduce size and assist researchers with relevant data intervals, original SODAR data, which contain wind data up to an altitude of 250 meters at 5-meter intervals, are focused in the IDP so that only the SODAR data for the actual altitude of the aircraft is displayed. Also included are the SODAR data for +-20 meters of the aircraft at 5-meter intervals so that the IDP has the actual altitude-based wind data for aircraft height as well as a little above and a little below the aircraft as long as the aircraft is at or below the 250-meter SODAR height limit.

The IDP also includes several minor feature-engineered columns or modified names, such as converting altitude columns from meters to feet (keeping and labeling both) and horizontal, vertical, and slant distances of the aircraft to the 01H vertiport and to the SODAR instrument.

The generation of the IDP yields a dataset file in both CSV and in Apache Parquet open-source file formats, as well as "cleaned" versions of the input data sources (IADS, DGPS, and SODAR).

To complement the IDP, ATI personnel developed an AAM IDP data dictionary which defines each field of the integrated data set.

The NC IDP is undergoing refinement to standardize attribute names across data instrumentation to account for different NC overarching goals that will become different foci across future flight events, and support differences in vehicle partners and instrumentation across upcoming NC-1 activities. The new IDP will also flex and shrink to customize various partner systems. Additionally, the new IDP will likely be processed with a null-fill technique whereby lower frequency data are reported at the actual time of reception and null, or blank, against higher frequencies.

Knowledge Graph System

Aerograph is the NASA official data management system for the NC. The primary purpose behind Aerograph is to support AAM research by providing a reliable and secure data management system that collects, stores, protects, and shares NC data. The overarching goal is to provide a system that AAM research scientists, aerospace engineers, data scientists, and analysts trust for obtaining NC data and performing key analyses.

An intuitive Aerograph User Interface provides qualified aerospace engineers, analysts, scientists, researchers, and other SMEs with secure access to raw and processed flight test data, as well as automated reports that share data views, figures, and charts. Automated reports help fulfill a NC goal to provide repeatable views and metrics across flight tests.

Data Governance

Data Governance is a framework of principles and processes that ensure the secure management of proprietary AAM NC data from NASA and external partners. Dry Run data were managed as a business asset, and formal accountability was established. Data quality was defined and managed consistently across the life cycle of data, in compliance with Findability, Accessibility, Interoperability, and Reuse (FAIR) principles. In addition to the official records maintained by the NASA Asset Management System (NAMS), the Data Management Team documented data sharing on the Confluence™ Collaboration Tool (Atlassian, Sydney, Australia). These records also included low-level decisions that did not impact governance policy or the NC project as a whole. Higher-level data-sharing decisions were brought up by the Data Management Team through AAM NC Management, Agency (NASA, the FAA, et cetera), Aeronautics Research Mission Directorate, Center Boards, other Boards (Security Management, Applications, Cloud, et cetera) and the NASA Data Governance Board (DGB) as appropriate.

Data governance policies allow NASA-badged personnel and external partners with NAMS-approved access privileges to view integrated data and utilize any tools or software necessary to analyze the data. User-specific access to data was granted to qualified individuals and organizations to the extent possible and when appropriate. Prior to gaining access, users consented to governance requirements and detailed audit trails of downloads with no expectation of privacy. Organizations desiring data access were required to maintain a chain-of-custody log prior to NAMS approval for new users. Data were released as needed from the data partners to the parties needing the information to conduct the NC planning and testing. Credentials were not to be shared (were for individual use only). Copies of the data – whether complete, partial, original, or transformed – were only to be transferred to individuals who consented to the data-sharing agreement. In addition to maintaining records of parties that received copies, the data-sharing agreement required users to track and preserve the versioning information provided to them and others (e.g., the date or the version number, or both, were embedded in file names).

In future builds, the Aerograph system is expected to provide a GUI to manage access and sharing of data. This approach would introduce an intuitive Web client with multi-faceted data access capabilities and role-based, secure access for NAMS-approved users. The GUI shall be suited for a variety of user experience levels, and an application programming interface (API) will also be available for Machine-to-Machine secure access for advanced users.

Table 2.36. Aerograph Features

Aerograph Features	
FEATURE	DESCRIPTION
Data Governance: • NAMS Approval • NASA Launchpad (SAML 2.0) Authentication • Role-based Access Control/Authorization	AAM NC data must be carefully protected to ensure access is limited to only those formally approved by the program. • Candidate Aerograph users must have a NASA identity and be a U.S. citizen • Candidate Aerograph users must submit an official NAMS request. This NAMS request then proceeds through a NASA workflow where the requester is vetted and approved for Aerograph access. • Aerograph authenticates users using NASA Launchpad identity (SAML 2.0) Authentication (NASA personnel that have not been approved in the previous will not be allowed to log in) • Aerograph authorizes users via Role Based Access Control (RBAC). RBAC is another security layer atop authentication where users are assigned to roles with various privileges. Before allowing users to access certain data, Aerograph vets the user’s role against allowable roles for the data.

Raw and Processed Data: • Viewing • Downloading	• Aerograph allows qualified users to view and download both raw and processed data. Raw data may include files such as an unprocessed differential GPS data file (DGPS) or an unprocessed IADS data file. Aerograph will serve these files to the user in much the same structure as they are received from the data source manager. Processed data include custom data tables and data frames that the ATI team designed to facilitate AAM NC research and analysis. This includes files such as the Integrated Data Product (IDP). The capability to view and download data will depend on the user's privileges as specified by assigned groups and roles. Some users will only be able to view data, whereas other users will be able to view and download data. Depending on the data provenance (e.g., DT flight test data), some users will not be able to view or download data.
Flight Test Reports: • Viewing • Downloading	• Aerograph will automatically generate flight test reports with various tables, figures, charts, and other data views to characterize and explain flight test data. The goal is to generate these reports as soon as possible after a day of flight testing, providing key stakeholders with a common and standard view of data and metrics. The capability to view and download these reports will likewise depend on the user's privileges as specified by assigned groups and roles.

Knowledge Graph System

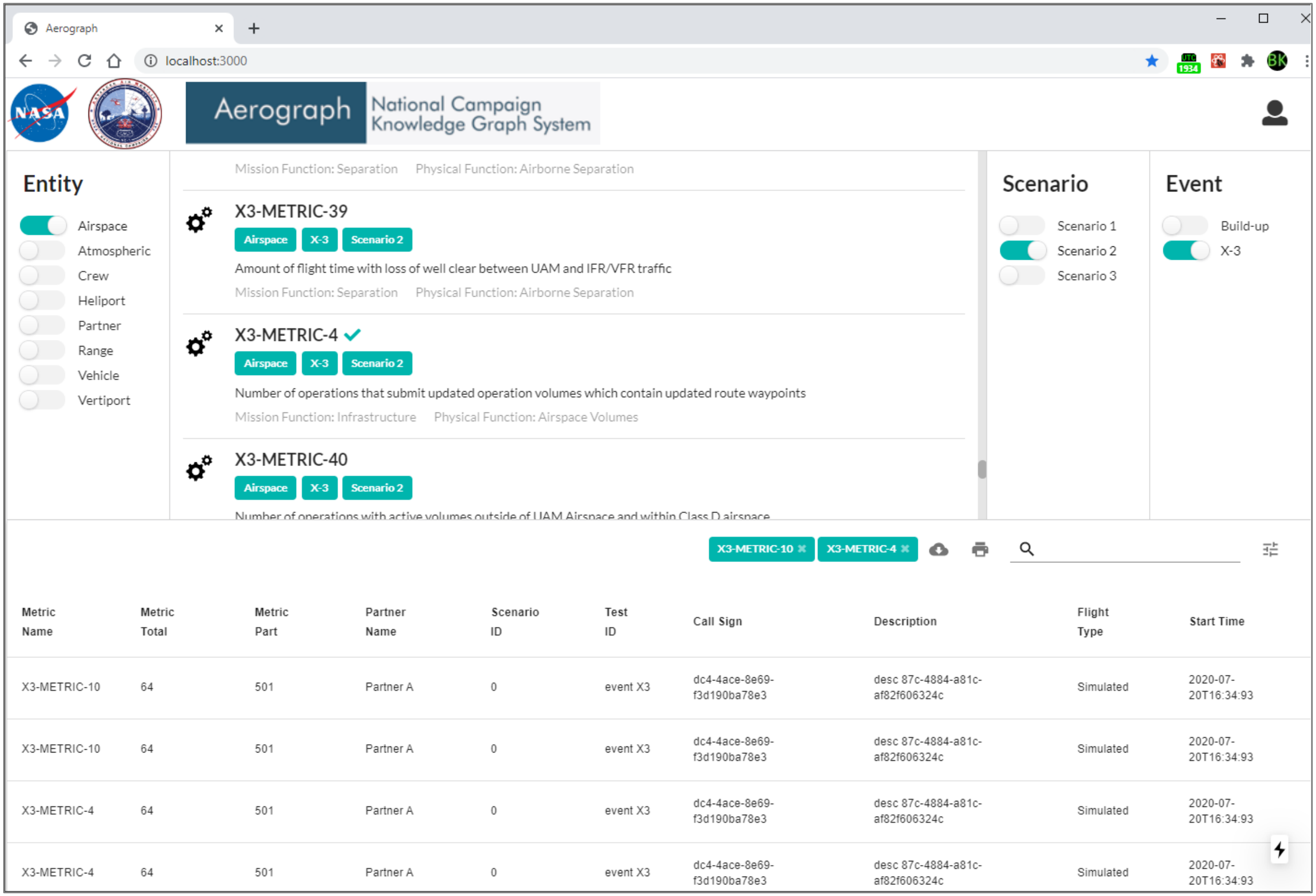


Figure 2.37. Aerograph Prototype for Access to Data Services.

Flight Test Data Instrumentation

The NC team provisioned instrumentation that covers data found within each aspect of operations. Data instrumentation covers flight surveillance, vehicle sensors (power, control, energy, status, position, rates, and acceleration), flight inspection software, time synchronization across instruments, differential Global Positioning System reference (DGPS), inertial data, weather via atmospheric condition instrumentation, acoustics evaluation equipment, and range safety and recording instruments. Data are expected to expand in great volume as research expands to sensor data on vehicles and airspace technologies in NC-1.

Instrumentation

Data Instrument	Data Attribute Types	Data Instrument	Data Attribute Types
FAA ADS-B & Pingstation ADS-B	Signal Integrity Velocities Engage Settings Position	Differential-GPS & IMU	Signal Integrity Velocities Position Attitude & Rates
Vehicle Sensors	Power Parameters Collective Positioning Energy Management Motor & Rotor Status Pressure Status Attitude & Rates Acceleration	SODAR, Radar & Surface Weather Stations	Temperature Solar Radiation Air Pressure Relative Humidity Wind Speed Wind Gusts Wind Direction
FAA Flight Inspection (FIAPA)	Position Tolerance Flight Technical Error ARINC Experimental Route Coding	Acoustics	Microphone Arrays Acoustic System Acoustic Weather
Synchronized Time	Stored as Coordinated Universal Time (UTC)	Reports & Recordings	Observations Test Cards Flight Reports Voice Communications Terminal Video

Data Instrument	Data Attribute Types
(NPSU) NASA Provider of Services for UAM	Exchange Messaging Exchange Timing Trajectory Monitoring Communication Protocols Discovery Services Authorization

Data Instrument	Data Columns
SBSM ADS-B	0395
Pingstation ADS-B	0033
Vehicle Sensors	0030
FIAPA	~49
d-GPS	0013
IMU	0025
Radar	0033
SODAR	1127
Weather Stations	0007
Acoustics	~20
X3 NPSU Metrics	0036
TOTAL	+/- 1750 Attributes

Credits: NASA Armstrong Range, Weather & Acoustics Teams

Figure 2.38. National Campaign Collections of Data.

The following topics are discussed in the this section: *Interactive Authoring Display Software, ADS-B SBSM, Real-Time ADS-B Pingstation, Portable Real-Time ADS-B Pingstation, Video, Audio, Radar, Flight Inspection Airborne Processor Application, dGPS & IMU* and *Test Cards & Dance Cards.*

Interactive Authoring Display Software

The OH-58C helicopter was equipped with an instrumentation system that sent real-time telemetry data to a server connected to the IADS, which allowed for monitoring of most onboard instrumentation sensors from a display client located in the control room (NC Build 2 Control Room Plan). An instrumentation technician from FRI converted the flight recorder data collected from the front-end system (Omega 3000 series) to .csv format, with output timestamps conformant to GPS syncing requirements. Following post-processing, the exported data were transmitted to the NC Range representative responsible for uploading to the internal NASA Box cloud for post-flight consumption.

Table 2.39. Surrogate Vehicle Interactive Authoring Display Software Attributes and Parameters

Parameter	Range	Units
Airspeed	0 to 120	KIAS
Altitude	0 to 20,000	ft
N_1	0 to 100	%
N_R (Rotor RPM)	0 to 100	%
ϕ, Roll	+/-80	°
Θ, Pitch Attitude	+/-90	°
Ψ, Heading	0 to 360	°
P, Roll Rate	+/-50	°/s
Q, Pitch Rate	+/-50	°/s
R, Yaw Rate	+/-50	°/s
Nx, fwd accel	+/-8	g
Ny, side accel	+/-8	g
Nz, normal accel	+/-8	g
Static Pressure	0 to 15	PSI
Dynamic Pressure	+/-2	PSI
Collective Control Position	0 to 100	%
Lateral Control Position	0 to 100	%
Longitudinal Position	0 to 100	%
Directional Control Position	0 to 100	%
Throttle Position	0 to 100	%
Torque	0 to 100	%
β, sideslip	+/-90	°
OAT	0 to 100	° C

ADS-B SBSM

The FAA shared a secondary, post-flight source of ADS-B data leveraging SBSM system, which is a constellation of ADS-B receivers that provide sweeping coverage of the NAS in order to collect time, space, and position information (TSPI) for surveillance and signal quality checks for the flight events.

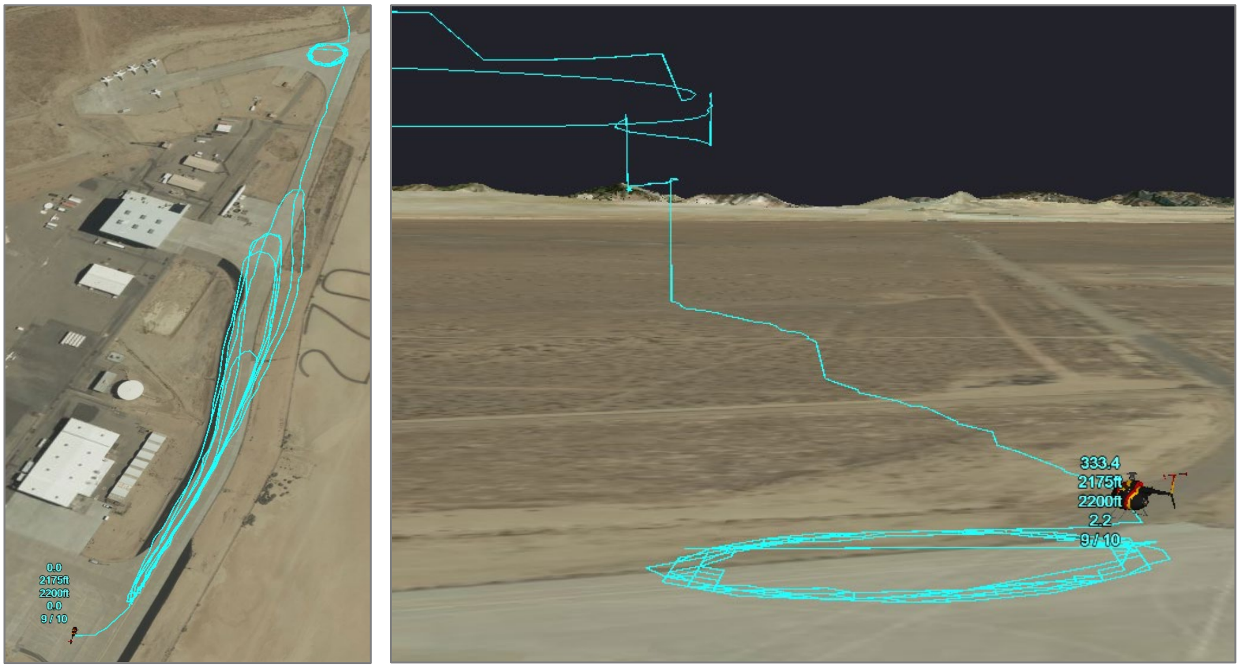


Figure 2.40. ADS-B SBSM track for pirouette and approach maneuvers.

Real-Time ADS-B Pingstation

Real-time position information for the surrogate vehicle was collected via the NASA ADS-B pingStation. The xTM Client collected position messages for the specific flight used in the test by filtering for ICAO address. The SURFER and the UDC collected ADS-B messages and latency metrics for all incoming messages from the pingStation, as well as Operation messages produced by the xTM Client. The pingStation was configured to send ADS-B data to the IP address of the ATI 2 laptop in the form of UDP packets. Though the pingStation may receive any ADS-B broadcast within range, the receiver was configured to filter out aircraft beyond a specified radius and altitude threshold to focus on aircraft within a reasonable proximity to the vehicle of interest (the OH-58C helicopter surrogate vehicle). The laptop ran the SURFER application to receive data as UDP packets, secure them, and forward them to the UDC. The UDC enabled the real-time logging of information received from multiple partners that is relevant to UAM operations, such as Operation and Vehicle Telemetry. Real-time ADS-B data were propagated to multiple display clients for live visualizations (e.g.; iUTM; Google Earth; or the Grafana open-source application) and forwarded to the Data Pipeline. All ADS-B messages were persisted in SURFER and stored on the ATI 2 laptop. All remaining data sources in this report were collected post-flight.

Portable Real-Time ADS-B Pingstation

A post-flight portable ADS-B receiver was deployed in Build 2 Follow-on Flight Test (11.02.21 and 12.06.21) to investigate if a strategically located receiver could compensate for coverage gaps. The new portable system successfully covered a majority of the existing pingStation ADS-B signal shortcomings and yielded 794 additional unique TSPI messages for the target vehicle (see the red in Figure 2.41).

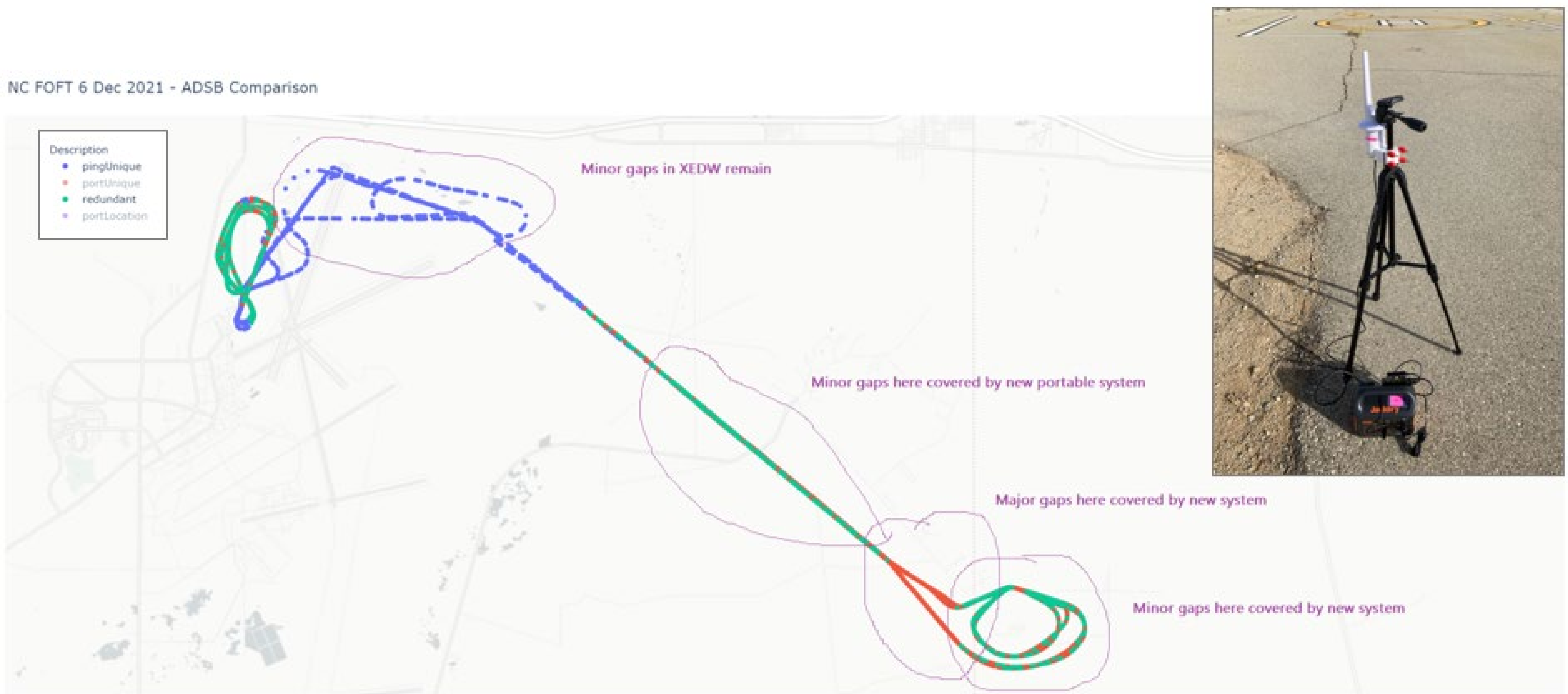


Figure 2.41. Portable PingStation ADS-B rectifies previous signal deficiencies in red.

Video

Videos of the Build 2 Flight Test were recorded from two perspectives within the standard Dryden Aeronautical Test Range (DATR) network. Ramp camera recordings captured aircrew step, takeoff, and landing on the taxiway. Airborne mission testing was captured by the Long Range Optics (LRO) camera. Following post-production by Armstrong TV after each flight, the Range Control Officer (RCO) transmitted the data to the NC Range POC responsible for uploading to the internal NASA Box cloud. National Campaign personnel processed the video for aircraft tracking purposes, event monitoring, anomaly detection, approach stability analysis, situational analysis, and playback of recorded incidents along with analysis and evidence capture.

Audio

Flight audio data consisted of air-to-ground and ground-to-ground communications across continuous, two-way ultra-high frequency (UHF) and very-high frequency (VHF) radio frequencies. Audio files included interactions between active mission participants (primary source) as well as operations personnel. Participants include the pilot, the FTE, and mission control. NASA recorded audio from the MCC located on the third floor of Building 4800 at AFRC. The interactions of each channel were output in .wav format onto a DVD, with each file labeled by circuit name. After each flight, the RCO transferred the audio data to the NC Range POC responsible for uploading to the internal NASA Box cloud. The ATI team actively investigated the application of speech-to-text software products and, depending on the translation success, the application of Natural Language Processing (NLP) technologies.

Radar

C-band Beacon tracking downlinked vehicle position information to Range radar station and the Mission Controller (MC) display using the standard DATR network. Raw data from the C-band Beacon were exported to .rdf and space delimited .txt formats using the Radar Information Processing System (RIPS). Upon exportation, the RCO transmitted the files to the NC Range POC responsible for uploading to the internal NASA Box cloud.

Flight Inspection Airborne Processor Application

The FAA Flight Check team provisioned the FIAPA. Developed at the Mike Monroney Aeronautical Center (Oklahoma City, Oklahoma) the FIAPA software is designed to measure coded path deviations for AAM (or surrogate) vehicles during NC flight events. The FIAPA software ingests FAA AirNav and ARINC 424 data via an antenna affixed to the AAM vehicle for centerline accuracy over landing. The FIAPA Trimble Yuma-7 tablet was secured onboard the vehicle (glare shield) for Build 2, with a geometry for the antenna of 4 feet 4 inches vertical; forward 2 feet, 8 inches; and right 2 feet 8 inches from the reference point. The tablet uses a Trimble EM-100 GNSS module for submeter accuracy using an EM-100 sensor module, Satellite Based Augmentation System (SBAS) Wide Area Augmentation System (WAAS) and Trimble processing techniques to check the consistency of spatial data correctness with respect to the marked vertipad. Data were collected from GPSs with Satellite Based Augmentation System (SBAS) monitoring with a +/-1 meter accuracy threshold. Once FIAPA data were validated post-flight using playback configuration software residing on FAA Flight Program computers, they were then securely transferred from an FAA representative to the data management team for upload to the NC repositories.

dGPS & IMU

The integrated DGPS and inertial measurement unit (IMU) system data were collected from a NovAtel PwrPak7-E1® (NovAtel Inc., Alberta, Canada) rover equipped with an Epson G320N (Epson Seiko Corporation, Nagano, Japan) micro-electromechanic system (MEMS) IMU onboard the flight vehicle. Measurements included the force, angular rate, and attitude (roll, pitch, and yaw) of the aircraft through a combination of accelerometers and gyroscopes. Timestamps in the data output were GPS synchronized. Following flights, bits (information/data) requests were submitted to enable AFRC Code 620 to receive electronically transmitted data from the rover and third-floor base station in order to post-process it using inertial explorer. Upon completion, Code 620 returned the post-processed data to the NC Range representative responsible for uploading it to the internal NASA Box cloud.

The NC DGPS and IMU units serve as a secondary source of information and validation for vehicle sensors and instruments. Additionally, the post-flight data provide a secondary surveillance for the flight tests. Data Services team used the various instruments to compare results and troubleshoot.

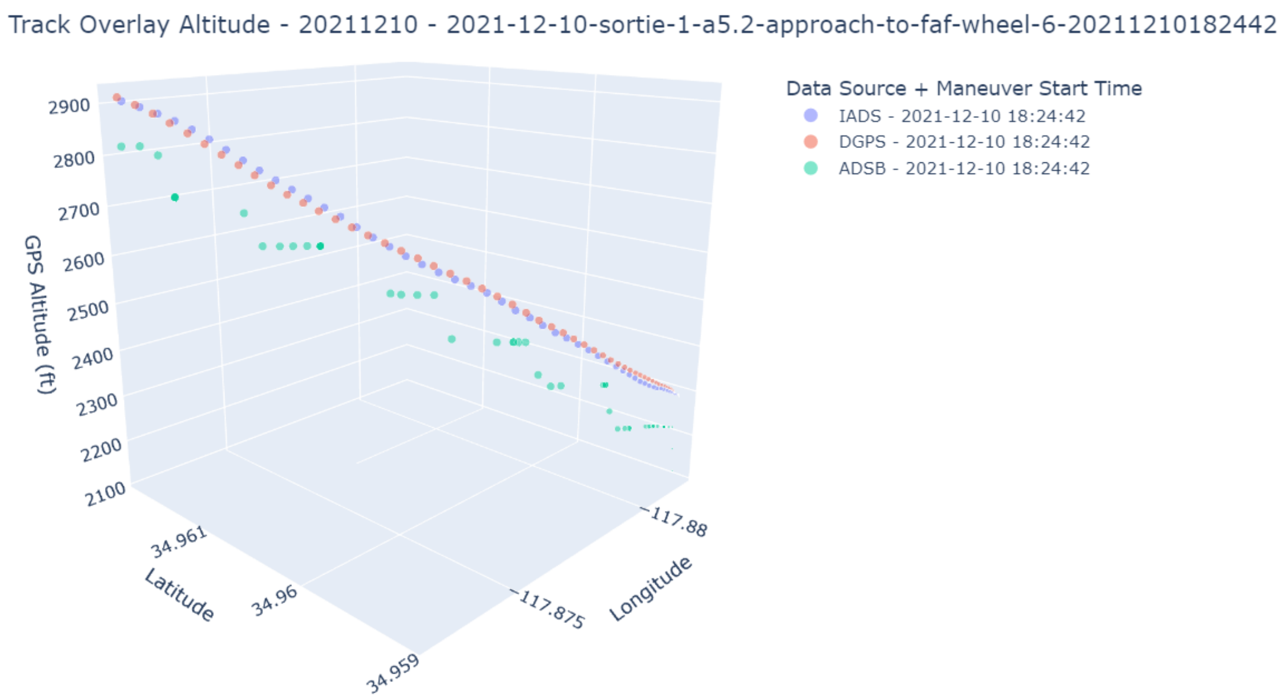


Figure 2.42. Track Overlay: altitude for an approach on December 10, 2021, observing synchronicity and offset between instruments (dGPS in red, new PingStation unit in green, vehicle data in purple).

Test Cards & Dance Cards

The NC Dance Cards provide daily sortie flight plans and serve as a tool to the range and flight crews to sequence the flight event and coordinate supporting activities. The NC Test Cards provide detailed information to the flight crew for each test or Airspace Procedure tested. The example cards in Figure 2.43 provide test maneuvers to a Precision Final Approach Fix utilizing a novel UAM wheel procedure, as a baseline for future UAM flight events, to test the controllability and passenger comfort with the surrogate vehicle for the approach maneuvers.

TEST A 5.2 Approach to FAF (Wheel) - 6

SETUP

Site	GW	CG	Speed	ALT (AGL)	HFAF	GPA
XEDW	Any	Any	Vrange to VFAF	Route to HFAF	2900 MSL	6

DATA: TRIM

ROUTE	ψ/V/G	APPRCH	VFAF	HFAF
			70 KIAS	

TEST PROCEDURE

IF: ANCHR

Establish V_{RANGE}, H_{FAF}
t0 arrive at IF
make standard rate turn at V_{RANGE} to
t1 arrive at Decel fix (DF)
DF:
t2 decelerate to V_{FAF}
make standard rate turn to FAF
t3 FAF
fly Approach (U8)

event		time
t0		103454
t1		103539
t2		103549
	Decel MARK	103619
t3		

	Crosstrack error	Altitude	Heading	V Error
DESIRED	+/- 300 ft	100 ft	+/- 5 deg	+/- 10 KIAS
ADEQUATE	+/- 600 ft	200 ft	+/- 10 deg	+/- 15 KIAS

FUEL		OPS CHECK	TIME	

TEST A 5.2 Approach to FAF (Wheel) - 6

HANDLING QUALITIES NOTESHEET
Notes/Comments

Pilot	1	Pilot	2

DATE:	SORTIE	AIRCRAFT:	REG NO:	callsign	MC	callsign	CARD #
	6	OH-58C	N173FR	Stryker 13	MOF	NASA 6	0

Ops #: | Crew: Davidovich, Jordan, Webber, Zahn

Mission Freqs	pri	alt
UHF	338.7	347.1
VHF	122.85	123.225

FLT: | ESGW: | FUEL:

	plan	actual
TO		
Land		
PLASI		
PLASI	MANKE	
PLASI	MORAN	

EVENT: NC SURROGATE UAM SUPPLEMENT FLIGHT TEST

Card	TEST	DESCRIPTION	COMMENT	ALT	KIAS	TIME
0		DANCE CARD				
	Pwr	Hover power checks IGE/OGE		4/50		5
	Cal	IADS/DGPS data calibration		0		
1	**Route**	**XEDW-XX33 - BRUCE 9 to GA**	Left pattern			15
	A1	Departure - Terminating Waypoint:	ANCHR			
	A2	Route Tracking - IF	SHRMA			
	A5.1	Approach Wheel 9 deg - Initial Fix:	RGNAR			
	U8	Approach (GA at 200 ft)	BRUCE9			
2	**Route**	**XX33-XEDW - GORDO 6**	Right pattern			15
	A1	Departure - Terminating Waypoint:	BJORN			
	A2	Route Tracking	STARR			
	A5.2	Approach Wheel 6 deg - Initial Fix:	ANCHR			
	U8	Approach	GORDO6			
3	**Route**	**XEDW-XX33 - BRUCE 9 to GA**	Left pattern			15
4	**Route**	**XX33-XEDW - GORDO 21**	Right pattern			15
	A1	Departure - Terminating Waypoint:	BJORN			
	A2	Route Tracking	STARR			
	A5.3	Approach Wheel 12 deg - Initial Fix:	PAULD			
	U8	Approach	GORDO12			

Figure 2.43. National Campaign Flight Test Cards (left and center) and Dance Card (right).

Key Flight Test Data Integration Developments

Through iterative development, key enablers to FTI were developed through Flight Test Data Integration:

Table 2.44. Key Flight Test Infrastructure Developments.

Key Flight Test Infrastructure Developments			
ASSET	SIGNIFICANCE	DEVELOPMENTAL ITERATIONS	LAUNCH POINT
Grafana	Eliminated potential blockers to view NC flights in real time and remotely	Developers reduced screen size compatibility from full-scale wall size to laptops for mobility and just in time for COVID-induced workplace limitations	Expansion of role Grafana plays with flight following to include Flight Errors and off-nominal flags for advanced analyses
Event Marker	Enabled well-defined data for post-flight analyses	Developers created a tool and methodology to improve metadata, tagging and analyses	Foundational to future development of automated phase of flight classification and associated metrics
Auto Glide Path Angle Finder	Enabled automated recognition of approaches and associated glide path angles	Developers corrected errors of closely-spaced intended landing surfaces	Improved glide path angle analyses will potentially play a role in Flyability and Go-Around procedures in urban environments
ADS-B	Enabled ADS-B reliability for comparative metrics against FAA surveillance	Comparative analysis identified dropouts in the Dry Run range requiring a new receiver	Low level operations are expected to experience poor FAA ADS-B surveillance
	Improved message reliability	Introduced additional portable system to address deficiencies	Reliable system for vehicle surveillance
Data Security and Governance	Assured permissioned access only	Security Officers reconstructed BOX hierarchies to manage growing complexities and permissions with incoming partner data	Trusted partnerships will enable valuable data for NC and relevant findings for the FAA
Metadata	Improved post-flight data storage and access	Great care was taken to optimize NC metadata	Enables sortable, identifiable access and analysis
Automated Data Product Generation	Provide data products, views, and metrics for easy user access	As standard data products are developed, a script runs against fused data and metadata to produce plots	Enable analysts to focus on new and novel research
Integrated Data Product	Provides a standardized platform for analyses	Data fusion is applied while data synchronization is verified	IDP underwent standardization to apply across various domains and research partners
Real-time and post-flight data ETL	Data are cleaned and available for use via Extract, Transform and Load processes	Timestamp and frequency synchronization of disparate data sources completed and verified for end-user	New data can be applied as research complexity grows
Aerograph	Data Managements System encompassing all ARMD data	Developed for roles, governance, raw and processed, store metrics, IDP and products	Scalable to store and access data across the ARMD projects

3 FLIGHT TEST DATA

3.1 Flight Test Operations Data

Flight test vehicles will be tracked and assessed across key domains of operational integration. Data are to be measured across flight operational domains including Vehicle, Obstacles, Weather, and PSU to support each Flight Path execution of each event Flight Plan; see Figure 3.1. The NC System of Systems approach aims to evaluate each component of flight and the necessary technologies, responsibilities, and interactions of each domain of the operation to ensure safe operations under maturation of autonomy.

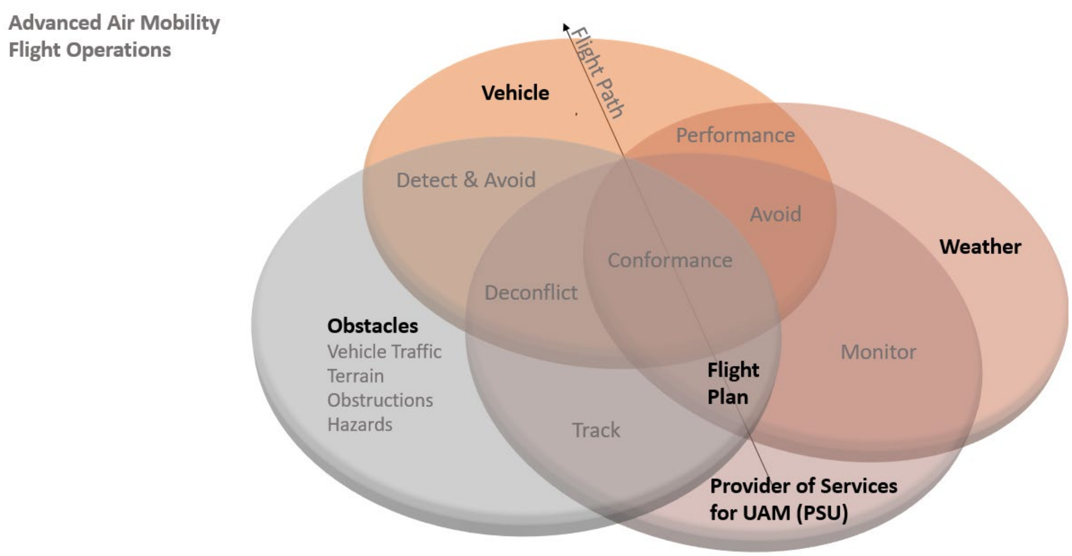


Figure 3.1. Advanced Air Mobility Flight Test Infrastructure and Data Service Overview.

Provider of Services for UAM: To address capabilities toward the PSU functions of the future, the NC ran Dry Run MOF V&V Testing for readiness to test components and capabilities of iterative development. The NC team will test various aspects of PSU possibilities in NC-1 series surrogate flights.

Obstacles: Data are measured against obstacle evaluations, Minimum Enroute Altitudes (MEA) and required obstacle clearance (ROC), terrain (Example Flight Level Engineering (FLE) Study), Hazards (NPSU Studies) and other vehicle traffic (injected through ATI and/or X-4 Airspace Mangement Architecture

Vehicle: The performance and flight characteristics of the target vehicle are the key focus for the NC and for desired data across the FAA. The NC-1 will begin to explore conformance to novel approaches and other terminal procedures. Some NC-1 projects will begin to research future DAA and deconfliction via automation.

Flight Plan and Flight Path: Flight track and surveillance is data under collection across flight activities to include flight tests and simulation. Additional features of flight plan will be assessed in NC-1 to include battery, temperature and other parameters.

Weather: National Campaign weather was captured to identify the impact of winds and other atmospheric measurements against vehicle performance. The NC team consulted with MCC Meteorologists before each flight as protocol but especially required the SME expertise to identify opportune flight days for specific weather conditions and limits specifically needed for Build 2 Follow-on Flight Test such as Dynamic Interface tests such as wind drafts shown in Figure 3.2.

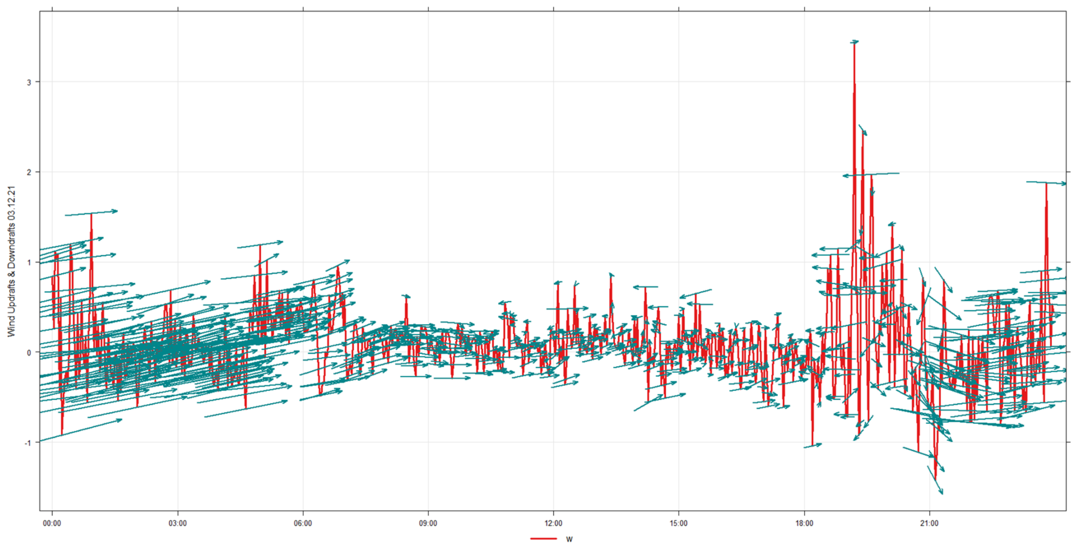


Figure 3.2. Wind Drafts meters/second with direction indicated by arrow.

<u>Obstacles</u>: Data against obstacle evaluations, MEA and ROC is evaluated such as the Infrastrucutre developed for Dry Run and prior to all future flight tests.

<u>Research Priorities</u>

Early NC series test events such as Dry Run Familiarization flight events were focused on answering a foundational set of research questions and topics utilizing a subset of related Data Elements and metrics as seen in Figure 3.3. As early research questions are baselined and characterized, the next complexity of any given focus will be expanded in the next round of testing.

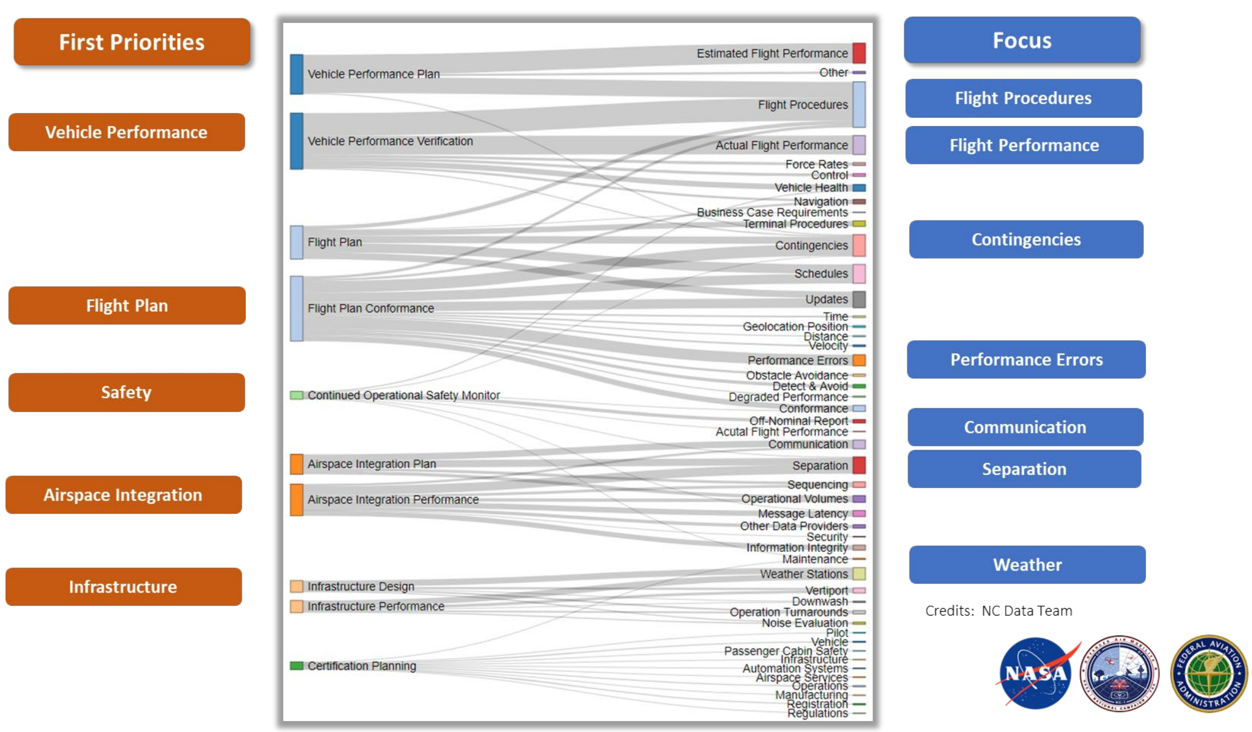


Figure 3.3 . National Campaign Early Data Priorities

Data Dependencies

Within the purview of the Data Elements portfolio and the developmental rollout of UAM Maturity Level for associated metrics, the NC Data team tracked categories of relationships and associations across the ecosystem in Figure 3.4.. As NC-1 develops and expands, the web of information, metrics and relationships will continue to evolve into a complex matrix of interdependences that will be ported into the MagicDraw Software Modeling Tool (Dassault Systemes, Velizy-Villacoublay, France) with System Engineering. This tracking inately develops a traceable approach to safety processes and data dependencies that could potentially benefit the FAA as AAM is operationalized.

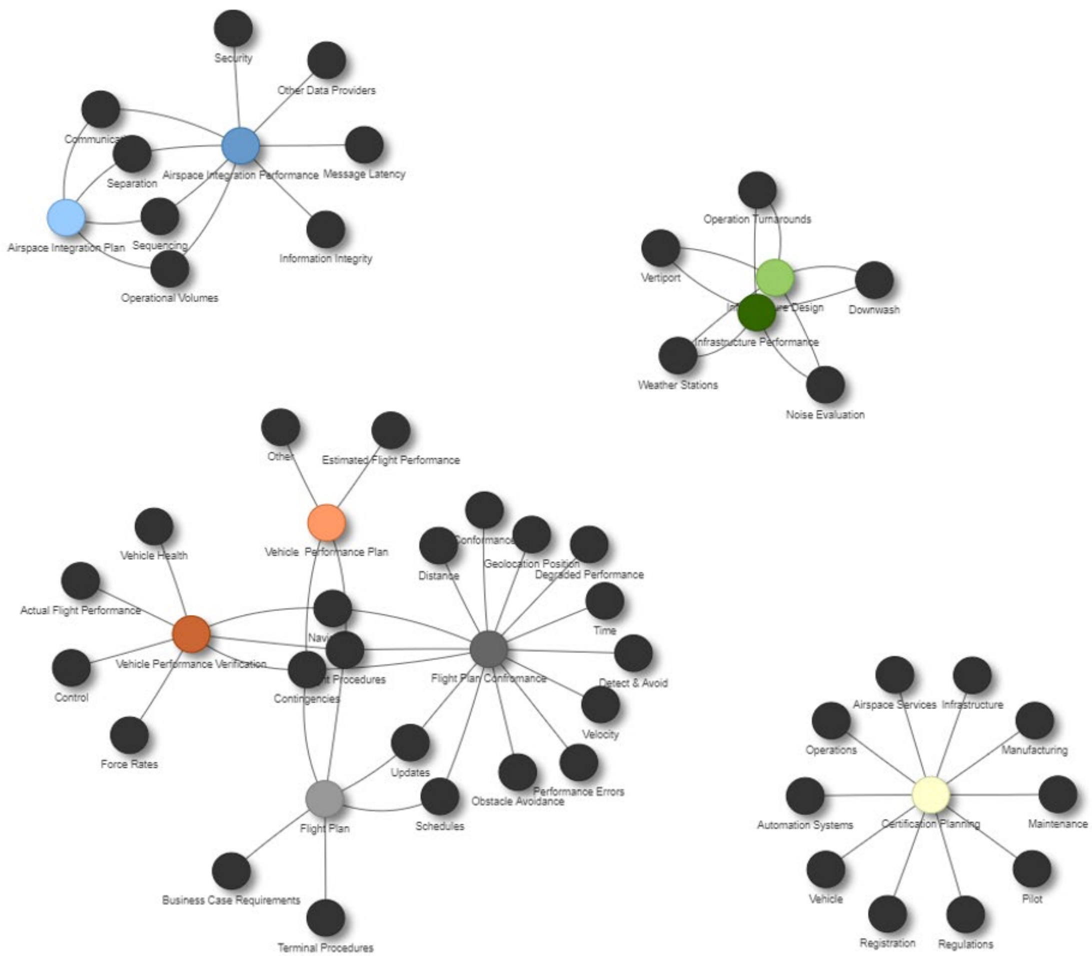


Figure 3.4. Graphical Representation of Early National Campaign Foci Associations.

Approach to Gaps

Gaps in technology or processes that are not accounted for are actively being identified and addressed through NC mini-white papers. The activity endeavors to enable further engagement starting at the National Campaign Working Group Focal level for each appropriate Line of Business or Staff Office and the integration offices of the FAA UAS Integration Office (AUS). The National Campaign team is identifying, tracking, and researching areas of opportunity that relate to current regulations and how research activities relate back to current operations and standards as well as identifying, tracking, and researching areas of opportunity that relate to emerging technologies, such as Figure 3.5.

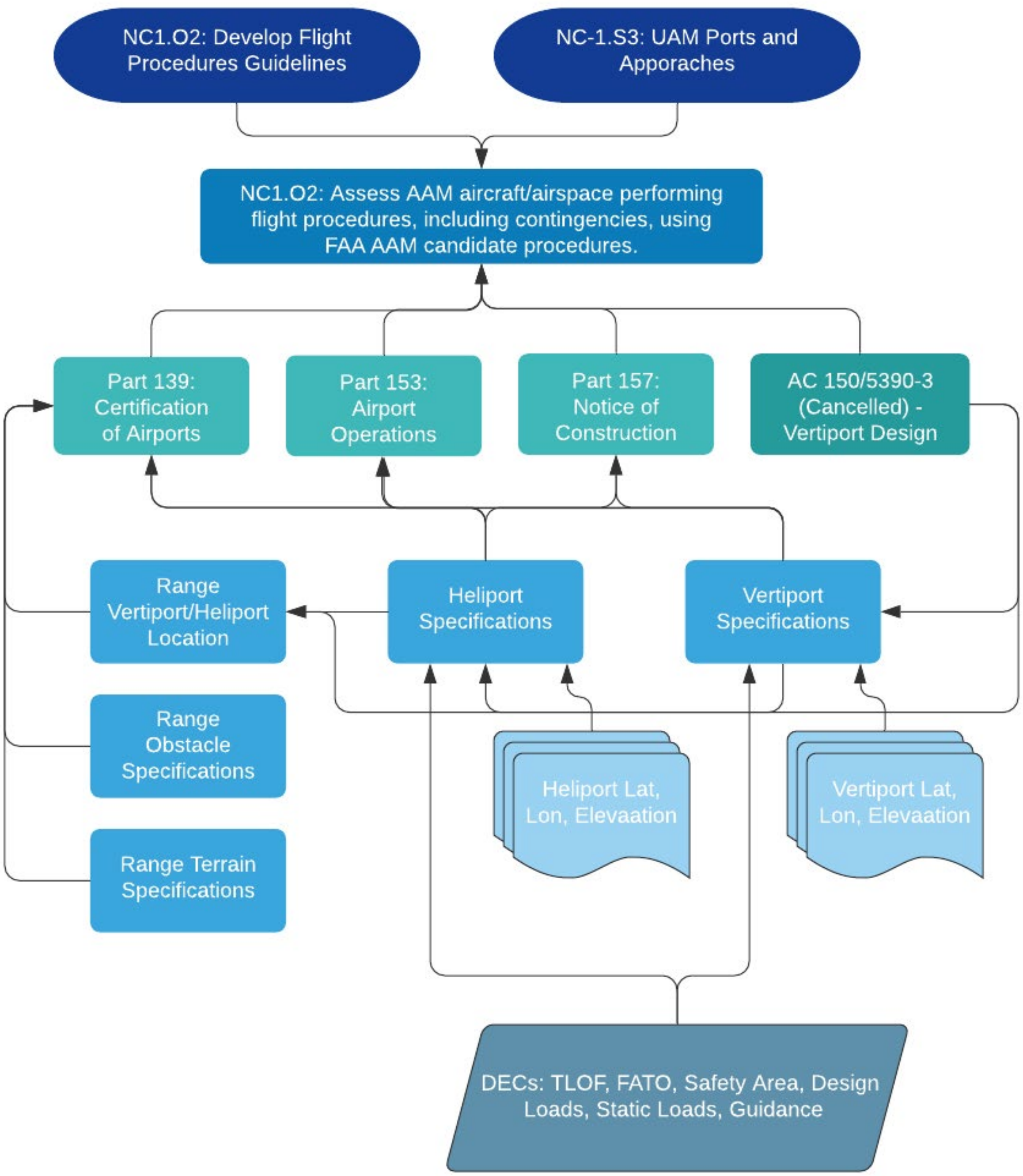


Figure 3.5. National Campaign Decomposition for Vertiport Considerations.

Research Plans & Technological Gaps

The National Campaign team endeavors to capture comprehensive details in mini-white papers or summary documents for each gap explored throughout the NC series. The NC team is managing a Gap Portfolio in an attempt to unpack the problems, including applicable standards, current state, new challenges, and shortfall for existing standards, related NC test objectives at general and specific levels, and future work remaining toward testing or data still needed. The intent then is to invoke the information (the connections to standards gaps) directly in NC test planning resulting in clear, traceable test objectives. Key details are captured around how current standards may be insufficient for AAM and why, then establish the potential ways in which NC tests and data may be able to contribute to the gap resolution as demonstrated in Figure 3.6. The NC gap analysis goal is to map, align, and trace NC testing to needed steps to resolve specific standards or technology gaps.

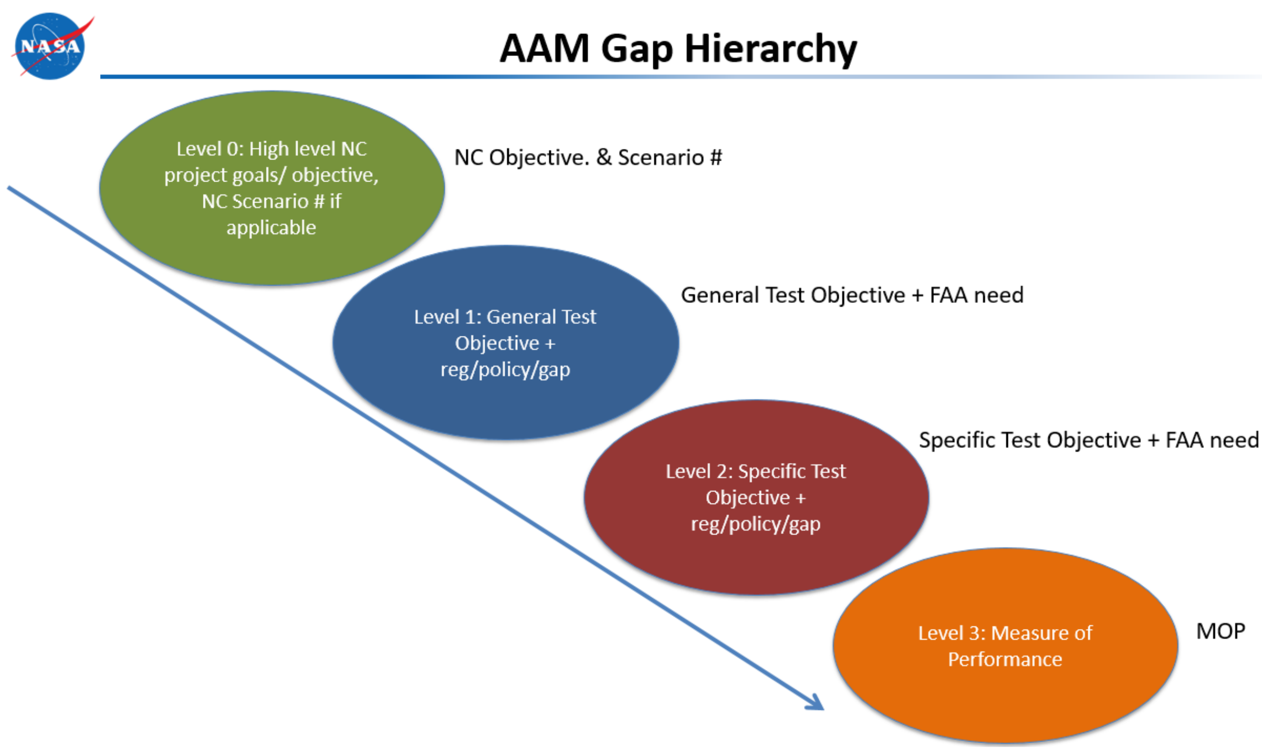


Figure 3.6. National Campaign Advanced Air Mobility Gap Hierarchy.

Gap Whitepapers

National Campaign gap mini-white papers decompose and describe all NC test activities and related standards gaps. Specifically, each white paper, sampled in Table 3.7, strives to capture the context and key details of each gap; describe the current state; break down related regulations, policies, or standards; describe the new AAM challenges, such as how or why the existing standards are insufficient; and then expand into how the gap can be resolved: how to get from the current to the desired future state and how the NC test efforts relate. Additionally, the work captures who will benefit from the testing, who are the customers for the data, and how or why the test results will add value. The NC team is developing the hierarchy and utilizing Magic Draw software (under development) to capture the decomposition from high-level NC objectives down to specific test points and data measures.

Table 3.7. Subset of National Campaign Tier 3 Gap Snapshot.

NC Gap Analysis
TIER 3 GAP SUBJECTS FOR FUTURE GAP WHITEPAPERS
Evaluate VHF/UHF coverage in urban areas with comparison to computer ElectroMagnetic (EM) modeling
Improve Global Navigation Satellite System (GNSS) interference locating
Determine latency requirements for surveillance solutions
Determine required ARINC 424 standard support AAM UML4
Evaluate integrity of RTK corrections as a GPS augmentation service
Evaluate draft mission task element performance metrics (desire/adequate criteria) for handling quality evaluations for compliance to the applicable airport certification controllability requirement (23.2135, related VTOL special condition, EASA VTOL 2135, et cetera) and other additional rules.

Findings and Results

The NC flight event generated data are available to permissioned users. The NASA researchers and FAA Lines of Business or Staff Offices have opportunity to acquire the data that are processed and integrated for specialized analyses. Additionally, a portfolio of data products is created by NC Data Services that cover Performance Graphs, Conformance Graphs, Flight Track, Signal Validation, Atmospheric Graphs, Deviation metrics, Messaging and ARINC Coding. Products and coding continue to develop and align to flight test plan objectives and metrics (Figure 3.8).

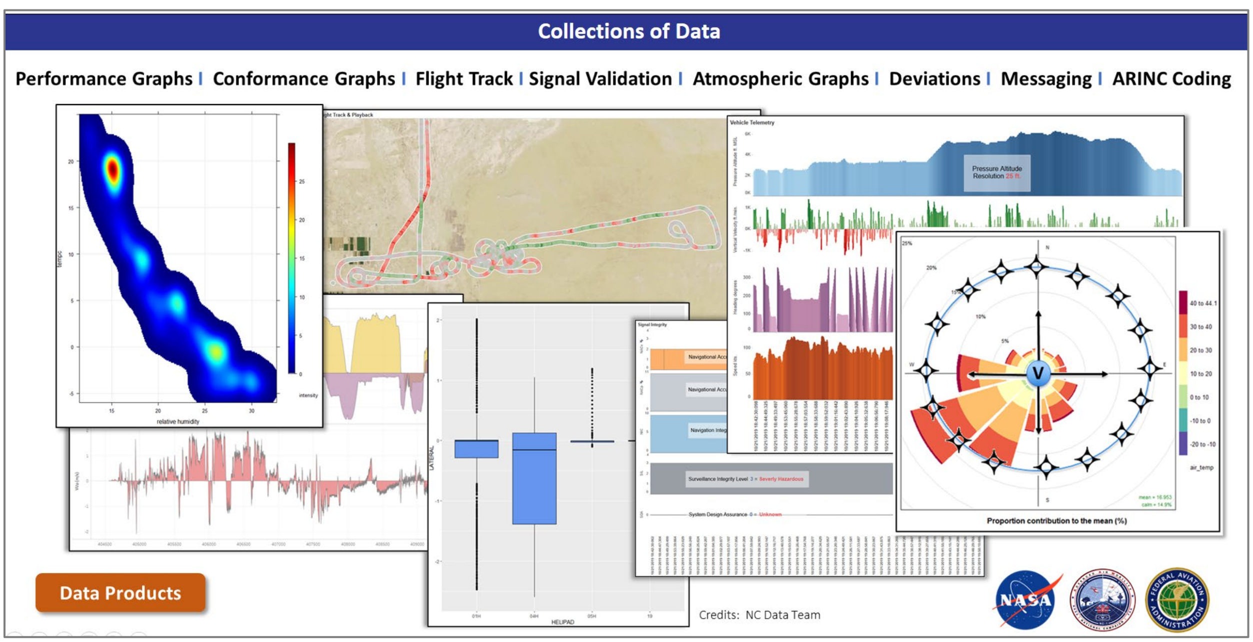


Figure 3.8. National Campaign Collections of Data and Data Products.

Data Elements

The NC team developed a portfolio of non-exhaustive expected and desired data at the elemental level. The scope of the Data Elements portfolio entails instruments (utilized and anticipated), data attributes from each system, metrics, and an effort to track the initiation of each data element as appropriate across UMLs. The Data Elements Portfolio served as a planning tool while data systems were still in infancy and flight plans were yet to be developed. The portfolio, while not definitive, assisted with FAA and NASA engagement, directing research, and tracking for various interdependencies among NC teams and subprojects. The portfolio captures the following content (Figure 3.9 from left to right and Figure 3.10):

Table 3.9 National Campaign Data Elements Snapshot

Function	Focus	Sub-Component	Entity	Metric	Data Element	Metric Type	Priority	Scenario	UML
Flight Plan	Terminal Procedures	Takeoff Accuracy	Vehicle	UTE 13	Reaction and Role (RR)	Distance	Safety	1 - 2 - 3	1
			Vehicle	UTE 14	Final Roll Out Point	Distance	Safety	1 - 2 - 3	1
			Vehicle		Termination Point/Altitude	Accuracy	Safety	1 - 2 - 3	1
			Vehicle		Climb Gradient	Accuracy	Safety	1 - 2 - 3	1
Flight Plan Conformance	Time	Phase Completion	Airspace		Phase Time	Time	Efficiency	1 - 2 - 3	1
			Airspace	X3-METRIC-19	Flight Time	Time	Efficiency	1 - 2 - 3	1
		Flight Time Planning	Airspace	T3SV.1.16	NOP Flight Plan Reliability	Time	Efficiency	1 - 2 - 3	1
	Geolocation Position	Latitude	Airspace		Latitude	Distance	Efficiency	1 - 2 - 3	1
		Longitude	Airspace		Longitude	Distance	Efficiency	1 - 2 - 3	1
		Altitude	Airspace		Altitude	Distance	Efficiency	1 - 2 - 3	1
	Distance	Total Flight Distance	Airspace	X3-METRIC-18	Total Distance	Distance	Efficiency	1 - 2 - 3	1
		Landing Distance	Airspace	X3-METRIC-21	Landing Location	Distance	Efficiency	1 - 2 - 3	1
	Velcoity	Ground Path	Airspace		Operation Ground Track	Quantitative	Efficiency	1 - 2 - 3	1
		Airborne	Airspace	X3-METRIC-6A	Operation Air Velocity	Quantitative	Efficiency	1 - 2 - 3	1
			Airspace	X3-METRIC-6B	PSU Average Air Velocity	Rate	Efficiency	1 - 2 - 3	1
	Conformance	Ground Path	Vehicle	UTE 9	Ground Track	Distance	Safety	1 - 2 - 3	1
		Flight Path	Vehicle	UTE 8	Vertical Flight Track	Distance	Safety	1 - 2 - 3	1
			Vehicle		Lateral Flight Track	Distance	Safety	1 - 2 - 3	1

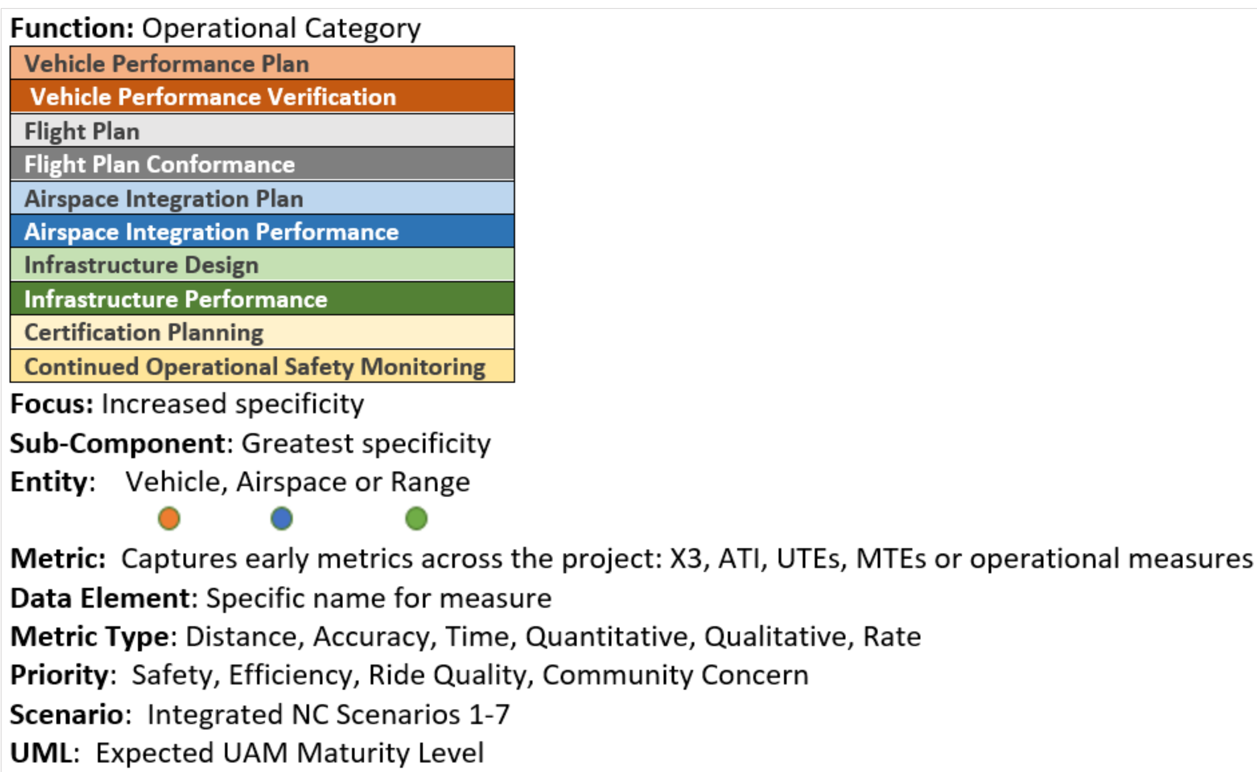


Figure 3.10. National Campaign Data Elements Format

Data Elements (1 of 11)

Table 3.11. National Campaign Data Elements

Agency POC	Function	Focus	Sub-Component	Entity	Metric	Data Element	Metric Type	Priority	Scenario	UML
AIR, AJF	**Vehicle Performance Plan**	Estimated Flight Performance	Departure	Vehicle		Aircraft Gross Weight	Quantitative	Safety	1 - 2 - 3	1
AIR, AJF				Vehicle		Pressure Altitude	Quantitative	Safety	1 - 2 - 3	1
AIR, AJF				Vehicle		Free Air Temperature (FAT) (total air temp)	Quantitative	Safety	1 - 2 - 3	1
AIR, AJF				Vehicle	UTE 25	Dual Motor Energy Capacity	Rate	Safety	1 - 2 - 3	1
AIR, AJF				Vehicle		Single Motor Energy Capacity	Quantitative	Safety	1 - 2 - 3	1
AIR, AJF				Vehicle		Battery Reserves	Rate	Efficiency	1 - 2 - 3	1
AIR, AJF				Vehicle		Fuel Reserves	Rate	Efficiency	1 - 2 - 3	1
AIR, AJF				Vehicle		Max Allowable Gross Weight	Quantitative	Safety	1 - 2 - 3	1
AIR, AJF				Vehicle		Predicted Hover Torque/Power (10 ft. IGE)	Rate	Safety	1 - 2 - 3	1
AIR, AJF				Vehicle		Predicted Hover Torque/Power (50 ft. OGE)	Rate	Safety	1 - 2 - 3	1
AIR, AJF				Vehicle		Hover Energy Flow	Rate	Safety	1 - 2 - 3	1
AIR, AJF				Vehicle		Hover Torque/Power Setting	Rate	Safety	1 - 2 - 3	1
AIR, AJF				Vehicle		Max Rate of Climb (Dual Motor)	Rate	Safety	1 - 2 - 3	1
AIR, AJF				Vehicle		Min Rate of Climb (Single Motor)	Rate	Safety	1 - 2 - 3	1
AIR, AJF				Vehicle		Max Acceleration	Rate	Safety	1 - 2 - 3	1
AIR, AJF				Vehicle		Nacelle Angle Change Rate	Rate	Safety	1 - 2 - 3	1
AIR, AJF			Cruise	Vehicle		Max Torque/Power Available	Rate	Safety	1 - 2 - 3	1
AIR, AJF				Vehicle		Velocity Never to Exceed (VNE) - Indicated Air Speed (IAS)	Rate	Safety	1 - 2 - 3	1
AIR, AJF				Vehicle		Cruise Speed (kts.)	Quantitative	Safety	1 - 2 - 3	1
AIR, AJF				Vehicle		Cruise Torque/Power Setting	Rate	Safety	1 - 2 - 3	1
AIR, AJF				Vehicle		Cruise Energy Flow	Rate	Safety	1 - 2 - 3	1
AIR, AJF				Vehicle		Max Range-Indicated Air Speed	Rate	Safety	1 - 2 - 3	1
AIR, AJF				Vehicle		Max Range Torque/Power	Rate	Safety	1 - 2 - 3	1
AIR, AJF				Vehicle		Max Endurance	Rate	Safety	1 - 2 - 3	1
AIR, AJF				Vehicle		Indicated Air Speed (IAS)	Rate	Safety	1 - 2 - 3	1
AIR, AJF				Vehicle		Max Endurance Torque/Power	Rate	Safety	1 - 2 - 3	1
AIR, AJF			Approach	Vehicle		Aircraft Gross Weight	Rate	Safety	1 - 2 - 3	1
AIR, AJF				Vehicle		Pressure Altitude	Rate	Safety	1 - 2 - 3	1
AIR, AJF				Vehicle		Free Air Temperature (FAT)	Rate	Safety	1 - 2 - 3	1
AIR, AJF				Vehicle		Hover Torque/Power	Rate	Safety	1 - 2 - 3	1
AIR, AJF				Vehicle		Hover Energy Flow	Rate	Safety	1 - 2 - 3	1
AIR, AJF				Vehicle		Max Allowable Gross Weight	Rate	Safety	1 - 2 - 3	1
AIR, AJF				Vehicle		Predicted Hover Torque/Power (10 ft. IGE)	Rate	Safety	1 - 2 - 3	1
AIR, AJF				Vehicle		Predicted Hover Torque/Power (50 ft. OGE)	Rate	Safety	1 - 2 - 3	1
AIR, AJF				Vehicle		Max Torque/Power Setting Available	Rate	Safety	1 - 2 - 3	1
AIR, AJF				Vehicle		Nacelle Angle Change Rate	Rate	Safety	1 - 2 - 3	1
AIR, AJF		Flight Procedures	Phases of Flight	Vehicle	MTE 1	Taxi	Qualitative	Safety	1 - 2 - 3	1
AIR, AJF				Vehicle			Distance	Safety	1 - 2 - 3	1
AIR, AJF				Vehicle			Qualitative	Safety	1 - 2 - 3	1
AIR, AJF				Vehicle			Time	Safety	1 - 2 - 3	1
AIR, AJF				Vehicle	MTE 3	Takeoff	Rate	Safety	1 - 2 - 3	1
AIR, AJF				Vehicle			Distance	Safety	1 - 2 - 3	1
AIR, AJF				Vehicle			Time	Safety	1 - 2 - 3	1
AIR, AJF				Vehicle		Transition to Cruise	Rate	Safety	1 - 2 - 3	1
AIR, AJF				Vehicle		Cruise	Rate	Safety	1 - 2 - 3	1
AIR, AJF				Vehicle	MTE 5	Flight Path Changes: Steep Turns	Rate	Safety	1 - 2 - 3	1
AIR, AJF				Vehicle		Flight Path Changes: Pull Up	Rate	Safety	1 - 2 - 3	1
AIR, AJF				Vehicle		Flight Path Changes: Push Over	Rate	Safety	1 - 2 - 3	1
AIR, AJF				Vehicle		Transition to Landing	Rate	Safety	1 - 2 - 3	1
AIR, AJF				Vehicle	MTE 6	Approach	Rate	Safety	1 - 2 - 3	1
AIR, AJF				Vehicle			Rate	Safety	1 - 2 - 3	1
AIR, AJF				Vehicle			Rate	Safety	1 - 2 - 3	1
AIR, AJF				Vehicle	MTE 6	Landing	Rate	Safety	1 - 2 - 3	1
AIR, AJF				Vehicle			Rate	Safety	1 - 2 - 3	1
AIR, AJF				Vehicle			Rate	Safety	1 - 2 - 3	1

Data Elements (2 of 11)

AIR, AJF			Performance Tests	Vehicle	MTE 2	All Azimuth	Distance	Safety	1 - 2 - 3	1
AIR, AJF				Vehicle			Qualitative	Safety	1 - 2 - 3	1
AIR, AJF				Vehicle			Qualitative	Safety	1 - 2 - 3	1
AIR, AJF				Vehicle			Distance	Safety	1 - 2 - 3	1
AIR, AJF				Vehicle	UTE 6	Hover Taxi	Distance	Safety	1 - 2 - 3	1
AIR, AJF				Vehicle	MTE 7	Takeoff and Abort	Distance	Safety	1 - 2 - 3	1
AIR, AJF				Vehicle	MTE 8	Landing	Distance	Safety	1 - 2 - 3	1
AIR, AJF			Ride Quality Tests	Vehicle	MTE 4	Level Flight	Qualitative	Ride Quality	1 - 2 - 3	1
AIR, AJF				Vehicle			Qualitative	Ride Quality	1 - 2 - 3	1
AIR, AJF				Vehicle			Distance	Ride Quality	1 - 2 - 3	1
AIR, AJF, AFS		Contingencies	Power	Vehicle		Reserve Energy Consumption	Rate	Safety	1 - 2 - 3	1
AIR, AJF, AFS				Vehicle		Power Hierarchy	Qualitative	Safety	1 - 2 - 3	1
AIR, AJF, AFS		Other	Additional	Vehicle		External Sling Load	Rate	Safety	1 - 2 - 3	1
AIR, AJF, AFS	**Vehicle Performance Plan**			Vehicle		Anti-Ice System	Rate	Safety	1 - 2 - 3	1
AIR, AJF, AFS				Vehicle		Environmental Control System	Rate	Safety	1 - 2 - 3	1
AIR, AJF, AFS				Vehicle		FMS	Qualitative	Safety	Future State	Future State
AJO, ANG, AFS, AJF, AIR	**Vehicle Performance Verification**	Actual Flight Performance	Departure	Vehicle		Aircraft Gross Weight	Quantitative	Safety	1 - 2 - 3	1
AJO, ANG, AFS, AJF, AIR				Vehicle		Pressure Altitude	Quantitative	Safety	1 - 2 - 3	1
AJO, ANG, AFS, AJF, AIR				Vehicle		Free Air Temperature (FAT)	Quantitative	Safety	1 - 2 - 3	1
AJO, ANG, AFS, AJF, AIR				Vehicle	UTE 25	Dual Motor Energy Capacity	Rate	Safety	1 - 2 - 3	1
AJO, ANG, AFS, AJF, AIR				Vehicle		Single Motor Energy Capacity	Quantitative	Safety	1 - 2 - 3	1
AJO, ANG, AFS, AJF, AIR				Vehicle		Max Allowable Gross Weight	Quantitative	Safety	1 - 2 - 3	1
AJO, ANG, AFS, AJF, AIR				Vehicle		Predicted Hover Torque/Power (10 ft. IGE)	Rate	Safety	1 - 2 - 3	1
AJO, ANG, AFS, AJF, AIR				Vehicle		Predicted Hover Torque/Power (50 ft. OGE)	Rate	Safety	1 - 2 - 3	1
AJO, ANG, AFS, AJF, AIR				Vehicle		Hover Energy Flow	Rate	Safety	1 - 2 - 3	1
AJO, ANG, AFS, AJF, AIR				Vehicle		Hover Torque/Power Setting	Rate	Safety	1 - 2 - 3	1
AJO, ANG, AFS, AJF, AIR				Vehicle		Max Rate of Climb (Dual Motor)	Rate	Safety	1 - 2 - 3	1
AJO, ANG, AFS, AJF, AIR				Vehicle		Min Rate of Climb (Single Motor)	Rate	Safety	1 - 2 - 3	1
AJO, ANG, AFS, AJF, AIR				Vehicle		Max Acceleration	Rate	Safety	1 - 2 - 3	1
AJO, ANG, AFS, AJF, AIR				Vehicle		Nacelle Angle Change Rate	Rate	Safety	1 - 2 - 3	1
AJO, ANG, AFS, AJF, AIR			Cruise	Vehicle		Max Torque/Power Available	Rate	Safety	1 - 2 - 3	1
AJO, ANG, AFS, AJF, AIR				Vehicle		Velocity Never to Exceed (VNE) - Indicated Air Speed (IAS)	Rate	Safety	1 - 2 - 3	1
AJO, ANG, AFS, AJF, AIR				Vehicle		Cruise Speed (kts.)	Quantitative	Safety	1 - 2 - 3	1
AJO, ANG, AFS, AJF, AIR				Vehicle		Cruise Torque/Power Setting	Rate	Safety	1 - 2 - 3	1
AJO, ANG, AFS, AJF, AIR				Vehicle		Cruise Energy Flow	Rate	Safety	1 - 2 - 3	1
AJO, ANG, AFS, AJF, AIR				Vehicle		Max Range-Indicated Air Speed	Rate	Safety	1 - 2 - 3	1
AJO, ANG, AFS, AJF, AIR				Vehicle		Max Range Torque/Power	Rate	Safety	1 - 2 - 3	1
AJO, ANG, AFS, AJF, AIR				Vehicle		Max Endurance	Rate	Safety	1 - 2 - 3	1
AJO, ANG, AFS, AJF, AIR				Vehicle		(Indicated Air Speed (IAS)	Rate	Safety	1 - 2 - 3	1
AJO, ANG, AFS, AJF, AIR				Vehicle		Max Endurance Torque/Power	Rate	Safety	1 - 2 - 3	1
AJO, ANG, AFS, AJF, AIR			Approach	Vehicle		Aircraft Gross Weight	Rate	Safety	1 - 2 - 3	1
AJO, ANG, AFS, AJF, AIR				Vehicle		Pressure Altitude	Rate	Safety	1 - 2 - 3	1
AJO, ANG, AFS, AJF, AIR				Vehicle		Free Air Temperature (FAT)	Rate	Safety	1 - 2 - 3	1
AJO, ANG, AFS, AJF, AIR				Vehicle		Hover Torque/Power	Rate	Safety	1 - 2 - 3	1
AJO, ANG, AFS, AJF, AIR				Vehicle		Hover Energy Flow	Rate	Safety	1 - 2 - 3	1
AJO, ANG, AFS, AJF, AIR				Vehicle		Max Allowable Gross Weight	Rate	Safety	1 - 2 - 3	1
AJO, ANG, AFS, AJF, AIR				Vehicle		Predicted Hover Torque/Power (10 ft. IGE)	Rate	Safety	1 - 2 - 3	1
AJO, ANG, AFS, AJF, AIR				Vehicle		Predicted Hover Torque/Power (50 ft. OGE)	Rate	Safety	1 - 2 - 3	1
AJO, ANG, AFS, AJF, AIR				Vehicle		Max Torque/Power Setting Available	Rate	Safety	1 - 2 - 3	1
AJO, ANG, AFS, AJF, AIR				Vehicle		Nacelle Angle Change Rate	Rate	Safety	1 - 2 - 3	1
AJO, ANG, AFS, AIR		Vehicle Health	Energy Supply Management	Vehicle	UTE 25	Battery Reserve	Rate	Efficiency	1 - 2 - 3	1
AJO, ANG, AFS, AIR				Vehicle		Fuel Reserve	Rate	Efficiency	1 - 2 - 3	1
AJO, ANG, AFS, AIR				Vehicle		Weather	Quantitative	Safety	1 - 2 - 3	
AJO, ANG, AFS, AIR			Temperature	Vehicle		Motor Controller Temperature	Quantitative	Efficiency	1 - 2 - 3	1
AJO, ANG, AFS, AIR				Vehicle		Thermal Control	Rate	Safety	1 - 2 - 3	1

Data Elements (3 of 11)

AJO, ANG, AFS, AIR			Rotor Systems	Vehicle		Configuration	Distance	Efficiency	1 - 2 - 3	1
AJO, ANG, AFS, AIR				Vehicle		Nacelle Angle	Distance	Efficiency	1 - 2 - 3	1
AJO, ANG, AFS, AIR				Vehicle		Rotor RPM	Rate	Efficiency	1 - 2 - 3	1
AJO, ANG, AFS, AIR				Vehicle		Fan RPM	Rate	Efficiency	1 - 2 - 3	1
AJO, ANG, AFS, AIR			Pressure	Vehicle		Static Pressure	Quantitative	Efficiency	1 - 2 - 3	1
AJO, ANG, AFS, AIR		Vehicle Health		Vehicle		Dynamic Pressure	Quantitative	Efficiency	1 - 2 - 3	1
AJO, ANG, AFS, SBSM		Navigation	ADS-B Monitor	Vehicle		Navigational Integrity Code (NIC)	Rate	Safety	1 - 2 - 3	1
AJO, ANG, AFS, SBSM				Vehicle		Navigational Accuracy Code Position (NACp)	Rate	Safety	1 - 2 - 3	1
AJO, ANG, AFS, SBSM				Vehicle		Navigational Accuracy Code Velocity (NACv)	Rate	Safety	1 - 2 - 3	1
AJO, ANG, AFS, SBSM				Vehicle		System Design Assurance (SDA)	Rate	Safety	1 - 2 - 3	1
AJO, ANG, AFS, SBSM				Vehicle		Source Integrity Level (SIL)	Rate	Safety	1 - 2 - 3	1
AJO, ANG, AFS, SBSM				Vehicle		Signal Integrity	Rate	Safety	1 - 2 - 3	1
AJO, ANG, AFS, AIR		Flight Procedures	Handling Qualities	Vehicle		Descend Transition	Rate	Ride Quality	1 - 2 - 3	1
AJO, ANG, AFS, AIR				Vehicle		Vertical Reposition and Hold	Rate	Ride Quality	1 - 2 - 3	1
AJO, ANG, AFS, AIR				Vehicle		Hovering Turn and Hold	Rate	Ride Quality	1 - 2 - 3	1
AJO, ANG, AFS, AIR				Vehicle		Acceleration and Deceleration	Rate	Ride Quality	1 - 2 - 3	1
AJO, ANG, AFS, AIR				Vehicle		Lateral Reposition and Hold	Rate	Ride Quality	1 - 2 - 3	1
AJO, ANG, AFS, AIR				Vehicle		Pirouette	Rate	Ride Quality	1 - 2 - 3	1
AJO, ANG, AFS, AIR				Vehicle		Pull-up - Pushover	Rate	Ride Quality	1 - 2 - 3	1
AJO, ANG, AFS, AIR				Vehicle		Decelerating Turn	Rate	Ride Quality	1 - 2 - 3	1
AJO, ANG, AFS, AIR				Vehicle		Decelerating Approach	Rate	Ride Quality	1 - 2 - 3	1
AJO, ANG, AFS, AIR			Phases of Flight	Vehicle	MTE 1	Taxi	Qualitative	Safety	1 - 2 - 3	1
AJO, ANG, AFS, AIR				Vehicle	MTE 3	Takeoff	Rate	Safety	1 - 2 - 3	1
AJO, ANG, AFS, AIR				Vehicle			Distance	Safety	1 - 2 - 3	1
AJO, ANG, AFS, AIR				Vehicle		Transition to Cruise	Rate	Safety	1 - 2 - 3	1
AJO, ANG, AFS, AIR				Vehicle		Cruise	Rate	Safety	1 - 2 - 3	1
AJO, ANG, AFS, AIR				Vehicle		Transition to Landing	Rate	Safety	1 - 2 - 3	1
AJO, ANG, AFS, AIR				Vehicle	MTE 6	Approach	Rate	Safety	1 - 2 - 3	1
AJO, ANG, AFS, AIR				Vehicle			Rate	Safety	1 - 2 - 3	1
AJO, ANG, AFS, AIR				Vehicle			Rate	Safety	1 - 2 - 3	1
AJO, ANG, AFS, AIR	Vehicle Performance Verification			Vehicle		Landing	Rate	Safety	1 - 2 - 3	1
AJO, ANG, AFS, AIR			Performance, Stability and Control	Vehicle	MTE 2	All Azimuth	Distance	Safety	1 - 2 - 3	1
AJO, ANG, AFS, AIR				Vehicle			Qualitative	Safety	1 - 2 - 3	1
AJO, ANG, AFS, AIR				Vehicle			Qualitative	Safety	1 - 2 - 3	1
AJO, ANG, AFS, AIR				Vehicle			Distance	Safety	1 - 2 - 3	1
AJO, ANG, AFS, AIR				Vehicle		Takeoff and Abort	Qualitative	Safety	1 - 2 - 3	1
AJO, ANG, AFS, AIR				Vehicle		Landing	Qualitative	Safety	1 - 2 - 3	1
AJO, ANG, AFS, AIR			Speed Changes	Vehicle		Acceleration	Qualitative	Safety	1 - 2 - 3	1
AJO, ANG, AFS, AIR				Vehicle		Deceleration	Qualitative	Safety	1 - 2 - 3	1
AJO, ANG, AFS, AIR				Vehicle		Lift Mode Transitions	Qualitative	Safety	1 - 2 - 3	1
AJO, ANG, AFS, AIR				Vehicle		Maneuver Characteristics	Qualitative	Safety	1 - 2 - 3	1
AJO, ANG, AFS, AIR			Handling Qualities	Vehicle	UTE 6	Precision Hover	Qualitative	Ride Quality	1 - 2 - 3	1
AJO, ANG, AFS, AIR				Vehicle		Vertical Reposition and Hold	Qualitative	Ride Quality	1 - 2 - 3	1
AJO, ANG, AFS, AIR				Vehicle		Hovering Turn and Hold	Qualitative	Ride Quality	1 - 2 - 3	1
AJO, ANG, AFS, AIR				Vehicle		Acceleration - Deceleration	Qualitative	Ride Quality	1 - 2 - 3	1
AJO, ANG, AFS, AIR				Vehicle		Lateral Reposition and Hold	Qualitative	Ride Quality	1 - 2 - 3	1
AJO, ANG, AFS, AIR				Vehicle		Pirouette	Qualitative	Ride Quality	1 - 2 - 3	1
AJO, ANG, AFS, AIR				Vehicle		Pull up - Push over	Qualitative	Ride Quality	1 - 2 - 3	1
AJO, ANG, AFS, AIR				Vehicle		Decelerating Turn	Qualitative	Ride Quality	1 - 2 - 3	1
AJO, ANG, AFS, AIR				Vehicle		Decelerating Approach	Qualitative	Ride Quality	1 - 2 - 3	1
AJO, ANG, AFS, AIR			Ride Quality Tests	Vehicle	MTE 4	Level Flight	Qualitative	Ride Quality	1 - 2 - 3	1
AJO, ANG, AFS, AIR				Vehicle			Qualitative	Ride Quality	1 - 2 - 3	1
AJO, ANG, AFS, AIR				Vehicle			Distance	Ride Quality	1 - 2 - 3	1

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AJO, ANG, AFS, AIR		Vehicle Impact	Force Rates	Vehicle		Vibrations	Rate	Ride Quality	4-5-6	Future State
AJO, ANG, AFS, AIR				Vehicle	MTE 4	Accelerations in Cabin	Rate	Ride Quality	4-5-6	Future State
AJO, ANG, AFS, AIR				Vehicle		Inertia	Rate	Ride Quality	4-5-6	Future State
AJO, ANG, AFS, AIR				Vehicle		G-Force	Rate	Ride Quality	4-5-6	Future State
AJO, ANG, AFS, AIR				Vehicle		Torque	Quantitative	Safety	1-2-3	1
AJO, ANG, AFS, AIR		Control	Positions	Vehicle		Collective	Quantitative	Safety	1-2-3	1
AJO, ANG, AFS, AIR				Vehicle		Lateral	Quantitative	Safety	1-2-3	1
AJO, ANG, AFS, AIR				Vehicle		Longitudinal	Quantitative	Safety	1-2-3	1
AJO, ANG, AFS, AIR				Vehicle		Directional	Quantitative	Safety	1-2-3	1
AJO, ANG, AFS, AIR				Vehicle		Throttle	Quantitative	Safety	1-2-3	1
AJO, ANG, AFS, AIR		Automated Flight Contingency Management	Time	Vehicle	AFCM-1	Timestamp	Time	Ride Quality	1-2-3	1
AJO, ANG, AFS, AIR			Position	Vehicle	AFCM-2	Latitude	Distance	Ride Quality	1-2-3	1
AJO, ANG, AFS, AIR				Vehicle	AFCM-3	Longitude	Distance	Ride Quality	1-2-3	1
AJO, ANG, AFS, AIR				Vehicle	AFCM-4	Altitude	Distance	Ride Quality	1-2-3	1
AJO, ANG, AFS, AIR			Distance	Vehicle	AFCM-5	Distance to Landing Zone	Distance	Ride Quality	1-2-3	1
AJO, ANG, AFS, AIR			Offset	Vehicle	AFCM-6	L/R Offset to Landing Zone	Distance	Ride Quality	1-2-3	1
AJO, ANG, AFS, AIR				Vehicle	AFCM-7	Fore/Aft Offset to Landing Zone	Distance	Ride Quality	1-2-3	1
AJO, ANG, AFS, AIR			Battery Reserve	Vehicle	AFCM-8	Energy Reserve	Quantitative	Ride Quality	1-2-3	1
AJO, ANG, AFS, AIR			Speed	Vehicle	AFCM-9	True Speed	Rate	Ride Quality	1-2-3	1
AJO, ANG, AFS, AIR				Vehicle	AFCM-10	Calibrated Airspeed	Rate	Ride Quality	1-2-3	1
AJO, ANG, AFS, AIR				Vehicle	AFCM-11	Vertical Velocity	Rate	Ride Quality	1-2-3	1
AJO, ANG, AFS, AIR				Vehicle	AFCM-12	Ground Speed	Rate	Ride Quality	1-2-3	1
AJO, ANG, AFS, AIR			Acceleration	Vehicle	AFCM-13	Acceleration	Quantitative	Ride Quality	1-2-3	1
AJO, ANG, AFS, AIR			Vehicle Orientation	Vehicle	AFCM-14	Heading	Quantitative	Ride Quality	1-2-3	1
AJO, ANG, AFS, AIR				Vehicle	AFCM-15	Magnetic Heading	Quantitative	Ride Quality	1-2-3	1
AJO, ANG, AFS, AIR				Vehicle	AFCM-16	Pitch Attitude (x)	Quantitative	Ride Quality	1-2-3	1
AJO, ANG, AFS, AIR				Vehicle	AFCM-16	Pitch Rate	Quantitative	Ride Quality	1-2-3	1
AJO, ANG, AFS, AIR				Vehicle	AFCM-16	Yaw (y)	Quantitative	Ride Quality	1-2-3	1
AJO, ANG, AFS, AIR				Vehicle	AFCM-16	Yaw Rate	Quantitative	Ride Quality	1-2-3	1
AJO, ANG, AFS, AIR				Vehicle	AFCM-17	Roll (z)	Quantitative	Ride Quality	1-2-3	1
AJO, ANG, AFS, AIR				Vehicle	AFCM-17	Roll Rate	Quantitative	Ride Quality	1-2-3	1
AJO, ANG, AFS, AIR				Vehicle	AFCM-18	Angle of Attack	Quantitative	Ride Quality	1-2-3	1
AJO, ANG, AFS, AIR				Vehicle	AFCM-19	Side-Slip Angle	Quantitative	Ride Quality	1-2-3	1
AJO, ANG, AFS, AIR				Vehicle	AFCM-20	Flight Path Angle	Quantitative	Ride Quality	1-2-3	1
AJO, ANG, AFS, AIR			Wind Factors	Vehicle	AFCM-21	Wind Direction	Quantitative	Ride Quality	1-2-3	1
AJO, ANG, AFS, AIR				Vehicle	AFCM-22	Wind Speed	Quantitative	Ride Quality	1-2-3	1
AJO, ANG, AFS, AIR			Camera	Vehicle	AFCM-25	Camera Tilt Angle	Quantitative	Ride Quality	1-2-3	1
AJO, ANG, AFS, AIR			Control Settings	Vehicle	AFCM-23	Lateral Stick	Quantitative	Ride Quality	1-2-3	1
AJO, ANG, AFS, AIR				Vehicle	AFCM-24	Longitude Stick	Quantitative	Ride Quality	1-2-3	1
AJO, ANG, AFS, AIR				Vehicle	AFCM-26	Collective Trim Up	Quantitative	Ride Quality	1-2-3	1
AJO, ANG, AFS, AIR				Vehicle	AFCM-27	Collective Trim Down	Quantitative	Ride Quality	1-2-3	1
AJO, ANG, AFS, AIR				Vehicle	AFCM-28	Pedal Trim Right	Quantitative	Ride Quality	1-2-3	1
AJO, ANG, AFS, AIR				Vehicle	AFCM-29	Pedal Trim Left	Quantitative	Ride Quality	1-2-3	1
AJO, ANG, AFS, AIR				Vehicle	AFCM-30	Stick Trim Up	Quantitative	Ride Quality	1-2-3	1
AJO, ANG, AFS, AIR				Vehicle	AFCM-31	Stick Trim Down	Quantitative	Ride Quality	1-2-3	1
AJO, ANG, AFS, AIR	**Vehicle**			Vehicle	AFCM-32	Rudder Pedal	Quantitative	Ride Quality	1-2-3	1
AJO, ANG, AFS, AIR	**Performance**	Contingencies	Power	Vehicle		Reserve Energy Consumption	Rate	Safety	1-2-3	1
AJO, ANG, AFS, AIR	**Verification**			Vehicle		Power Hierarchy	Qualitative	Safety	1-2-3	1
AJO, ANG, AFS	**Flight Plan**	Schedules	Clearance	Airspace		Closure Rate	Rate	Safety	4-5-6	Future State
AJO, ANG, AFS				Airspace		Weather Accuracy	Accuracy	Safety	1-2-3	1
AJO, ANG, AFS				Range	UTE 7	Traffic	Distance	Safety	1-2-3	1
AJO, ANG, AFS				Range		Weather	Distance	Safety	1-2-3	1
AJO, ANG, AFS				Range		Terrain	Distance	Safety	1-2-3	1
AJO, ANG, AFS				Range		Hazards	Distance	Safety	1-2-3	1
AJO, ANG, AFS				Range		Required Obstacle Clearance (ROC)	Distance	Safety	1-2-3	1

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AJO, ANG, AFS			Waypoints	Airspace	X3-METRIC-3	Operational Volume	Quantitative	Safety	1-2-3	1
AJO, ANG, AFS				Vehicle		Expedient Path	Distance	Efficiency	1-2-3	1
AJO, ANG, AFS			Pre-departure Scheduling	Vehicle	UTE 31	Pre-departure ETD	Time	Efficiency	1-2-3	1
AJO, ANG, AFS				Vehicle		Pre-departure ETA	Time	Efficiency	1-2-3	1
AJO, ANG, AFS				Airspace	X3-METRIC-10	Operational Volume Time	Time	Efficiency	1-2-3	1
AJO, ANG, AFS			Flight Plans / Alternatives	Vehicle		Five Flight Plans	Quantitiave	Safety	1-2-3	1
AJO, ANG, AFS			Flight Time Planning	Airspace	T3SV.1.16	NOP Flight Plan Reliability	Time	Efficiency	1-2-3	1
AJO, ANG, AFS			Vertiport Management	Airspace		Time at Vertiport	Rate	Efficiency	4.	Future State
AJO, ANG, AFS				Airspace	X3-METRIC-16	Vertiport Takeoff Throughput	Rate	Efficiency	3+	1
AJO, ANG, AFS				Airspace	X3-METRIC-17	Vertiport Landing Throughput	Rate	Efficiency	3+	1
AJO, ANG, AFS				Airspace	UTE 33	Pre-departure scheduling for conflict avoidance	Qualitative	Safety	7+	Future State
AJO, ANG, AFS		Updates	Clearance	Airspace		Closure Rate	Rate	Safety	4-5-6	Future State
AJO, ANG, AFS				Airspace		Weather Accuracy	Accuracy	Safety	1-2-3	1
AJO, ANG, AFS				Range	UTE 7	Traffic	Distance	Safety	1-2-3	1
AJO, ANG, AFS				Range		Weather	Distance	Safety	1-2-3	1
AJO, ANG, AFS				Range		Terrain	Distance	Safety	1-2-3	1
AJO, ANG, AFS				Range		Hazards	Distance	Safety	1-2-3	1
AJO, ANG, AFS				Range		Obstruction	Distance	Safety	1-2-3	1
AJO, ANG, AFS			Waypoints	Airspace	X3-METRIC-4	Updated Operational Volume	Quantitative	Safety	1-2-3	1
AJO, ANG, AFS				Vehicle		Expedient Path	Distance	Efficiency	4-5-6	Future State
AJO, ANG, AFS			In-flight Scheduling	Vehicle	UTE 32	In-flight ETD	Time	Efficiency	7+	Future State
AJO, ANG, AFS				Vehicle		In-flight ETA	Time	Efficiency	4-5-6	Future State
AJO, ANG, AFS				Airspace	X3-METRIC-5	Update Rate	Rate	Safety	1-2-3	1
AJO, ANG, AFS, AVP		Contingencies	Degraded Vehicle Systems	Vehicle	UTE 38	Degraded Vehicle Performance	Qualitative	Safety	4-5-6	Future State
AJO, ANG, AFS, AVP	Flight Plan			Vehicle	UTE 39	Degraded Avionics Performance	Qualitative	Safety	4-5-6	Future State
AJO, ANG, AFS, AVP				Vehicle	UTE 40	Degraded Vehicle Control	Qualitative	Safety	4-5-6	Future State
AJO, ANG, AFS, AVP			Airspace Emergencies	Airspace	UTE 47	Emergency Response	Qualitative	Safety	4-5-6	Future State
AJO, ANG, AFS, AVP			CNS	Airspace	UTE 27	Communication Navigation Surveillance Contingency	Qualitative	Safety	4-5-6	Future State
AJO, ANG, AFS, AVP			Operations Failure	Vehicle	MTE 7	Takeoff Failure Case	Qualitative	Safety	4-5-6	Future State
AJO, ANG, AFS, AVP				Vehicle	MTE 8	Landing Failure Case	Qualitative	Safety	4-5-6	Future State
AJO, ANG, AFS, AVP			Landing	Vehicle	UTE 28	Balked Landing	Qualitative	Safety	3	1
AJO, ANG, AFS, AVP				Vehicle	UTE 26	Precautionary Landing	Qualitative	Safety	1-2-3	1
AJO, ANG, AFS, AVP				Airspace	X3-METRIC-31	Distance to Contingent Landing	Distance	Safety	1-2-3	1
AJO, ANG, AFS, AVP			Divert & Reroute	Airspace	UTE 45	Weather Degradation	Qualitative	Safety	4-5-6	Future State
AJO, ANG, AFS, AVP				Airspace	UTE 45	Constrained Airspace	Qualitative	Safety	3	1
AJO, ANG, AFS, AVP			Airspace Sequence & Spacing	Airspace	UTE 46	Delayed Sequencing & Spacing	Qualitative	Safety	4-5-6	Future State
AJO, ANG, AFS, AVP		Business Case	Fleet Management	Vehicle		Operational Success Criteria	Rate	Efficiency	4-5-6	Future State
AJO, ANG, AFS		Flight Procedures	Phases of Flight Timing	Vehicle	MTE 1	Taxi	Time	Efficiency	1-2-3	1
AJO, ANG, AFS				Vehicle	MTE 3	Takeoff	Time	Efficiency	1-2-3	1
AJO, ANG, AFS				Vehicle		Transition to Cruise	Time	Efficiency	2-2-3	2
AJO, ANG, AFS				Vehicle		Cruise	Time	Efficiency	3-2-3	3
AJO, ANG, AFS				Vehicle		Transition to Landing	Time	Efficiency	4-2-3	4
AJO, ANG, AFS				Vehicle	MTE 6	Approach	Time	Efficiency	5-2-3	5
AJO, ANG, AFS				Vehicle		Landing	Time	Efficiency	6-2-3	6
AJO, ANG, AFS, AJF		Planned Conformance	Track Tolerances	Vehicle		Cross Track Tolerance	Distance	Safety	1-2-3	1
AJO, ANG, AFS, AJF				Vehicle		Vehicle Track Tolerance	Distance	Safety	1-2-3	1
AJO, ANG, AFS, AJF				Vehicle		Bank Angle	Quantitative	Safety	1-2-3	1
AJO, ANG, AFS, AJF		Terminal Procedures	Approach to Landing Accuracy	Vehicle		Decision Point	Distance	Safety	1-2-3	1
AJO, ANG, AFS, AJF				Vehicle		Glideslope	Rate	Safety	1-2-3	1
AJO, ANG, AFS, AJF				Vehicle	UTE 12	Turn Anticipation	Distance	Safety	1-2-3	1
AJO, ANG, AFS, AJF				Vehicle		Automated Flight Rules	Qualitative	Safety	7+	Future State
AJO, ANG, AFS, AJF				Vehicle		Initial Approach Ring	Distance	Safety	1-2-3	1
AJO, ANG, AFS, AJF				Vehicle		Turn Initiation Area (TIA)	Distance	Safety	1-2-3	1

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AJO, ANG, AFS, AJF	Flight Plan		Takeoff Accuracy	Vehicle	UTE 13	Reaction and Role (RR)	Distance	Safety	1 - 2 - 3	1
AJO, ANG, AFS, AJF				Vehicle	UTE 14	Final Roll Out Point	Distance	Safety	1 - 2 - 3	1
AJO, ANG, AFS, AJF				Vehicle		Termination Point/Altitude	Accuracy	Safety	1 - 2 - 3	1
AJO, ANG, AFS, AJF				Vehicle		Climb Gradient	Accuracy	Safety	1 - 2 - 3	1
AJO, ANG, AFS	Flight Plan Conformance	Time	Phase Completion	Airspace		Phase Time	Time	Efficiency	1 - 2 - 3	1
AJO, ANG, AFS				Airspace	X3-METRIC-19	Flight Time	Time	Efficiency	1 - 2 - 3	1
AJO, ANG, AFS			Flight Time Planning	Airspace	T3SV.1.16	NOP Flight Plan Reliability	Time	Efficiency	1 - 2 - 3	1
AJO, ANG, AFS, AJF		Geolocation Position	Latitude	Airspace		Latitude	Distance	Efficiency	1 - 2 - 3	1
AJO, ANG, AFS, AJF			Longitude	Airspace		Longitude	Distance	Efficiency	1 - 2 - 3	1
AJO, ANG, AFS, AJF			Altitude	Airspace		Altitude	Distance	Efficiency	1 - 2 - 3	1
AJO, ANG, AFS		Distance	Total Flight Distance	Airspace	X3-METRIC-18	Total Distance	Distance	Efficiency	1 - 2 - 3	1
AJO, ANG, AFS			Landing Distance	Airspace	X3-METRIC-21	Landing Location	Distance	Efficiency	1 - 2 - 3	1
AJO, ANG, AFS		Velocity	Ground Path	Airspace		Operation Ground Track	Quantitative	Efficiency	1 - 2 - 3	1
AJO, ANG, AFS			Airborne	Airspace	X3-METRIC-6A	Operation Air Velocity	Quantitative	Efficiency	1 - 2 - 3	1
AJO, ANG, AFS				Airspace	X3-METRIC-6B	PSU Average Air Velocity	Rate	Efficiency	1 - 2 - 3	1
AJO, ANG, AFS		Conformance	Ground Path	Vehicle	UTE 9	Ground Track	Distance	Safety	1 - 2 - 3	1
AJO, ANG, AFS			Flight Path	Vehicle	UTE 8	Vertical Flight Track	Distance	Safety	1 - 2 - 3	1
AJO, ANG, AFS				Vehicle		Lateral Flight Track	Distance	Safety	1 - 2 - 3	1
AJO, ANG, AFS				Vehicle	UTE 10	Delta ISA	Distance	Safety	1 - 2 - 3	1
AJO, ANG, AFS				Vehicle	UTE 11	Along Track Tolerance	Distance	Safety	1 - 2 - 3	1
AJO, ANG, AFS			Track Tolerances	Vehicle		Cross Track Tolerance	Distance	Safety	1 - 2 - 3	1
AJO, ANG, AFS				Vehicle		Vehicle Track Tolerance	Distance	Safety	1 - 2 - 3	1
AJO, ANG, AFS				Vehicle		Bank Angle	Distance	Safety	1 - 2 - 3	1
AJO, ANG, AFS			Timing	Vehicle	UTE 32	Pre-departure Scheduling	Time	Efficiency	1 - 2 - 3	1
AJO, ANG, AFS				Vehicle	UTE 33	ATD Metric	Time	Efficiency	1 - 2 - 3	1
AJO, ANG, AFS				Vehicle	UTE 32	TOA	Time	Efficiency	1 - 2 - 3	1
AJO, ANG, AFS			Operational Volumes	Airspace	X3-METRIC-11	Count Operational Volume Conformance	Quantitiave	Safety	1 - 2 - 3	1
AJO, ANG, AFS				Airspace	X3-METRIC-25	Time Operational Volume Non-Conformance	Time	Safety	1 - 2 - 3	1
AJO, ANG, AFS, AJV		Performance Errors	Flight Path Errors	Vehicle	UTE 15	Bias Errors	Rate	Safety	1 - 2 - 3	1
AJO, ANG, AFS, AJV				Vehicle	UTE 16	Body geometry (BGNB or BGWB)	Rate	Safety	1 - 2 - 3	1
AJO, ANG, AFS, AJV				Vehicle	UTE 17	Actual navigation performance error (ANPE)	Rate	Safety	1 - 2 - 3	1
AJO, ANG, AFS, AJV				Vehicle	UTE 18	Waypoint precision error (WPR)	Rate	Safety	1 - 2 - 3	1
AJO, ANG, AFS, AJV				Vehicle	UTE 19	Flight technical error (FTE)	Rate	Safety	1 - 2 - 3	1
AJO, ANG, AFS, AJV				Vehicle	UTE 20	Altimetry system error (ASE)	Rate	Safety	1 - 2 - 3	1
AJO, ANG, AFS, AJV				Vehicle	UTE 21	Vertical angle error (VAE)	Rate	Safety	1 - 2 - 3	1
AJO, ANG, AFS, AJV				Vehicle	UTE 22	Automatic terminal information system (ATIS)	Rate	Safety	1 - 2 - 3	1
AJO, ANG, AFS, AJV			RNP	Vehicle		FIAPA Required Navigational Performance 0.3 (?)	Quantitiave	Safety	1 -2 - 3	1
AJO, ANG, AFS, AJV			Flight Attitude	Vehicle		Heading	Quantitiave	Safety	1 - 2 - 3	1
AJO, ANG, AFS, AJV				Vehicle		Pitch Attitude	Rate	Safety	1 - 2 - 3	1
AJO, ANG, AFS, AJV				Vehicle		Roll	Rate	Safety	1 - 2 - 3	1
AJO, ANG, AFS, AJV				Vehicle		Yaw rate	Rate	Safety	1 - 2 - 3	1
AJO, ANG, AFS, AJV				Vehicle		Pitch Rate	Rate	Safety	1 - 2 - 3	1
AJO, ANG, AFS, AJV				Vehicle		Sideslip	Rate	Safety	1 - 2 - 3	1
AJO, ANG, AFS, AJV				Vehicle		OAT	Rate	Safety	1 - 2 - 3	1
AJO, ANG, AFS, AJV			Force Rates	Vehicle		Inertia	Rate	Safety	1 - 2 - 3	1
AJO, ANG, AFS, AJV				Vehicle		G-Force	Rate	Safety	1 - 2 - 3	1
AJO, ANG, AFS, AJV			Velocity	Vehicle		Air	Rate	Safety	1 - 2 - 3	1
AJO, ANG, AFS, AJV				Vehicle		Ground	Rate	Safety	1 - 2 - 3	1
AJO, ANG, AFS, AJV				Vehicle		Vertical	Rate	Safety	1 - 2 - 3	1
AJO, ANG, AFS, AJV			Acceleration	Vehicle		Acceleration	Rate	Safety	1 - 2 - 3	1

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AJO, ANG, AFS	Flight Plan Conformance	Schedules	Clearance	Airspace		Closure Rate	Rate	Safety	4-5-6	Future State
AJO, ANG, AFS				Airspace		Weather Accuracy	Accuracy	Safety	1-2-3	1
AJO, ANG, AFS				Range	UTE 7	Traffic	Distance	Safety	1-2-3	1
AJO, ANG, AFS				Range		Weather	Distance	Safety	1-2-3	1
AJO, ANG, AFS				Range		Terrain	Distance	Safety	1-2-3	1
AJO, ANG, AFS				Range		Hazards	Distance	Safety	1-2-3	1
AJO, ANG, AFS				Range		Required Obstacle Clearance (ROC)	Distance	Safety	1-2-3	1
AJO, ANG, AFS			Waypoints	Vehicle		Expedient Path	Distance	Efficiency	4-5-6	Future State
AJO, ANG, AFS			Pre-departure Scheduling	Vehicle	UTE 31	Pre-departure ATD	Time	Efficiency	7	Future State
AJO, ANG, AFS				Vehicle		Pre-departure ATA	Time	Efficiency	4-5-6	Future State
AJO, ANG, AFS			In-flight Scheduling	Vehicle	UTE 32	In-flight ATD	Time	Efficiency	7	Future State
AJO, ANG, AFS				Vehicle		In-flight ATA	Time	Efficiency	4-5-6	Future State
AJO, ANG, AFS				Airspace	X3-METRIC-5	Update Rate	Rate	Safety	1-2-3	1
AJO, ANG, AFS			Flight Plans and Alternatives	Vehicle		Five Flight Plans	Quantitiave	Safety	1-2-3	1
AJO, ANG, AFS			Vertiport Management	Airspace		Time at Vertiport	Rate	Efficiency	4+	Future State
AJO, ANG, AFS				Airspace	X3-METRIC-16	Vertiport Takeoff Throughput	Rate	Efficiency	3+	1
AJO, ANG, AFS				Airspace	X3-METRIC-17	Vertiport Landing Throughput	Rate	Efficiency	3+	1
AJO, ANG, AFS				Airspace	UTE 33	Pre-departure scheduling for conflict avoidance	Qualitative	Safety	7+	Future State
AJO, ANG, AFS		Updates	Clearance	Airspace	X3?	Closure Rate	Rate	Safety	4-5-6	Future State
AJO, ANG, AFS				Airspace		Weather Accuracy	Accuracy	Safety	1-2-3	1
AJO, ANG, AFS				Range	UTE 7	Traffic	Distance	Safety	1-2-3	1
AJO, ANG, AFS				Range		Weather	Distance	Safety	1-2-3	1
AJO, ANG, AFS				Range		Terrain	Distance	Safety	1-2-3	1
AJO, ANG, AFS				Range		Hazards	Distance	Safety	1-2-3	1
AJO, ANG, AFS				Range		Required Obstacle Clearance (ROC)	Distance	Safety	1-2-3	1
AJO, ANG, AFS			Waypoints	Vehicle		Expedient Path	Distance	Efficiency	4-5-6	Future State
AJO, ANG, AFS			Pre-departure Scheduling	Vehicle	UTE 31	Pre-departure ATD	Time	Efficiency	7	Future State
AJO, ANG, AFS				Vehicle		Pre-departure ATA	Time	Efficiency	4-5-6	Future State
AJO, ANG, AFS			In-flight Scheduling	Vehicle	UTE 32	In-flight ATD	Time	Efficiency	7	Future State
AJO, ANG, AFS				Vehicle		In-flight ATA	Time	Efficiency	4-5-6	Future State
AJO, ANG, AFS				Airspace	X3-METRIC-5	Update Rate	Rate	Safety	1-2-3	1
AJO, ANG, AFS			Flight Plans and Alternatives	Vehicle		Five Flight Plans	Quantitiave	Safety	1-2-3	1
AJO, ANG, AFS			Vertiport Management	Airspace		Time at Vertiport	Rate	Efficiency	4+	Future State
AJO, ANG, AFS				Airspace	X3-METRIC-16	Vertiport Takeoff Throughput	Rate	Efficiency	3+	1
AJO, ANG, AFS				Airspace	X3-METRIC-17	Vertiport Landing Throughput	Rate	Efficiency	3+	1
AJO, ANG, AFS				Airspace	UTE 33	Pre-departure scheduling for conflict avoidance	Qualitative	Safety	7+	Future State
AJO, ANG, AFS		Contingencies	Loiter	Vehicle	UTE 37	Degraded Communication	Qualitative	Safety	4-5-6	Future State
AJO, ANG, AFS			Return to Base	Vehicle		TBD	Qualitative	Safety	4-5-6	Future State
AJO, ANG, AFS			Deviate	Airspace	UTE 44	Divert & Reroute	Qualitative	Safety	4-5-6	Future State
AJO, ANG, AFS				Vehicle		Divert & Reroute	Qualitative	Safety	4-5-6	Future State
AJO, ANG, AFS			Land Now	Vehicle		Divert & Reroute	Qualitative	Safety	4-5-6	Future State
AJO, ANG, AFS			Conflict Management Maneuvers	Vehicle	UTE 41	Conflict Management – Horizontal Maneuver	Qualitative	Safety	4-5-6	Future State
AJO, ANG, AFS				Vehicle	UTE 42	Conflict Management – Vertical Maneuver	Qualitative	Safety	4-5-6	Future State
AJO, ANG, AFS				Vehicle	UTE 43	Conflict Management – Speed Change	Qualitative	Safety	4-5-6	Future State
AJO, ANG, AFS			Degraded Vehicle Systems	Vehicle	UTE 38	Degraded Vehicle Performance	Qualitative	Safety	4-5-6	Future State
AJO, ANG, AFS				Vehicle	UTE 39	Degraded Avionics Performance	Qualitative	Safety	4-5-6	Future State
AJO, ANG, AFS				Vehicle	UTE 40	Degraded Vehicle Control	Qualitative	Safety	4-5-6	Future State
AJO, ANG, AFS			Airspace Emergencies	Airspace	UTE 47	Emergency Response	Qualitative	Safety	4-5-6	Future State
AJO, ANG, AFS			CNS	Airspace	UTE 27	CNS Contingency	Qualitative	Safety	4-5-6	Future State
AJO, ANG, AFS			Operations Failure	Vehicle	MTE 7	Takeoff Failure Case	Qualitative	Safety	4-5-6	Future State
AJO, ANG, AFS				Vehicle	MTE 8	Landing Failure Case	Qualitative	Safety	4-5-6	Future State
AJO, ANG, AFS			Landing	Vehicle	UTE 28	Balked Landing	Qualitative	Safety	3	1
AJO, ANG, AFS				Vehicle	UTE 26	Precautionary Landing	Qualitative	Safety	1-2-3	1
AJO, ANG, AFS				Airspace	X3-METRIC-31	Distance to Contingent Landing	Distance	Safety	1-2-3	1
AJO, ANG, AFS			Weather Degradation	Airspace	UTE 45	Divert & Reroute	Qualitative	Safety	4-5-6	Future State
AJO, ANG, AFS			Constrained Airspace	Airspace	UTE 45	Divert & Reroute	Qualitative	Safety	3	1

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AJO, ANG, AFS	Flight Plan Conformance	Contingencies	Airspace Sequence & Spacing	Airspace	UTE 46	Delayed Sequencing & Spacing	Qualitative	Safety	4-5-6	Future State
AJO, ANG, AFS		Obstacle Avoidance	Ground Path	Vehicle	UTE 29		Rate	Safety	4-5-6	Future State
AJO, ANG, AFS				Vehicle		Ground Obstacle Avoidance	Rate	Safety	4-5-6	Future State
AJO, ANG, AFS			Air to Air	Vehicle	UTE 30		Rate	Safety	4-5-6	Future State
AJO, ANG, AFS				Vehicle		Air Obstacle Avoidance	Rate	Safety	4-5-6	Future State
AJO, ANG, AFS		Detect & Avoid	Contingency Procedures Execution	Vehicle	Future	TCAS	Qualitative	Safety	4-5-6	Future State
AJO, ANG, AFS				Vehicle	Future	Eyeball Closure Rate	Rate	Safety	4-5-6	Future State
AJO, ANG, AFS				Vehicle	Future	Autonomous Algorithm Closure Rates	Rate	Safety	4-5-6	Future State
AJO, ANG, AFS				Vehicle	Future	Autonomous Algorithm Avoidance Maneuvers	Rate	Safety	4-5-6	Future State
AJO, ANG, AFS			Weather Avoidance Optimization	Vehicle	Future	Onboard Weather Sensing	Qualitative	Safety	4-5-6	Future State
AJO, ANG, AFS				Vehicle	Future	Onboard Urban Wind Sensors	Qualitative	Safety	4-5-6	Future State
AJO, ANG, AFS		Navigation	Information Integrity	Vehicle		Navigational Integrity Code (NIC)	Quantitative	Safety	1-2-3	1
AJO, ANG, AFS				Vehicle		Navigational Accuracy Code Position (NACp)	Quantitative	Safety	1-2-3	1
AJO, ANG, AFS				Vehicle		System Design Assurance (SDA)	Quantitative	Safety	1-2-3	1
AJO, ANG, AFS				Vehicle		Source Integrity Level (SIL)	Quantitative	Safety	1-2-3	1
AJO, ANG, AFS		Degraded Performance	Redundant Systems	Vehicle			Qualitative	Safety	1-2-3	1
AJO, ANG, AFS			Occurrence Reporting	Vehicle			Qualitative	Safety	1-2-3	1
AJO, ANG, AFS		Flight Procedures	Speed Control	Vehicle			Qualitative	Ride Quality	1-2-3	1
AJO, ANG, AFS			All Azimuth	Vehicle	MTE 2		Qualitative	Ride Quality	1-2-3	1
AJO, ANG, AFS			Takeoff and Abort	Vehicle			Qualitative	Ride Quality	1-2-3	1
AJO, ANG, AFS			Flight Path Changes	Vehicle	MTE 5		Qualitative	Safety	3-5-6	Future State
AJO, ANG, AFS			Vibrations	Vehicle			Rate	Ride Quality	4-5-6	Future State
AJO, ANG, AFS		Terminal Procedures	Approach to Landing Accuracy	Vehicle		Decision Point	Distance	Safety	1-2-3	1
AJO, ANG, AFS				Vehicle		Glideslope	Rate	Safety	1-2-3	1
AJO, ANG, AFS				Vehicle	UTE 12	Turn Anticipation	Distance	Safety	1-2-3	1
AJO, ANG, AFS				Vehicle		Automated Flight Rules	Qualitative	Safety	7+	Future State
AJO, ANG, AFS				Vehicle		Initial Approach Ring	Distance	Safety	1-2-3	1
AJO, ANG, AFS				Vehicle		Turn Initiation Area (TIA)	Distance	Safety	1-2-3	1
AJO, ANG, AFS			Takeoff Accuracy	Vehicle	UTE 13	Reaction and Role (RR)	Distance	Safety	1-2-3	1
AJO, ANG, AFS				Vehicle	UTE 14	Final Roll Out Point	Distance	Safety	1-2-3	1
AJO, ANG, AFS				Vehicle		Termination Point/Altitude	Qualitative	Safety	1-2-3	1
AJO, ANG, AFS				Vehicle		Climb Gradient	Qualitative	Safety	1-2-3	1
AJO, ANG, AFS	**Airspace Integration Plan**	Separation	Airborne	Airspace	X3-METRIC 8	Separated Operational Volumes	Quantitative	Safety	1-2-3	1
AJO, ANG, AFS				Airspace	X3-METRIC-7	Intersected Operational Volumes	Quantitative	Safety	1-2-3	1
AJO, ANG, AFS				Airspace	X3-METRIC-27	Contingent Intersected Operational Volumes	Quantitative	Safety	1-2-3	1
AJO, ANG, AFS				Airspace	X3-METRIC-28	Contingent Intersected Replanned Operational Volumes	Quantitative	Safety	1-2-3	1
AJO, ANG, AFS				Airspace	X3-METRIC-13	Constraint Intersected Operational Volumes	Quantitative	Safety	1-2-3	1
AJO, ANG, AFS				Airspace	X3-METRIC-12A	Airborne Constraint Intersected Operational Volumes	Quantitative	Safety	1-2-3	1
AJO, ANG, AFS				Airspace	X3-METRIC-12B	Before Airborne Constraint Intersected Operational Volumes	Quantitative	Safety	1-2-3	1
AJO, ANG, AFS				Airspace	X3-METRIC-14	Replanned Airborne Constraint Intersected Operational Volumes	Quantitative	Safety	1-2-3	1
AJO, ANG, AFS				Airspace	X3-METRIC-39	Loss of Well Clear	Time	Safety	1-2-3	1
AJO, ANG, AFS				Airspace	X3-METRIC-38	3D Distance	Distance	Safety	1-2-3	1
AJO, ANG, AFS				Airspace	X3-METRIC-20	Spacing	Distance	Safety	1-2-3	1
AJO, ANG, AFS				Airspace	UTE 34	Tactical In-flight Separation	Time	Safety	7+	Future State
AJO, ANG, AFS			Surface	Airspace	Future				4-5-6	Future State
AJO, ANG, AFS		Sequencing	Prioritization	Airspace	Future	Operational Status	Qualitative		4-5-6	Future State
AJO, ANG, AFS				Airspace	Future	Reservation Order	Time	Efficiency	4-5-6	Future State
AJO, ANG, AFS			Optimization	Airspace	Future	Consistent Flow	Rate		4-5-6	Future State
AJO, ANG, AFS				Airspace	Future	Wake Vortex Separation; Sequence on Final	Rate	Efficiency	1-2-3	1
AJO, ANG, AFS			Fleet Management	Airspace	UTE 49	Virtual Traffic	Rate		1-2-3	1
AJO, ANG, AFS				Airspace	Future	Live Traffic	Rate		4-5-6	Future State
AJO, ANG, AFS		Operational Volumes	Operational Volume Size x, y, z	Airspace	X3-METRIC-9	Latitude	Quantitative	Safety	1-2-3	1
AJO, ANG, AFS				Airspace		Longitude	Quantitative	Safety	1-2-3	1
AJO, ANG, AFS				Airspace		Altitude	Quantitative	Safety	1-2-3	1
AJO, ANG, AFS			Route	Airspace	X3-METRIC-2	Route Active Operational Volumes	Quantitative	Efficiency	1-2-3	1
AJO, ANG, AFS			Airspace	Airspace	X3-METRIC-1	Airspace Active Operational Volumes	Quantitative	Efficiency	1-2-3	1

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AJO, ANG, AFS	Airspace Integration Plan		Class D	Airspace	X3-METRIC-40	Class D Active Operational Volumes	Quantitative	Efficiency	1-2-3	1
AJO, ANG, AFS		Communication	PSU	Airspace	X3-METRIC-37	Reported Flights Nearby	Quantitative	Safety	1-2-3	1
AJO, ANG, AFS				Airspace	X3-METRIC-34	PSU Messages	Time	Safety	1-2-3	1
AJO, ANG, AFS				Airspace	X3-METRIC-35	PSU Response	Time	Safety	1-2-3	1
AJO, ANG, AFS			Contingency Updates	Airspace	X3-METRIC-15	Constraint Plan Update	Time	Safety	1-2-3	1
AJO, ANG, AFS				Airspace	X3-METRIC-26	Contingent Status	Quantitative	Safety	1-2-3	1
AJO, ANG, AFS				Airspace	X3-METRIC-29	PSU Contingent Update	Time	Safety	5-2-3	1
AJO, ANG, AFS				Airspace	X3-METRIC-22	Non-Conforming Status	Quantitative	Safety	5-2-3	1
AJO, ANG, AFS				Airspace	X3-METRIC-23	Non-Conforming Status	Time	Safety	5-2-3	1
AJO, ANG, AFS			ATC Interaction	Airspace	UTE 51	ATC Communications	Time	Safety	1-2-3	1
AJO, ANG, AFS			Validation Tokens	Airspace	X3-METRIC-36	Request Rate	Rate	Efficiency	1-2-3	1
AJO, ANG, AFS				Airspace	X3-METRIC-32	Unsuccessful Response	Accuracy	Safety	1-2-3	1
AJO, ANG, AFS			Discovery Service	Airspace	X3-METRIC-33	Non-Conforming Status	Time	Safety	5-2-3	1
AJO, ANG, AFS	Airspace Integration Performance	Separation	Airborne	Airspace	X3-METRIC 8	Separated Operational Volumes	Accuracy	Safety	1-2-3	1
AJO, ANG, AFS				Airspace	X3-METRIC-7	Intersected Operational Volumes	Accuracy	Safety	1-2-3	1
AJO, ANG, AFS				Airspace	X3-METRIC-27	Contingent Intersected Operational Volumes	Accuracy	Safety	1-2-3	1
AJO, ANG, AFS				Airspace	X3-METRIC-28	Contingent Intersected Replanned Operational Volumes	Accuracy	Safety	1-2-3	1
AJO, ANG, AFS				Airspace	X3-METRIC-13	Constraint Intersected Operational Volumes	Accuracy	Safety	1-2-3	1
AJO, ANG, AFS				Airspace	T3SV.1.13	NPSU Constraint Intersected Operational Volumes	Quantitative	Safety	1-2-3	1
AJO, ANG, AFS				Airspace	X3-METRIC-12A	Airborne Constraint Intersected Operational Volumes	Accuracy	Safety	1-2-3	1
AJO, ANG, AFS				Airspace	X3-METRIC-12B	Before Airborne Constraint Intersected Operational Volumes	Accuracy	Safety	1-2-3	1
AJO, ANG, AFS				Airspace	T3SV.1.12	NPSU Post Constraint Submissions	Quantitative	Safety	1-2-3	1
AJO, ANG, AFS				Airspace	X3-METRIC-14	Replanned Airborne Constraint Intersected Operational Volumes	Accuracy	Safety	1-2-3	1
AJO, ANG, AFS				Airspace	T3SV.1.14	NPSU Replanned Airborne Constraint	Quantitative	Safety	1-2-3	1
AJO, ANG, AFS				Airspace	X3-METRIC-39	Loss of Well Clear	Time	Safety	1-2-3	1
AJO, ANG, AFS				Airspace	X3-METRIC-38	3D Distance	Distance	Safety	1-2-3	1
AJO, ANG, AFS				Airspace	X3-METRIC-20	Spacing	Distance	Safety	1-2-3	1
AJO, ANG, AFS				Airspace	UTE 34	Tactical In-flight Separation	Safety	Safety	7+	Future State
AJO, ANG, AFS			Surface	Airspace	Future		Distance	Safety	1-2-3	1
AJO, ANG, AFS		Sequencing	Prioritization	Airspace	Future	Operational Status	Qualitative	Efficiency	7+	Future State
AJO, ANG, AFS				Airspace	Future	Reservation Order	Time	Efficiency	7+	Future State
AJO, ANG, AFS			Optimization	Airspace	Future	Consistent Flow	Rate	Efficiency	1-2-3	1
AJO, ANG, AFS				Airspace	Future	Wake Vortex Separation; Sequence on Final	Rate	Efficiency	1-2-3	1
AJO, ANG, AFS			Fleet Management	Airspace	UTE 49	Virtual Traffic	Rate	Efficiency	1-2-3	1
AJO, ANG, AFS				Airspace	Future	Live Traffic	Rate	Efficiency	4-5-6	Future State
AJO, ANG, AFS		Operational Volumes	Operational Volume Size x, y, z	Airspace	X3-METRIC-9	Latitude	Quantitative	Safety	1-2-3	1
AJO, ANG, AFS				Airspace		Longitude	Quantitative	Safety	1-2-3	1
AJO, ANG, AFS				Airspace		Altitude	Quantitative	Safety	1-2-3	1
AJO, ANG, AFS			Route	Airspace	X3-METRIC-2	Route Active Operational Volumes	Accuracy	Efficiency	1-2-3	1
AJO, ANG, AFS			Airspace	Airspace	X3-METRIC-1	Airspace Active Operational Volumes	Accuracy	Efficiency	1-2-3	1
AJO, ANG, AFS			Class D	Airspace	X3-METRIC-40	Class D Active Operational Volumes	Accuracy	Efficiency	1-2-3	1
AJO, ANG, AFS		Communication	PSU Reporting	Airspace	X3-METRIC-37	Reported Flights Nearby	Accuracy	Safety	1-2-3	1
AJO, ANG, AFS			Contingency Updates	Airspace	X3-METRIC-26	Contingent Status	Accuracy	Safety	1-2-3	1
AJO, ANG, AFS				Airspace	X3-METRIC-22	Non-Conforming Status	Accuracy	Safety	5-2-3	1
AJO, ANG, AFS			ATC Interaction	Airspace	UTE 51	ATC Communications	Qualitative	Safety	1-2-3	1
AJO, ANG, AFS		Status Monitoring	Other Service Providers	Airspace	UTE 53	Vehicle Status	Qualitative	Safety	4-5-6	Future State
AJO, ANG, AFS				Airspace		Fleet Status	Qualitative	Safety	4-5-6	Future State
AJO, ANG, AFS				Airspace		Terminal Status	Qualitative	Safety	4-5-6	Future State
AJO, ANG, AFS				Airspace	UTE 52	Airspace Service Providers	Qualitative	Safety	4-5-6	Future State
AGC, ATR, ANG, AJO		Information Integrity	Validation Tokens	Airspace	X3-METRIC-36	Request Rate	Rate	Efficiency	1-2-3	1
AGC, ATR, ANG, AJO				Airspace	X3-METRIC-32	Unsuccessful Response	Accuracy	Safety	1-2-3	1
AGC, ATR, ANG, AJO				Airspace	T3SV.1.1	NPSU Registration	Qualitative	Safety	1-2-3	1
AGC, ATR, ANG, AJO				Airspace	T3SV.1.2	NPSU Time	Qualitative	Safety	1-2-3	1
AGC, ATR, ANG, AJO				Airspace	T3SV.1.3	NPSU Time Review	Qualitative	Safety	1-2-3	1
AGC, ATR, ANG, AJO				Airspace	T3SV.1.4	NPSU Time Acceptance	Qualitative	Safety	1-2-3	1
AGC, ATR, ANG, AJO			Updates	Airspace	T3SV.1.5	NPSU Time Position Update	Qualitative	Safety	1-2-3	1

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AGC, ATR, ANG, AJO	Airspace Integration Performance		Reliability	Airspace	T3SV.1.11	Message Dropouts	Accuracy	Safety	1 - 2 - 3	1
AGC, ATR, ANG, AJO				Airspace	T3SV.1.17	Tablet to NOP	Accuracy	Safety	1 - 2 - 3	1
AGC, ATR, ANG, AJO		Information Integrity	Security	Airspace	Future	Message Security	Qualitative	Safety	1 - 2 - 3	1
AGC, ATR, ANG, AJO		Message Latency	Contingency Updates	Airspace	X3-METRIC-29	PSU Contingent Update	Time	Safety	5 - 2 - 3	1
AGC, ATR, ANG, AJO				Airspace	T3SV.1.7	NPSU Contingent Update	Time	Safety	1 - 2 - 3	1
AGC, ATR, ANG, AJO				Airspace	X3-METRIC-15	Constraint Plan Update	Time	Safety	1 - 2 - 3	1
AGC, ATR, ANG, AJO				Airspace	T3SV.1.7	NPSU Constraint Update	Time	Safety	1 - 2 - 3	1
AGC, ATR, ANG, AJO				Airspace	X3-METRIC-23	Non-Conforming Status	Time	Safety	5 - 2 - 3	1
AGC, ATR, ANG, AJO				Airspace	T3SV.1.8	NPSU Non-Conforming Update	Time	Safety	1 - 2 - 3	1
AGC, ATR, ANG, AJO			Network to Network	Airspace	X3-METRIC-33	Time PSU to Discovery	Time	Safety	5 - 2 - 3	1
AGC, ATR, ANG, AJO				Airspace	T3SV.1.6	Time Vehicle to NOP	Time	Safety	1 - 2 - 3	1
AGC, ATR, ANG, AJO				Airspace	X3-METRIC-34	Time PSU to PSU	Time	Safety	1 - 2 - 3	1
AGC, ATR, ANG, AJO				Airspace	T3SV.1.9	NPSU Consistency	Accuracy	Safety	1 - 2 - 3	1
AFS, TSI, ARP, ATR, ASH	**Infrastructure Design**	Vertiport Safety Plan	Safety Dimensions	Range	UTE 1	TLOF	Distance	Safety	1 - 2 - 3	1
AFS, TSI, ARP, ATR, ASH				Range	UTE 2	FATO	Distance	Safety	1 - 2 - 3	1
AFS, TSI, ARP, ATR, ASH				Range	UTE 3	Safety Area	Distance	Safety	1 - 2 - 3	1
AFS, TSI, ARP, ATR, ASH				Range	UTE 4	Parking Separation	Distance	Safety	1 - 2 - 3	1
AFS, TSI, ARP, ATR, ASH		Heliport Safety Plan	Safety Dimensions	Range	UTE 1	TLOF Rectangular	Distance	Safety	1 - 2 - 3	1
AFS, TSI, ARP, ATR, ASH				Range	UTE 1	TLOF Circular	Distance	Safety	1 - 2 - 3	1
AFS, TSI, ARP, ATR, ASH				Range	UTE 2	FATO	Distance	Safety	1 - 2 - 3	1
AFS, TSI, ARP, ATR, ASH				Range	UTE 3	Safety Area	Distance	Safety	1 - 2 - 3	1
AFS, TSI, ARP, ATR, ASH				Range	UTE 4	Parking Separation	Distance	Safety	1 - 2 - 3	1
AFS, TSI, ARP, ATR, ASH		Operation Turnaround	Pre-flight	Range	UTE 24	Function & Reliability	Rate	Efficiency	Future State	Future State
AFS, TSI, ARP, ATR, ASH				Vehicle	UTE 23	Energy Resupply	Time	Efficiency	1 - 2 - 3	1
AFS, TSI, ARP, ATR, ASH				Vehicle	Future	Load	Time	Efficiency	1 - 2 - 3	1
AEE, APL, ARP	Infrastructure Performance	Landing Conditions	ISA	Range	UTE 10	Delta ISA	Distance	Safety	1 - 2 - 3	1
AEE, APL, ARP		Downwash	Rotor	Range	UTE 5		Distance	Safety	1 - 2 - 3	1
AEE, APL, ARP		Operation Turnaround	Pre-flight	Range	UTE 24	Function & Reliability	Rate	Efficiency	Future State	Future State
AEE, APL, ARP				Vehicle	UTE 23	Energy Resupply	Time	Efficiency	1 - 2 - 3	1
AEE, APL, ARP				Vehicle	Future	Load	Time	Efficiency	1 - 2 - 3	1
AEE, APL, ARP		Acoustics Evaluation	Acoustics Microphone Array Evaluation	Range	ACOUSTICS-1	Acoustics Analysis	Rate	Community Acceptance	4+	1
AEE, APL, ARP				Range			Rate	Community Acceptance	4+	1
AEE, APL, ARP			Acoustics Wind Evaluation	Range	ACOUSTICS-2	Wind Speed	Rate	Community Acceptance	4+	1
AEE, APL, ARP				Range		Wind Direction	Quantitative	Community Acceptance	4+	1
AEE, APL, ARP				Range		Altitude	Quantitative	Community Acceptance	4+	1
AEE, APL, ARP			Acoustics Weather Evaluation	Range	ACOUSTICS-3	Wind Speed	Quantitative	Community Acceptance	4+	1
AEE, APL, ARP				Range		Wind Direction	Quantitative	Community Acceptance	4+	1
AEE, APL, ARP				Range		Air Pressure	Quantitative	Community Acceptance	4+	1
AEE, APL, ARP				Range		Temperature	Quantitative	Community Acceptance	4+	1
AEE, APL, ARP				Range		Humidity	Quantitative	Community Acceptance	4+	1
AEE, ANG, ATR, AJV		Range Weather	Range Weather Stations	Range	WX -1	Wind Speed- Campbell Scientific Wx Tower	Rate	Safety	1 - 2 - 3	1
AEE, ANG, ATR, AJV				Range	WX -2	Wind Direction- Campbell Scientific Wx Tower	Rate	Safety	1 - 2 - 3	1
AEE, ANG, ATR, AJV				Range	WX -3	Air Temperature- Campbell Scientific Wx Tower	Quantitative	Safety	1 - 2 - 3	1
AEE, ANG, ATR, AJV				Range	WX -4	Relative Humidity- Campbell Scientific Wx Tower	Quantitative	Safety	1 - 2 - 3	1
AEE, ANG, ATR, AJV				Range	WX -5	Solar Radiation- Campbell Scientific Wx Tower	Rate	Safety	1 - 2 - 3	1
AEE, ANG, ATR, AJV				Range	WX -6	Air Pressure - Campbell Scientific Wx Tower	Quantitative	Safety	1 - 2 - 3	1
AEE, ANG, ATR, AJV				Range	WX -7	Visibility	Quantitative	Safety	1 - 2 - 3	1
AEE, ANG, ATR, AJV				Range	WX -8	SoDAR	Quantitative	Safety	1 - 2 - 3	1
AFS	**Certification Planning**	Pilot					Qualitative	Safety	Future State	Future State
AFS		Pilot School					Qualitative	Safety	Future State	Future State
AFS, AIR		Vehicle				FS AEG Aircraft Evaluation Group AFS 100	Qualitative			
AFS, AIR		Vehicle				AIR Aircraft Evaluation Group	Qualitative	Safety	Future State	Future State
AFS		Infrastructure					Qualitative	Safety	Future State	Future State
AFS, AAM, AIR		Passenger Cabin					Qualitative			
AFS		Automation Systems					Qualitative	Safety	Future State	Future State
AFS, AJO		Airspace Services					Qualitative	Safety	Future State	Future State

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AFS		Operations					Aircraft Certification Group		Qualitative	Safety	Future State	Future State
AFS		Maintenance							Qualitative	Safety	Future State	Future State
AFS		Maintenance School							Qualitative	Safety	Future State	Future State
AFS		Manufacturing					FS AEG Aircraft Evaluation Group AFS 300		Qualitative	Safety	Future State	Future State
AFS		Registration	Vehicle Partners		Vehicle		Flight Readiness Review		Qualitative	Safety	1 - 2 - 3	1
AFS			Airspace Partners		Airspace		Airspace Annex Agreements		Qualitative	Safety	1 - 2 - 3	1
AFS			Vertiport		Range		Range Annex Agreements		Qualitative	Safety	1 - 2 - 3	1
AFS	**Certification**		Heliport		Range		Range Annex Agreements		Qualitative	Safety	1 - 2 - 3	1
All	**Planning**	Regulations							Qualitative	Safety	Future State	Future State
AIR, AFS, AVP	**Continued**	Off-Nominal Report	Incidents & Accidents		Vehicle				Qualitative	Safety	1 - 2 - 3	1
AIR, AFS, AVP	**Operational Safety**	Contingencies	Incidents & Accidents		Vehicle				Qualitative	Safety	1 - 2 - 3	1
AIR, AFS	**Monitor**	Off-Nominal Report	Vehicle Deviations		Vehicle				Qualitative	Safety	1 - 2 - 3	1
AIR, AFS		Conformance	Vehicle Deviations		Vehicle		Pilot (near term) or Vehicle Deviations		Qualitative	Safety	1 - 2 - 3	1
AIR, AFS		Off-Nominal Report	Service Difficulty		Vehicle				Qualitative	Safety	1 - 2 - 3	1
AIR, AFS		Vehicle Health	Service Difficulty		Vehicle		Subsystem Failures: log failure, total time running, time since last mai		Qualitative	Safety	1 - 2 - 3	1
AIR, AFS		Maintenance	Maintenance Reports		Vehicle		Scheduled & Unscheduled Maintenance		Qualitative	Safety	1 - 2 - 3	1
AIR, AFS		Off-Nominal Report	Mechanical Interruption Summary		Vehicle				Qualitative	Safety	1 - 2 - 3	1
AIR, AFS		Vehicle Health	Malfunction & Defect		Vehicle		Subsystem Failures: log failure, total time running, time since last mai		Qualitative	Safety	1 - 2 - 3	1
AFS, AJO		Off-Nominal Report	Airspace Technical Summary		Airspace				Qualitative	Safety	1 - 2 - 3	1
AJO, AVP		Separation	Infrastructure Mishap		Airspace				Qualitative	Safety	1 - 2 - 3	1
AFS, AVP		Off-Nominal Report	Airspace Failures		Airspace				Qualitative	Safety	1 - 2 - 3	1
ANG		Message Latency	Airspace Technical Failures		Airspace				Qualitative	Safety	1 - 2 - 3	1

3.2 Data Elements Card Overview

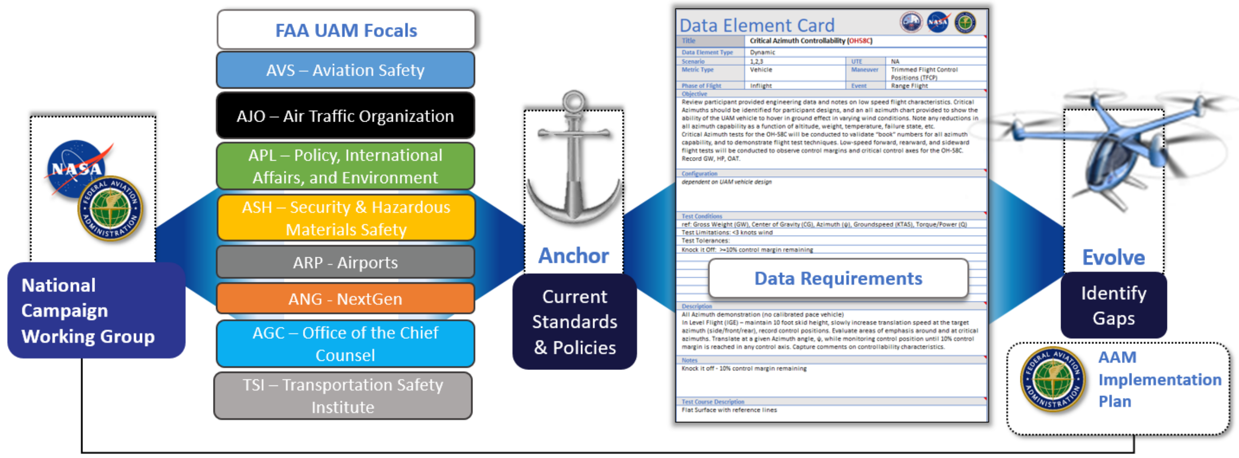


Figure 3.12. NASA-FAA National Campaign Working Group Overview

Data Collection Plan: The purpose of the Data Element Plan is to assemble various research tasks, supporting data elements and SMEs from the FAA and NASA required to execute each phase of the National Campaign. To that end, the plan provided a points of contact list which records the policy and technical POCs, SMEs assigned to each task, the data element and the required equipment needed for data capture from each task.

Data Collection Plan Objectives: The Data Plan contains primary and secondary objectives along with the success criteria for each objective. To ensure traceability throughout the National Campaign test, each data element was filtered through a regulatory and technical POC in the National Campaign Working Group (NCWG), which took place weekly for over 18 months.

Objectives

The following tables itemize the objectives for the data collection as it relates to NCWG Data Elements Cards.

Table 3.13. Data Collection Plan Primary Objectives and Success Criteria.

Primary Objectives	
DCPPO	SUCCESS CRITERIA
Provide situational awareness for all NC participants to all other NC participants	All NC participants have access to a regularly updated POC list for all other NC participants
Standardize the data captures by the SMEs	SMEs provided with data element cards upon which to record the data captures needed by the data managers
Provide SMEs with the information needed to engage in a data capture task	SMEs have regularly updated required data capture equipment lists and associated reference material
Provide agency managers with situational awareness of all tasks being executed and the processes for all data captures	Agency managers have access to a regularly updated data collection plan showing which data captures have occurred and which ones are still pending and who are the POCs for each

Table 3.14. Data Collection Secondary Objectives and Success Criteria.

Secondary Objectives	
DCPPO	SUCCESS CRITERIA

Provide all NC participants with references for each data element capture	NC participants provided with regularly updated data element references improving the coordination of efforts across the NC
Provide SMEs with situational awareness on intersecting data capture tasks	SMEs are empowered to identify intersecting data capture tasks and interface with their counterparts on those tasks.

Data Collection Plan Scope and Rationale: The scope of the Data Collection Plan is to illuminate participants managing each task and data element and to provide the SMEs, selected to perform the research tasks, with clear guidance on the information, metrics and fidelity that needs to be captured for analysis. The Data Collection Plan is not intended to be the authority on the assignment of tasks, nor is it intended to replace applicable standards for that task.

Data Review: Once the data have been captured by a given SME, those data will be provided to the NASA and the FAA point of contact identified on the Data Element Cards, for processing and review with the Data Management team. After review, adjustments to the Data Element Cards may occur.

Related Documentation: Table 3.15 contains a list of documents of supplemental information to guide SMEs and Data Managers in the application of documentation.

Table 3.15. List of Reference Documents.

Reference Documents	
DOCUMENT NUMBER	DOCUMENT TITLE
AFOP-7900.3-023 Revision G	Airworthiness and Flight Safety Review Process
AAM-NC-006-001	NC-DT Mishap Plan
AAM-NC-002-001	NC Sub-Project Plan
AAM-NC-005-001	NC Scenarios Document
AAM-NC-32-001	National Campaign Dry Run Build Up 1 Control Room Plan
AAM-NC-031-001	Helicopter Statement of Work
AAM-NC-018-001	UTE Spreadsheet

Data Collection Instrumentation List: Table 3.16 contains a list of the Data Collection Instrumentation List to be provided by NASA and integrated into the vehicle. The data collection instrumentation will be installed by the contractor and inspected by AFRC.

Table 3.16. Data Collection Instrumentation List.

Data Collection Instrumentation List
Instrumentation Box-DGPS/INS rover and battery
ATI Tablet
FIAPA Tablet

Vehicle Instrumentation List: Vehicle Instrumentation assets enable vehicle tracking, ATI connectivity, more precise vehicle maneuvering, and the collection of baseline vehicle performance data.

Table 3.17. Vehicle Instrumentation List.

Vehicle Instrumentation List
ADS-B Out and C-band Beacon
RNAV
Interactive Authoring Display

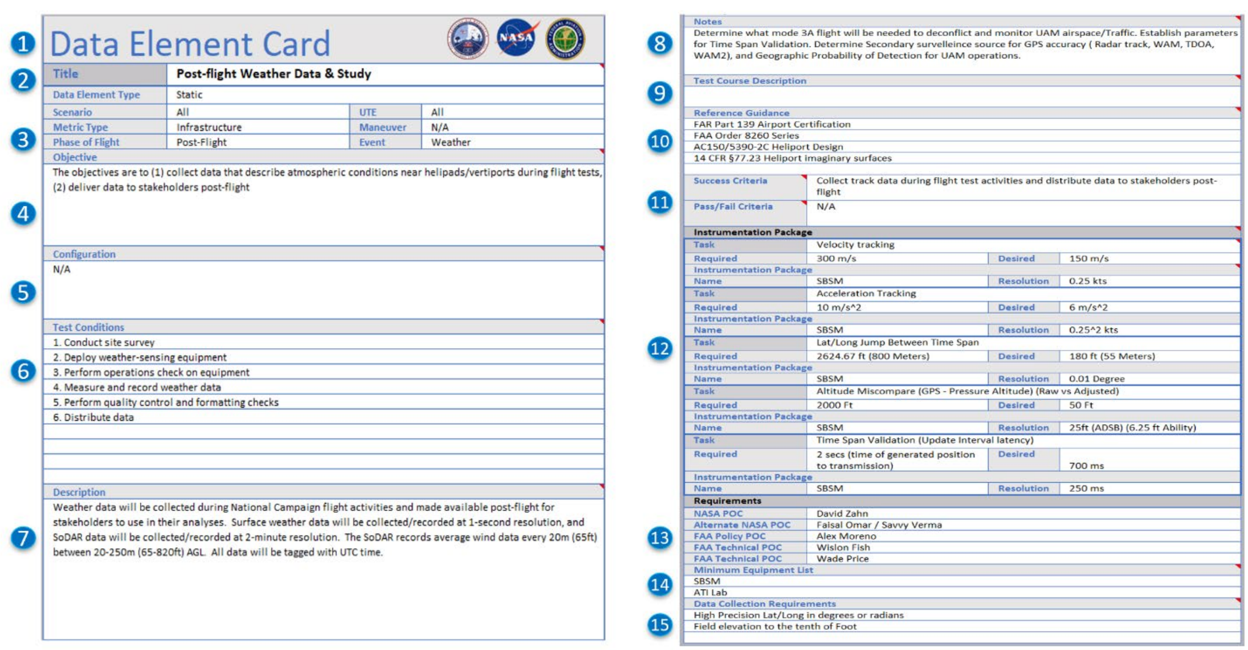
Range Equipment List: Range Equipment List encompasses the equipment and interfaces required for providing data and real-time communications and situational awareness in support of conducting National Campaign flight tests.

Table 3.18. Range Equipment List.

Range Equipment List
Air-to-ground UHF or VHF voice communications
Ground-to-ATC communications voice communications via UHF or VHF
Ground-to-ground voice communications via Land Mobile Radio (LMR) on VHF at 130 to 174 MHz and UHF at 225 to 500 MHz
Video recording capabilities, which may be aided by use of a deployable video van
C-band Beacon tracking to facilitate vehicle position tracking
Meteorological instruments including weather stations and Sonic Detection and Ranging (SODAR) sensors

Airspace: All Dry Run flights will occur within the R-2508 complex. The majority of Dry Run flights will occur within the R-2515 complex, to allow communication between the MOF and helicopter. For the first build-up, the vehicle will be communicating with the MCC, so line-of-sight MOF communications matters were not of concern.

NCWG Data Element Cards: The Data Element Plan uses Data Element Cards to capture data for tasks or sub-tasks. Data Element Cards were reverse-engineered from the NC data network that mapped each scenario, maneuver, or event to the correct instrumentation package as well as the phase of flight. The following breakdown is an example of the Data Element Card drop-down menus designed for multiple users to title the data required and annotate the applicable regulations the data element will support.


Data Element Card

Title	Post-flight Weather Data & Study		
Data Element Type	Static		
Scenario	All	UTE	All
Metric Type	Infrastructure	Maneuver	N/A
Phase of Flight	Post-Flight	Event	Weather

Objective
The objectives are to (1) collect data that describe atmospheric conditions near helipads/vertiports during flight tests, (2) deliver data to stakeholders post-flight

Configuration
N/A

Test Conditions
1. Conduct site survey
2. Deploy weather-sensing equipment
3. Perform operations check on equipment
4. Measure and record weather data
5. Perform quality control and formatting checks
6. Distribute data

Description
Weather data will be collected during National Campaign flight activities and made available post-flight for stakeholders to use in their analyses. Surface weather data will be collected/recorded at 1-second resolution, and SoDAR data will be collected/recorded at 2-minute resolution. The SoDAR records average wind data every 20m (65ft) between 20-250m (65-820ft) AGL. All data will be tagged with UTC time.

Notes
Determine what mode 3A flight will be needed to deconflict and monitor UAM airspace/Traffic. Establish parameters for Time Span Validation. Determine Secondary survelleince source for GPS accuracy (Radar track, WAM, TDOA, WAM2), and Geographic Probability of Detection for UAM operations.

Test Course Description

Reference Guidance
FAR Part 139 Airport Certification
FAA Order 8260 Series
AC150/5390-2C Heliport Design
14 CFR §77.23 Heliport imaginary surfaces

Success Criteria	Collect track data during flight test activities and distribute data to stakeholders post-flight
Pass/Fail Criteria	N/A

Instrumentation Package

Task	Velocity tracking		
Required	300 m/s	Desired	150 m/s
Instrumentation Package			
Name	SBSM	Resolution	0.25 kts
Task	Acceleration Tracking		
Required	10 m/s^2	Desired	6 m/s^2
Instrumentation Package			
Name	SBSM	Resolution	0.25^2 kts
Task	Lat/Long Jump Between Time Span		
Required	2624.67 ft (800 Meters)	Desired	180 ft (55 Meters)
Instrumentation Package			
Name	SBSM	Resolution	0.01 Degree
Task	Altitude Miscompare (GPS - Pressure Altitude) (Raw vs Adjusted)		
Required	2000 Ft	Desired	50 Ft
Instrumentation Package			
Name	SBSM	Resolution	25ft (ADSB) (6.25 ft Ability)
Task	Time Span Validation (Update Interval latency)		
Required	2 secs (time of generated position to transmission)	Desired	700 ms
Instrumentation Package			
Name	SBSM	Resolution	250 ms

Requirements

NASA POC	David Zahn
Alternate NASA POC	Faisal Omar / Savvy Verma
FAA Policy POC	Alex Moreno
FAA Technical POC	Wislon Fish
FAA Technical POC	Wade Price

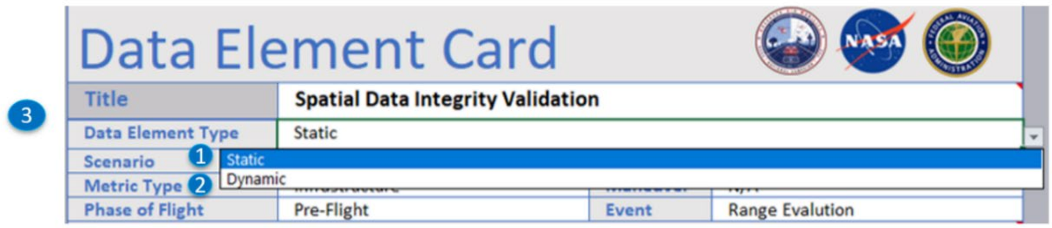
Minimum Equipment List
SBSM
ATI Lab

Data Collection Requirements
High Precision Lat/Long in degrees or radians
Field elevation to the tenth of Foot

Figure 3.19. NCWG Data Element Cards.

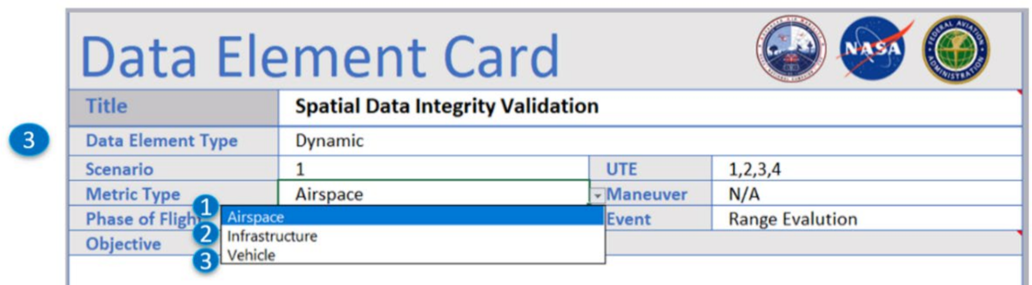
1. Header: Data Element Card, collaborative effort between NASA/FAA research with National Campaign.

2. Title: Name of Data Element that will be tested - assigned from UTE, MTE, Scenario's document, or Flight Test Plan.



1. Static: Data Element type that does not involve flight. (Example Site evaluation)

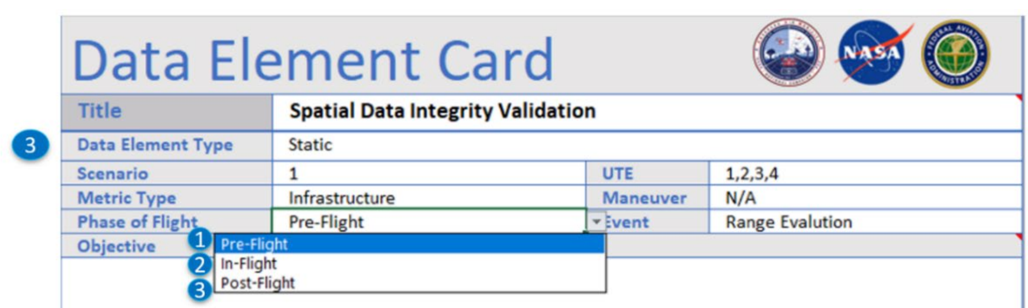
2. Dynamic: Data Element type that does involve flight activity. (Example hover)



1. Airspace: Data Element Card, collaborative effort between NASA/FAA research with National Campaign.

2. Infrastructure: Data Element Card, collaborative effort between NASA/FAA research with National Campaign.

3. Vehicle: Name of Data Element that will be tested - assigned from UTE, MTE, Scenario's document, or Flight Test Plan.



1. Pre-Flight: Needed to be completed before take off.
2. In-Flight: Any movement from departure, enroute, approach and taxi.
3. Post Flight: All post flight analysis.

Data Element Card

3

Title	Spatial Data Integrity Validation		
Data Element Type	Static		
Scenario	1	UTE	1,2,3,4
Metric Type	Infrastructure	Maneuver	N/A
Phase of Flight	Pre-Flight	Event	Range Evalution
Objective			

1 Range Evalution
2 Range Flight
3 Acoustics
4 Weather

1. Range Evaluation: Data broken down for site selection, evaluation, analysis and operation.
2. Range Flight: Data derived from flight activities on selected range.
3. Acoustics: Data derived from acoustic testing objectives.
4. Weather: Pre-In-Post flight weather centered data.

4

Objective
To obtain standard deviations of spatial data providers to UAM navigation services in the vertical and horizontal axis. Compare and contract the fidelity of Digital Terrain Evaluation Databases (DTED) in use for UAM flight planning of point in space departure and approaches.

4 Objective: Mission statement of the test, defined by the functional objectives derived from the Flight Test Plan, Scenarios Document, Flight Test Operations Document. Will include intended deliverable(s). Defining the "why" the tests are being conducted.

5

Configuration
Configuration: Landing Approach configuration (gear/flaps down)

5 Configuration: Based on vehicle, respective to make model series of tested aircraft. Applies to vehicle test.

6

Test Conditions
• Light and moderate turbulence levels
• Winds up to maximum recovery headwind and 17 knots crosswind from the critical direction
• AUW or maximum permissible hover weight if lower

6 Test Conditions: Conditions needed to baseline date for respective research. Includes weather, vehicle, and airspace simulations.

7

Description
1. Starting from an altitude of greater than 10 ft., maintain an essentially steady descent to a prescribed landing point. It is acceptable to arrest sink rate momentarily to make last minute corrections before touchdown. 2. Accomplish a gentle landing with a smooth continuous descent, with no objectionable oscillations 3. Final position shall be the position that existed at touchdown. It is not acceptable to adjust the aircraft position and heading after all elements of the landing gear have made contact with the pad.

7 Description: Detailed analysis of the "how" the tests will be conducted. Should align with the functions described in Objective statement.

8

Notes
This task is to evaluate the air vehicle control response characteristics to perform a precision landing. If there are pilot selectable response types to maneuver the vehicle in this task or if the loss of sensor feedback results in a change in response type, the air vehicle shall be assessed in each control response type for this task.

8 Notes: Place holder for applicable information that is not an objective or test description that will inform other entities, partners, or evaluators on aspects within the research.

9

Test Course Description
1. Conduct site survey
2. Deploy weather-sensing equipment
3. Perform operations check on equipment
4. Measure and record weather data
5. Perform quality control and formatting checks
6. Distribute data

9 Test Course Description: Step by step breakdown of how the test will be performed, may site previous test matrix.

10

Reference Guidance
FAR Part 21.17B
FAR Part 27 (23.2135) Controllability
FAR Part 27 (23.2145) Stability
ADS-33 Pirouette Task
ADS-33 Landing Task

10 Reference Guidance: The "anchor and evolve" of applicable regulations, policy, criteria, standards and advisory circulars.

11

Adequate Criteria (1)	Operational State I: - CHR 1 to 3
Desired Criteria (2)	Operational State II, III and moderate turbulence and crosswinds – CHR 4 to 6

1. Adequate Criteria: Baseline performance, conformance, conditions needed to conduct tests. A meet or exceed benchmark of safety or validation.
2. Desired Criteria: Focused parameters of performance targeted in the tests.

12

Instrumentation Package			
Task (1)	Wind speed (surface)		
Required (2)	1 knot	(3) Desired	0.1 knot
Instrumentation Package			
Name (4)	RM Young Wind Monitor AQ	(5) Resolution	0.1 knot, 1 Hz
Task	Wind direction (surface)		
Required	10 degrees	Desired	0.1 degree
Instrumentation Package			
Name	RM Young Wind Monitor AQ	Resolution	0.1 degree, 1Hz
Task	Temperature		

1. Task: Broken down data element individual for each test, not based on instrumentation. (Example Wind + Direction same instrument but different data.)
2. Required: Baseline performance, conformance, conditions needed to conduct tests. A meet or exceed benchmark of safety or validation.
3. Desired Criteria: Focused parameters of performance targeted in the tests.
4. Name of Instrument Package: Part of minimum equipment list.
5. Resolution: Fidelity of instrumentation deliverable.

13

Requirements	
NASA POC (1)	Kyle Pascioni
Alternate NASA POC	Erin Waggoner
FAA Policy POC (2)	Keri Lyons
FAA Technical POC (3)	Wesley Major & Robert Bassey
FAA Technical POC	Jay Sandwell

1. NASA POC: Point of contact from NASA responsible for Objectives and research.
2. FAA Policy POC: Point of contact from FAA responsible for the policy mapping of data to applicable lines of business.
3. FAA Technical POC: Point of contact from FAA responsible for the technical mapping of data to applicable lines of business.

14

Minimum Equipment List
Microphone array
Weather monitoring systems
Aircraft tracking module

14 Minimum Equipment List: List of minimum equipment needed to conduct test.

4 AIRSPACE OPERATIONS

4.1 Airspace Operations Overview

The AAM NC built a physical airspace at Edwards Air Force Base to test early NC series flight events. The AAM NC UAM Helicopter testing utilized the R-2515 range which is comprised of the following sections, limits, and altitude constraints (Figure 4.1):

Forbes (East of Rosamond Boulevard): surface to 5,000 feet AGL
UAS Corridor: 5,000 ft to 10,000 feet MSL
UAS Work Area: surface to 10,000 feet MSL
East and West PIRA: surface to 10,000 feet MSL

The following blocks of airspace were built within the R-2515 complex for National Campaign and received a Notification to Air Mission (NOTAM) status:

X-33 NOTAM and X-33 NOTAM Addendum: surface to 5,300 feet MSL
* X-33 NOTAM and the X-33 NOTAM Addendum are two separate areas, therefore use of each airspace block was coordinated separately.
Forbes Extension: surface to 5,000 feet AGL
Critical/All Azimuth testing was executed at the North Base Runway. The runway offers a 6,000-foot paved surface with runway markings to provide appropriate reference for the tests.

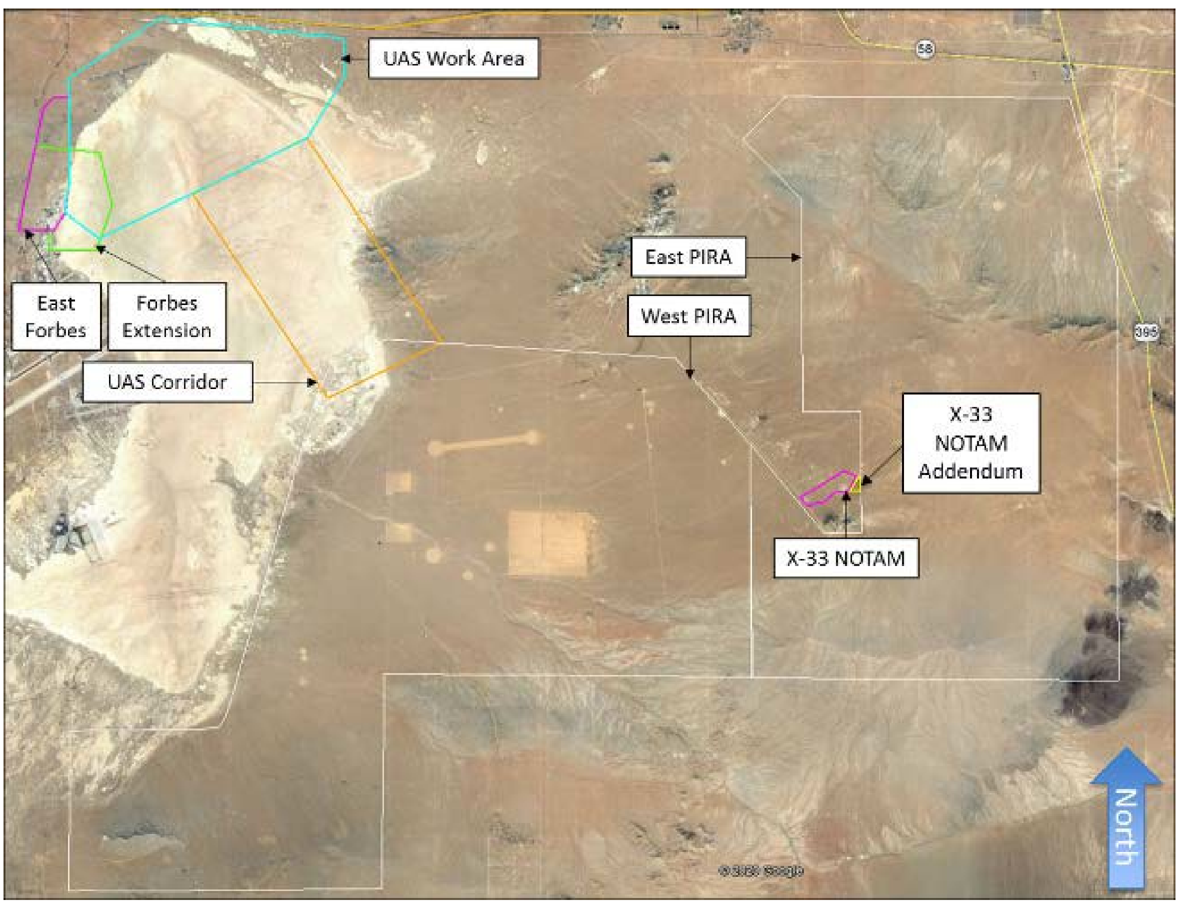


Figure 4.1. Test Site Airspace High-Level View.

R-2515 Airspace

R-2515 Restricted Airspace exemplifies a complex set of airspace volumes, reservation, airspeed, and altitude constraints that emulate an expected urban environment (Figure 4.2). The NC routes and scenarios were constructed to utilize the Edwards Air Force Base (EAFB) lakebed, avoid vertical obstructions, align with final approach paths, and avoid disruption to EAFB operations. The unique set of challenges enabled National Campaign Airspace Procedure team to exercise multiple contingency routing that did not fly over containment areas nor restricted areas.

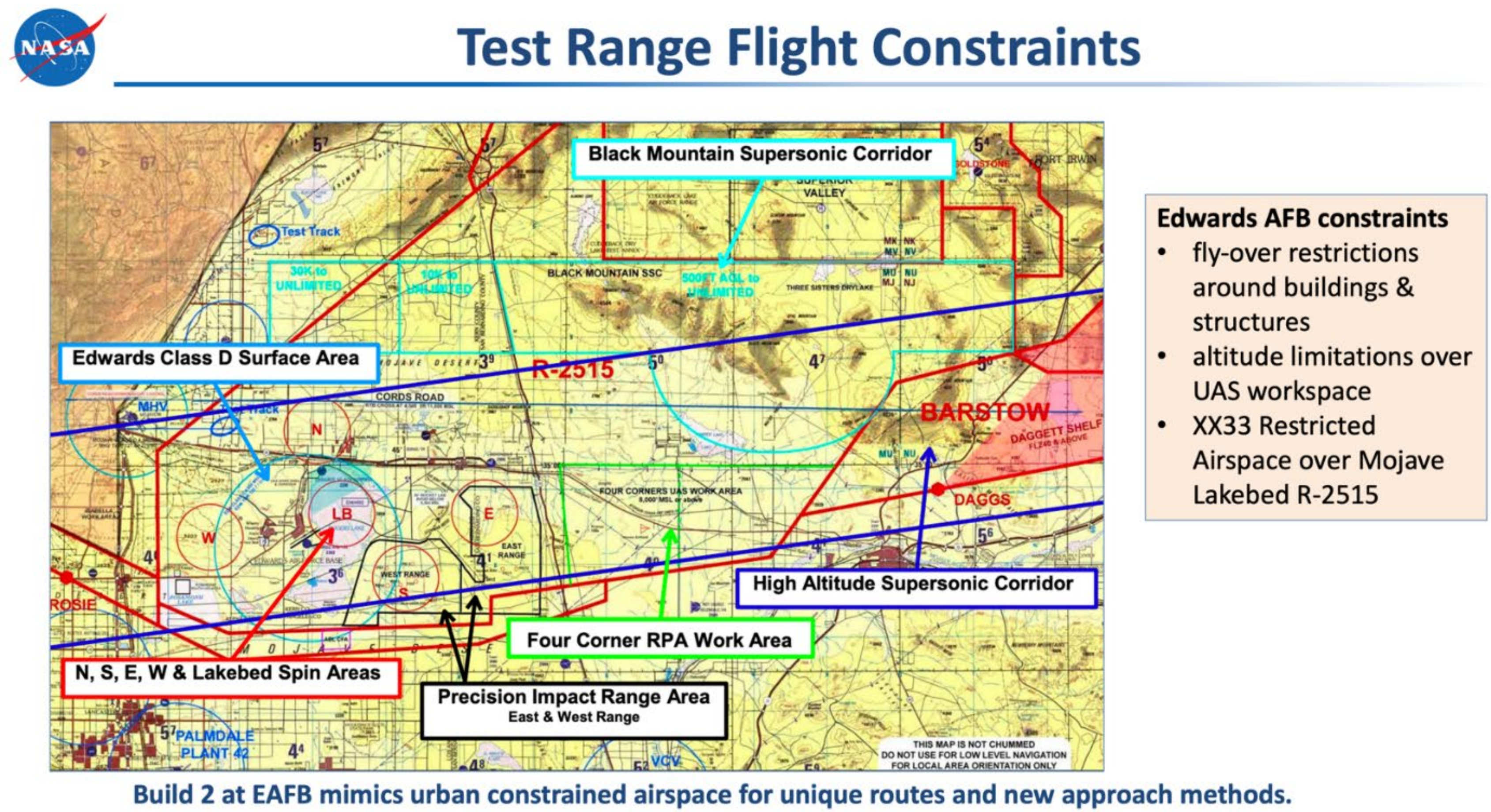


Figure 4.2. Test Range Flight Constraints.

The airspace coordinated for Build 2 is depicted in Figure 4.3 and is described as follows:

> The UAS work area (teal) includes UAS Work Area Route 1 (red) and 2 (green) surface to 10,000 feet MSL. X-33 Route 1 (red) restricts to at or below 500 feet AGL when over the lakebed. X-33 Route 2 (purple) requires at or below 500 feet AGL when over the lakebed. UAS Corridor (orange box) requires at or above 5,000 feet MSL to 10,000 feet MSL. The X-33 site (pink) and Precision Impact Range Area (PIRA) bridge (teal) include surface to 5,300 feet MSL but no lower than 300 feet AGL unless on approach. Route Bravo is 500 feet AGL out and back (under the purple route to just past the lakebed). Forbes (over the vertiport) and Forbes Extension (pink) is surface to 5000 feet AGL. East and West PIRA (white) cover surface to 5,300 feet MSL but available with prior coordination to 10,000 feet MSL.

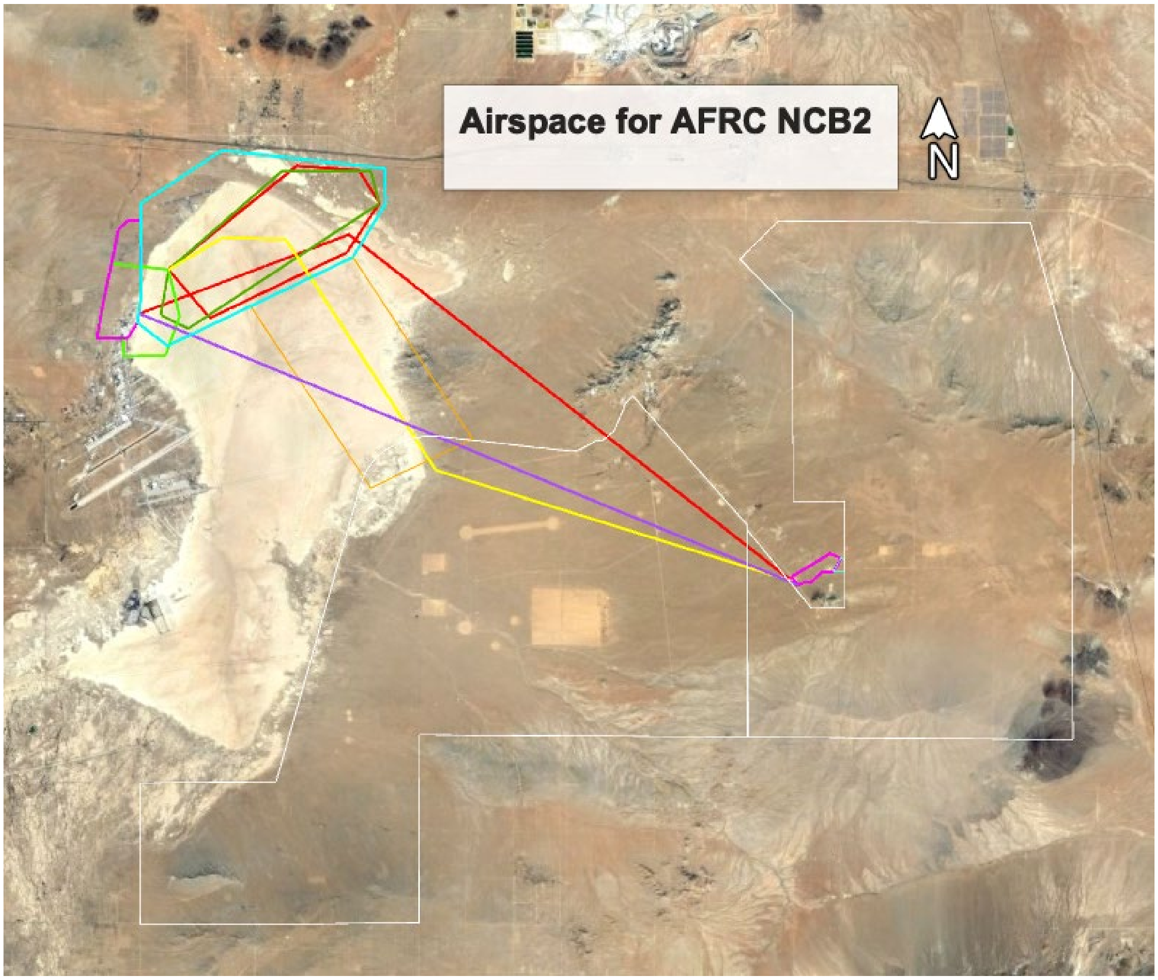


Figure 4.3. National Campaign Build 2 Airspace Routes.

The airspace was coordinated to create, using some of the natural constraints at EAFB, a simulated UAM environment where airspace is extremely limited, and aircraft must negotiate obstacles (real or restricted) to optimum approach and departure paths. Because of the described concept and the restrictions on the airspace, routes to landing zones were purposely kept tight for NC scenarios in order to test the ability of the surrogate aircraft to navigate in simulated UAM airspace.

UAM Terminal Approach Infrastructure (1 of 3)

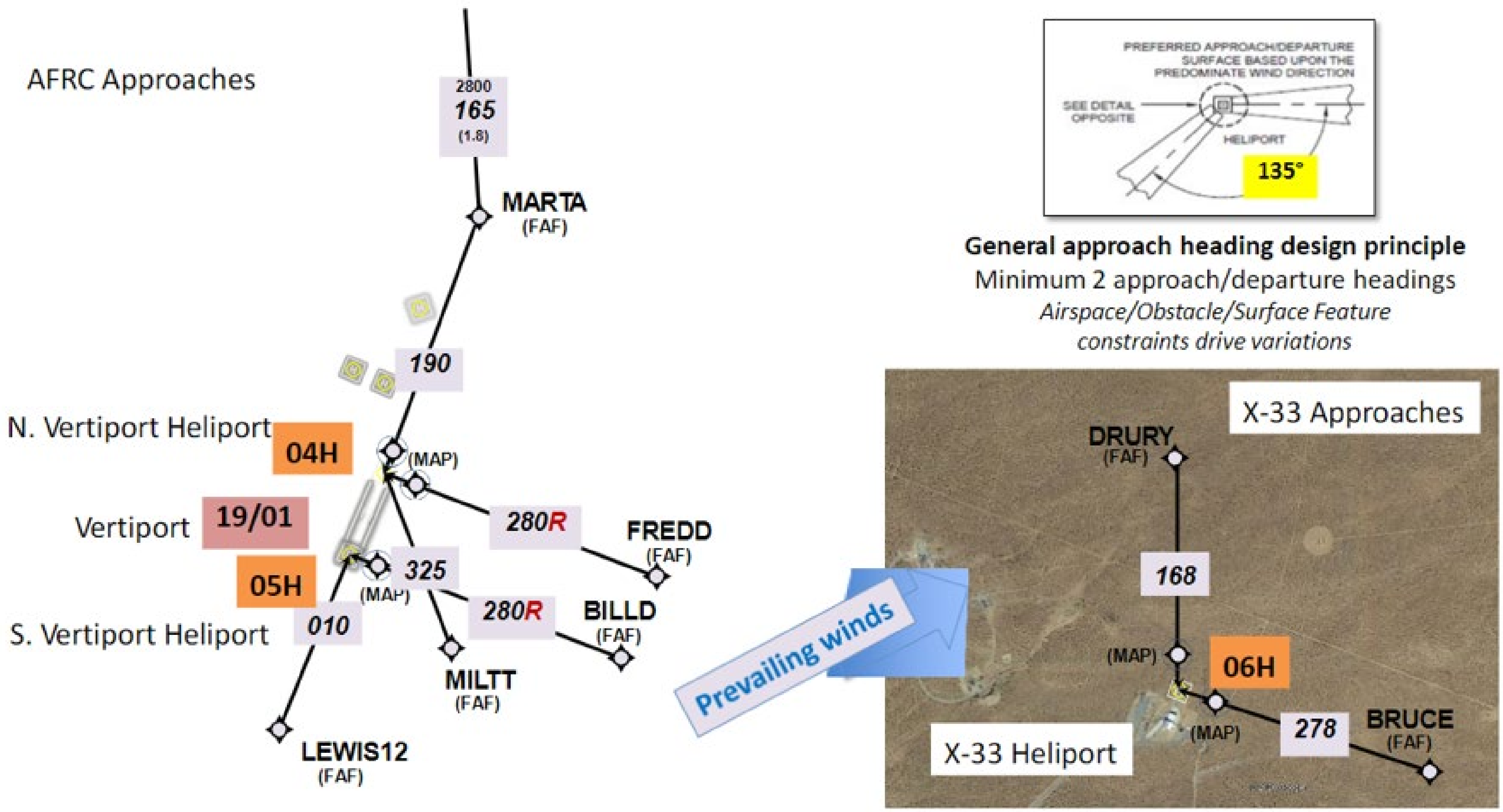


Figure 4.4. National Campaign Terminal Approach Infrastructure 1.

UAM Terminal Approach Infrastructure (2 of 3)

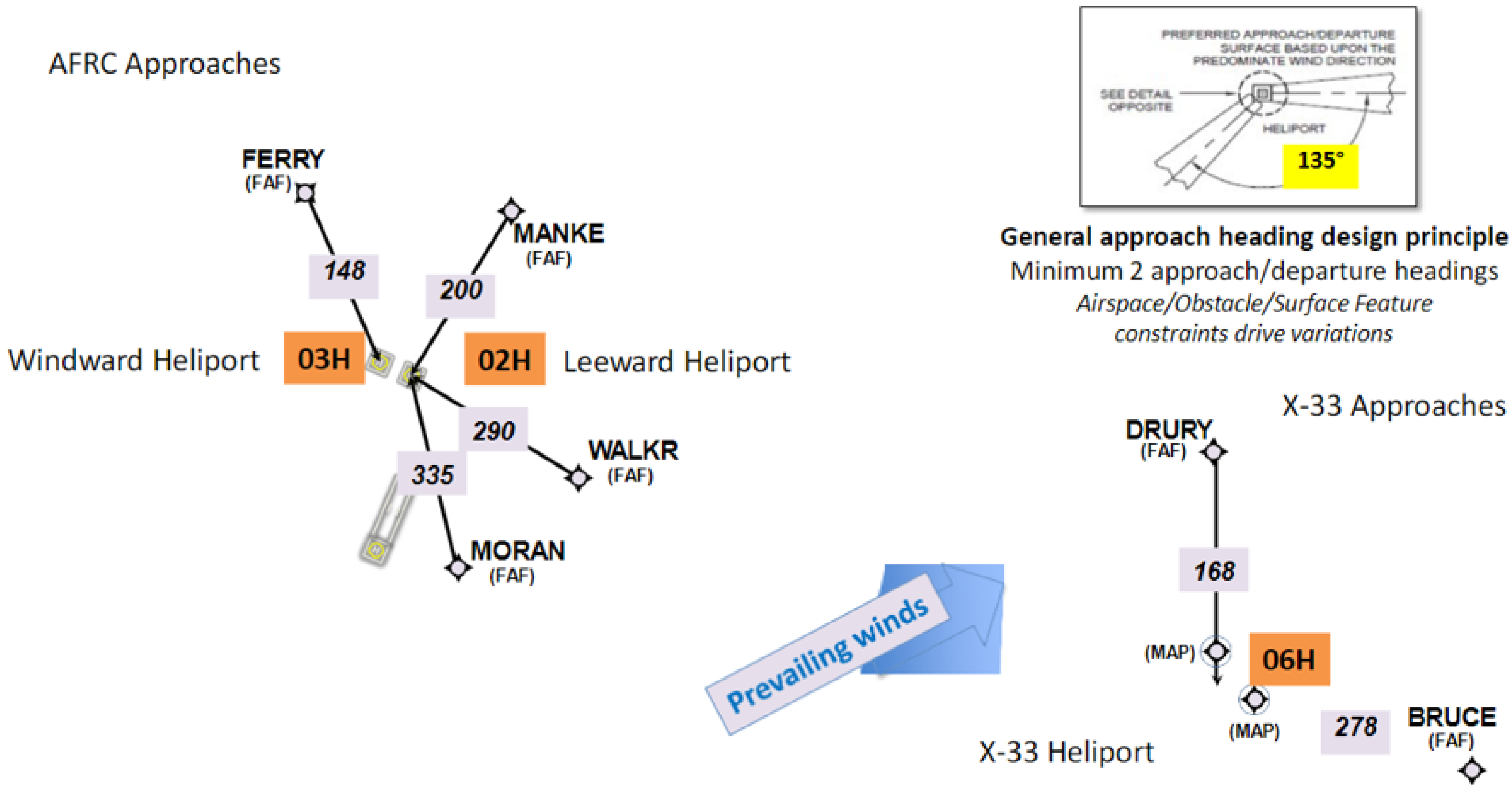


Figure 4.5. National Campaign Terminal Approach Infrastructure 2.

UAM Terminal Approach Infrastructure (3 of 3)

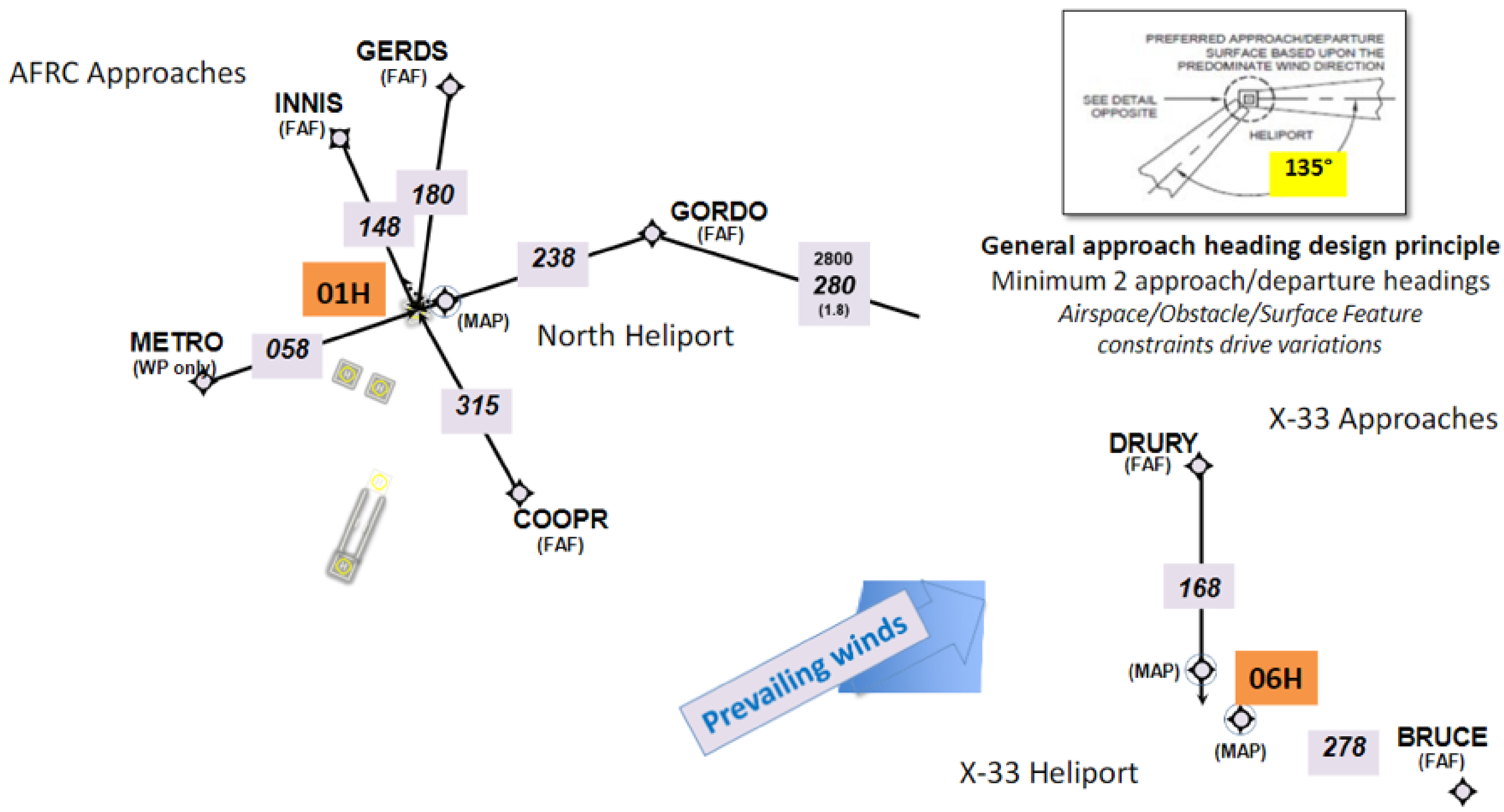


Figure 4.6. National Campaign Terminal Approach Infrastructure 3.

4.2 Terminal Procedures

Background

Using a non-flight assisted piloted surrogate aircraft, the OH-58C helicopter, the NC sought to obtain baseline data from both terminal and enroute flight scenarios to be used as a measure for emerging market aircraft looking to operate in future UAM terminal and enroute airspace. A research aim is to determine if emerging aircraft would be able to duplicate or improve upon the performance of the surrogate aircraft in these tests, whose long history of safe flight and capabilities in current flight environments is already well established when flown by an onboard pilot. The baseline surrogate data provide a comparison for future test event against a flight-assisted piloted surrogate aircraft. Eventually, NC partners will fly autonomously operating aircraft. The expectation is that future flights can improve upon the baseline performances utilizing emerging and near-future planned technologies to merit reduced separation minimums, tighter turn ratios, more aggressive approach and departure paths, reduced airspace requirements, and more automated, or reduced, air traffic control interactions for operations in future UAM environments. The NC team collaborated with the FAA Instrument Flight Procedures Group, the FAA Flight Check Group, and the FAA Aviation Technologies Group, all from Mike Moroney Aeronautical Center in Oklahoma City, toward the research concepts and execution.

The following topics are discussed in the this section: *Waypoints, Waypoint Gap Analysis, Fixed Displacement, Distance of Reaction and Roll (D_{rr}) Bias Error, UAM Minimum Enroute Altitiudes (MEA*) and *Vertical Separation.*

Waypoints

Once an established departure and landing location was determined, the center point of the desired heliport/vertiport (or 'vertipoint') enables a subset of waypoints to bind the UAM route structure from one departure location to an arrival location. Waypoints are traditionally based on a point in space that has a fixed-use against a navigational aide or an airport with a single role to function as a holding point, an initial approach fix, or enroute navigation. A waypoint, sometimes known as a fix, is published in the *Radio Fix and Holding Data Record*. One of the gaps recognized was updating the form to account for the new use cases, or multiple use cases, that would be required for UAM precision path point routing. As seen in Figure 4.7, the waypoint and waypoint subset list will be used for future state AAM operations, much like company routes or helicopter routes exist today in the FAA waypoint directory. The resultant data would enable AAM operations to redefine the waypoints best suited for low level truncated routing while still providing the same level of safety and precision associated with IFR routing today.

Waypoint Gap Analysis

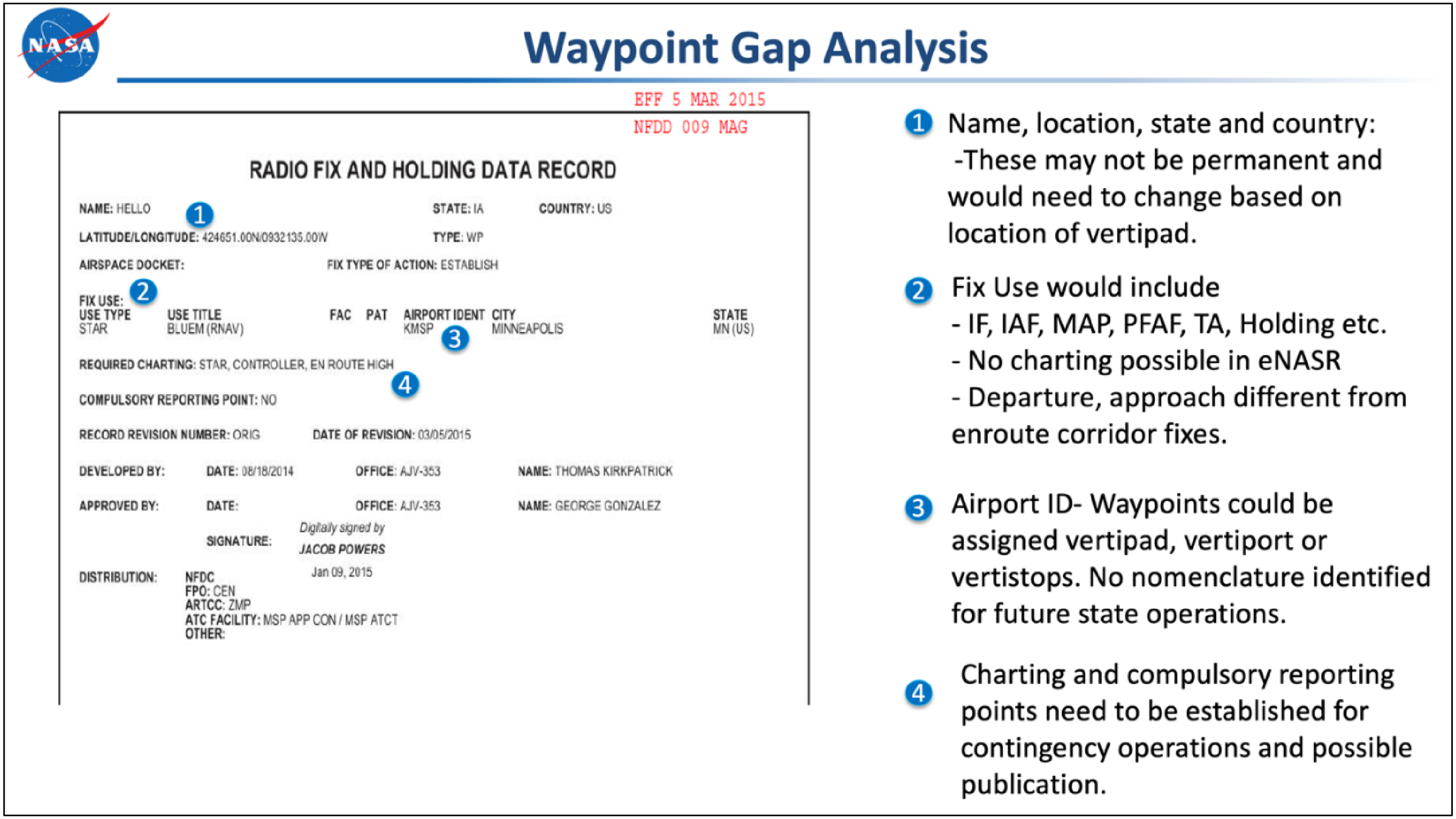


Figure 4.7. Waypoint Gap Analysis.

Fixed Displacement

The NC team explored a way to update and advise candidate UAM waypoints for an urban operation. Use cases were considered for the waypoint subset list, which allowed the team to dissect the bias errors associated with a waypoint in the traditional navigation feature. The leg type associated with each waypoint, whether a track to fix (TF), radius to fix (RF) or direct to fix (DF), was applied with respect to criteria for a track to fix leg type as seen in Figure 4.8. The first portion of candidate AAM waypoint routing was the cross-track tolerance applicable with the associated required navigational performance (RNP) value that would determine the lateral limits of the fixed displacement area. The RNP value was pulled from the 8260 Series that defines the navigational accuracy of a phase to an advanced RNP, or a prior authorized navigational performance which would simulate a low, close to the ground final approach segment. Next, the turn radius, which determines the bank angle required at the maximum ground speed associated with the fixed displacement, remained constant and, therefore, required no changes.

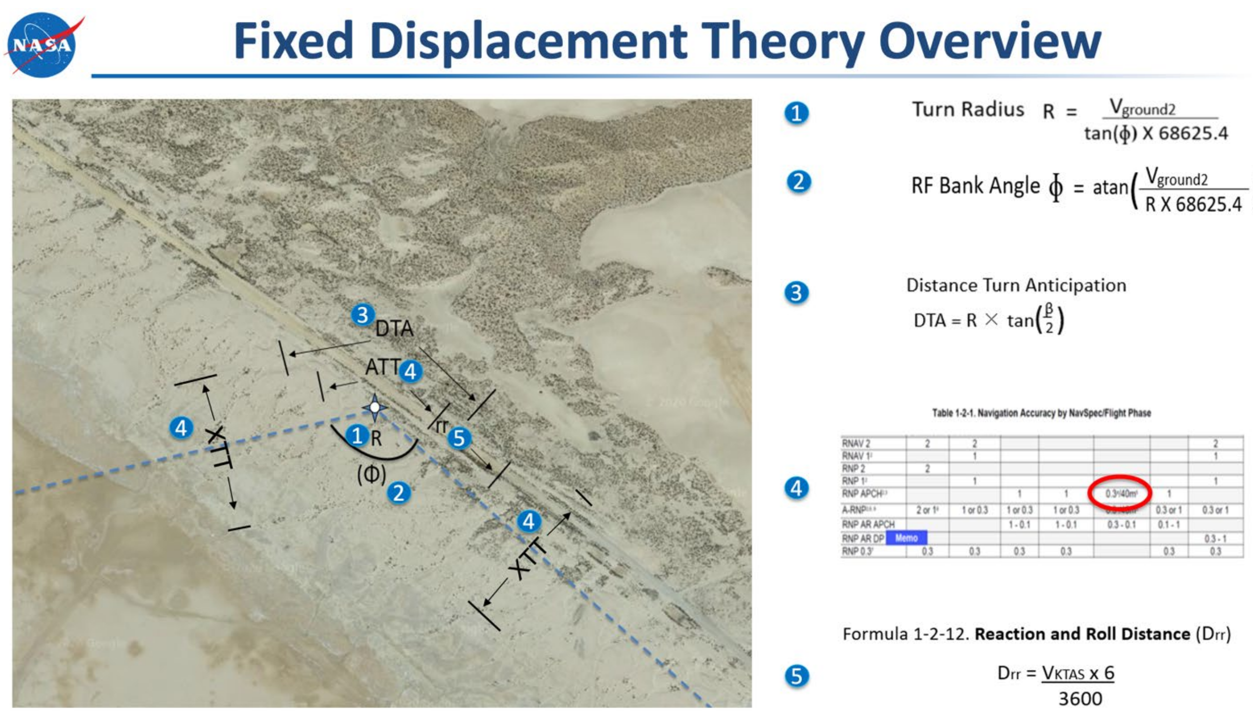
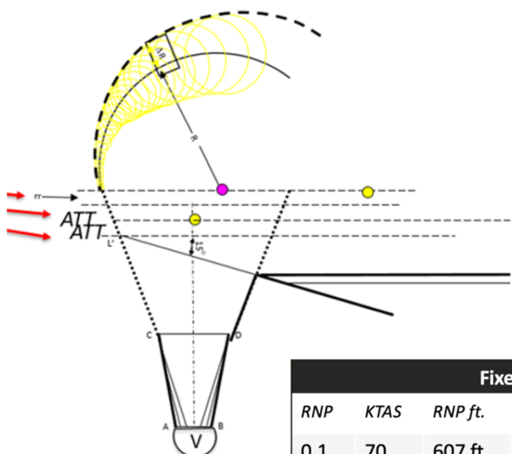


Figure 4.8. Fixed Displacement Theory Overview.

Distance of Reaction and Roll (D_{rr}) Bias Error

The National Campaign team applied legacy distance of reaction and roll bias errors to routes to update and account for automation with the same ratios of safety applicable to an AAM vehicle on an AAM route. The bias error associated with the reaction and roll rate is a function of time for six seconds flown at the intended air speed. Three of the six seconds are given to the Navigational Aid (NAVAID) to display the position and three seconds are allocated to the pilot to interpret the display and make the correct inputs into the flight controls, according to the conventional definition of the reaction and roll rate. Figure 4.9 is a simplified table further explaining the breakdown of the candidate UAM reaction and roll rate bias error associated with a turn at a waypoint. The variables are broken down into a Punnett Square associated with conservative and aggressive values of time allotment and conservative and aggressive values for RNP. The values will be tested to reduce the conventional containment area. In either case, the reaction and roll distance derived from the speed at the seconds value is added in feet to the end of the fixed displacement area, as defined in feet from the later end of the along-track tolerance variable. The distance caps the apex of the turn as shown in the example Figure 4.9.

Fixed Displacement Theory Drr



Formula 1-2-12. **Reaction and Roll Distance** (D_{rr})

$$D_{rr} = \frac{V_{KTAS} \times 6}{3600}$$

70 KTAS x 6 sec./3600 x 6076.12 NM in ft. = 708.8807 ft.

70 KTAS x 3 sec./3600 x 6076.12 NM in ft. = 354.4403 ft.

Fixed Displacement Theory for Distance Reaction & Roll (Drr)

RNP	*KTAS*	*RNP ft.*	*Drr Error*	*Containment Area*	*Time for Drr*	*NAVAID*	*Pilot*	*Autopilot*
0.1	70	607 ft.	708 ft.	1315 ft. CONSERVATIVE	6 sec. CONSERVATIVE	3 sec.	3 sec.	NA
0.05	70	304 ft.	354 ft.	658 ft. AGGRESSIVE	3 sec. AGGRESSIVE	3 sec.	NA	TBD

AAM automation may enable reduced reaction and roll displacement allowances to condense flight paths.

Figure 4.9. Fixed Displacement Theory Application.

UAM Minimum Enroute Altitiudes (MEA)

The National Campaign team addressed the altitude selections for candidate AAM routing by dissecting the conventional requirements for obstacle clearance when navigating by reference to instrumentation. Figure 4.10 explains the breakdown of required obstacle clearance that is a function of terrain airspace and vertical obstructions. Once the obstacle clearance altitude has cleared terrain and vertical obstructions, radio reception navigational aid reception is determined. The NC team introduced the idea of gust rejection tolerance as a variable to account with enroute altitude. A fixed displacement error in the vertical axis was also added when determining a distance of turn anticipation while climbing to the same azimuth.

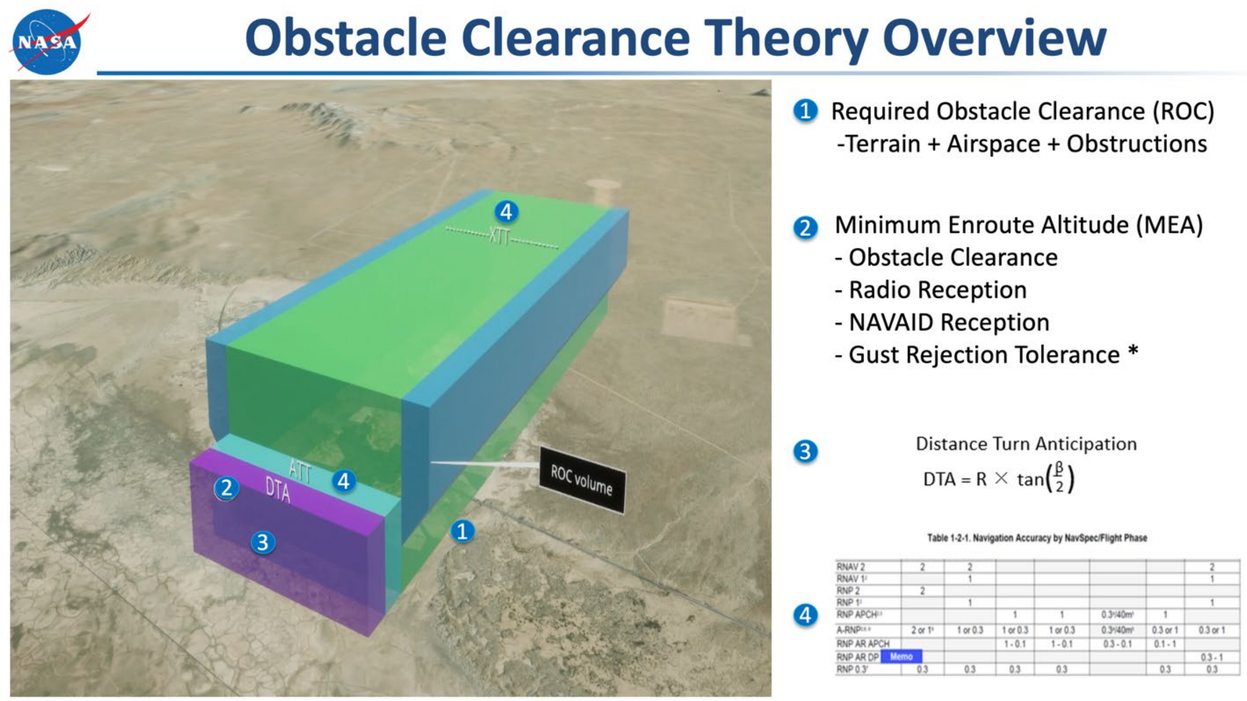


Figure 4.10. Obstacle Clearance Theory Overview.

Vertical Separation

The gust rejection tolerance, or vertical separation theory, for NC AAM altitude deconfliction, was based on the concept of the minimum altimetry system error designed for large transport category aircraft utilizing an identical Victor Airway but on opposing paths. The altimetry system error is set at 1000 feet with an acceptable error of 300 feet. Using the same ratio of safety, the NC team reduced the 1000 feet buffer in half to 500 feet and increased the ratio of acceptable error from what would be 100 feet to a 150 feet tolerance. Using the reduced ratio, the NC team applied legacy updraft rates in feet per minute and calculated the aircraft movement in feet per second. The results reflected the amount of time an AAM vehicle would bust the theoretical containment area of 100 feet per the same ratio of the conventional altimeter system error, and at 150 feet as an increased variable to the altimetry system error. The results in Figure 4.11 were computed as seconds required for the pilot in command, air traffic controller, or other third party service, such as a PSU, to initiate some form of a contingency. Further research is required to determine the human factor element in deconfliction. The intent of the test was to determine the two-sigma vertical containment area for candidate AAM routing.

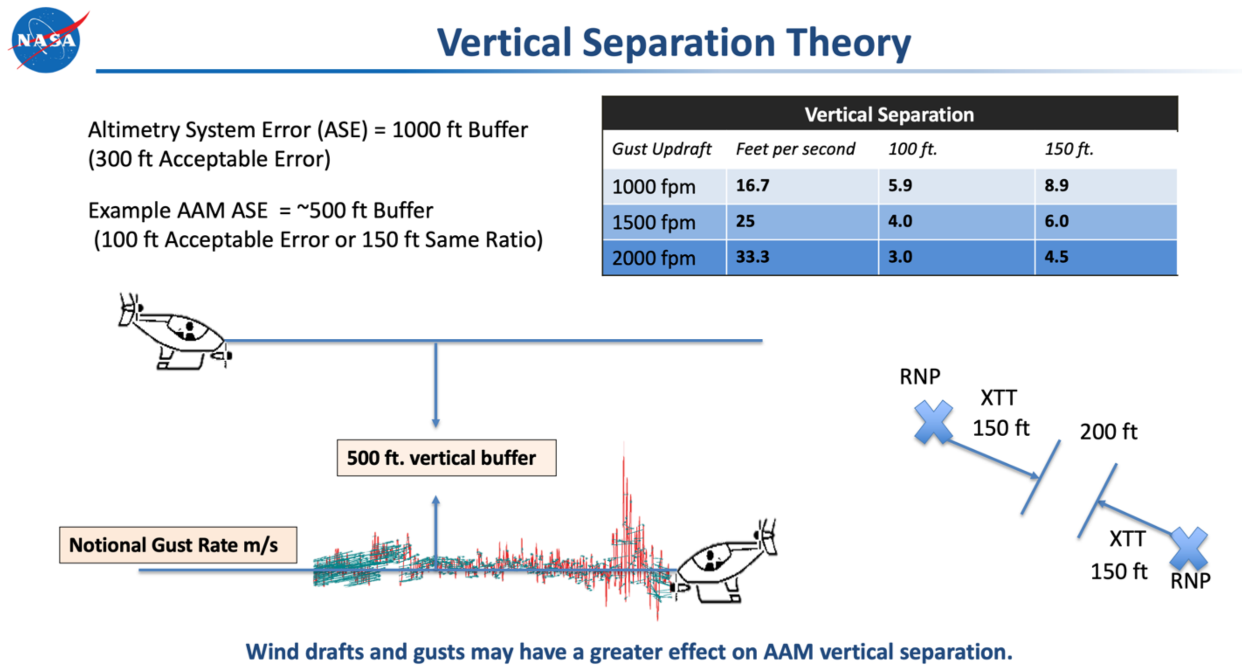


Figure 4.11. Vertical Separation Theory.

Flight path conformance and bias errors, along with significant flight characteristics and terminal airspace data, were captured during Dry Run events.

XEDW 01H Procedure:

The NC team applied candidate theories to conventional approaches to build an airspace architecture representative of AAM operations. The intent was to replicate the current process while comparing and contrasting NC theories against conventional methods. The following topics are discussed in the this section: *Conservation of Airspace Theory, Radius, Conrolling Obstacle, Departure and Approach Procedures, 360-Degree Discrete Paths* and *Airspeed to Angle.*

Conservation of Airspace Theory

The conservation of airspace theory is a concept to house all operations to include approach, departure, traffic pattern, landing alignment, missed, and holding sequence entirely contained in one cylinder of airspace above a vertiport. This conservation will avoid the need for AAM operations to take large swaths of airspace in a condensed cityscape requiring adequate spacing, sequencing, and contingency actions. The cylinder of airspace will be evaluated against terrain, vertical obstructions and other time-spliced airspace constraints that could impact AAM operations in an urban environment.

Radius

Currently, the obstacle evaluation assessment (OEA) area radius is defined by the operation, size and speed of the aircraft flown in and around the airfield. Expected AAM operations will be a "compensation-for-hire" operation, so controlling the gravitational force to maintain passenger comfort will be the driving force of the radius in obstacle evaluation assessment areas. The resulting radius will be a function of airspeed to angle based on an assumption of 1.03 g-force (defined as an acceptable range for current transport category aircraft operating in an IFR environment) (see resultant force Figure 4.12 below).

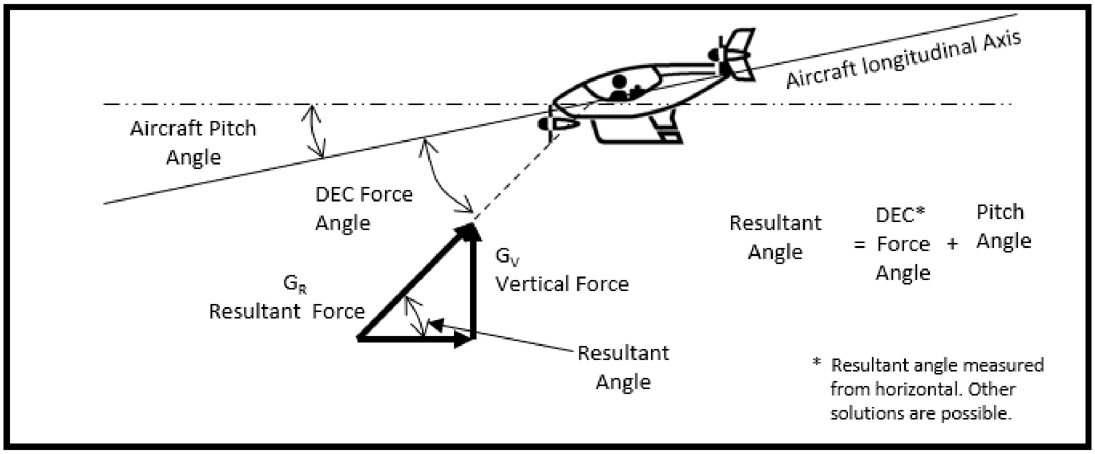


Figure 4.12. Final Approach Segment Considerations.

Controlling Obstacles

Once a radius is established, 360 degrees from the intended point of landing is evaluated to create a base, for example, a 1.5-nautical-mile diameter for a 12-degree approach. With the lateral dimensions defined, the height of the volume of airspace is determined for the operation, thereby completing the cylinder. Within the cylinder of airspace, terrain, vertical obstructions, wake vortices and other airspace constraints, such as dynamic interface (measurement of potential hazardous wind azimuths that may create mechanical turbulence on the leeward side of a surrounding structure), are evaluated. The combined variables will determine the controlling obstacle or obstacles in the OEA (see red structure and the corresponding dark blue circular area below it in Figure 4.13) to ultimately drive the height of the cylinder of the UAM operation.

Departure and Approach Procedures

Once the controlling obstacle has been determined, departure and approach procedures are constructed within the cylinder of air space (see green cone below in Fgiure 4.13). The intention is to unnecessarily avoid duplicate evaluations of the same airspace. The most conservative flight profiles are assessed as a baseline of safety and separation from terrain and controlling obstacles. As the procedure construction sequence begins, a departure climb gradient is assessed based upon the lowest performing aircraft operating within the cylinder of airspace. Since candidate AAM aircraft are neither efficient fixed-wing (requiring a 200-feet-per-nautical-mile departure path) nor efficient rotor wing, (requiring a 400-feet-per-nautical-mile departure path), the NC team assumed a mean 300-feet-per-nautical-mile AAM obstacle clearance slope. From this assumption, a 300-feet-per-nautical-mile departure climb gradient is applied in a 360-degree funnel, away from the center of the airfield or vertiport (see ygreen volume of airspace in Figure 4.13 with yellow buffer). Departure criteria have a lower rise-over-run value, so every approach will automatically be within the evaluated funnel and inherently protected to execute nominal operations. As a result, no further evaluation will need to be performed.

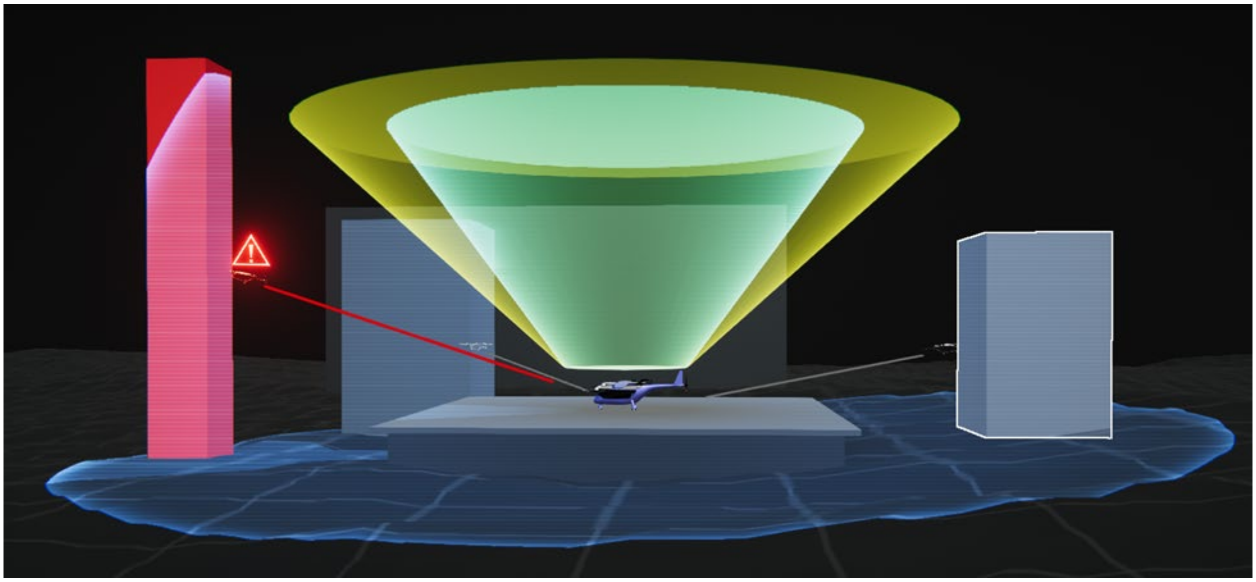


Figure 4.13. NASA National Campaign Approach/Departure Analysis Tool.

360-Degree Discrete Paths

An "IFR 360," or 360 discrete approach paths to a point in space, was the method selected for evaluation by the National Campaign team. A disturbed electric propulsion systems approach path requires an approach that is streamlined into the wind as much as possible. This condition is a safety case because lift-plus-cruise, inducted fan, or multirotor designs have sensitives to crosswind component for critical azimuths at much lower airspeeds than do traditional fixed- and rotor-wing limitations. Thus, omni-directional arrival and departures embedded in fixed waypoints will likely need to be defined to provide prescribed routing to and from the vertiport cylinder, holding along the outer edge of the cylinder and aligning rollout points to a final approach segment (wings-level on a glidepath). Since 360 unique approaches per vertiport is not reasonable, the minimum weather binning reporting of azimuth and velocity that consists of 20-degree segments was applied, which resulted in eighteen equal distant waypoints creating a "wheel" with the vertiport located at the center (see Figure 4.14).

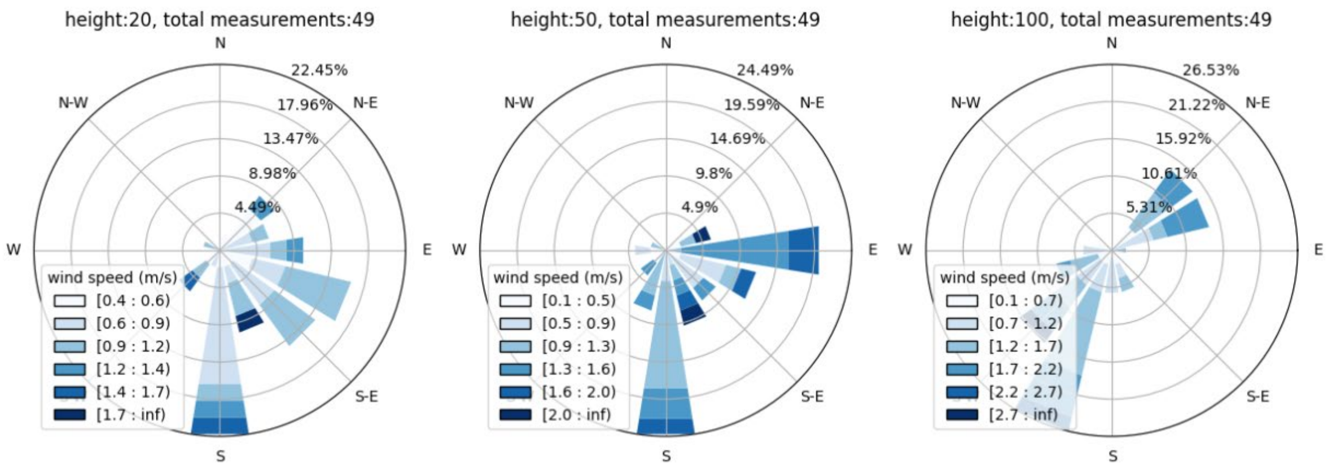


Figure 4.14. Wind Azimuth And Velocity Bins at Helipad Heights in Feet; Wind and Azimuth Coupled with Wheel Approach Points Potentially Enables Targeted Dynamic Approach Opportunities.

Airspeed to Angle

Reverse planning from the resulting wreath waypoints along the radius defines the airspeed to angle formula derived at-or-below g- force constraints (1.03 g) and are set tangentially along a 360-degree arc equal distance from the vertiport center point, creating a circle, wheel, or wreath (Figure 4.15). The importance of the fixed waypoints is not within the isolated function, navigational mechanism, or unique identifier, but rather the ability to anchor multiple waypoints splayed from one high-precision location (latitude/longitude) and elevation (ellipsoidal height). With waypoints attached to the vertiports, greater utility per waypoint (precision) is realized than what is provided by the current -2 radio/fix form. Simultaneously, vertiport waypoints do not burden the FAA Instrument Flight Procedure database with tens of thousands of new waypoints. Each waypoint will become an Initial Fix (IF), Initial Approach Fix (IAF), Final Approach Fix (FAF), Final Roll-Out Point (FROP), Distance Measuring Equipment (DME) ARC, Holding Fix, or Terminating Altitude (TA) relative to the navigation and alignment required for the eighteen different departure and approach paths to be coded for each individual vertiport.

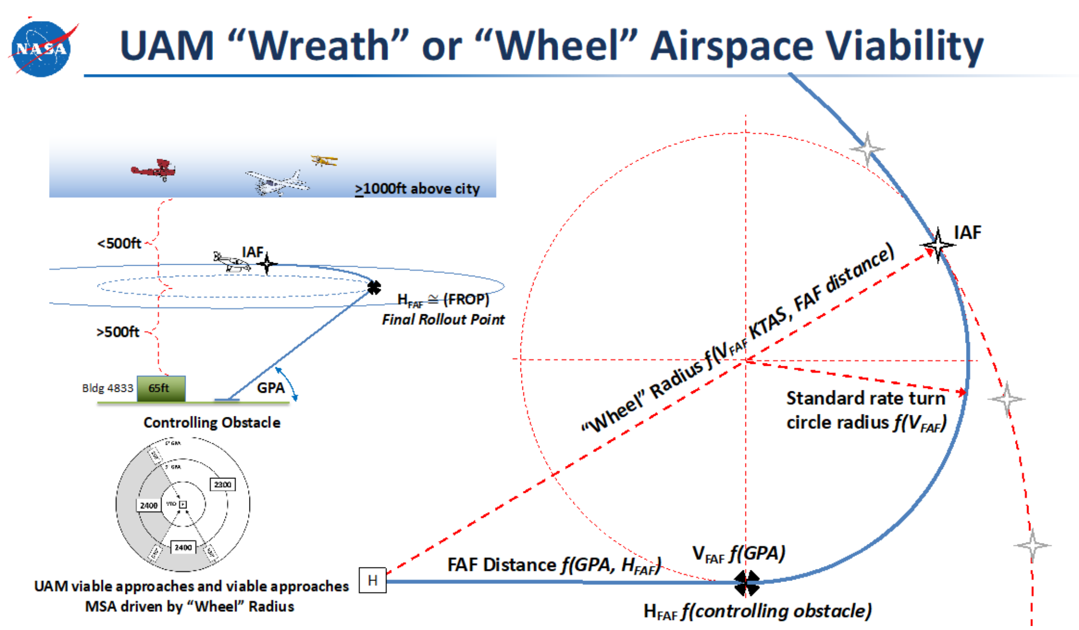


Figure 4.15. Urban Air Mobility Wheel Airspace Viability.

As illustrated in Figure 4.15, the aircraft is able to fly the wreath or wheel construct from any approach azimuth or on any GPA. In a sterile environment with no terrain or vertical obstructions, the glide path angle could be utilized down to a traditional or conventional 3-degree approach and still provide omni-directional departure and arrival capabilities. The gravitational force applied to the airframe, as well as passengers, will be the mitigating factor for the airspeed to angle limitation and forthcoming NC research into the standardization of vertically-guided precision descent procedures.

XEDW 01H GORDO Procedure:

Three airports and six landing locations were constructed as part of the AFRC flight test. Each landing location had several approach procedures that were surveyed, constructed, evaluated, and flown. In order to avoid confusion on closely spaced procedures, or highly similar procedures at a different locations, only one procedure will be discussed in detail, and the remaining procedures that were flown as part of a flight plan or scenario are located in Annex 6.3 for reference. The XEDW 01H GORDO procedure and airspace evaluation will be the representative example of the airspace analysis, procedure build, coding, simulation, and evaluation of the AAM candidate procedure architecture conducted at AFRC. The first example at XEDW 01H GORDO will be the overlay airspace required for a conventional approach compared to the NC candidate airspace model, procedure file, and final approach segment for UAM operations.

The following topics are discussed in the this section***:*** *Conservation Of Airspace Test Outcome, Conventional Lpv Approach, Conventional Approach Procedure XEDW, Conventional Versus Candidate Airspace Architecture, Airspace Conservation at XEDW 01H, Constraints, XEDW 01H Airspace Sectors, Flying The Wheel, Approaches Design* and *ARINC 424 Coding***.**

Conservation of Airspace Test Outcome

Given airspace constraints at AFRC, the National Campaign team compared and contrasted conventional RNAV approach procedures overlaid on a candidate AAM approach procedure. The purpose of the test was to analyze the lateral airspace (area), not including the vertical axis (volume) in which a single approach procedure would take. Figure 4.16 outlines the total footprint (area) of a conventional approach procedure, given one azimuth with two standard RNAV initial approach fixes, one LPV final approach segment, one missed approach procedure and a transition that terminates in holding (standard). The radius of the airspace was 28.31 nautical miles as outlined in the blue circle. The NC team used standard leg lengths, secondary areas, and initial climb areas to include a Section 1 of the missed approach. The overall area was considerably higher compared to the candidate approach procedures outlined in Figure 4.16.

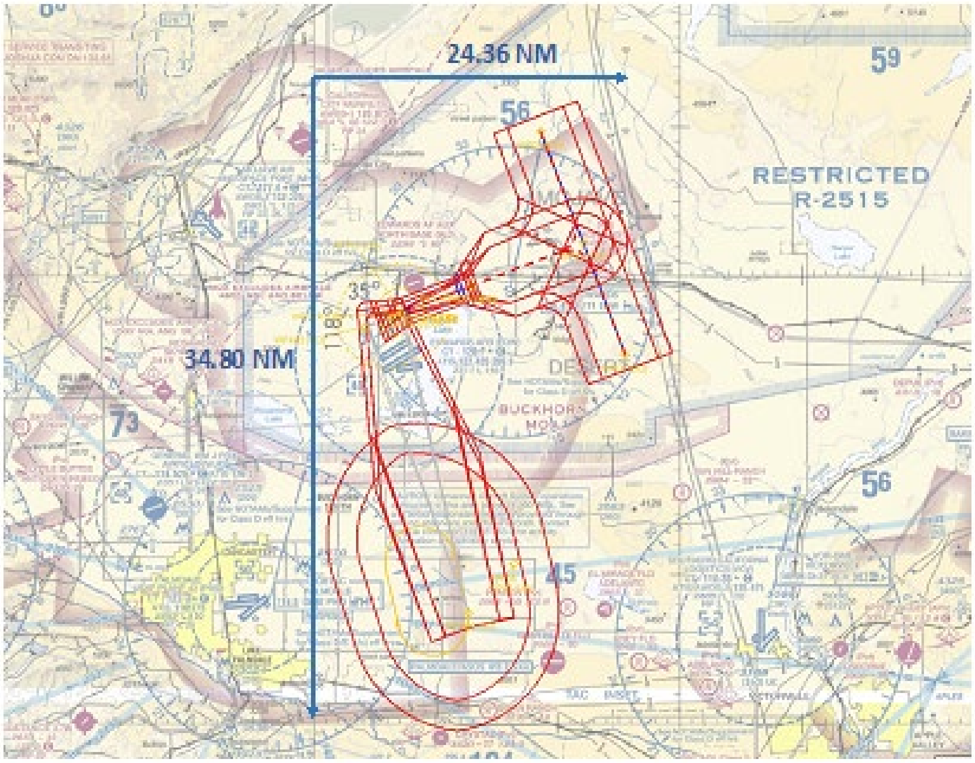


Figure 4.16. Conventional Approach Procedure on VFR Sectional at XEDW.

Conventional LPV Approach

Although the conventional LPV approach was not flown, the total impact over the airspace was evaluated with current standards, criteria, policies, and regulations. Evaluation included each segment of evaluation areas as well as containment areas allotted for an instrument approach procedure terminating with a performance based navigation (PBN) approach with vertical guidance (LPV). Given the Advanced Air Mobility use case to take off, navigate and land in multiple locations in an urban environment, the current set of instrument procedures and associated criteria or regulations that allow prescribed routing for closely spaced operations, in lieu of human eyeballs with dynamic deconfliction trajectories, would not be feasible or arguably possible.

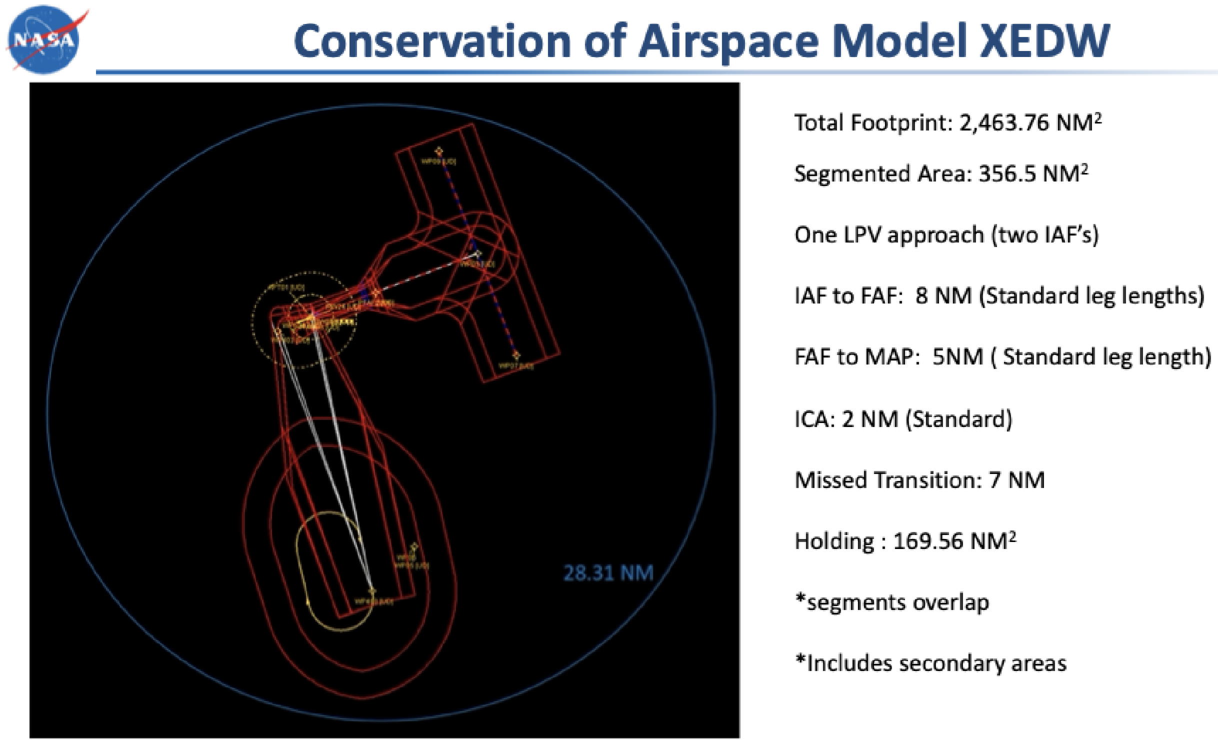


Figure 4.17. Conventional Approach Procedure at XEDW.

Given the current spacing required for traditional performance-based navigation operations and associated required navigational performance, Advanced Air Mobility procedures resulting in the same level of safety will have to individually address the components of an approach procedure from the Initial Approach Fix all the way through the Missed Approach and Holding sequence. The figure below was built in TARGETS, as part of the FAA instrument procedures group (AJV). Utilizing TARGETS software, the conventional RNAV build was constructed over the FAA digital terrain database and evaluated over several archived maps. Since the VFR sectional chart is most commonly used, the conventional procedure is displayed highlighting the size and proximity of airspace (Figure 4.18).

Conventional Approach Procedure XEDW

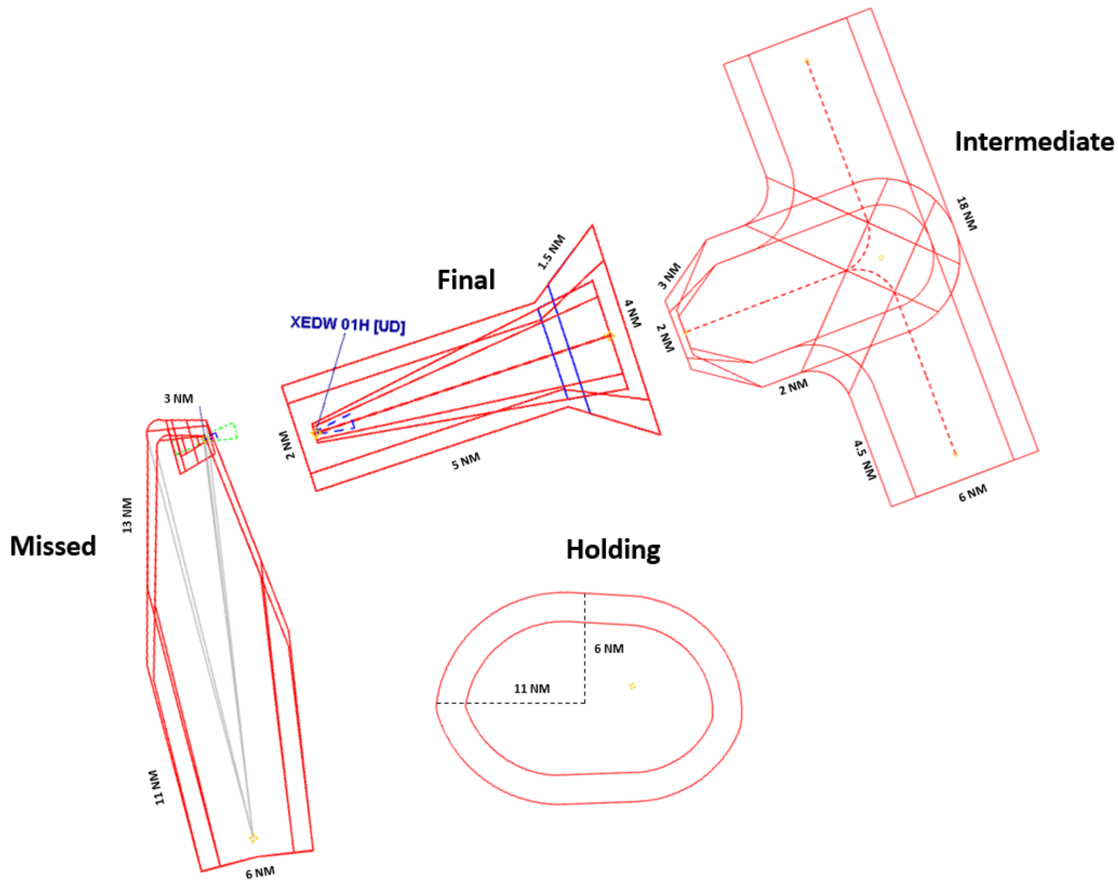


Figure 4.18. Conventional Approach Procedure Segmented Breakdown at XEDW.

In an effort to replicate every aspect of the current procedure evaluation, construction, and certification, the NC team created the 8260 Procedure Build (Figure 4.19) for 01H in an effort to identify gaps associated with the implementation of urban air mobility. Although many instrument approach procedure plates were built for every approach path, only one approach was filed per the FAA AJV requirements. Further evaluation will be required to dissect the applicable portions of the form that will need to be updated to account for future non-traditional entrants and operations seeking standardized precision routines in the National Airspace System.

XEDW 01H (1 of 4)

NOTE: ALL HEADINGS ARE MAGNETIC UNLESS IDENTIFIED AS TRUE	XEDW 01H (GPS) RWY 24 GORDO	CHECK CURRENT AIRPORT/FACILITY NOTAMS

PROCEDURE INFORMATION	AIRPORT NAME: APT01 Airport	AIRPORT ID: PT01	CITY: EDWARDS	STATE: CA	AIRPORT ELEVATION: 2241	TDZE: 2241	MAGVAR: 12E	EPOCH YEAR:	FACILITY: RNAV	CONTROL TOWER: NO

FIX NAME (FROM)	COORDINATES	SEGMENT/ FIX TYPE	FIX NAME (TO)	COORDINATES	LEG TYPE	FO/FB	RNP	Magnetic (True) Course or RADIUS/Turn Direction/RF Center Point	DISTANCE	START ALTITUDE/VAA	END ALTITUDE/VAA	SPEED RESTRICTION	PRECIPITOUS EVAL/AMT
WP07	345443.950N/1173432.831W	IAF	WP03	350213.382N/1173800.286W	TF	FB	1.00	327.21 (339.21° T)	8.00	4500	4200		YES/0
WP09	350942.706N/1174128.372W	IAF	WP03	350213.382N/1173800.286W	TF	FB	1.00	147.15 (159.15° T)	8.00	4500	4200		YES/0
WP03	350213.382N/1173800.286W	IF	PFAF	345922.154N/1174706.339W	TF	FB	1.00	237.18 (249.18° T)	8.00	4200	3900		YES/0
PFAF	345922.154N/1174706.339W	FAF	WP524	345732.981N/1175253.032W	TF	FO	0.30	237.09 (249.09° T)	5.08	3900			YES
WP524	345732.981N/1175253.032W	MAP	2700 MSL		CA			237.09 (249.09° T)			2700		YES/0
2700 MSL			WP408	343727.803N/1174725.596W	DF	FO	1.00				6000		YES/0

PBN REQUIREMENTS NOTE: RNP APCH - GPS	RNP RADIUS TURN CNF COORDINATES

HIL										
ARRIVAL HOLDING										
MISSED HOLDING	WP408 343727.803N/1174725.596W	WP RAD/CRS/BRG 335.25	HOLD NW, RT, 155.25 INBOUND	MIN/MAX ALTITUDE: 6000/6000	MIN/MAX PATTERN: 6/6	DME: 5	SPEED OF MIN PATTERN: 200	PRECIPITOUS EVAL: YES PRECIPITOUS AMT: 0.00	PRECIPITOUS TERRAIN EVALUATION COMPLETED HOLDING LIMITED TO ESTABLISHED PATTERN(S)	

CIH	CLEARANCE LIMIT OCS ALT (FT): 5489.35	CLEARANCE LIMIT AC ALT (FT): 6489.35	MISSED HOLD ALTITUDE: 6000.00	CIH REQUIRED: NO

PROFILE	LINE 2: PROFILE STARTS AT WP03	FAC: 237.09	FAF: PFAF	DISTANCE FAF TO MAP: 5.08	DISTANCE FAF TO THLD: 5.08	MIN ALT: WP03 4200, PFAF 3900,	HAT DIST: NA	34:1 IS CLEAR	20:1 IS CLEAR	MSA FROM: WP524 7800

ADDL FLIGHT DATA/ NOTES	CIRCLING 20:1 RESTRICTIONS: NO	RUNWAYS NOT AUTHORIZED: NONE	CRITICAL LOW TEMP: NA	CRITICAL HIGH TEMP: NA	FINAL OFFSET ANGLE: 0.00 LEFT	LTP DISTANCE TO FAC INTERCEPT (FT): 0	CHART VDP: 0.63 NM TO WP524	(LNAV/LP ONLY) VDA: PFAF to RW24 3.00/40 (FOR ST-IN ALIGNED NPA SIAPS W/O PA OR APV MINIMUMS)	MANDATORY ALTITUDES: NO
	HELICOPTER VISIBILITY RESTRICTION: NO	CHART PROFILE NOTE: VGSI AND DESCENT ANGLES NOT COINCIDENT (VGSI ANGLE {ANGLE}/TCH {FEET}).	CIRCLING CAT/DIRECTION RESTRICTIONS: NO		VGS: NA FOR NPA LINES OF MINIMA		AIRSPEED RESTRICTIONS: NO	HOLD NW, RT, 155.25 INBOUND	
	CHART FAS OBST		7:1 AT PFAF: NOT TAKEN (LP) 7:1 AT PFAF: NOT TAKEN (LNAV)						

ALTERNATE	NA ☒

MINIMUMS (PRIMARY) APT01 [UD]	CATEGORY (CIRCLING RADII)	CAT A (0)			CAT B (0)			CAT C (0)			CAT D (0)			CAT E (0)			
	FINAL TYPE	DA/MDA	VIS	HAT/HAA	DA/MDA	VIS	HAT/HAA	DA/MDA	VIS	HAT/HAA	DA/MDA	VIS	HAT/HAA	DA/MDA	VIS	HAT/HAA	HMAS
	LP MDA	2620	1	379		NA			NA			NA					2391
	LNAV MDA	2660	1	419		NA			NA			NA					2391

Figure 4.19 XEDW.

XEDW 01H (2 of 4)

NOTE: ALL HEADINGS ARE MAGNETIC UNLESS IDENTIFIED AS TRUE

XEDW 01H (GPS) RWY 24 GORDO

CHECK CURRENT AIRPORT/FACILITY NOTAMS

VISIBILITY DATA	APP LIGHTS: NONE	PHYSICAL RWY LENGTH: 154	SURVEY TYPE: VG (ANALPV)	RWY SURFACE: Asphalt/Concrete ()	RWY MARKINGS: NONPRECISION	RWY EDGE LIGHTS: NONE	RVR: TD/MID/ROLL NO/NO/NO	TDZE AND C/L: No	ALS extends to displaced runway threshold: N/A	At least one other runway has edge lights: No
	HIGHEST CAT: A	GPA: NA	TCH: 40.0	THRE: 2241.0	DISTANCE MAP TO THLD (FT): 0	34:1 IS CLEAR 20:1 IS CLEAR				

LINE OF MINIMA	34:1	20:1	VGS	WHEN A SURFACE IS PENETRATED ONLY ONE OBSTACLE WILL BE DISPLAYED IN THIS TABLE, THAT WILL BE THE OBSTACLE WITH THE HIGHEST PENETRATION VALUE. SEE TARGETS FOR ADDITIONAL OBSTACLE DATA AS REQUIRED.
NPA VISUAL AREA	ASC	ASC	NA	

PRECISION APPROACH (PA)	ILS	PAR	GLS	MMLS							
APPROACH WITH VERTICAL GUIDANCE (APV)	LPV	LNAV/VNAV	RNP	LDA WITH GLIDE SLOPE							
NON PRECISION APPROACH (NPA)	LP	LNAV	LOCALIZER	LOC BC	LDA	VOR	NDB	ASR	TACAN	CIRCLING	

FAS DATA: LPV /LP or GLS PROCEDURE TYPES ONLY	APT ID: PT01	LTP/FTP COORDINATES: 345732.9810N/ 1175253.0320W	ELLIPSOIDAL HEIGHT (M):	FPAP COORDINATES: 345701.0410N/ 1175434.2490W	*TCH: 00040.0	*GPA: 03.00	COURSE WIDTH AT THLD: 106.75	LENGTH OFFSET: 2704	HAL: 40.0	VAL: 0.0
Raw data with the ten thousandth's digits of 1 through 4 are rounded to 0. Raw data with the ten thousandth's digits of 5 through 9 are rounded to 5.			*FOR VDA REMOVAL - CHANGE THRESHOLD CROSSING HEIGHT (TCH) TO 00000.0 AND GLIDEPATH (GPA) TO 00.00							

MSA FROM: WP524 (RADIUS 25 NM)	SECTOR: 360-360 (M)	OBSTRUCTION: WINDMILL (06-234911) N351239.25/W1181424.28	BEARING (M): 299	DISTANCE: 23.2	ELEV MSL: 6767	HORZ: 250	VERT: 50	AC: 4D	ROC: 1000	MIN ALT: 7800

WX/ALTIMETER SOURCE	TYPE	WX SERVICE	WX LOCATION	HRS OPERATION	ALTIMETER SOURCE	DISTANCE	WMSCR	ADJUSTMENTS
	PRIMARY ALTIMETER - LOCAL					0		0

WX REMARKS				

GLIDESLOPE ANGLE	ELEV RWY THRESHOLD	TCH	ELEV GS ANTENNA	DISTANCE FROM RWY	VGSI ANGLE	TCH
					3.00	50 (50.0)

FINAL APPROACH COURSE AIMING					
RUNWAY THRESHOLD	X		FT FROM THRESHOLD	DISPLACED THRESHOLD DISTANCE	0
ON CENTERLINE	X		FT FROM CENTERLINE		

CRITICAL TEMPS	CRITICAL LOW:	CRITICAL HIGH:	ACT:	APT ISA:	DESCENT RATE (FPM): STANDARD TEMP	DESCENT RATE (FPM): HIGH TEMP

REMARKS	PRECIPITOUS TERRAIN EVALUATION COMPLETED: YES	VDP PUBLISHED: YES	VEGETATION HEIGHT: 0 FT	AIRSPACE	FINAL: 3900 5.08 NM	HIGH TERRAIN IN FINAL: 2312 (2300)	FINAL COURSE (TRUE): 249.09	INTERMEDIATE SEGMENT 249.18T 1200/300 3113 (3100)	
				RUNWAY APCH END AND DIST FURTHEST FROM ARP: RUNWAY 06S DISTANCE 1.12 NM		RWY THLD COORDINATES: N345732.98 W1175253.03	ARP COORDINATES: N345732.98 W1175253.03	PFAF COORDINATES: N345922.15 W1174706.34	
							GPA: NA	TCH: 40.0	THRE: 2241.0

XEDW 01H (3 of 4)

NOTE: ALL HEADINGS ARE MAGNETIC UNLESS IDENTIFIED AS TRUE

XEDW 01H (GPS) RWY 24 GORDO

CHECK CURRENT AIRPORT/FACILITY NOTAMS

CONTROLLING OBSTACLES

SEGMENT	ADJ AREA	START POINT	END POINT	OBSTACLE TYPE	COORDINATES	HT AMSL	(H/V) AC	APPL'D AC	ADJ EFF HT AMSL	MT	PRI ROC/ SLOPE	RA	XL	ADJ SA	ADJ PRI EQUIV HT AMSL	PR	ADJ MIN OBS ALT AMSL
Initial from WP07	Secondary	WP07	WP03	TOWER (06-020637)	345453.94N/1173128.37W	3363	(+500/+125) 5E	0	3363		1000			-711	2652	0	3700
Initial from WP09		WP09	WP03	ASC													
Intermediate from WP03		WP03	PFAF	ASC													
Final LP		PFAF	APT01:RW24	ASC													
Final LNAV		PFAF	APT01:RW24	ASC													
Missed LP CG/HAT/CGTA	Primary			TOWER (06-002133)	345643.00N/1175452.00W	2680	(+250/+50) 4D	50	2730		168				2730		3700
Missed LNAV CG/HAT/CGTA	Primary			TOWER (06-002133)	345643.00N/1175452.00W	2680	(+250/+50) 4D	50	2730		155				2730		3700
Missed Level Surface	Secondary			TOWER (06-152054)	343624.63N/1174933.33W	2801	(+20/+3) 1A	0	2797		1000			-4	2797	0	3800
MSA	MSA			WINDMILL (06-234911)	351239.25N/1181424.28W	6767	(+250/+50) 4D	0	6767		1000					NA	7800
Holding WP408 (200KTS)	T6:Primary	WP408	WP408	TOWER (06-152054)	343624.63N/1174933.33W	2801	(+20/+3) 1A	0	2801		1000				2801	0	3900

AIRSPACE ALTITUDES

SEGMENT	START POINT	END POINT	COORDINATES	ELEVATION	AIRSPACE FLOOR/BUFFER	MIN AIRSPACE ALT
Initial from WP07	WP07	WP03	345521.00N/1173439.00W	3106 (3100)	AS1500 1200/300	4600
Initial from WP09	WP09	WP03	350333.00N/1173727.00W	3113 (3100)	AS1500 1200/300	4600
Intermediate from WP03	WP03	PFAF	350333.00N/1173727.00W	3113 (3100)	AS1500 1200/300	4600
Final	PFAF	APT01:RW24:AER	345839.00N/1174718.00W	2312 (2300)		
Missed	Missed	WP408	344039.00N/1174751.00W	3559 (3600)	AS1500 1200/300	5100
Holding	WP408		344039.00N/1174751.00W	3559 (3600)	AS1500 1200/300	5100

TF SEGMENT	ALT	KIAS	KTAS	HAA	VKTW	TR	BA	DTA	COURSE CHG	DVEB	VEB OCS	RF CENTER/DISTANCE
PFAF	3900	90	97.88	1659.19	30.00 (DEFAULT)	0.00	0.00	0.00	0.00			
WP07	7901	150	173.52	5660.32	62.64 (DEFAULT)	0.00	0.00	0.00	0.00			
WP07 (90° ATC VECTOR)	7901	150	173.52	5660.32	62.64 (DEFAULT)	1.70	25.49	1.70	90.00			
WP09	7901	150	173.52	5660.32	62.64 (DEFAULT)	0.00	0.00	0.00	0.00			
WP09 (90° ATC VECTOR)	7901	150	173.52	5660.32	62.64 (DEFAULT)	1.70	25.49	1.70	90.00			
WP03	5900	150	168.21	3659.66	58.68 (DEFAULT)	1.57	25.49	1.57	90.00			
WP03 (90° ATC VECTOR)	5900	150	168.21	3659.66	58.68 (DEFAULT)	1.57	25.49	1.57	90.00			

Note: If alt - apt_{elev} <= 2000, V_{KTW} = 30

XEDW 01H (4 of 4)

NOTE: ALL HEADINGS ARE MAGNETIC UNLESS IDENTIFIED AS TRUE

XEDW 01H (GPS) RWY 24 GORDO

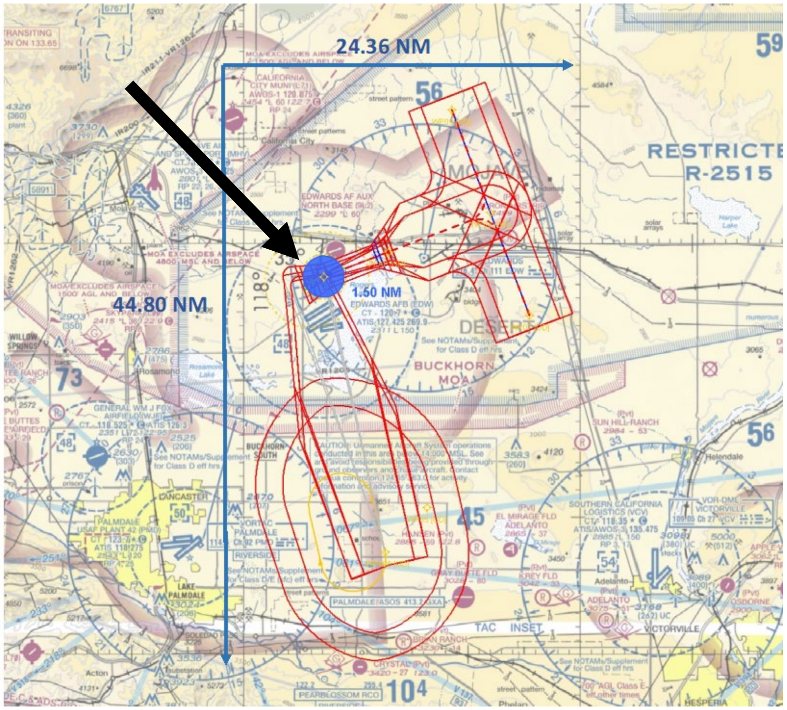
CHECK CURRENT AIRPORT/FACILITY NOTAMS

OTHER RUNWAYS AT AIRPORT				
RWY #	SURVEY	SURFACE	LIGHTING	VGSI
06	ANALPV		NONE	YES
24R	(NO SURVEY)		NONE	YES
06L	(NO SURVEY)		NONE	YES
24S	(NO SURVEY)		NONE	YES
06S	(NO SURVEY)		NONE	YES

VG/NVG SURVEY EQUIVALENTS	
VG	ANAPC/LPV, PIR
NVG	(NO SURVEY), D, AV, BV, ANP, C, SUPLC, ADAMS

Conventional Versus Candidate Airspace Architecture

The main purpose of the conventional versus candidate evaluation is the actual conservation of airspace that could result in maintaining the same functionality while reducing the volume required to operate. Figure 4.20 below contains both the concept architecture as well as conventional architecture overlaid in the 01H build. As the figure illustrates, the 6-degree wheel ended up taking 1.9 percent of the same airspace that only allotted one approach path inbound and out bound. The 12-degree wheel resulted in 0.56 percent of the same airspace. The important takeaway in the comparison is that the wheel or wreath model supports an omni-directional ingress and egress of the same point in space operation, while impacting only a fraction of the airspace. Follow-on research will be required to provide further data to support the Conservation of Airspace Theory.



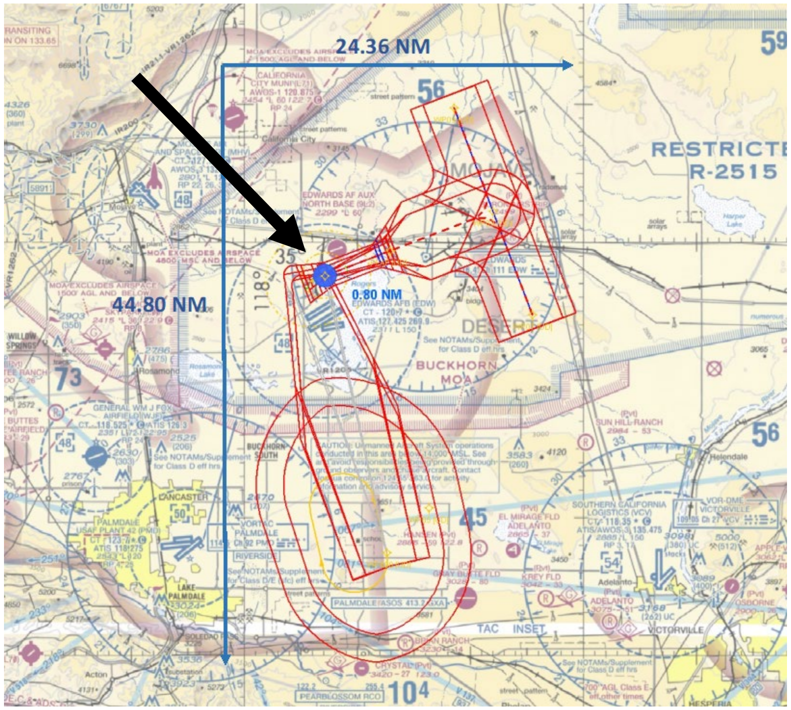


Figure 4.20. 6-Degree GPA with 3nm Diameter at XEDW 01H (left) and 12-Degree GPA with 1.6nm Diameter at XEDW 01H (right).

<u>Airspace Conservation at XEDW 01H</u>

XEDW 01H landing site was constructed for the NC Conservation of Airspace Model. Two rings were constructed, flown, and evaluated around 01H: a 6-degree and a 12-degree glidepath angle that resulted in two OEAs and flight paths. The 6-degree wheel began at a height of 600 feet with a controlling obstacle of 65 feet, derived by the OEA. The radius was just below a 0.5 nautical mile and had a total area of seven square nautical miles which includes the final approach segment, initial approach fix, final rollout point, missed approach point, initial climb area, traffic pattern, and holding pattern. The 12-degree wheel had the same height of 65 feet due to the same controlling obstacle. The total area impacted was just over 2 square nautical miles and also allowed all of the same operations as the 6-degree ring with no perceived discomfort reported by the air crew.

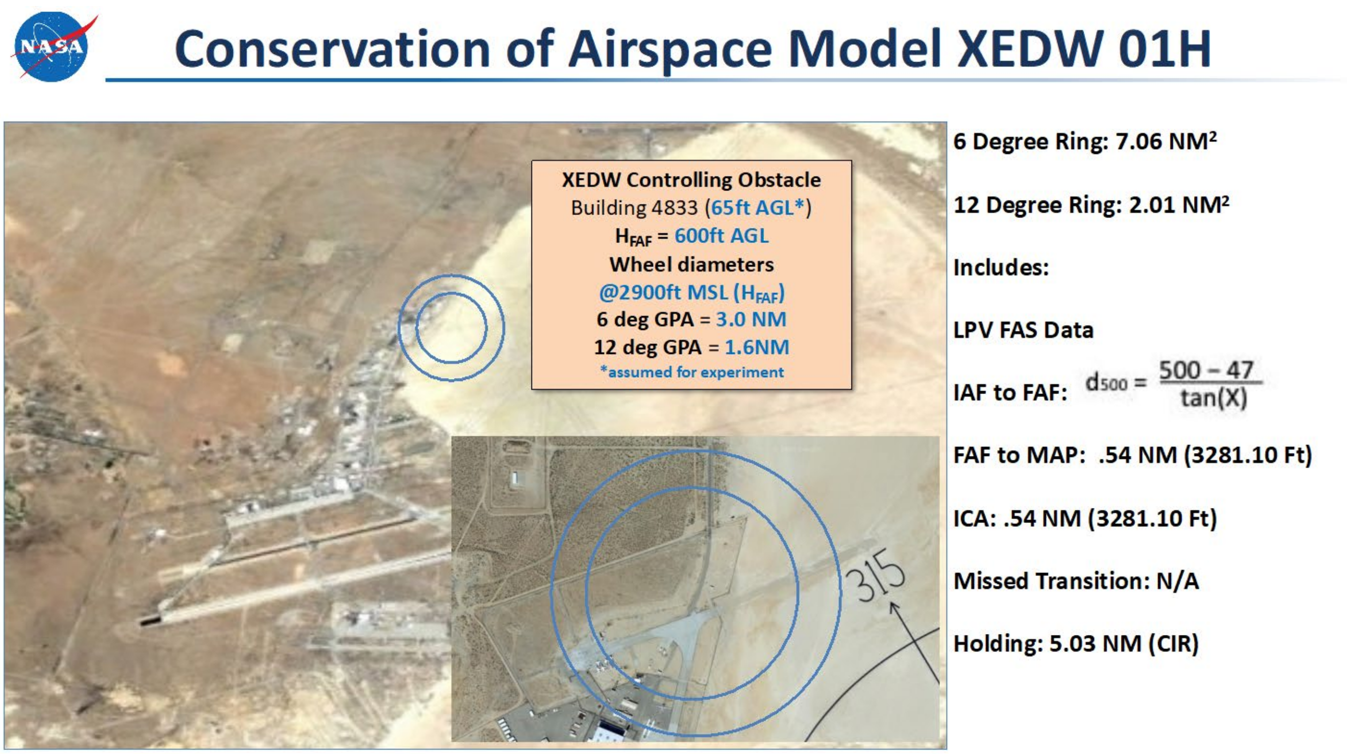


Figure 4.21. Conservation of Airspace XEDW 01H.

Constraints

As the urban environment poses many constraints to vehicle operation ingress and egress routing, the NC test series attempted to emulate the variables in obstructions, noise abatement and airspace restrictions. As depicted in Figure 4.22, the cylinder of airspace required for omnidirectional departure and approach procedures has sectors based on a controlling obstacle that was defined in the survey. The controlling obstacle of the cylinder of airspace will drive the holding, maneuvering, and traffic pattern altitude above the vertiport. Secondary controlling obstacles will be identified per each section, however, that will drive the climb and descent criteria based on a 20-degree splay on either side of the controller. This variation will allow shallower approach paths in and out of the vertiport, depending on their proximity to any identified hazard, physical or not.

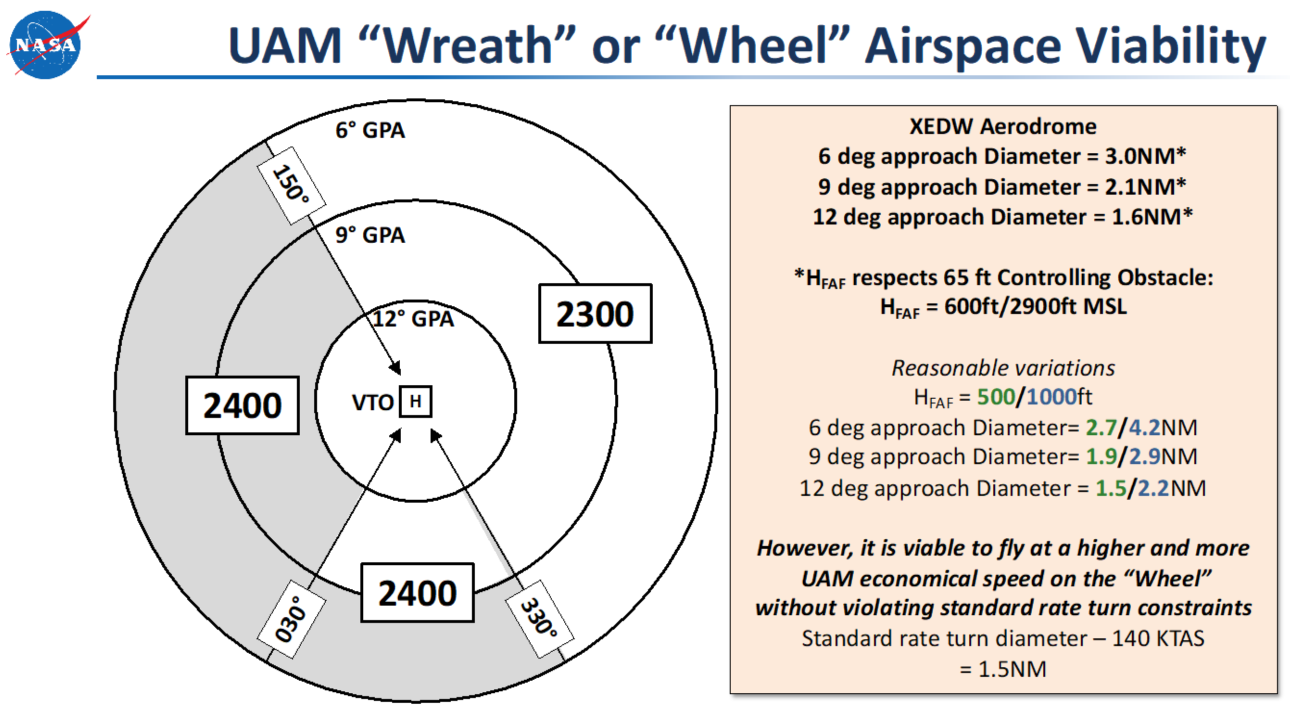


Figure 4.22. Wheel Airspace Viability.

XEDW 01H Airspace Sectors

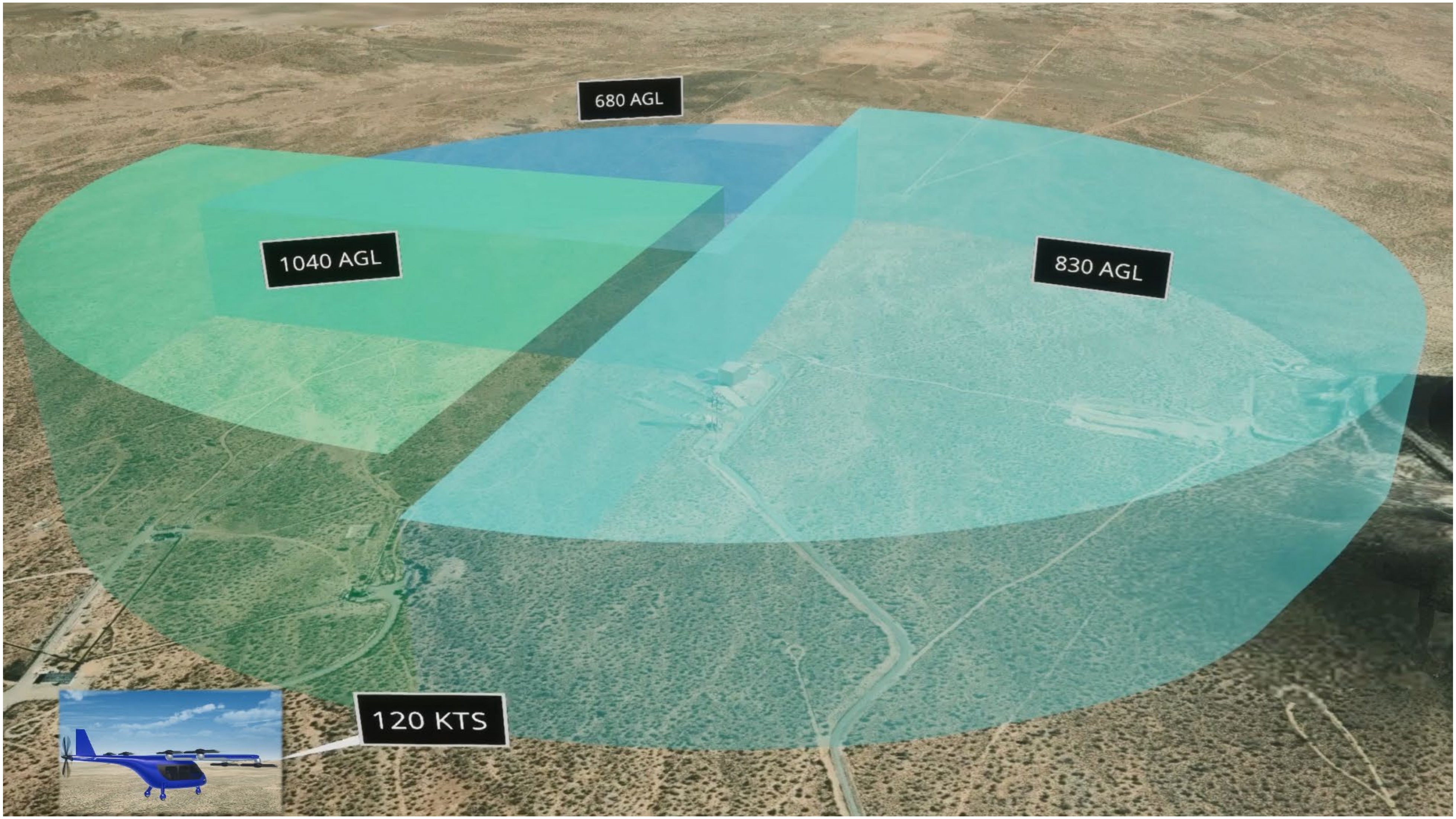


Figure 4.23. Airspace Slice.

Flying the Wheel

As the wheel model is constructed, the term "wreath" becomes prevalent because the "wheel" is actually not a solid line in the sky but rather a collection of waypoints fixed along a radius with the purpose of precision navigation to a final rollout course on an approach path that provides optimal wind alignment. For continuity, the final approach fix of GORDO will be used to showcase the maneuverability of the ring method, the predictability of path point recording, bank angle, and wings-level position in order to provide a safe, stabilized aircraft proceeding into the final approach segment. As depicted in Figure 4.24, the terminal navigation point of the aircraft will be at the circle intercept, associated with a speed restriction for entry into the wheel in order to maintain spacing with other traffic that may be utilizing the same altitude for approach or departure sequencing. If no other traffic is impeding the highlighted aircraft, then a final rollout point will be established, based upon the current wind condition, and a final rollout point will be backwards-planned from that approach course - shown where the black final approach segment meets the blue arrow, making a turn off of holding pattern of the wheel. While initiating the turn to final, the aircraft is authorized to begin deceleration to the intended approach speed, since the aircraft will be out of the wheel spacing pattern. The intent is for the aircraft to have a standardized sequence of maneuvers to ensure the vehicle is wings-level and on final course at the designed airspeed and altitude to initiate the descent sequence into the vertiport.

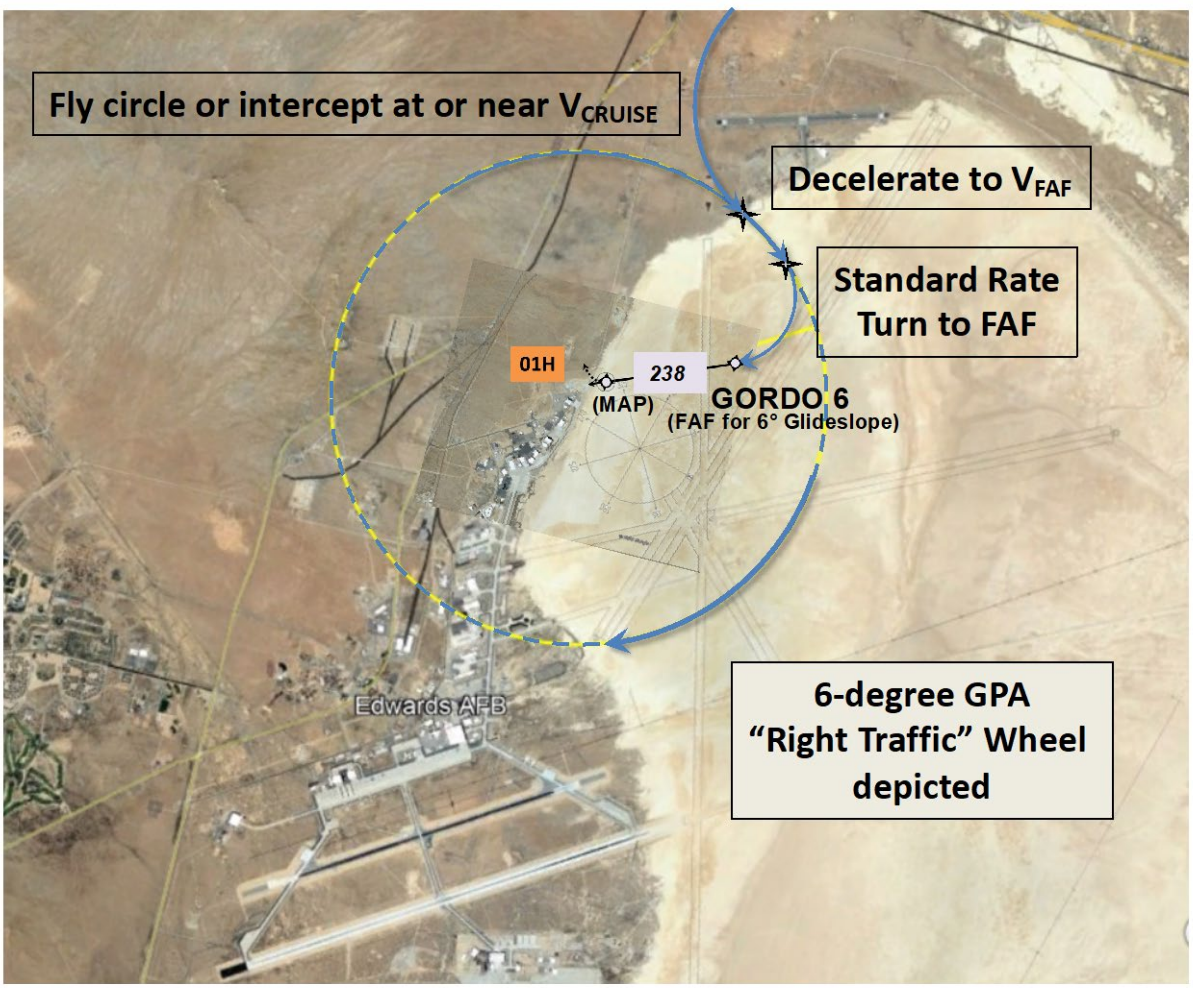


Figure 4.24. 6-Degree Wheel.

Approach Design

Approach is defined as the final approach segment (FAS data block) in which the aircraft is wings-level-aligned with the final approach course and begins a descent into the landing surface. Traditionally, aircraft maintain a specified airspeed, which is bucketed in approach categories based on 1.3 times the stall speed of the aircraft. For this test, the NC team developed a "quad zero" approach, which is defined as zero ceiling, zero visibility, zero airspeed and zero altitude termination to a point in space (PinS). In order to test this theory, the NC team started with the assumption that the vehicle would begin the Final Approach segment at a Precision Final Approach Fix (PFAF). Given the altitude and airspeed initiated at the PFAF, the aircraft would begin two types of descents and decelerations into the landing surface. The first descent and deceleration would be constant-rate, in which the aircraft would dissipate its airspeed equal distant along the glide path to the final touchdown point. The second descent would be a constant speed descent followed by a rapid deceleration specified at a point along the glidepath. As part of the test, the NC team developed speed gateways to monitor the aircraft conformance to the descending deceleration. First, Barrow glide path distance is calculated, which is a change-in-altitude distance that subtracts the radius of the earth (Napier's Constant) to determine the exact linear distance travelled between two points across the ground. Instead of utilizing the conventional "one" missed approach point, the NC team explored the idea of having multiple missed approach points which are defined by height above missed approach surface (HMAS).

An approach procedure is comprised of two products that result from the terminal procedure designer's build. The first is the instrument approach plate that is designed for human consumption. As depicted in Figure 4.25, GORDO 01H instrument approach plate (right) is comprised of a header, communication, overhead section, airport diagram and profile view. The second product produced from the terminal procedure designer is the coding of the approach designed for machine consumption. The coding is intended for a Flight Management System to identify the safe altitudes, airspeeds and alignments that are required to orient the aircraft in space and away from the ground and all obstacles, as defined by the terminal procedure designer.

XEDW 01H GORDO

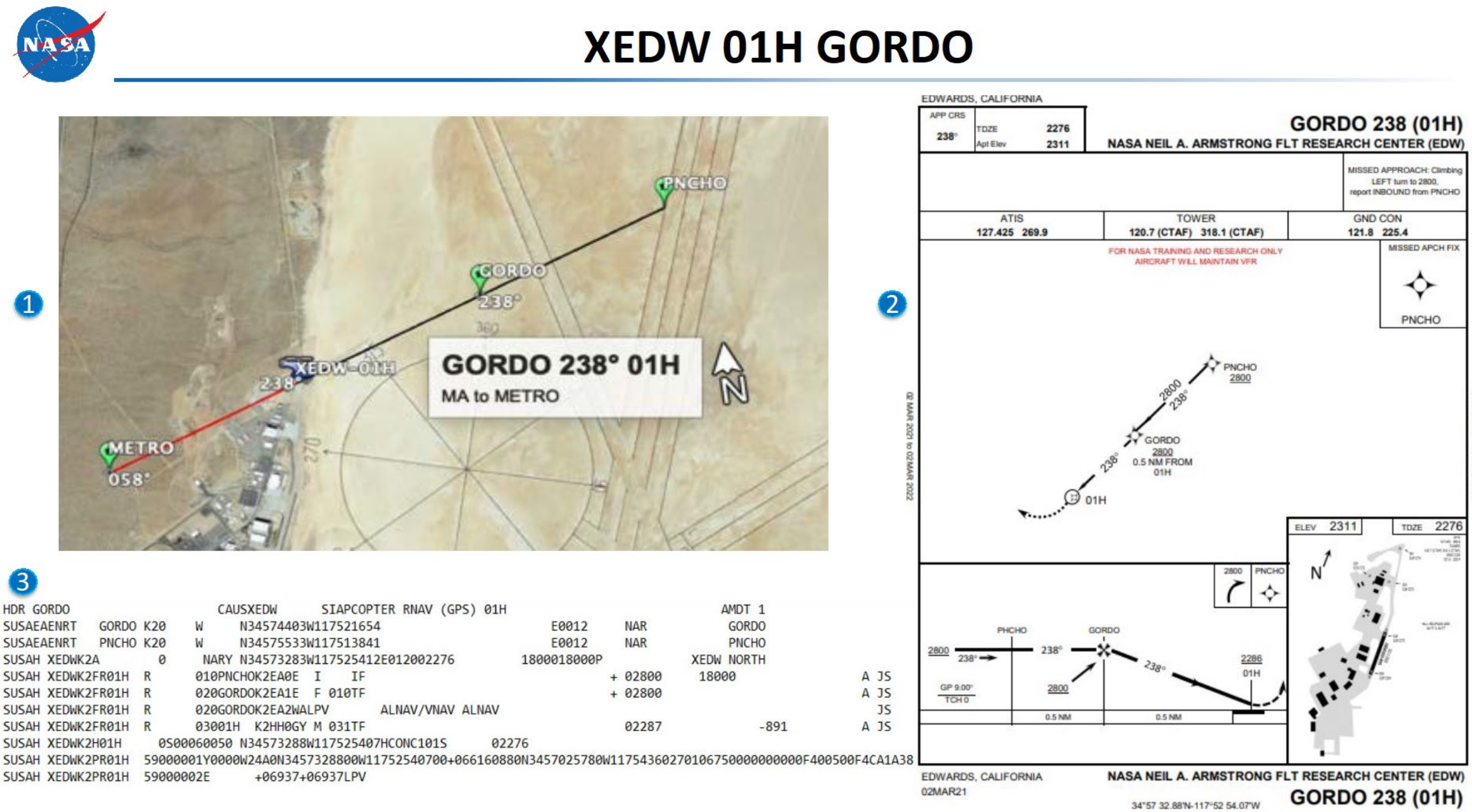


Figure 4.25. Gordo: (1) Satellite View; (2) Experimental Approach Plate; and (3) Experimental ARINC 424 Coding.

ARINC 424 Coding

As part of the AFRC test, the NC team worked with FAA Air Traffic Control Services (AJV-A) for experimental ARINC 424 coding. Although unable to ingest the coding of the procedure in the helicopter, the NC team produced unique experimental coding for the following purposes: standardization of different constraints, ground check for flight inspection evaluation, and spatial data integrity. One of the results of this test resulted in identification that current FAA software does not have the allocation to evaluate a low level flight with truncated routing and reduced leg lengths.

XEDW 01H GORDO

```
HDR GORDO                        (1)CAUSXEDW      SIAPCOPTER RNAV (GPS) 01H                     AMDT 1
(2)SUSAEAENRT   GORDO K20     W     N34574403W117521654      (3)E0012   (4)NAR        GORDO
SUSAEAENRT   PNCHO K20     W     N34575533W117513841         E0012      NAR        PNCHO
SUSAH XEDWK2A        0     NARY N34573283W117525412E012002276  (5)1800018000P        XEDW NORTH
SUSAH XEDWK2FR01H  R       010PNCHOK2EA0E  I    IF                     + 02800    18000              A JS
SUSAH XEDWK2FR01H  R       020GORDOK2EA1E  F 010TF                     + 02800                       A JS
SUSAH XEDWK2FR01H  R       020GORDOK2EA2WALPV(6)    ALNAV/VNAV ALNAV                                   JS
SUSAH XEDWK2FR01H  R       03001H  K2HH0GY M 031TF                       02287            -891       A JS
SUSAH XEDWK2H01H     0S00060050 N34573288W117525407HCONC101S      02276
SUSAH XEDWK2PR01H  59000001Y0000W24A0N3457328800W11752540700+066160880N3457025780W11754360270106750000000000F400500F4CA1A38
SUSAH XEDWK2PR01H  59000002E       +06937+06937LPV
```

1. An experimental heliport was used and filed under the California database.
2. Special use tailored data was made for the FAS data block with unique waypoint subset list
3. Standard magnetic variation was used for each approach bearing
4. WGS-84 Datum (ITRF 2014) was used for all references
5. Overlying airspace was assumed at Flight Level 18,000 MSL due to intended low level flight operations
6. Procedure built for precision RNAV approach as Localizer Performance with Vertical Guidance (LPV)

Figure 4.26. Gordo Experimental ARINC 424 Coding.

Follow-on tests will be needed to exercise the standardization of the experimental coding and addition of waypoint restrictions associated with AAM routing. Figure 4.27 illustrates the breakdown of the coding used and identifies the areas that will be needed to define AAM routing, as well as establish a waypoint subset list. Fix names and locations will need to change as addressed earlier in the 8260-2 form. Additional research will be required for adequate leg type usage intended for AAM operations that will define the mechanism for navigation within a corridor and routing limitations.

XEDW 01H GORDO Coding

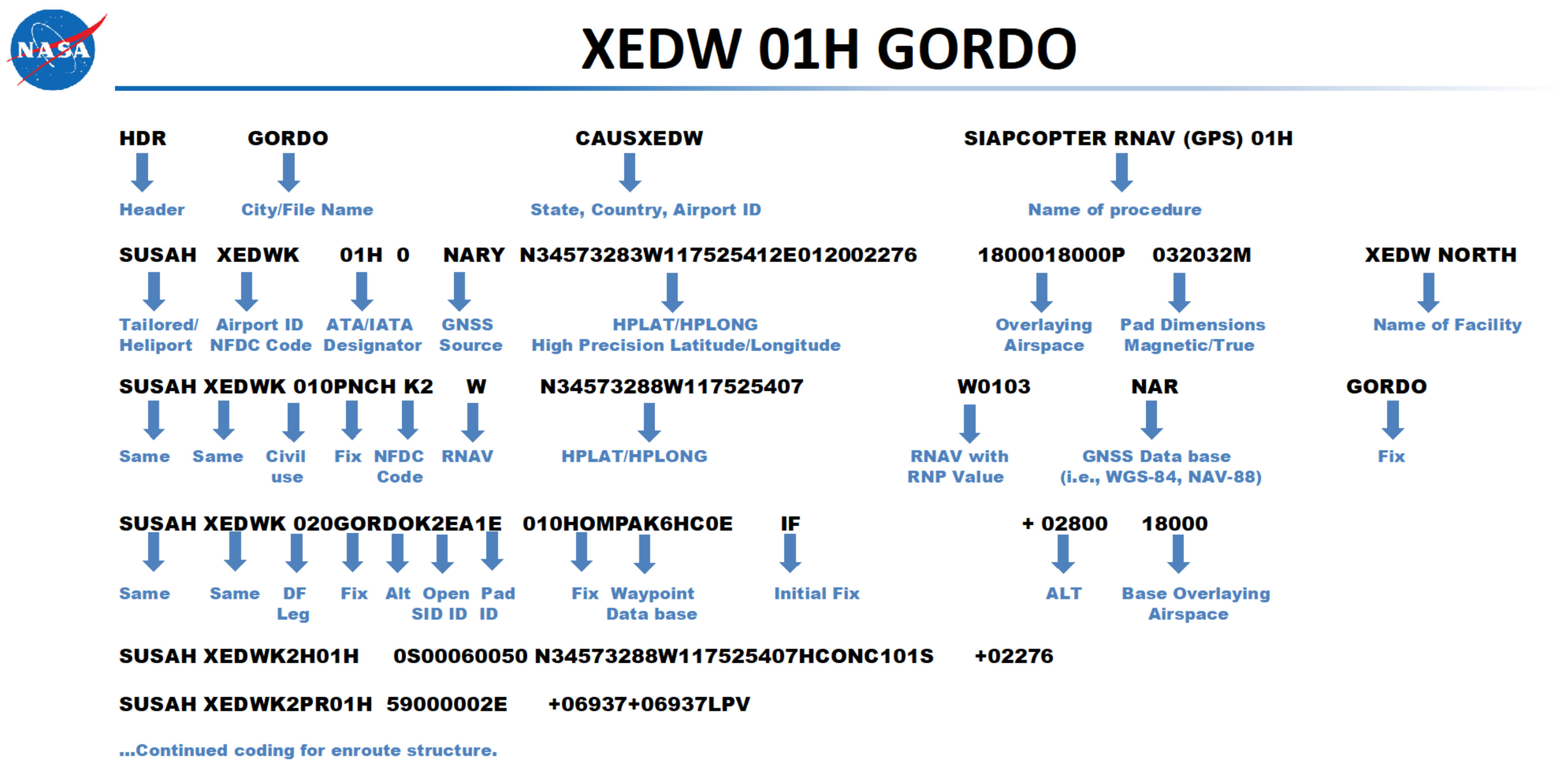


Figure 4.27. Gordo Experimental ARINC 424 Coding Breakdown.

Simulation XEDW 01H:

In partnership with the RVLT program, the NC team provided approach procedures that were constructed in the RVLT fixed-base simulator and vertical motion simulator (VMS). The RVLT high-fidelity aircraft modeling was used in the construction of the build as well as landscape, infrastructure, and atmospheric data. Two of the RVLT vehicles were selected by the group to fly the NC procedures in simulation at the AFRC test site as well as apply two test pilots for handling qualities through the different inceptor designs that map to the unique control surfaces for the multirotor or fixed-wing aircraft configurations: *Lift-Plus-Cruise* and *Turboelectric Quadrotor.*

Lift-Plus-Cruise

The RVLT LPC model was flown as part of an interagency test utilizing multiple pilots flying the same XEDW 01H GORDO approach procedure. The test pilots ranged from fixed-wing and rotary-wing backgrounds and were from civilian, military and government (the FAA or NASA) organizations. Many iterations of the GORDO approach were flown from a wings-level, set airspeed and altitude in which the test pilots started inbounding in the winged configuration and utilized the experimental inceptors to transition to vertical flight and execute a landing within the flight envelope and parameters of the LPC vehicle. The pilots were allowed to initiate a deceleration sequence based on information provided by the PFD regarding which flight mode the model was transitioning to as the vehicle speed decayed on the approach.

Table 4.28. The RVLT Turboelectric Lift-Plus-Cruise Parameters.

	Descriptive Data	Specification
	Passengers + Crew	5 + 1
1 Weight		
	Number of Lifting rotors	8
	Disk loading (lb/ft2)	9.6 – 10.26
	Design Gross Weight (lb)	6013
	- Payload	1200
	- Weight Empty	5269
	- Operating Weight	5279
2 Dimensions		
	Wingspan	47.72ft
	Wing Area	183=1.3ft ^{2}
3 Effectors		
	Ailerons	+/- 20 deg
	Elevator	+/- 30 deg
	Rudder	+/- 20 deg
	Propeller Blade Pitch	-20 – 8.3* deg
4 Lifting Rotors		
	Number of blades	2
	Rotor radius (ft)	5
	Hover tip-speed (ft/s)	550
	Rotational speed (rad/s)	110.0
	Flapping frequency (/rev)	1.25
	Number of motors	9 + gen
	Hover Torque	450 ft-lbs
	Hover Rotor RPM	1089[114 rad/sec)
	Rotor Torque	0 – 900 ft-lbs
	Max Rotor RPM	1528
	Thrust/Weight Ratio =	1.45

RVLT turboelectric Lift-Plus-Cruise (LPC) concept model was designed and developed using NASA Design and Analysis of Rotorcraft (NDARC) tool. The ART LPC (Gen-1) model was integrated into FlightDeckZ with the addition of actuator models, gear/ground models, and modifications to incorporate nonlinear terms. See Figures 4.29-4.30.

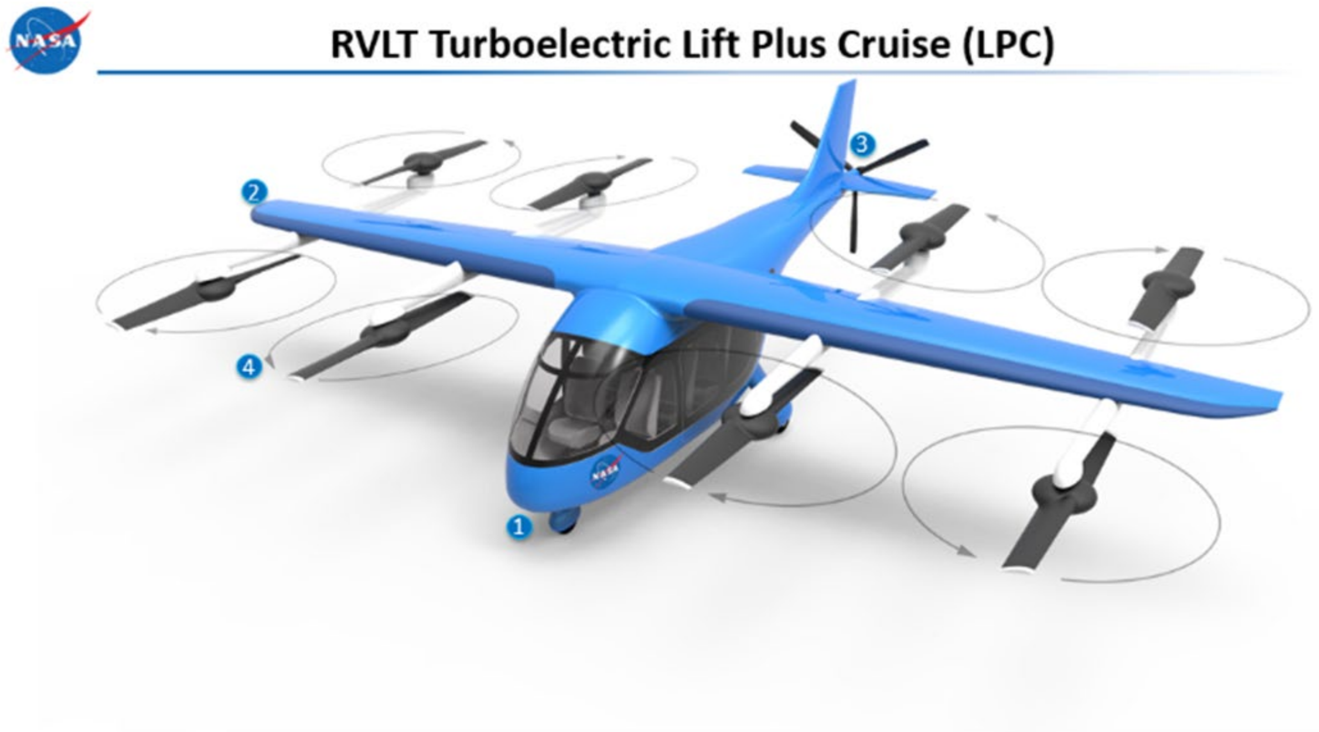


Figure 4.29. The RVLT Turboelectric Lift-Plus-Cruise Model.

1. HQTE Performance Data, Distance, Battery, and Flight Time
2. Turn and Slip Indicator
3. Lift and/or Control Modes (pitch, heading, roll command etc.)
4. Ground Speed as a function of time for ETA and RTA
5. Altitude reporting in Mean Sea Level (barometric) and Above Ground Level (radar)
6. Reference Aircraft: Turboelectric LPC
7. Inertial Flight Path Indicator (not standard for more information contact RVLT team)
8. Horizontal Situation Indicator with ground track reference

XEDW 01H GORDO Lift-Plus-Cruise Approach

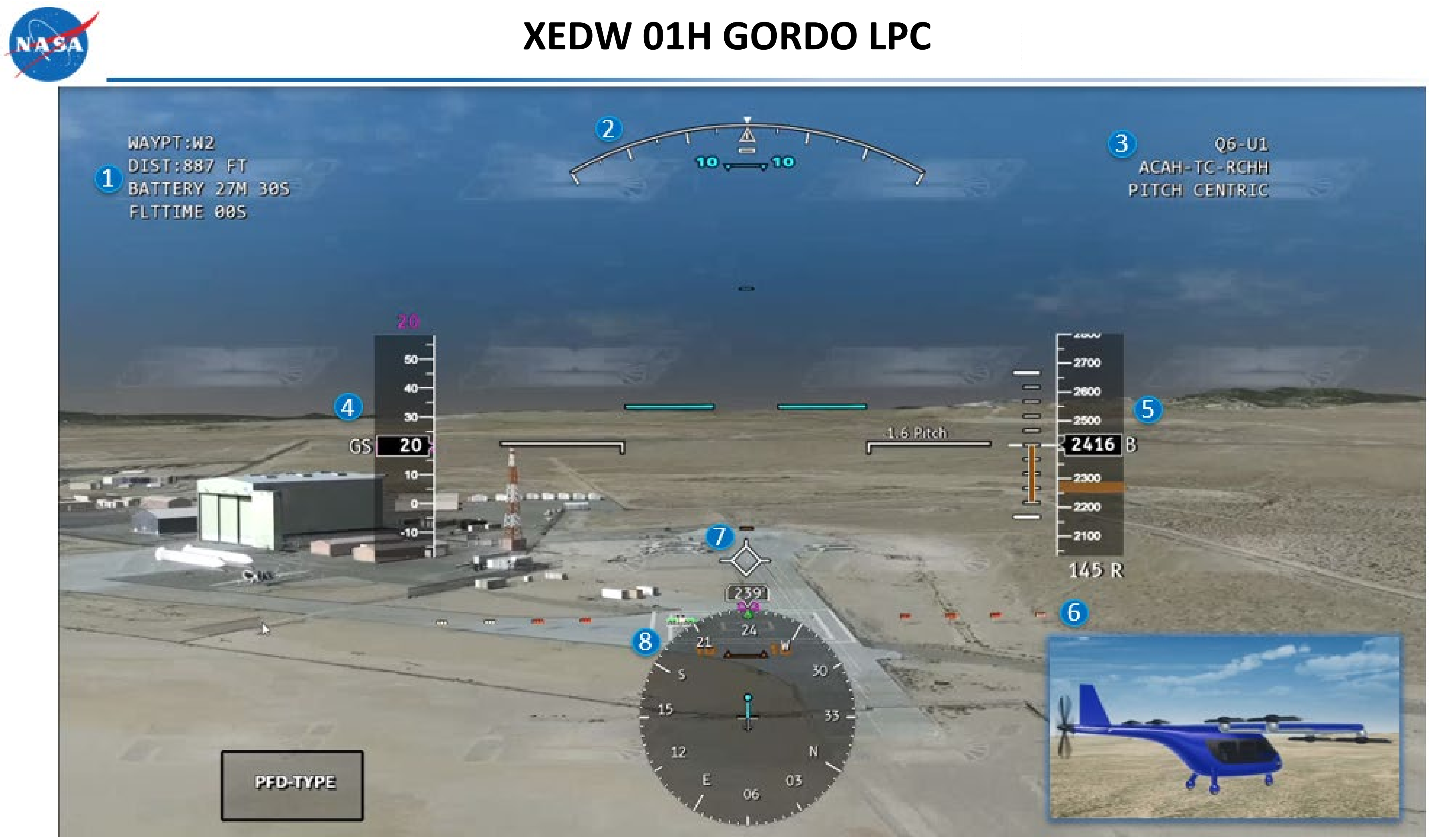


Figure 4.30. XEDW 01H GORDO RVLT Turboelectric Lift-Plus-Cruise Approach.

Turboelectric Quadrotor

The RVLT Quadcopter model was flown as part of an interagency test utilizing multiple pilots flying the same XEDW 01H GORDO approach procedure. The test pilots ranged from fixed-wing and rotary-wing backgrounds and were from civilian, military and government (the FAA or NASA) organizations. The quadrotor model was flown wings-level at a specified airspeed and altitude for each test pilot that initiated the approach. The final approach segment was evaluated in the simulation study, which required the pilot to initiate a descent and deceleration in order to negotiate a safe and secure landing. Utilizing the inceptors provided by the RVLT team, the pilots were asked to gauge the glide path conformance via the PLASI light located at the base of 01H. The pilots were given the freedom to decide where and when they would initiate the deceleration while on glidepath while also managing the descent and rate of closure of the vehicle.

Table 4.31. The RVLT Turboelectric Quadcopter Parameters.

	Parameter	Value
1 Size		
	Crew + Passengers	1 + 5
	Rotor radius (ft)	13.1
	Outside Airframe diameter (D) (estimated)	72ft
2 Weight		
	Number of rotors	4
	Disk loading (lb/ft2)	3.0
	Design Gross Weight (lb)	6,480
	- Payload	1,200
	- Weight Empty	5,269
	- Operating Weight	5,279

The NASA RVLT Quadrotor is a six-place electric propulsion VTOL aircraft with four lifting rotors mounted on arms above the aircraft with controllable pitch rotors. The quadrotor for the study is utilizes Unified Control System concept with envelope protection and no reversionary modes.

1. HQTE Performance Data, Distance, Battery, and Flight Time
2. Turn and Slip Indicator
3. Lift and/or Control Modes (pitch, heading, roll command etc.)
4. Ground Speed as a function of time for ETA and RTA
5. Altitude reporting in Mean Sea Level (barometric) and Above Ground Level (radar)
6. Reference Aircraft: Quadcopter
7. Inertial Flight Path Indicator (not standard for more information contact RVLT team)
8. Horizontal Situation Indicator with ground track reference

Figure 4.32. The RVLT Turboelectric Quadcopter

XEDW 01H GORDO Turboelectric Quadrotor Approach

XEDW 01H GORDO

Figure 4.33. XEDW 01H GORDO RVLT Turboelectric Quadcopter Approach.

<u>Expected Messages for Approach</u>

As part of the Build 2, the NC team attempted to calculate the theoretical message sets based on baro glidepath total distance of FAS and the calculated deceleration rate along that distance to determine the times the aircraft would transit between each speed gateway fixed along the glide path. Figure 4.34 below highlights the theoretical message sets between two speed gateways in a constant deceleration along the glide path. The theoretical message sets are based on ADS-B transceiver update rates at 750 milliseconds, which in the example would be spread across 21.32 seconds to produce 28 ADS-B message exchanges in the FAS, given equal distance speed gateways. The results of these data are found below. As the aircraft transited lower altitudes, ADS-B coverage, and signal quality deteriorated, given the specific EAFB range. Conversely, on the constant rate approach and descent, as the aircraft slowed down rapidly, the lower and slower the aircraft was in proximity to the ground, the more message sets were available, thus making final approach flight-following data of higher quality. More tests will be needed to determine specific variables in message sets based on time, airspeed, altitude, descent rate, battery dissipation, battery temperature, and other contributing factors that would be applicable to the safety of the flight.

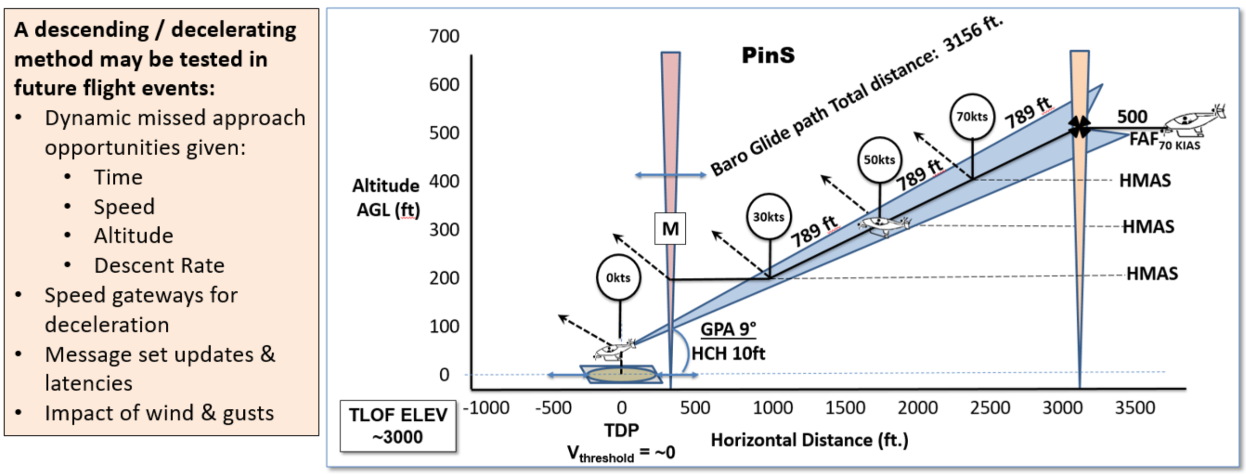


Figure 4.34. National Campaign Point-in-Space (PinS) Approach.

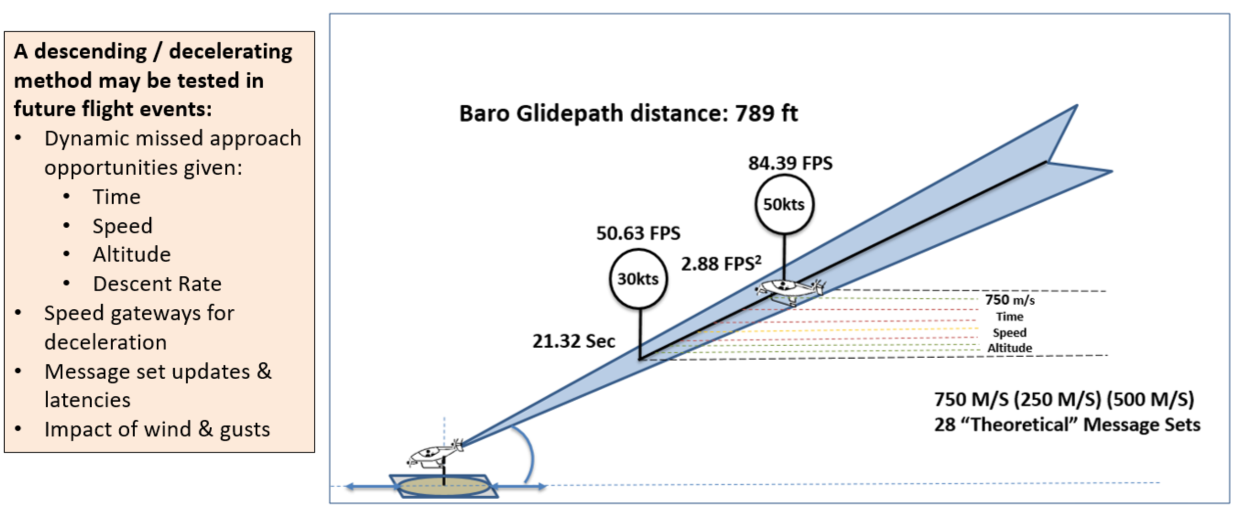


Figure 4.35. National Campaign segment of Point-in-Space (PinS) Approach.

<u>Approach Glide Path Angle Results</u>

The NC vertipads (01H, 02H, 03H, 04H, 05H, and 06H) and vertiport (RWY 01/19) and approaches were accessed for Scenario Tests. The target approach angle for each scenario was 9 degrees. Approaches were also tested at 6 degrees and 12 degrees to provide baselines to measure future tested aircraft which either cannot yet meet 9 degrees or have already exceeded it up to 12 degrees.

Each of the approaches depicted to follow Figures 4.36 - 4.41 represent the best and worst of the 6-degree, 9-degree, and 12-degree approaches. The Lewis 12-degree approach could not be flown during AFRC Build 2 Flight Test because there were airspace constraints near the main EAFB runway and the limitations on overflight of the Center prevented Lewis 12-degree approach attempts during this test event. Positive traffic and airspace deconfliction from the tower, on a “by request” basis, as well as special permission to overfly the Center, will be needed to test approaches to the vertipad runway 01 and LZ 05H during future test events.

6-Degree Glidepath Angles

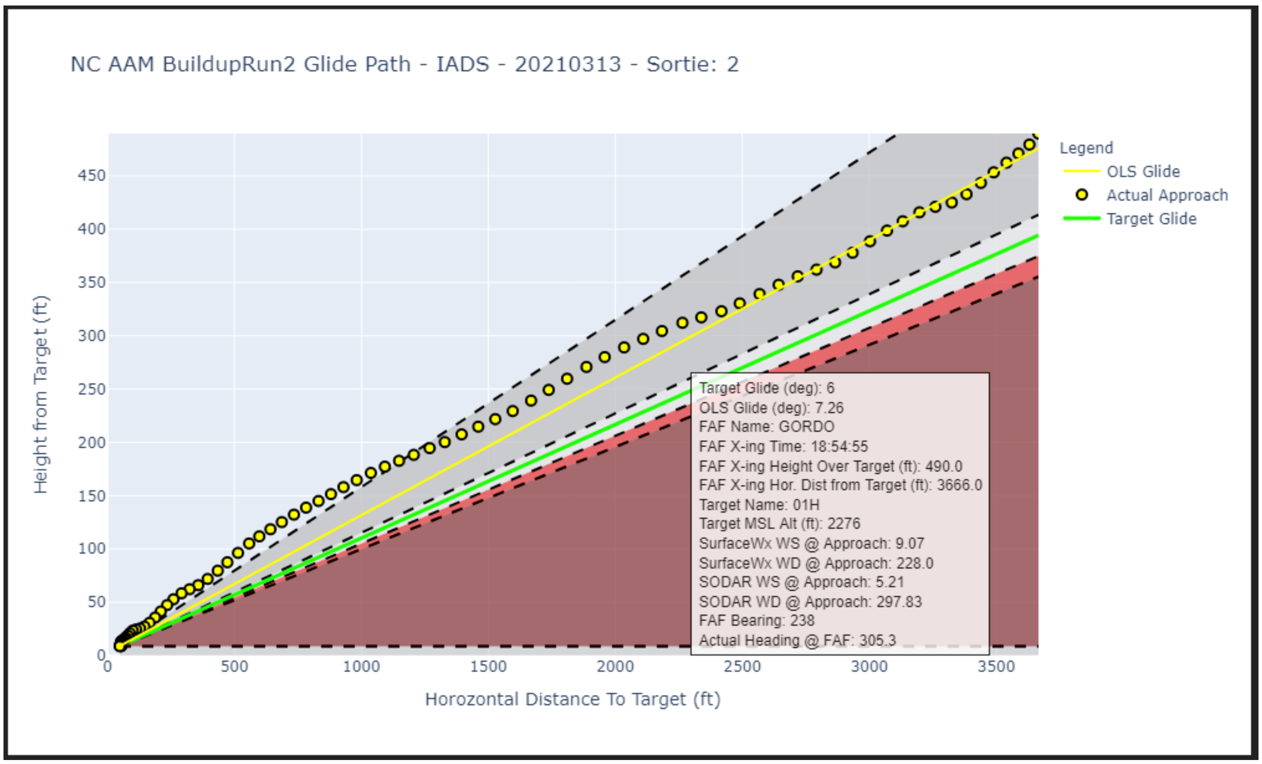


Figure 4.36. Best 6-Degree Glidepath Angle via IADS: Gordo 03.13.21 18:54:55.

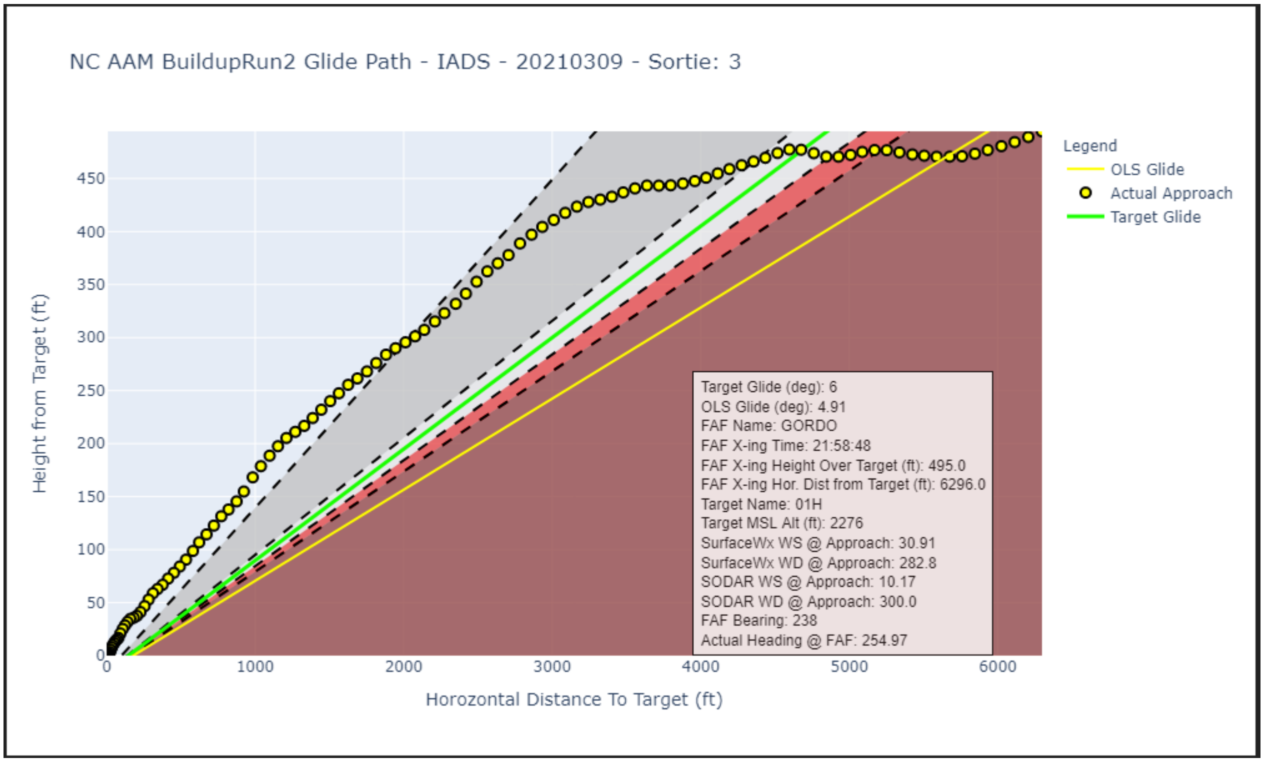


Figure 4.37. Worst 6-Degree Glidepath Angle via IADS: Gordo 03.09.21 21:58:48.

9-Degree Glidepath Angles

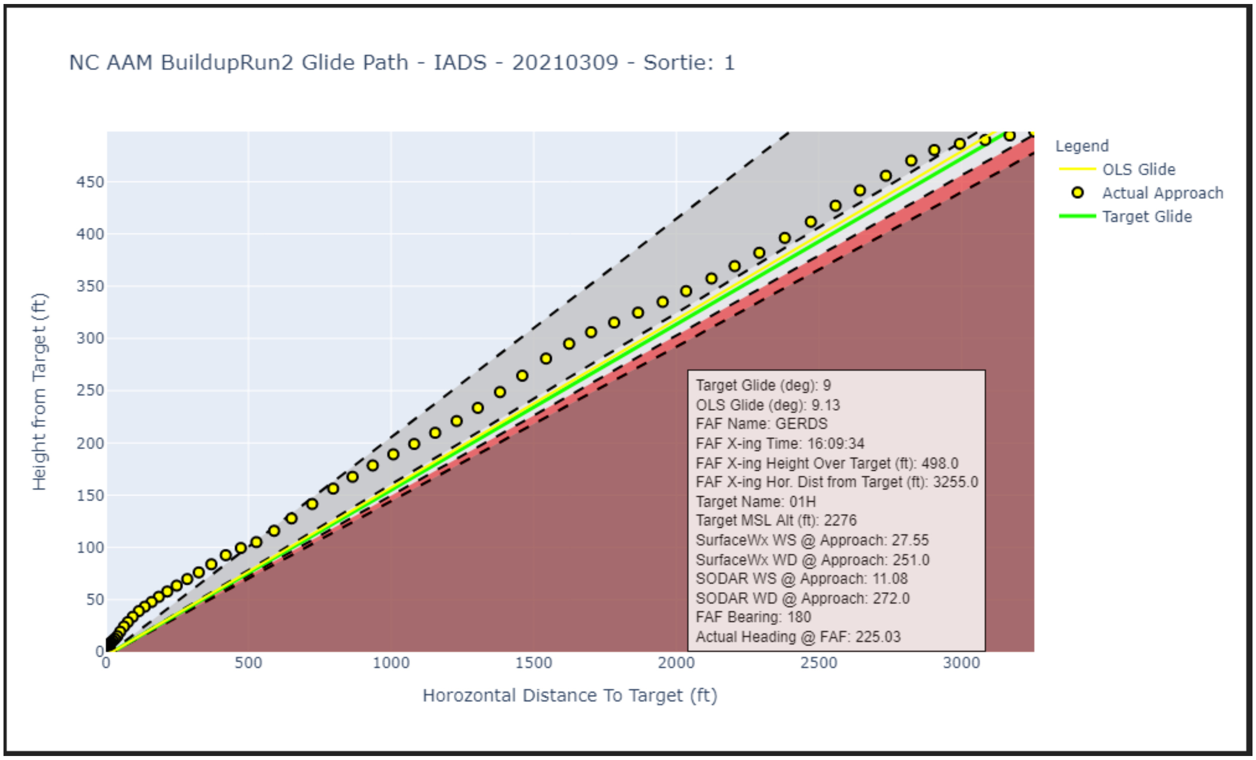


Figure 4.38. Best 9-Degree Glide Path Angle via IADS: Gerds 03.09.21 16:09:34.

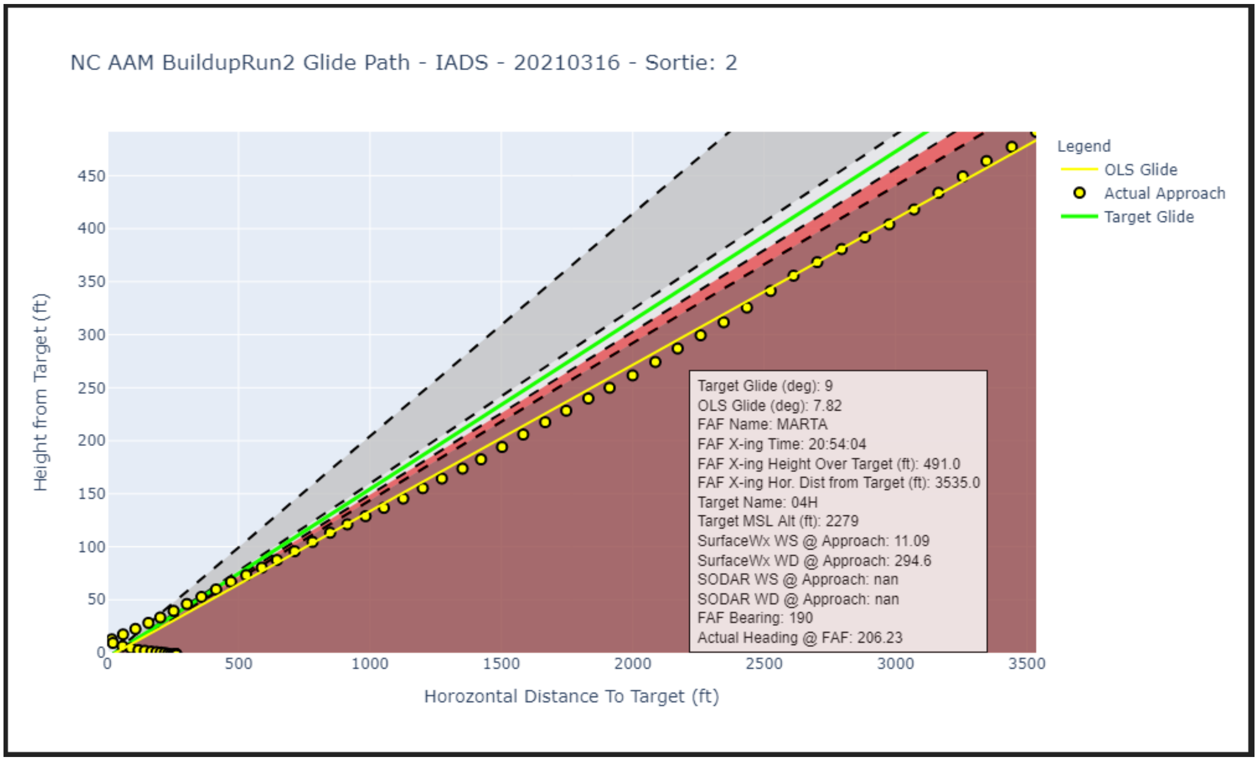


Figure 4.39. Worst 9-Degree Glidepath Angle via IADS: Marta 03.16.21 20:54:04.

12-Degree Glidepath Angles

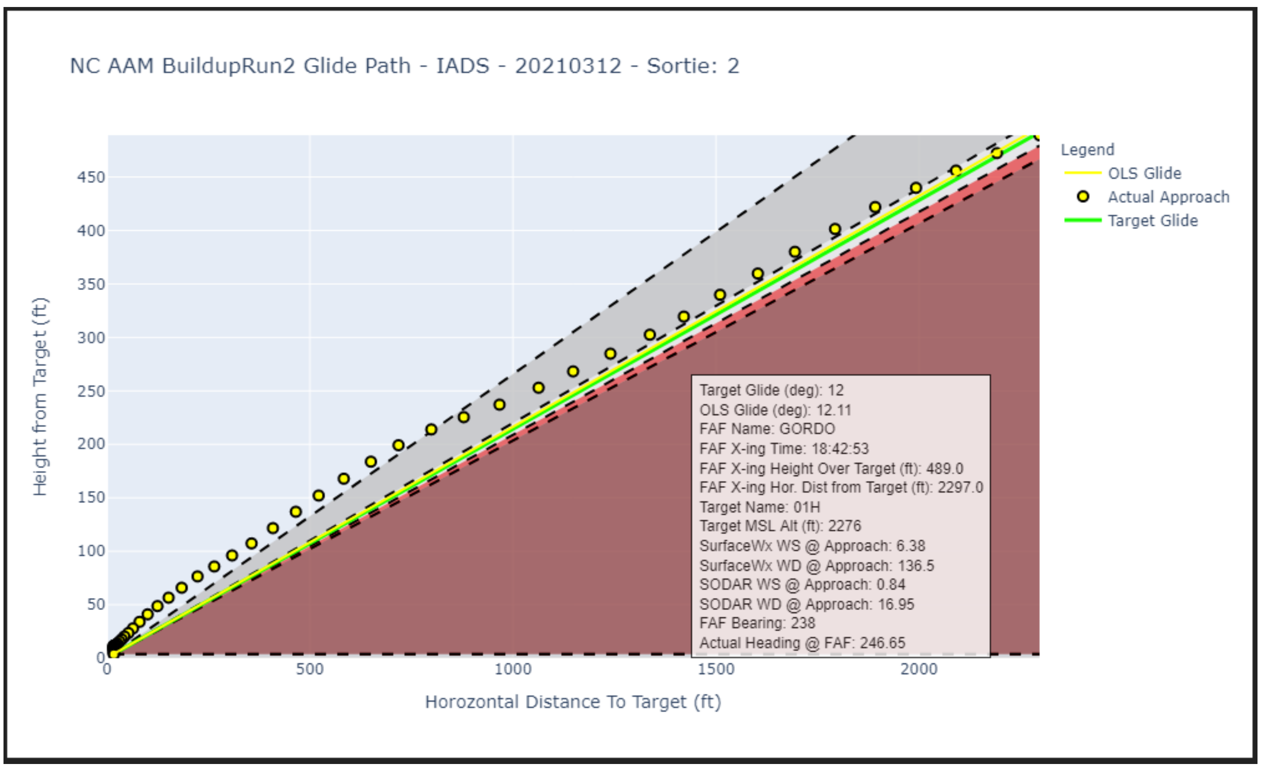


Figure 4.40. Best 12-Degree Glidepath Angle via IADS: Gordo 03.12.21 18:42:53.

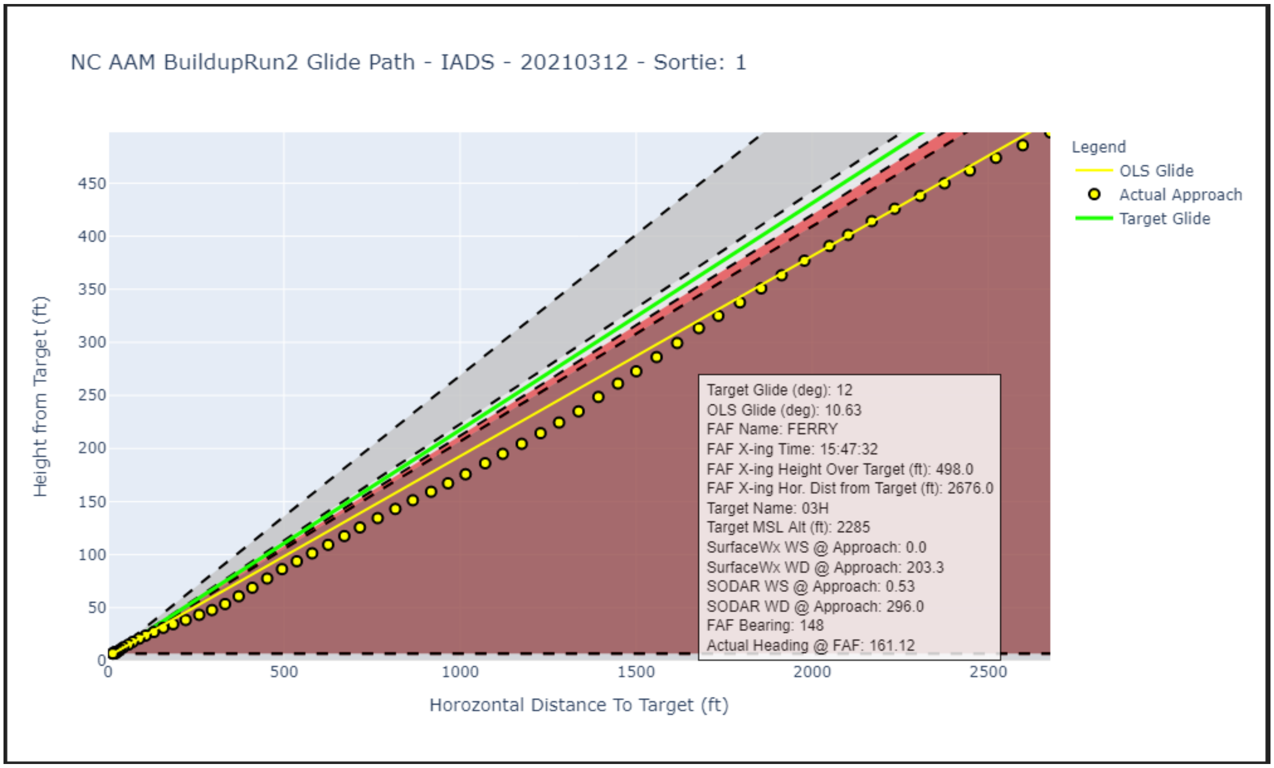


Figure 4.41. Worst 12-Degree Glidepath Angle via IADS: Ferry 03.12.21 15:47:32.

4.3 Routes And Scenarios

NC applied the designed Scenarios concepts to the flight tests as depicted in Figure 4.42 below:

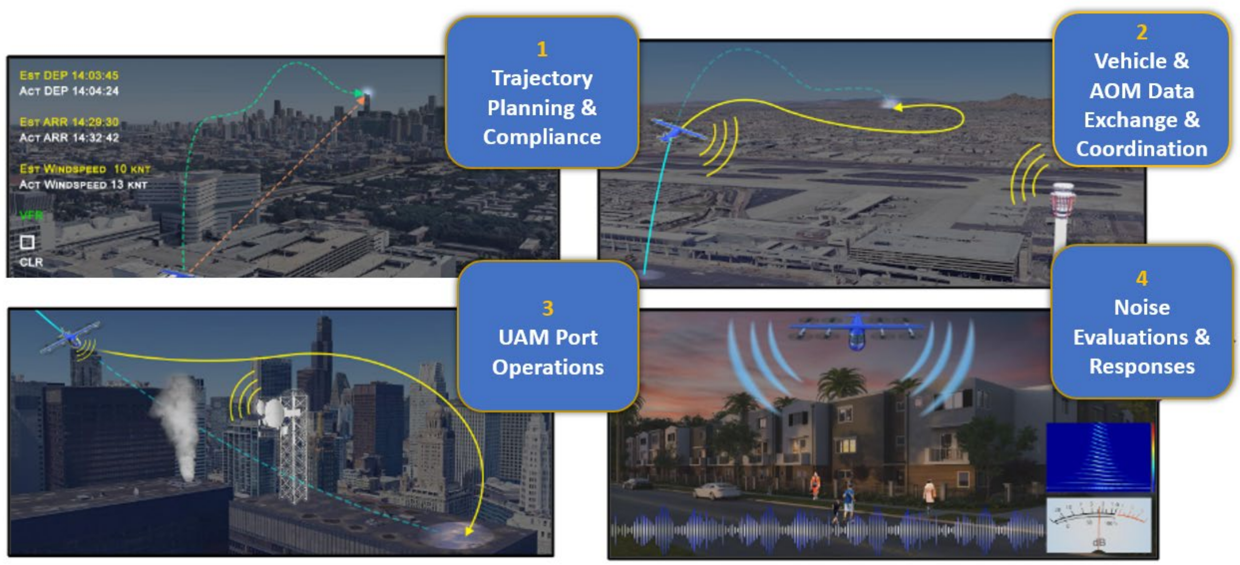


Figure 4.42. NASA-FAA National Campaign Working Group Overview.

<u>Scenario 1: Trajectory Planning and Compliance</u>

The first scenario tested operational and flight planning capabilities for nominal operations, and interoperability of the vehicle and the airspace service provider. The vehicle flew an intended flight plan “filed” with the [for Build 2, NASA PSU] airspace service, and executed the fight as planned after receiving approval from [for Build 2, NASA Mission Controller] the provider. The airspace provider [for

Build 2, the NASA Mission Control Team] monitored the flight for conformance to the approved plan. There were no contingencies planned or required for Scenario 1.

Scenario 2: Vehicle and AOM Data Exchange and Coordination

The second scenario tested in-flight re-planning, negotiation, and execution that accommodated the [for Build 2, simulated] airspace system and vehicle constraints and responded to [for Build 2, pre-planned] real-world uncertainties. The airspace system communicated a new constraint [for Build 2, via pre-planned routes] that required the vehicle to execute a re-route while airborne. Note that the contingency in scenario 2 was a simple re-route due to an airspace restriction imposed after takeoff.

Scenario 3: UAM Port Operations

The third scenario tested scalable UAM Port designs and procedures, exploring factors such as turn-around times, ground operations, airspace scheduling impacts around UAM ports, localized weather information, and impacts of balked landings or go-arounds. There are three sub-scenarios within scenario 3, progressively more time sensitive situation requiring [for Build 2, pre-planned, simulated] go-around or balked landing, loiter, and re-route to a landing site.

Scenario 4: Noise Evaluation and Responses

The fourth scenario tested the RVLT acoustics array and performed acoustic evaluation with the Joby Aviation, Inc. AAM vehicle during the Developmental Testing Flight test. The test also evaluated energy supply for flight phases and a subset of vehicle characterization objectives.

Introduction to Scenario Applications for NC Dry Run Tests

Scenarios were tested for the National Campaign Dry-Run and routes were selected to test them. The NC team began with scenario 1, to test nominal flight planning and operations, and then progressed through Scenarios 2 and 3 which progressively increased the complexity of the scenarios "to exercise advanced technologies and verify readiness for operational use by standardized testing in partnership with the FAA." (UAM Helicopter Flight Test Plan, Appendix A, page 105) The flight planning portions of scenario 1 were repeated for Scenarios 2, 3A-C.

The following routes were created to facilitate the scenarios: Route Discovery, Apollo, Galileo, Mercury 1 and 2, Orion 1, 2, 3, and 4, Endeavor, Sophia, Atlantis, Enterprise, Gemini 1 and 2, Magellan, Ulysses 1 and 2, Artemis, and Lewis. The names of the routes were taken from the names of legacy NASA programs. The routes were constructed using waypoints named after NC team members; the final approach fix waypoints were named for deceased NASA test pilots.

Scenario performance and conformance utilizes the FAA ADS-B via SBSM. The ADS-B is passively monitored through the FAA system. Portions of the TSPI data are parsed through a converter software to KMZ and shared with National Campaign. The track is overlaid on the routes to identify adherence to the scenarios as they apply to the airspace design for the flight event range. The SBSM ADS-B is chosen as the truth source for scenario route conformance as a baseline study for early integration of new entrants into the NAS with existing FAA technologies and methods. See Annex 6 for coded routes.

Scenario 1: Nominal Routes

"The purpose of [Scenario 1] is to exercise the planning and execution of nominal operations supported by a NASA Provider of Services for UAM (NPSU) within the bounds of vehicle constraints and to assess the precision of the vehicle trajectory's spatial and temporal conformance to the flight plan across a range of density altitudes [and to] evaluate the format for exchange of trajectory information between vehicle and PSU system." UAM Helicopter Flight Test Plan, Appendix A Page 105). To facilitate this purpose, the flight check team will, "Perform nominal vehicle and airspace operations, to include preflight planning and basic airspace/vehicle information exchanges. Takeoff utilizing a NASA defined heliport/vertiport departure, fly approximately 15 nautical miles using nominal operations and procedures while maintaining contact with the airspace provider at all times, land using nominal heliport/vertiport approaches as defined by NASA. [These] operations will take place in simulated Class G airspace. All Scenario 1 flights will occur in VMC conditions during daylight hours. Routes can transit from one site to another or begin and end at the same site. (UAM Helicopter Flight Test Plan, Appendix A, page 105).

For the NC Dry-Run, the preflight planning and basic airspace and vehicle information exchanges were conducted using a simulated flight plan construct consisting of a modification of current flight plan theory methods, as shown below in Figure 4.43, but adjusted to a waypoint-by-waypoint plan which could be easily disseminated to the flight crew and data teams. This flight planning and airspace to vehicle information method was used for all tested scenarios 1, 2, 3A-C.

TYPE FLT PLAN	TRUE AIRSPEED	POINT OF DEPARTURE	PROPOSED DEPARTURE TIME (Z)	ALTITUDE	ROUTE OF FLIGHT	TO	ETE
I	245	KHBG	1200	160	LBY1.LBY LBY.RYTHM4 TINEE	KNBG	0+34
I	243	KNBG	1400	50	HRV SLIDD V20 CLERY KHSA		0+11
					® KHSA D0+15 KBIX		

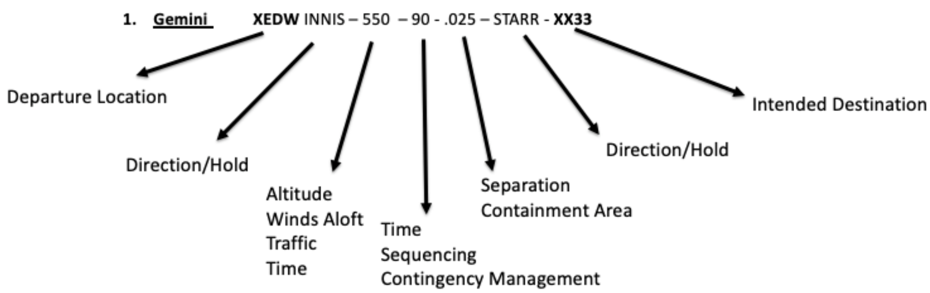


Figure 4.43. National Campaign Flight Plan Theory.

Scenario 1 Routes- DISCOVERY, APOLLO, GALILEO, MERCURY & ORION

Five test routes were created for scenario 1: Discovery, Apollo, Galileo, Mercury 1, and Orion 1. Of these routes, two, Discovery and Mercury 1, were selected for Dry Run flight test. Routes Discovery, Apollo and Galileo were all contained with the UAS work area; routes Mercury and Orion 1 were routes between the vertiport at EAFB and XX-33. Scenario routes between the vertiport and XX33 were preferred by the flight crew over those wholly within the UAS work area. As such, the routes in the UAS work area were only evaluated when the routes to XX33 were not available. Therfore, only UAS Work Area route Discovery v1 Figure 4.45, was evaluated while the rest of the scenario was flown using Route Mercury 1.

'Deproach' Theory

As routes were constructed, the NC team attempted to backwards-plan from a validation process in use today via FAA FIAPA Flight Check. The current software in use today for Flight Check could not ingest the low level routes, and, therefore, the NC team constructed 'Deproach'. A 'deproach' is the departure location coded as an IF, which initiates the route from the aircraft point of departure. The resulting lines of code included the departure - enroute - approach sections which totaled 14 nautical miles from end to end (Figure 4.44). A conventional approach totals 14 nautical miles not including the additional enroute and departure portions of flight.

Experimental UAM Routing from Takeoff (IF) to Landing (MAP)

ROUTE APOLLO

Experimental "DEPROACH"

```
SUSAP XVPTK6GRW19     0010611892 N34571364W117525772        +0217102279000056100I                                    106521804
SUSAP XVPTK6GRW01     0010610096 N34570389W117530240        +0217102276000056100I                                    106521804
SUSAH XEDWK6A         0      NARY N34573283W117525412E012002276        1800018000P         M XEDW North             100102013
SUSAH XVPTK6A         0      NARN N34571364W117525772E012002277        1800018000P         M XVPT North             100202013
SUSAH XX33K6A         0      NARN N34523317W117370408E012002277        1800018000P         M XX33                   100202013
SUSAH XEDWK6H01H      0S00060050 N34573273W117525425HCONC101S      02276                                             200102013
SUSAH XEDWK6H02H      0S00060050 N34572437W117525772HCONC101S      02279                                             200202013
SUSAH XEDWK6H03H      0S00060050 N34572614W117530312HCONC101S      02279                                             200302013
SUSAH XVPTK6H04H      0S00060050 N34571320W117525808HCONC101S      02276                                             200402013
SUSAH XVPTK6H05H      0S00060050 N34570431W117530227HCONC101S      02276                                             200502013
SUSAH XX33K6H06H      0S00060050 N34523317W117370408HCONC101S      02981                                             200502013
SUSAP XVPTK6FR01   AEDW   010EDW  K6D 0V      IF                                        18000             A JS   300102013
SUSAP XVPTK6FR01   AEDW   020MRPHYK6EA0E   R  TF                 24880080    + 05000                      A JS   300202013
SUSAP XVPTK6FR01   R      010MRPHYK6EA0E      IF                             + 05000    18000             A JS   300302013
SUSAP XVPTK6FR01   R      020ROBSTK6EA0E   R  TF                 35890005    + 04000                      A JS   300402013
SUSAP XVPTK6FR01   R      030WEBBDK6EA0E   R  TF                 01120005    + 03000                      A JS   300502013
SUSAP XVPTK6FR01   R      040ERINWK6EA0E   R  TF                 01120005    + 03000                      A JS   300602013
SUSAP XVPTK6FR01   R      050GRANDK6EA0E   R  TF                 01120005    + 03000                      A JS   300702013
SUSAP XVPTK6FR01   R      060CHLNGK6EA0E  IR  TF                 13360008    + 03000                      A JS   300802013
SUSAP XVPTK6FR01   R      070BILLDK6EA0E  FL  TF                 21070002    + 03000                      A JS   300902013
SUSAP XVPTK6FR01   R      080RW01 K6PG0GY M   TF                 35600014      01339           -900       A JS   301002013
SUSAH XEDWK6FR01H  AEDW   010EDW  K6D 0V      IF                                        18000             A JS   301102013
SUSAH XEDWK6FR01H  AEDW   020BILLDK6EA0E   R  TF                 24880080    + 05000                      A JS   301202013
SUSAH XEDWK6FR01H  R      010BILLDK6EA0E      IF                             + 05000    18000             A JS   301302013
SUSAH XEDWK6FR01H  R      020CHLNGK6EA0E   R  TF                 35890005    + 04000                      A JS   301402013
SUSAH XEDWK6FR01H  R      030GRANDK6EA0E   R  TF                 01120005    + 03000                      A JS   301502013
SUSAH XEDWK6FR01H  R      040ERINWK6EA0E   R  TF                 01120005    + 03000                      A JS   301602013
SUSAH XEDWK6FR01H  R      050WEBBDK6EA0E   R  TF                 01120005    + 03000                      A JS   301702013
SUSAH XEDWK6FR01H  R      060ROBSTK6EA0E  IR  TF                 13360008    + 03000                      A JS   301802013
SUSAH XEDWK6FR01H  R      070MRPHYK6EA0E  FL  TF                 21070002    + 03000                      A JS   301902013
SUSAH XEDWK6FR01H  R      08001H  K6HH0GY M   TF                 35600014      01339           -900       A JS   302002013
```

Figure 4.44. National Campaign Urban Air Mobility APOLLO Route.

<u>DISCOVERY Version 1</u>

The simulated flight plan for DISCOVERY Version 1 is as follows:
XVPT (04H)—FREDD—CHLNG—FASST—ERINW—CMILL—WEBBD—INNIS—XEDW (01H)

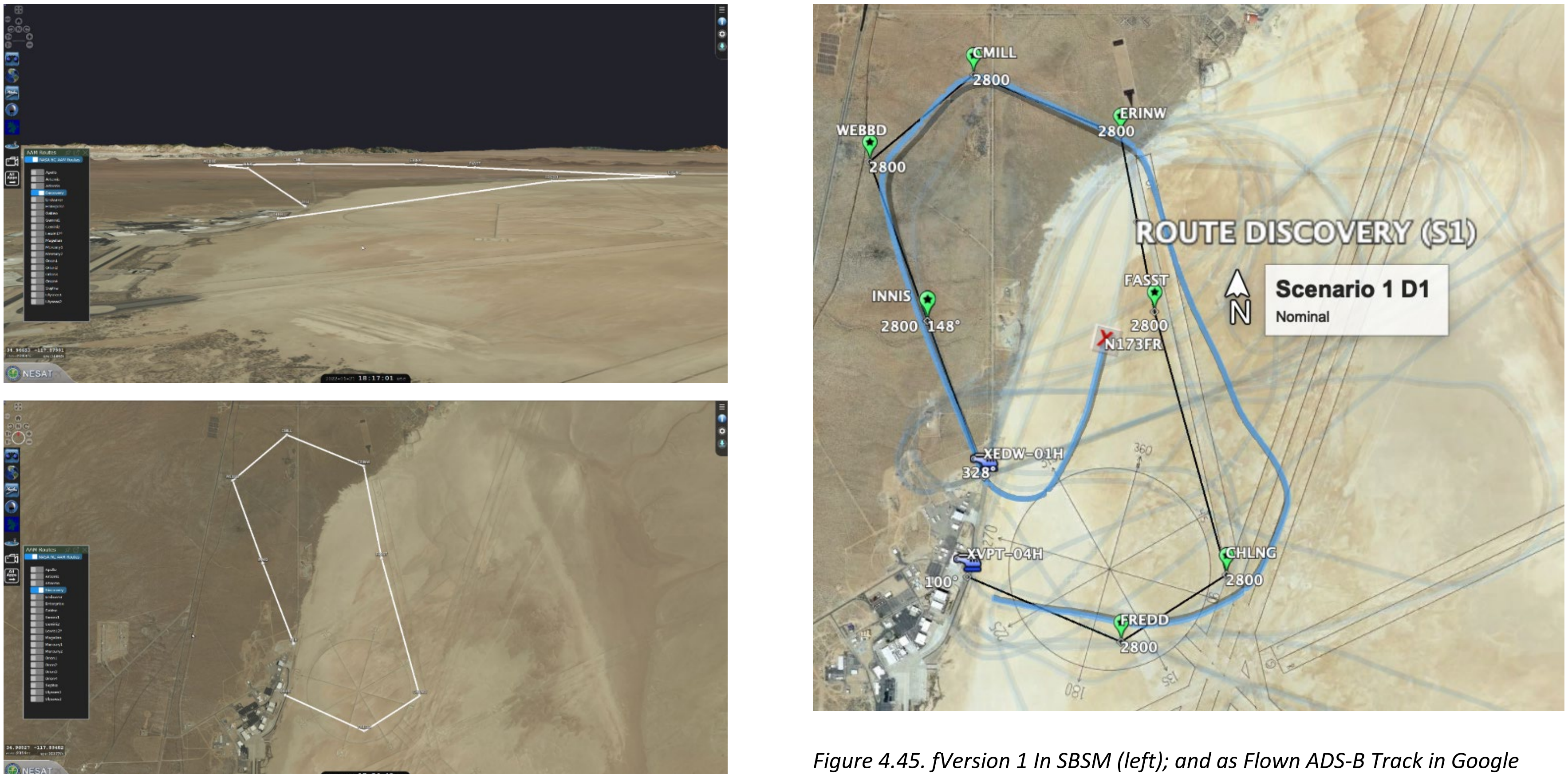


Figure 4.45. fVersion 1 In SBSM (left); and as Flown ADS-B Track in Google Earth (right).

DISCOVERY Version 1 Outcome

DISCOVERY Version 1 Scenario route was flown with the track shown in blue within Figure 4.45 (above). The aircraft was intended to depart 04H on a 100-degree heading to FREDD while climbing to the planned altitude of 2,800 feet MSL and then proceeding along the course using the waypoints to the FAF at INNIS to begin a 9-degree approach. The aircraft struggled slightly with the tight turns from the outset of the scenario but was able to recover in time to begin the approach at the FAF. Despite this, the aircrew requested a longer route which resulted in a redesign of the route. The redesign of the scenario route was never flown, however, because the XX33 routes were available for most of the following test flight events. Finally, the redesign of the DISCOVERY Route 1 also led to the same lengthened redesign for all other non-XX33 routes.

DISCOVERY Version 2

The simulated flight plan for DISCOVERY Version 2 is as follows:

XVPT (RWY01)—FASST—ANCHR—SIMPLO—JAFFE—SHRMA—FALCN—CAPPS—COOPER—XEDW (01H)

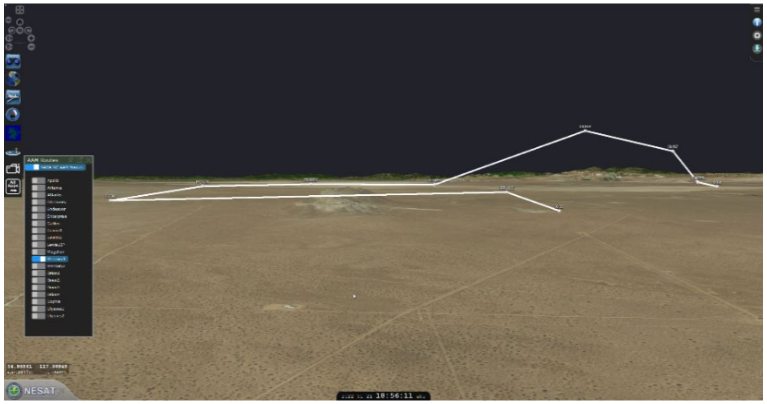
Figure 4.46. Discovery Version 2.

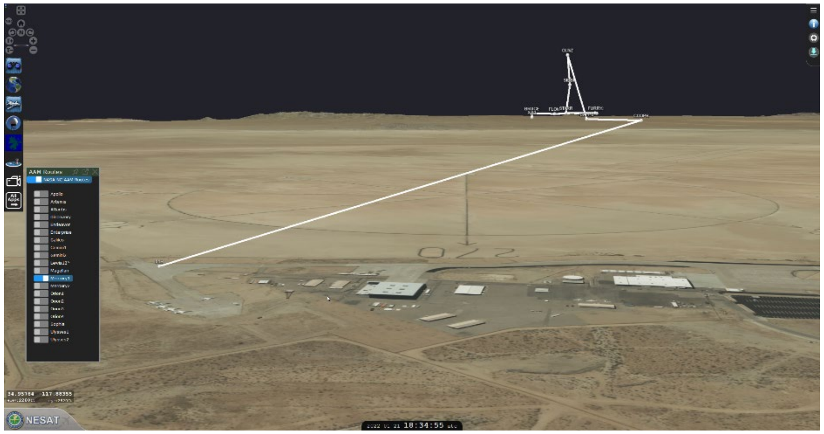
DISCOVERY Version 2 Outcome

Route DISCOVERY Version 2 was adjusted to this longer version to accommodate the entire UAS work area; however, it was not flown because the XX33 route, MERCURY 1, became available to complete Scenario 1 flights.

MERCURY 1 Version 1

The simulated flight plan for MERCURY 1 Version 1 is as follows:
XEDW (01H)—COOPR—CAPPS—OLIVZ—SIDBR—STARR—FURRY—POTTR—FLOKI—BRUCE—XX33 (06H)





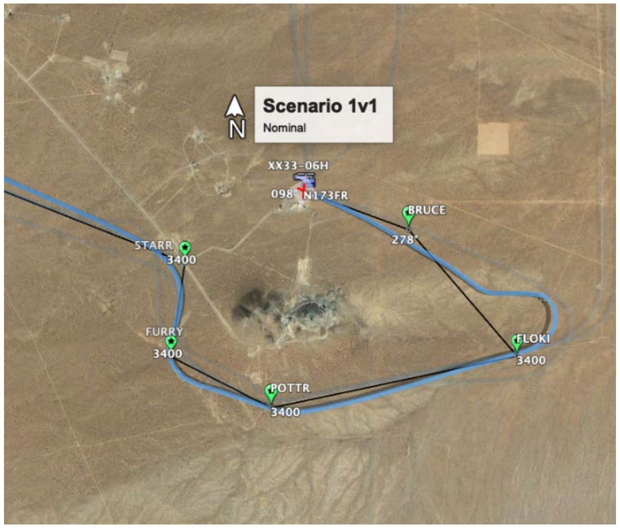


Figure 4.47. MERCURY 1 Version 1 In SBSM (left and top right); and as flown ADS-B track in Google Earth (bottom Rrght).

MERCURY 1 Version 1 Outcome

An initial attempt for BRUCE route arrival approach was made when flying into XX33 from the Southeast. The simulated obstacles on this scenario being the mountain in the center, the higher elevation to the South and simulated UAM environment to the Northeast. The aircraft struggled with the tight turn at the IAF, however, and was never able to fully recover for the approach to begin properly at the FAF, BRUCE as seen in Figure 4.48.

MERCURY 1 Version 1.5 Outcome

Figure 4.48. MERCURY 1 Version 1.5.

A second attempt at the BRUCE arrival into XX33 was made. On the second iteration, the aircraft was able to swing wide of the IAF to properly set up for the PFAF at waypoint BRUCE. The track in Figure 4.48 indicates the necessity for a small adjustment to the arrival, moving FLOKI to the apex of the left turn to final, allowing the aircraft to begin the approach as planned at BRUCE. After discussion with the aircrew, safety, and airspace teams, it was decided that, for passenger comfort, this turn might not be acceptable. As such, a redesign was implemented on this arrival, as shown in to follow in Figure 4.49, with which the aircraft was able to maintain a tight track without such aggressive turns required. The conversation about this arrival led to discussions about passenger comfort and the effect on future route planning for both test and live flight events.

MERCURY 1 Version 2

The simulated flight plan for MERCURY 1 V 1 is as follows:
XEDW (01H)—COOPR—CAPPS—OLIVZ—SIDBR—FURRY—POTTR—FLOKI—BRUCE—XX33 (06H)

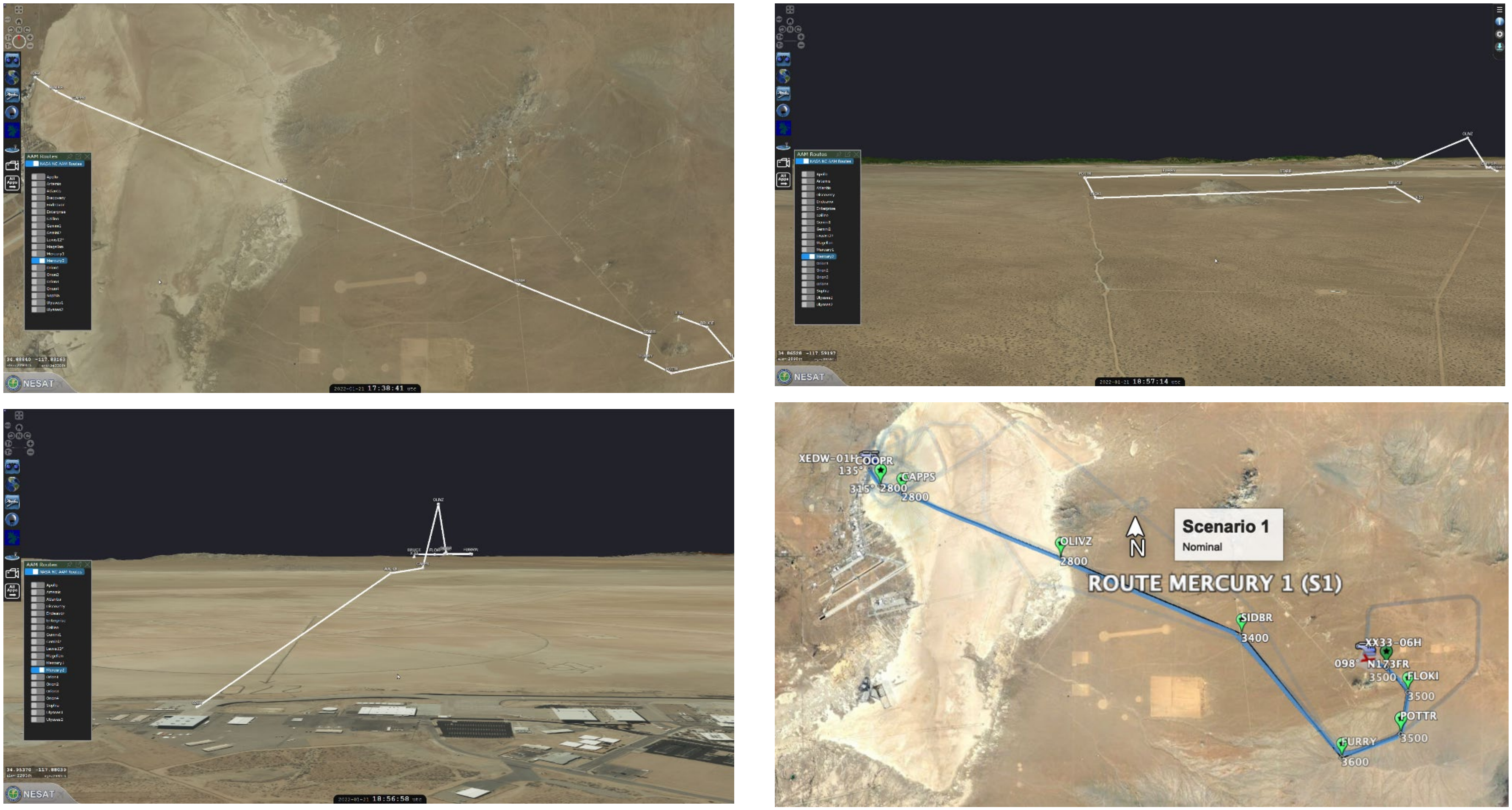


Figure 4.49. MERCURY 1 Version 2 In Sbsm (left and top right); and as flown ADS-B Track in Google Earth (bottom right).

MERCURY 1 Version 2 Outcome

As a result of the surrogate aircraft unable to make the greater than standard rate turn at FLOKI, attempting to simulate a constrained UAM environment, MERCURY 1 Version 2 was created and flown with the aircraft departing XEDW-01H enroute to XX33-06H. The aircraft was able to maintain a tight track to the planned route including the new arrival path into XX33 as shown above in Figure 4.49.

Scenario 2: In-Flight Re-Route

The purpose of scenario 2 is the "In-flight re-planning, negotiation and execution that accommodates PSU system and vehicle constraints and responds to real-world uncertainties. Exercise exchange of trajectory information, PSU system and vehicle constraints, and user preferences between vehicle and airspace management systems." UAM Helicopter Flight Test, Appendix A, page 111.

The NC team performed nominal vehicle operations and executed airspace negotiations, including preflight planning and basic airspace and vehicle information exchanges in order to facilitate the purpose of scenatio 2. Takeoffs and landings will have occurred in simulated Class D airspace, separated by a section of simulated Class G airspace. Takeoffs and landings were executed using heliport/vertiport approaches and departures as defined by NASA. Namely, take off, fly approximately 15 miles using nominal operations and procedures while maintaining contact with the airspace provider at all times to allow for airspace negotiation, which occurred during the cruise phase of the flight. After takeoff, while the vehicle is still in simulated Class D airspace, a UVR (UAM Volume Restriction) was issued that indicates a conflict with the current operation which required the vehicle to update its route and the ATI system updated the current operation to avoid the UVR. The ATI system updated the operation to utilize a route that avoids the conflict and the vehicle selected and begin flying the alternate route on the cockpit navigation aid. The alternate route rejoined the original route and included flight through a portion of simulated Class G airspace. To conclude the flight, the vehicle re-entered simulated Class D airspace and landed. Up to 50 virtual UAM tilt-rotor aircraft with no planned interference will be utilized as background traffic. All Scenario 2 flights occurred in VMC conditions during daylight hours.

Scenario Routes ORION 3 and ENDEAVOR

Scenario 2 consisted of two routes; ORION 3 to and from XX33 and Endeavor contained within the UAS work area. Only ORION 3 was tested during this flight check since the XX33 route was available for all flights.

ORION 3

The simulated flight plan for ORION 3 is as follows:
XEDW (01H)—GORDO—PNCHO—ANCHR—EVOLV—FALCN—MOHAG—OLIVZ—HOMLA—EGGMS—FURRY—POTTR—FLOKI—BRUCE—XX33 (06H)
RE-ROUTE@ FALCN—WGGNR—DEEZR—HOMLA—OC

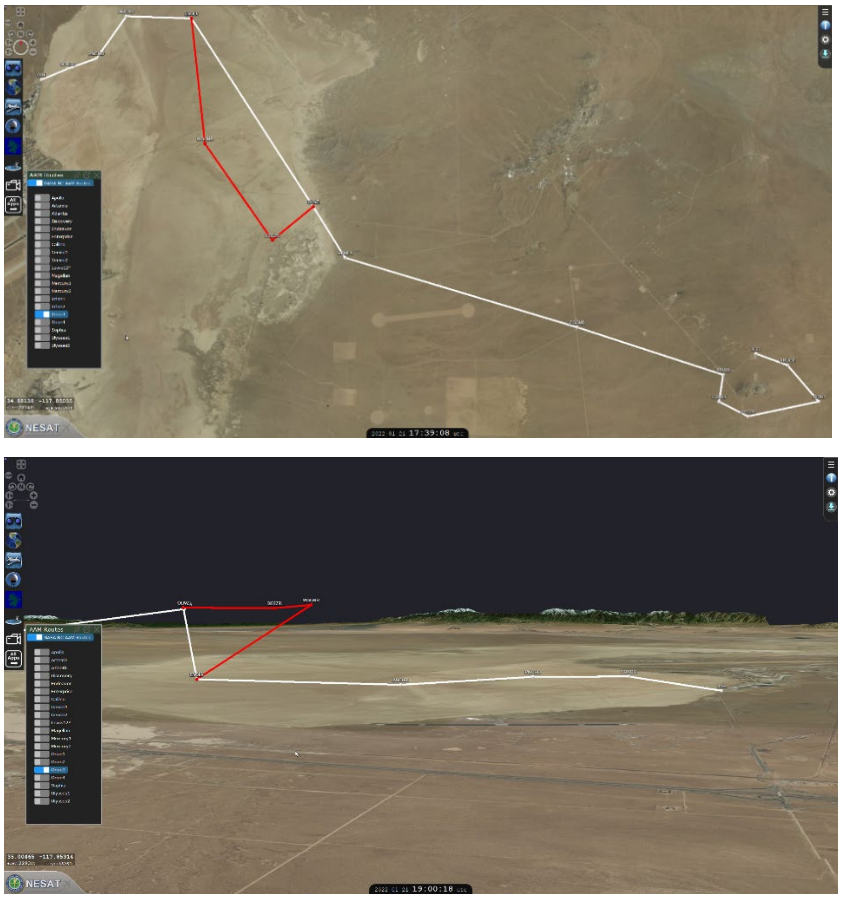


Figure 4.50. ORION 3 In SBSM (left); and as flown ADS-B Track In Google Earth (right).

ORION 3 Outcome

In the scenario 2, a re-route was sent to the aircraft via simulated air traffic control, or in the future, an automated system, and the aircraft adjusted to the new course enroute. The surrogate piloted aircraft was easily able to adjust to the change in course and followed a tight track from departure at XEDW-01H all the way to landing at XX33-06H. The scenario route also made use of the adjustment to the BRUCE arrival first made for MERCURY 1.

Scenario 3: UAM Ports and Missed Approaches

The purpose of Scenario 3 was to 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 or go-arounds. To facilitate this purpose, Scenario 3 focuses on terminal area operations. Vehicle takeoff can occur from any of the NC Dry Run Helipads or Vertiports. All takeoff procedures and "planned" landing profiles will be defined by NASA personnel. The vehicle may remain close to the heliport/vertiport to allow the participant to execute several Scenario 3 profiles within one day. All Scenario 3 profiles are entirely within simulated Class-D airspace. In Scenario 3a, the participant will execute a go-around, loiter, and land at the originally intended site. In Scenario 3b, the participant will execute a balked landing resulting in a diversion to an alternate heliport/vertiport. In Scenario 3c, the participant will execute a balked landing resulting in a diversion to an active vertiport runway, where the vehicle will have to get worked into the existing pattern traffic. There will be simulated background traffic consisting of up to 50 virtual UAM tilt-rotor aircraft. The virtual traffic will "fly" predefined routes on a static schedule with consistent spacing to emulate UML2-type operations. All Scenario 3 flights will occur in VMC conditions during daylight hours.

Scenario 3A: Missed Approach to Holding; Routes ATLANTIS and SOPHIA

Scenario 3A consisted of two routes: ATLANTIS, the XX33 route, and SOPHIA, the UAS work area route. Since the XX33 route was available for this scenario, only Route ATLANTIS was flown for this scenario. The purpose of Scenario 3A is to show the ability of the piloted, non-assisted, surrogate aircraft to respond to a missed approach with holding instruction and to establish track tolerances along the route, the missed approach path, and the holding pattern.

ATLANTIS Version 1

The simulated flight plan for ATLANTIS is as follows:
XX33(06H)—DRURY—LGTHA—RGNAR—BJORN—POTTR—FURRY--STARR—EGGMS—HOMLA—OLIVZ—MOHAG—FALCN—SPEDE—CHIPP--BILLD—[MAP@XVPT]—MARTA—FASST—ANCHR—SPEDE—CHIPP—FASST—OR—BILLD—XVPT (05H)

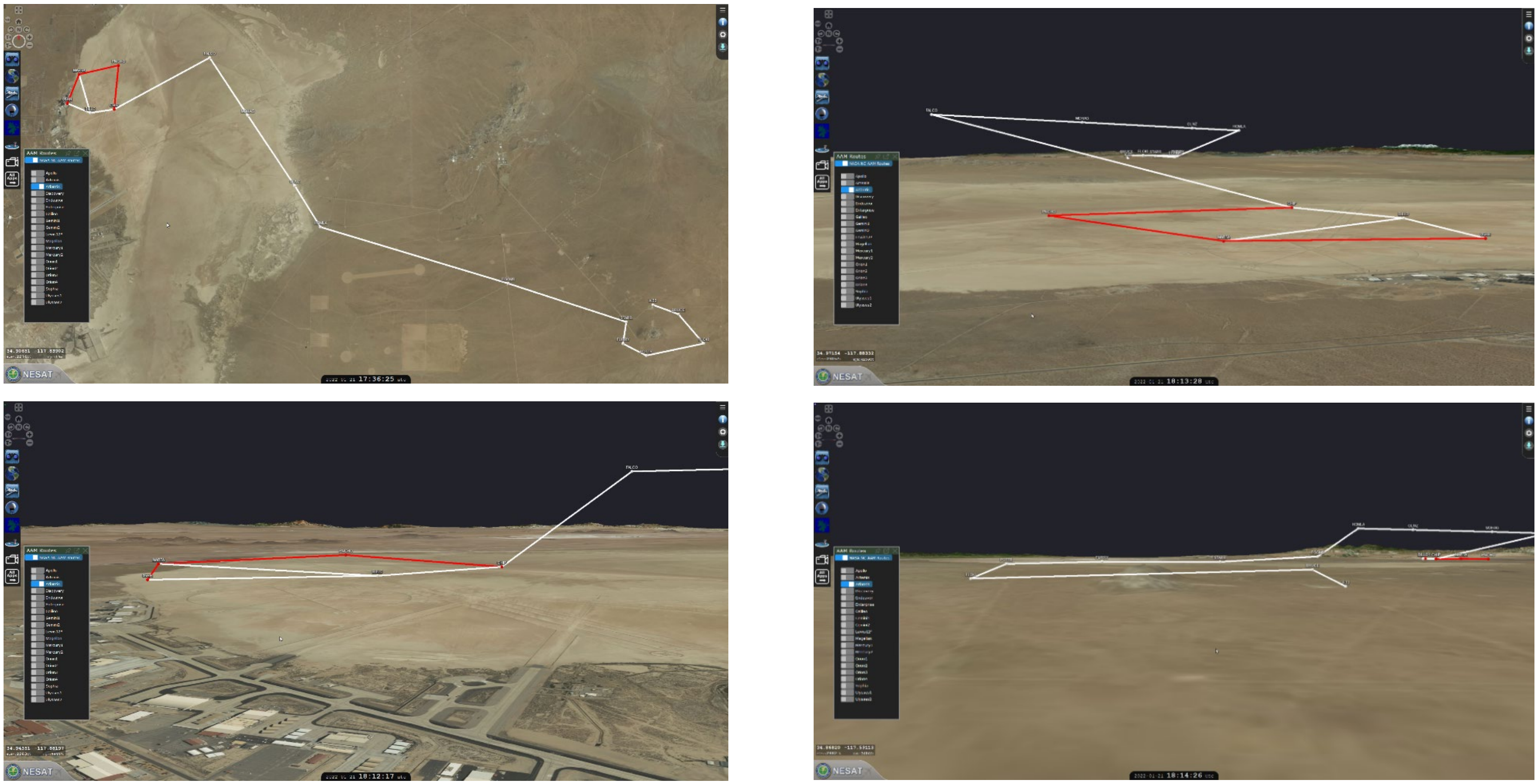


Figure 4.51. ATLANTIS Version 1 in SBSM.

ATLANTIS Version 1 Outcome

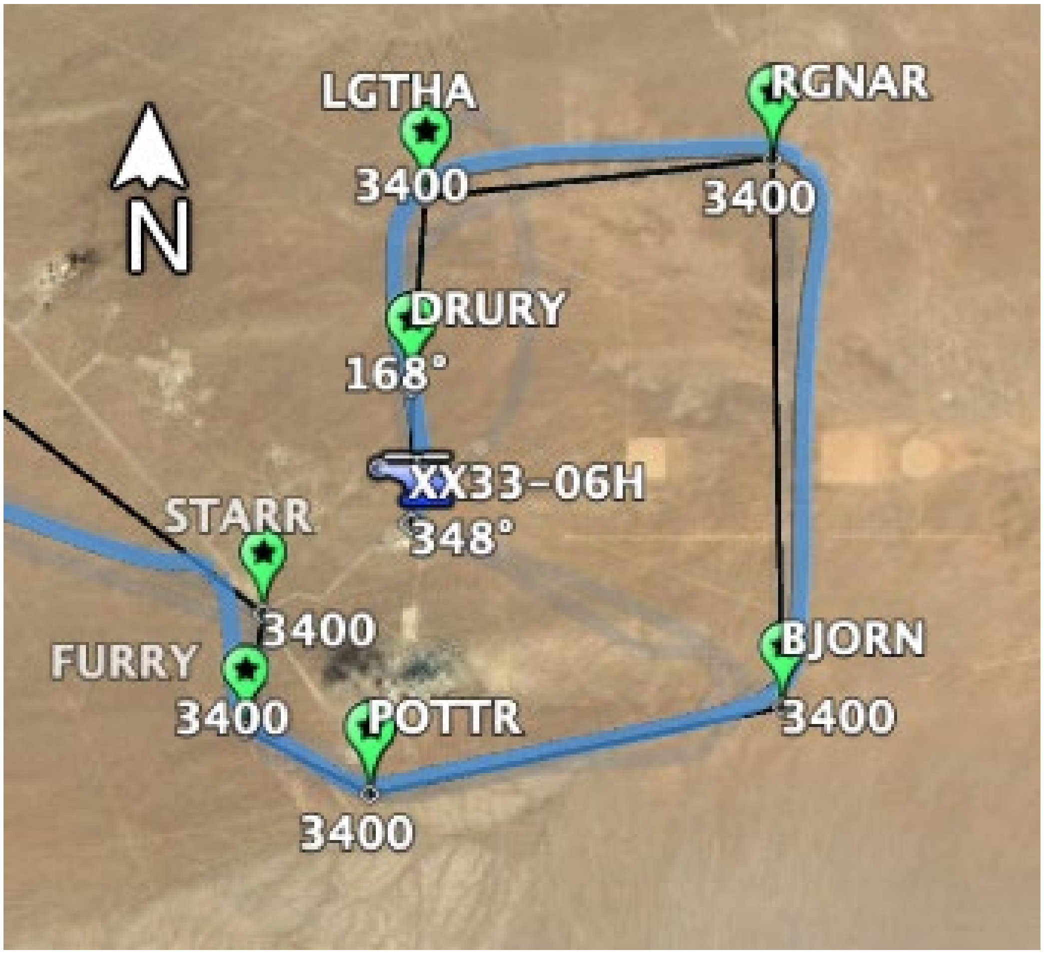


Figure 4.52. ATLANTIS Version 1 as flown ADS-B Track in Google Earth.

The departure portion for route Atlantis initially began with a tight departure track out of XX33 to the north followed by right turns around the mountain to the south and then on course. This departure pattern was necessary because of the gap between coordinated airspace to the northwest which was both actual and complementary to the scenarios associated with restricted airspace in the UAM environment. However, the aggressive turns on the departure and around the mountain to the south required the NC team to further address passenger comfort and to identify a way to soften the extreme angle of the departure turns. The result was the new DRURY departure and arrival track shown in Figure 4.53.

ATLANTIS Version 1.5 Outcome

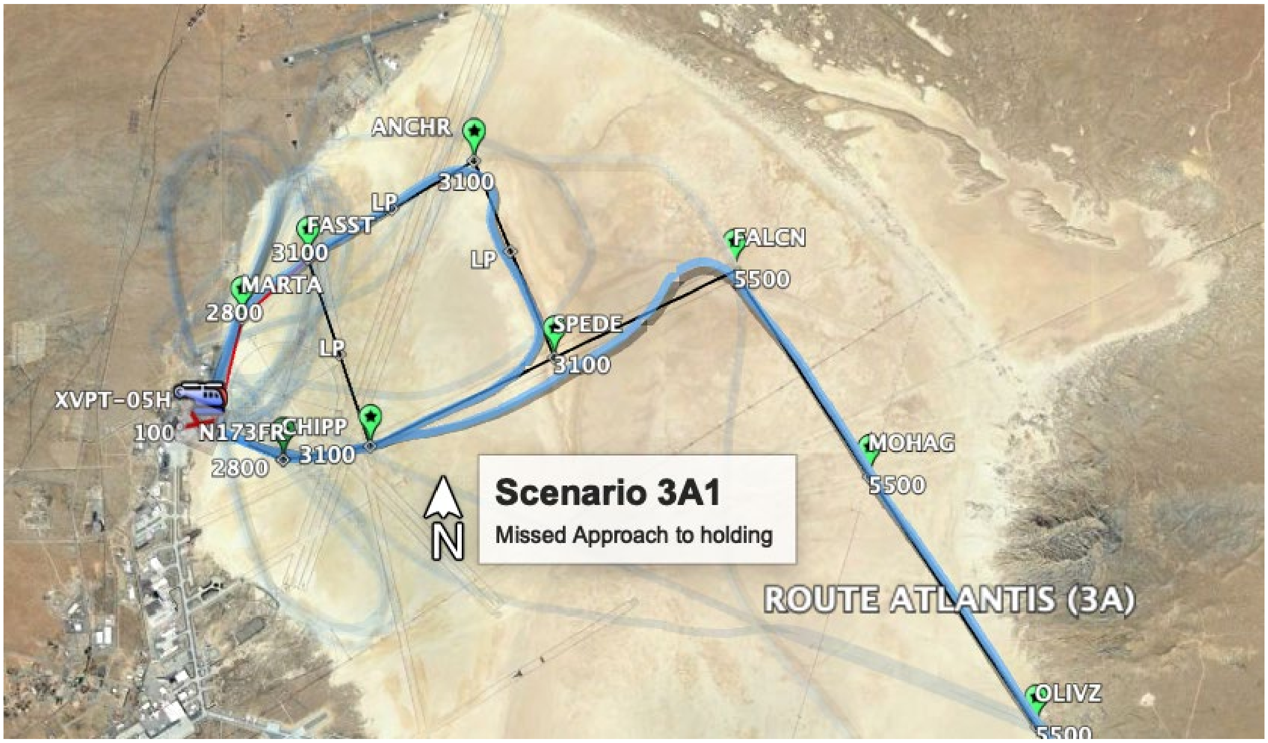


Figure 4.53. ATLANTIS Version 1.5 as Flown ADS-B Track in Google Earth.

Initially, Route ATLANTIS for Scenario 3A was to depart XX33 and follow a course up through the UAS corridor (which has a floor of 5,000 feet MSL), make a left turn at FALCN followed by an aggressive descent to the missed approach point and then to the holding track before landing. However, the left turn into, and the immediate steep descent on the route after FALCN, caused the aircraft overshoot the turn and struggle to get down to altitude in time for the missed approach maneuver. This was another approach where a discussion in after-action review turned toward passenger comfort. Consequentially, the route was adjusted.

ATLANTIS Version 2

The simulated flight plan for ATLANTIS Version 2 is as follows: XX33 (06H)—DRURY—LGTHA—RGNAR—BJORN—POTTR—FURRY—STARR—HACKN—BLOOM—SHRMA—SPEDE—CHIPP--BILLD—[MAP@XVPT]—MARTA—FASST—ANCHR—SPEDE—CHIPP—FASST—OR—BILLD—XVPT (05H)

Figure 4.54. ATLANTIS Version 2 as flown ADS-B Track in Google Earth.

ATLANTIS Version 2 Outcome

A modified north departure and arrival course was applied for XX33 routes once additional airspace was approved to the North. The new departure created much larger turns and airspace and conceptually requires going around obstacles and restricted airspace rather than cutting in front of them. Using the adjusted course, the aircraft was able to maintain a tight track on the route. However, there was much debate as to whether the new North departure and arrival course is at odds with passenger comfort over battery performance characteristics of future UAM vehicle (which seek to minimize large patterns to maximize battery life). Once again, the route adjustment leads to the need to closely study passenger comfort for data reflecting how turn radius and course may be planned for future UAM aircraft to strike the proper balance between comfort and efficiency.

Figure 4.55. ATLANTIS Version 2 North as Flown ADS-B Track in Google Earth.

In the adjusted Atlantis route scenario 3A, the inbound track from XX33 was moved north taking it out of the UAS corridor and thus keeping the aircraft to a manageable altitude prior to the new turn at SHRMA, which was also moved further north to assist with the descent into the FAF at BILLD. The new course allowed the aircraft to maintain a tight track with the route and complete the scenario, including the missed approach back to the loiter pattern followed by a 9-degree approach into XVPT-05H.

Scenario 3B: Missed Approach/Balked Landing to Alternate; Routes ENTERPRISE and GEMINI 1

Scenario 3B consisted of two routes: GEMINI 1, the XX33 route, and ENTERPRISE, the UAS work area route. In this scenario, the NC team was able to fly both the XX33 route and the UAS work area route. The purpose of Scenario 3B is to show the ability of the piloted, non-assisted, surrogate aircraft to perform a balked landing with a missed approach to an alternate landing site.

GEMINI 1

The simulated flight plan for GEMINI 1 is as follows:
XX33 (06H)—DRURY—LGTHA—RGNAR—BJORN--POTTR—FURRY—STARR—HACKN—BLOOM—SHRMA—GOCKL—ERINW—CMILL—WEBBD—INNIS—[MAP@XEDW]—TERPS—GOCKL—ERINW—MARTA—XVPT (RWY 19)

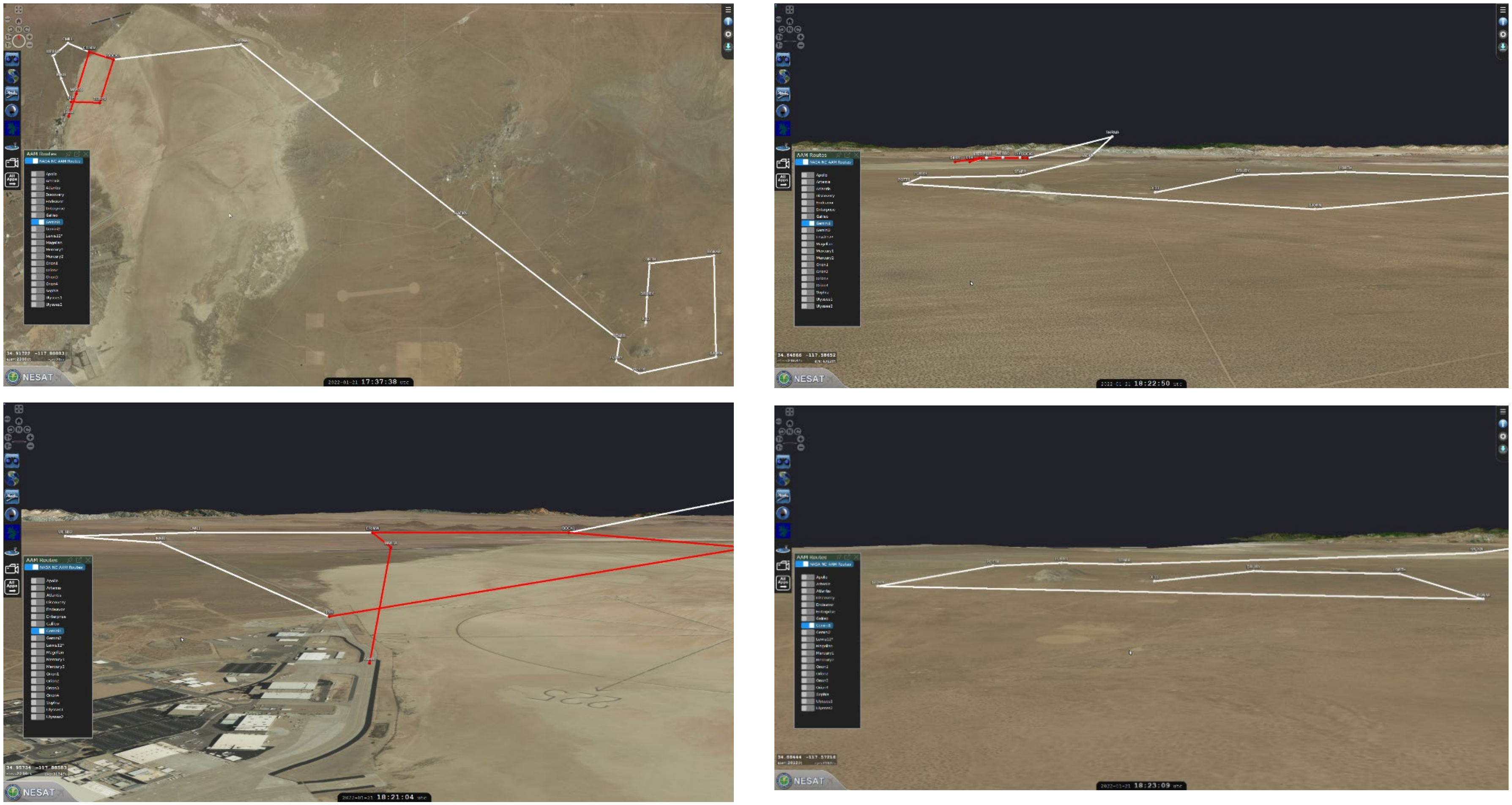


Figure 4.56. GEMINI 1 in SBSM.

GEMINI 1 Outcome

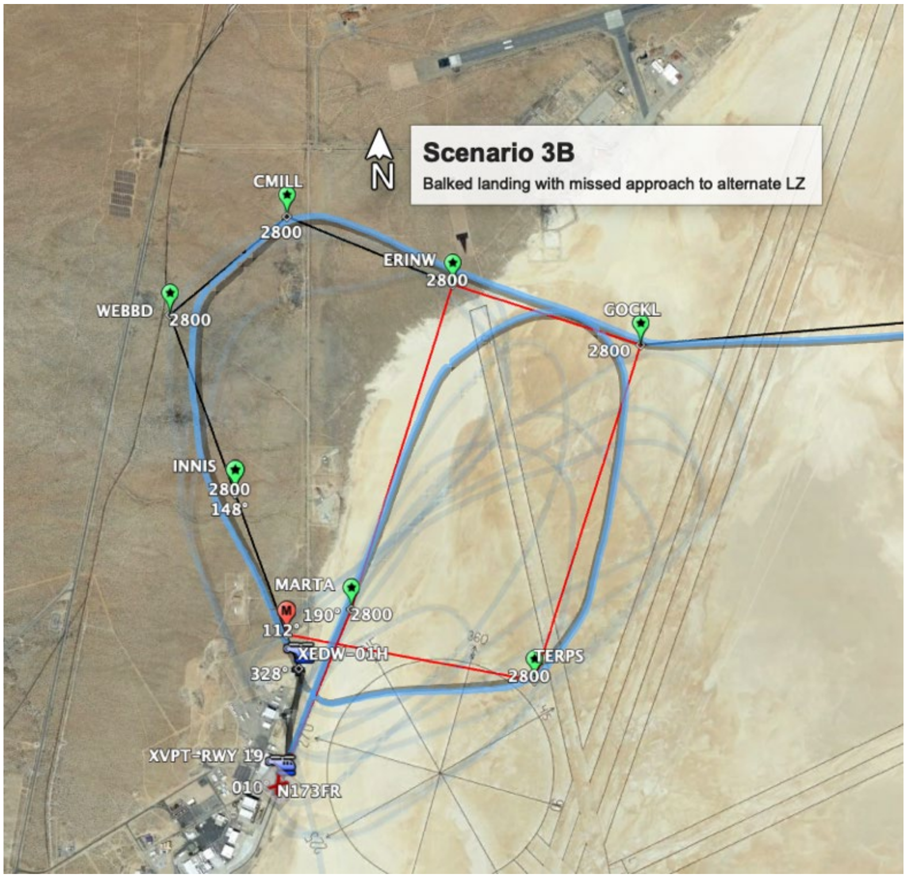
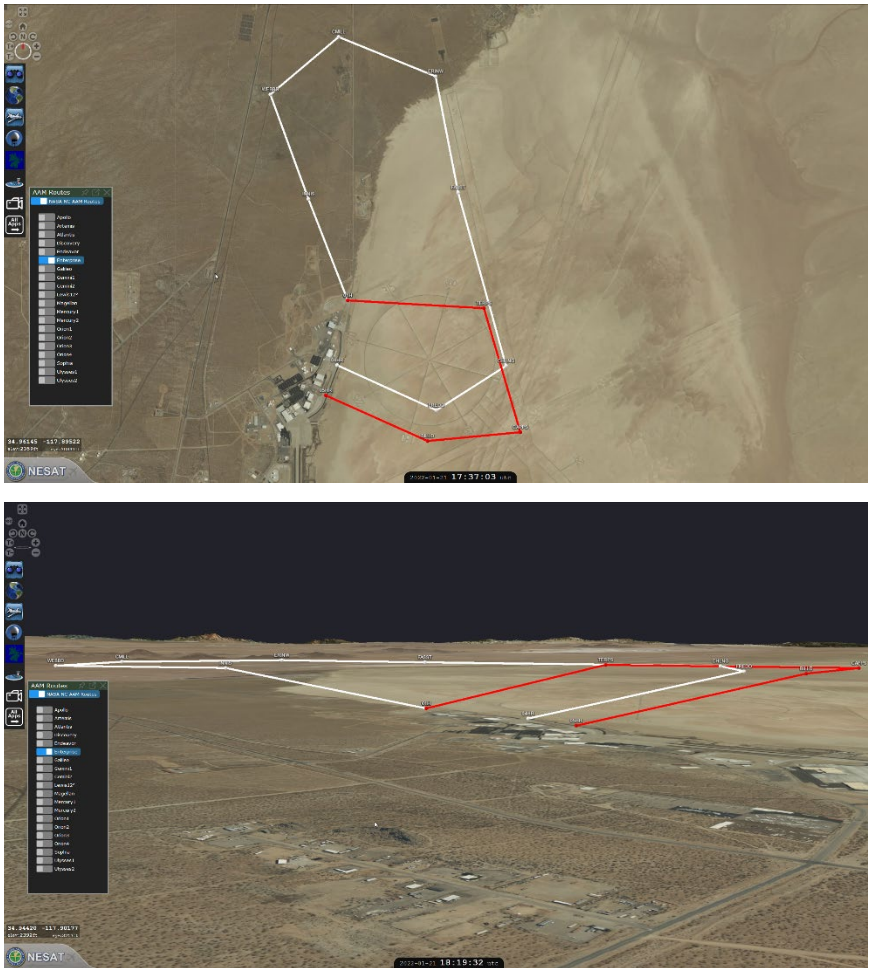


Figure 4.57. GEMINI 1 as flown ADS-B Track in Google Earth.

Route GEMINI for Scenario 3B was flown and the arrival evaluated as shown above in Figure 4.56-4.57. Route GEMINI departs XX33 to the North, then circles the mountain to the South and picks up the north corridor. The route then intercepts with the arrival portion of the scenario at GOCKL. The aircraft then follows the route to the FAF at INNIS for a 148-degree heading into XEDW-01H, where a simulated obstacle obstructs the landing surface causing a missed approach to an alternate landing zone. The missed approach procedure for route Gemini requires the aircraft to proceed to TERPS and then to re-intercept the arrival course at GOCKL, only this time the aircraft will turn at ERINW for the MARTA 190-degree heading into the vertiport runway 19. As is shown in Figure 4.57, the aircraft struggled a little making the turn from the IAF at WEBBD to get a good intercept of the PFAF at INNIS. However, it was able to maintain a close enough track to complete this portion of the scenario. After the balked landing, the aircraft was able to execute the missed approach to TERPS, but again it struggled with tight turns between GOCKL and ERINW. The tight turns wound up looking more like a continuous turn on the track. Regardless, the aircraft was able to establish itself on the approach at MARTA to complete the scenario. While the tight confines of this route were a challenge, the surrogate aircraft was able to negotiate the airspace successfully.

ENTERPRISE

The simulated flight plan for ENTERPRISE is as follows:
XVPT (04H)—FREDD—CHLNG—FASST—ERINW—CMILL—WEBBD—INNIS—[MAP@XEDW]—TERPS—CHIPP—BILLD—XVPT (05H)



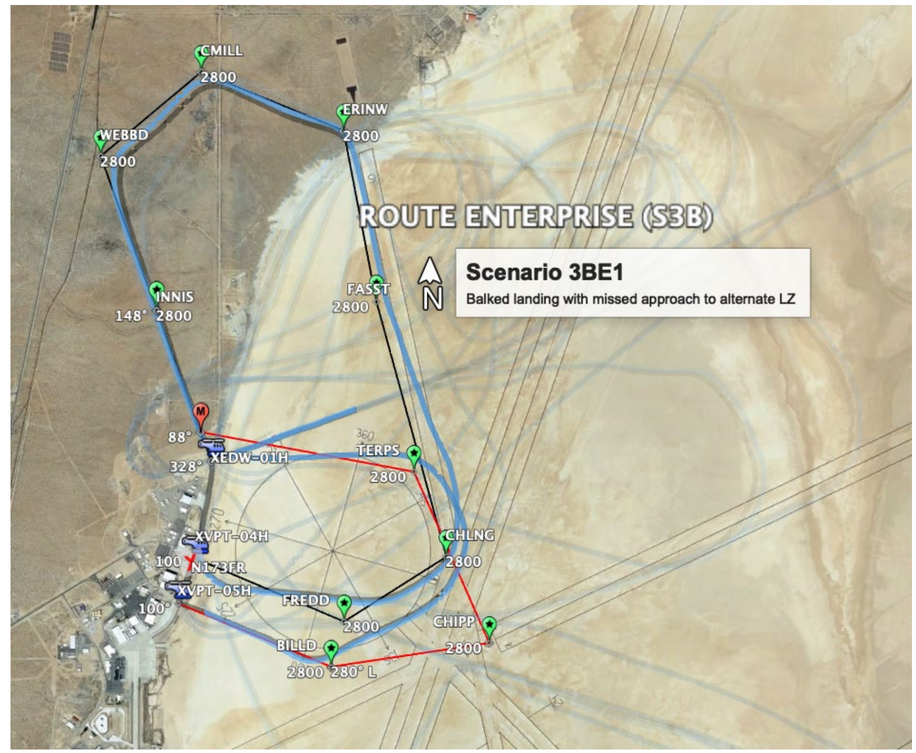


Figure 4.58. ENTERPRISE Balked Landing In SBSM (left); and as flown ADS-B track in Google Earth (right).

ENTERPRISE Outcome

While scenario 3A was successfully completed using route Gemini above, the aircrew was also able to fly the UAS work area version of this scenario, Route ENTERPRISE. The aircraft departs XVPT-04H for FREDD and then follows the route to the FAF at INNIS to begin its approach into XEDW-01H. At 01H there is a simulated obstacle blocking the LZ causing the aircraft begin a balked landing with a missed approach and back to land at the alternate LZ, provided by simulated Air Traffic Control (ATC), at XVPT-05H. The surrogate aircraft was able to maintain a close track up until the balked landing portion of the scenario, but it struggled to make close fly-bys of all the planned missed approach waypoints. Still, the aircraft was able to establish itself at the FAF, BILLD, for a successful 9-degree approach and landing at 05H and completing the UAS work area version of this scenario. However, the brevity of this route made it difficult for the aircrew to get themselves fully established into the scenario before it began, much the same challenge as with the initial version of route Discovery mentioned above. Because of these challenges, all the UAS work area routes were adjusted to use up the entire UAS work area. But since the scenarios were getting completed mostly with XX33 routes, these new larger UAS work area routes were left for future flight test events to be flown.

Scenario 3C: Emergency Divert; Routes ULYSSES and MAGELLAN

Scenario 3C consisted of two routes: one near the vertiport and one between the vertiport and XX33. The purpose of Scenario 3C was to show the ability of the piloted, non-assisted, surrogate aircraft to perform an emergency divert maneuver to the vertiport runway and to establish track tolerances along the missed approach path to the emergency divert runway.

ULYSSES 1

The simulated flight plan for ULYSSES 1 is as follows:
XX33 (06H)-–DRURY—LGTHA—RGNAR—BJORN--POTTR—FURRY—SIDBR—OLIVZ—CAPPS—FIAPA--MILTT—[MAP@XVPT]—TERPS—GOCKL—ERINW—MARTA—XVPT (RWY19)

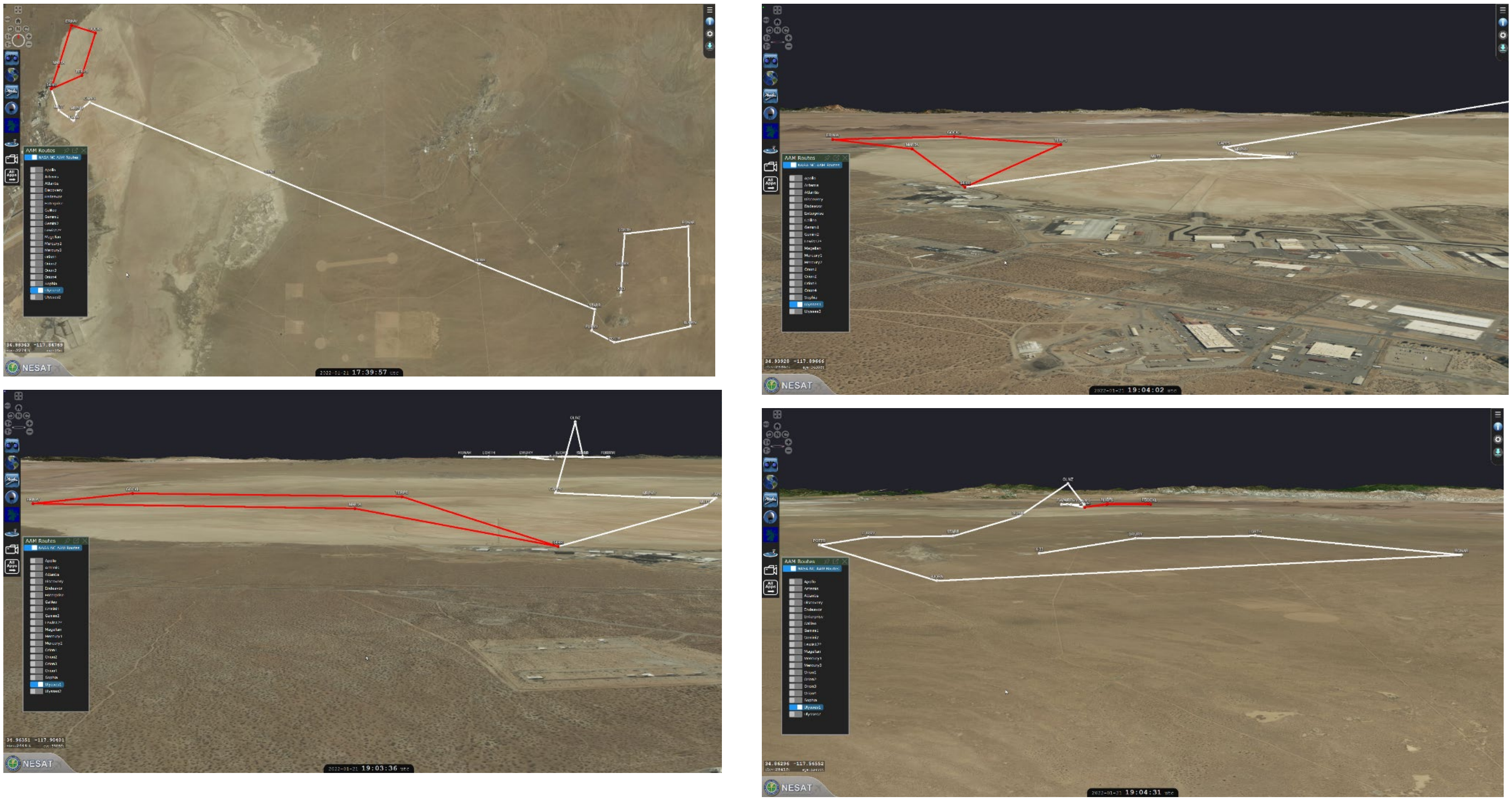


Figure 4.59. ULYSSES 1 in SBSM.

ULYSSES 1 Outcome

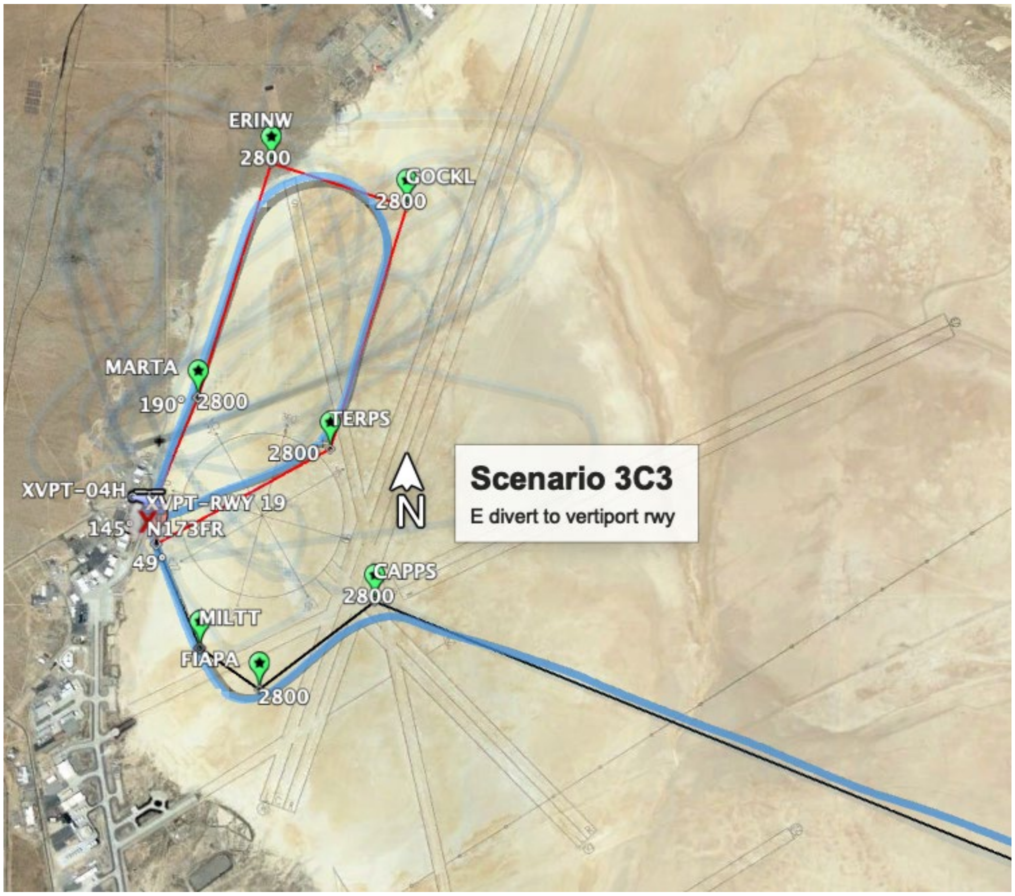


Figure 4.60. ULYSSES 1 as Flown ADS-B track in Google Earth.

For Scenario 3C, an Emergency divert to the vertiport runway Route ULYSSES required the aircraft to depart XX33 to the north, follow the DRURY departure around the mountain to the South and track inbound on the south arrival beginning at CAPPS. The tight turns at CAPPS to FIAPA were necessitated by the route restrictions in this area making it the first possible point to turn south. This prevented a milder turn just past the tower fly-by line. Despite the challenge, the aircraft was able to negotiate the turns to set up for a 9-degree approach beginning at the PFAF, MILTT. The aircraft was able to execute the approach and maintain a tight track with the planned missed approach route back to land at the vertiport runway 19 to successfully complete Scenario 3C.

Scenario 4: Acoustics Test
National Campaign ran an acoustics test with an industry partner to evaluate the acoustic array and testing infrastructure for a UAM prototype vehicle as part of the NC Developmental Testing series.

4.3 Airspace Operations Surveillance

Airspace datum plays an important role in precision procedures and operations for UAM. NC partnered with various FAA specialists to evaluate the flight events with current state data systems.

Surveillance Broadcast Services Monitor:

The following topics are discussed in the this section: *FAA Surveillance Broadcast Services Monitor, FAA NAS Engineering|ASR-8, ASR-11,* BI-5, BI-6, CTD*, PRM, SBSM,* WAM Engineering and *Mike Monroney Aeronautical Center, OKC.*

National Campaign partnered with FAA Surveillance Broadcast Services AJW-145 team from the Mike Monroney Aeronautical Center (Oklahoma City, Oklahoma) to utilize the SBSM via NAS Engineering. The tool, NAS-Impact Enhanced Strategic Awareness Toolbox (NESAT), is a 3D Web browser based surveillance analysis tool that visualizes national live and historic ADS-B based surveillance data. The NESAT visualizes U.S. airspace 3D flight data on a virtual globe similar to Google Earth, and was developed by the FAA from a virtual globe software development kit (SDK) known as NASA WorldWind.

The NESAT provides output similar to a 3D flight simulator where each aircraft can be clicked to display information about that flight and aircraft, and the data are updated live once per second. NASA National Campaign Evtol flight tests conducted at Edwards Air Force Base were monitored through SBSM. Several fight playbook scenarios were ahead for the Evotl surrogate aircraft, which were provided for programming into NESAT. This allowed the playbook routes to be visualized live in 3D, along with a 3D version of the Evotl surrogate aircraft, so that each Evtol aircraft equipped with an onboard ADS-B transponder flying the test flights could be compared live (or historically) to the exact 3D predetermined routes to monitor conformance to the course.

Figure 4.61. NESAT ADS-B Flight Tracking in 3D.

Post-analysis within NESAT enables deviation measurements in four dimensions (x, y, z, and time), altitude drops, wind effects, climb rates, et cetera along with a variety of other flight ADS-B data fields such as flight integrity and accuracy fields such as Navigational Integrity Category (NIC); Navigational Accuracy Category (NAC); Surveillance Integrity Level (SIL); System Design Assurance value (SDA); and a multitude of other flight parameters. The SBSM receives one-second updates from each aircraft, and each one second update contains a spectrum of data field parameters such as altitude, latitude, longitude, speed, heading, and time among others.

The NESAT code is written primarily in JavaScript with WebGL to render the full 3D environment. In addition to flight data, NESAT provides Airway Obstructions, 3D airspaces such as the Class D airspace at Edwards and its surrounding Military Operation Areas (MOAs), and any current Temporary Flight Restriction (TFR) areas. Live weather, radar and ADS-B ground station coverage patterns, and many other features can also be toggled on as needed or desired during the live flights or for post-flight analysis. The GPS satellite constellation is also tracked and monitored in NESAT for reliability of the ADS-B positions at any given point on the globe.

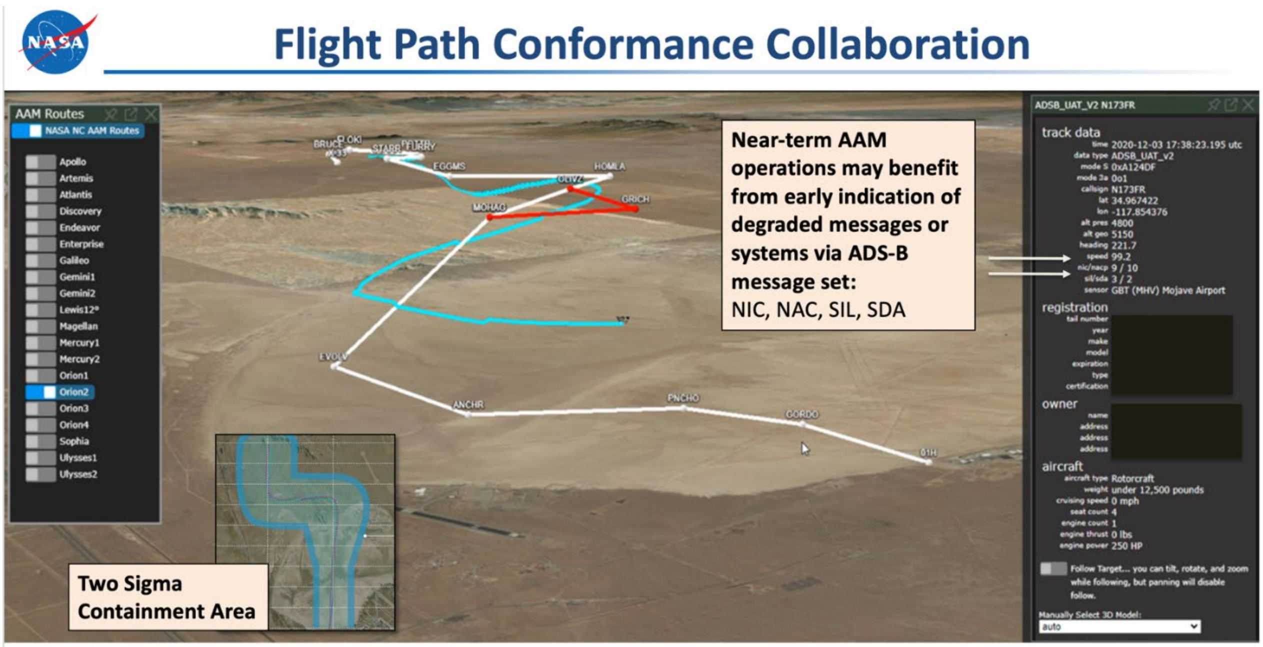


Figure 4.62. NESAT ADS-B Flight Track Conformance against Flight Plan Route.

4.4 Reduced Separation Theory

For enroute corridor construction, obstacle evaluation and authorization through ROC altitude are required to be established. Current criteria mandate that all passenger-carrying aircraft in the IFR structure must have a minimum of 1000 feet of obstacle clearance in non-mountainous terrain and 2000 feet of clearance in mountainous terrain. Given the history of reduced lateral separation requirements provided by signal validation, refresh rates, and redundancies, it can be assumed that vertical separation may also be adjusted with the same levels of assurance. Air Route Surveillance Radar (ARSR) or Long Range radar provided a 10- to 15-second refresh rate and a conservative 5 miles of separation which is mitigated down to 3 miles of separation with Airport Surveillance Radar (ASR) using a 6-second refresh rate and further mitigated down to 1.5 mile separation utilizing ADS-B Out (GPS) with a 1-second refresh rate. This same logic can be applied to adjusting the vertical ROC, or separation from the ground.

02/16/2018 | Order 8260.3D
Chapter 2

Chapter 2. General Criteria

Section 2-1. Common Information

2-1-2. Required Obstacle Clearance (ROC). This order specifies the minimum measure of obstacle clearance considered by the FAA to supply a satisfactory level of vertical protection. The validity of the protection is dependent, in part, on assumed aircraft performance. In the case of TERPS, it is assumed that aircraft will perform within certification requirements.

a. These criteria are predicated on normal aircraft operations for considering obstacle clearance requirements. Normal aircraft operation means all aircraft systems are functioning normally, all required navigation systems are performing within flight inspection parameters, and the pilot is conducting instrument operations utilizing IFPs based on the TERPS standard to provide ROC.

b. While the application of TERPS criteria indirectly addresses issues of flyability and efficient use of navigation systems, the major safety contribution is the provision of obstacle clearance standards. This facet of TERPS allows aeronautical navigation in instrument meteorological conditions (IMC) without fear of collision with unseen obstacles. ROC is provided through application of level and sloping obstacle clearance surface (OCS).

Figure 4.63. Order 8260.3d Chapter 2 ROC.

From the definition within 8260.3D - that is subsequently based on repeatable vehicle performance - data will need to be collected for calculation of the horizontal and vertical axis of the containment areas. Graphical representation of tracks will include the vertical and horizontal tolerances of autonomous instrumentation flying the aircraft. An initial 1000 feet. The ROC can be established as a conservative “yardstick” of measurement that can be reduced based on navigation, signal, and vehicle performance to 500 feet and 250 feet, as applicable.

Reduced separation criteria are predicated upon the assumption that AAM vehicle navigation tolerances will be maintained within the desired and required standards. Operating under the constraints of ADS-B parameters and ARINC interface specifications, ROC during enroute operations can be evaluated to determine realistic safety assurance. Primary flight path traps can be constructed around the “desired” performance and secondary areas can be built on “required” standards in the MTEs to establish a safety baseline.

Figure 4.64 is a snapshot of an ADS-B Out system accuracy, integrity, and sourcing from the SBSM program. All vehicle avionic and navigation packages should have Complaint Architecture (TSO-C166b) that meets or exceeds the Integrity Metric Latency Analysis to ensure position source, fault, and transmission delays. If the SDA (which measures the likelihood of bad data being sent), and SIL (which measures the probability of not being within the containment radius) can be monitored by the vehicle and the ground station, then a trend analysis can be performed to alert a third party of any unintended altitude or azimuth deviations, resulting in reduced minimums given a repeatable flight path or track.

Figure 8. Source Integrity Level Supplement Table

SIL Supplement	Basis for SIL Probability
1	Probability of exceeding NIC containment radius is based on per sample
0	Probability of exceeding NIC containment radius is based on per hour

Figure 9. System Design Assurance Table

SDA Value	Supported Failure Condition [Note 2]	Probability of Failure causing transmission of False or Misleading Information [Note 3,4]	Software & Hardware Design Assurance Level [Note 1,3]
3	Hazardous	$\leq 1x10^{-7}$ Per Hour	B
2	Major	$\leq 1x10^{-5}$ Per Hour	C
1	Minor	$\leq 1x10^{-3}$ Per Hour	D
0	Unknown/ No safety effect	$> 1x10^{-3}$ Per Hour or Unknown	N/A

Figure 4.64. ADS-B Out, SIL and SDA with SBSM Example Flight Output.

Navigation Integrity Category

The Navigation Integrity Category (NIC) specifies a position integrity containment radius. The NIC is reported so that surveillance applications, such as ATC or in this case other UAM aircraft, may determine whether the reported geometric position has an acceptable level of integrity for the intended use of airspace. The NIC parameter is closely associated with the SIL. While the NIC specifies the integrity containment radius, the SIL specifies the probability of the actual position lying outside that containment radius without indication. A minimum NIC value of seven must be transmitted to operate in airspace defined in 14 CFR § 91.225. A similar rule can be established for UAM airspace.

Table 4.65. ADS-B Out with NACp Estimated Position Uncertainty (EPU).

Table A-13: Encoding of Navigation Accuracy Category for Position (NAC_P)

Coding (Binary)	Coding (Decimal)	Meaning = 95% Horizontal Accuracy Bounds (EPU)
0000	0	EPU ≥ 18.52 km (10 NM) - Unknown accuracy
0001	1	EPU < 18.52 km (10 NM) - RNP-10 accuracy
0010	2	EPU < 7.408 km (4 NM) - RNP-4 accuracy
0011	3	EPU < 3.704 km (2 NM) - RNP-2 accuracy
0100	4	EPU < 1852 m (1NM) - RNP-1 accuracy
0101	5	EPU < 926 m (0.5 NM) - RNP-0.5 accuracy
0110	6	EPU < 555.6 m (0.3 NM) - RNP-0.3 accuracy
0111	7	EPU < 185.2 m (0.1 NM) - RNP-0.1 accuracy
1000	8	EPU < 92.6 m (0.05 NM) - e.g., GPS (with SA)
1001	9	EPU < 30 m - e.g., GPS (SA off)
1010	10	EPU < 10 m - e.g., WAAS
1011	11	EPU < 3 m - e.g., LAAS
1100 - 1111	12 - 15	Reserved

Navigation Accuracy Category for Position

The Navigation Accuracy Category for Position (NACp) specifies the accuracy of the horizontal position information (latitude and longitude) of the aircraft as transmitted from the aircraft avionics. The ADS-B equipment derives an NACP value from the accuracy of the position source output. The NACP specifies with 95-percent probability that the reported information is correct within an associated allowance. A minimum NACP value of eight must be transmitted to operate in airspace defined in 14 CFR § 91.225. Likewise, a similar rule can be implemented for UAM operations.

4.5 Flight Inspection Airborne Processing Application

Flight Inspection Airborne Processor Application (FIAPA)

National Campaign Exploratory Candidate Flight Inspection Software
FAA Flight Program Operations | Aviation Technology Group
Mike Monroney Aeronautical Center (Oklahoma City, Oklahoma)

Overview

The FIAPA is the primary tool for Coding Preflight Validation (CPV) and flight inspection for all types of RNAV(GPS) and RNAV(RNP) instrument approaches. The FAA Flight Program Operations team collaborated with National Campaign team to develop a branch of the FIAPA software, which accomplishes the normal inspection function and measures deviation from coded path. This branch was specifically designed for AAM vehicles or surrogate vehicles during NC flight events. The FIAPA software processes data utilizing a high-grade GNSS receiver with an antenna affixed to the AAM vehicle. Following each flight test, FIAPA data were uploaded to software residing on FAA Flight Program computers and securely transferred from the FAA to the NC repositories. Output from the FIAPA includes an array of files:

Table 4.66. FIAPA Files for Candidate Software Development.

FIAPA Files for National Campaign		Folder	File
FIAPA GPS Daily Log	Raw GNSS data without aircraft datum correction	Monitor	.csv
FIAPA GPS Event Log	Record of GPS anomalies	Monitor	.csv
FIAPA KML File	Raw GNSS position for visualization in Google Earth	Inspection	.kml
FIAPA Deviation File	Record of lateral and vertical deviations	Inspection	.csv
FIAPA Aircraft Vertical Angle	Record of angle and distance to landing threshold point	Inspection	.csv
FIAPA GPS Height MSL	Record of GPS Height (MSL)	Inspection	.csv
FIAPA GPS Latitude	Record of Latitude (WGS-84)	Inspection	.csv
FIAPA GPS Longitude	Record of Longitude (WGS-84)	Inspection	.csv
Additional Files	Files to rerun a flight in FIAPA simulation AFIS | FirpsSummary JSON | LOGX	Inspection	varies
Text Documents	Files for FIAPA software engineer debugging cni |engineering | fiapa | sdc	Application	.txt

FIAPA Configurations

The FIAPA software is currently integrated into FAA fixed-wing aircraft assigned to the Flight Inspection mission. The branch of the FIAPA software used for this test was based on development of a portable Flight Inspection Software (FIS) configuration intended for flight inspection of helicopter procedures.

Fixed-Wing Aircraft

- Ingests FAA AIRNAV data
- Ingests ARINC 424 for RNAV procedures
- Performs data quality checks
- Collects detailed data over runway threshold and runway end (e.g., Camera Image, Rad Alt, Inertial Reference Unit (IRU), air data, GNSS)
- Estimates the North, East, Up errors of the spatial data used for the procedure
- Logs all data for replay and/or analysis

Helicopter

- Ingests FAA AIRNAV data
- Ingests ARINC 424 for helicopter RNAV procedures
- Performs data quality checks
- Provides lateral and vertical deviation in a typical PFD format
- Estimates the North, East, Up errors of the helipad spatial data used for the procedure
- Logs all data for replay and/or analysis

FIAPA GUI for RNAV Procedures

The FIAPA software GUI for RNAV procedures displays current vertical and lateral deviation from the intended path by comparing current GNSS/ Satellite Based Augmentation System (SBAS) position to the selected procedure (ARINC 424 coding). The branch of the FIAPA software developed for NC Build 2 flight test activities is capable of logging these deviations for post-flight analysis.

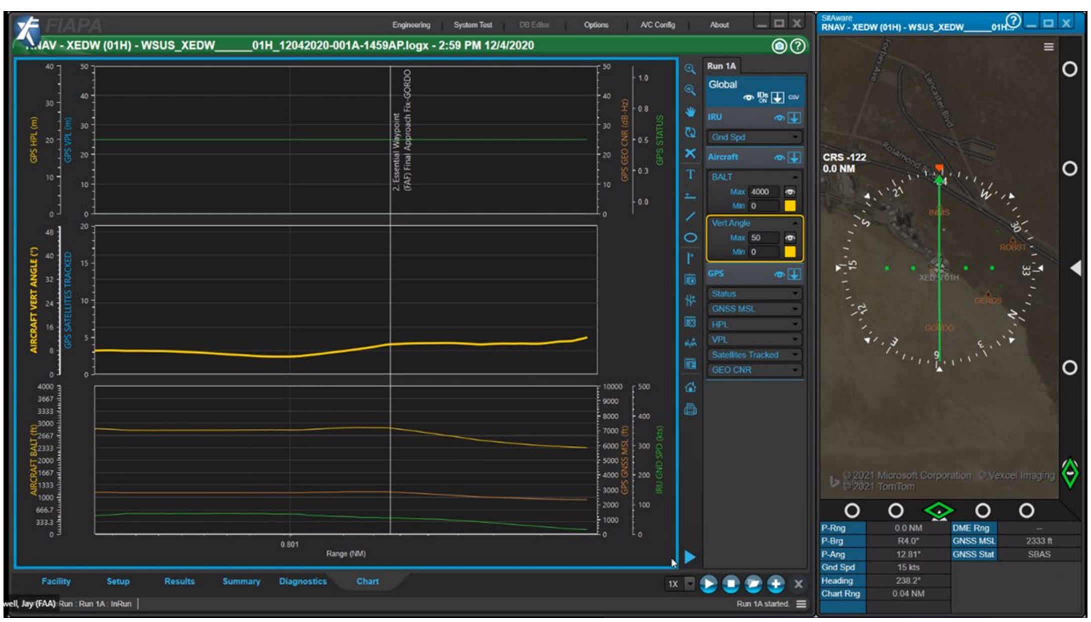


Figure 4.67. FIAPA Software Interface for Helicopter RNAV Procedures.

FIAPA AAM Adaptation New Data Files

The partnership with NC enabled development of the FIAPA portable configuration toward future AAM procedure inspections. The FIAPA candidate system iterated with Developmental Test flight events. The FIAPA software was first synchronized in Build 1 flight events and second during Build 2 flight events. New additional output was requested and developed for Build 2. The additional files enable comparison between the various data sources applied for flight events and greater insight into flight test campaigns:

- Distance from Landing Touch Point
- FIAPA Internal Timing Metric
- Glide Path Angle
- Precision Latitude and Longitude

Build 2 Development for GPS Daily Log Files

A GPS error was indicated in the GPS Daily Log anytime a GPS/WAAS position was not being provided by the GNSS receiver. The GPS/WAAS receivers take several minutes to receive the full WAAS message set to begin providing a GPS/WAAS position; therefore, the GPS Daily Logs showed errors for the first several minutes of each file. An update to the FIAPA software was made to withhold these errors until seven minutes after power-on.

Build 2 Survey Validation Method

The FIAPA portable configuration uses a YUMA-7 tablet with an EM-100 GNSS receiver for sub-meter accuracy. Since the GNSS receiver reports position of the antenna, it is necessary to correct the reported position based on offset from the vehicle's reference point. The reference point for the vehicle is an arbitrary point at skid level, which the pilot can attempt to place on the vertipad center point. The antenna offset for this test was 4'4" vertical, forward 2'8" and right 2'8" from the reference point. Following each landing, the crew inputs the current heading and estimated position error of the reference point relative to the vertipad center (e.g., heading 250°, back 2', right 1'). FIAPA then provides the estimated East, North, and Up error of the coded vertipad location.

Build 2 Position Reference in Motion Consideration

Since the GNSS sensor is unable to provide current aircraft heading, FIAPA only provides correction to the aircraft reference point for the static survey validation. It is important to consider that GPS Log Files, KML files, lateral deviation, and vertical deviations are all referenced to the GNSS location. It is recommended to mount the portable GNSS antenna as close as possible to the aircraft centerline.

Build 2 GNSS Receiver Compatibility

FIAPA is an object oriented software application that can be adapted to any receiver type. The portable FIAPA configuration was initially configured and test using the Trimble R-1 receiver. The receiver used for Build 2 was the Trimble EM-100 which had not been fully tested for compatibility. The EM-100 receiver has the advantage of using Trimble RTX, which provides sub-meter accuracy. During Build 2 flight test, a discrepancy was discovered where the position would randomly drop out. Although it was thought that the dropouts were caused by the RTX service, it was discovered to be compatible with the EM-100 receiver. This issue was corrected and tested after Build 2.

Data Integrity and Datums

Spatial data requirements for AAM application will require high integrity and accuracy to support automation in the AAM ecosystem. One example of aeronautical data inaccuracy exists due to difference between the NAD83 and WGS84 datums. Figure 4.62 demonstrates the horizontal (red) and vertical (green) difference in feet between the two datums. Nearly all RNAV approaches in the US are affected because aircraft GNSS receivers reference the WGS84 vertical datum while FAA aeronautical data reference a vertical datum based on NAD83. This results in a Path Definition Error (PDE) up to 5.5 ft. in Southeast Florida. Use of consistent geospatial datums will be a critical point of safety for zero-zero-zero operations. Build 2 survey data utilized the WGS84 horizontal reference datum and Height-above-Ellipsoid (HaE). This should be a continued for NC activities with respect to procedure design, aircraft avionics, and airspace services.

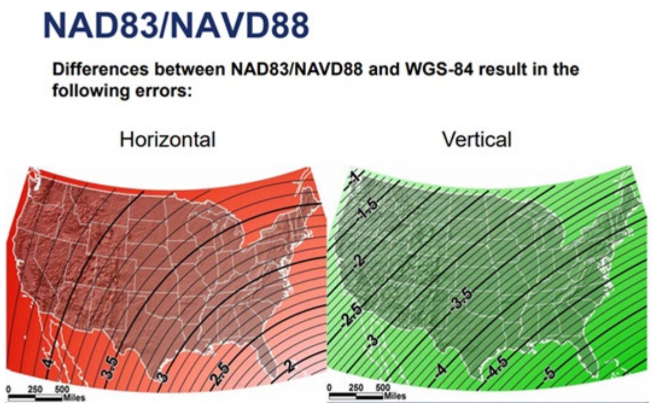


Figure 4.68. Datum Impact on Path Definition Error

GNSS Interference Considerations

Build 2 testing occurred in an environment free from obstructions and reflections that may exist in an urban environment. FIAPA has a limited capability to log data which could discern these affects, but other systems will be required to troubleshoot multipath rich environments and locating GNSS interference sources.

Build 2 Geospatial Data Quality Control

Maintaining quality control of geospatial data in the Build 2 airspace was a challenge. The confined airspace and operational restrictions at Edwards AFB required dynamic changes in airspace design. While the location of the vertipads never changed, the survey data used changed from December 2020 to March 2021. Whereas an intended function of FIAPA is to validate survey data used in aeronautical data, the survey validation results clearly showed the variations in the geospatial data used for procedure revisions. Measurement uncertainty of East and North errors in the FIAPA survey validation is affected by GNSS sensor uncertainty and uncertainty in estimation of the distance between aircraft reference point and vertipad reference point (center). Measurement uncertainty of the Up Error is affected by GNSS sensor uncertainty only. Representative results using March 2021 data are shown in Table 4.69.

Table 4.6.9 FIAPA Survey Validation Results

LOCATION			SURVEY			ERRORS		
AIRPORT	HELIPAD	APPROACH	MEASURED LATITUDE	MEASURED LONGITUDE	MEASURED ELLIPSOID HEIGHT (FT)	NORTH ERROR	EAST ERROR	UP ERROR
XX33	06H	BRUCE2	N34 52 33.13	W117 37 04.21	2877.8	4.3	10.5	-2.7
XVPT	04H	MARTA1	N34 57 13.20	W117 52 58.08	2172.8	-0.2	-0.4	-1.4
XEDW	01H	GORDO1	N34 57 32.72	W117 52 54.28	2174.7	1.3	2.3	-4.2

XEDW	01H	GORDO2	N34 57 32.69	W117 52 54.31	2174.0	4.4	4.8	-3.4
XEDW	01H	GORDO3	N34 57 32.68	W117 52 54.33	2173.4	5.1	6.5	-2.8
XEDW	01H	GORDO4	N34 57 32.70	W117 52 54.27	2170.3	4.0	1.5	0.3
XEDW	01H	GORDO5	N34 57 32.70	W117 52 54.25	2172.5	3.1	-0.2	-1.9
XEDW	01H	INNIS6	N34 57 32.70	W117 52 54.22	2167.8	3.3	-3	2.7
XEDW	01H	INNIS7	N34 57 32.72	W117 52 54.23	2168.7	1.2	-1.7	1.9

Multiple Approaches to Same Pad

ARINC 424 can be applied to multiple approaches with different inbound courses to the same runway/helipad, but careful management of the data is required. Multiple approaches to the same surface introduce potential confusion when attempting to ingest, use, or validate the ARINC 424 code, which defines those approaches. There were times when an approach was loaded in FIAPA which were to the correct pad but were coded with a different inbound course. These led to erroneous lateral deviation, vertical deviation, and distance to touchdown. It is recommended to carefully manage the flight validation plan so that the loaded procedure matches what the aircraft is attempting to fly.

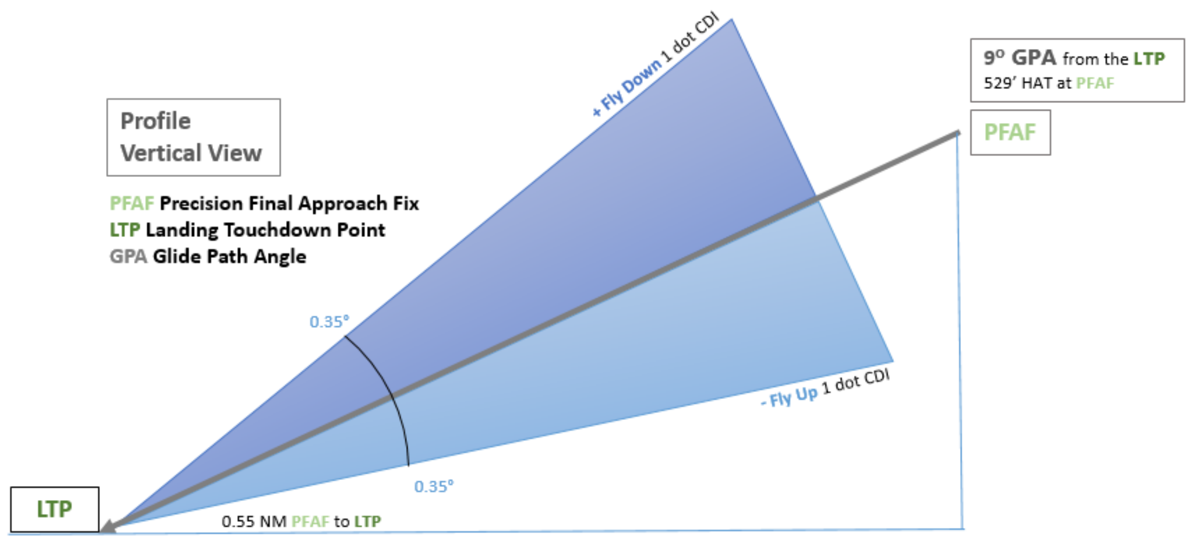


Figure 4.70. Vertical Profile and Path Definition for LPV

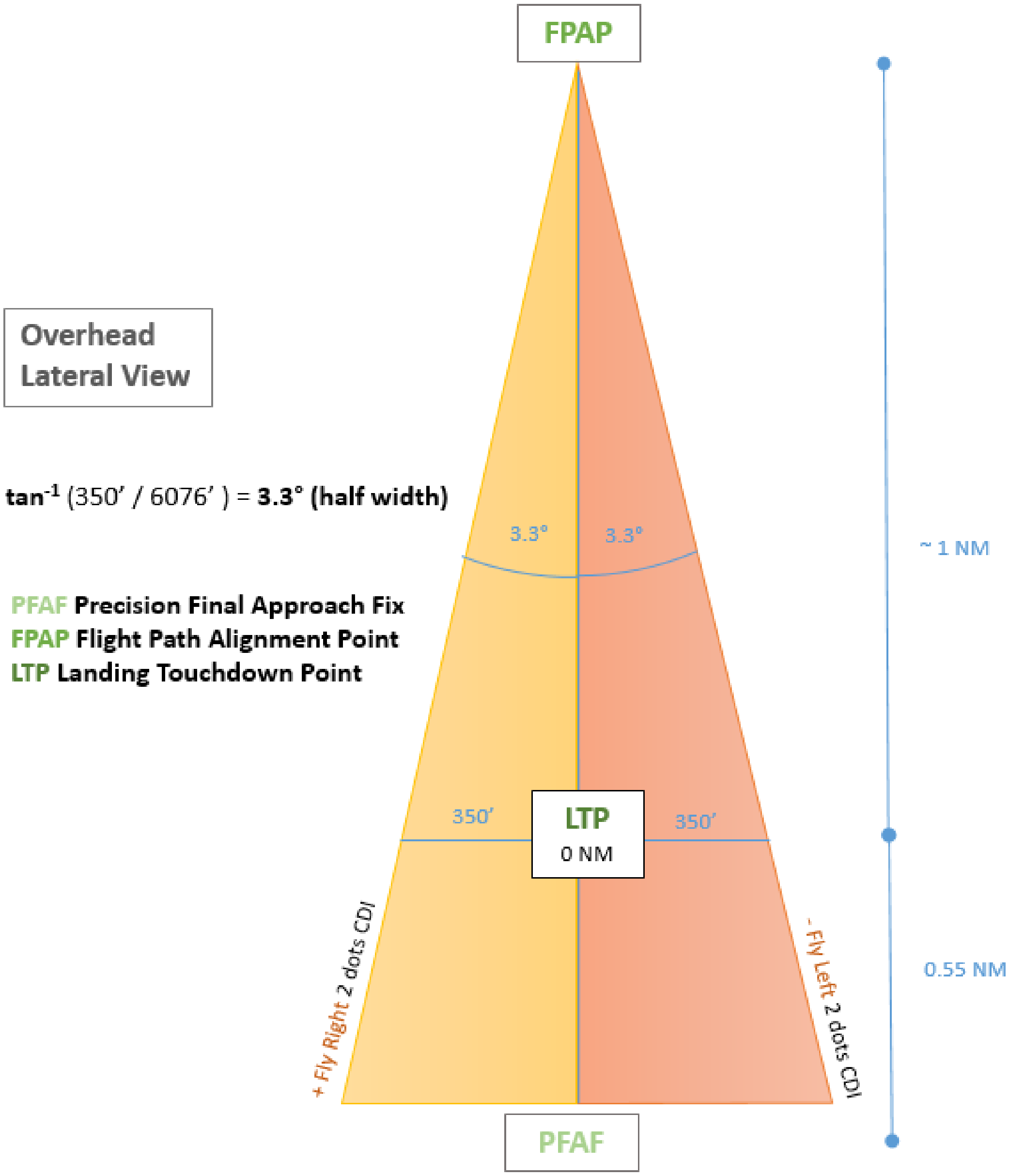


Figure 4.71. Lateral Profile and Path Definition for LPV

Flight Technical Error Without Automation

FIAPA computes the current difference between aircraft position and coded path (FTE) so that it can display deviations for the pilot. Due to test plan design, short legs, and lack of automation in the OH-58, it was not possible for the pilots to follow the designed paths within a reasonable tolerance. It is recommended that future flight testing be accomplished with full automation and sufficient intermediate legs for alignment.

Lateral Deviations

Lateral deviation (FTE) from PFAF to LTP were analyzed and charted using several different methods to experiment with data analysis techniques.

Method 1: Mean and Standard Deviation per Approach

Mean and standard deviation of lateral FTE was computed per approach. Table 4.71 below shows mean and standard deviation for representative approach runs. Negative lateral deviations are right of coded path; positive deviations are left of coded path. Mean value for all runs was -0.02 degrees from coded path with a standard deviation of 0.26 degrees.

Table 4.72. Lateral Deviation Means and Standard Deviations by Approach.

LOCATION			LATERAL DEVIATIONS (degrees)	
AIRPORT	HELIPAD	APPROACH	MEAN	STANDARD DEVIATION
XVPT	04H	MARTA1	-0.534713	0.072107
XEDW	01H	GORDO1	-0.036125	0.065698
XEDW	01H	GORDO2	0.017595	0.081818
XEDW	01H	GORDO3	0.210436	0.052452
XEDW	01H	GORDO4	0.171673	0.049536
XEDW	01H	GORDO5	0.089472	0.059800

Method 2: Graphical Results

The statistical data provided by the FTE were plotted conventionally in various formats. One unique method for visualizing these data was the violin plot, as shown in Figure 4.73.

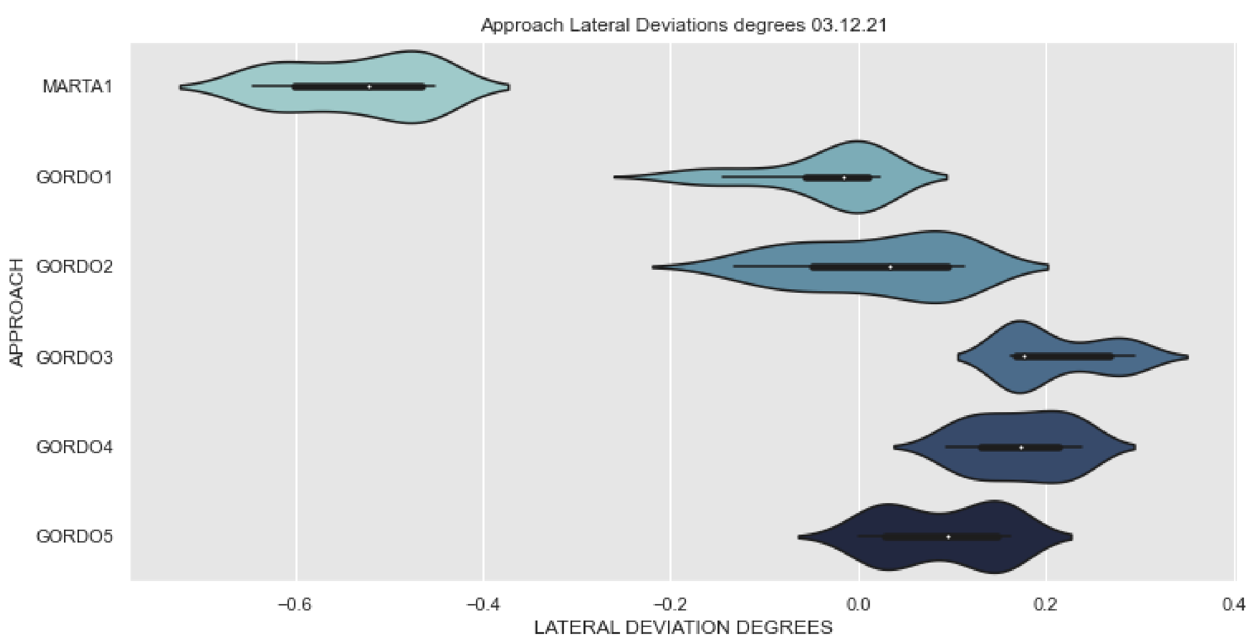


Figure 4.73. Lateral Deviation Violin Plot (December 03,2021).

Vertical Deviations

Lateral deviation (FTE) from PFAF to LTP were analyzed and charted using several different methods to experiment with data analysis techniques.

Method 1: Mean and Standard Deviation per Approach

Mean and standard deviation of Vertical Fligh Technical Error (FTE) was computed per approach. Table 4.74 shows mean and standard deviation for representative approach runs. Negative lateral deviations are to the right of the coded path; positive deviations are to the left of the coded path. The mean value for all runs was 0.27 degrees from the coded path with a standard deviation of 1.43 degrees.

Table 4.74. Vertical Deviation Means and Standard Deviations by Approach.

LOCATION			VERTICAL DEVIATIONS (degrees)	
AIRPORT	HELIPAD	APPROACH	MEAN	STANDARD DEVIATION
XVPT	04H	MARTA1	-0.853045	0.327639
XEDW	01H	GORDO1	-0.209500	0.197452
XEDW	01H	GORDO2	1.060277	0.975741
XEDW	01H	GORDO3	1.630205	0.932069
XEDW	01H	GORDO4	-1.822333	0.235498
XEDW	01H	GORDO5	1.349052	1.080589

Method 2: Graphical Results

The statistical data provided by the FTE were plotted conventionally in various formats. One unique method for visualizing these data was the violin plot, as shown in Figure 4.75.

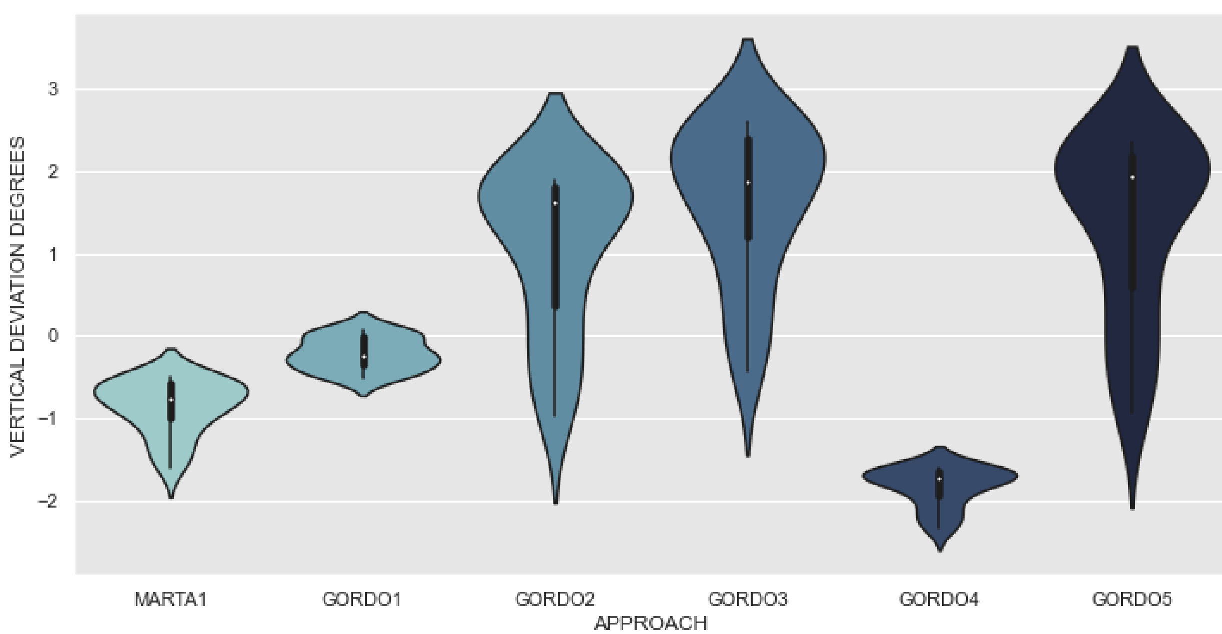


Figure 4.75. Vertical Deviation Violin Plot (December 03, 2021).

Method 3: Flight Technical Error versus Coded GPA

Approaches were coded and flown at steep angles up to 11 degrees. Table 4.76 shows the mean GPA for approaches from 8 degrees to 11 degrees. Path angle tracking is consistent with short alignment legs, prohibition against using flight path guidance, and lack of automation in the OH-58C helicopter.

Table 4.76. Coded and Mean GPA by Approach.

LOCATION			GLIDEPATH ANGLES (degrees)	
AIRPORT	HELIPAD	APPROACH	CODED GLIDE PATH ANGLE	MEAN GPA
XVPT	04H	MARTA1	9	07.96
XEDW	01H	GORDO1	9	08.74
XEDW	01H	GORDO2	10	10.01
XEDW	01H	GORDO3	11	10.58
XEDW	01H	GORDO4	8	07.13
XEDW	01H	GORDO5	11	10.30

4.6 Related Work: Flight Level Engineering

The Flight Level Engineering team evaluated the in-flight performance of the predicted urban air mobility instrument approach paths for the NC team. Two pilot training levels were compared. Two locations were selected for tests: Spanish Fork, Utah (KSPK) and West Desert Airpark, Fairfield, Utah (KUT9).

SVO1: The flight activity tested the ability of a fixed-wing-trained pilot to fly a simplified vehicle operation (SVO) with vertical capability and a decelerating descending approach to a vertical landing.

SVO2: The flight activity tested a non-pilot's ability to fly SVO with vertical capability and a decelerating descending approach to a vertical landing.

The NC team collaborated with AJV-A for encoded novel approach and encoded return to approach procedures. The FAA ARI File at KUT9 was flown on November 22, 2021; the full approach at KPSK and KUT9 were all flown successfully by the test pilot. The candidate FLE and FAA files were both flown and produced statistically similar results. The accuracy of the data was a validation that a vehicle with a customizable flight management system (FMS) can be flown with standardized ARINC 424 procedures coding as well as a customizable flight path management coding.

As part of follow-on work in procedure coding and flight evaluation, the NC team contracted a Flight Performance Evaluation of Predicted Urban Air Mobility Instrument Approach Paths utilizing a Flight Level Engineering Navion (Ryan Aeronautical Company, San Diego, CA) , a fixed-wing aircraft outfitted with a custom programmable FMS, autopilot, and SVO1 controls. Testing began on the fixed-wing pilot's ability to fly SVO1 to an approach with decelerating descending approach to a vertical landing that was waved-off due to the status of the fixed-wing aircraft. Two locations were selected for tests: Spanish Fork, Utah (KSPK); and West Desert Airpark (KUT9) as pictured in the figures below.

Figure 4.77. Flight Level Engineering Airspace Test, Spanish Fork, Utah

Figure 4.78. Flight Level Engineering Airspace Test, West Desert Airpark, Fairfield, Utah.

As part of the NASA/FAA collaboration, the NC team solicited help from the FAA AJV-A branch, which manages the quality control of standardized ARINC 424 coding of procedures. Two individuals were dispatched from AJV-A to help develop and define the novel approach and return-to-approach procedures executed during the two flight tests. The FAA/NASA/FLE team developed was a figure-8 type of traffic pattern designed to maximize the turn to final and approach segments requiring a descending and decelerating turn. As shown in Figure 4.79, the unique traffic pattern was deconflicted against local airfield manager and local traffic.

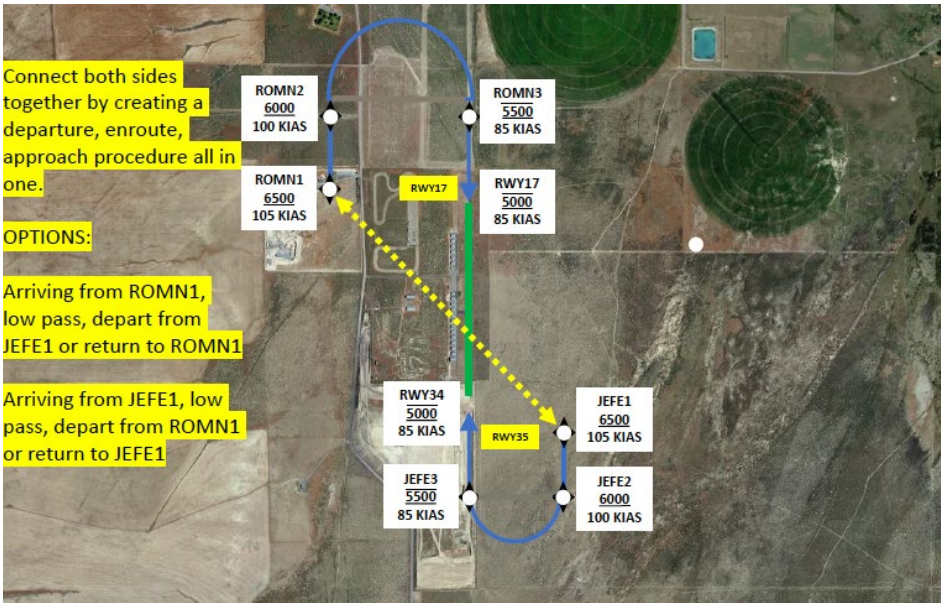


Figure 4.79. The Figure-8 Pattern.

The FLE test was comprised of two unique coded flight procedures: one from FLE and the other from the FAA. The FLE flew the full FAA ARI file or approach at KSPK and KUT9 successfully on November 22, 2021, with the resulting data and tolerances tweaked from 120-feet boundaries to 60-feet boundaries.

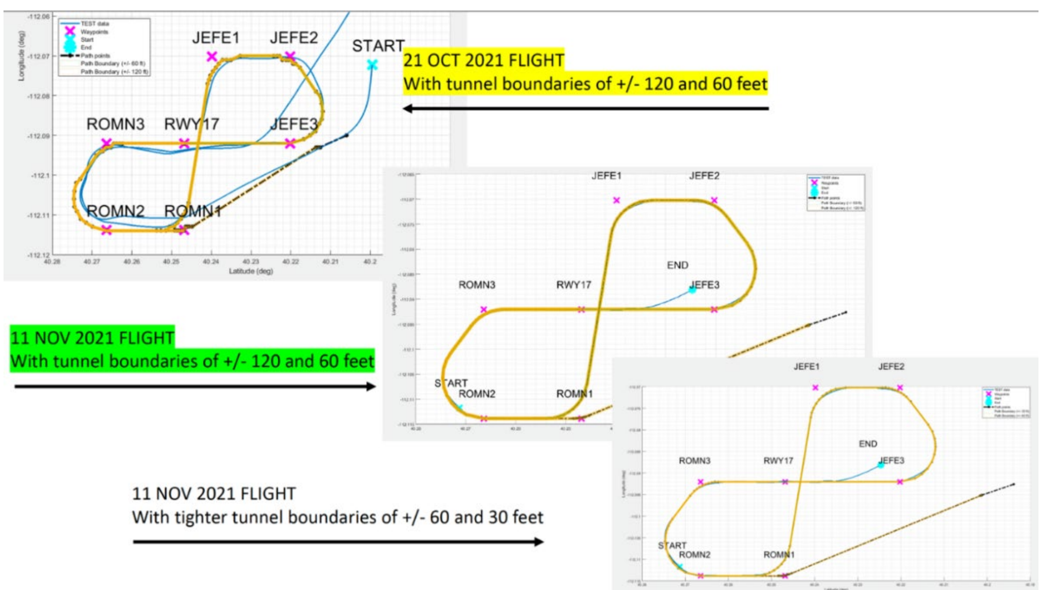


Figure 4.80 Flight Track Results on the Figure-8 Pattern.

The tolerances were reduced as the aircraft remained within the allotted sigma containment area. The boundary tolerances were reduced from the 120-feet secondary area and 60-feet primary area to a 60-feet secondary area and a 30-feet primary area. It was noted that the tolerances were so tight that a traditional pilot with exceptional skill would have a difficult time maintaining the allotted containment area; thus the recommendation derived from the test was to provide and extend the autopilot for any such authorization in low altitude and closely-spaced UAM operations.

Urban Canyon Simulation

The landscape in the Spanish Fork, Utah area provided excellent mimic of an urban environment given the physical terrain towering above the intended flight paths. The precipitous terrain, rapidly rising on each side of the approach courses, was much like what would be experienced while flying through an Urban Canyon corridor (see Figure 4.81). The UAM operations being modeled will potentially be flown utilizing some of the same software that was on board the test aircraft.

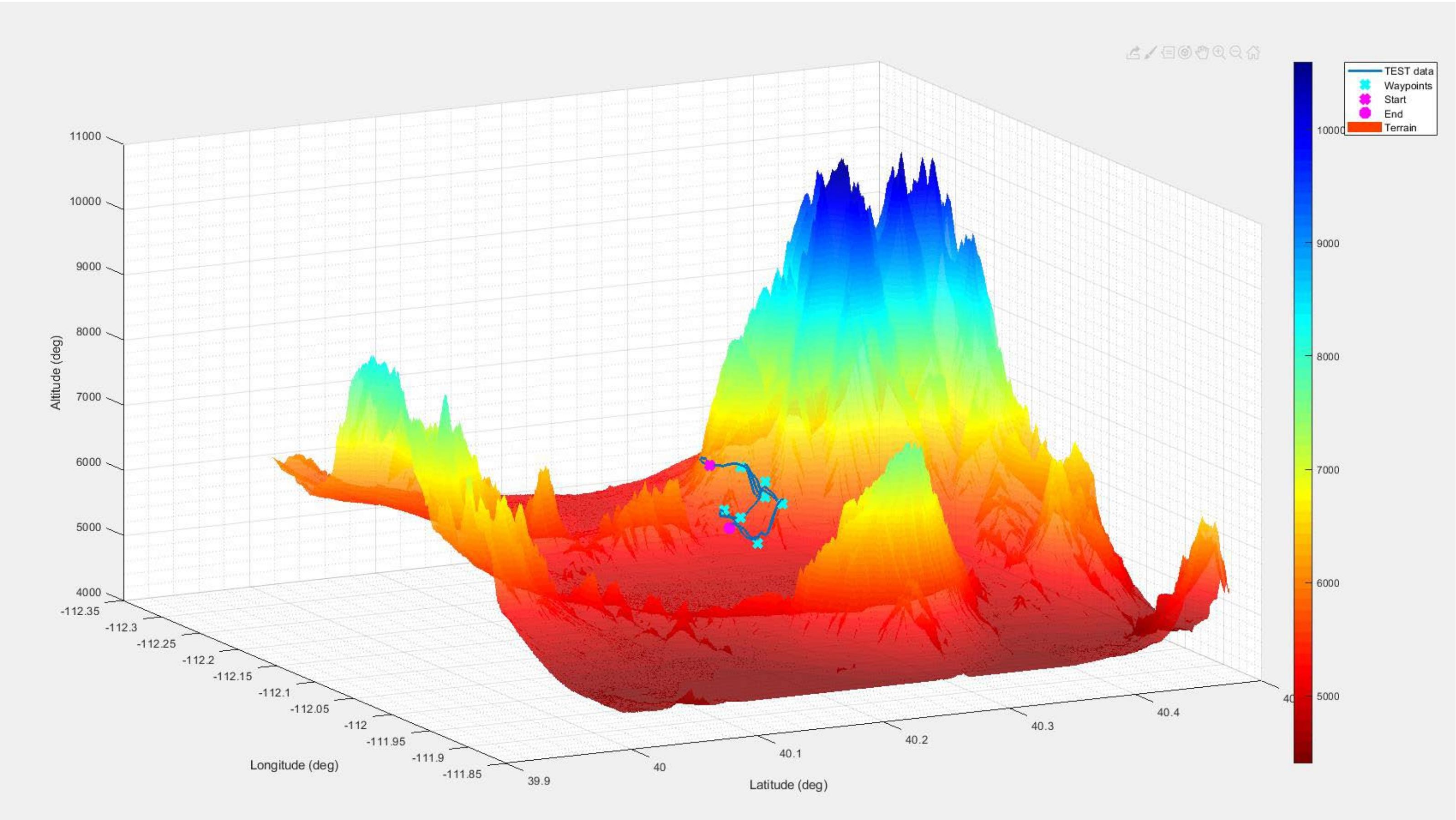


Figure 4.81. Track Against Mountainous Train Mimicking an Urban Canyon.

FLE Procedure Test

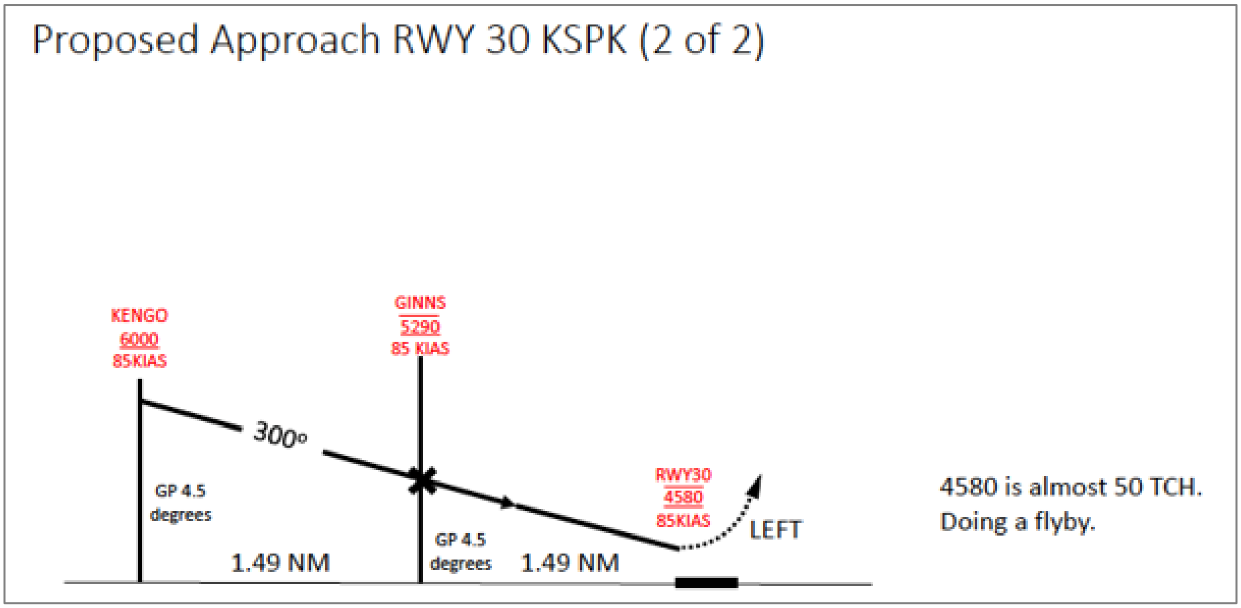


Figure 4.82. Profile View for Final Approach Segment.

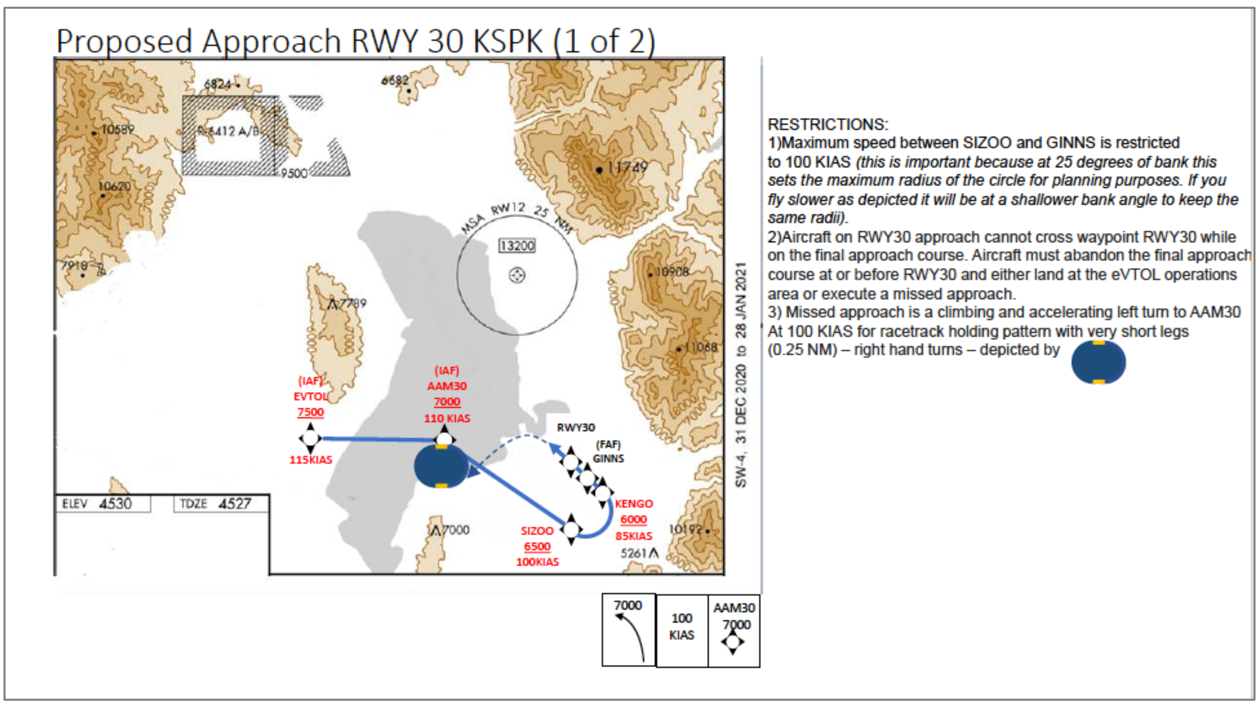


Figure 4.83. Overhead view of KSPK with Test Flight Path.

The product of the outputs of the FAA process of the procedure, presenting the airspeed airspace requirements and showing November and December for one of the instrument approaches at Spanish Fork with a missed approach is shown below in Figure 4.84. The figure describes the current state of the art of what is currently being produced in the National Airspace System. Of note are the following:

Assumption for manual control of the flight path is allowed and is within the FAA aircrew pilot certification requirements - an important point that the NC team wanted to stress and the differences of which are shown.

Assumption that the autopilot and FMS are allowed to fly this approach procedure, but are not required to do so because the approach procedure falls within the certification requirements for a aircrew pilot certification.

Airspace at Spanish Fork, Utah

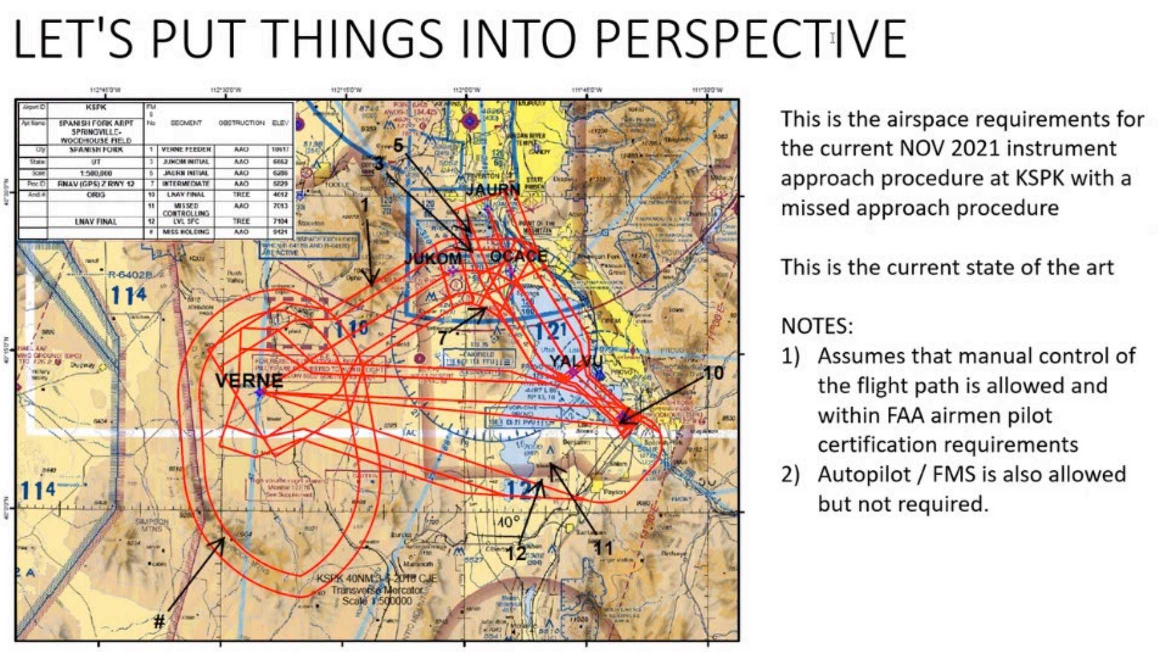


Figure 4.84. Conventional Procedure Build, Spanish Fork, Utah.

Airspace at Spanish Fork, Utah with Dimensions

To put overall airspace requirements into perspective, the distance reference was added to Figure 4.85 in order to show the dimensions of the airspace. The total airspace consumed is betweem the green arrow with 45 nautical miles horizontally and 38 nautical miles north to south. The purple oval represents what was done at KUT9 and is an attempt to represent the overall area entirely. Clearly, there is a huge contrast in airspace requirements between what the NC team completed in the purple shape at KUT9 and the conventional procedure at KSPK outlined in red below in Figure 4.85.

This validates the type of operations occurring within the terminal area in current national airspace of what the FAA is doing now.

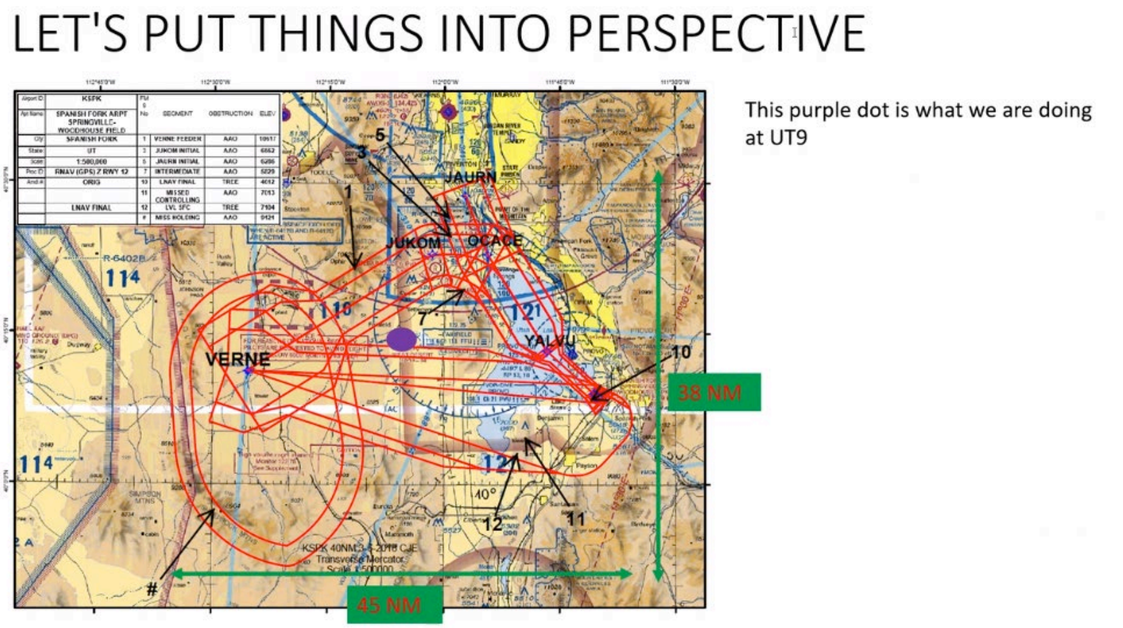


Figure 4.85. Convential procedure build versus candidate procedure build, Spanish Fork, Utah.

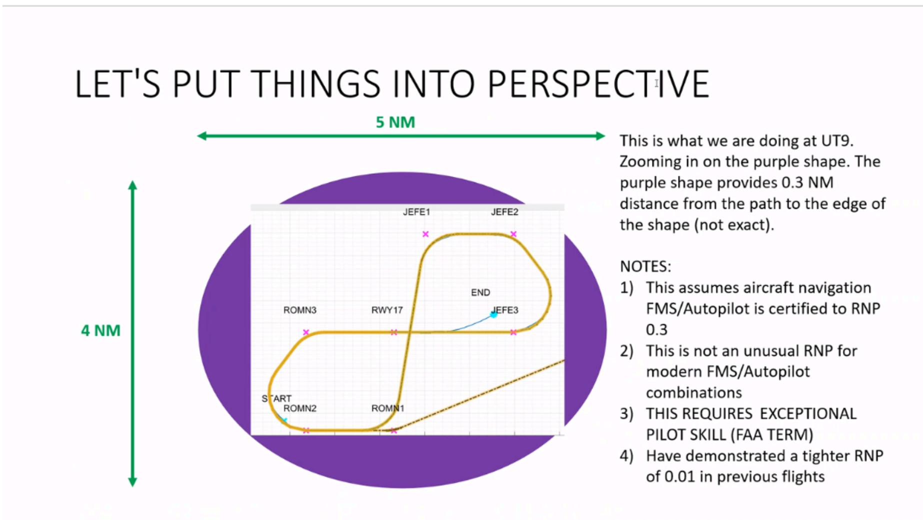


Figure 4.86. Candidate procedure build traffic pattern, Spanish Fork, Utah.

Zooming into the purple area which is five nautical miles by four nautical miles and the approach and return-to-approach tested at KUT9. The purple essentially provides the form, and the edge of any side is an estimated 0.3 nautical miles in distance. This assumption is least conservative in terms of the FMS autopilot combinations that are certified to an RNP of 0.3. Tighter volumes and tolerances require exceptional pilot skill and thus a greater need for automation; regulations require that an aircraft cannot require exceptional pilot skill for normal operations. Thus, this approach procedure, manually flown, would require exceptional pilot skill and would not be certifiable.

5 LESSONS LEARNED

The following topics are discussed in the this section: *Flight Test Infrastructure Integration Summary, Data Elements, Airspace Operations Summary* and *Next Steps.*

5.1 Flight Test Infrastructure Integration Summary

Developmental iterations of the Flight Test Infrastructure from a data integration perspective yielded several key pathways for the NC ecosystem of systems and associated processes. At onset, data were collected and delays ensued to provide data validation to end users. To ensure key data points were captured, a process of quick looks and verification checkpoints was created through a validation process to alleviate the problem. Additionally, data products took time to develop post-flight, which created a lag for reporting results. A new, streamlined process developed to record data, ingest into the data pipeline, and then ETL the data for storage, governance and consumption created a system of systems for data to culminate in a Knowledge Graph System, Aerograph. The graphing database enabled metrics, products, documents, and raw data to be retrieved as needed through complex coding, calls, and relationships inherent through fully enabled metadata. The creation of an event marker provided not only the opportunity to properly store and retrieve data, but the ability for researchers and analysts to access key portions of the data collection all the way down to the granularity of a maneuver or a timestamp, which was not possible before.

Additionally, a standardized approach to NC data was achieved in two ways. Data security and governance was strictly designed and enforced to ensure approved access to all information and data relevant to the campaign. This process was shared with industry partners and evidenced by their ability to entrust proprietary or sensitive information with the project, where necessary. Issues that abounded with disparate data instrumentation yielding data in different units and rates proved problematic to synchronize. Again, a new process to verify the data proved vital to NC data. To avoid problems of reporting out differently on a like attribute or metric, a standardized approach was also applied to an integrated data product, which provisions meaningful transformations across like data regardless of activity type or partner, such that analysts and stakeholders across agencies and partnerships can understand data in the same way and without disclosing proprietary information or attributes from vehicles or airspace technologies. This also was confirmed useful by NC stakeholders.

Data products continue to develop to summarize and measure data aligned to key metrics and Measures of Performance (MOPs) for flight plan objectives. The analysis framework of the NC continued to evolve throughout the Dry Run series and beyond, generating automated products that enabled crews and teams to validate data in a timely manner and for analysts to focus attention toward new, more complex questions or off-nominal occurrences within the data. Data products include the ability to check data source outputs for calibration and accuracy. Flight test visualization continues to develop through the Grafana open-source application and iUTM to enable greater systematic insight into all aspects of flights. All of the developments have been critical toward the campaign endeavor to provide useful data for research initiatives and stakeholders, to include the FAA.

5.2 Flight Test Data Summary

Data are a key asset of the NC. The output is critical to forward progress for research, iterations and identifying current gaps to Advanced Air Mobility. Early NC work to derive a Data Elements portfolio which captured elemental data, tracked the data and metrics across related subprojects and identify relationships among data proved useful. Similar data that will be used across simulation and flight test or across subprojects is tracked for continuity. A method in data organization to ‘test/evaluate all metrics planned’ and verify the ‘conformance to the plan’ has proven to be another success of the data approach applied by the NC team. This method is also being applied toward future flight test plans and will iterate in complexity as originally intended. Data Element cards proved a viable method to divert tasks to key stakeholders across both NASA and the FAA for collaboration and expert input through a standardized method.

Data instrumentation and attributes have so far substantiated desired assumptions, insight, and metrics for the NC Dry Run series. While success has been achieved with the current battery of instrumentation and early metrics, the NC team continues to look forward for new sources of additional data in micro-weather and forecasting.

5.3 Flight Inspection Airborne Processor Application (FIAPA)

Next steps for development of Flight Inspection for management of aeronautical data for AAM include the following:

Flight Validation Requirement: Numerous geospatial data discrepancies were observeding during DT. Due to geospatial data errors latent in existing helicopter IFR approaches and the difficulties dealing with data in DT, it is essential that some form of flight validation be accomplished is extended to on AAM flight procedures.

Preparation of aeronautical and procedure data: In some cases, data were being changed dynamically on the fly which made version control and validation difficult. Due to the potential for error and complexity in the aeronautical data chain, it is recommended to complete survey data and procedure coding at least several weeks in advance of planned flight validations.

Standardize to WGS-84: While this is an existing requirement, it is not currently being implemented consistently by the FAA and there are many opportunities for error. Management of aeronautical data with respect to the WGS-84 horizontal and vertical datum is essential for integrated AAM operations in the NAS to maintain the desired aircraft, terrain, and obstacle clearances. Whereas ambiguities in the horizontal datum are not severe, handling of the vertical datum can be misapplied in several different ways. Standardized use of feet (versus meters) should be considered, even though the FAA currently uses meters in LPV approach data and the X4 simulations has defined meters as the elevation reference unit. In addition, extreme caution needs to be exercised to differentiate between WGS84 Height above Ellipsoid (HaE) and orthometric altitudes based on WGS-84 HaE. Yet another lack of standardization exists in the tables used by various GNSS receivers. There is no standard for the tables used by GNSS receivers to derive orthometric altitude from WGS-84 HaE. Finally, the NAD83 errors in current US IFR approach procedures should not be propagated into the AAM data architecture.

Future NC Flight Test Configurations

Next confiugrations of testing may include the following:

Flight test procedure design: For approaches where accurate path tracking is desired, the pilots need to be allowed access to the FIAPA CDI in their primary field of view and should be allowed to set up and stabilize on at least 5-nautical-mile finals. With a couple practice runs, fixed-wing flight inspection pilots have demonstrated the ability to remain within a few hundredths of a degree. Note that this test procedure setup is beneficial for aircraft performance evaluations but is not representative of Flight Technical Error (FTE) for the average pilot hand flying such a procedure. For flight test objectives where actual system FTE characterization is desired, the procedure should be flown as designed.

Portable FIS Configuration: Since other tablets are being planned in NC test activities, consideration should be given to using that tablet and finding a Trimble GNSS receiver compatible with that tablet. This will minimize variations in equipment and make test design more efficient. The FIAPA software can run on most Microsoft Windows (Microsoft Corporation, Redmond, Washington) -based tablets.

FIAPA Improvements

The following topics cover areas of improvement towards UAM Flight Check:

Standardize and improve FIAPA FTE logging and scaling: Depending on the path being followed and type of procedures, FTE can be reported as a distance or angular. FTE can also be reported as how a specific aircraft avionics configuration reports distance or angular deviation in dots of CDI deflection. The FIAPA software is configured to display CDI deflections based on typical aircraft avionics; however, logging of FTE should be standardized to raw deviations only: angular deviation for LP/LPV type approaches and distance deviation for all other procedures. This improvement will make the FIAPA software more useful as a tool to collect empirical data for validating reduced RNP seen as necessary for enablement of AAM ecosystem.

Add FIAPA capability to track any procedural segments: Currently the FIAPA software can provide flight guidance and record FTE for final approach segments of approaches. More capability will benefit collection of empirical data for validation of reduced RNP, including enroute segments.

Added sensor options: The FIAPA software would provide increased capability for NC evaluation with the addition of IMU acceleration data. Low rate XYZ acceleration data would be beneficial in making evaluations of passenger ride quality during maneuvering required for AAM turning, climbing, descending, acceleration, and deceleration segments. This would increase complexity of a portable configuration because it would require consideration to IMU mounting orientation. Furthermore, the addition of a heading input would be helpful for slow speed and hover conditions.

5.4 Airspace Operations Summary

The National Campaign Dry-Run and Follow-on Flight Tests produced airspace data that positively reinforced the conservation of airspace model. The model is based on gravitational force defining an approach as a function of airspeed to angle. The resulting radius from the approach path inbound was validated as an acceptable means to construct a UAM obstacle OEA as detailed within the infrastructure section and known as the wheel method. The overall reduction of flight volume in the conservation of airspace for a single IFR procedure with missed and holding was 98 percent (356 square nautical miles) compared to the 6-degree wheel model (7.06 square nautical miles). Additionally, NC Developmental Test series were able to confirm the previously calculated Phi, or projected passenger comfort, while maneuvering within the wheel as reported from the aircrew during flight tests at AFRC. While flight testing at Spanish Fork, Utah with FLE and fixed-wing Navion, the turn to final initially constructed was not suitable for passenger carry operations. The turn required the aircraft to use a 30-degree maximum bank angle to achieve the designed flight path. A shallower FROP radius was calculated and used on the second iteration. Since most UAM vehicles designs will have some form of fixed-wing. this was a pertinent rework in developing future airspace procedures. During route coding and final approach segments, it was discovered that UAM route conformance can extend beyond altitude, leg type and lateral positioning to a point in space. It can also include hard coding: airspeed constraints, battery temperatures, energy remaining, required times of arrival, and phase of flight tracking. The resulting options opened a new world of possibilities in automation for reimagining the flight plan as a derivative of performance planning characteristics based on vehicle weight, altitude, temperature, and required navigation performance. Finally, the NC team learned that ADS-B coverage under 400 feet AGL will be a safety critical feature for flight following and message setting. After Dry Run analyses, the FAA and NASA ADS-B data sources confirmed that the lower and slower the vehicle arrived in proximity to the ground, the more message sets were available for position and system reporting. This theoretical messaging setting, based on 750 m/s, can be applied for reduced separation criteria through the ground but may not be available off airport at lower latitudes and especially at 400 feet AGL and below.

5.5 Next Steps

Based on insights derived from the surrogate flight test, additional research is required to test an integrated flight environment for novel approach and departure procedures interfacing with a PSU and multiple pilots. The intersection of flight planning and conformance will be a critical function distributed through the pilot, controller, and dispatch operator. Further engagement with the FAA in the areas of sequencing, spacing, flight validation, human factors, accident/incident reporting, and wake categorization will help define the NC test series for real-world modeling of vehicle, air traffic management, and airspace architecture design.

Since the NC team developed coded procedures and routes, further flight testing will be required to not only fly the departure and approach segments as one, but validate the spatial data using the FAA vertical profile flight check inspection software (FIAPA). With the information obtained from this report, the NC desires to answer research questions in future testing that help further evolve the roles and responsibilities of the future airspace automation, validate the conservation of airspace model and introduce 3 axis COTS autopilot into the coding validation.

The future test design is expected to incorporate a:

1. Representative UAM airspace architecture/procedures of a constrained urban environment
2. Representative airspace automation (e.g. PSU) that will filter the layers of message latency, connectivity, flight following, contingency management, weather, phase of flight monitoring and flight planning
3. Representative vehicle with autopilot to test pilot workload, safety, and passenger comfort levels.

These UAM representative entities will be utilized for end-to-end UAM operations that will reflect real-world scenarios based on distance, terrain, vertical obstructions, noise abatements, residential/commercial/agricultural zoning, routing and simulated or emulated traffic. The tests will require a number of pilots with varying skill sets and experience. While pilots will not be measuring handling qualities or flight characteristics, pilots will be gauging safety, workload, and feasibility of low altitude truncated and prescribed routing while on the controls. The NC team will cross-monitor autopilot conformance to waypoint restrictions when a pilot is not on the controls.

Range site selection will be based upon real-world community partner locations to showcase either the feasibility or potential disruption to current day operations. With maximum input from airfield managers, controllers and city officials, the flight test will produce the most realistic results to be presented for industry, government, and academia consideration.

Flight test cards will be a combination of procedure approach plates and coding. An experimental UAM approach plate (for human use) with departure, route, approach, and missed instructions will be hand flown with the anticipation of a pilot utilizing maximum reference to flight instrumentation. Experimental UAM coding (for mechanical use) for the FMS to fly “DEPROACH” procedures with waypoint restrictions will be furthered from the FLE testing that took place under Dry Run. The NC test also plans to assimilate a rating scale, similar to Cooper-Harper for the pilot and the FTE, to respond according to workload for automation, NSPU interaction, safety, comfort, and other aspects of the workload.

6 ANNEX

6.1 References

[1] U.S Department of Transportation, FAA (2020). *United States Standard for Terminal Instrument Procedures (TERPS) 8260.3* https://www.faa.gov/documentlibrary/media/order/nd/8260_3.pdf

[2] U.S Department of Transportation, FAA (2022). *United States Standard for Performance Based Navigation (PBN) Instrument Procedure Design (PBN) 8260.58.* https://www.faa.gov/documentlibrary/media/order/nd/8260_58.pdf

[3] U.S Department of Transportation, FAA (2005). *United States Standard for Required Navigation Performance (RNP) Approach Procedures with Special Aircraft and Aircrew Authorization Required (SAAAR) 8260.52.* https://www.faa.gov/documentlibrary/media/order/nd/8260_52.pdf

[4] Clarke, S., Redifer, M., Papathakis, K., Samuel, A. & Foster, T. (2017, May 02). *NASA Conference Paper, X-57 Power and Command System Design.* Document ID: 20170005797. Source: NTRS https://ntrs.nasa.gov/citations/20170005797

[5] NASA-STD-3001, Volume2, Revision C, *NASA Space Flight Human-System Standard*

Volume 2: Human Factors, Habitability, And Environmental Health

[6] Pascioni, K.A., Watts, M.E., Houston, M.L., Lind, A.H., Stephenson, J.H., & Bain, J.J. (2022, May 2). *NASA Conference Paper, Acoustic Flight Test of the Joby Aviation Advanced Air Mobility Prototype Vehicle* Document ID: 20220006729. Source: NTRS https://ntrs.nasa.gov/citations/20220006729

[7] Zahn, D. & Sharma, S. (2020). *NASA Conference Paper, Microplex: Integrated UAM Operations in a Multimodal Transportation System* PID 6535875. Source: AIAA

[8] Swenson, H.N., Hamlin, J.R., & Wilson, G.W. (1983, February 1) *NASA-FAA Helicopter Microwave Landing System Curved Path Flight Test.* Document ID 19840015549. Source: NTRS https://ntrs.nasa.gov/citations/19840015549

[9] Evaluation of Wide Area Augmentation System Helicopter Operations including Localizer Performance with Vertical Guidance (LPV) to a Point in Space (PinS) Approach, FAA, 2011

[10] U.S Department of Transportation, FAA (2016). *Order 8200.1D - US Standard Flight Inspection Manual (USSFIM) with CHG 1* Order 8200.1D - US Standard Flight Inspection Manual (USSFIM) with CHG 1 (faa.gov)

6.2 Abbreviations

This section details the abbreviations that are used throughout this document.

Abbreviation	Description
AAM	Advanced Air Mobility
ADS-B	Automatic Dependent Surveillance-Broadcast
AFB	Air Force Base
AFRC	Armstrong Flight Research Center
AFRL	Air Force Research Laboratory
AFSRB	Airworthiness Flight Safety Review Board
AGL	Above Ground Level
AIRNAV	FAA Database for Airport, Lighting, Runway & Spatial Data
AJV-A	FAA Air Traffic Control Services
AOL	Airspace Operations Lab
AOM	Airspace Operations Management
ARC	Ames Research Center
ARINC	Aeronautical Radio Incorporated
ARMD	Aeronautics Research Mission Directorate
ASR	Airport Surveillance Radar
ATC	Air Traffic Control
ATI	Airspace Testing and Integration
CDI	Course Deviation Indicator
CNS	Communication, Navigation, and Surveillance
COA	Certification of Authorization
CONOPS	Concept of Operations
CRM	Crew Resource Management
DF	Direct to Fix waypoint
DGPS	Differential Global Positioning System
DMP	Data Management Plan
DRPO	Dry Run Primary Objective
EAFB	Edwards Air Force Base
EASA	Eurpoean Union Aviation Safety Agency
EM	Electromagnetic Modeling
EPU	Estimated Position Uncertainty
ETL	Extract, Transform and Load
Evtol	electric Vertical Take-Off and Landing
FAA	Federal Aviation Administration
FAF	Final Approach Fix
FATO	Final Approach and Take-Off
FIAPA	Flight Inspection Airborne Processor Application
FIMS	Flight Information Management System
FIS	Flight Inspection Software
FLE	Flight Level Engineering
FMS	Flight Management System
FOFT	Follow-on Flight Test
FPAP	Final Precision Approach Point
FRI	Flight Research Inc (Mojave, California)
FRR	Flight Readiness Review
FTE	Flight Test Engineer
FTI	Flight Test Infrastructure
FTS	Flight Test System
GCS	Ground Control Station

GNSS	Global Navigation Satellite Systems
GPA	Glidepath Angle
GPS	Global Positioning System
GUI	Graphical User Interface
HaE	Height-above-Ellipsoid
IADS	Interactive Authoring and Display Software
IAF	Initial Approach Fix
ICAO	International Civil Aviation Organization
IDP	Integrated Data Product
IF	Initial Fix
IMC	Instrument Meteorological Conditions
IMU	Inertial Measurement Unit
IRIG	Inter-Range Instrumentation Group
KML	Keyhole Markup Language
LiDAR	Light Detection and Ranging
LMR	Land Mobile Radio
LPV	Localizer Performance with Vertical Guidance
LRU	Line Replaceable Units
LVC	Live, Virtual, Constructive
LZ	Landing Zone
MC	Mission Controller
MCC	Mission Control Center
MEA	Minimum Enroute Altitudes
MOA	Military Operations Area
MOF	Mobile Operations Facility
MSL	Mean Sea Level
NACv	Navigational Accuracy Category for Velocity Value
NACp	Navigational Accuracy Category for Position value
NAMS	NASA Asset Management System
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NC	National Campaign
NC-DT	National Campaign - Developmental Testing
NESAT	NAS-Impact Enhanced Strategic Awareness Toolbox
NIC	Navigational Integrity Category
NPSU	NASA Provider of Services for UAM
NTP	Network Time Protocol
OEA	Obstacle Evaluation Assessment
PCM	Pulse Control Modulation
PDE	Path Definition Error
PFAF	Precision Final Approach Fix
PFD	Pilot Flight Display
PIRA	Precision Impact Range Area
PLASI	Pulse Light Approach Slope Indicator
POC	Point of Contact
PSU	Provider of Services for UAM
RCC	Range Commanders Council
RF	Radius to Fix waypoint
RNAV	Area Navigation
RNP	Required Navigational Performance
ROC	Required Obstacle Clearance

RSO	Range Safety Officer
RTK	Real-Time Kinematic Positioning
RVLT	Revolutionary Vertical Lift Technology
SA	Safety Area
SBSM	Surveillance Broadcast Services Monitor
SDA	System Design Assurance value
SDK	Software Development Kit
SIL	Surveillance Integrity Level
SME	Subject Matter Expert
SODAR	Sonic Detection And Ranging
STOL	Short Take-Off and Landing
sUAS	Small Unmanned Aircraft System
SURFER	Simple UDP Receiver Filter Extractor Router
SVO	Simplified Vehicle Operation
TCL	Technical Capability Level
TECCS	Test & Evaluation Command and Control System
TF	Track to Fix waypoint
TFR	Temporary Flight Restriction
TLOF	Touch-down and Lift-off
TPM	Technical Performance Measure
UAM	Urban Air Mobility
UAS	Unmanned Aircraft System
UDC	Universal Data Collector
UDP	User Datagram Protocol
UHF	Ultra-High Frequency
UML	AAM/UAM Maturity Level
USS	UAM Service Supplier Provider
UTC	Coordinated Universal Time
UTE	UAM Task Element
UTM	Unmanned Traffic Management
V&V	Verification & Validation
VHF	Very-High Frequency
VMC	Visual Meteorological Conditions
VP	Virtual Presence
VPN	Virtual Private Network
VTOL	Vertical Take-Off and Landing
WAAS	Wide Area Augmentation System
xTM	Experimental Traffic Management; Identifies the xTM Client Application

6.3 Geodetic Sites

GEODETIC SITE INFORMATION					
LOCATION (INSTALLATION / CITY, STATE / COUNTRY) **Edwards AFB, CA/USA**			DATUM **WGS 84**		
POINT	LATITUDE (deg min sec)	LONGITUDE (deg min sec)	ELLIPSOID HEIGHT OF POINT (meters)	HEIGHT OF POINT ABOVE GROUND (meters)	ELLIPSOID HEIGHT AT GROUND (meters)
BV1-ARP	**N 34 57 00.14445**	**W 117 53 13.82413**	**678.224**	**N/A**	**N/A**
BV1-PC	**N 34 57 00.14445**	**W 117 53 13.82413**	**678.346**	**N/A**	**N/A**

DESCRIPTION

BV1-ARP and BV1-PC are located in the NASA Neil A. Armstrong Flight Research Center on Edwards AFB, California.

To reach the station from the intersection of Rosamond Boulevard and North BaseRoad proceed south on Rosamond Boulevard for 2.4 miles to a stop sign at LillyAvenue. Turn left onto Lilly Avenue and go 0.5 mile east then northeast to Walker Road on the right. Turn right, southeast, and go 0.2 mile entering the NASA secure area to Building 4800 and the station on the roof. You will need aNASA badge to proceed into the secure area.

The station is mounted on the center portion of the roof of Building 4800.It isan Ashtech GPS-700718B-NONE antenna. The points of survey are the antenna reference point (ARP) and antenna phase center (PC).

PHOTO/SKETCH

PREPARED BY	DATE PREPARED	CHECKED BY	DATE CHECKED
N. Rosa	**February 2021**	**M. Baumann**	**February 2021**

GEODETIC SITE INFORMATION					
LOCATION (INSTALLATION / CITY, STATE / COUNTRY) **Edwards AFB, CA/USA**			DATUM **WGS 84**		
POINT	LATITUDE (deg min sec)	LONGITUDE (deg min sec)	ELLIPSOID HEIGHT OFPOINT (meters)	HEIGHT OF POINT ABOVE GROUND (meters)	ELLIPSOIDHEIGHT ATGROUND (meters)
BV1-ARP	**N 34 57 00.14445**	**W 117 53 13.82413**	**678.224**	**N/A**	**N/A**
BV1-PC	**N 34 57 00.14445**	**W 117 53 13.82413**	**678.346**	**N/A**	**N/A**

DESCRIPTION

BV1-ARP and BV1-PC are located in the NASA Neil A. Armstrong Flight Research Center on Edwards AFB, California.

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PHOTO/SKETCH

PREPARED BY	DATE PREPARED	CHECKED BY	DATE CHECKED
N. Rosa	**February 2021**	**M. Baumann**	**February 2021**

GEODETIC SITE INFORMATION					
LOCATION (INSTALLATION / CITY, STATE / COUNTRY) **Edwards AFB, CA/USA**			DATUM **WGS 84**		
POINT	LATITUDE (deg min sec)	LONGITUDE (deg min sec)	ELLIPSOID HEIGHT OF POINT (meters)	HEIGHT OF POINT ABOVE GROUND (meters)	ELLIPSOID HEIGHT AT GROUND (meters)
N 1140-BV1	**N 34 59 09.89396**	**W 117 51 44.55716**	**661.816**	**0.20**	**N/A**

DESCRIPTION

Station N 1140-BV1 (140N-BV1) is located on the North Base portion of Edwards AFB, CA.

To reach the station from the intersection of Rosamond Boulevard and North BaseRoad, go 1.5 mile on North Base Road east then northeast to an intersection witha paved road on the right. Turn right and go 0.1 mile southeast to the stationon the right.

The station is a standard U.S. Coast & Geodetic Survey brass disk set flush withthe top of the northwest end of the southwest concrete headwall of a culvert, stamped N 1140 1961. It is 5 meters southwest of the center line of the street, 18 meters east of the southeast corner of Building 4444, and 0.2 meter higher than the street.

PHOTO/SKETCH

PREPARED BY	DATE PREPARED	CHECKED BY	DATE CHECKED
N. Rosa	**February 2021**	**M. Baumann**	**February 2021**

GEODETIC SITE INFORMATION					
LOCATION (INSTALLATION / CITY, STATE / COUNTRY) **Edwards AFB, CA/USA**			DATUM **WGS 84**		
POINT	LATITUDE (deg min sec)	LONGITUDE (deg min sec)	ELLIPSOID HEIGHT OF POINT (meters)	HEIGHT OF POINT ABOVE GROUND (meters)	ELLIPSOID HEIGHT AT GROUND (meters)
KEDWA 2020-BV1	**N 34 59 40.95197**	**W 117 52 24.43652**	**680.942**	**10.33**	**N/A**

DESCRIPTION

Station KEDWA 2020-BV1 is located on North Base portion of Edwards AFB,California.

To reach the station from the intersection of Rosamond Boulevard and North Base Road, proceeded east on North Base Road for 0.5 mile to Laboratory Road on the left. Turn left, north, then northeast, and go 0.8 mile to the end of pavement.Turn left, northwest, and go for 0.15 mile through a fence gate to Building 4221on the right.
Station KEDWA-BV1 is the top center of the tripod atop the control tower on thenortheast corner of Building 4221. Point of survey is the bottom mount of KEDWA 2020-BV1.

PHOTO/SKETCH

PREPARED BY	DATE PREPARED	CHECKED BY	DATE CHECKED
N. Rosa	**February 2021**	**M. Baumann**	**February 2021**

GEODETIC SITE INFORMATION					
LOCATION (INSTALLATION / CITY, STATE / COUNTRY) **Edwards AFB, CA/USA**			DATUM **WGS 84**		
POINT	LATITUDE (deg min sec)	LONGITUDE (deg min sec)	ELLIPSOID HEIGHT OF POINT (meters)	HEIGHT OF POINT ABOVE GROUND (meters)	ELLIPSOID HEIGHT AT GROUND (meters)
NAS9-BV1	**N 34 56 53.05428**	**W 117 53 44.98178**	**682.983**	**0.15**	**N/A**

DESCRIPTION

Station NASA 9-BV1 (NAS9-BV1) is located in the NASA Neil A. Armstrong Flight Research Center on Edwards AFB, California.

To reach the station from the intersection of Rosamond Boulevard and North Base Road proceed south on Rosamond Boulevard for 2.4 miles to a stop sign at Lilly Avenue. Turn left onto Lilly Avenue and go 0.15 mile east to a railroad track and a dirt road about 15 meters east of track. Turn right onto the dirt road andgo 0.1 mile south to the station.

The station is a U.S. Army Corps of Engineers brass disk set in the top of a 0.1meter square concrete monument projecting 0.15 meter above the ground, stamped NASA-9 1969 LA DIST. It is 27 meters east of the railroad track centerline and 8meters west of the southwestern most of two manholes.

PHOTO/SKETCH

PREPARED BY	DATE PREPARED	CHECKED BY	DATE CHECKED
N. Rosa	**October 2020**	**M. Baumann**	**February 2021**

GEODETIC SITE INFORMATION

LOCATION (INSTALLATION / CITY, STATE / COUNTRY)			DATUM		
Edwards AFB, CA/USA			**WGS 84**		
POINT	LATITUDE (deg min sec)	LONGITUDE (deg min sec)	ELLIPSOID HEIGHT OF POINT (meters)	HEIGHT OF POINT ABOVE GROUND (meters)	ELLIPSOID HEIGHT AT GROUND (meters)
GWM 18 2449-BV1	**N 34 52 17.75511**	**W 117 38 55.13414**	**867.084**	**0.23**	**N/A**

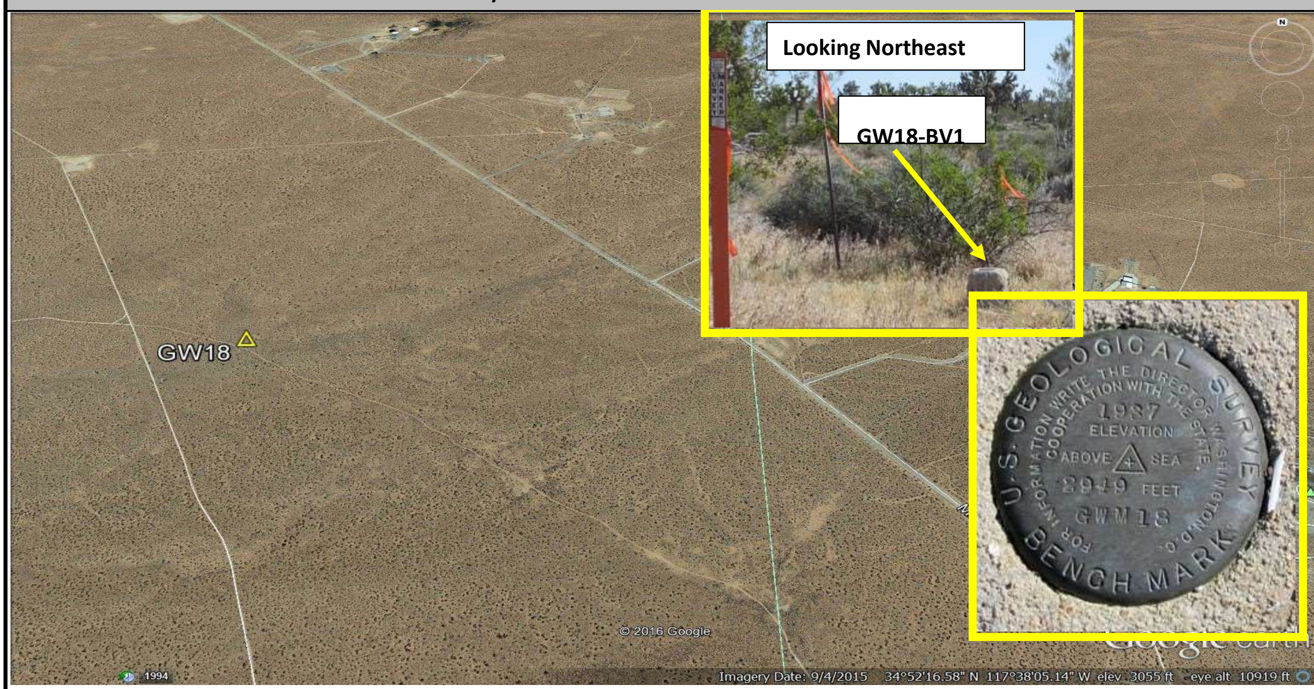
DESCRIPTION

Station GWM 18 2449-BV1 (GW18-BV1) is located on the Precision Impact Range Area (PIRA) of Edwards AFB, California.

To reach the station from the intersection of North Base Road and Rosamond Boulevard on Edwards AFB, go north on Rosamond Boulevard for 1.7 miles passing through the North Gate, to the intersection with State Highway 58. Take the east ramp merging onto State Highway 58 and go 6.5 miles to Exit 193. At the stop sign turn right and follow Twenty Mule Team Road southeast for 2.0 miles to the intersection with Rocket Site Road (Rich Road). Turn right and go 6.2 miles to the intersection with Mercury Boulevard. Turn left and go 1.3 miles east to the DOWNFALL PIRA gate on the right. Turn right and go
1.3 miles southeast to the PIRA range control complex. At this point you must sign-in with the rangecontrol staff and obtain radios and GPS tracker. Drive southeast on A4 Road (a graded dirt road) for
2.0 miles to B4 road, continue southeast on A4 Road for 0.7 mile to a dirt road on the left. Turnleft and go 0.2 mile east to the station on the left.

The station is a U.S. Geological Survey Bench Mark disk set in the top of a 0.15 square concrete monument protruding 0.23 meters above the ground, stamped GWM 18 2449 1937. It is 9 meters northeastof the road centerline.

PHOTO/SKETCH



PREPARED BY	DATE PREPARED	CHECKED BY	DATE CHECKED
N. Rosa	**February 2021**	**M. Baumann**	**February 2021**

GEODETIC SITE INFORMATION

LOCATION (INSTALLATION / CITY, STATE / COUNTRY)	DATUM
Edwards AFB, CA/USA	**WGS 84**

POINT	LATITUDE (deg min sec)	LONGITUDE (deg min sec)	ELLIPSOID HEIGHT OF POINT (meters)	HEIGHT OF POINT ABOVE GROUND (meters)	ELLIPSOID HEIGHT AT GROUND (meters)
LAZAR 1-BV1	**N 34 55 16.37317**	**W 117 42 44.17505**	**870.549**	**0.00**	**N/A**

DESCRIPTION

Station LAZAR 1-BV1 (LZR1-BV1) is located in the southwest portion of the Air Force ResearchLaboratory on Edwards AFB, California.

To reach the station from the intersection of Rosamond Boulevard and North Base Road, go 1.7 miles north on Rosamond Boulevard passing through the North Gate, to the ramp for the eastbound lanes of State Highway 58. Take the ramp east and go 6.4 miles to the 193 exit for Twenty Mule Team Road. Atthe stop sign turn right and go 2.0 miles southeast then east to the intersection with Rocket Site Road (Rich Road) on the right. Turn right and go 6.1 miles south to the intersection with Mercury Boulevard. Turn left and go 1.2 miles east-northeast on to a graded dirt road on the left, northwest. Turn left onto the dirt road and proceed northwest up the hill for 0.3 mile to an intersection with another graded dirt road. Turn right and proceed northwest for 0.4 mile to a concrete pad and station on the left.

It is marked by a standard DMA brass disk set flush in the center of a 2.4x3.0 meter concrete pad,stamped LAZAR 1 1984 GSS DET 1.

PHOTO/SKETCH

PREPARED BY	DATE PREPARED	CHECKED BY	DATE CHECKED
N. Rosa	**February 2021**	**M. Baumann**	**February 2021**

GEODETIC SITE INFORMATION					
LOCATION (INSTALLATION / CITY, STATE / COUNTRY) **Edwards AFB, CA/USA**			DATUM **WGS 84**		
POINT	LATITUDE (deg min sec)	LONGITUDE (deg min sec)	ELLIPSOID HEIGHT OF POINT (meters)	HEIGHT OF POINT ABOVE GROUND (meters)	ELLIPSOID HEIGHT AT GROUND (meters)
MASTER SOUTH BASE-BV1	**N 34 55 18.62567**	**W 117 52 41.77888**	**665.512**	**-0.31**	**N/A**

DESCRIPTION

Station MASTER SOUTH BASE-BV1 (_MSB-BV1) is located on the flight line area ofEdwards AFB, California.

To reach the station from the Building 1600 gate, proceed onto the flight line atSouth Flight Line Road. Turn left and proceed 0.26 mile to the stop bar for crossing the intersection of Taxiways Charlie, Echo, and Foxtrot on the right.
Cross the taxiway intersection and proceed for 0.1 mile along Taxiway Charlie toa road on the left. Turn left and go north 50 meters to three roads on the right. Turn right onto the southern most of the roads and proceed southeast forapproximately 0.15 mile to the station on the left.

The station is a National Engineering Company brass disk set in a concrete monument 0.31 meters below the ground surface, stamped MASTER SOUTH BASE 12-55.It is 610 meters east of the control tower, 12 meters northeast of the road centerline and 5 meters northwest of station C111.

PHOTO/SKETCH

PREPARED BY	DATE PREPARED	CHECKED BY	DATE CHECKED
K. Archuleta	**March 2017**	**B. Wilson**	**March 2017**

GEODETIC SITE INFORMATION

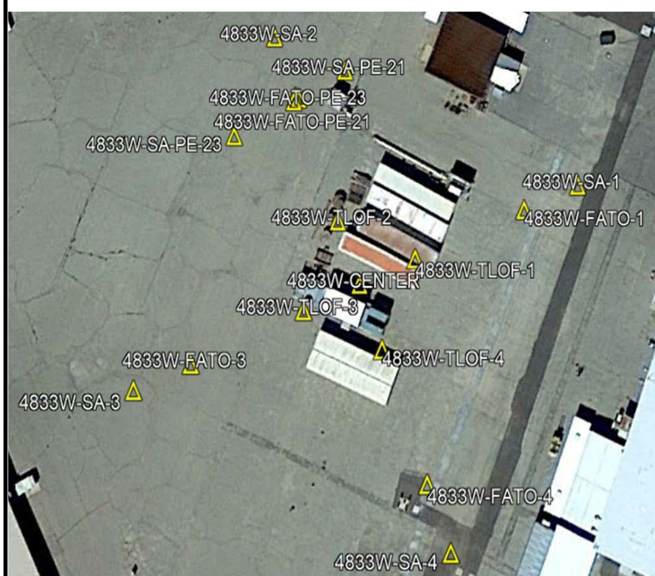
LOCATION (INSTALLATION / CITY, STATE / COUNTRY)			DATUM		
Edwards AFB, CA/USA			**WGS 84**		
POINT	LATITUDE (deg min sec)	LONGITUDE (deg min sec)	ELLIPSOID HEIGHT OF POINT (meters)	HEIGHT OF POINT ABOVE GROUND (meters)	ELLIPSOID HEIGHT AT GROUND (meters)
4833W-CENTER	**Varies**	**Varies**	**Varies**	**0.00**	**N/A**
through					
4833E-TLOF-4					

DESCRIPTION

Stations on the Building 4833 Helipads are corners and center of TLOF, FATO, andSA marked (when conditions allowed) with a 3/16-inch drill hole set in the concrete/asphalt, point of survey is at the top of the concrete/asphalt.

PHOTO/SKETCH

Building 4833
West Helipad

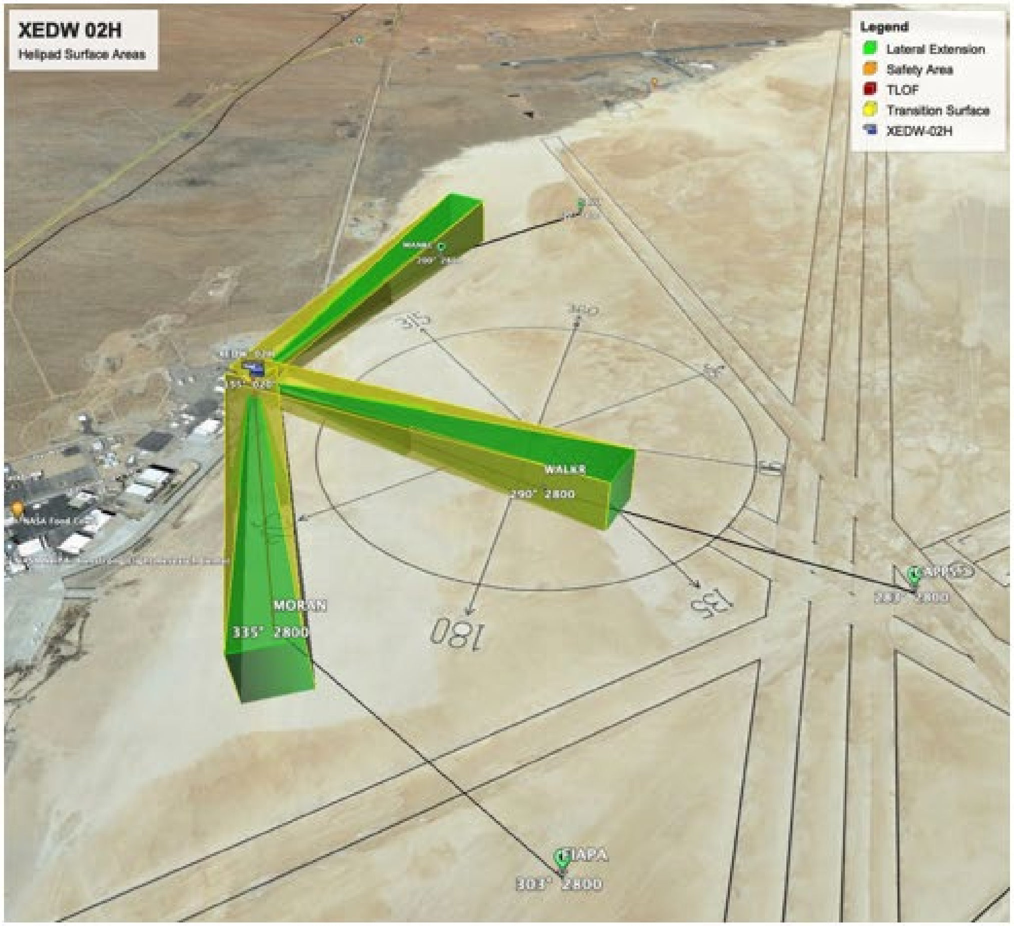


Building 4833
East Helipad

PREPARED BY	DATE PREPARED	CHECKED BY	DATE CHECKED
N. Rosa	**February 2021**	**M. Baumann**	**February 2021**

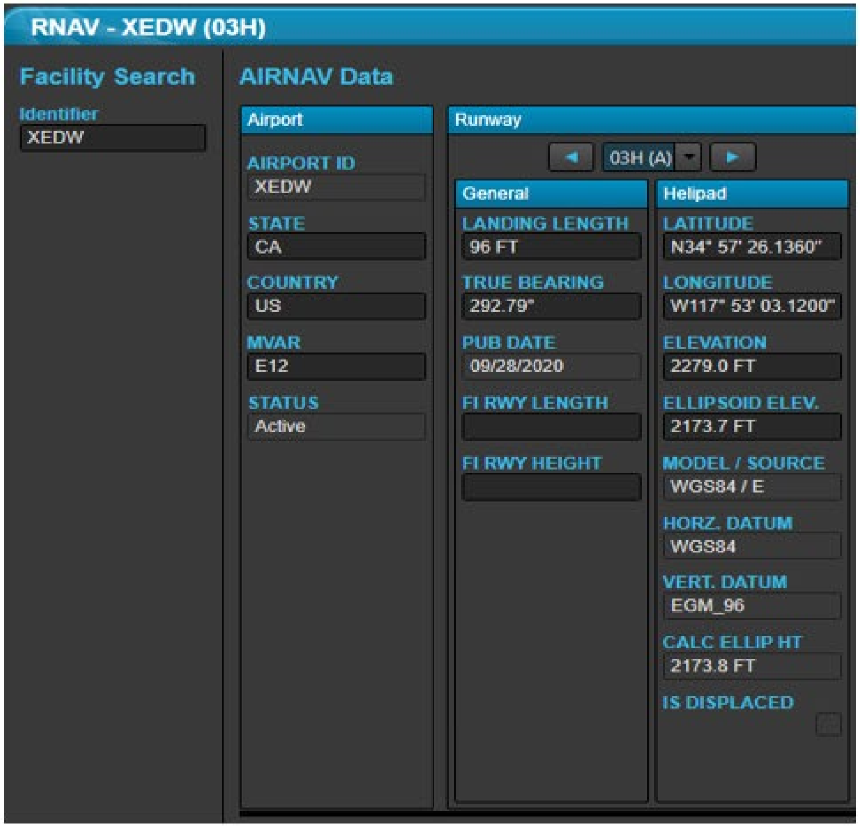
6.4 Landing Surface RNAV and Heliport Airspace Construction

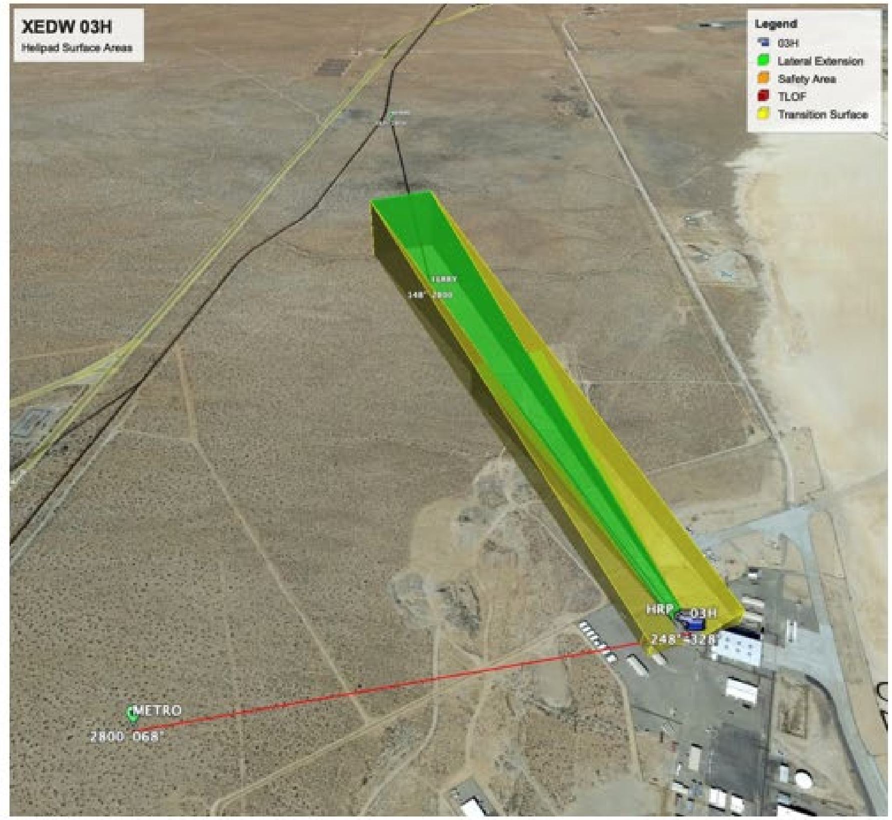
02H



Depicts XEDW 02H selected for dynamic interface calculated magnetic variation, publication date, lat/long geodetic datum, and ellipsoidal heights in feet, surveyed thresholds required by the FAA to be accurate in any landing surface with a takeoff or approach procedure

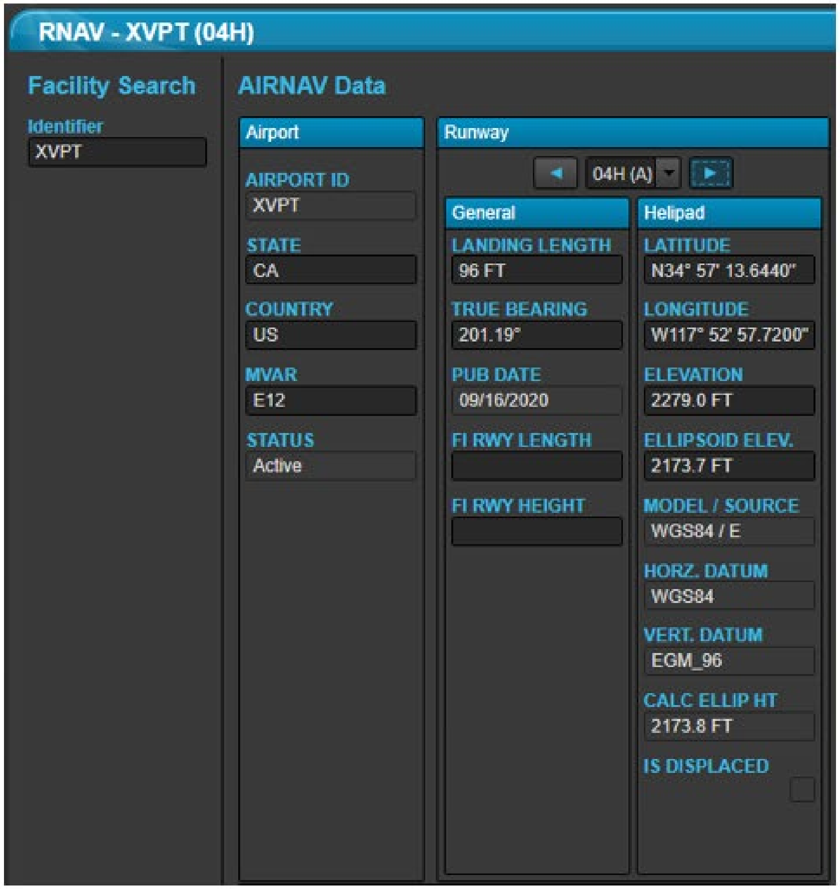
03H

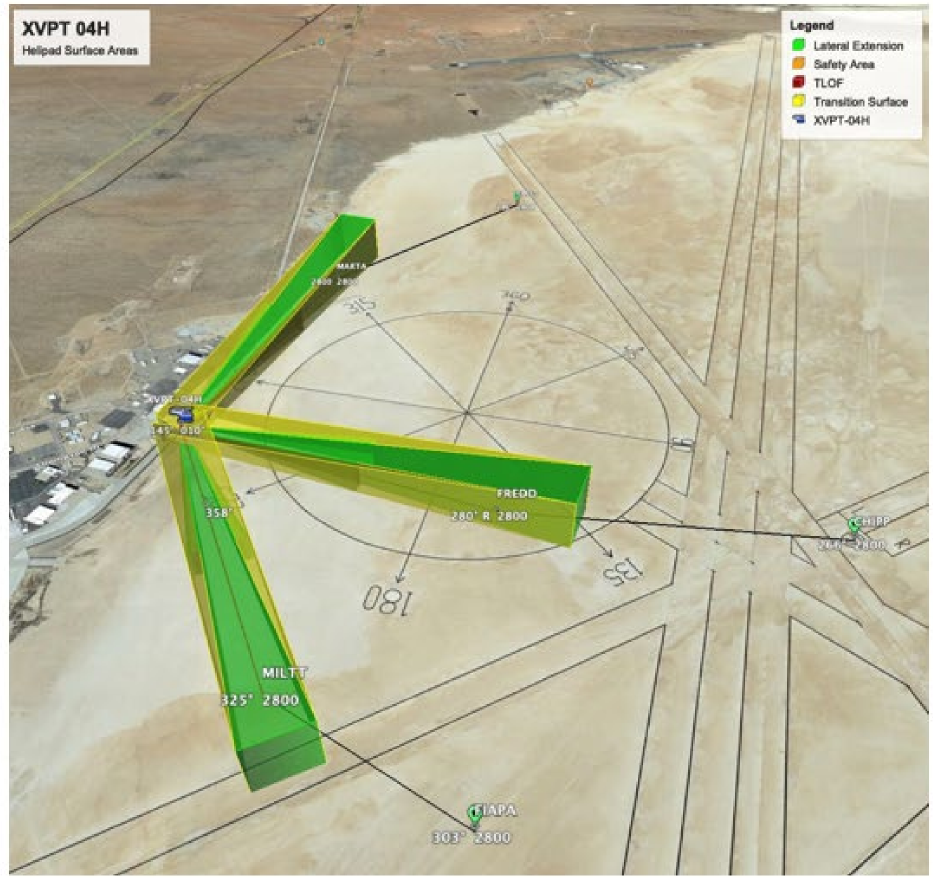




Depicts XEDW 03H selected for dynamic interface. the calculated magnetic variation, publication date, lat/long geodetic datum, and ellipsoidal heights in feet, surveyed thresholds required by the FAA to be accurate in any landing surface with a takeoff or approach procedure.

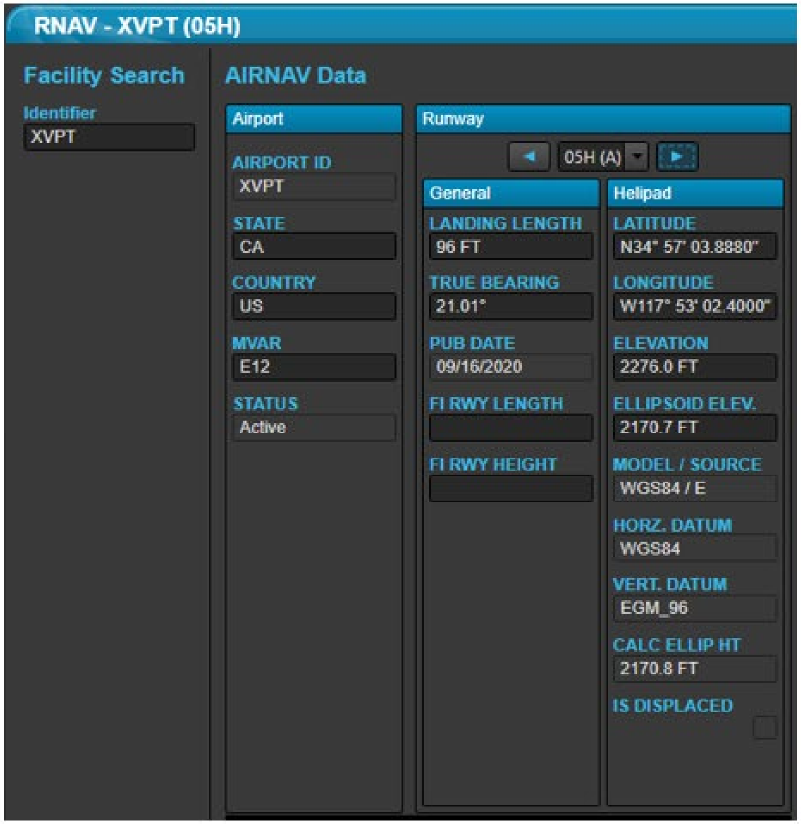
04H

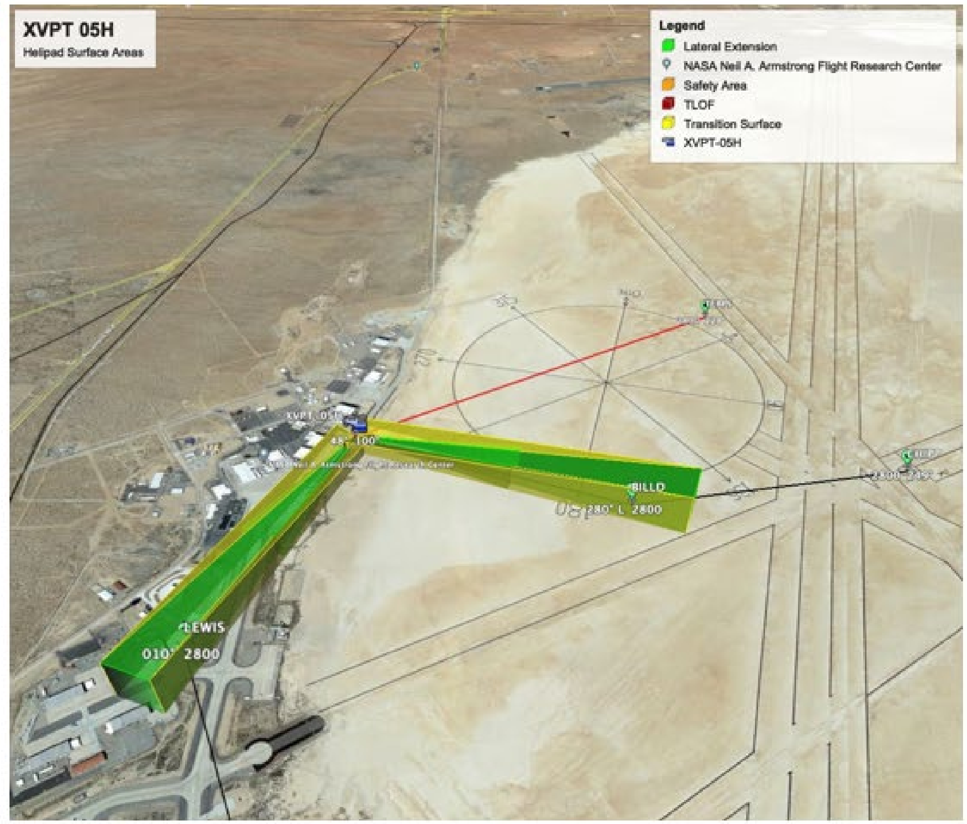




Depicts XVPT 04H selected for simulated parallel approaches coincident with 05H that bind the XVPT runway. the calculated magnetic variation, publication date, lat/long geodetic datum, and ellipsoidal heights in feet, surveyed thresholds required by the FAA to be accurate in any landing surface with a takeoff or approach procedure.

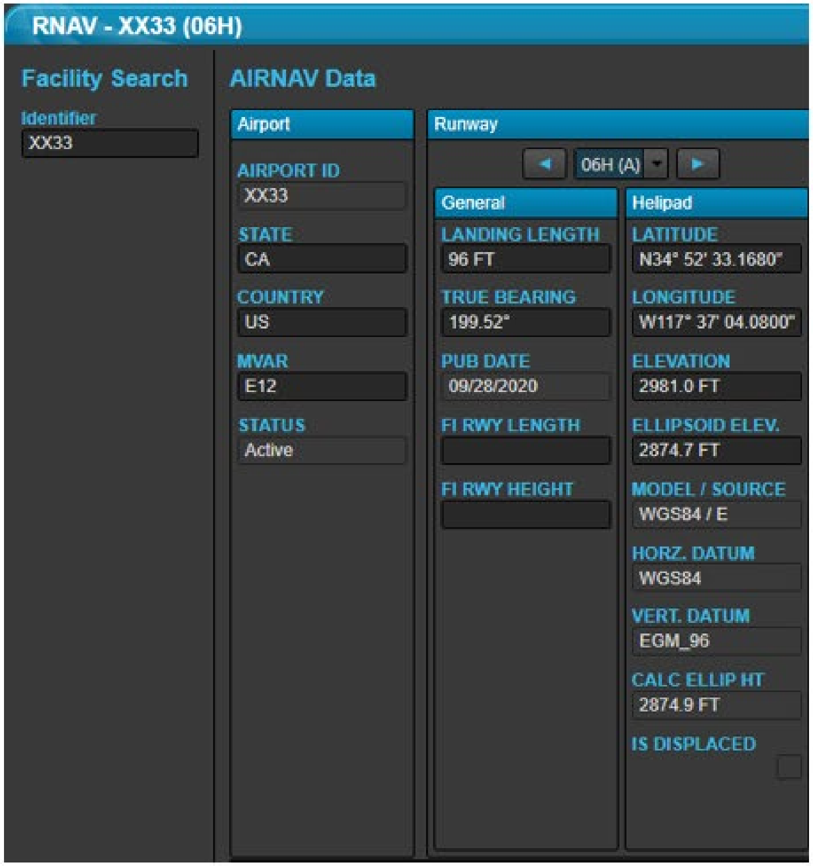
05H





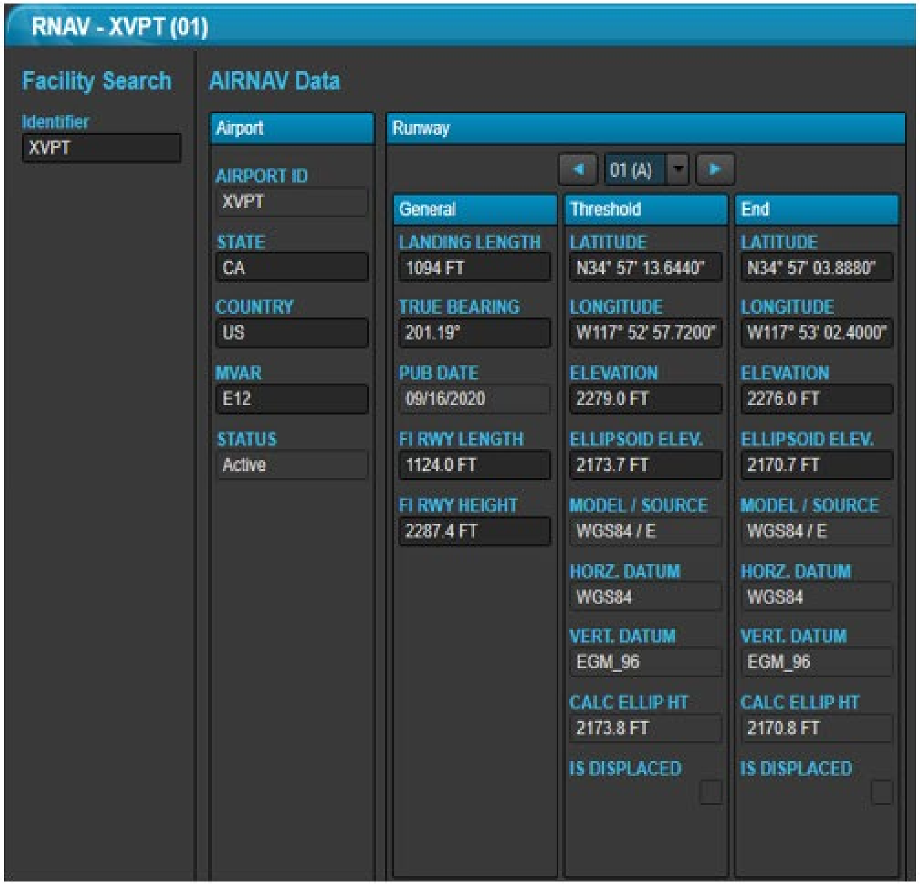
Depicts XVPT 05H selected for simulated parallel approaches coincident with 04h that bind the XVPT runway. the calculated magnetic variation, publication date, lat/long geodetic datum, and ellipsoidal heights in feet, surveyed thresholds required by the FAA to be accurate in any landing surface with a takeoff or approach procedure.

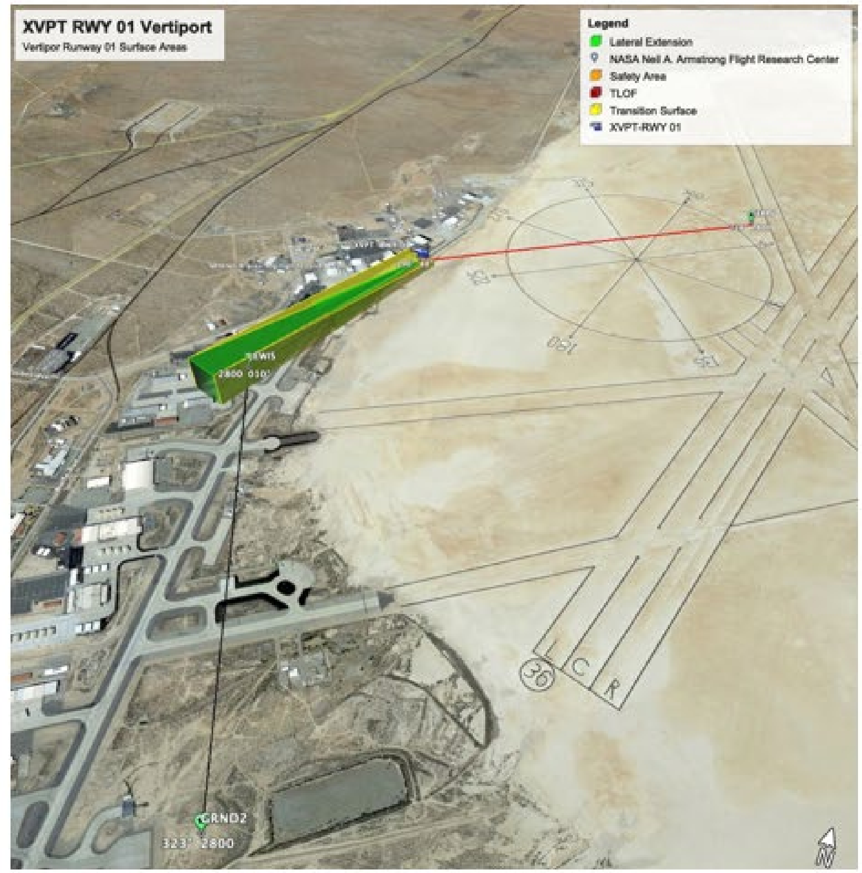
06H



Depicts XVPT 06H selected for route planning and flight following. the calculated magnetic variation, publication date, lat/long geodetic datum, and ellipsoidal heights in feet, surveyed thresholds required by the FAA to be accurate in any landing surface with a takeoff or approach procedure.

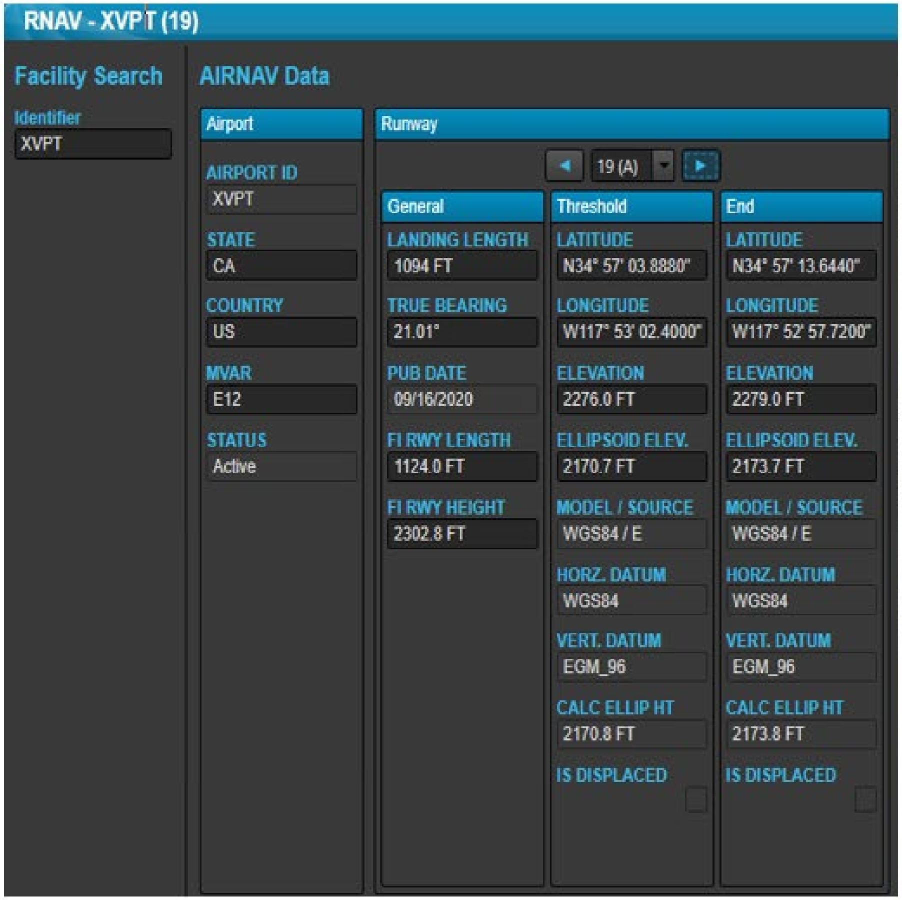
RUNWAY 01

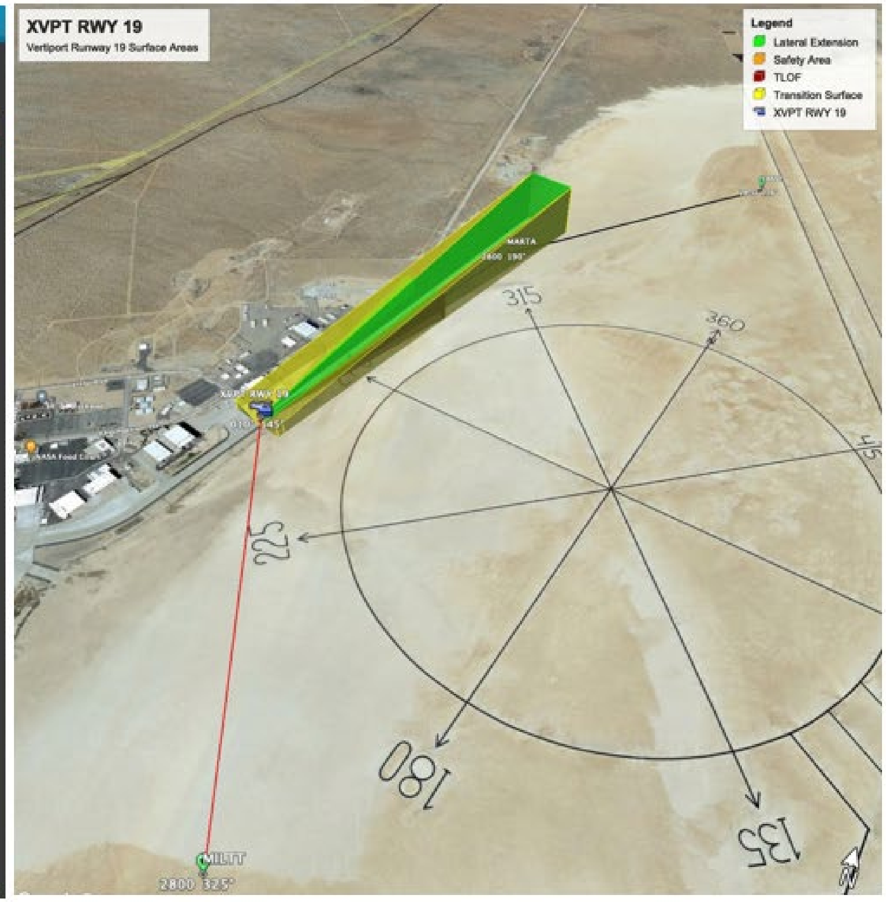




Depicts XVPT RWY 01 selected for short take-off and landing (stol) testing. the calculated magnetic variation, publication date, lat/long geodetic datum, and ellipsoidal heights in feet, surveyed thresholds required by the FAA to be accurate in any landing surface with a takeoff or approach procedure.

RUNWAY 19

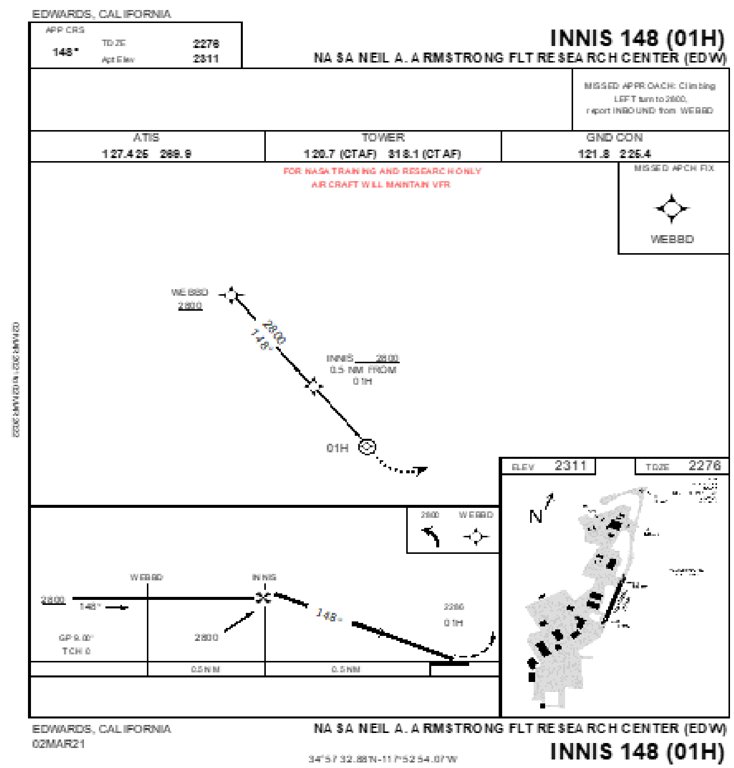




Depicts XVPT RWY 19 selected for short take-off and landing (STOL) testing. the calculated magnetic variation, publication date, lat/long geodetic datum, and ellipsoidal heights in feet, surveyed thresholds required by the FAA to be accurate in any landing surface with a takeoff or approach procedure.

6.5 Approaches and Approach Plates

INNIS 148




```
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SUSAEAENRT   INNIS K20    W     N34580336W117530756                      E0012     NAR          INNIS
SUSAEAENRT   WEBBD K20    W     N34583447W117532136                      E0012     NAR          WEBBD
SUSAH XEDWK2A         0     NARY N34573283W117525412E012002276        1800018000P          XEDW NORTH
SUSAH XEDWK2FR01H  R      010WEBBDK2EA0E  I    IF                          + 02800     18000                A JS
SUSAH XEDWK2FR01H  R      020INNISK2EA1E  F 010TF                          + 02800                          A JS
SUSAH XEDWK2FR01H  R      020INNISK2EA2WALPV      ALNAV/VNAV ALNAV                                            JS
SUSAH XEDWK2FR01H  R      03001H  K2HH0GY M 031TF                            02287            -891          A JS
SUSAH XEDWK2H01H      0S00060050 N34573288W117525407HCONC101S      02277
SUSAH XEDWK2PR01H  59000001Y0000W15A0N3457328800W11752169685+066160891N3456090265W1175216968510675000000000F4005009DE01475
SUSAH XEDWK2PR01H  59000002E      +06937+06937LPV
```
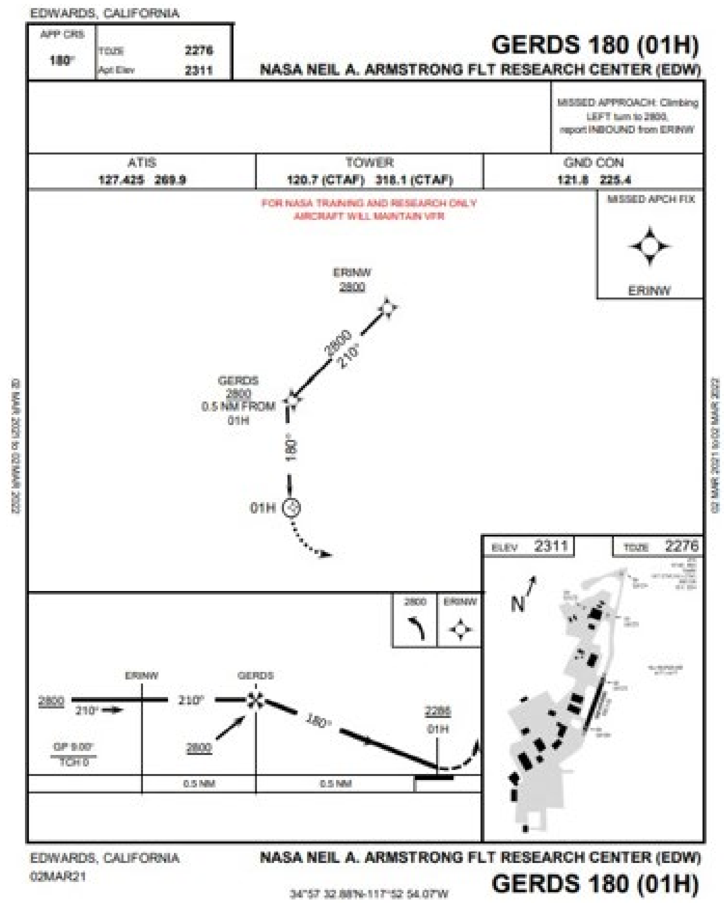
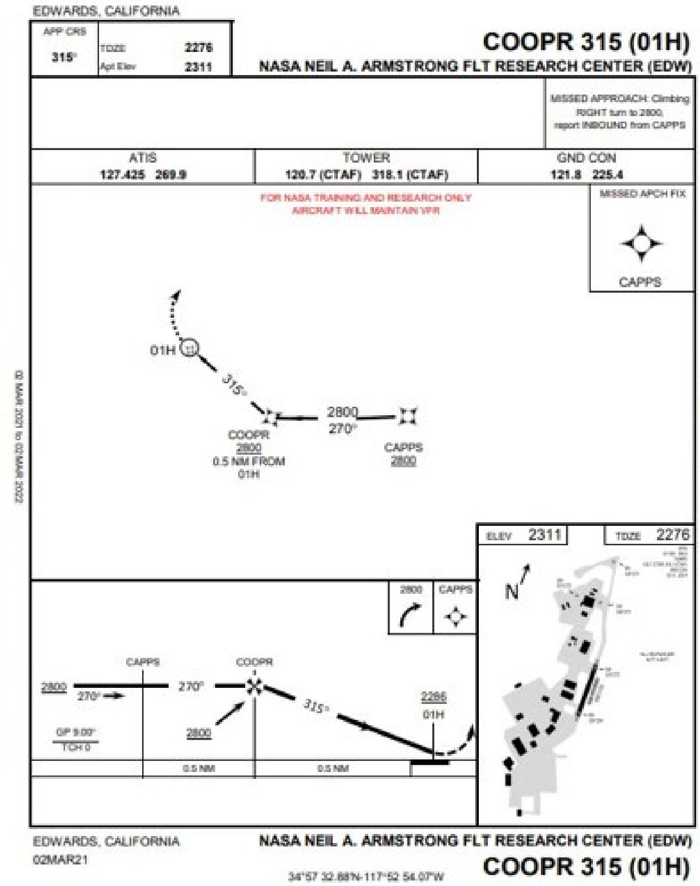

GERDS 180




```
HDR GERDS                     CAUSXEDW      SIAPCOPTER RNAV (GPS) 01H                             AMDT 1
SUSAEAENRT   ERINW K20    W     N34583986W117522151                  E0012      NAR          ERINW
SUSAEAENRT   GERDS K20    W     N34580478W117524578                  E0012      NAR          GERDS
SUSAH XEDWK2A        0     NARY N34573283W117525412E012002276        1800018000P          XEDW NORTH
SUSAH XEDWK2FR01H  R      010ERINWK2EA0E  I    IF                          + 02800     18000                   A JS
SUSAH XEDWK2FR01H  R      020GERDSK2EA1E  F 010TF                          + 02800                             A JS
SUSAH XEDWK2FR01H  R      020GERDSK2EA2WALPV       ALNAV/VNAV ALNAV                                              JS
SUSAH XEDWK2FR01H  R      03001H  K2HH0GY M 031TF                          02287            -891               A JS
SUSAH XEDWK2H01H     0S00060050 N34573288W117525407HCONC101S      02276
SUSAH XEDWK2PR01H  59000001Y0000W18A0N3457328800W11752540700+066160886N3456056095W11753167425106750000000000F400500ADD5F74D
SUSAH XEDWK2PR01H  59000002E      +06937+06937LPV
```

COOPR 315




```
HDR COOPR                    CAUSXEDW      SIAPCOPTER RNAV (GPS) 01H                         AMDT 1
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SUSAEAENRT    COOPR K20     W     N34570530W117523226                      E0012     NAR         COOPR
SUSAH XEDWK2A         0      NARY N34573283W117525412E012002276        1800018000P          XEDW NORTH
SUSAH XEDWK2FR01H  R       010CAPPSK2EA0E  I    IF                                + 02800     18000              A JS
SUSAH XEDWK2FR01H  R       020COOPRK2EA1E  F 010TF                                + 02800                        A JS
SUSAH XEDWK2FR01H  R       020COOPRK2EA2WALPV       ALNAV/VNAV ALNAV                                               JS
SUSAH XEDWK2FR01H  R       03001H  K2HH0GY M 031TF                                  02287             -891       A JS
SUSAH XEDWK2H01H      0S00060050 N34573288W117525407HCONC101S      02276
SUSAH XEDWK2PR01H  59000001Y0000W32A0N3457328800W11752540700+066160878N3458476670W11753532280106750000000000F4005006D04DBB9
SUSAH XEDWK2PR01H  59000002E      +06937+06937LPV
```
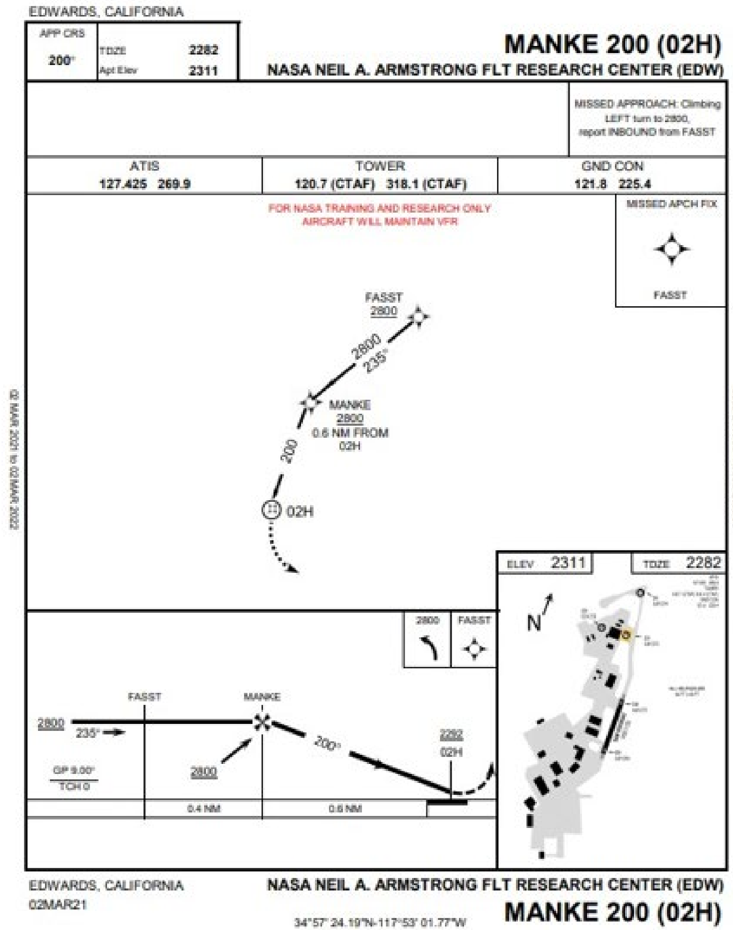

MANKE 200

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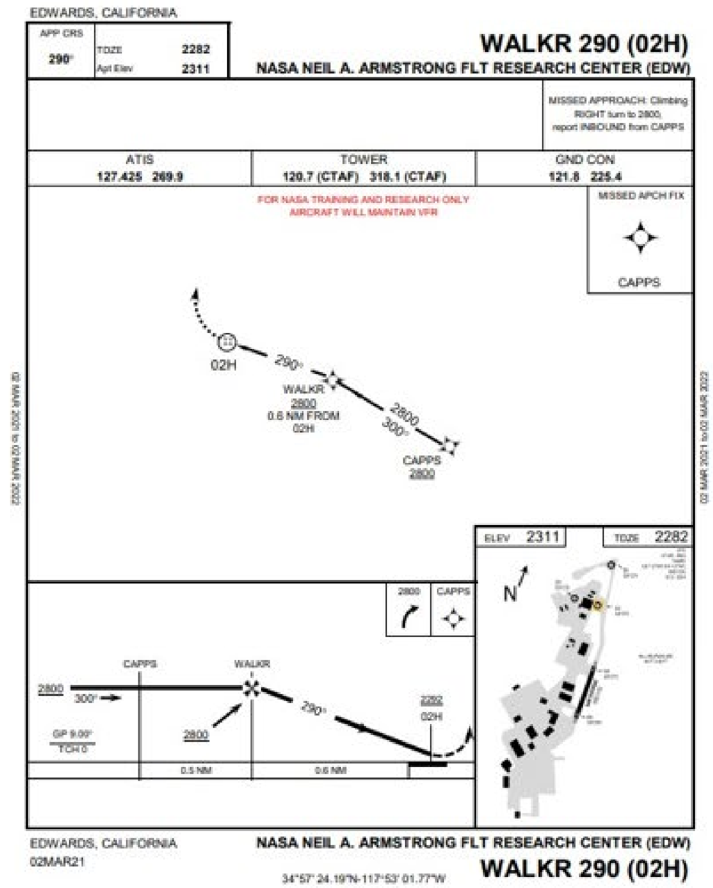
SUSAEAENRT   COOPR K20    W     N34570530W117523226                      E0012     NAR          COOPR
SUSAH XEDWK2A         0     NARY N34573283W117525412E012002276        1800018000P          XEDW NORTH
SUSAH XEDWK2FR01H  R      010CAPPSK2EA0E  I    IF                              + 02800    18000                 A JS
SUSAH XEDWK2FR01H  R      020COOPRK2EA1E  F 010TF                              + 02800                          A JS
SUSAH XEDWK2FR01H  R      020COOPRK2EA2WALPV       ALNAV/VNAV ALNAV                                               JS
SUSAH XEDWK2FR01H  R      03001H  K2HH0GY M 031TF                                02287             -891         A JS
SUSAH XEDWK2H01H      0S00060050 N34573288W117525407HCONC101S      02276
SUSAH XEDWK2PR01H  59000001Y0000W32A0N3457328800W11752540700+066160878N3458476670W117535322801067500000000000F4005006D04DBB9
SUSAH XEDWK2PR01H  59000002E      +06937+06937LPV
```

WALKR 290




```
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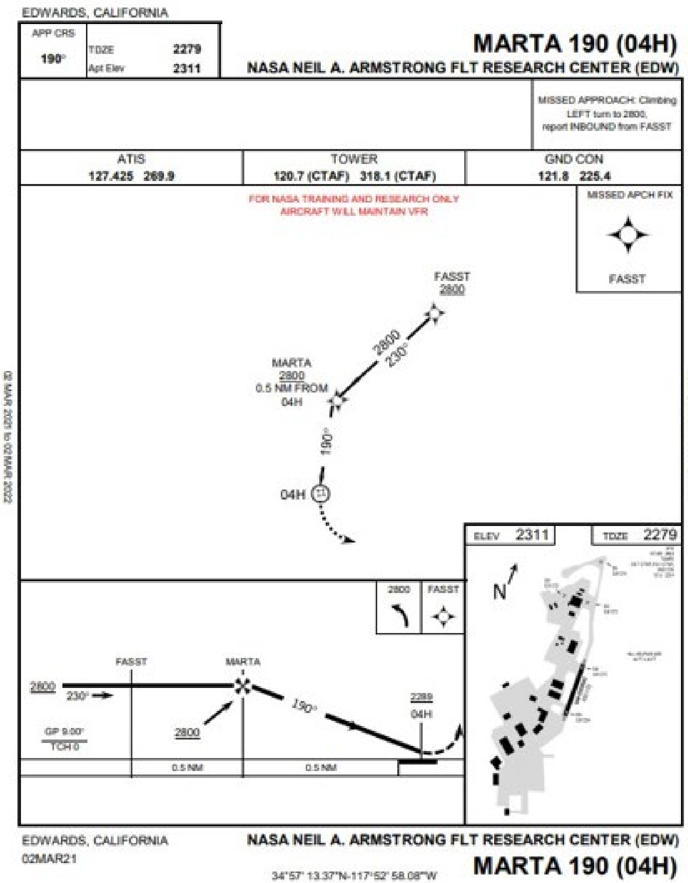
SUSAEAENRT    CAPPS K20    W     N34565399W117515084                   E0012     NAR        CAPPS
SUSAEAENRT    COOPR K20    W     N34570530W117523226                   E0012     NAR        COOPR
SUSAH XEDWK2A        0      NARY N34573283W117525412E012002276       1800018000P           XEDW NORTH
SUSAH XEDWK2FR01H  R      010CAPPSK2EA0E  I    IF                           + 02800    18000              A JS
SUSAH XEDWK2FR01H  R      020COOPRK2EA1E  F 010TF                           + 02800                       A JS
SUSAH XEDWK2FR01H  R      020COOPRK2EA2WALPV      ALNAV/VNAV ALNAV                                          JS
SUSAH XEDWK2FR01H  R      03001H  K2HH0GY M 031TF                             02287            -891       A JS
SUSAH XEDWK2H01H     0S00060050 N34573288W117525407HCONC101S      02276
SUSAH XEDWK2PR01H  59000001Y0000W32A0N3457328800W11752540700+066160878N3458476670W11753532280106750000000000F4005006D04DBB9
SUSAH XEDWK2PR01H  59000002E      +06937+06937LPV
```

MARTA 190

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HDR MARTA                      CAUSXVPT      SIAPCOPTER RNAV (GPS) 04H                              AMDT 1
SUSAEAENRT   FASST K20    W     N34580530W117521336                             E0012     NAR          FASST
SUSAEAENRT   MARTA K20    W     N34574325W117524295                             E0012     NAR          MARTA
SUSAH XVPTK2A        0     NARN N34571364W117525772E012002277          1800018000P             XVPT NORTH
SUSAH XVPTK2FR04H  R      010FASSTK2EA0E  I    IF                                 + 02800     18000                   A JS
SUSAH XVPTK2FR04H  R      020MARTAK2EA1E  F 010TF                                 + 02800                             A JS
SUSAH XVPTK2FR04H  R      020MARTAK2EA2WALPV       ALNAV/VNAV ALNAV                                                     JS
SUSAH XVPTK2FR04H  R      03004H  K2HH0GY M 031TF                                   02287           -891              A JS
SUSAH XVPTK2H04H     0S00060050 N34571324W117525799HCONC101S      02279
SUSAH XVPTK2PR04H  59000001Y0000W19A0N3457132400W11752579900+066250885N3455507405W11753393235106750000000000F400500F84B5E33
SUSAH XVPTK2PR04H  59000002E      +06946+06946LPV
```
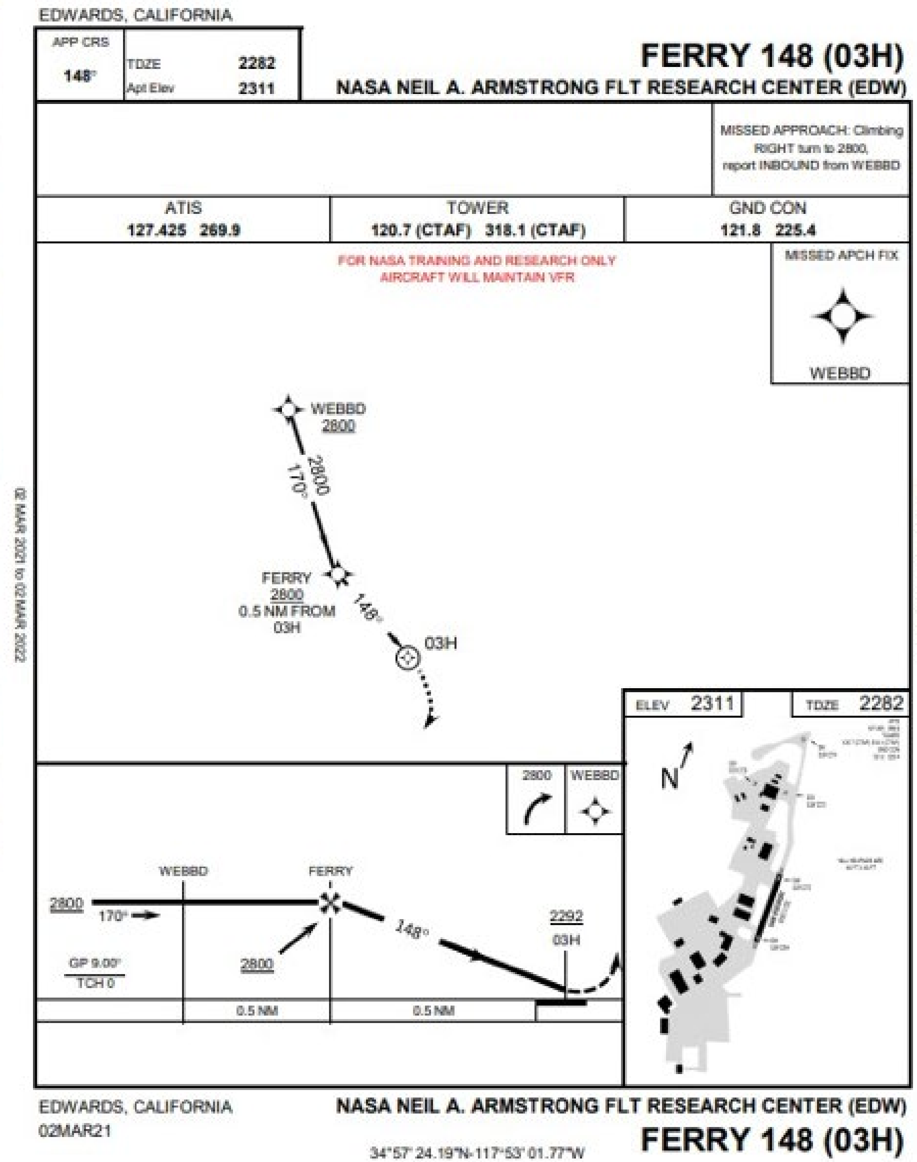
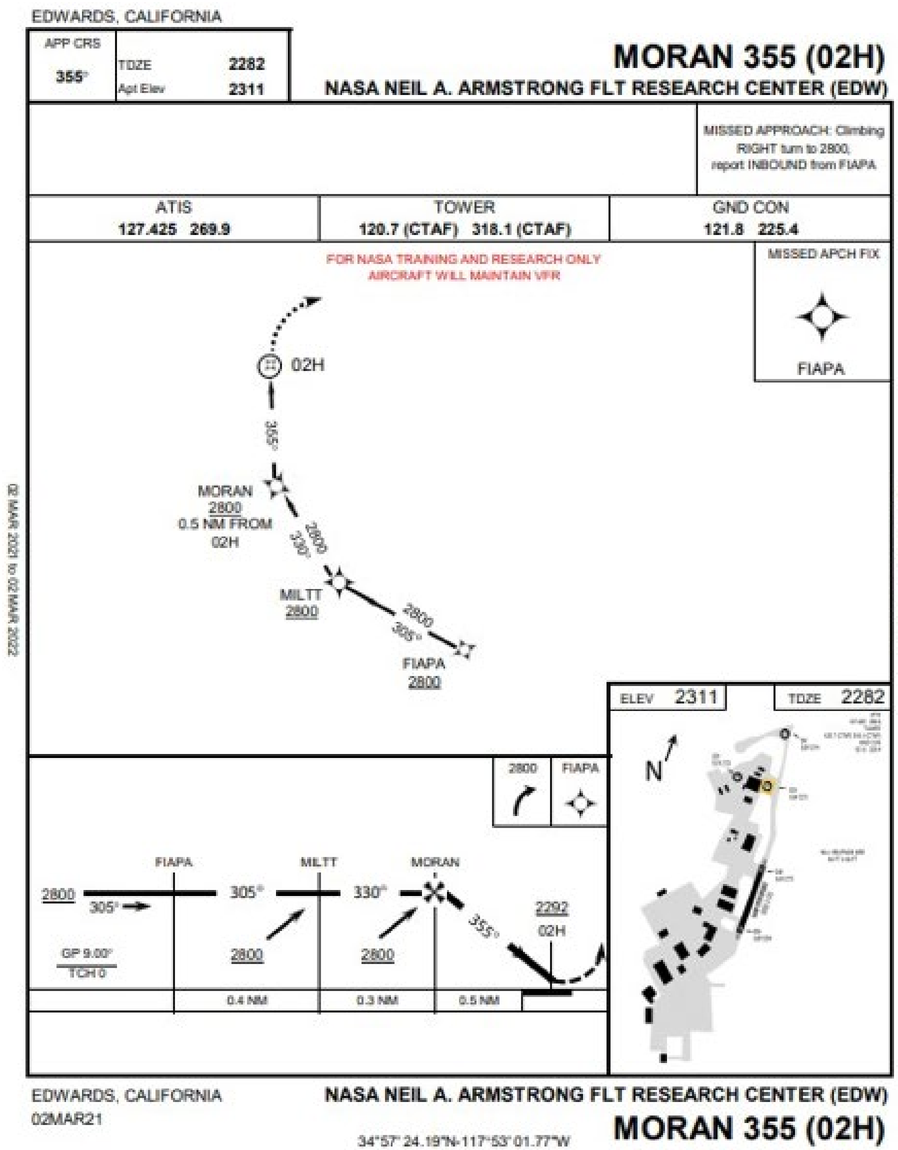

FERRY 148


WEBBD
FERRY
148°
328°
03H
METRO
272°
092°
FERRY 148° 03H
MA to METRO
N
315
360
270


EDWARDS, CALIFORNIA
APP CRS
148°
TDZE 2282
Apt Elev 2311
FERRY 148 (03H)
NASA NEIL A. ARMSTRONG FLT RESEARCH CENTER (EDW)
MISSED APPROACH: Climbing RIGHT turn to 2800, report INBOUND from WEBBD
ATIS
127.425 269.9
TOWER
120.7 (CTAF) 318.1 (CTAF)
GND CON
121.8 225.4
FOR NASA TRAINING AND RESEARCH ONLY
AIRCRAFT WILL MAINTAIN VFR
MISSED APCH FIX
WEBBD
WEBBD
2800
170°
2800
FERRY
2800
0.5 NM FROM
03H
148°
03H
02 MAR 2021 to 02 MAR 2022
ELEV 2311
TDZE 2282
N
2800
WEBBD
WEBBD
FERRY
2800
170°
148°
2292
03H
GP 9.00°
TCH 0
2800
0.5 NM
0.5 NM
EDWARDS, CALIFORNIA
02MAR21
NASA NEIL A. ARMSTRONG FLT RESEARCH CENTER (EDW)
34°57' 24.19"N-117°53' 01.77"W
FERRY 148 (03H)

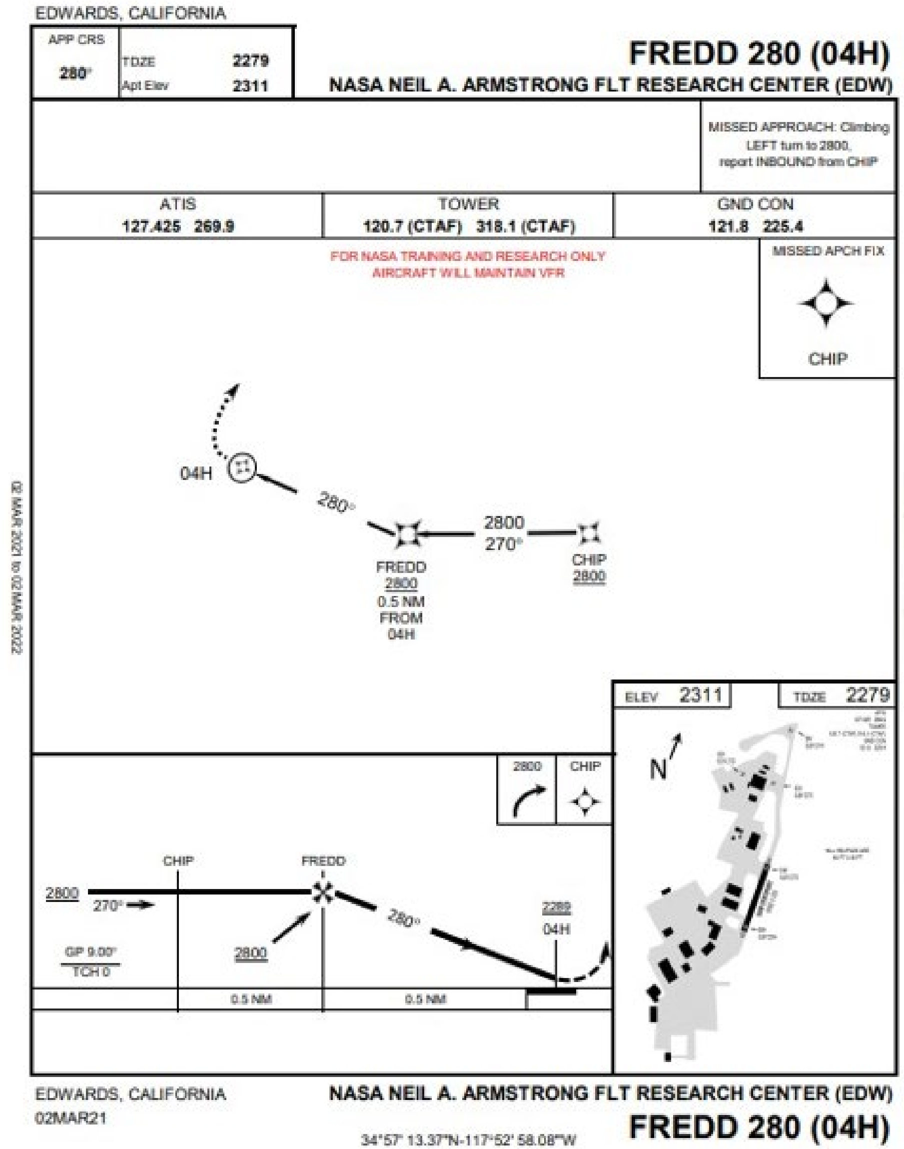
MORAN 355


MANKE
200°
02H
155°
MORAN 335° 02H
MA to MANKE
MORAN
335°
MILTT
FIAPA
N


EDWARDS, CALIFORNIA
APP CRS
355°
TDZE 2282
Apt Elev 2311
MORAN 355 (02H)
NASA NEIL A. ARMSTRONG FLT RESEARCH CENTER (EDW)
MISSED APPROACH: Climbing RIGHT turn to 2800, report INBOUND from FIAPA
ATIS
127.425 269.9
TOWER
120.7 (CTAF) 318.1 (CTAF)
GND CON
121.8 225.4
FOR NASA TRAINING AND RESEARCH ONLY
AIRCRAFT WILL MAINTAIN VFR
MISSED APCH FIX
FIAPA
02H
355°
MORAN
2800
0.5 NM FROM
02H
2800
330°
MILTT
2800
2800
305°
FIAPA
2800
02 MAR 2021 to 02 MAR 2022
ELEV 2311
TDZE 2282
N
2800
FIAPA
FIAPA
MILTT
MORAN
2800
305°
305°
330°
355°
2292
02H
2800
2800
GP 9.00°
TCH 0
0.4 NM
0.3 NM
0.5 NM
EDWARDS, CALIFORNIA
02MAR21
NASA NEIL A. ARMSTRONG FLT RESEARCH CENTER (EDW)
34°57' 24.19"N-117°53' 01.77"W
MORAN 355 (02H)

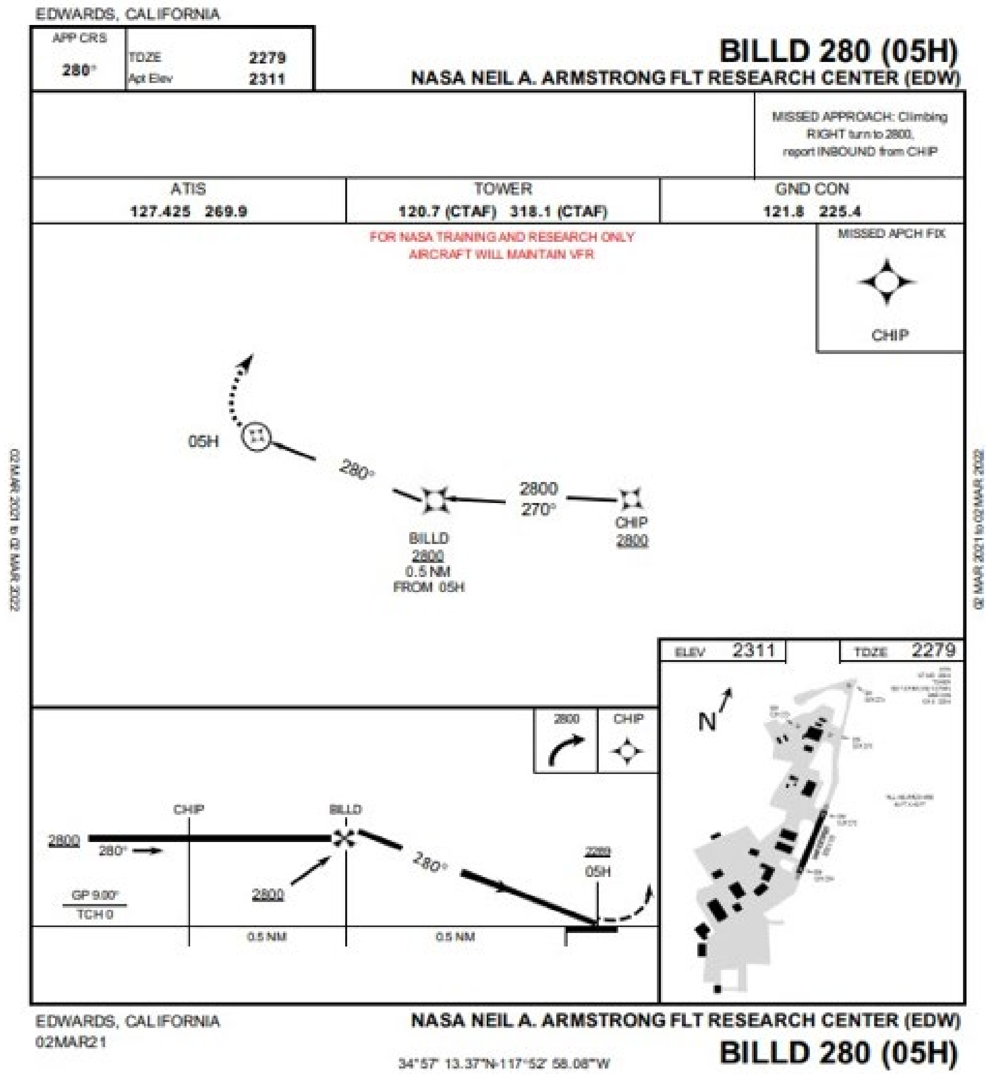
FREDD 280


MARTA
190°
360
315
45
FREDD 280°R 04H
MA to MARTA
N
010-XVPT-04H
100°
FREDD
280°R
CHIP
225
135
180

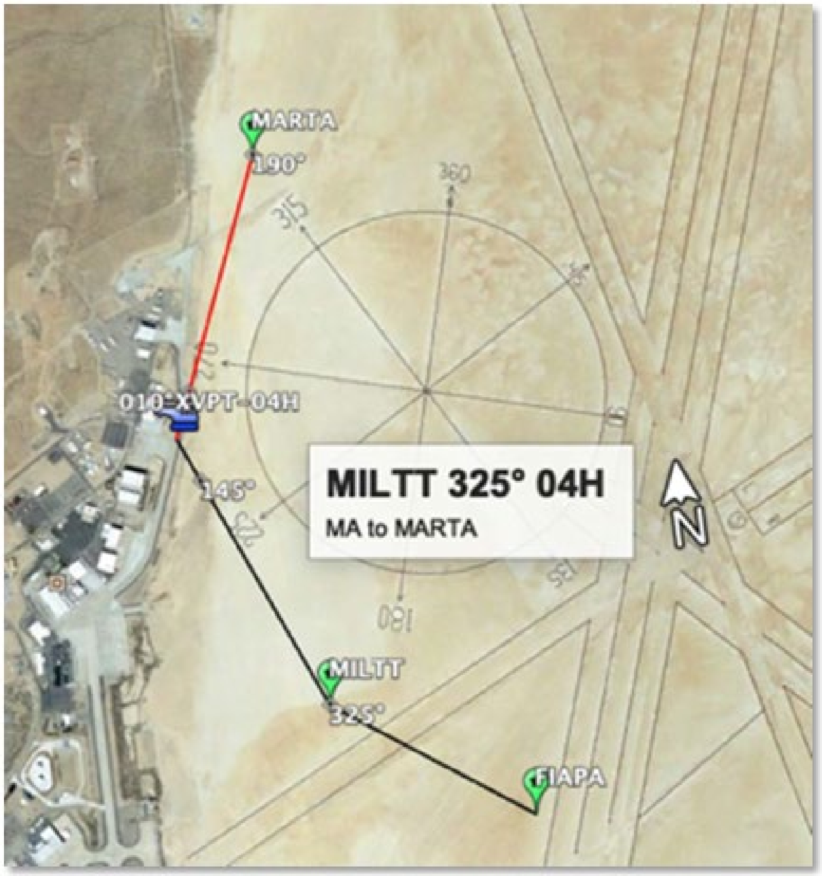

EDWARDS, CALIFORNIA
APP CRS
280°
TDZE 2279
Apt Elev 2311
FREDD 280 (04H)
NASA NEIL A. ARMSTRONG FLT RESEARCH CENTER (EDW)
MISSED APPROACH: Climbing LEFT turn to 2800, report INBOUND from CHIP
ATIS
127.425 269.9
TOWER
120.7 (CTAF) 318.1 (CTAF)
GND CON
121.8 225.4
FOR NASA TRAINING AND RESEARCH ONLY
AIRCRAFT WILL MAINTAIN VFR
MISSED APCH FIX
CHIP
04H
280°
2800
270°
FREDD
2800
0.5 NM
FROM
04H
CHIP
2800
02 MAR 2021 to 02 MAR 2022
ELEV 2311
TDZE 2279
N
2800
CHIP
CHIP
FREDD
2800
270°
280°
2289
04H
GP 9.00°
TCH 0
2800
0.5 NM
0.5 NM
EDWARDS, CALIFORNIA
02MAR21
NASA NEIL A. ARMSTRONG FLT RESEARCH CENTER (EDW)
FREDD 280 (04H)
34°57' 13.37"N-117°52' 58.08"W

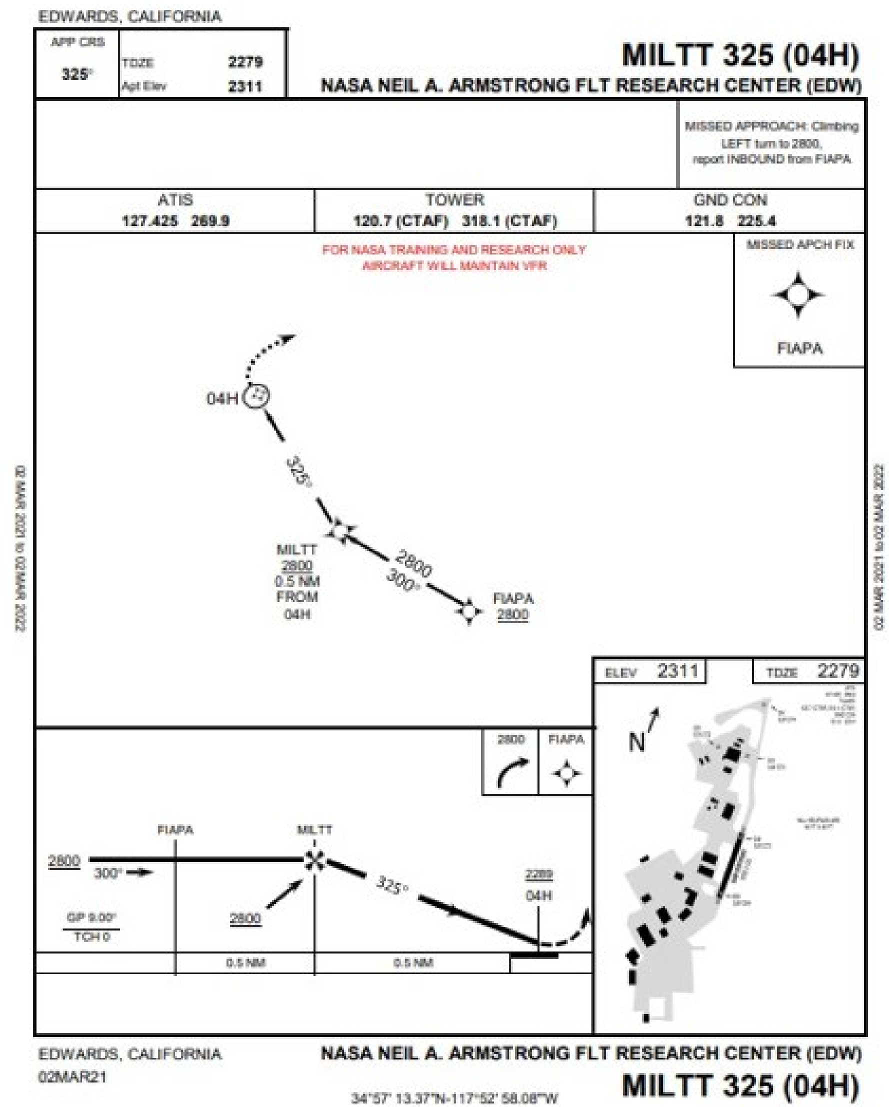
BILLD 280


MARTA
214°
BILLD 280°L 05H
MA to MARTA
N
34-XVPT-05H
100°
CHIP
BILLD
280° L


EDWARDS, CALIFORNIA
APP CRS
280°
TDZE 2279
Apt Elev 2311
BILLD 280 (05H)
NASA NEIL A. ARMSTRONG FLT RESEARCH CENTER (EDW)
MISSED APPROACH: Climbing RIGHT turn to 2800, report INBOUND from CHIP
ATIS
127.425 269.9
TOWER
120.7 (CTAF) 318.1 (CTAF)
GND CON
121.8 225.4
FOR NASA TRAINING AND RESEARCH ONLY
AIRCRAFT WILL MAINTAIN VFR
MISSED APCH FIX
CHIP
05H
280°
2800
270°
BILLD
2800
0.5 NM
FROM 05H
CHIP
2800
02 MAR 2021 to 02 MAR 2022
ELEV 2311
TDZE 2279
N
2800
CHIP
BILLD
2800
280°
GP 9.00°
TCH 0
05H
0.5 NM
0.5 NM
EDWARDS, CALIFORNIA
02MAR21
NASA NEIL A. ARMSTRONG FLT RESEARCH CENTER (EDW)
34°57' 13.37"N-117°52' 58.08"W
BILLD 280 (05H)

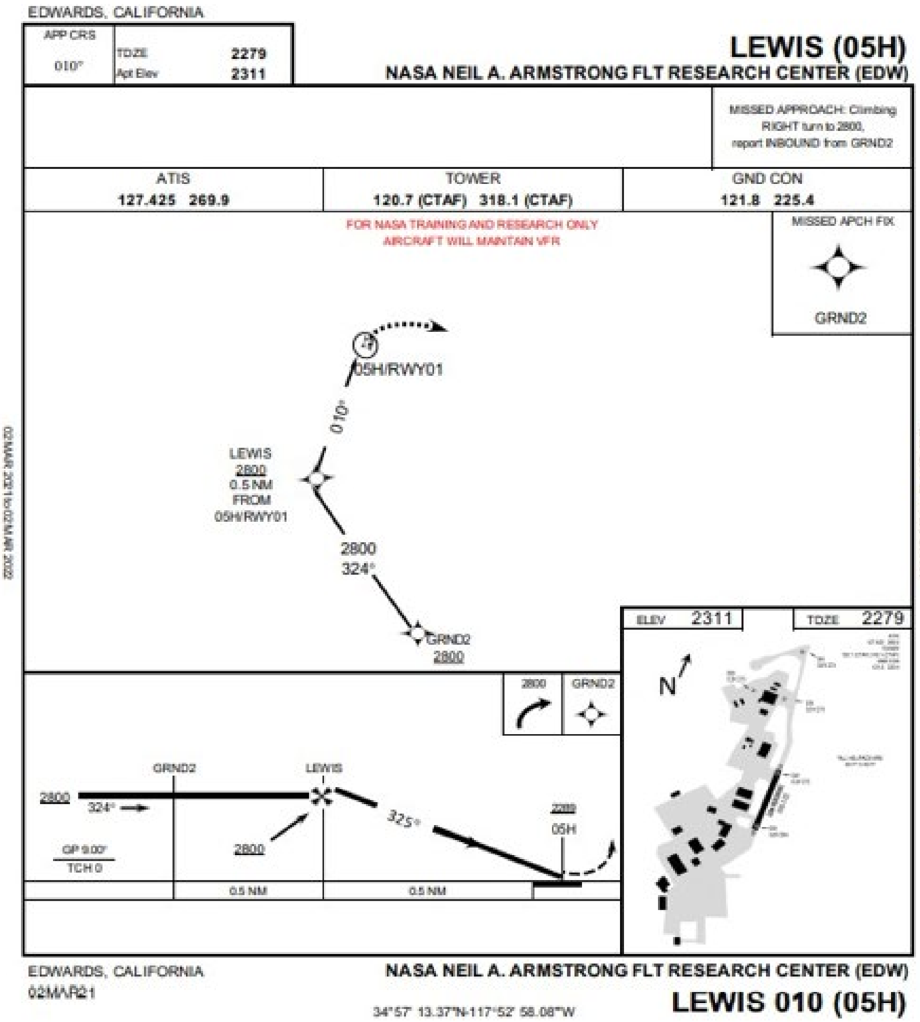
MILTT 325


MARTA
190°
360
315
010-XVPT-04H
145°
MILTT 325° 04H
MA to MARTA
N
180
MILTT
325°
FIAPA

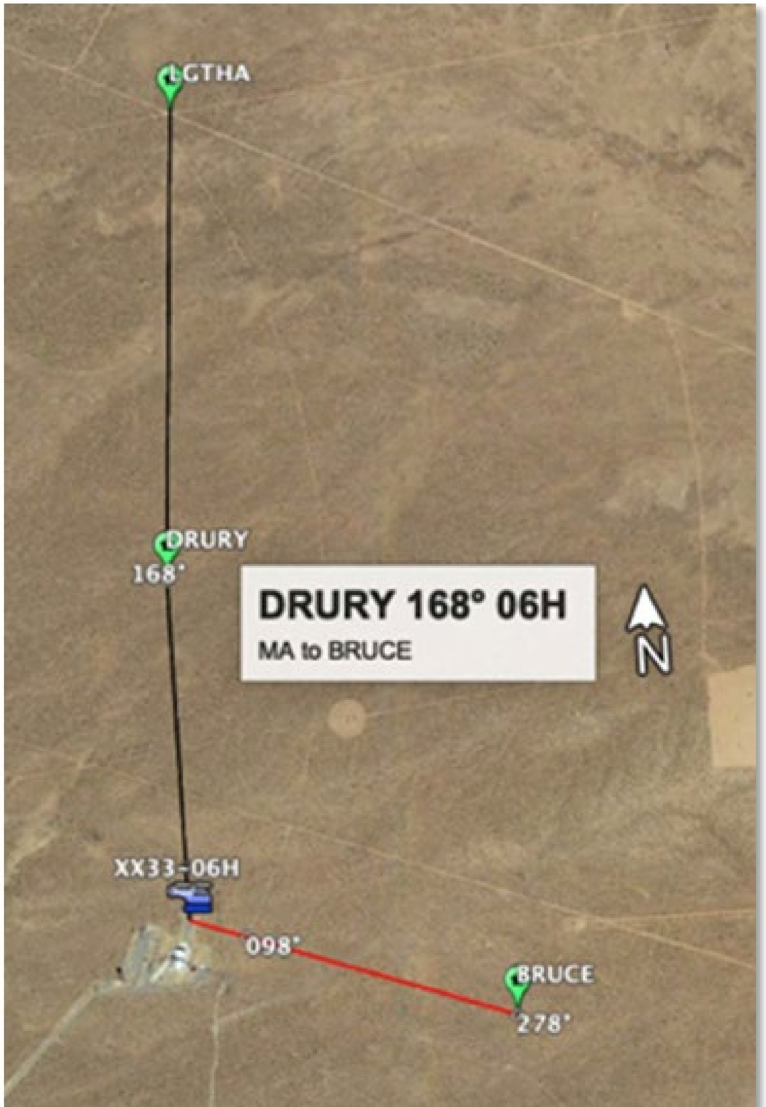

EDWARDS, CALIFORNIA
APP CRS
325°
TDZE 2279
Apt Elev 2311
MILTT 325 (04H)
NASA NEIL A. ARMSTRONG FLT RESEARCH CENTER (EDW)
MISSED APPROACH: Climbing LEFT turn to 2800, report INBOUND from FIAPA
ATIS
127.425 269.9
TOWER
120.7 (CTAF) 318.1 (CTAF)
GND CON
121.8 225.4
FOR NASA TRAINING AND RESEARCH ONLY
AIRCRAFT WILL MAINTAIN VFR
MISSED APCH FIX
FIAPA
04H
325°
MILTT
2800
0.5 NM
FROM
04H
2800
300°
FIAPA
2800
ELEV 2311
TDZE 2279
N
2800
FIAPA
FIAPA
MILTT
2800
300°
325°
2289
04H
GP 9.00°
TCH 0
2800
0.5 NM
0.5 NM
EDWARDS, CALIFORNIA
02MAR21
NASA NEIL A. ARMSTRONG FLT RESEARCH CENTER (EDW)
MILTT 325 (04H)
34°57' 13.37"N-117°52' 58.08"W
02 MAR 2021 to 02 MAR 2022

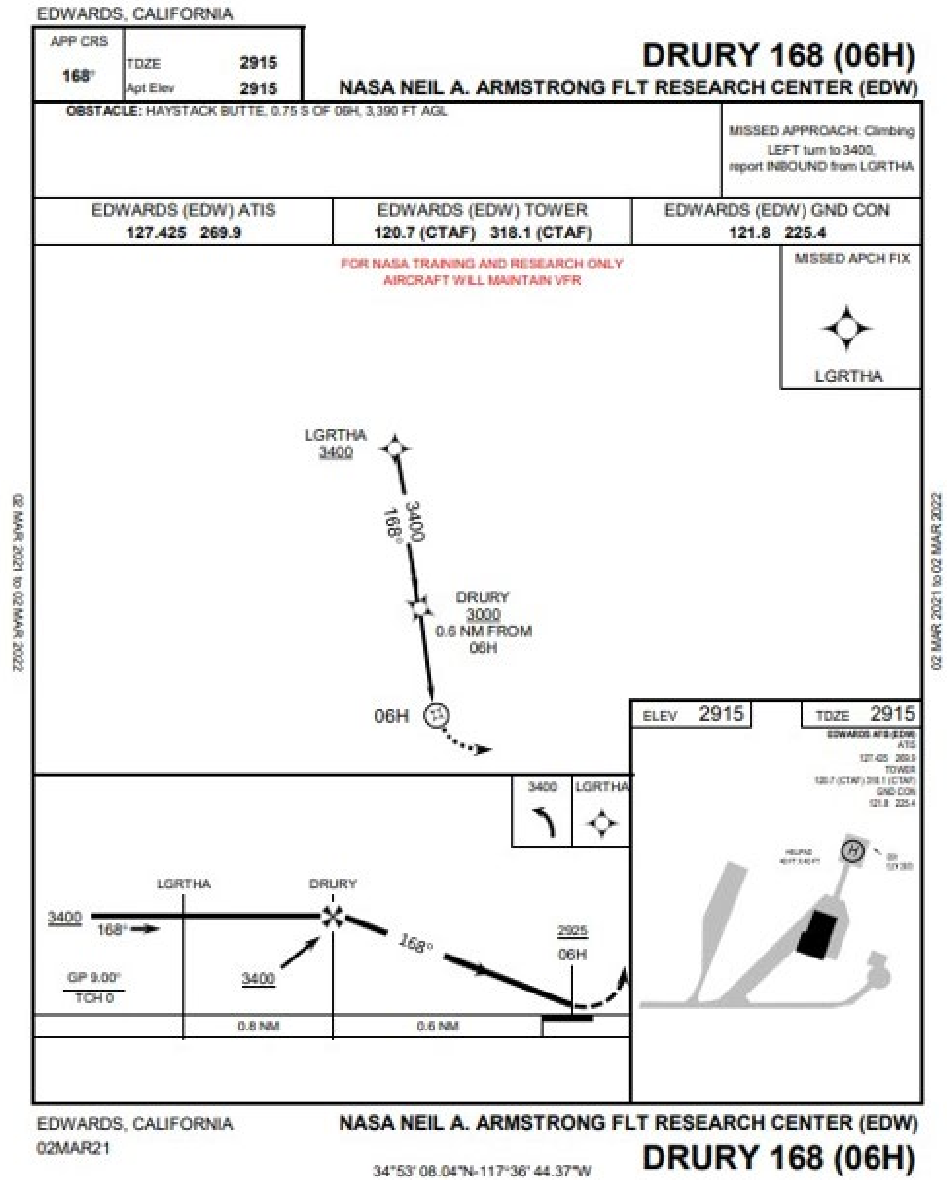
LEWIS 010


TERPS
252°
190°
LEWIS 12°
010°
LEWIS 12° 010° 05H
MA to TERPS
N
GRND2

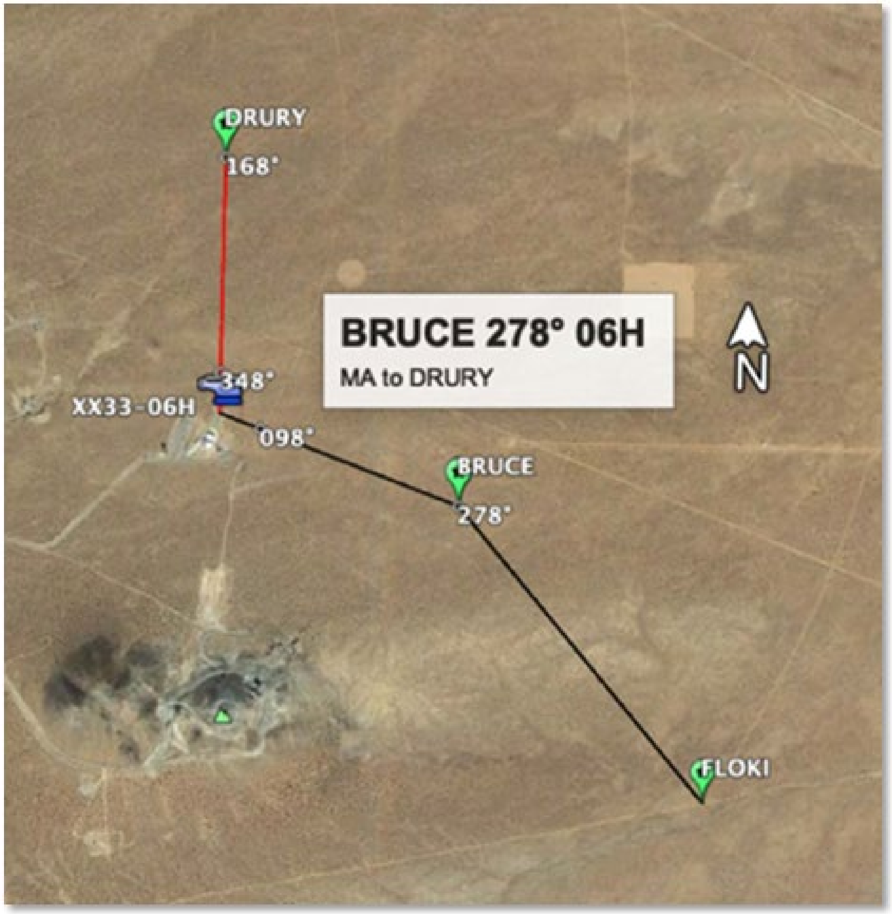

EDWARDS, CALIFORNIA
APP CRS
010°
TDZE 2279
Apt Elev 2311
LEWIS (05H)
NASA NEIL A. ARMSTRONG FLT RESEARCH CENTER (EDW)
MISSED APPROACH: Climbing RIGHT turn to 2800, report INBOUND from GRND2
ATIS
127.425 269.9
TOWER
120.7 (CTAF) 318.1 (CTAF)
GND CON
121.8 225.4
FOR NASA TRAINING AND RESEARCH ONLY
AIRCRAFT WILL MAINTAIN VFR
MISSED APCH FIX
GRND2
05H/RWY01
010°
LEWIS
2800
0.5 NM
FROM
05H/RWY01
2800
324°
GRND2
2800
ELEV 2311
TDZE 2279
N
2800
GRND2
GRND2
LEWIS
2800
324°
325°
05H
2800
GP 0.00°
TCH 0
0.5 NM
0.5 NM
EDWARDS, CALIFORNIA
02MAR21
NASA NEIL A. ARMSTRONG FLT RESEARCH CENTER (EDW)
34°57' 13.37"N-117°52' 58.08"W
LEWIS 010 (05H)

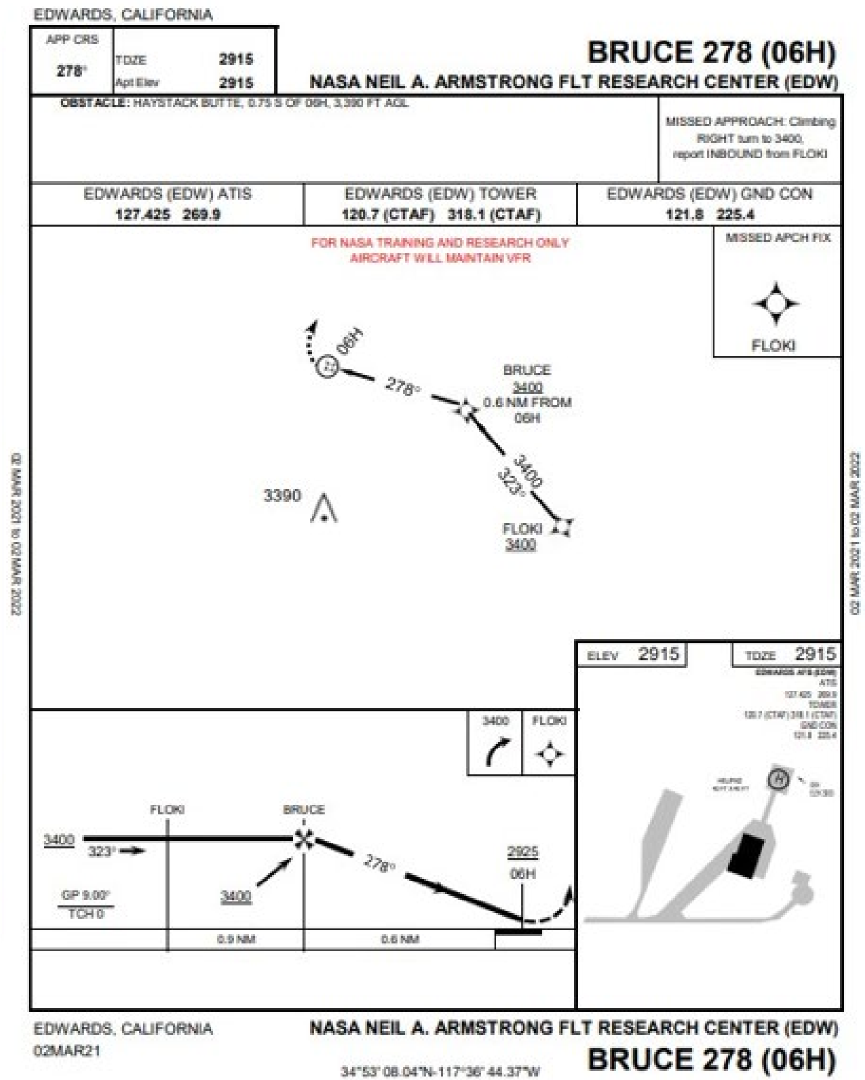
DRURY 168


LGTHA
DRURY
168°
DRURY 168° 06H
MA to BRUCE
N
XX33-06H
098°
BRUCE
278°


EDWARDS, CALIFORNIA
APP CRS 168°
TDZE 2915
Apt Elev 2915
DRURY 168 (06H)
NASA NEIL A. ARMSTRONG FLT RESEARCH CENTER (EDW)
OBSTACLE: HAYSTACK BUTTE, 0.75 S OF 06H, 3,390 FT AGL
MISSED APPROACH: Climbing LEFT turn to 3400, report INBOUND from LGRTHA
EDWARDS (EDW) ATIS 127.425 269.9
EDWARDS (EDW) TOWER 120.7 (CTAF) 318.1 (CTAF)
EDWARDS (EDW) GND CON 121.8 225.4
FOR NASA TRAINING AND RESEARCH ONLY
AIRCRAFT WILL MAINTAIN VFR
MISSED APCH FIX
LGRTHA
LGRTHA 3400
3400
168°
DRURY 3000 0.6 NM FROM 06H
06H
02 MAR 2021 to 02 MAR 2022
ELEV 2915
TDZE 2915
3400 LGRTHA
LGRTHA
DRURY
3400
168°
168°
2925
06H
GP 9.00°
TCH 0
3400
0.8 NM
0.6 NM
EDWARDS, CALIFORNIA
02MAR21
NASA NEIL A. ARMSTRONG FLT RESEARCH CENTER (EDW)
34°53' 08.04"N-117°36' 44.37"W
DRURY 168 (06H)

BRUCE 278


DRURY
168°
BRUCE 278° 06H
MA to DRURY
N
348°
XX33-06H
098°
BRUCE
278°
FLOKI


EDWARDS, CALIFORNIA
APP CRS
278°
TDZE 2915
Apt Elev 2915
BRUCE 278 (06H)
NASA NEIL A. ARMSTRONG FLT RESEARCH CENTER (EDW)
OBSTACLE: HAYSTACK BUTTE, 0.75 S OF 06H, 3,390 FT AGL
MISSED APPROACH: Climbing RIGHT turn to 3400, report INBOUND from FLOKI
EDWARDS (EDW) ATIS 127.425 269.9
EDWARDS (EDW) TOWER 120.7 (CTAF) 318.1 (CTAF)
EDWARDS (EDW) GND CON 121.8 225.4
FOR NASA TRAINING AND RESEARCH ONLY
AIRCRAFT WILL MAINTAIN VFR
MISSED APCH FIX
FLOKI
06H
278°
BRUCE
3400
0.6 NM FROM 06H
3400
323°
3390
FLOKI
3400
02 MAR 2021 to 02 MAR 2022
ELEV 2915
TDZE 2915
3400
FLOKI
FLOKI
BRUCE
3400
323°
278°
2925
06H
GP 9.00°
TCH 0
3400
0.9 NM
0.6 NM
EDWARDS, CALIFORNIA
02MAR21
NASA NEIL A. ARMSTRONG FLT RESEARCH CENTER (EDW)
34°53' 08.04"N-117°36' 44.37"W
BRUCE 278 (06H)

6.6 Data Element Cards

Data Element Card

Title	**Cruise Noise Evaluation**		
Data Element Type	Static		
Scenario	4	UTE	
Metric Type	Infrastructure	Maneuver	NA
Phase of Flight	Preflight	Event	Range Flight
Objective			
To acquire vehicle source noise during forward flight cruise through ground based acoustic measurements. Data will be processed and used to characterize the noise footprint during this phase of flight.			
Configuration			
Cruise/forward flight vehicle configuration			
Test Conditions			
Light to no winds at altitude			
No fog if VFR			
No anomalous thermal inversions			
Minimal background noise with comparable levels to those measured during test setup			
Description			
1. The pilot will approach the acoustic array from a sufficiently large distance and prepare to be on the prescribed test point condition before crossing a predefined location prior to the acoustic array. 2. Once on condition, the pilot will make any last adjustments to ensure the flight path is centered with the ground microphone array and at the predefined altitude. 3. Notification will be sent that acoustic acquisition has begun. 4. The pilot will maintain the prescribed constant flight speed and limit control input throughout the flyover event. 5. The test point is complete when the pilot has been notified that acoustic data recording has stopped. 6. The pilot will then maneuver out as desired and set up for the subsequent test point.			
Notes			
Noise during cruise/forward flight will be conducted over several test points at different airspeeds and other parameters that are of typical cruise operation specific to the vehicle being tested.			
Test Course Description			
The course may take the form of a racetrack loop (GA-like traffic pattern), in which a single straight leg of the loop would be centered over the array for a flyover event. Ground markers will be deployed to visually indicate reference points along the flight path. For example, the crossing point in which the pilot should be on condition will be appropriately marked; the center of the array may also be clearly marked with a series of reflective banners.			
Reference Guidance			
Adequate Criteria	Acquire acoustic data during flyover events representative of cruise/forward flight		
Desired Criteria	Pass: Prescribed fight condition performed along the prescribed track under benign environmental conditions; Fail: Off track, off condition, undesired variability of control inputs, or inappropriate environmental conditions		
Instrumentation Package			
Task			
Adequate		Desired	
Instrumentation Package			
Name		Resolution	
Requirements			
NASA POC	Kyle Pascioni	Email	
Alternate NASA POC	Erin Waggoner	Email	
FAA FOCAL POC		Email	
FAA Policy POC		Email	
FAA Technical POC		Email	
FAA Technical POC		Email	
Minimum Equipment List			
Microphone array			
Weather monitoring systems			
Aircraft tracking module			
Data Collection Requirements			
High Precision Lat/Long in degrees or radians			
High quality acoustic pressure time series over all microphone channels			
Wind speed and direction on ground and at altitude			

Data Element Card

Title	ARINC 424 Approach Coding		
Data Element Type	Dynamic		
Scenario	1	UTE	
Metric Type	Airspace	Maneuver	NA
Phase of Flight	Inflight	Event	Range Flight
Objective			
Code heliport/helipad and approach records for Route Discovery Scenario 1. Define heliports, helipads, & enroute waypoints. **4.1.4 Waypoint Record (EA):** The Enroute Waypoint file (EA) contains all enroute on-airway and off-airway waypoints within a desired geographical area. **4.2.1 Heliport Records (HA)** **4.2.3 Heliport Approach (HF)** **4.2.9 Heliport Helipad Record (HH)**			
Configuration			
NA			
Test Conditions			
1. Apply results from site survey (lat/lon, elevations) for application to fixes			
2. Load data into FIAPA software			
3. Identify coding errors, if applicable			
Description			
Procedures do not exist for Route Discovery Scenario 1 and other demonstrations for advanced air mobility, therefore we want to explore the steps necessary to create ARINC 424 coding for the new vehicle routes. 1. Demonstrate how FIAPA can be utilized to inspect approach heliport routes for safe operations of Advanced Air Mobility. 2. Fly and inspect automation accuracies in coding			
Notes			
Test Course Description			
Reference Guidance			
FAR Part 139 Airport Certification			
FAA Order 8260 Series			
AC150/5390-2C Heliport Design			
14 CFR §77.23 Heliport imaginary surfaces			
ARINC SPECIFICATION 424-22			
Adequate Criteria	Survey is sufficient to identify errors for coding		
Desired Criteria	Propery survey data is avialable to build error-free coding		
Instrumentation Package			
Task	High Precision Lat/Long		
Adequate	0.01 degrees	Desired	0.0005 degrees
Instrumentation Package			
Name	dGPS	Resolution	0.1
Task	Field Elevation		
Adequate	.01 Ft	Desired	.001 Ft
Instrumentation Package			
Name		Resolution	
Task	Altitude		
Adequate		Desired	FAA Order 8260 Series
Instrumentation Package			
Name	Laser Range Finder	Resolution	FAA Order 8260 Series
Task	Altitude		
Adequate		Desired	FAA Order 8260 Series
Instrumentation Package			
Name	Air Data Computer 3000	Resolution	FAA Order 8260 Series
Task	Inertial Reference Unit		
Adequate		Desired	FAA Order 8260 Series
Instrumentation Package			
Name	Model HG 2195 AB	Resolution	FAA Order 8260 Series
Requirements			
NASA POC	David Zahn	Email	david.zahn@nasa.gov
Alternate NASA POC	Faisal Omar / RJ Harris	Email	faisal.g.omar@nasa.gov
FAA FOCAL POC		Email	
FAA Policy POC	Jay Sandwell / Brad Snelling	Email	Jay.Sandwell@faa.gov
FAA Technical POC	Ben James	Email	Ben.James@faa.gov
FAA Technical POC		Email	
Minimum Equipment List			
GNSS receiver			
Data Collection Requirements			
High Precision Lat/Long in degrees or radians			
Field elevation to the tenth of Foot			

Data Element Card

Title	**Spatial Data Integrity Validation**		
Data Element Type	Static		
Scenario	1	UTE	
Metric Type	Airspace	Maneuver	N/A
Phase of Flight	Preflight	Event	Range Flight
Objective			
To obtain standard deviations of spatial data providers to UAM navigation services in the vertical and horizontal axis. Compare and contract the fidelity of Digital Terrain Evaluation Databases (DTED) in use for UAM flight planning of point in space departure and			
Configuration			
N/A			
Test Conditions			
1. Select test site locations			
2. Conduct site survey			
3 Establish Baseline Lat/Long and Field elevation			
4. Run test digital terrain databases			
5. Compare and plot deviation data points			
Description			
In order to establish On demand mobility, high precision lat/longs must be established for each landing site, as site surveys will not be readily available to service operational urban enviroments like Dallas or San Francisco. UAM services to the prospective metropolis will depend on an accurate DTED for safe launch and recovery of flight. With respect to automation accuracies in coding, route conformance, containment areas (RNP), and bias errors will hinge entirely on the integrity of the spatial data at the take-off and landing surface.			
Notes			
Must reference to common datum (identify datum error typically ~6ft. Horizontal/Vertical). Must know true value to comapre sd			
Test Course Description			
Reference Guidance			
FAR Part 139 Airport Certification			
FAA Order 8260 Series			
AC150/5390-2C Heliport Design			
14 CFR §77.23 Heliport imaginary surfaces			
Adequate Criteria	NA		
Desired Criteria	NA		
Instrumentation Package			
Task	High Precision Lat/Long		
Adequate	0.01 degrees	Desired	0.0005 degrees
Instrumentation Package			
Name	SBSM	Resolution	0.1
Task	High Precision Lat/Long		
Adequate	0.01 degrees	Desired	0.0005 degrees
Instrumentation Package			
Name	TARGETS	Resolution	0.1
Task	High Precision Lat/Long		
Adequate	0.01 degrees	Desired	0.0005 degrees
Instrumentation Package			
Name	Google Earth	Resolution	0.01
Task	High Precision Lat/Long		
Adequate	0.005 degrees	Desired	0.0005 degrees
Instrumentation Package			
Name	FIAPA	Resolution	.0005 degrees
Task	Field Elevation		
Adequate	.01 Ft	Desired	0.001 Ft
Instrumentation Package			
Name	SBSM	Resolution	.01 Ft
Task	Field Elevation		
Adequate	.01 Ft	Desired	.001 Ft
Instrumentation Package			
Name	TARGETS	Resolution	0.001
Task	Field Elevation		
Adequate	.01 Ft	Desired	.001 Ft
Instrumentation Package			
Name	Google Earth	Resolution	.01 Ft
Task	Field Elevation		
Adequate	.01 Ft	Desired	.001 Ft
Instrumentation Package			
Name	FIAPA	Resolution	.001 Ft
Requirements			
NASA POC	David Zahn	Email	
Alternate NASA POC	Erin Waggoner	Email	
FAA FOCAL		Email	
FAA Policy POC	Keri Lyons	Email	
FAA Technical POC	Wesley Major & Robert Bassey	Email	
FAA Technical POC	Jay Sandwell	Email	
Minimum Equipment List			
Garmin GPS locator			
SBSM DTED			
FIAPA Tablet			
Google Earth DTED			
TARGETS DTED			
Data Collection Requirements			
High Precision Lat/Long in degrees or radians			
Field elevation to the tenth of Foot			

Data Element Card

Title	Navigation ADSB Monitoring (SBSM)		
Data Element Type	Dynamic		
Scenario	1	UTE	
Metric Type	Airspace	Maneuver	N/A
Phase of Flight	Inflight	Event	Range Flight
Objective			
Monitor ADSB system output for navigation, postion, source strength and system integrity for UAM application and route conformance. Research will be conducted utilizing the highest levels of conformance to validate UAM vehicles adhereance to prescribed flight paths and required navigation performance (RNP) parameters. Additonal research will be conducted on contingecy management through applicable distress fields, message latency and the SBSM system ability to alert governing authority in realtime.			
Configuration			
N/A			
Test Conditions			
1. Track and monitor NIC values			
2. Track and monitor NACp - NACv values			
3. Track and monitor SIL values			
4.Track and monitor SDA values			
5. Digitally reconstructing 3D flight			
Description			
Researching low level routing in a condensed enviroment and exploring ways to flight follow, deconflict closely spaced containment areas for UAM, UAS, and general aircraft in the NAS. Utilizing SBSM system to help FAA track, enforce and monitor future state UAM			
Notes			
Determine what mode 3A flight will be needed to deconflict and monitor UAM airspace/Traffic. Establish parameters for Time Span Validation. Determine Secondary surveilleince source for GPS accuracy (Radar track, WAM, TDOA, WAM2), and Geographic Probability of Detection for UAM operations.			
Test Course Description			
Reference Guidance			
FAR Part 139 Airport Certification			
FAA Order 8260 Series			
AC150/5390-2C Heliport Design			
14 CFR §77.23 Heliport imaginary surfaces			
Adequate Criteria	NA		
Desired Criteria	NA		
Instrumentation Package			
Task	Velocity tracking		
Required	300 m/s	Desired	150 m/s
Instrumentation Package			
Name	SBSM	Resolution	0.25 kts
Task	Acceleration Tracking		
Required	10 m/s^2	Desired	6 m/s^2
Instrumentation Package			
Name	SBSM	Resolution	0.25^2 kts
Task	Lat/Long Jump Between Time Span		
Required	2624.67 ft (800 Meters)	Desired	180 ft (55 Meters)
Instrumentation Package			
Name	SBSM	Resolution	0.01 Degree
Task	Altitude Miscompare (GPS - Pressure Altitude) (Raw vs Adjusted)		
Required	2000 Ft	Desired	50 Ft
Instrumentation Package			
Name	SBSM	Resolution	25ft (ADSB) (6.25 ft Ability)
Task	Time Span Validation (Update Interval latency)		
Required	2 secs (time of generated position to transmission)	Desired	700 ms
Instrumentation Package			
Name	SBSM	Resolution	250 ms
Task	Navigational Accurancy Code (Position) (NACp)		
Required		Desired	
Instrumentation Package			
Name	SBSM	Resolution	
Task	Navigational Accuracy Code (Vertical) (NACv)		
Required		Desired	
Instrumentation Package			
Name		Resolution	
Task	Navigational Integrity Code (NIC)		
Required		Desired	
Instrumentation Package			
Name		Resolution	
Task	System Desgin Assurance (SDA)		
Required		Desired	
Instrumentation Package			
Name		Resolution	
Task	Source Integrity Level (SIL)		
Required		Desired	
Instrumentation Package			
Name		Resolution	
Requirements			
NASA POC	David Zahn	Email	
Alternate NASA POC	Faisal Omar / Savvy Verma	Email	
FAA FOCAL		Email	
FAA Policy POC	Alex Moreno	Email	
FAA Technical POC	Wilson Fish	Email	
FAA Technical POC	Wade Price	Email	
Minimum Equipment List			
SBMS			
ATI Lab			
Data Collection Requirements			
High Precision Lat/Long in degrees or radians			
Field elevation to the tenth of Foot			

Data Element Card

Title	**ARINC 424 Approach Coding**		
Data Element Type	Dynamic		
Scenario	1	UTE	MTE 6
Metric Type	Airspace	Maneuver	NA
Phase of Flight	Inflight	Event	Range Evaluation
Objective			
Code heliport/helipad and approach records for Route Discovery Scenario 1. Define heliports, helipads, & enroute waypoints. **4.1.4 Waypoint Record (EA)**: The Enroute Waypoint file (EA) contains all enroute on-airway and off-airway waypoints within a desired geographical area. **4.2.1 Heliport Records (HA)** **4.2.3 Heliport Approach (HF)** **4.2.9 Heliport Helipad Record (HH)**			
Configuration			
NA			
Test Conditions			
1. Apply results from site survey (lat/lon, elevations) for application to fixes			
2. Load data into FIAPA software			
3. Identify coding errors, if applicable			
Description			
Procedures do not exist for Route Discovery Scenario 1 and other demonstrations for advanced air mobility, therefore we want to explore the steps necessary to create ARINC 424 coding for the new vehicle routes. 1. Demonstrate how FIAPA can be utilized to inspect approach heliport routes for safe operations of Advanced Air Mobility. 2. Fly and inspect automation accuracies in coding			
Notes			
Test Course Description			
Reference Guidance			
FAR Part 139 Airport Certification			
FAA Order 8260 Series			
AC150/5390-2C Heliport Design			
14 CFR §77.23 Heliport imaginary surfaces			
ARINC SPECIFICATION 424-22			
Adequate Criteria	Survey is sufficient to identify errors for coding		
Desired Criteria	Propery survey data is avialable to build error-free coding		
Instrumentation Package			
Task	High Precision Lat/Long		
Adequate	0.01 degrees	Desired	0.0005 degrees
Instrumentation Package			
Name	dGPS	Resolution	0.1
Task	Field Elevation		
Adequate	.01 Ft	Desired	.001 Ft
Instrumentation Package			
Name		Resolution	
Task	Altitude		
Adequate		Desired	FAA Order 8260 Series
Instrumentation Package			
Name	Laser Range Finder	Resolution	FAA Order 8260 Series
Task	Altitude		
Adequate		Desired	FAA Order 8260 Series
Instrumentation Package			
Name	Air Data Computer 3000	Resolution	FAA Order 8260 Series
Task	Inertial Reference Unit		
Adequate		Desired	FAA Order 8260 Series
Instrumentation Package			
Name	Model HG 2195 AB	Resolution	FAA Order 8260 Series
Requirements			
NASA POC	David Zahn	Email	david.zahn@nasa.gov
Alternate NASA POC	Faisal Omar / RJ Harris	Email	faisal.g.omar@nasa.gov
FAA FOCAL POC		Email	
FAA Policy POC	Jay Sandwell / Brad Snelling	Email	Jay.Sandwell@faa.gov
FAA Technical POC	Ben James	Email	Ben.James@faa.gov
FAA Technical POC		Email	
FAA Technical POC		Email	
Minimum Equipment List			
GNSS receiver			
Data Collection Requirements			
High Precision Lat/Long in degrees or radians			
Field elevation to the tenth of Foot			

Data Element Card

Title	**Spatial Data Integrity Validation**		
Data Element Type	Static		
Scenario	1	UTE	
Metric Type	Infrastructure	Maneuver	NA
Phase of Flight	Preflight	Event	Range Flight
Objective			
To obtain standard deviations of spatial data providers to UAM navigation services in the vertical and horizontal axis. Compare and contract the fidelity of Digital Terrain Evaluation Databases (DTED) in use for UAM flight planning of point in space departure and			
Configuration			
N/A			
Test Conditions			
1. Select test site locations			
2. Conduct site survey			
3 Establish Baseline Lat/Long and Field elevation			
4. Run test digital terrain databases			
5. Compare and plot deviation data points			
Description			
In order to establish On demand mobility, high precision lat/longs must be established for each landing site, as site surveys will not be readily available to service operational urban enviroments like Dallas or San Francisco. UAM services to the prospective metropolis will depend on an accurate DTED for safe launch and recovery of flight. With respect to automation accuracies in coding, route conformance, containment areas (RNP), and bias errors will hinge entirely on the integrity of the spatial data at the take-off and landing surface.			
Notes			
Must reference to common datum (identify datum error typically ~6ft. Horizontal/Vertical). Must know true value to comapre sd			
Test Course Description			
Reference Guidance			
FAR Part 139 Airport Certification			
FAA Order 8260 Series			
AC150/5390-2C Heliport Design			
14 CFR §77.23 Heliport imaginary surfaces			
Adequate Criteria	NA		
Desired Criteria	NA		
Instrumentation Package			
Task	High Precision Lat/Long		
Adequate	0.01 degrees	Desired	0.0005 degrees
Instrumentation Package			
Name	SBSM	Resolution	0.1
Task	High Precision Lat/Long		
Adequate	0.01 degrees	Desired	0.0005 degrees
Instrumentation Package			
Name	TARGETS	Resolution	0.1
Task	High Precision Lat/Long		
Adequate	0.01 degrees	Desired	0.0005 degrees
Instrumentation Package			
Name	Google Earth	Resolution	0.01
Task	High Precision Lat/Long		
Adequate	0.005 degrees	Desired	0.0005 degrees
Instrumentation Package			
Name	FIAPA	Resolution	.0005 degrees
Task	Field Elevation		
Adequate	.01 Ft	Desired	0.001 Ft
Instrumentation Package			
Name	SBSM	Resolution	.01 Ft
Task	Field Elevation		
Adequate	.01 Ft	Desired	.001 Ft
Instrumentation Package			
Name	TARGETS	Resolution	0.001
Task	Field Elevation		
Adequate	.01 Ft	Desired	.001 Ft
Instrumentation Package			
Name	Google Earth	Resolution	.01 Ft
Task	Field Elevation		
Adequate	.01 Ft	Desired	.001 Ft
Instrumentation Package			
Name	FIAPA	Resolution	.001 Ft
Requirements			
NASA POC	David Zahn	Email	
Alternate NASA POC	Erin Waggoner	Email	
FAA FOCAL POC		Email	
FAA Policy POC	Keri Lyons	Email	
FAA Technical POC	Wesley Major & Robert Bassey	Email	
FAA Technical POC	Jay Sandwell	Email	
Minimum Equipment List			
Garmin GPS locator			
SBSM DTED			
FIAPA Tablet			
Google Earth DTED			
TARGETS DTED			
Data Collection Requirements			
High Precision Lat/Long in degrees or radians			
Field elevation to the tenth of Foot			

Data Element Card

Title	**Vertiport Evaluation**		
Data Element Type	Static		
Scenario	1	UTE	
Metric Type	Infrastructure	Maneuver	NA
Phase of Flight	Preflight	Event	Range Flight
Objective			
The objective of Vertiport Evalution is to baseline Airport and Heliport standards, regulations, and criteria to identify operational safety gaps in vertiport deisgn, evaluation and integration. The resulting analysis will drive FATO, TLOF, Safety Area, Well clear and Parking Separation.			
Configuration			
N/A			
Test Conditions			
1. Establish projected landing site location			
2. Perform Airport and Airspace Analysis for UAM operations			
3. Determine safety area boundaries			
4 Establish terrain and vertical obstruction clearances			
5. Determine power sourcing to landing site			
6. Establish acoustic noise abatement impacts			
7. Identify orographic effects of wind			
8. Delta ISA- Crtical High and Critical Low			
Description			
The National Campaign team will evaluate the proposed landing surface against design guidance, hazard materials management, safety marking and lighting, in an effort to baseline UAM operational assumptions and identify gaps in safety. The evaluation will serve as a performanced based, point in space, take off and land surface against proposed minimum UAM vehicle performance standards in which to anchor precision take-off and landing profiles.			
Notes			
weather- predominant wind...limit cross-wind operations...calculate critical high and low for standard vehicle instrumentation at facility placard			
Test Course Description			
N/A			
Reference Guidance			
14 CFR §139 Certification of Airports			
FAA Order 8260 Series			
AC150/5390-2C Heliport Design			
Airport Circulars Landing Page			
FAA Advisory Circular, AC 70/7460-1L, Obstruction Marking & Lighting			
FSIMS 8900.1 Vol-8, Chp-3, Sec-3, Evaluation & Surveillance of Heliports			
14 CFR §157 - Notice Of Construction, Alteration, Activation, And Deactivation Of Airports			
14 CFR §77.23 Heliport imaginary surfaces			
PART 77 SAFE, EFFICIENT USE, AND PRESERVATION OF THE NAVIGABLE AIRSPACE			
Adequate Criteria	NA		
Desired Criteria	NA		
Instrumentation Package			
Task			
Adequate		Desired	
Instrumentation Package			
Name		Resolution	
Requirements			
NASA POC	Erin Waggoner	Email	
Alternate NASA POC	David Zahn	Email	
FAA FOCAL POC		Email	
FAA Policy POC	Wesley Major, Robert Bassey	Email	
FAA Technical POC		Email	
FAA Technical POC	Keri Lyons	Email	
Minimum Equipment List			
Garmin Hand Held			
SBSM			
FIAPA Tablet			
Google Earth			
TARGETS			
Data Collection Requirements			
Site Survey			
Range diagrams			
Safety area distances			
minor weather study for prevailing wind conditions			

Data Element Card

Title	**Vertiport Registration**		
Data Element Type	Static		
Scenario	1	UTE	
Metric Type	Infrastructure	Maneuver	N/A
Phase of Flight	Preflight	Event	Range Flight
Objective			
Obtain vertiport registration for operations governing piloted, simplified/optionally piloted, remote-piloted, and autonomous systems utilizing vertical take off and land profiles.			
Configuration			
N/A			
Test Conditions			
1. Submit Notice of Construction (Modified 7480) – Annex 1			
2. Conduct site survey (TSI/ASI) – Annex 2			
3. Receive notional Letter of Determination (TSI/ASI) – Annex 3			
4. Vertiport Master Record (5410) – Annex 4			
5. Grant notional Activation Letter – Annex 5			
Description			
Vertiport Registry will consist of industry partner submitting a modified Grand Challenge Notice of Construction form (7480), which will initiate a TSI/ASI site survey that will account for piloted, remote-piloted, and autonomous operations to and from the prospective vertiport. A notional Letter of Determination, Master Record (5410) and Activation Letter will be produced by grand challenge team through current regulations while identifying gaps in safety for UAM operations.			
Notes			
Test Course Description			
This task may be performed using the ADS-33E hover course with the designated landing point being directly under the reference point on the aircraft when the pilot's eye is at the hover point. Refer to figure XX for an example course.			
Reference Guidance			
FAR Part 139 Airport Certification			
FAA Order 8260 Series			
AC150/5390-2C Heliport Design			
Adequate Criteria	NA		
Desired Criteria	NA		
Instrumentation Package			
Task			
Adequate		Desired	
Instrumentation Package			
Name		Resolution	
Requirements			
NASA POC	David Zahn	Email	
Alternate NASA POC	Erin Waggoner	Email	
FAA FOCAL POC		Email	
FAA Policy POC	Keri Lyons	Email	
FAA Technical POC		Email	
FAA Technical POC	Alex Moreno	Email	
Minimum Equipment List			
Applicable Forms listed above.			
Data Collection Requirements			
Subtmit forms with identified gaps.			
Submit suggestions for change in vertiport registration process.			

Data Element Card

Title	Post-flight Weather Data & Study		
Data Element Type	Static		
Scenario	All	UTE	All
Metric Type	Infrastructure	Maneuver	NA
Phase of Flight	Preflight	Event	Range Flight
Objective			
The objectives are to (1) collect data that describe atmospheric conditions near helipads/vertiports during flight tests, (2) deliver data to stakeholders post-flight			
Configuration			
N/A			
Test Conditions			
1. Conduct site survey			
2. Deploy weather-sensing equipment			
3. Perform operations check on equipment			
4. Measure and record weather data			
5. Perform quality control and formatting checks			
6. Distribute data			
Description			
Weather data will be collected during National Campaign flight activities and made available post-flight for stakeholders to use in their analyses. Surface weather data will be collected/recorded at 1-second resolution, and SoDAR data will be collected/recorded at 2-minute resolution. The SoDAR records average wind data every 20m (65ft) between 20-250m (65-820ft) AGL. All data will be tagged			
Notes			
Test Course Description			
Reference Guidance			
FAA Aviation Weather Services, Advisory Circular 00-45H Change 2 (2019)			
FCM-S4-2019, Federal Standards for Siting Meteorological Sensors at Airports			
JO-6560.20C, Siting Criteria for Automated Weather Observing Systems			
Adequate Criteria	Collect weather data during flight test activities and distribute data to stakeholders post-flight		
Desired Criteria	NA		
Instrumentation Package			
Task	Wind speed (surface)		
Adequate	1 knot	Desired	0.1 knot
Instrumentation Package			
Name	RM Young Wind Monitor AQ	Resolution	0.1 knot, 1 Hz
Task	Wind direction (surface)		
Adequate	10 degrees	Desired	0.1 degree
Instrumentation Package			
Name	RM Young Wind Monitor AQ	Resolution	0.1 degree, 1Hz
Task	Temperature		
Adequate	1 degree	Desired	0.1 degree
Instrumentation Package			
Name	Scottech EE181 Temperature/RH Probe	Resolution	0.1 degree, 1Hz
Task	Relative humdity		
Adequate	N/A	Desired	0.1%
Instrumentation Package			
Name	Scottech EE181 Temperature/RH Probe	Resolution	0.1%, 1Hz
Task	Station pressure		
Adequate	0.01inHg	Desired	0.01inHg
Instrumentation Package			
Name	Vaisala PTB110 barometer	Resolution	0.01inHg, 1Hz
Task	Density altitude		
Adequate	N/A	Desired	N/A
Instrumentation Package			
Name	Calculation	Resolution	10ft, 1Hz
Task	Wind speed (aloft)		
Adequate	N/A	Desired	N/A
Instrumentation Package			
Name	Radiometrics SoDAR model 4000	Resolution	0.1 knots, 2 minutes
Task	Wind direction (aloft)		
Adequate	N/A	Desired	N/A
Instrumentation Package			
Name	Radiometrics SoDAR model 4000	Resolution	1 degree, 2 minutes
Task	GPS location of instrument platforms		
Adequate	N/A	Desired	N/A
Instrumentation Package			
Name	Garmin GPS16X-HVS puck and/or NGA site survey	Resolution	0.00001 degrees
Requirements			
NASA POC	Luke Bard	Email	
Alternate NASA POC	Tegan French	Email	
FAA FOCAL POC		Email	
FAA Policy POC		Email	
FAA Technical POC		Email	
FAA Technical POC		Email	
Minimum Equipment List			
Surface weather stations, at least 1 near each active helipad/vertiport during flight tests			
SoDAR, 1 near each test area with active helipads/veritiports during flight tests			
Data Collection Requirements			
Surface weather conditions, see data elements above			
Winds aloft			

Data Element Card

Title	Departure Estimated Flight Performance		
Data Element Type	Dynamic		
Scenario	1,2,3	UTE	NA
Metric Type	Vehicle	Maneuver	NA
Phase of Flight	Inflight	Event	Range Flight
Objective			
Estimate Flight Performance for Departure: Aircraft Gross Weight, Pressure Altitude, Free Air Temperature (FAT), Energy Capacity (see separate DEC for UTE 25), Max Allowable Gross Weight, Predicted Hover Torque/Power (10 ft. IGE), Predicted Hover Torque/Power (50 ft. OGE), Hover Energy Flow, Hover Torque/Power Setting, Max Rate of Climb (Dual Motor), Min Rate of Climb (Single Motor), Max Acceleration, Nacelle Angle Change			
Configuration			
Test Conditions			
Description			
Notes			
Test Course Description			
Reference Guidance			
Adequate Criteria			
Desired Criteria			
Instrumentation Package			
Task			
Adequate		Desired	
Instrumentation Package			
Name		Resolution	
Requirements			
NASA POC		Email	
Alternate NASA POC		Email	
FAA FOCAL POC		Email	
FAA Policy POC		Email	
FAA Technical POC		Email	
FAA Technical POC		Email	
Minimum Equipment List			
Data Collection Requirements			

Data Element Card

Title	**Climb/Descent/Glide**		
Data Element Type	Dynamic		
Scenario	1,2,3	UTE	NA
Metric Type	Vehicle	Maneuver	NA
Phase of Flight	Inflight	Event	Range Flight
Objective			
Intent of these tests is to determine control margins in order to assure that, at any point in the aircraft envelope, there is sufficient control margin to overcome gusts and allow maneuvering, and that inceptors are operated in the proper sense. FCS/Trim tests for the OH-58C will be evaluated in level flight, climb and descent at various speeds >30 KCAS to evaluate control margins and other FCS characteristics. General comments on control characteristics will be captured.			
Configuration			
Test Conditions			
Test Limitations: little to no turbulence			
Test Tolerances:			
Knock it Off: >= 10% control margin remaining			
Description			
Level Flight – At test HP – maintain altitude, vary collective to vary speed, record control positions at discrete speeds from 30 KIAS up to VH (longitudinal cyclic, collective, lateral cyclic, anti-torque pedals) **Climb/Descent** – At several test airspeeds, vary collective to vary climb/descent rate, record control positions (long cyclic, collective, lateral cyclic, anti-torque pedals)			
Notes			
Test Course Description			
Reference Guidance			
Adquate Criteria	Operational State I: - CHR 1 to 3		
Desired Criteria	Operational State II, III and moderate turbulence and crosswinds – CHR 4 to 6		
Instrumentation Package			
Task			
Adequate		Desired	
Instrumentation Package			
Name		Resolution	
Requirements			
NASA POC		Email	
Alternate NASA POC		Email	
FAA FOCAL POC		Email	
FAA Policy POC		Email	
FAA Technical POC		Email	
FAA Technical POC		Email	
Minimum Equipment List			
Data Collection Requirements			

Data Element Card

Title	**Critical Azimuth Controllability (OH58C)**		
Data Element Type	Dynamic		
Scenario	1,2,3	**UTE**	NA
Metric Type	Vehicle	**Maneuver**	Trimmed Flight Control Positions (TFCP)
Phase of Flight	Inflight	**Event**	Range Flight

Objective

Review participant provided engineering data and notes on low speed flight characteristics. Critical Azimuths should be identified for participant designs, and an all azimuth chart provided to show the ability of the UAM vehicle to hover in ground effect in varying wind conditions. Note any reductions in all azimuth capability as a function of altitude, weight, temperature, failure state, etc.

Critical Azimuth tests for the OH-58C will be conducted to validate "book" numbers for all azimuth capability, and to demonstrate flight test techniques. Low-speed forward, rearward, and sideward flight tests will be conducted to observe control margins and critical control axes for the OH-58C.

Record GW, HP, OAT.

Configuration

dependent on UAM vehicle design

Test Conditions

ref: Gross Weight (GW), Center of Gravity (CG), Azimuth (ψ), Groundspeed (KTAS), Torque/Power (Q)

Test Limitations: <3 knots wind

Test Tolerances:

Knock it Off: >=10% control margin remaining

Description

All Azimuth demonstration (no calibrated pace vehicle)

In Level Flight (IGE) – maintain 10 foot skid height, slowly increase translation speed at the target azimuth (side/front/rear), record control positions. Evaluate areas of emphasis around and at critical azimuths. Translate at a given Azimuth angle, ψ, while monitoring control position until 10% control margin is reached in any control axis. Capture comments on controllability characteristics.

Notes

Knock it off - 10% control margin remaining

Test Course Description

Flat Surface with reference lines

Reference Guidance

§27/29.143 Controllability & Maneuverability

Advisory Circular 27-1B Certification of Normal Category Rotorcraft

Advisory Circular 29-2C Certification of Transport Category Rotorcraft

Adequate Criteria	N/A
Desired Criteria	N/A

Instrumentation Package			
Task	Weight		
Adequate		**Desired**	
Instrumentation Package			
Name	Gross Weight (GW)	**Resolution**	+/-10 lbs
Task			
Adequate		**Desired**	
Instrumentation Package			
Name	Azimuth (ψ)	**Resolution**	+/-1°
Task			
Adequate		**Desired**	
Instrumentation Package			
Name	Center of Gravity (cg)	**Resolution**	
Task	True Airspeed (KTAS)		
Adequate		**Desired**	
Instrumentation Package			
Name	Groundspeed	**Resolution**	+/-1 knot
Task	Inceptor		
Adequate		**Desired**	
Instrumentation Package			
Name	Longitudinal Cyclic	**Resolution**	+/-0.5%
Task	Inceptor		
Adequate		**Desired**	
Instrumentation Package			
Name	Lateral Cyclic	**Resolution**	+/-0.5%
Task	Inceptor		
Adequate		**Desired**	
Instrumentation Package			
Name	Anti-torque pedal	**Resolution**	+/-0.5%
Task	Inceptor		
Adequate		**Desired**	
Instrumentation Package			
Name	Collective	**Resolution**	+/-0.5%
Task	Power		
Adequate		**Desired**	
Instrumentation Package			
Name	Torque (Q)	**Resolution**	+/-1%
Task	Winds		
Adequate		**Desired**	
Instrumentation Package			
Name	winds at 10 feet	**Resolution**	+/-1 knot
Requirements			
NASA POC		**Email**	
Alternate NASA POC		**Email**	
FAA FOCAL POC		**Email**	
FAA Policy POC	David Webber	**Email**	david.webber@faa.gov
FAA Technical POC		**Email**	
FAA Technical POC	David Webber	**Email**	david.webber@faa.gov

Minimum Equipment List

Data Collection Requirements

actual KTAS to be calculated from recorded groundspeed, winds, static pressure and Outside Air Temperature (OAT)

Data Element Card

Title	**Departure Estimated Flight Performance**		
Data Element Type	Dynamic		
Scenario	1,2,3	UTE	NA
Metric Type	Vehicle	Maneuver	NA
Phase of Flight	Inflight	Event	Range Flight
Objective			
Estimate Flight Performance for Departure: Max Torque/Power Available, Velocity Never to Exceed (VNE) - Indicated Air Speed (IAS), Cruise Speed (kts.), Cruise Torque/Power Setting, Cruise Energy Flow, Max Range-Indicated Air Speed, Max Range Torque/Power, Max Endurance, (Indicated Air Speed (IAS)), Max Endurance Torque/Power			
Configuration			
Test Conditions			
Description			
Notes			
Test Course Description			
Reference Guidance			
Adequate Criteria			
Desired Criteria			
Instrumentation Package			
Task			
Adequate		Desired	
Instrumentation Package			
Name		Resolution	
Requirements			
NASA POC		Email	
Alternate NASA POC		Email	
FAA FOCAL POC		Email	
FAA Policy POC		Email	
FAA Technical POC		Email	
FAA Technical POC		Email	
Minimum Equipment List			
Data Collection Requirements			

Data Element Card

Title	**Dynamic Stability**		
Data Element Type	Dynamic		
Scenario	1,2,3	UTE	NA
Metric Type	Vehicle	Maneuver	NA
Phase of Flight	Inflight	Event	Range Flight
Objective			
Dynamic Stability tests for the OH-58C under Flight Characteristics will be open loop tests with specific inputs, followed by observation of the aircraft response with controls fixed, and free . Oscillation Period and Damping will be evaluated. Natural Gust observations will also be captured when weather conditions permit. Closed loop, mission related, testing will occur with the conduct of UAM Task Elements.			
Configuration			
Test Conditions			
Test Limitations: little to no disturbance for open loop tests; natural turbulence for natural gust observations			
Test Tolerances:			
Knock it Off:			
Description			
Open Loop tests Stabilize at trim Airspeed: "Heave" mode – insert collective step input (δC) and observe vertical rate (w) response Pitch mode – insert pitch step input (δlong) and observe pitch rate (q) response Phugoid – change airspeed from trim (Δ15 kts), slowly return cyclic to neutral and observe response Short Period – insert pitch impulse, observe response			
Notes			
Caution- Recovery from unusual attitude			
Test Course Description			
Reference Guidance			
Adequate Criteria	Operational State I: - CHR 1 to 3		
Desired Criteria	Operational State II, III and moderate turbulence and crosswinds – CHR 4 to 6		
Instrumentation Package			
Task			
Adequate		Desired	
Instrumentation Package			
Name		Resolution	
Requirements			
NASA POC		Email	
Alternate NASA POC		Email	
FAA FOCAL POC		Email	
FAA Policy POC		Email	
FAA Technical POC		Email	
FAA Technical POC		Email	
Minimum Equipment List			
Data Collection Requirements			

Data Element Card

Title	**Hover Power Margin (IGE/OGE) Free Flight Method**		
Data Element Type	Dynamic		
Scenario	1,2,3	UTE	NA
Metric Type	Vehicle	Maneuver	NA
Phase of Flight	Inflight	Event	Range Flight

Objective

Review participant provided Flight Manual and/or engineering charts for power/thrust available, and power/thrust Adequate to hover. Review limiting factors for a given UAM vehicle's design with regard to the intended operating envelope and incorporate provisions to record appropriate engine/motor parameters on the flight test card (Structural, Temperature, Engine/EPU component Speeds, Energy discharge rate, other). Make note of parameters that can be directly, or indirectly, controlled by the pilot, and those limit parameters that cannot. Determine transition height from IGE to OGE for a given vehicle design. Power Margin tests for the OH-58C will be used to validate "book" numbers for IGE/OGE hover, and to demonstrate flight test techniques. Record GW, HP, OAT. In order to compare measured performance to Hover Charts and Hover Ceiling.

Configuration

Test Conditions

Test Limitations: <3 knots

Test Tolerances:

Knock it Off: any engine anomalies

Description

Hover IGE – OH-58C – Bleeds Off, pick up helicopter into Hover at 2-10 foot skid heights, minimize cyclic/anti-torque inputs, fix collective and NR – stabilize with minimal translation, and record engine data (Q, NR, TOT, N1, FF) I think it makes sense to pick up a few skid heights between 2 and 10(?) as a foundation – given the fact that a lot of participants will have relatively small diameter props/rotors?
Hover OGE – OH-58C - Repeat above test technique at OGE (defined as 2 times Rotor Diameter) ≈60 foot skid height – - what is typical industry practice for capturing OGE hover in a SE helicopter? Monitor engine then simply make a vertical ascent, climb avoiding H-V and reestablish? Other?

Notes

Test Course Description

Reference Guidance

Adequate Criteria	Operational State I: - CHR 1 to 3
Desired Criteria	Operational State II, III and moderate turbulence and crosswinds – CHR 4 to 6

Instrumentation Package

Task			
Adequate		Desired	
Instrumentation Package			
Name		Resolution	

Requirements

NASA POC		Email	
Alternate NASA POC		Email	
FAA FOCAL POC		Email	
FAA Policy POC		Email	
FAA Technical POC		Email	
FAA Technical POC		Email	

Minimum Equipment List

Data Collection Requirements

Data Element Card

Title	**Landing Handling Quality**		
Data Element Type	Static		
Scenario	1	UTE	
Metric Type	Vehicle	Maneuver	Landing
Phase of Flight	Inflight	Event	Range Flight
Objective			
Evaluate vehicle controllability and stability during the VTOL aircraft task of a final descent to a precision landing point. The task is designed to check vehicle dynamics when the pilot is forced into tight compensatory tracking behavior. The task is designed to maneuver the vehicle in a moderately aggressive manner up to what would be considered safe in an operational context.			
Configuration			
Configuration: Landing Approach configuration (gear/flaps down)			
Test Conditions			
• Light and moderate turbulence levels			
• Winds up to maximum recovery headwind and 17 knots crosswind from the critical direction			
• AUW or maximum permissible hover weight if lower			
Description			
1. Starting from an altitude of greater than 10 ft., maintain an essentially steady descent to a prescribed landing point. It is acceptable to arrest sink rate momentarily to make last minute corrections before touchdown. 2. Accomplish a gentle landing with a smooth continuous descent, with no objectionable oscillations 3. Final position shall be the position that existed at touchdown. It is not acceptable to adjust the aircraft position and heading after all elements of the landing gear have made contact with the pad.			
Notes			
This task is to evaluate the air vehicle control response characteristics to perform a precision landing. If there are pilot selectable response types to maneuver the vehicle in this task or if the loss of sensor feedback results in a change in response type, the air vehicle shall be assessed in each control response type for this task.			
Test Course Description			
This task may be performed using the ADS-33E hover course with the designated landing point being directly under the reference point on the aircraft when the pilot's eye is at the hover point. Refer to figure XX for an example course.			
Reference Guidance			
FAR Part 21.17B			
FAR Part 27 (23.2135) Controllability			
FAR Part 27 (23.2145) Stability			
ADS-33 Pirouette Task			
ADS-33 Landing Task			
Adequate Criteria	HQ Evaluation Metrics (reference only for OH-58C): CHR 1 to 3		
Desired Criteria	Moderate turbulence and crosswinds targets: CHR 4 to 6		
Instrumentation Package			
Task	Once altitude is below 10 ft., complete the landing within X seconds		
Adequate	Ex. 10 seconds	Desired	Ex. 10 seconds
Instrumentation Package			
Name	Ex. Flight Tracking	Resolution	Ex. 3 feet
Task	Touch down within ±X ft. longitudinally of the designated reference point		
Adequate	Ex. 3 feet	Desired	Ex. 1 foot
Instrumentation Package			
Name		Resolution	
Task	Touch down within ±X ft. laterally of the designated reference point		
Adequate	Ex. 3 feet	Desired	Ex. 0.5 foot
Instrumentation Package			
Name		Resolution	
Task	Attain an aircraft heading at touchdown that is aligned with the reference heading within ±X degrees		
Adequate	Ex. 10 degrees	Desired	Ex. 5 degrees
Instrumentation Package			
Name		Resolution	
Requirements			
NASA POC		Email	
Alternate NASA POC		Email	
FAA FOCAL POC		Email	
FAA Policy POC		Email	
FAA Technical POC		Email	
FAA Technical POC		Email	
Minimum Equipment List			
Data Collection Requirements			

Data Element Card

Title	**Lateral Reposition (varied winds)**		
Data Element Type	Dynamic		
Scenario	1,2,3	UTE	xx
Metric Type	Vehicle	Maneuver	Reposition
Phase of Flight	Inflight	Event	Range Flight
Objective			
Configuration			
Test Conditions			
Description			
Notes			
• Detailed Flight Control System Design/Description • Inceptor Design • Pilot Displays/Flight Reference parameters • Flight Guidance Design • Flight Envelope/Limitations			
Test Course Description			
The target hover point shall be oriented approximately 45 degrees relative to the heading of the aircraft. The target hover point will reference the center of a Helipad from which aircraft deviations can be measured. Reference figure XX			
Reference Guidance			
Adequate Criteria	HQ Evaluation Metrics (reference only for OH-58C): CHR 1 to 3		
Desired Criteria	Moderate turbulence and crosswinds targets: CHR 4 to 6		
Instrumentation Package			
Task	Maintain lateral-longitudinal position within:		
Adequate	6 ft.	Desired	3 ft.
Instrumentation Package			
Name		Resolution	
Task	Maintain altitude within:		
Adequate	8 ft.	Desired	5 ft.
Instrumentation Package			
Name		Resolution	
Task	Maintain heading within:		
Adequate	10 degrees	Desired	5 degrees
Instrumentation Package			
Name		Resolution	
Task	Attain stabilized hover within:		
Adequate	8 sec.	Desired	5 sec.
Instrumentation Package			
Name		Resolution	
Task	Maintain stabilized hover:		
Adequate	>30 sec.	Desired	>30 sec.
Instrumentation Package			
Name		Resolution	
Requirements			
NASA POC		Email	
Alternate NASA POC		Email	
FAA FOCAL POC		Email	
FAA Policy POC		Email	
FAA Technical POC		Email	
FAA Technical POC		Email	
Minimum Equipment List			
Data Collection Requirements			

Data Element Card

Title	**Level Flight**		
Data Element Type	Dynamic		
Scenario	1,2,3	UTE	NA
Metric Type	Vehicle	Maneuver	NA
Phase of Flight	Inflight	Event	Range Flight
Objective			
Review participant provided level flight performance charts. Determine key performance parameters (e.g., Vh, Vmax range, Vcruise, Vmax endurance). Record any environmental or system factors that affect these speeds (Altitude, Temperature, battery health, other). Level Flight Performance tests for the OH-58C will be used to validate "book" numbers for level flight performance at various airspeeds, and to demonstrate flight test techniques. Record GW, HP, OAT, KIAS/KTAS, NR to compare measured performance to level flight			
Configuration			
Test Conditions			
Test Limitations: little to no turbulence			
Test Tolerances:			
Knock it Off:			
Description			
At test GW, HP: Stabilize at test Airspeed, record OAT, minimize cyclic/anti-torque inputs, fix collective, and record engine data (Q, NR, TOT, N1, FF) Repeat at different airspeeds (all key parameters), Gross Weights, and Rotor Speeds (NR). proposal will be to limit Dry Run testing to the altitude of interest (no need to do higher altitudes)			
Notes			
Test Course Description			
Reference Guidance			
Adequate Criteria	Operational State I: - CHR 1 to 3		
Desired Criteria	Operational State II, III and moderate turbulence and crosswinds – CHR 4 to 6		
Instrumentation Package			
Task			
Adequate		Desired	
Instrumentation Package			
Name		Resolution	
Requirements			
NASA POC		Email	
Alternate NASA POC		Email	
FAA FOCAL POC		Email	
FAA Policy POC		Email	
FAA Technical POC		Email	
FAA Technical POC		Email	
Minimum Equipment List			
Data Collection Requirements			

Data Element Card

Title	**Maneuverability**		
Data Element Type	Dynamic		
Scenario	1,2,3	UTE	NA
Metric Type	Vehicle	Maneuver	
Phase of Flight	Inflight	Event	Range Flight
Objective			
Maneuverability tests for the OH-58C will be a simple demonstration of several airspeeds conducted to demonstrate flight test techniques and collect a sample of rotorcraft data to be compared to UAM aircraft characteristics.			
Configuration			
Test Conditions			
ref: Aft CG			
Test Limitations: little to no disturbance			
Test Tolerances:			
Knock it Off: $\phi > 70°$			
Description			
Windup Turn (WUT) Stabilize at trim Airspeed, fix collective, note cyclic position, perform slow Windup Turn (WUT) to 2gs (60° ϕ) and record cyclic position at 15°, 30°, 45°, and 60° ϕ – observe FS vs NZ.			
Notes			
Caution- Avoid unloading (<+0.5g limit)			
Test Course Description			
Reference Guidance			
Adequate Criteria	Operational State I: - CHR 1 to 3		
Desired Criteria	Operational State II, III and moderate turbulence and crosswinds – CHR 4 to 6		
Instrumentation Package			
Task			
Adequate		Desired	
Instrumentation Package			
Name		Resolution	
Requirements			
NASA POC		Email	
Alternate NASA POC		Email	
FAA FOCAL POC		Email	
FAA Policy POC		Email	
FAA Technical POC		Email	
FAA Technical POC		Email	
Minimum Equipment List			
Data Collection Requirements			

Data Element Card

Title	**Partial Power & Glide**		
Data Element Type	Dynamic		
Scenario	1,2,3	**UTE**	NA
Metric Type	Vehicle	**Maneuver**	Climb.Descent.Glide
Phase of Flight	Inflight	**Event**	Range Flight
Objective			
Review participant provided climb, descent and partial power descent (glide, if applicable) performance charts. Determine key performance parameters (e.g., VY, VTOSS, VAPP, Vmin-I, Vfor min Rate of descent, Vfor min angle of descent, Vmax Glide, Glide angle). Record any environmental or system factors that affect these speeds (Altitude, Temperature, battery health, failure scenarios, other). Climb/Descent/Glide Flight Performance tests for the OH-58C will be used to validate "book" numbers for performance at various			
Configuration			
Test Conditions			
Test Limitations: little to no turbulence			
Test Tolerances:			
Knock it Off:			
Description			
Determine test GW, HP0, percent power target: Test band HP0 +/-500ft. Stabilize test Airspeed at ~200ft above test band, reduce Q and establish test airspeed at reduced Q. Hack at HP0 +500ft, record data (Q, NR, KIAS, and HP), take several time hacks/records with a final hack at HP0 -500ft Repeat at different airspeeds (all key parameters), several Gross Weights			
Notes			
Test Course Description			
Reference Guidance			
Adequate Criteria	Operational State I: - CHR 1 to 3		
Desired Criteria	Operational State II, III and moderate turbulence and crosswinds – CHR 4 to 6		
Instrumentation Package			
Task			
Adequate		**Desired**	
Instrumentation Package			
Name		**Resolution**	
Requirements			
NASA POC		**Email**	
Alternate NASA POC		**Email**	
FAA FOCAL POC		**Email**	
FAA Policy POC		**Email**	
FAA Technical POC		**Email**	
FAA Technical POC		**Email**	
Minimum Equipment List			
Data Collection Requirements			

Data Element Card

Title	**Precision Hover FTP Table 29**		
Data Element Type	Dynamic		
Scenario	1,2,3	UTE	xx
Metric Type	Vehicle	Maneuver	Hover
Phase of Flight	Inflight	Event	Range Flight

Objective

Check ability to transition from translating flight to a stabilized hover with precision and a mild amount of aggressiveness.

- Check ability to maintain precise position, heading, and altitude in the presence of a moderate wind from the most critical direction.
- Check for inceptor control harmony in all axes.
- Identify pilot-induced oscillation tendencies, if present.

Configuration

Configuration: Landing Approach configuration (gear/flaps down)

Test Conditions

Maximum Gross Weight (or maximum permissible hover weight if lower)

1. Calm winds
2. Maximum recovery headwind*
3. 17 knot wind from critical azimuth (suggest change to "UAM certification requirement") background – there is an open question as to
4. 17 knot wind from critical azimuth with light turbulence

Description

- Initiate the maneuver at a ground speed between 6 and 10 knots, at 15 ft or Landing Decision Point altitude, whichever is greater.
- The ground track should be such that the aircraft will arrive over the target hover point after performing a 45 degree translation toward hover point. For capturing the hover point the pilot should apply a smooth deceleration.
- The pilot shall attempt to attain a stabilized hover within the specified performance times after the initiation of the deceleration.
- After capturing a stabilized hover, the pilot shall maintain a stabilized hover for 30 seconds while attempting to maintain the specified desired position tolerances.

Notes

NORMAL OPS (No degraded performance, No agility limits, No Degraded Visual Environment)
OH-58C utilizes a Reversible FCS, Collective/Cyclic/Anti-torque pedals, No Autopilot, No FMS

- Detailed Flight Control System Design/Description
- Inceptor Design
- Pilot Displays/Flight Reference parameters
- Flight Guidance Design
- Flight Envelope/Limitations

There shall be no undesirable motions (e.g., pitch or roll axis bobble) in any axis either during the transition to hover or the stabilized hover

Test Course Description

The target hover point shall be oriented approximately 45 degrees relative to the heading of the aircraft. The target hover point will reference the center of a Helipad from which aircraft deviations can be measured. Reference figure XX

Reference Guidance

AC 27-1
AC 27-2
FAA Order 4040-26

Adequate Criteria	HQ Evaluation Metrics (reference only for OH-58C): CHR 1 to 3
Desired Criteria	Moderate turbulence and crosswinds targets: CHR 4 to 6

Instrumentation Package

Task	Maintain lateral-longitudinal position within:		
Adequate	6 ft.	Desired	3 ft.
Instrumentation Package			
Name		Resolution	
Task	Maintain altitude within:		
Adequate	8 ft.	Desired	5 ft.
Instrumentation Package			
Name		Resolution	
Task	Maintain heading within:		
Adequate	10 degrees	Desired	5 degrees
Instrumentation Package			
Name		Resolution	
Task	Attain stabilized hover within:		
Adequate	8 sec.	Desired	5 sec.
Instrumentation Package			
Name		Resolution	
Task	Maintain stabilized hover:		
Adequate	>30 sec.	Desired	>30 sec.
Instrumentation Package			
Name		Resolution	

Requirements

NASA POC	Mike Feary	Email	
Alternate NASA POC	Sam Simpliciano	Email	
FAA FOCAL POC		Email	
FAA Policy POC	John Jordan	Email	
FAA Technical POC		Email	
FAA Technical POC	David Webber	Email	

Minimum Equipment List

dGPS
IMU
Torque

Data Collection Requirements

Data Element Card

Title	**Sawtooth Climb & Descent**		
Data Element Type	Dynamic		
Scenario	1,2,3	**UTE**	NA
Metric Type	Vehicle	**Maneuver**	Climb.Descent.Glide
Phase of Flight	Inflight	**Event**	Range Flight
Objective			
Review participant provided climb, descent and partial power descent (glide, if applicable) performance charts. Determine key performance parameters (e.g., VY, VTOSS, VAPP, Vmin-I, Vfor min Rate of descent, Vfor min angle of descent, Vmax Glide, Glide angle). Record any environmental or system factors that affect these speeds (Altitude, Temperature, battery health, failure scenarios, other). Climb/Descent/Glide Flight Performance tests for the OH-58C will be used to validate "book" numbers for performance at various			
Configuration			
Test Conditions			
Test Limitations: little to no turbulence			
Test Tolerances:			
Knock it Off:			
Description			
At test GW, HP0: Stabilize at test Airspeed, record OAT, minimize cyclic/anti-torque inputs, fix collective, and record level flight engine data (Q, NR, OAT, KIAS) Test band HP0 +/-500ft. Descend below test band ~200ft, and start climb at test Airspeed, and maintain target NR for climbs and descents. At HP0-500ft, time hack and climb through test band recording (Q, NR, KIAS, and HP) at several time increments up to HP0+500ft. Continue climb above test band ~200ft, start descent at test airspeed through the test band. At HP0+500ft, time hack and descend through test band recording (Q, NR, KIAS, and HP) at several time increments down to HP0-500ft. Repeat at different airspeeds (all key parameters), several Gross Weights			
Notes			
Test Course Description			
Reference Guidance			
Adequate Criteria	Operational State I: - CHR 1 to 3		
Desired Criteria	Operational State II, III and moderate turbulence and crosswinds – CHR 4 to 6		
Instrumentation Package			
Task			
Adequate		**Desired**	
Instrumentation Package			
Name		**Resolution**	
Requirements			
NASA POC		**Email**	
Alternate NASA POC		**Email**	
FAA FOCAL POC		**Email**	
FAA Policy POC		**Email**	
FAA Technical POC		**Email**	
FAA Technical POC		**Email**	
Minimum Equipment List			
Data Collection Requirements			

Data Element Card

Title	Scenario 1		
Data Element Type	Dynamic		
Scenario	1,2,3	UTE	xx
Metric Type	Vehicle	Maneuver	NA
Phase of Flight	Inflight	Event	Range Flight

Objective

Scenario 1 – Flight Ops Planning/Execution – Nominal A-B
A nominal flight of at least 15 NM will be conducted from Heliport/Vertiport A to Heliport/Vertiport B. Flight Crew shall announce all waypoints throughout the flight. Up to 20 virtual aircraft with no planned interference will be utilized as back ground traffic. Virtual Traffic will be visible on ATI tablet but no action is Adequate on the part of the flight crew.
Prior engine start - Flight crew will verify flight test plan has been received from PSU on the ATI tablet. Flight crew will then confirm that the Airspace Data Exchange has occurred by confirming with Control Room/MOF that aircraft state information is valid, and the approved, flight plan and revisions are being received. Fuel State, expected fuel use, and expected reserves at destination shall be confirmed and recorded. Any subsequent flight test plans (e.g., a return flight test plan) shall be verified.
After engine start, Prior departure - flight crew will ensure any flight plan updates are entered in the vehicle navigation tool. Planned departure time, weather, airspace constraints, departure and arrival heliport/vertiport information and scheduled time of arrival will be recorded per the flight test card(s).
Departure - Flight Crew will taxi to takeoff position (as Adequate) and perform takeoff at planned departure time and execute the approved flight plan. Flight Crew will continually report waypoints and any updates to ETA in accordance with the Flight Test Card(s).
Enroute – Flight Crew will report lateral, altitude, airspeed, and temporal deviations from approved 4-D flight plan and associated operation volumes as well as environmental conditions, range constraints, and Flight Test-, or ATC directed- deviations.
Approach and Landing – a UAM Heliport, or UAM Vertiport, approach will be flown and a vertical landing executed. Actual landing time and fuel state will be recorded.

Configuration

Test Conditions

Description

Notes

- Detailed Flight Control System Design/Description
- Inceptor Design
- Pilot Displays/Flight Reference parameters
- Flight Guidance Design
- Flight Envelope/Limitations

Test Course Description

Reference Guidance

Adequate Criteria	Operational State I: - CHR 1 to 3
Desired Criteria	Operational State II, III and moderate turbulence and crosswinds – CHR 4 to 6

Instrumentation Package

Task			
Adequate		Desired	
Instrumentation Package			
Name		Resolution	

Requirements

NASA POC		Email	
Alternate NASA POC		Email	
FAA FOCAL POC		Email	
FAA Policy POC		Email	
FAA Technical POC		Email	
FAA Technical POC		Email	

Minimum Equipment List

Data Collection Requirements

Data Element Card

Title	Scenario 2		
Data Element Type	Dynamic		
Scenario	1,2,3	UTE	xx
Metric Type	Vehicle	Maneuver	NA
Phase of Flight	Inflight	Event	Range Flight

Objective

Scenario 2 – Inflight Ops Re-planning/Execution – A-B

A flight of at least 15 NM will be planned and initiated from Heliport/Vertiport A to Heliport/Vertiport B. During the Enroute portion of the flight, ground control will issue a route advisory, and a revised flight plan will be transmitted to the aircraft. Flight Crew shall announce all waypoints throughout the flight. Up to 50 virtual aircraft with no planned interference will be utilized as background traffic. Virtual Traffic will be visible on ATI tablet but no action is Adequate on the part of the flight crew.

Prior engine start - Flight crew will verify flight test plan has been received from PSU on the ATI tablet. Flight crew will then confirm that the Airspace Data Exchange has occurred by confirming with Control Room/MOF that aircraft state information is valid, and the approved flight plan and revisions are being received. Fuel State, expected fuel use, and expected reserves at destination shall be confirmed and recorded. Any subsequent flight test plans (e.g., a return flight test plan) shall be verified.

After engine start, prior departure - Flight crew will ensure any flight plan updates are entered in the vehicle navigation tool. Planned departure time, weather, airspace constraints, departure and arrival heliport/vertiport information and scheduled time of arrival will be recorded per the flight test card(s).

Departure - Flight Crew will taxi to takeoff position (as Adequate) and perform takeoff at planned departure time and execute the approved flight plan. Flight Crew will continually report waypoint passage and any updates to ETA in accordance with the Flight Test Card(s).

Enroute – Flight Crew will report lateral, altitude, airspeed, and temporal deviations from approved 4-D flight plan and associated operation volumes as well as environmental conditions, range constraints/instructions. During this segment, a route advisory will be transmitted from ground control, followed by a revised flight plan. Flight crew will acknowledge receipt of the advisory and the revised flight plan. Flight plan will be confirmed and accepted by the flight crew, and the remainder of the flight will be flown against the revised flight plan. Revised fuel state, ETA, expected fuel use, and expected reserves at destination shall be recorded and transmitted to ground control.

Approach and Landing – a UAM Heliport, or UAM Vertiport, approach will be flown and a vertical landing executed. Actual landing time and fuel state will be recorded.

Configuration

Test Conditions

Description

Notes

- Detailed Flight Control System Design/Description
- Inceptor Design
- Pilot Displays/Flight Reference parameters
- Flight Guidance Design
- Flight Envelope/Limitations

Test Course Description

Reference Guidance

Adequate Criteria	Operational State I: - CHR 1 to 3
Desired Criteria	Operational State II, III and moderate turbulence and crosswinds – CHR 4 to 6

Instrumentation Package

Task			
Adequate		Desired	
Instrumentation Package			
Name		Resolution	

Requirements

NASA POC		Email	
Alternate NASA POC		Email	
FAA FOCAL POC		Email	
FAA Policy POC		Email	
FAA Technical POC		Email	
FAA Technical POC		Email	

Minimum Equipment List

Data Collection Requirements

Data Element Card

Title	Scenario 3a		
Data Element Type	Dynamic		
Scenario	1,2,3	UTE	xx
Metric Type	Vehicle	Maneuver	NA
Phase of Flight	Inflight	Event	Range Flight

Objective

Scenario 3 – Deviations from Flight Plans – A-B-C

Scenario 3a – Go-Around to Holding

A flight of at least 15 NM will be planned and initiated from Heliport/Vertiport A to Heliport/Vertiport B. During the final approach, a go-around will be executed, and the aircraft will enter the holding pattern associated with the missed approach procedure. A revised flight plan will be transmitted to the aircraft. Flight Crew shall announce all waypoints throughout the flight. Up to 50 virtual aircraft with no planned interference will be utilized as background traffic.

Prior engine start - Flight crew will verify flight test plan has been received from PSU on the ATI tablet. Flight crew will then confirm that the Airspace Data Exchange has occurred by confirming with Control Room/MOF that aircraft state information is valid, and the approved flight plan and revisions are being received. Fuel State, expected fuel use, and expected reserves at destination shall be confirmed and recorded. Any subsequent flight test plans (e.g., a return flight test plan) shall be verified.

After engine start, prior departure - Flight crew will ensure any flight plan updates are entered in the vehicle navigation tool. Planned departure time, weather, airspace constraints, departure and arrival heliport/vertiport information and Scheduled time of arrival will be recorded per the test card(s).

Departure - Flight Crew will taxi to takeoff position (as Adequate) and perform takeoff at planned departure time and execute the approved flight plan. Flight Crew will continually report waypoint passage and any updates to ETA in accordance with the Flight Test Card(s).

Enroute – Flight Crew will report lateral, altitude, airspeed, and temporal deviations from approved 4-D flight plan and associated operation volumes as well as environmental conditions, range constraints/instructions.

Approach and Landing – a UAM Heliport, or UAM Vertiport approach will be flown to a simulated missed approach point, and a go-around/missed approach executed to holding. A route advisory will be transmitted from ground control, followed by a revised flight plan. Flight crew will acknowledge receipt of the advisory and the revised flight plan. Flight plan will be confirmed and accepted by the flight crew, and after at least one complete holding pattern, and upon receipt and acknowledgement of transmitted clearance from PSU (or at the direction of ground control, if no message received) the remainder of the flight will be flown against the revised flight plan. Revised fuel state, ETA, expected fuel use, and expected reserves at the destination shall be recorded and transmitted to ground control. The approach will be re-flown and a vertical landing executed. Actual landing time and fuel state will be recorded.

Configuration

Test Conditions

Description

Notes

- Detailed Flight Control System Design/Description
- Inceptor Design
- Pilot Displays/Flight Reference parameters
- Flight Guidance Design
- Flight Envelope/Limitations

Test Course Description

Reference Guidance

Adequate Criteria	Operational State I: - CHR 1 to 3
Desired Criteria	Operational State II, III and moderate turbulence and crosswinds – CHR 4 to 6

Instrumentation Package

Task			
Adequate		Desired	
Instrumentation Package			
Name		Resolution	

Requirements

NASA POC		Email	
Alternate NASA POC		Email	
FAA FOCAL POC		Email	
FAA Policy POC		Email	
FAA Technical POC		Email	
FAA Technical POC		Email	

Minimum Equipment List

Data Collection Requirements

Data Element Card

Title	**Scenario 3b**		
Data Element Type	Dynamic		
Scenario	1,2,3	UTE	xx
Metric Type	Vehicle	Maneuver	NA
Phase of Flight	Inflight	Event	Range Flight

Objective

Scenario 3 – Deviations from Flight Plans – A-B-C
Scenario 3b – Balked Landing to Holding
A flight of at least 15 NM will be planned and initiated from Heliport/Vertiport A to Heliport/Vertiport B. During the final approach, at <10 feet skid/wheel height a balked landing will be executed, and the aircraft will transition to a missed approach and enter the holding pattern. A revised flight plan will be transmitted to the aircraft. Flight Crew shall announce all waypoints throughout the flight. Up to 50 virtual aircraft with no planned interference will be utilized as background traffic.
Prior engine start - Flight crew will verify flight test plan has been received from PSU on the ATI tablet. Flight crew will then confirm that the Airspace Data Exchange has occurred by confirming with Control Room/MOF that aircraft state information is valid, and the approved flight plan and revisions are being received. Fuel State, expected fuel use, and expected reserves at destination shall be confirmed and recorded. Any subsequent flight test plans (e.g., a return flight test plan) shall be verified. Test missed approach procedures will be briefed.
After engine start, prior departure - Flight crew will ensure any flight plan updates are entered in the vehicle navigation tool. Planned departure time, weather, airspace constraints, departure and arrival heliport/vertiport information and Scheduled time of arrival will be recorded per the test card(s).
Departure - Flight Crew will taxi to takeoff position (as Adequate) and perform takeoff at planned departure time and execute the approved flight plan. Flight Crew will continually report waypoint passage and any updates to ETA in accordance with the Flight Test Card(s).
Enroute – Flight Crew will report lateral, altitude, airspeed, and temporal deviations from approved 4-D flight plan and associated operation volumes as well as environmental conditions, range constraints/instructions.
Approach and Landing – a UAM Heliport, or UAM Vertiport approach will be flown to <10 feet skid/wheel height, and a balked landing will be executed and transition into a missed approach to holding. A route advisory will be transmitted from ground control, followed by a revised flight plan to an alternate landing UAM Heliport/Vertiport. Flight crew will acknowledge receipt of the advisory and the revised flight plan. Flight plan will be confirmed and accepted by the flight crew, and upon receipt and acknowledgement of transmitted clearance from PSU (or direction of ground control, if no message received) the remainder of the flight will be flown against the revised flight plan. Revised fuel state, ETA, expected fuel use, and expected reserves at the destination shall be recorded and transmitted to ground control if time allows. The revised approach will be re-flown and a vertical landing executed. Actual landing time and fuel state will be recorded.

Configuration

Test Conditions

Description

Notes

- Detailed Flight Control System Design/Description
- Inceptor Design
- Pilot Displays/Flight Reference parameters
- Flight Guidance Design
- Flight Envelope/Limitations

Test Course Description

Reference Guidance

Adequate Criteria	Operational State I: - CHR 1 to 3
Desired Criteria	Operational State II, III and moderate turbulence and crosswinds – CHR 4 to 6

Instrumentation Package

Task			
Adequate		Desired	
Instrumentation Package			
Name		Resolution	

Requirements

NASA POC		Email	
Alternate NASA POC		Email	
FAA FOCAL POC		Email	
FAA Policy POC		Email	
FAA Technical POC		Email	
FAA Technical POC		Email	

Minimum Equipment List

Data Collection Requirements

Data Element Card

Title	**Scenario 3c**		
Data Element Type	Dynamic		
Scenario	1,2,3	UTE	xx
Metric Type	Vehicle	Maneuver	NA
Phase of Flight	Inflight	Event	Range Flight

Objective

Scenario 3 – Deviations from Flight Plans – A-B-C
Scenario 3c – Go-Around to Alternate
A flight of at least 15 NM will be planned and initiated from Heliport/Vertiport A to Heliport/Vertiport B. During the final approach, a go-around will be executed, and the aircraft will immediately transition to a missed approach and request an immediate landing at the nearest alternate UAM Heliport/Vertiport. A revised flight plan will be transmitted to the aircraft. Flight Crew shall announce all waypoints throughout the flight. Up to 50 virtual aircraft with no planned interference will be utilized as background traffic.
Prior engine start - Flight crew will verify flight test plan has been received from PSU on the ATI tablet. Flight crew will then confirm that the Airspace Data Exchange has occurred by confirming with Control Room/MOF that aircraft state information is valid, and the approved flight plan and revisions are being received. Fuel State, expected fuel use, and expected reserves at destination shall be confirmed and recorded. Any subsequent flight test plans (e.g., a return flight test plan) shall be verified. Test missed approach procedures will be briefed.
After engine start, prior departure - Flight crew will ensure any flight plan updates are entered in the vehicle navigation tool. Planned departure time, weather, airspace constraints, departure and arrival heliport/vertiport information and Scheduled time of arrival will be recorded per the test card(s).
Departure - Flight Crew will taxi to takeoff position (as Adequate) and perform takeoff at planned departure time and execute the approved flight plan. Flight Crew will continually report waypoint passage and any updates to ETA in accordance with the Flight Test Card(s).
Enroute – Flight Crew will report lateral, altitude, airspeed, and temporal deviations from approved 4-D flight plan and associated operation volumes as well as environmental conditions, range constraints/instructions.
Approach and Landing – a UAM Heliport, or UAM Vertiport, approach will be flown to the missed approach point, and a go-around will be executed and transition to an immediate approach and landing at the nearest alternate UAM Heliport/Vertiport. A route advisory will be transmitted from ground control, followed by a revised flight plan to an alternate landing UAM Heliport/Vertiport. Flight crew will acknowledge receipt of the advisory and the revised flight plan. Flight plan will be confirmed and accepted by the flight crew, and upon receipt and acknowledgement of transmitted clearance from PSU (or direction of ground control, if no message received) the aircraft will execute an approach at the alternate Heliport/Vertiport. Revised fuel state, ETA, expected fuel use, and expected reserves at the destination shall be recorded and transmitted to ground control if time allows. A vertical landing will be executed. Actual landing time and fuel state will be recorded.

Configuration

Test Conditions

Description

Notes

- Detailed Flight Control System Design/Description
- Inceptor Design
- Pilot Displays/Flight Reference parameters
- Flight Guidance Design
- Flight Envelope/Limitations

Test Course Description

Reference Guidance

Adequate Criteria	Operational State I: - CHR 1 to 3
Desired Criteria	Operational State II, III and moderate turbulence and crosswinds – CHR 4 to 6

Instrumentation Package

Task			
Adequate		Desired	
Instrumentation Package			
Name		Resolution	

Requirements

NASA POC		Email	
Alternate NASA POC		Email	
FAA FOCAL POC		Email	
FAA Policy POC		Email	
FAA Technical POC		Email	
FAA Technical POC		Email	

Minimum Equipment List

Data Collection Requirements

Data Element Card

Title	**Static Lateral/Directional Stability**		
Data Element Type	Dynamic		
Scenario	1,2,3	UTE	NA
Metric Type	Vehicle	Maneuver	NA
Phase of Flight	Inflight	Event	Range Flight
Objective			
Lateral/Directional Stability tests for the OH-58C will be a simple demonstration of several airspeeds conducted to demonstrate flight test techniques and collect a sample of rotorcraft data to be compared to UAM aircraft characteristics.			
Configuration			
Test Conditions			
ref: Aft CG			
Test Limitations: little to no disturbance- small inputs			
Test Tolerances: KIAS +/-1 kt, HP0 +/-1000ft, β +/-1°			
Knock it Off:			
Description			
Steady Heading Sideslip (SHSS) Stabilize at trim Airspeed (Level, Climb and Descent), fix collective, vary β and balance with cyclic (steady heading sideslip (SHSS)), maintain airspeed (accept altitude variation), record cyclic positions and ϕ at varied β – observe directional stability and dihedral effect (lateral stability).			
Notes			
Test Course Description			
Reference Guidance			
Adequate Criteria	Operational State I: - CHR 1 to 3		
Desired Criteria	Operational State II, III and moderate turbulence and crosswinds – CHR 4 to 6		
Instrumentation Package			
Task			
Adequate		Desired	
Instrumentation Package			
Name		Resolution	
Requirements			
NASA POC		Email	
Alternate NASA POC		Email	
FAA FOCAL POC		Email	
FAA Policy POC		Email	
FAA Technical POC		Email	
FAA Technical POC		Email	
Minimum Equipment List			
Data Collection Requirements			

Data Element Card

Title	**Static Longitudinal Stability**		
Data Element Type	Dynamic		
Scenario	1,2,3	**UTE**	NA
Metric Type	Vehicle	**Maneuver**	NA
Phase of Flight	Inflight	**Event**	Range Flight
Objective			
Highly augmented, fly-by-wire aircraft may not yield definitive results if only classical longitudinal stability flight test methods are applied. However, in a general sense, the intent of these tests should be to investigate if the aircraft is perturbed from a trimmed condition by a gust, with controls fixed or free, there is a tendency for the aircraft to return to the trimmed value. However, the tendency shall not be so pronounced as to be unacceptable to either the pilot or the passengers in turbulence. For the OH-58C, longitudinal stability characteristics will be evaluated around several trim airspeeds that cover the normal operating envelope. Max continuous power, Power for level flight, and autorotation (power off) characteristics will be evaluated.			
Configuration			
Test Conditions			
Test Limitations: little to no disturbance			
Test Tolerances:			
Knock it Off: none specified			
Description			
Stabilize at trim Airspeed, fix collective (record longitudinal cyclic position), use longitudinal cyclic to vary airspeed +/-15 knots from trim, allow aircraft to climb/descend (stabilize at 5 knot increments), record cyclic positions at varied speeds – slowly release cyclic and measure free return speed. Repeat at different airspeeds, CGs – observe cyclic position vs airspeed, relate to instrument S&C requirements like VMIN-I and relevance to instrument departures and approaches.			
Notes			
Test Course Description			
Reference Guidance			
Adequate Criteria	Operational State I: - CHR 1 to 3		
Desired Criteria	Operational State II, III and moderate turbulence and crosswinds – CHR 4 to 6		
Instrumentation Package			
Task			
Adequate		**Desired**	
Instrumentation Package			
Name		**Resolution**	
Requirements			
NASA POC		**Email**	
Alternate NASA POC		**Email**	
FAA FOCAL POC		**Email**	
FAA Policy POC		**Email**	
FAA Technical POC		**Email**	
FAA Technical POC		**Email**	
Minimum Equipment List			
Data Collection Requirements			

Data Element Card

Title	**Climb/Descent/Glide**		
Data Element Type	Dynamic		
Scenario	1,2,3	**UTE**	NA
Metric Type	Vehicle	**Maneuver**	Climb.Descent.Glide
Phase of Flight	Inflight	**Event**	Range Flight
Objective			
Review participant provided climb, descent and partial power descent (glide, if applicable) performance charts. Determine key performance parameters (e.g., VY, VTOSS, VAPP, Vmin-I, Vfor min Rate of descent, Vfor min angle of descent, Vmax Glide, Glide angle). Record any environmental or system factors that affect these speeds (Altitude, Temperature, battery health, failure scenarios, other). Climb/Descent/Glide Flight Performance tests for the OH-58C will be used to validate "book" numbers for performance at various			
Configuration			
Test Conditions			
Test Limitations: little to no turbulence			
Test Tolerances:			
Knock it Off:			
Description			
At test GW, TLOF height: Takeoff, acquire VY (or VTOSS if applicable – should we imagine a VTOSS for the OH-58C?) and climb at constant airspeed at max continuous power. At TLOF height +200ft, time hack and record (Q, NR, OAT, HP and KIAS) – continue climb and transition to VY (if applicable), take several time hacks/recordings, including TLOF +1000ft, test complete at TLOF +1200ft			
Notes			
Test Course Description			
Reference Guidance			
Adequate Criteria	Operational State I: - CHR 1 to 3		
Desired Criteria	Operational State II, III and moderate turbulence and crosswinds – CHR 4 to 6		
Instrumentation Package			
Task			
Adequate		**Desired**	
Instrumentation Package			
Name		**Resolution**	
Requirements			
NASA POC		**Email**	
Alternate NASA POC		**Email**	
FAA FOCAL POC		**Email**	
FAA Policy POC		**Email**	
FAA Technical POC		**Email**	
FAA Technical POC		**Email**	
Minimum Equipment List			
Data Collection Requirements			

6.7 Experimental Route Coding

Apollo Route

ROUTE APOLLO

```
HDR APOLLO (Scenario 1)      PAUSXVPT      SIAPCOPTER VOR/DME 291                                AMDT 2     W          20150130V18A
SUSAD        EDW   K6010920VTLW N34585651W117435739   N34585651W117435739W0090010001    NARMILTON                     000102013
SUSAEAENRT   INNIS K60    W    L N34572165W117533159                        E0012     NAR          INNIS              000302013
SUSAEAENRT   GORDO K60    W    L N34574403W117521654                        E0012     NAR          GORDO              000402013
SUSAEAENRT   BILLD K60    W    L N34565137W117522442                        E0012     NAR          BILLD              000502013
SUSAEAENRT   FREDD K60    W    L N34570053W117522123                        E0012     NAR          FREDD              000602013
SUSAEAENRT   GERDS K60    W    L N34580478W117524578                        E0012     NAR          GERDS              000702013
SUSAEAENRT   COOPR K60    W    L N34570530W117523226                        E0012     NAR          COOPR              000802013
SUSAEAENRT   LEWIS K60    W    L N34564113W117531364                        E0012     NAR          LEWIS              000902013
SUSAEAENRT   MARTA K60    W    L N34574325W117524295                        E0012     NAR          MARTA              001002013
SUSAEAENRT   MILTT K60    W    L N34564271W117524232                        E0012     NAR          MILTT              001102013
SUSAEAENRT   ALLAZ K60    W    L N34573953W117532175                        E0012     NAR          ALLAZ              001202013
SUSAEAENRT   TERPS K60    W    L N34573087W117520400                        E0012     NAR          TERPS              001302013
SUSAEAENRT   SIDBR K60    W    L N34531314W117410023                        E0012     NAR          SIDBR              001402013
SUSAEAENRT   ANCHR K60    W    L N34584144W117505879                        E0012     NAR          ANCHR              001502013
SUSAEAENRT   EVOLV K60    W    L N34583917W117493207                        E0012     NAR          EVOLV              001602013
SUSAEAENRT   MRPHY K60    W    L N34573963W117533310                        E0012     NAR          MRPHY              001702013
SUSAEAENRT   ROBST K60    W    L N34580782W117532655                        E0012     NAR          ROBST              001802013
SUSAEAENRT   STARR K60    W    L N34521164W117375009                        E0012     NAR          STARR              001902013
SUSAEAENRT   SHRMA K60    W    L N34584446W117480540                        E0012     NAR          SHRMA              002002013
SUSAEAENRT   ERINW K60    W    L N34581849W117524507                        E0012     NAR          ERINW              002102013
SUSAEAENRT   GRAND K60    W    L N34575965W117520790                        E0012     NAR          GRAND              002202013
SUSAEAENRT   CHLNG K60    W    L N34571371W117515601                        E0012     NAR          CHLNG              002302013
SUSAEAENRT   WEBBD K60    W    L N34583676W117531103                        E0012     NAR          WEBBD              002402013
SUSAEAENRT   CMILL K60    W    L N34582421W117530471                        E0012     NAR          CMILL              002502013
SUSAEAENRT   HOMLA K60    W    L N34541910W117460535                        E0012     NAR          HOMLA              002602013
SUSAEAENRT   EGGMS K60    W    L N34530261W117410157                        E0012     NAR          EGGMS              002702013
SUSAEAENRT   MOHAG K60    W    L N34564518W117480114                        E0012     NAR          MOHAG              002802013
SUSAEAENRT   SPEDE K60    W    L N34571882W117515353                        E0012     NAR          SPEDE              002902013
SUSAEAENRT   FASST K60    W    L N34582078W117521375                        E0012     NAR          FASST              003002013
SUSAEAENRT   HACKN K60    W    L N34545621W117420930                        E0012     NAR          HACKN              003102013
SUSAEAENRT   PNCHO K60    W    L N34580468W117521240                        E0012     NAR          PNCHO              003202013
SUSAEAENRT   CAPPS K60    W    L N34565399W117515084                        E0012     NAR          CAPPS              003302013
SUSAEAENRT   FIAPA K60    W    L N34580564W117525434                        E0012     NAR          FIAPA              003402013
SUSAEAENRT   OLIVZ K60    W    L N34551318W117464625                        E0012     NAR          OLIVZ              003502013
SUSAEAENRT   GRICH K60    W    L N34554495W117482254                        E0012     NAR          GRICH              003602013
SUSAEAENRT   FURRY K60    W    L N34523861W117371489                        E0012     NAR          FURRY              003702013
SUSAEAENRT   WGGNR K60    W    L N34561979W117490583                        E0012     NAR          WGGNR              003802013
SUSAEAENRT   DEEZR K60    W    L N34543756W117473888                        E0012     NAR          DEEZR              003902013
SUSAEAENRT   GOCKL K60    W    L N34575885W117523936                        E0012     NAR          GOCKL              004002013
SUSAEAENRT   POTTR K60    W    L N34524023W117365483                        E0012     NAR          POTTR              004102013
SUSAEAENRT   METRO K60    W    L N34580336W117530756                        E0012     NAR          METRO              004202013
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Apollo Route Deproach

ROUTE APOLLO

Experimental "DEPROACH"

```
SUSAP XVPTK6GRW19    0010611892 N34571364W117525772         +021710227900005610OI                                         106521804
SUSAP XVPTK6GRW01    0010610096 N34570389W117530240         +021710227600005610OI                                         106521804
SUSAH XEDWK6A        0     NARY N34573283W117525412E012002276        1800018000P         M XEDW North                      100102013
SUSAH XVPTK6A        0     NARN N34571364W117525772E012002277        1800018000P         M XVPT North                      100202013
SUSAH XX33K6A        0     NARN N34523317W117370408E012002277        1800018000P         M XX33                            100202013
SUSAH XEDWK6H01H     0S00060050 N34573273W117525425HCONC101S     02276                                                     200102013
SUSAH XEDWK6H02H     0S00060050 N34572437W117525772HCONC101S     02279                                                     200202013
SUSAH XEDWK6H03H     0S00060050 N34572614W117530312HCONC101S     02279                                                     200302013
SUSAH XVPTK6H04H     0S00060050 N34571320W117525808HCONC101S     02276                                                     200402013
SUSAH XVPTK6H05H     0S00060050 N34570431W117530227HCONC101S     02276                                                     200502013
SUSAH XX33K6H06H     0S00060050 N34523317W117370408HCONC101S     02981                                                     200502013
SUSAP XVPTK6FR01   AEDW   010EDW  K6D 0V       IF                                      18000                 A JS   300102013
SUSAP XVPTK6FR01   AEDW   020MRPHYK6EA0E   R   TF                 24880080   + 05000                         A JS   300202013
SUSAP XVPTK6FR01   R      010MRPHYK6EA0E       IF                            + 05000   18000                 A JS   300302013
SUSAP XVPTK6FR01   R      020ROBSTK6EA0E   R   TF                 35890005   + 04000                         A JS   300402013
SUSAP XVPTK6FR01   R      030WEBBDK6EA0E   R   TF                 01120005   + 03000                         A JS   300502013
SUSAP XVPTK6FR01   R      040ERINWK6EA0E   R   TF                 01120005   + 03000                         A JS   300602013
SUSAP XVPTK6FR01   R      050GRANDK6EA0E   R   TF                 01120005   + 03000                         A JS   300702013
SUSAP XVPTK6FR01   R      060CHLNGK6EA0E  IR   TF                 13360008   + 03000                         A JS   300802013
SUSAP XVPTK6FR01   R      070BILLDK6EA0E  FL   TF                 21070002   + 03000                         A JS   300902013
SUSAP XVPTK6FR01   R      080RW01 K6PG0GY M    TF                 35600014     01339            -900         A JS   301002013
SUSAH XEDWK6FR01H  AEDW   010EDW  K6D 0V       IF                                      18000                 A JS   301102013
SUSAH XEDWK6FR01H  AEDW   020BILLDK6EA0E   R   TF                 24880080   + 05000                         A JS   301202013
SUSAH XEDWK6FR01H  R      010BILLDK6EA0E       IF                            + 05000   18000                 A JS   301302013
SUSAH XEDWK6FR01H  R      020CHLNGK6EA0E   R   TF                 35890005   + 04000                         A JS   301402013
SUSAH XEDWK6FR01H  R      030GRANDK6EA0E   R   TF                 01120005   + 03000                         A JS   301502013
SUSAH XEDWK6FR01H  R      040ERINWK6EA0E   R   TF                 01120005   + 03000                         A JS   301602013
SUSAH XEDWK6FR01H  R      050WEBBDK6EA0E   R   TF                 01120005   + 03000                         A JS   301702013
SUSAH XEDWK6FR01H  R      060ROBSTK6EA0E  IR   TF                 13360008   + 03000                         A JS   301802013
SUSAH XEDWK6FR01H  R      070MRPHYK6EA0E  FL   TF                 21070002   + 03000                         A JS   301902013
SUSAH XEDWK6FR01H  R      08001H  K6HH0GY M    TF                 35600014     01339            -900         A JS   302002013
```

Discovery Route

ROUTE DISCOVERY

```
HDR DISCOVERY (Scenario 1)   PAUSXVPT      SIAPCOPTER VOR/DME 291                                AMDT 2    W         20150130V18A
SUSAD        EDW   K6010920VTLW N34585651W117435739    N34585651W117435739W0090010001    NARMILTON                 000102013
SUSAEAENRT   INNIS K60    W    L N34572165W117533159                   E0012     NAR          INNIS               000302013
SUSAEAENRT   GORDO K60    W    L N34574403W117521654                   E0012     NAR          GORDO               000402013
SUSAEAENRT   BILLD K60    W    L N34565137W117522442                   E0012     NAR          BILLD               000502013
SUSAEAENRT   FREDD K60    W    L N34570053W117522123                   E0012     NAR          FREDD               000602013
SUSAEAENRT   GERDS K60    W    L N34580478W117524578                   E0012     NAR          GERDS               000702013
SUSAEAENRT   COOPR K60    W    L N34570530W117523226                   E0012     NAR          COOPR               000802013
SUSAEAENRT   LEWIS K60    W    L N34564113W117531364                   E0012     NAR          LEWIS               000902013
SUSAEAENRT   MARTA K60    W    L N34574325W117524295                   E0012     NAR          MARTA               001002013
SUSAEAENRT   MILTT K60    W    L N34564271W117524232                   E0012     NAR          MILTT               001102013
SUSAEAENRT   ALLAZ K60    W    L N34573953W117532175                   E0012     NAR          ALLAZ               001202013
SUSAEAENRT   TERPS K60    W    L N34573087W117520400                   E0012     NAR          TERPS               001302013
SUSAEAENRT   SIDBR K60    W    L N34531314W117410023                   E0012     NAR          SIDBR               001402013
SUSAEAENRT   ANCHR K60    W    L N34584144W117505879                   E0012     NAR          ANCHR               001502013
SUSAEAENRT   EVOLV K60    W    L N34583917W117493207                   E0012     NAR          EVOLV               001602013
SUSAEAENRT   MRPHY K60    W    L N34573963W117533310                   E0012     NAR          MRPHY               001702013
SUSAEAENRT   ROBST K60    W    L N34580782W117532655                   E0012     NAR          ROBST               001802013
SUSAEAENRT   STARR K60    W    L N34521164W117375009                   E0012     NAR          STARR               001902013
SUSAEAENRT   SHRMA K60    W    L N34584446W117480540                   E0012     NAR          SHRMA               002002013
SUSAEAENRT   ERINW K60    W    L N34581849W117524507                   E0012     NAR          ERINW               002102013
SUSAEAENRT   GRAND K60    W    L N34575965W117520790                   E0012     NAR          GRAND               002202013
SUSAEAENRT   CHLNG K60    W    L N34571371W117515601                   E0012     NAR          CHLNG               002302013
SUSAEAENRT   WEBBD K60    W    L N34583676W117531103                   E0012     NAR          WEBBD               002402013
SUSAEAENRT   CMILL K60    W    L N34582421W117530471                   E0012     NAR          CMILL               002502013
SUSAEAENRT   HOMLA K60    W    L N34541910W117460535                   E0012     NAR          HOMLA               002602013
SUSAEAENRT   EGGMS K60    W    L N34530261W117410157                   E0012     NAR          EGGMS               002702013
SUSAEAENRT   MOHAG K60    W    L N34564518W117480114                   E0012     NAR          MOHAG               002802013
SUSAEAENRT   SPEDE K60    W    L N34571882W117515353                   E0012     NAR          SPEDE               002902013
SUSAEAENRT   FASST K60    W    L N34582078W117521375                   E0012     NAR          FASST               003002013
SUSAEAENRT   HACKN K60    W    L N34545621W117420930                   E0012     NAR          HACKN               003102013
SUSAEAENRT   PNCHO K60    W    L N34580468W117521240                   E0012     NAR          PNCHO               003202013
SUSAEAENRT   CAPPS K60    W    L N34565399W117515084                   E0012     NAR          CAPPS               003302013
SUSAEAENRT   FIAPA K60    W    L N34580564W117525434                   E0012     NAR          FIAPA               003402013
SUSAEAENRT   OLIVZ K60    W    L N34551318W117464625                   E0012     NAR          OLIVZ               003502013
SUSAEAENRT   GRICH K60    W    L N34554495W117482254                   E0012     NAR          GRICH               003602013
SUSAEAENRT   FURRY K60    W    L N34523861W117371489                   E0012     NAR          FURRY               003702013
SUSAEAENRT   WGGNR K60    W    L N34561979W117490583                   E0012     NAR          WGGNR               003802013
SUSAEAENRT   DEEZR K60    W    L N34543756W117473888                   E0012     NAR          DEEZR               003902013
SUSAEAENRT   GOCKL K60    W    L N34575885W117523936                   E0012     NAR          GOCKL               004002013
SUSAEAENRT   POTTR K60    W    L N34524023W117365483                   E0012     NAR          POTTR               004102013
SUSAEAENRT   METRO K60    W    L N34580336W117530756                   E0012     NAR          METRO               004202013
```

Discovery Route Deproach

ROUTE DISCOVERY

Experimental "DEPROACH"

```
SUSAP XVPTK6GRW19    0010611892 N34571364W117525772         +02171022790000056100I                                        106521804
SUSAP XVPTK6GRW01    0010610096 N34570389W117530240         +02171022760000056100I                                        106521804
SUSAH XEDWK6A        0     NARY N34573283W117525412E012002276         1800018000P          M XEDW North                   100102013
SUSAH XVPTK6A        0     NARN N34571364W117525772E012002277         1800018000P          M XVPT North                   100202013
SUSAH XX33K6A        0     NARN N34523317W117370408E012002277         1800018000P          M XX33                         100202013
SUSAH XEDWK6H01H     0S00060050 N34573273W117525425HCONC101S      02276                                                   200102013
SUSAH XEDWK6H02H     0S00060050 N34572437W117525772HCONC101S      02279                                                   200202013
SUSAH XEDWK6H03H     0S00060050 N34572614W117530312HCONC101S      02279                                                   200302013
SUSAH XVPTK6H04H     0S00060050 N34571320W117525808HCONC101S      02276                                                   200402013
SUSAH XVPTK6H05H     0S00060050 N34570431W117530227HCONC101S      02276                                                   200502013
SUSAH XX33K6H06H     0S00060050 N34523317W117370408HCONC101S      02981                                                   200502013
SUSAH XEDWK6FR01H  AEDW   010EDW  K6D 0V       IF                                      18000                    A JS   300102013
SUSAH XEDWK6FR01H  AEDW   020MARTAK6EA0E   R   TF                24880080    + 05000                            A JS   300202013
SUSAH XEDWK6FR01H  R      010MARTAK6EA0E       IF                            + 05000   18000                    A JS   300302013
SUSAH XEDWK6FR01H  R      020GORDOK6EA0E   R   TF                35890005    + 04000                            A JS   300402013
SUSAH XEDWK6FR01H  R      030WEBBDK6EA0E   R   TF                01120005    + 03000                            A JS   300502013
SUSAH XEDWK6FR01H  R      040ROBSTK6EA0E  IR   TF                13360008    + 03000                            A JS   300602013
SUSAH XEDWK6FR01H  R      050MRPHYK6EA0E  FL   TF                21070002    + 03000                            A JS   300702013
SUSAH XEDWK6FR01H  R      06001H  K6HH0GY M    TF                35600014      01339          -900              A JS   300802013
SUSAP XVPTK6FR19   AEDW   010EDW  K6D 0V       IF                                      18000                    A JS   300902013
SUSAP XVPTK6FR19   AEDW   020MRPHYK6EA0E   R   TF                24880080    + 05000                            A JS   301002013
SUSAP XVPTK6FR19   R      010MRPHYK6EA0E       IF                            + 05000   18000                    A JS   301102013
SUSAP XVPTK6FR19   R      020ROBSTK6EA0E   R   TF                35890005    + 04000                            A JS   301202013
SUSAP XVPTK6FR19   R      030WEBBDK6EA0E   R   TF                01120005    + 03000                            A JS   301302013
SUSAP XVPTK6FR19   R      040GORDOK6EA0E  IR   TF                13360008    + 03000                            A JS   301402013
SUSAP XVPTK6FR19   R      050MARTAK6EA0E  FL   TF                21070002    + 03000                            A JS   301502013
SUSAP XVPTK6FR19   R      060RW19 K6PG0GY M    TF                35600014      01339          -900              A JS   301602013
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Galileo Route

ROUTE GALILEO

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HDR GALILEO (Scenario 1)     PAUSXVPT      SIAPCOPTER VOR/DME 291                               AMDT 2     W        20150130V18A
SUSAD        EDW   K6010920VTLW N34585651W117435739    N34585651W117435739W0090010001    NARMILTON                     000102013
SUSAEAENRT   INNIS K60     W    L N34572165W117533159                      E0012     NAR        INNIS                  000302013
SUSAEAENRT   GORDO K60     W    L N34574403W117521654                      E0012     NAR        GORDO                  000402013
SUSAEAENRT   BILLD K60     W    L N34565137W117522442                      E0012     NAR        BILLD                  000502013
SUSAEAENRT   FREDD K60     W    L N34570053W117522123                      E0012     NAR        FREDD                  000602013
SUSAEAENRT   GERDS K60     W    L N34580478W117524578                      E0012     NAR        GERDS                  000702013
SUSAEAENRT   COOPR K60     W    L N34570530W117523226                      E0012     NAR        COOPR                  000802013
SUSAEAENRT   LEWIS K60     W    L N34564113W117531364                      E0012     NAR        LEWIS                  000902013
SUSAEAENRT   MARTA K60     W    L N34574325W117524295                      E0012     NAR        MARTA                  001002013
SUSAEAENRT   MILTT K60     W    L N34564271W117524232                      E0012     NAR        MILTT                  001102013
SUSAEAENRT   ALLAZ K60     W    L N34573953W117532175                      E0012     NAR        ALLAZ                  001202013
SUSAEAENRT   TERPS K60     W    L N34573087W117520400                      E0012     NAR        TERPS                  001302013
SUSAEAENRT   SIDBR K60     W    L N34531314W117410023                      E0012     NAR        SIDBR                  001402013
SUSAEAENRT   ANCHR K60     W    L N34584144W117505879                      E0012     NAR        ANCHR                  001502013
SUSAEAENRT   EVOLV K60     W    L N34583917W117493207                      E0012     NAR        EVOLV                  001602013
SUSAEAENRT   MRPHY K60     W    L N34573963W117533310                      E0012     NAR        MRPHY                  001702013
SUSAEAENRT   ROBST K60     W    L N34580782W117532655                      E0012     NAR        ROBST                  001802013
SUSAEAENRT   STARR K60     W    L N34521164W117375009                      E0012     NAR        STARR                  001902013
SUSAEAENRT   SHRMA K60     W    L N34584446W117480540                      E0012     NAR        SHRMA                  002002013
SUSAEAENRT   ERINW K60     W    L N34581849W117524507                      E0012     NAR        ERINW                  002102013
SUSAEAENRT   GRAND K60     W    L N34575965W117520790                      E0012     NAR        GRAND                  002202013
SUSAEAENRT   CHLNG K60     W    L N34571371W117515601                      E0012     NAR        CHLNG                  002302013
SUSAEAENRT   WEBBD K60     W    L N34583676W117531103                      E0012     NAR        WEBBD                  002402013
SUSAEAENRT   CMILL K60     W    L N34582421W117530471                      E0012     NAR        CMILL                  002502013
SUSAEAENRT   HOMLA K60     W    L N34541910W117460535                      E0012     NAR        HOMLA                  002602013
SUSAEAENRT   EGGMS K60     W    L N34530261W117410157                      E0012     NAR        EGGMS                  002702013
SUSAEAENRT   MOHAG K60     W    L N34564518W117480114                      E0012     NAR        MOHAG                  002802013
SUSAEAENRT   SPEDE K60     W    L N34571882W117515353                      E0012     NAR        SPEDE                  002902013
SUSAEAENRT   FASST K60     W    L N34582078W117521375                      E0012     NAR        FASST                  003002013
SUSAEAENRT   HACKN K60     W    L N34545621W117420930                      E0012     NAR        HACKN                  003102013
SUSAEAENRT   PNCHO K60     W    L N34580468W117521240                      E0012     NAR        PNCHO                  003202013
SUSAEAENRT   CAPPS K60     W    L N34565399W117515084                      E0012     NAR        CAPPS                  003302013
SUSAEAENRT   FIAPA K60     W    L N34580564W117525434                      E0012     NAR        FIAPA                  003402013
SUSAEAENRT   OLIVZ K60     W    L N34551318W117464625                      E0012     NAR        OLIVZ                  003502013
SUSAEAENRT   GRICH K60     W    L N34554495W117482254                      E0012     NAR        GRICH                  003602013
SUSAEAENRT   FURRY K60     W    L N34523861W117371489                      E0012     NAR        FURRY                  003702013
SUSAEAENRT   WGGNR K60     W    L N34561979W117490583                      E0012     NAR        WGGNR                  003802013
SUSAEAENRT   DEEZR K60     W    L N34543756W117473888                      E0012     NAR        DEEZR                  003902013
SUSAEAENRT   GOCKL K60     W    L N34575885W117523936                      E0012     NAR        GOCKL                  004002013
SUSAEAENRT   POTTR K60     W    L N34524023W117365483                      E0012     NAR        POTTR                  004102013
SUSAEAENRT   METRO K60     W    L N34580336W117530756                      E0012     NAR        METRO                  004202013
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Galileo Route Deproach

ROUTE GALILEO

Experimental "DEPROACH"

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SUSAP XVPTK6GRW19    0010611892 N34571364W117525772         +02171022790000056100I                                   106521804
SUSAP XVPTK6GRW01    0010610096 N34570389W117530240         +02171022760000056100I                                   106521804
SUSAH XEDWK6A        0     NARY N34573283W117525412E012002276        1800018000P         M XEDW North                100102013
SUSAH XVPTK6A        0     NARN N34571364W117525772E012002277        1800018000P         M XVPT North                100202013
SUSAH XX33K6A        0     NARN N34523317W117370408E012002277        1800018000P         M XX33                      100202013
SUSAH XEDWK6H01H     0S00060050 N34573273W117525425HCONC101S     02276                                               200102013
SUSAH XEDWK6H02H     0S00060050 N34572437W117525772HCONC101S     02279                                               200202013
SUSAH XEDWK6H03H     0S00060050 N34572614W117530312HCONC101S     02279                                               200302013
SUSAH XVPTK6H04H     0S00060050 N34571320W117525808HCONC101S     02276                                               200402013
SUSAH XVPTK6H05H     0S00060050 N34570431W117530227HCONC101S     02276                                               200502013
SUSAH XX33K6H06H     0S00060050 N34523317W117370408HCONC101S     02981                                               200502013
SUSAH XVPTK6FR04H  AEDW   010EDW   K6D 0V       IF                                       18000              A JS   301102013
SUSAH XVPTK6FR04H  AEDW   020MARTAK6EA0E   R    TF                 24880080    + 05000                      A JS   301202013
SUSAH XVPTK6FR04H  R      010MARTAK6EA0E        IF                             + 05000   18000              A JS   301302013
SUSAH XVPTK6FR04H  R      020GERDSK6EA0E   R    TF                 35890005    + 04000                      A JS   301402013
SUSAH XVPTK6FR04H  R      030CMILLK6EA0E   R    TF                 01120005    + 03000                      A JS   301502013
SUSAH XVPTK6FR04H  R      040FASSTK6EA0E   R    TF                 01120005    + 03000                      A JS   301602013
SUSAH XVPTK6FR04H  R      050SPEDEK6EA0E  IR    TF                 13360008    + 03000                      A JS   301802013
SUSAH XVPTK6FR04H  R      060FREDDK6EA0E  FL    TF                 21070002    + 03000                      A JS   301902013
SUSAH XVPTK6FR04H  R      07004H   K6HH0GY M    TF                 35600014      01339          -900        A JS   302002013
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Orion Route

ROUTE ORION

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HDR ORION (Scenario 1)       PAUSXVPT       SIAPCOPTER VOR/DME 291                                  AMDT 2     W        20150130V18A
SUSAD        EDW   K6010920VTLW N34585651W117435739    N34585651W117435739W0090010001     NARMILTON                       000102013
SUSAEAENRT   INNIS K60     W     L N34572165W117533159                 E0012      NAR          INNIS                      000302013
SUSAEAENRT   GORDO K60     W     L N34574403W117521654                 E0012      NAR          GORDO                      000402013
SUSAEAENRT   BILLD K60     W     L N34565137W117522442                 E0012      NAR          BILLD                      000502013
SUSAEAENRT   FREDD K60     W     L N34570053W117522123                 E0012      NAR          FREDD                      000602013
SUSAEAENRT   GERDS K60     W     L N34580478W117524578                 E0012      NAR          GERDS                      000702013
SUSAEAENRT   COOPR K60     W     L N34570530W117523226                 E0012      NAR          COOPR                      000802013
SUSAEAENRT   LEWIS K60     W     L N34564113W117531364                 E0012      NAR          LEWIS                      000902013
SUSAEAENRT   MARTA K60     W     L N34574325W117524295                 E0012      NAR          MARTA                      001002013
SUSAEAENRT   MILTT K60     W     L N34564271W117524232                 E0012      NAR          MILTT                      001102013
SUSAEAENRT   ALLAZ K60     W     L N34573953W117532175                 E0012      NAR          ALLAZ                      001202013
SUSAEAENRT   TERPS K60     W     L N34573087W117520400                 E0012      NAR          TERPS                      001302013
SUSAEAENRT   SIDBR K60     W     L N34531314W117410023                 E0012      NAR          SIDBR                      001402013
SUSAEAENRT   ANCHR K60     W     L N34584144W117505879                 E0012      NAR          ANCHR                      001502013
SUSAEAENRT   EVOLV K60     W     L N34583917W117493207                 E0012      NAR          EVOLV                      001602013
SUSAEAENRT   MRPHY K60     W     L N34573963W117533310                 E0012      NAR          MRPHY                      001702013
SUSAEAENRT   ROBST K60     W     L N34580782W117532655                 E0012      NAR          ROBST                      001802013
SUSAEAENRT   STARR K60     W     L N34521164W117375009                 E0012      NAR          STARR                      001902013
SUSAEAENRT   SHRMA K60     W     L N34584446W117480540                 E0012      NAR          SHRMA                      002002013
SUSAEAENRT   ERINW K60     W     L N34581849W117524507                 E0012      NAR          ERINW                      002102013
SUSAEAENRT   GRAND K60     W     L N34575965W117520790                 E0012      NAR          GRAND                      002202013
SUSAEAENRT   CHLNG K60     W     L N34571371W117515601                 E0012      NAR          CHLNG                      002302013
SUSAEAENRT   WEBBD K60     W     L N34583676W117531103                 E0012      NAR          WEBBD                      002402013
SUSAEAENRT   CMILL K60     W     L N34582421W117530471                 E0012      NAR          CMILL                      002502013
SUSAEAENRT   HOMLA K60     W     L N34541910W117460535                 E0012      NAR          HOMLA                      002602013
SUSAEAENRT   EGGMS K60     W     L N34530261W117410157                 E0012      NAR          EGGMS                      002702013
SUSAEAENRT   MOHAG K60     W     L N34564518W117480114                 E0012      NAR          MOHAG                      002802013
SUSAEAENRT   SPEDE K60     W     L N34571882W117515353                 E0012      NAR          SPEDE                      002902013
SUSAEAENRT   FASST K60     W     L N34582078W117521375                 E0012      NAR          FASST                      003002013
SUSAEAENRT   HACKN K60     W     L N34545621W117420930                 E0012      NAR          HACKN                      003102013
SUSAEAENRT   PNCHO K60     W     L N34580468W117521240                 E0012      NAR          PNCHO                      003202013
SUSAEAENRT   CAPPS K60     W     L N34565399W117515084                 E0012      NAR          CAPPS                      003302013
SUSAEAENRT   FIAPA K60     W     L N34580564W117525434                 E0012      NAR          FIAPA                      003402013
SUSAEAENRT   OLIVZ K60     W     L N34551318W117464625                 E0012      NAR          OLIVZ                      003502013
SUSAEAENRT   GRICH K60     W     L N34554495W117482254                 E0012      NAR          GRICH                      003602013
SUSAEAENRT   FURRY K60     W     L N34523861W117371489                 E0012      NAR          FURRY                      003702013
SUSAEAENRT   WGGNR K60     W     L N34561979W117490583                 E0012      NAR          WGGNR                      003802013
SUSAEAENRT   DEEZR K60     W     L N34543756W117473888                 E0012      NAR          DEEZR                      003902013
SUSAEAENRT   GOCKL K60     W     L N34575885W117523936                 E0012      NAR          GOCKL                      004002013
SUSAEAENRT   POTTR K60     W     L N34524023W117365483                 E0012      NAR          POTTR                      004102013
SUSAEAENRT   METRO K60     W     L N34580336W117530756                 E0012      NAR          METRO                      004202013
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Orion Route Deproach

ROUTE ORION

Experimental "DEPROACH"

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SUSAP XVPTK6GRW19    0010611892 N34571364W117525772        +02171022790000056100I                                      106521804
SUSAP XVPTK6GRW01    0010610096 N34570389W117530240        +02171022760000056100I                                      106521804
SUSAH XEDWK6A        0     NARY N34573283W117525412E012002276        1800018000P         M XEDW North                  100102013
SUSAH XVPTK6A        0     NARN N34571364W117525772E012002277        1800018000P         M XVPT North                  100202013
SUSAH XX33K6A        0     NARN N34523317W117370408E012002981        1800018000P         M XX33                        100202013
SUSAH XEDWK6H01H     0500060050 N34573273W117525425HCONC101S      02276                                                200102013
SUSAH XEDWK6H02H     0500060050 N34572437W117525772HCONC101S      02279                                                200202013
SUSAH XEDWK6H03H     0500060050 N34572614W117530312HCONC101S      02279                                                200302013
SUSAH XVPTK6H04H     0500060050 N34571320W117525808HCONC101S      02276                                                200402013
SUSAH XVPTK6H05H     0500060050 N34570431W117530227HCONC101S      02276                                                200502013
SUSAH XX33K6H06H     0500060050 N34523317W117370408HCONC101S      02981                                                200502013
SUSAH XEDWK6FR01H  AEDW   010EDW  K6D 0V        IF                                   18000                  A JS   301102013
SUSAH XEDWK6FR01H  AEDW   020STARRK6EA0E   R    TF                24880080   + 05000                        A JS   301202013
SUSAH XEDWK6FR01H  R      010STARRK6EA0E        IF                           + 05000   18000                A JS   301302013
SUSAH XEDWK6FR01H  R      020EGGMSK6EA0E   R    TF                35890005   + 04000                        A JS   301402013
SUSAH XEDWK6FR01H  R      030HOMLAK6EA0E   R    TF                01120005   + 03000                        A JS   301502013
SUSAH XEDWK6FR01H  R      040OLIVZK6EA0E   R    TF                01120005   + 03000                        A JS   301602013
SUSAH XEDWK6FR01H  R      050MOHAGK6EA0E   R    TF                01120005   + 03000                        A JS   301602013
SUSAH XEDWK6FR01H  R      060EVOLVK6EA0E   R    TF                01120005   + 03000                        A JS   301602013
SUSAH XEDWK6FR01H  R      070ANCHRK6EA0E   R    TF                01120005   + 03000                        A JS   301602013
SUSAH XEDWK6FR01H  R      080PNCHOK6EA0E   IR   TF                13360008   + 03000                        A JS   301802013
SUSAH XEDWK6FR01H  R      090MARTAK6EA0E   FL   TF                21070002   + 03000                        A JS   301902013
SUSAH XEDWK6FR01H  R      10001H   K6HH0GY M    TF                35600014     01339           -900         A JS   302002013
SUSAH XX33K6FR06H  AEDW   010EDW  K6D 0V        IF                                   18000                  A JS   301102013
SUSAH XX33K6FR06H  AEDW   020MARTAK6EA0E   R    TF                24880080   + 05000                        A JS   301202013
SUSAH XX33K6FR06H  R      010MARTAK6EA0E        IF                           + 05000   18000                A JS   301302013
SUSAH XX33K6FR06H  R      020PNCHOK6EA0E   R    TF                35890005   + 04000                        A JS   301402013
SUSAH XX33K6FR06H  R      030ANCHRK6EA0E   R    TF                01120005   + 03000                        A JS   301502013
SUSAH XX33K6FR06H  R      040EVOLVK6EA0E   R    TF                01120005   + 03000                        A JS   301602013
SUSAH XX33K6FR06H  R      050MOHAGK6EA0E   R    TF                01120005   + 03000                        A JS   301602013
SUSAH XX33K6FR06H  R      060OLIVZK6EA0E   R    TF                01120005   + 03000                        A JS   301602013
SUSAH XX33K6FR06H  R      070HOMLAK6EA0E   R    TF                01120005   + 03000                        A JS   301602013
SUSAH XX33K6FR06H  R      080EGGMSK6EA0E   IR   TF                13360008   + 03000                        A JS   301802013
SUSAH XX33K6FR06H  R      090STARRK6EA0E   FL   TF                21070002   + 03000                        A JS   301902013
SUSAH XX33K6FR06H  R      10006H   K6HH0GY M    TF                35600014     01339           -900         A JS   302002013
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Waypoint Subset List (1 of 2)

Waypoint Subset List

INNIS	34°58'3.36"N 117°53'7.56"W	MANKE	34°57'52.23"N 117°52'35.75"W	GRND1	34°56'28.65"N 117°52'57.97"W
GORDO	34°57'44.03"N 117°52'16.54"W	WALKR	34°57'6.82"N 117°52'23.47"W	CHLNG	34°57'13.71"N 117°51'56.01"W
BILLD	34°56'51.37"N 117°52'24.42"W	MORAN	34°56'51.92"N 117°52'48.26"W	WEBBD	34°58'34.47"N 117°53'21.36"W
FREDD	34°57'0.53"N 117°52'21.23"W	FERRY	34°57'56.61"N 117°53'16.46"W	CMILL	34°58'51.60"N 117°52'56.66"W
GERDS	34°58'4.78"N 117°52'45.78"W	ALLAZ	34°57'39.53"N 117°53'21.75"W	HOMLA	34°54'19.10"N 117°46'5.35"W
COOPR	34°57'5.30"N 117°52'32.26"W	TERPS	34°57'30.87"N 117°52'4.00"W	EGGMS	34°53'2.61"N 117°41'1.57"W
LEWIS 12°	34°56'41.13"N 117°53'13.64"W	SIDBR	34°53'13.14"N 117°41'0.23"W	MOHAG	34°56'45.18"N 117°48'1.14"W
LEWIS 9°	34°56'33.09"N 117°53'17.63"W	ANCHR	34°58'41.44"N 117°50'58.79"W	SPEDE	34°57'28.91"N 117°50'22.62"W
MARTA	34°57'43.25"N 117°52'42.95"W	EVOLV	34°58'39.17"N 117°49'32.07"W	FASST	34°58'5.30"N 117°52'13.36"W
MILTT	34°56'42.71"N 117°52'42.32"W	MRPHY	34°56'40.50"N 117°52'12.36"W	HACKN	34°56'20.44"N 117°44'20.32"W
MCKAY	34°59'56.66"N 117°50'38.49"W	ROBST	34°58'7.82"N 117°53'26.55"W	PNCHO	34°57'55.33"N 117°51'38.41"W
BRUCE	34°52'21.27"N 117°36'24.59"W	STARR	34°54'8.15"N 117°40'53.54"W	CAPPS	34°56'53.99"N 117°51'50.84"W
BLOOM	34°57'32.48"N 117°46'12.80"W	SHRMA	34°58'44.46"N 117°48'5.40"W		
DRURY	34°53'7.70"N 117°37'4.06"W	ERINW	34°58'39.86"N 117°52'21.51"W		

Waypoint Subset List (2 of 2)

Waypoint Subset List

FIAPA	34°56'32.68"N 117°52'24.80"W	WLCOX	35° 0'8.90"N 117°50'37.57"W
OLIVZ	34°55'13.18"N 117°46'46.25"W	SMPLO	35° 0'4.34"N 117°49'37.02"W
GRICH	34°55'44.95"N 117°48'22.54"W	JAFFE	34°59'58.16"N 117°48'8.07"W
FURRY	34°49'59.87"N 117°37'50.27"W	TEERA	34°58'20.72"N 117°50'12.32"W
WGGNR	34°56'19.79 "N 117°49'5.83"W	PAULD	34°58'58.66"N 117°51'7.41"W
DEEZR	34°54'37.56"N 117°47'38.88"W	01H	34°57'32.88"N 117°52'54.07"W
GOCKL	34°58'29.40"N 117°51'41.53"W	04H-R19	34°57'13.24"N 117°52'57.99"W
POTTR	34°50'36.56"N 117°35'57.51"W	05H-R01	34°57'4.10"N 117°53'2.21"W
METRO	34°57'21.65"N 117°53'31.59"W	X-33	34°52'33.19"N 117°37'4.13"W
FALCN	34°58'0.82"N 117°49'1.83"W	02H	34°57'24.61"N 117°52'57.48"W
LGTHA	34°53'54.83"N 117°36'59.67"W	03H	34°57'25.95"N 117°53'2.64"W
RGNAR	34°54'14.15"N 117°33'24.07"W		
BJORN	34°52'9.06"N 117°33'31.38"W		
FLOKI	34°51'41.78"N 117°35'43.45"W		
CHIPP	34°56'56.22"N 117°51'45.32"W		
GRND2	34°55'42.56"N 117°52'49.96"W		