Atmospheric Sensing and Prediction System (ASAPS) enabled onboard BVLOS UAS

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Nomenclature

AATI	American Aerospace Technologies, Inc.
AGL	Above Ground Level
ASAPS	Atmospheric Sensing and Prediction System (PEMDAS Sensor)
AWD	ASAPS Warning Display
BVLOS	Beyond Visual Line of Sight
CG	Center of Gravity
COA	Certificate of Authorization/Waiver
CONOP	Concept of Operations
DAA	Detect and Avoid
EINC	Environmental Intelligence NOWcasting (PEMDAS Sensor)
FAA	Federal Aviation Administration
FCC	Federal Communications Commission
Ft	Feet (US Measurement)
GIS	Geographic Information System
ICD	Interface Control Document
LOS	Line of Sight
MSL	Mean Sea Level
NAS	National Airspace and System
NM	Nautical Miles
NOTAM	Notice to Airmen
NPUASTS	Northern Plains UAS Test Site
OGC	Open Geospatial Consortium
PEMDAS	PEMDAS Technologies and Innovations
RP	Recommended Practices
ROW	Right of Way
SAC-EAC	Special Authorization Certificate – Experimental Aircraft Certificate (FAA Form 8130-7)
TC	Type Certification
UAS	Unmanned Aircraft System
UAV	Unmanned Aircraft Vehicle

1. Executive Summary

The project to develop a waiver application and safety case enabling safe medium altitude unmanned aircraft systems (UAS) flight beyond visual line of sight (BVLOS) in Visual Meteorological Conditions (VMC) at night as well as to enhance marginal and cold weather daytime operations by integrating real-time and localized weather intelligence was completed successfully. Testing was conducted at the Northern Plains UAS Test Site (NPUASTS) in North Dakota and in the San Joaquin Valley near Bakersfield, California. The project leveraged the Atmospheric Sensing and Prediction System (ASAPS), and complementary Environmental Intelligence NOWcasting (EINC) system to provide the Remote Pilot in Command (RPIC) with "right-now" awareness of environmental conditions and inflight adverse weather.

The flight test campaigns safely demonstrated the effectiveness of the ASAPS/EINC sensors onboard the UAS during day and night BVLOS operations in an operational environment setting. To support controlled night BVLOS required an extensive safety case to be approved using strict test protocols. The team ultimately flew a structured set of night BVLOS test points to stress and verify the Concept of Operations (CONOPS) underpinned by the technologies provided by ASAPS and EINC.

Results from flight tests included RPIC feedback that ASAPS/EINC system provided enhanced situational awareness of unsafe or changing atmospheric flight conditions and improved safety during the flight.

2. Introduction

A. Purpose

The purpose of this project was to develop the basis for an FAA application and safety case to enable safe medium altitude (1,000' – 5,000') BVLOS UAS nighttime VMC flight operations - as well as to enhance marginal and cold weather daytime operations - by integrating real-time and localized weather intelligence. Utilizing the AiRanger™ UAS, a medium altitude, long endurance platform capable of 15-hour flights, with integrated ASAPS and EINC systems, testing was conducted in California and North Dakota with the support of the NPUASTS.

The concept of operations for nighttime operations was conducted near Williston, North Dakota and enabled AATI to conduct a BVLOS demonstration of the AiRanger UAS utilizing the NPUASTS's Vantis Network, as an alternative to AATIs onboard detect and avoid (DAA) technology, and PEMDAS's ASAPS and EINC systems, to provide operators with "right-now" awareness of changing environmental conditions and inflight adverse weather. See Figure 4 below.

B. Background

AATI is the original manufacturer and operator of the AiRanger™, a medium altitude, long endurance BVLOS UAS[6] designed to fly safely in civil airspace with manned aircraft. See Appendix D for technology overview. PEMDAS is the original equipment manufacturer and operator of the ASAPS and EINC systems.

The AiRanger has received SAC-EAC, see Appendix A (2023-CSA-415-SAC) and Appendix B (SAC-EAC – 8130-7: N642RE). In addition, it is the subject of a Type Certification (TC) application[7] and has been granted airworthiness and airspace approval reviews from the FAA – MIDO office for an Area of Operations in Williston, North Dakota and supported by the Northern Plains UAS Test Site (NPUASTS) for operation on the Vantis UAS Network[8].

[6] https://americanaerospace.com/
[7] TC17190LA-A
[8] https://www.vantisuas.com/news/article/american-aerospace-technologies-inc-announces-first-flight-on-vantis

AATI and PEMDAS conducted the daytime flight testing at the AATI regional operations center located at Vince Dusters airfield in Buttonwillow, California, approximately 30 NM northwest of Meadows Field Airport, Bakersfield, CA (KBFL) as displayed in Figure 1. Flight tests were flown in December 2023 and January 2024 during daylight hours, under VFR conditions.

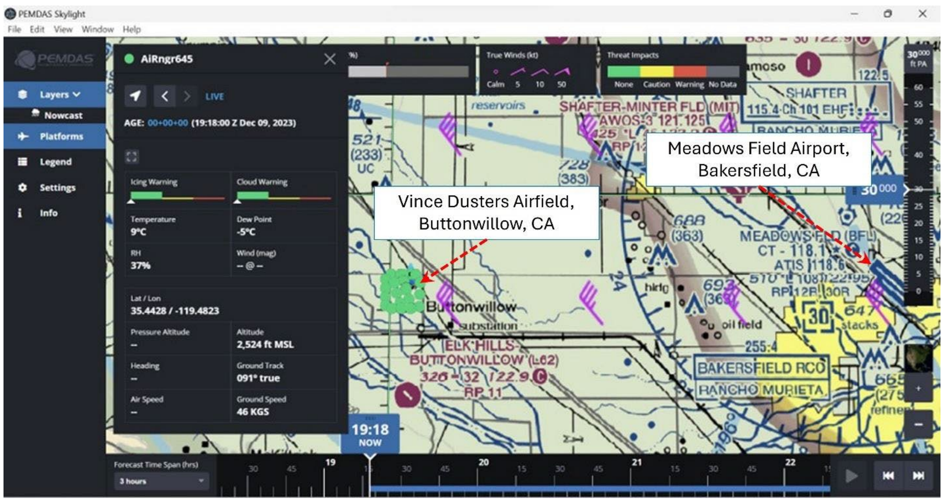


Figure 1 Flight Test Area – California – Daytime

In the spring of 2024 (April and June), the nighttime flights were authorized in accordance with a Special Authorization Certification and Experimental Aircraft Certificate[9] (SAC-EAC) and completed at the Williston Basin International Airport (KXWA) in North Dakota with cooperation of the NPUAST Site utilizing Vantis Network Radars, backed by ground observers, and chase plane observers. See Figure 2.

Figure 2 Flight Test Area – North Dakota – Nighttime

[9] See Exhibit A: FAA 7711-1 2023-CSA-415-SAC

During the daytime tests, ASAPS provided real-time weather situational awareness of cloud and icing warnings, within a designated operating area to safely expand safe BVLOS UAS operations at medium altitudes. This included characterizing ASAPS sensor outputs for aircraft characteristics at various altitudes, ultimately demonstrating the ASAPS/EINC capability to provide for cloud-free line-of-sight operations, and threat polygons to the RPIC designating recommended areas of avoidance that contain select environmental threats. The employment of ASAPS and EINC provides the following decision information during night operations:

- ***Real-time icing and cloud indications and warnings,***
- ***Near-real time weather situational awareness within a designated operating area***
- ***Wind speed and direction,***
- ***Icing at various altitudes,***
- ***Clouds at and below altitudes enabling line-of-sight operations, and***
- ***Designated threat areas to avoid based on select environmental threats***

The goal was to demonstrate the ASAPS sensor system onboard UAS as well as the EINC portal in the GCS "right-now" awareness of environmental conditions and inflight adverse weather enhanced safety during day and night BVLOS operations. The ASAPS and NOWcasting EINC prototype systems have been tested in various configurations; however, to support controlled night BVLOS in the NAS required AATI to develop an extensive safety case that would enable the FAA to approve flight operations within 9 months of the project start. Using strict test protocols at a North Dakota approved UAS test site, AATI was successful in obtaining approvals to safely fly a structured set of test points with Chase aircraft to stress and verify a night BVLOS Concept of Operations (CONOPS) underpinned by the technologies provided by ASAPS and EINC.

For the daytime flight tests at AATIs facility in California, only local flights were required to complete the test cards – ground observers were used and no Chase plane was required. Notably, since that time, the AiRanger's airborne Detect-and-Avoid (DAA) system received a 14 CFR 91.113(b) Waiver to fly BVLOS safely in civil airspace alongside manned aircraft. The DAA system consists of a dual Echodyne Echoflight RADAR, ADS-B, enhanced lighting, high visibility paint and tail camera mounted on the UAS. The system's DAA radar provides an essential safety feature for integrating unmanned aircraft into civil airspace. Cooperative aircraft DAA was achieved via integration of the Sagetech MXS ADS-B In/Out Transponder. The AiRanger platform, equipped with state-of-the-art PEMDAS ASAPS/ EINC weather detect and avoid system in addition to cooperative and non-cooperative DAA sensing technologies, is expected to deliver the technological capability to enable safe operation of unmanned aircraft in Class E and G national airspace during both day and night VMC operations.

For the nighttime flight tests, the AiRanger was not equipped with the AATI-developed DAA as the Test Site had an established equivalent alternative to support the operation safely (See Figure 3). The flights were conducted at AATIs leased facility in North Dakota, utilizing the Vantis Network, Chase plane observers, and ground visual observers to conduct BVLOS flights . NPUASTS's Vantis Network Radars were utilized during the flight tests, as an additional situational awareness tool.

The Vantis Network supports unmanned aircraft, provides airspace surveillance, and enables other services to safely integrate unmanned aircraft in the National Airspace System (NAS). Key elements of the Vantis System that were tested during the nighttime flight operation included the following (Figure 3):

- ***Remote infrastructure for airspace surveillance (command and control (C2) capability not used)***
- ***A backhaul data network***
- ***A centralized Mission and Network Operations Center (MNOC)***
- ***Standard Operating Procedures (SOPs)***

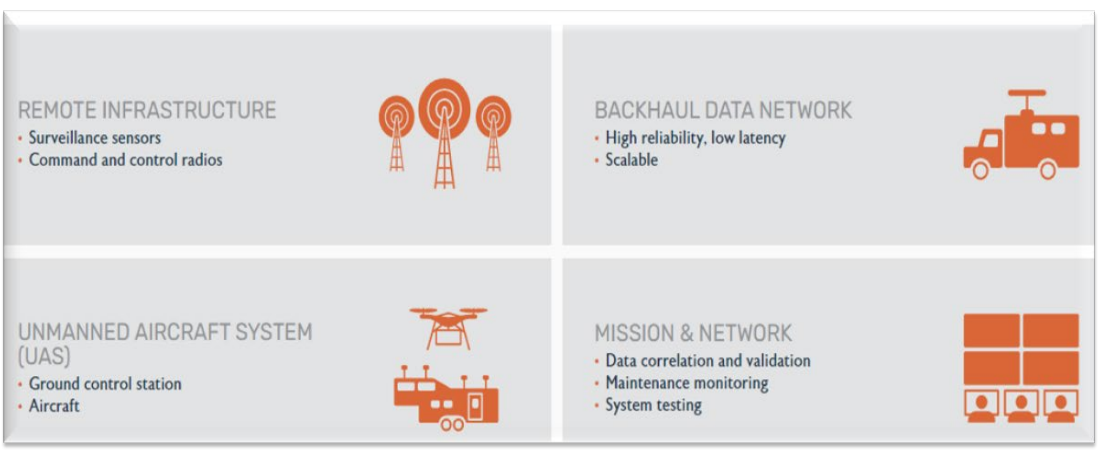


Figure 3 North Dakota's Vantis Network

Collecting real-time and localized weather data is limited for several reasons including the ability to carry sensors on the UAS. Current operations do not include the capability to avoid weather. The employment of ASAPS and EINC provided the RPIC with real time weather situational awareness of cloud and icing warnings as described above.

C. Scope

This daytime flight test campaign focused on day VMC conditions under FAA airspace approvals at Vince Dusters airfield, CA. Tests were conducted at medium altitudes (1,000' to 5,000' MSL) to:

i) measure and evaluate real-time icing and cloud indications and warnings;
ii) provide near-real time weather situational awareness within a designated operating area; and
iii) generate advisory information (threat polygons) including clouds, icing and winds at altitude to provide cloud-free line-of- sight operations and avoid environmental threats.

Data and flight test recommendations were utilized to establish and characterize enhanced operational EINC weather windows for optimal BVLOS operations and to develop the basis for a Concept of Operations (CONOPS) and Safety Case for night operations waiver. Initial plans called for the use of a NPUASTS 44803c Certificate of Authorization (COA). However, a decision was made to change to the use of a SAC-EC COA to expedite processing. Figure 4 below graphically depicts this CONOPS.

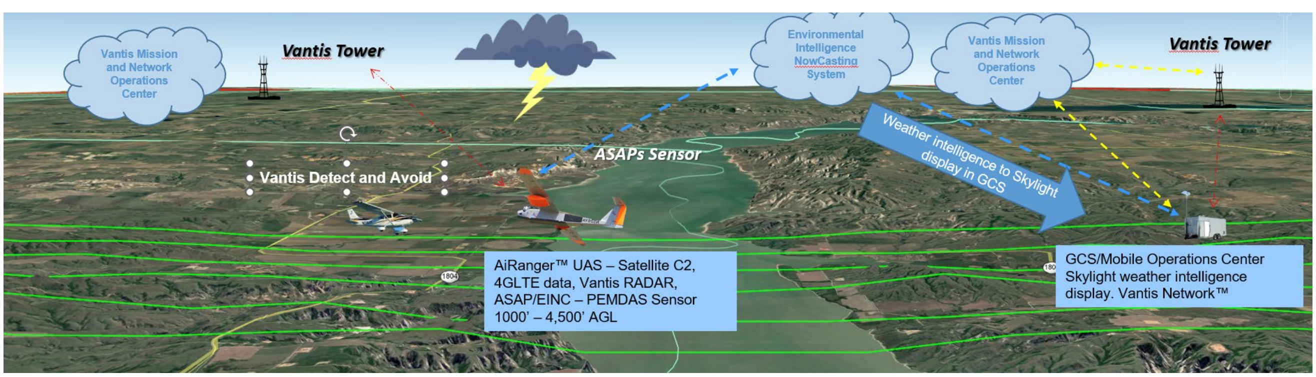


Figure 4 Vantis OV-1 CONOP

D. Integration

Atmospheric Sensing and Prediction System (ASAPS®). ASAPS is comprised of a sensor package, controller, and propriety algorithms to calculate environmental warnings. ASAPS measures and calculates environmental parameters including temperature, pressure, relative humidity, and dew point to provide a standalone warning of weather threats such as clouds and icing. ASAPS data are also used to update weather models (like EINC) with real-time in situ measurements of critical atmospheric parameters. ASAPS was designed for easy integration on UAS and has been demonstrated on more than twenty different types of platforms. Complementary to ASAPS is the EINC system. EINC is a cloud or server based large data analytic system that ingests and fuses traditional and non-traditional weather information (ASAPS, pilot reports, weather balloons, surface observations, and other widely accepted data) and uses this data to remove the errors inherent in weather models. Using M2M and AI algorithms, EINC increases the fidelity and resolution of weather model information and outputs using tailored 2D, 3D, and 3D + Time decision products for display on specified devices. Examples of these products include visualized icing or cloud layers, wind fields, and exclusion zones for thunderstorms or other adverse weather condition. EINC products are Open Geospatial Consortium (OGC) compliant and can map directly to the user's displays in the cockpit or ground control station (GCS). The user can define risk thresholds for these 2D, 3D or 4D EI products and have them outlined using color coded boxes, routes, or cross-sections.

E. Test Articles

The environmental intelligence system consists of two primary parts: a) ASAPS; and b) EINC high-resolution forecast software. ASAPS is a sensor suite which measures and calculates environmental parameters including temperature, pressure, relative humidity, and dew point to provide a stand-alone warning of weather threats such as clouds and icing and to this data is assimilated into the EINC system. AATI installed an ASAPS sensor on the right wingtip of the AiRanger aircraft shown in Figure 5.

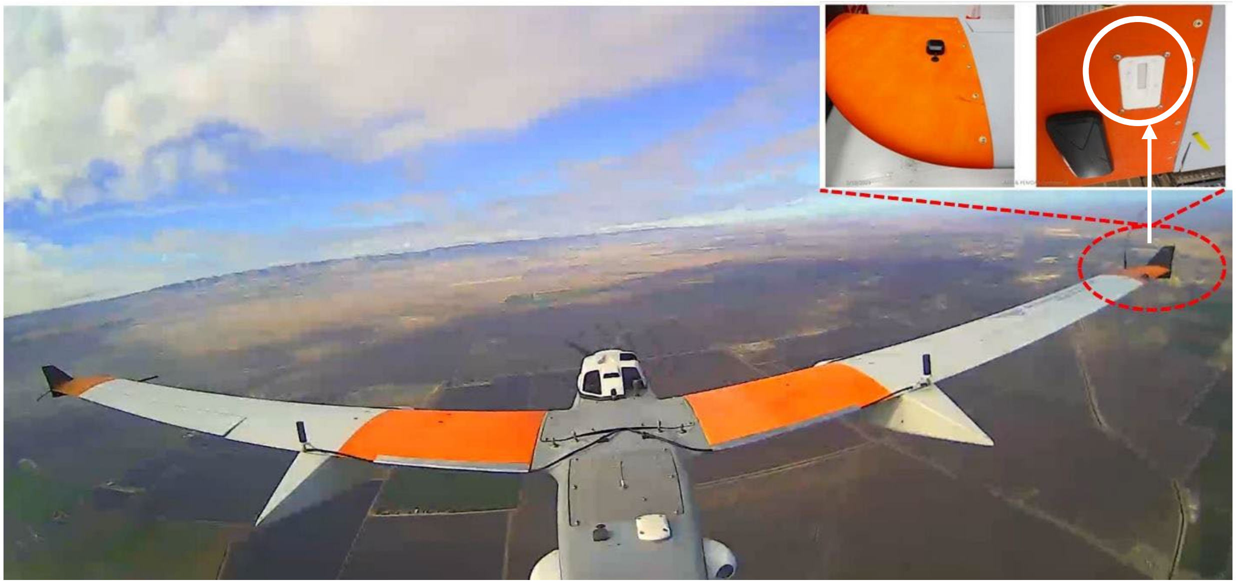


Figure 5 ASAPS Installed on AiRanger's Right Wingtip

The EINC system employs a US government approved weather model, then ingests traditional and non-traditional weather data from a multitude of sources, such as ASAPS, to improve the weather model fidelity. EINC then generates near real-time, high-resolution information of specific weather parameters such as cloud and icing and winds aloft for display to UAS operators to improve mission safety and execution. For this test, ASAPS and EINC data was presented to the AiRanger pilots through a PEMDAS developed mapping display software suite, Skylight. Exhibit 4 below provides an example of Skylight with EINC and ASAPS warning displays.

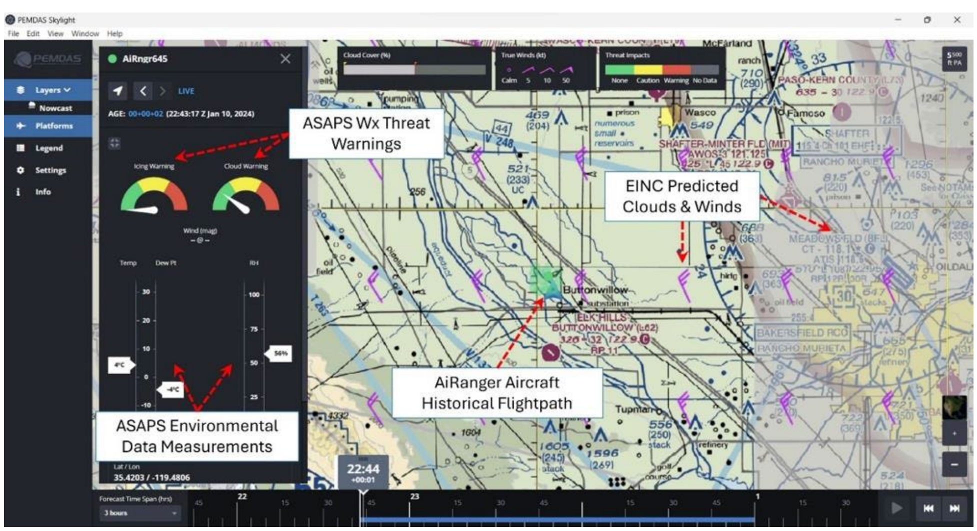


Figure 6 ASAPS/EINC Data Display on Skylight

3. Methodology

A. AiRanger / ASAPS System Integration Evaluation

AATI and PEMDAS first conducted four flights as functional checks to verify the ASAPS / EINC systems met the data collection and display criteria. Following flights were performed according to a test plan with the following objectives:

1. Does the ASAPS system measure and record all the environmental parameters required for operation of the system warnings and to provide critical weather data to the EINC system?
2. Is the ASAPS data able to be data-linked directly to the AiRanger GCS and display warnings on the PEMDAS provided Skylight system?
3. Can ASAPS data be directly linked via the internet to the EINC system?
4. Can EINC forecast be directly linked via the internet to the AiRanger GCS?
5. Is all data recordable for post-flight analysis on the AiRanger GCS computers and does the data (and collection rate) match between the onboard recording of data and the data collected at the GCS?

B. Flight Test Profile Design Criteria

Flight test profiles were designed to meet data collection objectives and perform post flight ASAPS-to-AiRanger integration error analyses. Therefore, repeatable flight tests profiles were planned in variable environmental conditions to properly characterize these installation errors. The specific flight profiles to collect the data needed for error analyses are described in the subsections below.

1. ASAPS Installation Error Corrections

During takeoff, environmental data was collected at zero knots and compared to data immediately after launch to ensure airflow is smooth and undisturbed during flight. This data was compared to ground measurements from various ground observation systems for consistency and accuracy.

2. ASAPS Compression Error Corrections

Compression error results from the impingement of air molecules on the ASAPS housing causing sensor temperatures reading to bias high. To perform compression analyses, data must be collected in various atmospheric conditions to ensure corrections across the system performance envelope are complete. Flight profiles were thus designed to collect data at various airspeeds and altitudes in consistent, homogeneous atmospheric conditions to determine these errors. The data was collected in straight-and-level unaccelerated flight, processed, and evaluated to verify error corrections.

3. ASAPS Sensor Lag Measurements and Corrections

Lag errors are attributable to various conditions such as rate of climb, movement from warmer (colder) to colder (warmer) air masses and environmental conditions. To correct for sensor lag, flight profiles were developed to collect data during numerous climbs, descents, and level-off conditions to determine the performance of Kalman filters utilized in the system for lag corrections. A variety of methods and time-constants for the filters were then developed to ensure the system performance is adequate.

4. Data Accuracy and Use

As outlined in the previous three paragraphs, collecting data during specific planned maneuvers ensured all measurement inaccuracies from a) installation errors, b) compression heating caused by increased airflow inflight, and c) sensor measurement lag from rapidly changing conditions were accounted for. Once accurate values for temperature and relative humidity were determined, the data could be used to provide pilots with precise weather warnings for environmental threats such as the potential for clouds and icing conditions. Finally, the corrected data could be assimilated into the EINC system to correct weather forecasts with these real-time, accurate local measurements of the atmosphere.

C. Flight Test Objectives

To effectively meet data test objectives, the following seven flight test objectives were required to fulfill the overall purpose of this flight test program.

1. Objective 1

Establish an EINC "window" over the proposed test site. This 3D volume of airspace over a given region is the area of increased resolution and fidelity characterization of environmental conditions attained by the big data analytics of the EINC system.

2. **Objective 2**

Devise flight test points to assess how the AiRanger can collect the necessary atmospheric information using ASAPS to support proper decision products for night BVLOS flights. This included a series of climbs and descents through the earth's atmospheric boundary layer (ABL) to more properly assess moisture. This knowledge is relevant to the formation of clouds and the inversion layer.

3. **Objective 3**

Perform EINC modeling and error correction on an appropriate government weather model for this test (e.g.; the Weather Research and Forecasting Model). This correction process includes ingesting various weather observations and information, to include ASAPS data from the flight test points, processing this in the iCloud and outputting high resolution, real-time weather decision products for evaluation.

4. **Objective 4**

Visualize the EINC information on the PEMDAS Skylight software to be installed in the Ground Control Station (GCS).

5. **Objective 5**

Support enroute flight navigation of the AiRanger with real-time EINC and ASAPS decision products.

6. **Objective 6**

Perform validation on the EINC output to verify accuracy and fidelity.

7. **Objective 7**

Conduct user feedback sessions to understand the usefulness of the ASAPS/EINC decision information for flight navigation and operational display.

D. Improvements Arising from AATI Flight Test Support

Pressure for Geolocation of Data. The ingestion of ASAPS data into the EINC model is dependent on knowing the specific location the data is recorded and ensuring it is placed in the model at this appropriate location. The ASAPS system initially installed on the AiRanger did not include a software interface to obtain aircraft measured static pressure to provide the pressure level at which the measurements were taken but instead included a GPS antenna and receiver that provide geolocation of data for EINC. This GPS provided altitude in feet mean sea level, not in pressure altitude. PEMDAS adjusted the ASAPS software after the January flight tests to collect AiRanger autopilot flight control system data including pressure and winds. For all remaining sorties, the autopilot data was used to geolocate all the observations and the aircraft winds were used to validate the EINC wind model forecasts.

E. Flight Test Approach And Procedures

Specific flight maneuvers were designed during the flight test plan development for the AiRanger sortie profiles to meet mission objectives outline in Section 2.C. This profile included initial system verification to ensure data and weather warnings could be viewed in the AiRanger ground control station (GCS) and then integrated with the EINC system. Repeatable maneuvers were planned at various altitudes to ensure the environmental data collected was accurate and able to influence the EINC forecast system by providing real-time in situ weather data for inclusion in the weather model forecasts. Multiple flights and test profiles were flown during the two weeks of flight testing. A copy of the flight profile flown on each sortie is outlined in *Figure 7*.

Phase 1:

- Preflight
    - Start aircraft on run-stand/launcher
    - Verify proper operation of Sensor on ground
        - Ensure Sensor is powered On
    - T/O / Climb out on 900MHz
    - Check System
- Monitor engine temperature, rpm, and flight characteristics
- Level in traffic pattern (1000’ AGL)
- EP Stick check in pattern to check controllability. Then, return control to IP when complete.

Phase 2:

- Perform Test Points 1 - 10.
- Test Point 1: Remain at 1000' AGL Level Flight
    - Level off, a minimum of 1:00 minute and collect data
- Test Point 2: Climb to 4500' AGL in Rectangular Pattern @ 500fpm
    - Collect Data
- Test Point 3a: @4500' AGL enter left-hand orbit (Sensor Wing High) for 4:00 minutes
    - Collect Data
- Test Point 3b: @4500' AGL reverse course to right-hand orbit (Sensor Wing Low) for 4:00 minutes
    - Collect Data
- Test Point 4: @4500' AGL Level Acceleration in Rectangular Pattern; Speed Range 50kts (Min) to 75kts (Max)
    - Collect Data
- Test Point 5: @4500' AGL Level Deceleration in Rectangular Pattern; Speed Range 75kts (Max) to 50kts (Min)
    - Collect Data
- Test Point 6: Descend at max rate from 4500' AGL to 1000' AGL in Rectangular Pattern.
    - Collect Data
- Test Point 7: Climb at max rate from 1000' AGL to 4500' AGL in Rectangular Pattern.
    - Collect Data
- Test Point 8a: @4500' AGL enter left-hand orbit (Sensor Wing High) for 4:00 minutes
    - Collect Data
- Test Point 8b: @4500' AGL reverse course to right-hand orbit (Sensor Wing Low) for 4:00 minutes
    - Collect Data
- Test Point 9: Saw tooth descent (normal descent) in Rectangular Pattern; Leveling off every 500 feet for 0:30 Seconds; 4500AGL to 1000' AGL
    - Collect Data
- Test Point 10: Saw tooth climb (normal climb) in Rectangular Pattern; Leveling off every 500 feet for 1:00 minute; 1000' AGL to 4500' AGL.
    - Collect Data
- Descend to 1000' AGL and prepare for Landing

Phase 3:

- Perform go around and monitor track
- Verify 900 MHz primary radio prior to engine kill
- Standard AP recovery
- Save Piccolo Log, Telemetry Files, and Other Related Aircraft Files
- Save Tail Cam Files
- Retrieve PEMDAS Sensor File

Figure 7 Daytime Flight Test Maneuver Line-up Card

4. Results and Discussion

A. Environmental Evaluation

A summary of the weather during each day of the flight tests is outlined below, followed by a summary of the in situ environmental data collected during each sortie and, finally, a detailed analysis of the performance of the combined ASAPS / EINC system for flights during the final two test days is provided.

Weather Synopsis Per Flight Day - DECEMBER

Synoptic Situation 08 December 2023: A 1029 mb high pressure centered over northern California produced fair weather conditions. Valley haze and low ceilings developed overnight and were slow to burn off in the southern valley as light northerly surface winds advected moisture southward.

Synoptic Situation 09 December 2023: Pacific high pressure strengthened off the coast as a 992 mb low pressure system over northwestern Canada trailed a cold frontal boundary westward. The low transitioned southeast and the cold front crossed into central California by afternoon producing light northwesterly winds on station.

Synoptic Situation 10 December 2023: Valley haze formed overnight as weak high pressure maintained fair weather across the domain.

Synoptic Situation 11 December 2023: High pressure strengthens over central California producing fair weather across the domain.

Weather Synopsis Per Flight Day - JANUARY

Synoptic Situation 10 January 2024: Weak Pacific high pressure extended east over California as a 1007 low pressure system centered over Oregon extended a cold frontal boundary westward. This system transitioned southeast. At KBFL, Bakersfield Meadows Field, winds at take-off were 300 at 5 kt with overcast skies at 3,600 feet. Skies over Vince Dusters airstrip in Buttonwillow were clear with light winds. Satellite overview is illustrated in Figure 8 and Figure 9.

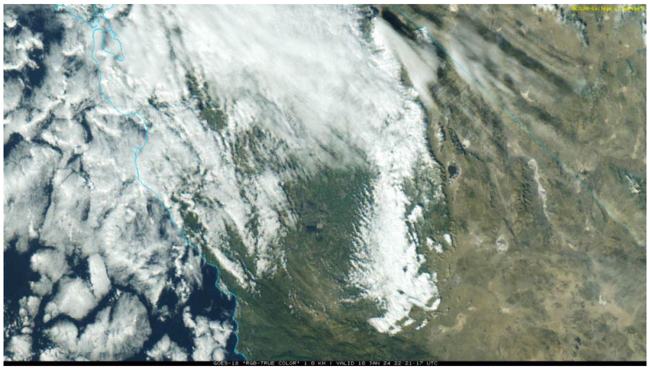


Figure 9: January 10 2024 Initial Take-off Satellite

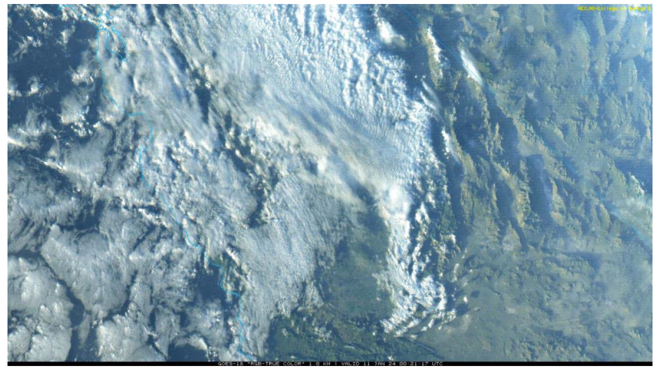


Figure 8: January 10 2024 Final Approach Satellite

Synoptic Situation 13 January 2024: A 1000mb low centered off the coast of Oregon extended a cold frontal boundary west and moved east-southeast inland. An extensive cloud shield from this low began to impact KBFL producing mostly cloudy skies. Take-off winds were 14003 kt with clear skies and unrestricted visibility. Satellite overview is illustrated in Figure 10 and Figure 11.

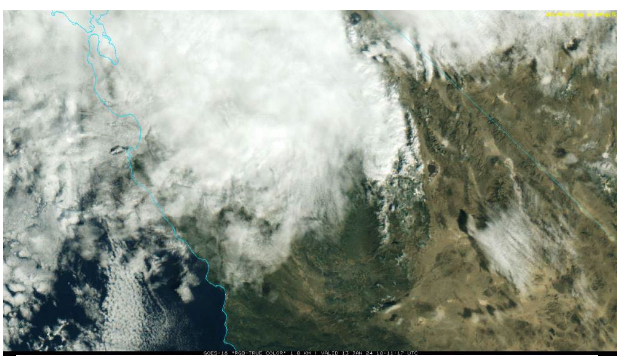


Figure 11 January 13 2024 Initial Take-off Satellite

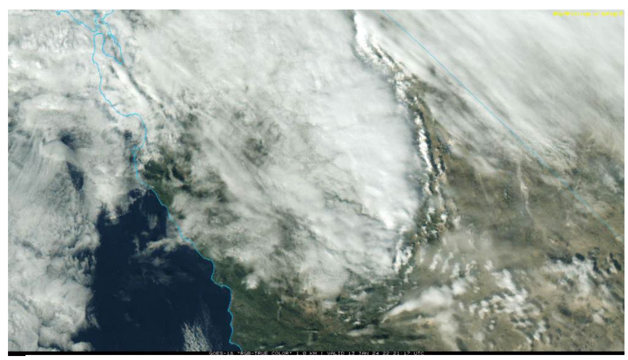


Figure 10 January 13 2024 Final Approach Satellite

Environmental Data Collection Summaries

A summary of the flight times, sortie parameters and ASAPS data collected during each flight in December is shown in *Figure 12* below. ASAPS data was not ingested in the EINC forecast models for these flights. Though aircraft sometimes lost link in turns on the southwest portion of the test area for a few seconds during some orbits, ASAPS data was recorded on an SD card onboard the aircraft. Review of the data post-flight revealed ASAPS had zero dropouts throughout all the flights.

AATI AiRanger December Flight Summary				
	08 DEC	09 DEC	10 DEC	11 DEC
Start Times (UTC)	19:45:41	19:07:12	17:07:30	22:24:23
End Times (UTC)	21:17:49	21:23:28	19:24:49	(12 DEC) 00:21:19
Collection Durations	1:32	2:16	02:17	1:57
Maximum Altitude (ft MSL)	2795	4920	4799	4794
Number of ASAPS Measurements Collected (1Hz)	5600	8320	8410	7520
Number of ASAPS Measurements Assimilated (1Hz)	N/A	N/A	N/A	N/A

Figure 12 December 2023 Flight Summary

Flights were flown in January 2024 from the 9th through the 15th. The flight on the 9th recorded ASAPS data and was utilized to determine how the ASAPS system performed prior to the remainder of the tests. Multiple test collections were made during sorties flown from the 13th – 15th. A total of five test events were analyzed during the 14th and 15th flight period by PEMDAS engineers and scientists. ASAPS observations were assimilated into the EINC model during each of these flights. Details of each flight and the number of ASAPS observations assimilated are listed in the flight summary below, Figure 13. A total of 16,855 ASAPS observations were assimilated into the EINC model over the duration of these flights[10].

AATI AiRanger January Flight Summary					
	9 JAN	10 JAN	13 JAN	14 JAN	15 JAN
Start Times (UTC)	22:29	22:21	18:13 19:57 21:19	18:15 19:39 21:24	18:47 21:49
End Times (UTC)	00:44	(11 JAN) 00:15	19:56 21:13 22:23	19:33 21:18 22:34	19:44 23:10
Collection Durations	02:15	01:54	01:43 01:16 01:04	01:18 01:39 01:10	00:57 01:21
Maximum Altitude (ft MSL)	4798	4788	4810	4797	4801
Number of ASAPS Measurements Collected (1Hz)	8,100	10,304	10,600 7910 6909	7567 8768 6482	1000 1570
Number of ASAPS Measurements Assimilated (1Hz)	N/A	2755	2753 2202 1754	2435 2358 1689	359 550

Figure 13 January 2024 Flight Summary

[10]Note: ASAPS measures at 10HZ to provide the pilot with warnings at a rapid rate. The EINC system does not require high-rate observations to assimilate ASAPS date into the model (ie., the smallest resolution cell for the EINC system is 1 km; so, the thousands of measurements taken by ASAPS in each of the kilometers are not needed by the forecast model EINC).

14 January Flight 1 In-Depth Analysis

During the first data collection from 18:15 to 19:33 UTC, temperatures ranged from 8.5° to 15.3°C and relative humidity from 34% to 69% after take-off, with minimum temperatures and maximum relative humidity values corresponding to in flight cloud warnings between 3,800 to 4,600 feet that AiRanger encountered in the northern portions of the flight area as shown in *Figure 14, 15* and *16* below. During this time KBFL reported broken cloud layers at 3,700 feet and KDLO, Delano Airport, 24 miles to the northwest reported clouds scattered at 3,500 feet and broken at 3,300 feet.

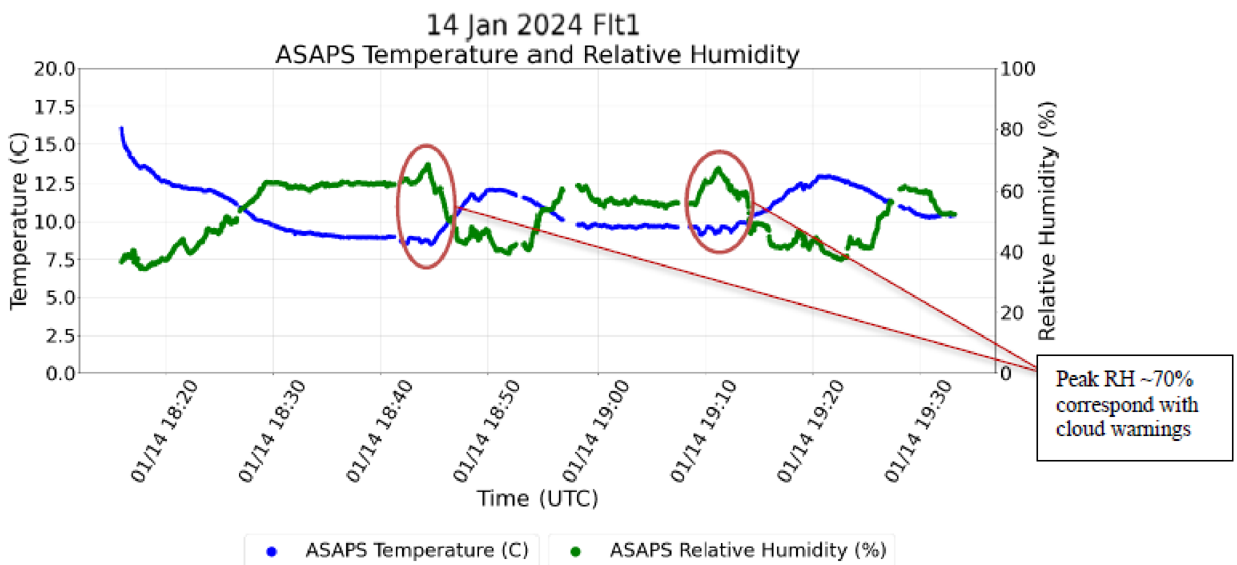


Figure 14 14 January 2024 Flight 1 ASAPS Temperature and Relative Humidity

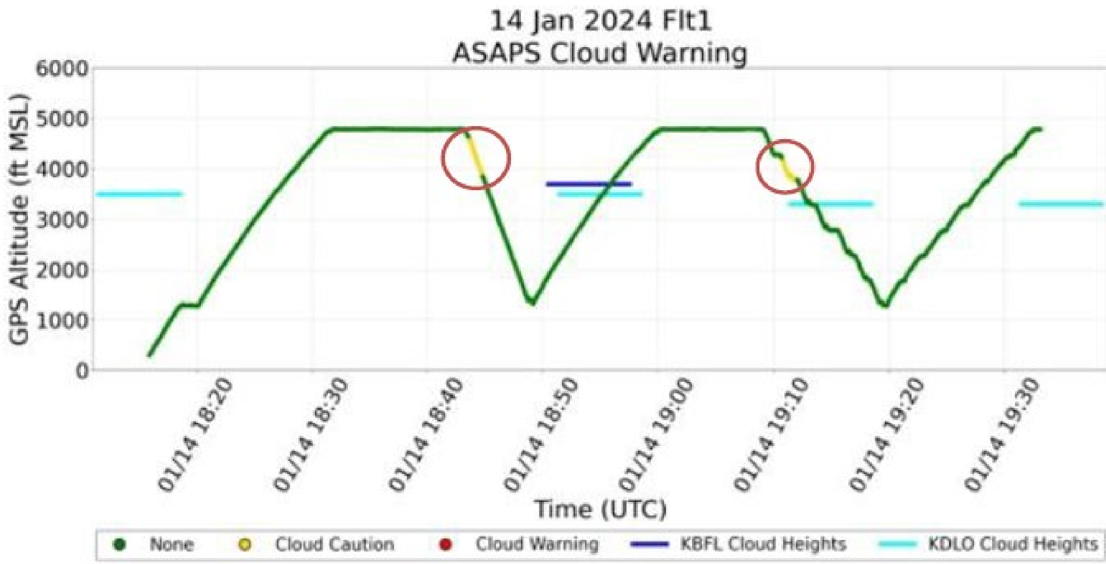


Figure 15 14 January 2024 Flight 1 ASAPS Altitude Color-Coded Cloud Warnings

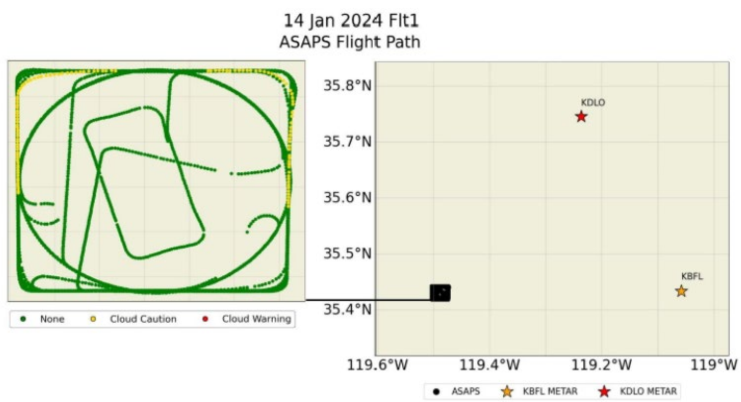


Figure 16 14 January 2024 Flight 1 ASAPS Flight Path and Color-Coded Cloud Warnings

B. ASAPS Cloud Warnings

Figure 17 details the relative humidity, ASAPS cloud warnings, clouds reported at nearby airports, AiRanger tailcam or other on-site photos with coincident time and altitude obtained from the ASAPS warning display, and images from geostationary satellites during these four flights. Reporting airports include Meadows Field (KBFL, elevation 510 ft) and Delano (KDLO, elevation 316 ft) for California flights, and Williston, ND (KWXA, elevation 2,356 ft) and Sher-Wood, MT (KPWD, elevation 2,264 ft) for North Dakota flights. All cloud base heights in this report are presented in feet above mean sea level (MSL) and have been converted from above ground level (AGL) as reported by the source.

Flight Start/End	Max Relative Humidity	ASAPS Cloud Warnings	Lowest Reported Cloud Base	Verification Source
10:15 PST / 11:33 PST 18:15 UTC / 19:33 UTC 14 Jan 2024	69%	Caution 3,800-4,600 ft MSL	KBFL: 3,700 ft KDLO: 3,800 ft	AiRanger tailcam photo and ground photo from GCS with AWD altitude
10:47 PST / 11:44 PST 18:47 UTC / 19:44 UTC 15 Jan 2024	69%	Caution 2,100-2,500 ft MSL 256 to 800 ft MSL	KBFL: CLR KDLO: CLR	AiRanger tailcam photo with AWD altitude
13:49 PST / 20:11 PST 21:49 UTC / 23:11 UTC 15 Jan 2024	69%	Caution 1,650-1,750 ft MSL 256 to 2,000 ft MSL	KBFL: CLR KDLO: 2,000 ft	Ground photo from GCS with AWD altitude
20:30 CDT / 23:43 CDT 10 Jun 2024 01:30 UTC / 04:43 UTC 11 Jun 2024	81%	Warning 4,000-6,400 ft MSL Caution 4,000-6,500 ft MSL	KXWA: 7,000 ft KPWD: 11,000 ft	AiRanger tailcam photo with AWD altitude

Figure 17 Summary of ASAPS Cloud Warnings During Test Flights

During these four flights, clouds were reported in the vicinity of the aircraft. Cloud cautions indicate increasing potential for clouds and are interpreted to indicate that the aircraft is approaching a cloud environment. Increasing cloud potential can also indicate, especially during level flight, that the atmospheric moisture content is increasing, and clouds may begin to form at that altitude in the near future. Cloud warnings indicate high potential for clouds, but do not necessarily indicate that the aircraft is physically in clouds.

14 Jan 2024 Flight

High pressure over central California produced primarily fair weather and calm winds on 14 Jan 2024. Troughing offshore resulted in the advection of a shallow layer of moist air across southern California that produced clouds around 4,000 ft MSL. *Figure 18* depicts a time series of ASAPS altitude and cloud warnings.

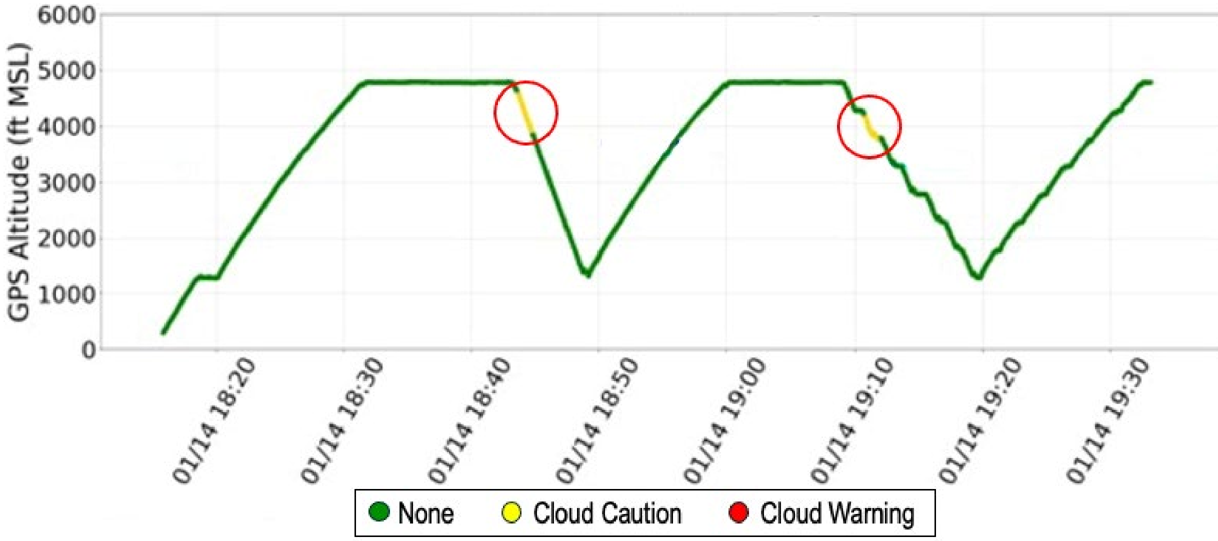


Figure 18 ASAPS Altitude Color-Coded Cloud Warnings (14 Jan 2024)

Breadcrumbs indicate past aircraft position and corresponding ASAPS cloud warning value. Green breadcrumbs indicate no clouds, and yellow markers indicate increased cloud potential or "caution." *Figure 19* shows the AiRanger flight path color-coded to indicate ASAPS cloud warning (left) and the location of the KBFL and KDLO reporting sites relative to the flight area. A geostationary satellite image underlay (right) depicts the location of clouds relative to the AiRanger operating area and nearby airports. ASAPS reported increased potential for clouds ("yellow" / caution) between 3,800 and 4,600 ft MSL between 18:40 and 19:10 UTC when the aircraft was in the northern half of the operating area. The cautions for increased cloud potential coincided with periods of peak relative humidity measured by ASAPS. During this time period, KBFL reported broken cloud layers at 3,700 feet MSL (blue) and KDLO reported scattered clouds at 3,800 feet MSL (cyan).

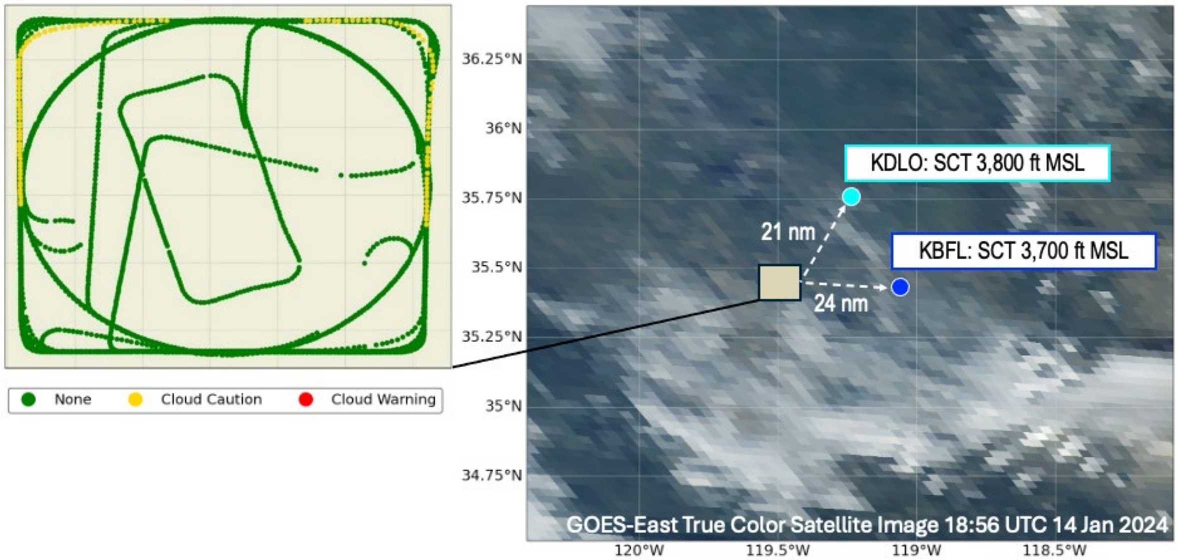


Figure 19 AiRanger Flight Path w/ Color-Coded Cloud Warnings and Satellite (14 Jan 2024)

Figure 20 presents the ASAPS cloud warnings for a portion of the flight visualized in Skylight. The flight path of the AiRanger is depicted with green and yellow breadcrumbs over time. During this portion of the flight, ASAPS indicated increased potential for clouds on the western edge of the test area coincident with increased cloud coverage to the west. As shown in *Figure 21*, these warnings were validated by a photo taken from the GCS looking to the west and an image from the AiRanger tailcam which shows the clouds just above the aircraft developing west of the GCS (looking northwest).

Figure 20 ASAPS Cloud Warnings Displayed on Skylight (14 Jan 2024)

Figure 21 Clouds Looking West from GCS & Tailcam Looking Northwest (14 Jan 2024)

15 Jan 2024 Flight 1

A strong inversion in the San Joaquin Valley trapped moist air and shallow clouds in the lower atmosphere on the morning of 15 Jan. Above the inversion at 4,000 ft MSL, relative humidity values were less than 50% and skies were clear. However, below the inversion, where relative humidity values reached 69%, ASAPS indicated increased potential for clouds between 2,100 and 2,500 ft MSL during the flight. KBFL and KDLO reported clear skies and haze, indicating increased moisture in the lower atmosphere, but not enough to support cloud development. *Figure 22* shows the local conditions at Vince Dusters Airfield just prior to takeoff at 17:54 UTC, with haze reducing visibility and indicating increasing moisture at the surface. During the flight, warming of this shallow moist layer resulted in the rapid development of clouds very close to the ground and forced early termination of the sortie. As the aircraft approached the airfield and descended, ASAPS again indicated increased potential for clouds below 800 feet MSL. *Figure 23*, an image from the AiRanger tail cam, shows this shallow cloud layer below the aircraft and the ASAPS warnings display seen by the pilot which indicated cloud caution during the descent. A second planned sortie that day was delayed until the shallow cloud layer dissipated.

Figure 22 Vince Dusters Airstrip Runway 34 Airfield Conditions

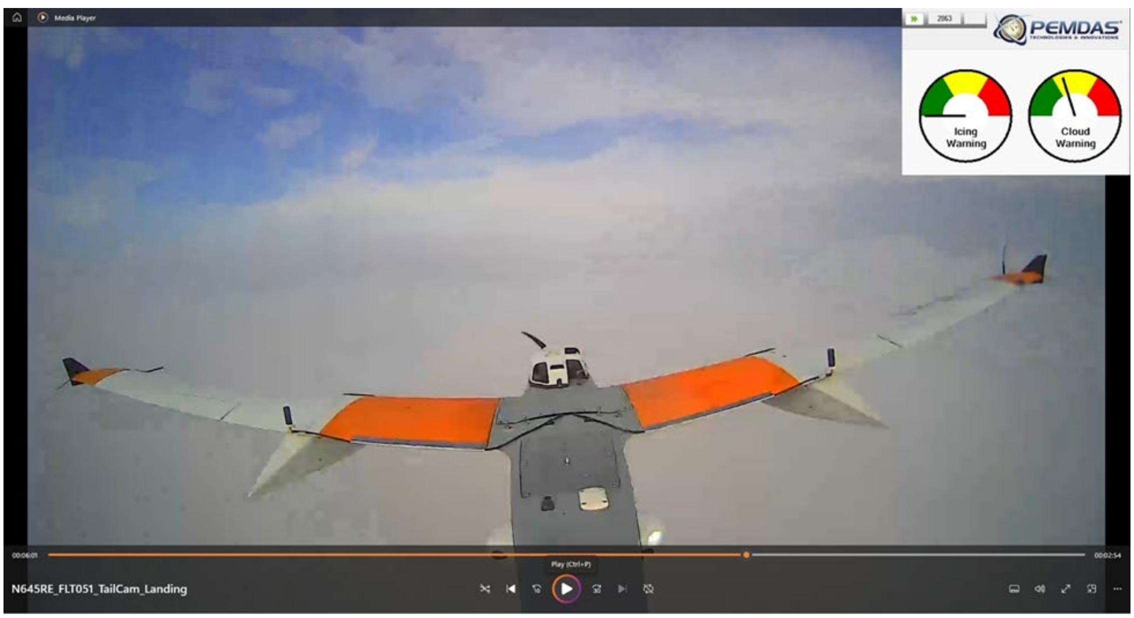


Figure 23 AiRanger Tail Camera Video and ASAPS Cloud Caution Display During Descent

10 June 2024 Flight

Thick, layered clouds associated with a cold front transited eastward across the flight area several hours prior to the flight. Prior to takeoff, KWXA reported scattered clouds at 7,000 ft MSL, broken clouds at 8,000 ft MSL (ceiling), and overcast clouds at 11,000 ft MSL. *Figure 24* shows the sky behind the front, dominated by layered clouds with lowest bases around 6,000 to 7,000 ft MSL lingering in the flight area and a GOES-West true color satellite image at 01:31 UTC 11 Jun. The satellite image indicated deep layered clouds over eastern North Dakota associated with the front and clearing skies to the west. Clear skies were reported by KWXA during the final two hours of the flight. This gradual decrease in cloud cover and moisture was depicted in the ASAPS cloud warnings during the flight. Early in the flight, when more clouds were present, ASAPS cloud warnings indicated increasing potential for clouds between 4,000 and 6,500 ft MSL (moistening of the environment needed for cloud formation). However, as the flight progressed and clouds dissipated in the drier environment behind the front, ASAPS indicated decreased cloud potential (green/no clouds after about 03:00 UTC). *Figure 25* shows an AiRanger tailcam image captured at 6,200 ft MSL level with the clouds, along with ASAPS warning display given to the pilots at that same point in time. *Figure 26* shows the Skylight breadcrumbs display a little later in the flight which shows the flight track from "green," to "yellow," to "red," and back.

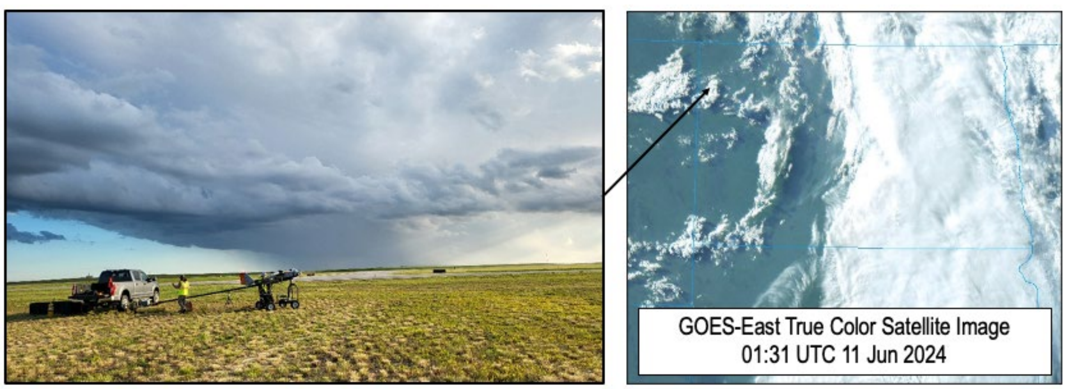


Figure 24 Pre-launch Weather Observations, Williston Airport

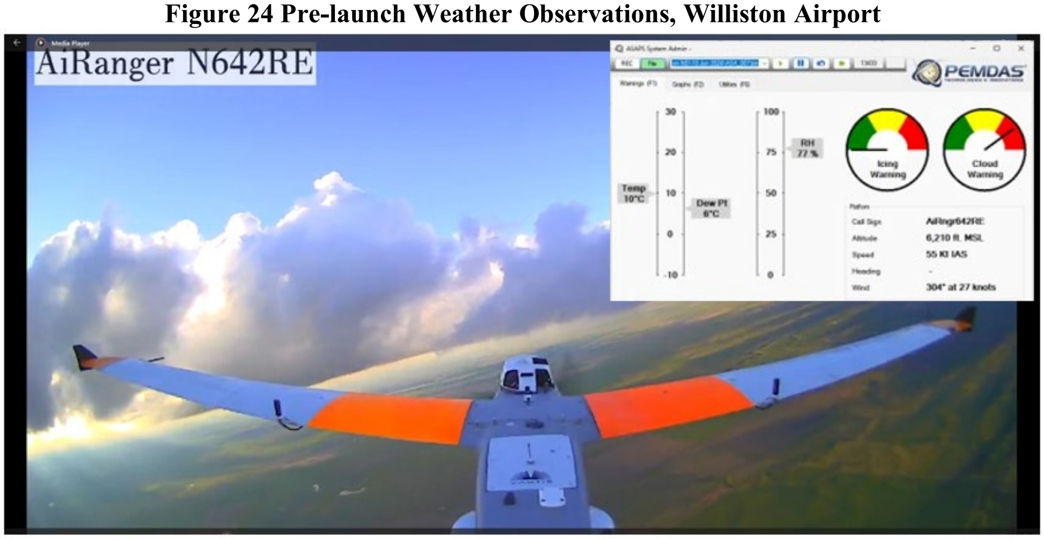


Figure 25 AiRanger Tailcam Image of Clouds at 6,000' MSL (10 Jun 2024)

Figure 26 Skylight - ASAPS 6,000' MSL Cloud Warnings, Williston Airport (10 Jun 2024)

Figure 27 is a time series of the ASAPS measured relative humidity, which contributes to the cloud and icing warnings (through PEMDAS proprietary algorithms). The lower plot depicts the aircraft altitude throughout the flight showing the numerous climbs and descents as described in the test card (section 3). At the top of the plot is the cloud warning level (red, yellow, or green) provided to the pilots throughout the flight and the comparison Kestrel sensor observations taken on the ground at the GCS prior to takeoff and after landing.

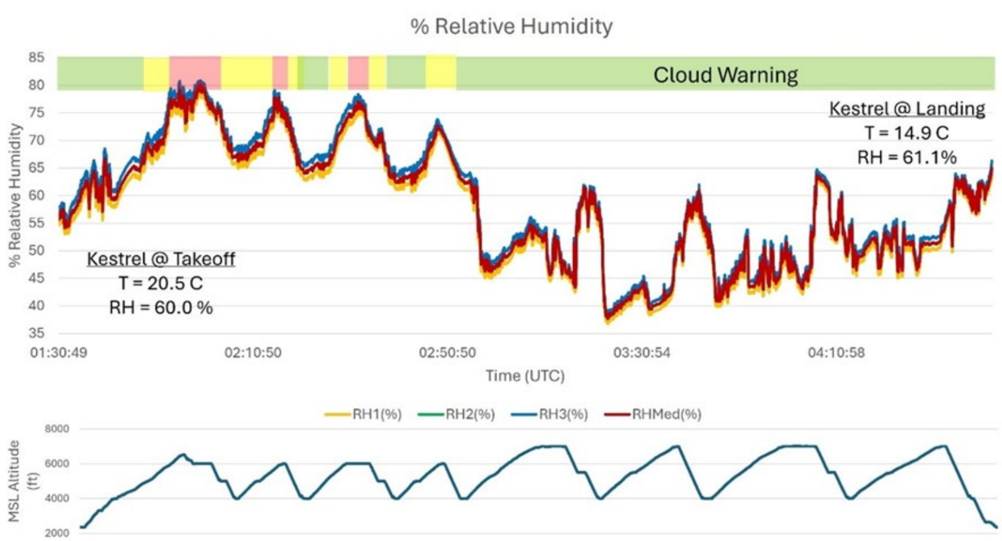


Figure 27 ASAPS RH Measurements & Cloud Warning Levels, Sloulin Field (10 Jun 2024)

C. EINC Winds

EINC wind forecasts were compared to aircraft winds reported during the flights. *Exhibit 19* details aircraft (A/C) and forecast winds at several altitudes during the flights on 10 and 11 Jun. EINC winds were interpreted from the Skylight visualization which depicts wind speed barbs in five knot increments, and wind direction was estimated to the nearest 10 degrees. EINC winds were consistent with aircraft winds as shown in *Exhibit 20 and Exhibit 21,* which depict examples of these winds displayed in Skylight. Aircraft location is indicated by the blue triangle.

Flight Date	Pressure Altitude	A/C Winds	EINC Winds
10 Jun	3,500 ft	277º / 19 kt	280º / 20 kt
	4,000 ft	292º / 21 kt	280º / 25 kt
	5,500 ft	287º / 29 kt	290º / 30 kt
	6,000 ft	297º / 29 kt	290º / 25 kt
11 Jun	4,000 ft	304º / 24 kt	290º / 20 kt
	6,000 ft	274º / 20 kt	270º / 20 kt

Figure 28 Aircraft and EINC Winds

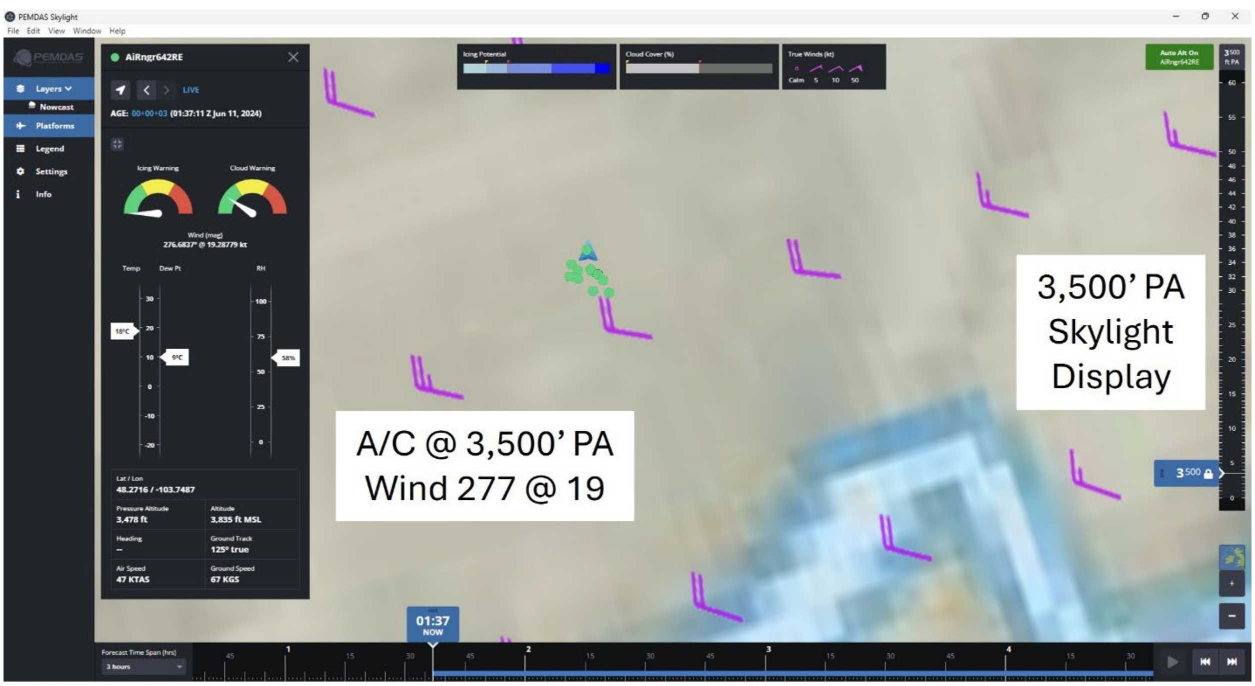


Figure 29 Aircraft and EINC Winds at 3,500' PA – Williston Airport (10 Jun 2024)

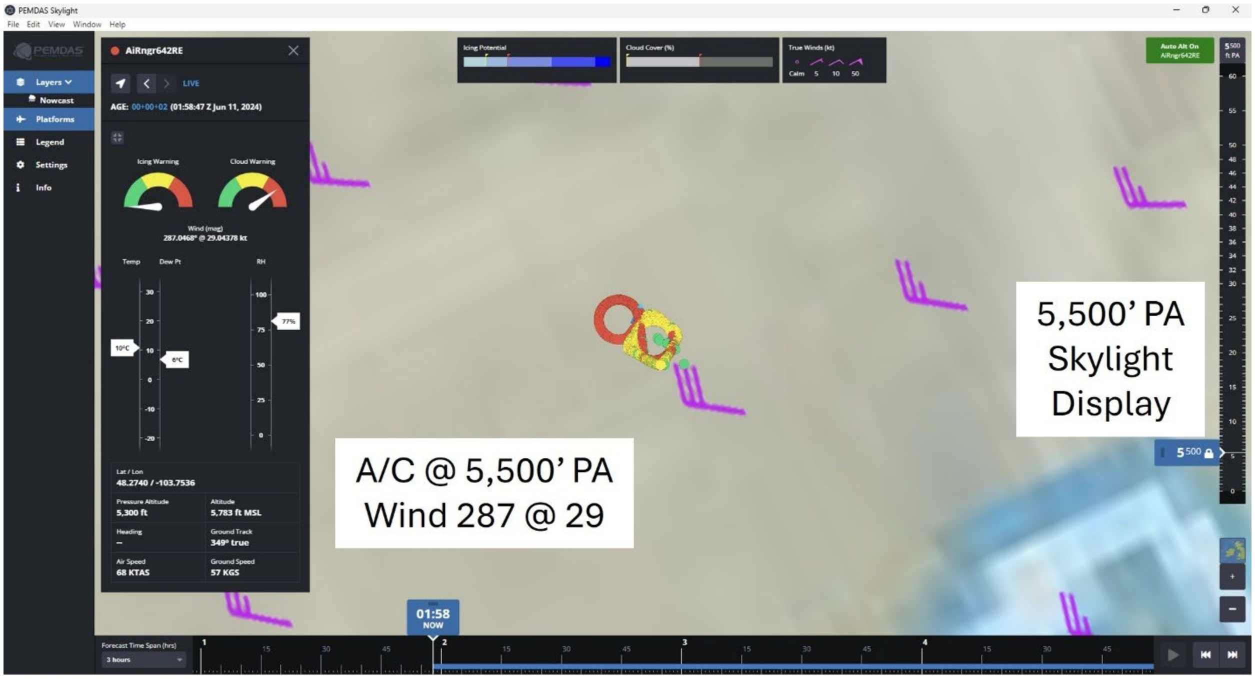


Figure 30 Aircraft and EINC Winds at 5,500’ PA – Williston Airport (10 Jun 2024)

11 June 2024 Flight

The flight on 11 June was the culmination of the test series, where the aircraft performed a night BVLOS flight down-range (with a chase aircraft per requirements). The sortie began with a weather data collect profile, followed by the down-range portion accompanied by the chase aircraft and ended with another weather data collect profile over the airfield. Prior to and during the flight, the main concern of the pilots was the winds from the west at altitude causing a slow ground speed for the chase aircraft to follow during the return to the airfield. Similar to the 10 June flight, EINC again accurately predicted the winds throughout the flight area and at various altitudes as shown in *Exhibit 22* and *Exhibit 23. This* provided the pilots increased situational awareness of expected winds both prior to and during the flight. This allowed them to select the “best” altitude for flight operations.

Figure 31 Aircraft and EINC Winds at 4,000’ PA – Williston Airport (11 June 2024)

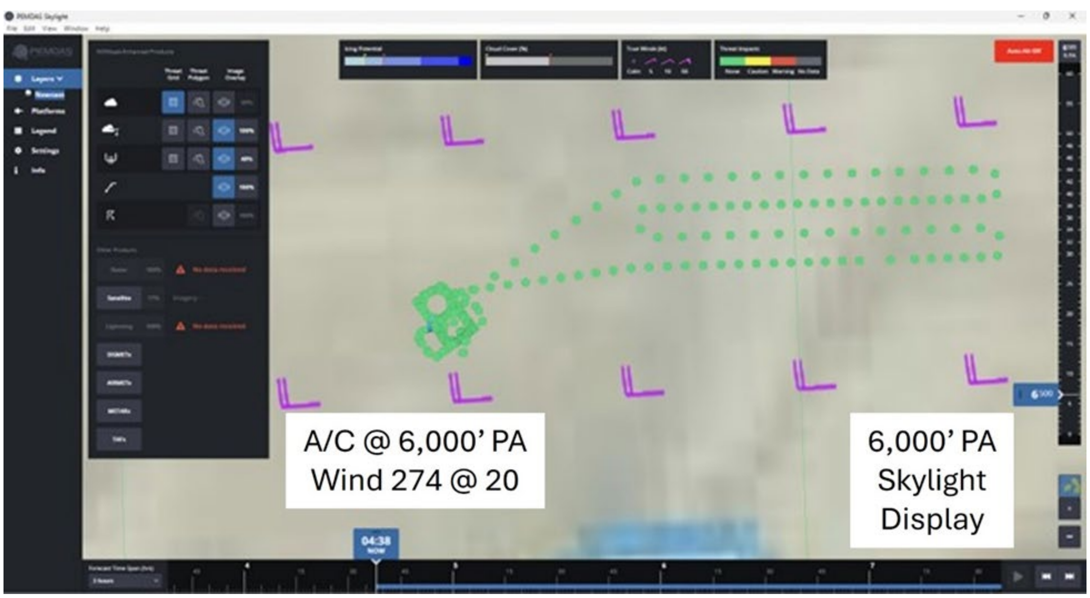


Figure 32 Aircraft and EINC Winds at 6,000’ PA – Williston Airport (11 June 2024)

D. Results of Feedback

The AiRanger pilot monitored the Skylight presentation of the EINC and ASAPS Warnings throughout the flight tests. The pilot generally rated the system as very helpful in increasing their situational awareness of weather and environmental threats during flight operations. Two areas of improvement included the “hands-on” requirement to adjust forecast levels during flight and the background map display used for the Skylight software. *Exhibit 24* displays the manual slider bar used to adjust EINC weather overlays on the right side of the Skylight display with the aircraft altitude on the left side. The suggestion was to enable the overlay altitude to adjust automatically with the aircraft altitude to allow “hands-free” operation and display of critical weather information as the aircraft climbs and descends. The Skylight software was adjusted by PEMDAS engineers and included this “auto-altitude” capability for flights in June 2024 as illustrated in *Exhibit 25*.

After the auto-altitude function was introduced, the pilots used this capability during all critical phases of flight including takeoff and landing. This was particularly helpful with wind forecasts in the test area as the aircraft executed its initial climb out as depicted in the 10 and 11 June flight analysis.

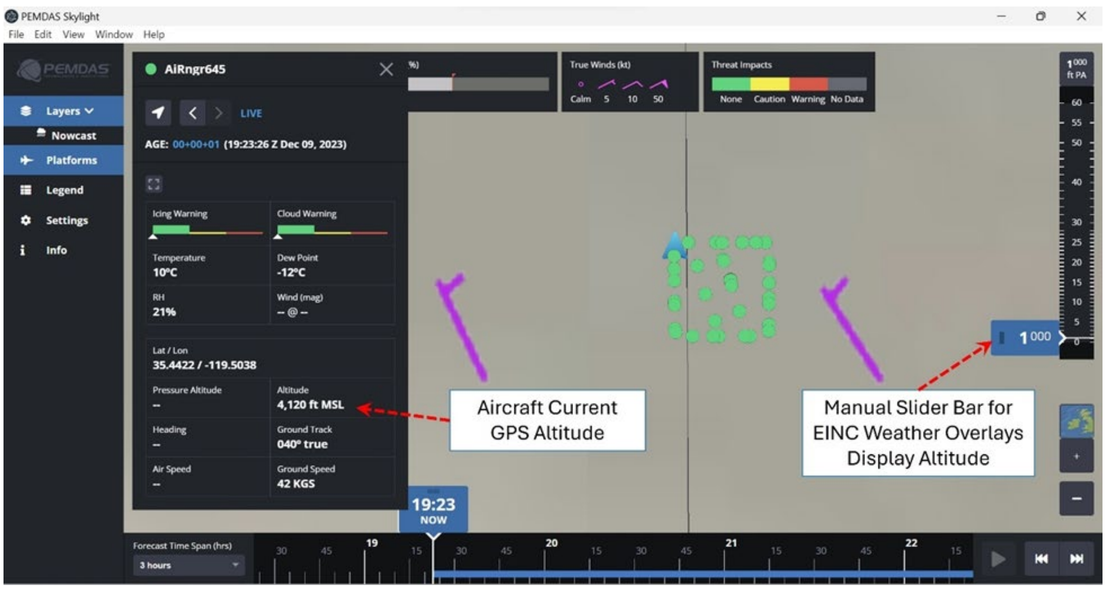


Figure 33 Skylight Altitude Adjustment Operation

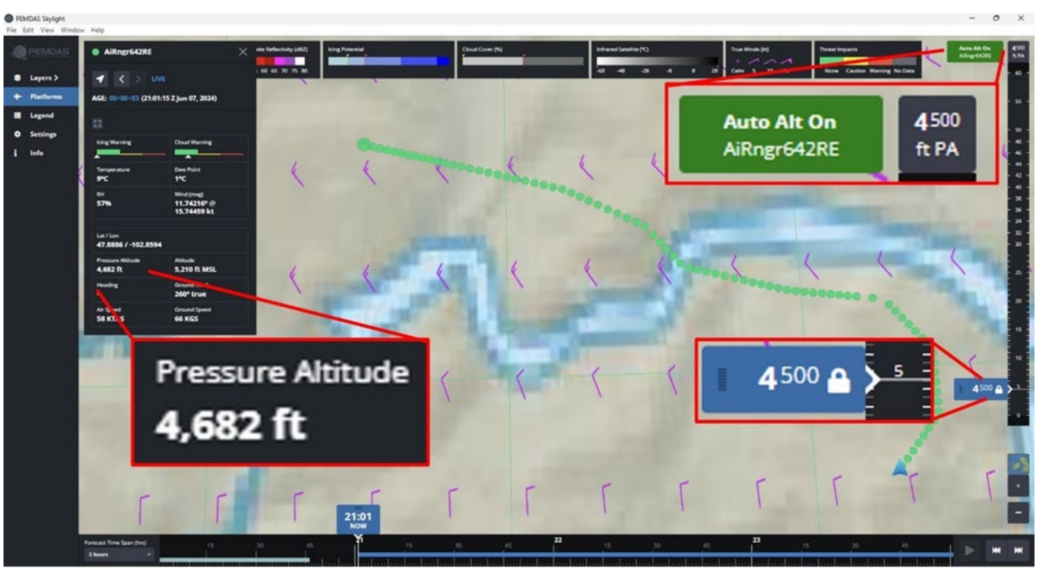


Figure 34 Skylight Altitude Adjustment Operation

Pilots also gave feedback on the map displays which sometimes were confusing where cloud overlays looked similar to background map colors. Shown in *Exhibit 26* is an example of a Skylight screen where the background terrain looks like a cloud background while *Exhibit 36* illustrates the same picture "zoomed in" where the background appears to be clouds.

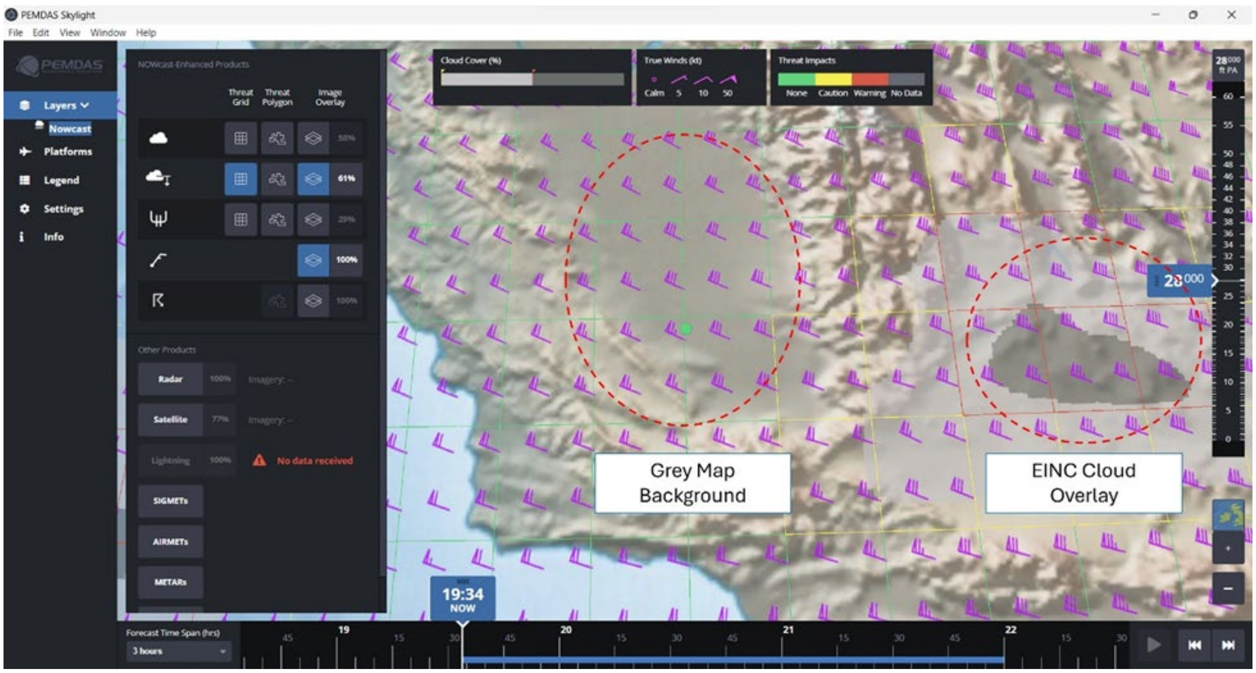


Figure 35 Skylight Map Background Shading

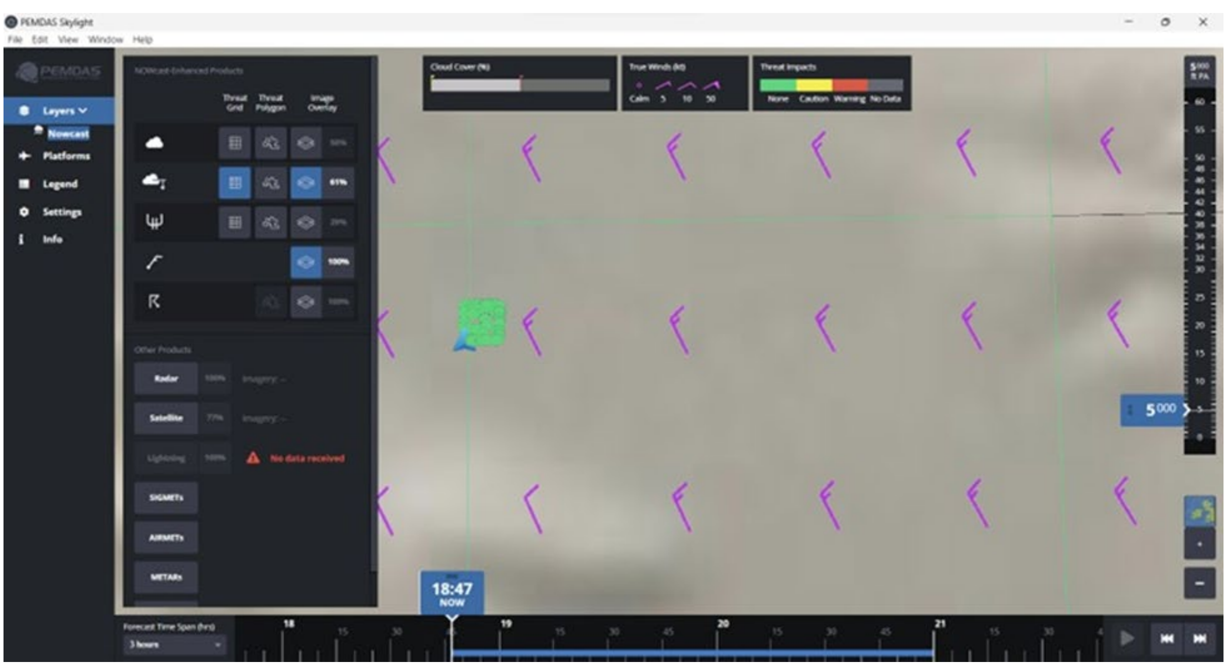


Figure 36 Skylight Map Background Shading "Zoomed In"

Adjusting to the FAA sectional map background (one of the currently provided choices) eliminates this confusion, however, the FAA map background has many colors and details which can distract from the warning levels provided by the ASAPS breadcrumbs of the aircraft's historical flight path as in *Exhibit 28*. While no single map background is optimized for every possible selection of weather products, providing additional map options for Skylight in the future could help minimize this confusion, along with training on recommended combinations and operational techniques.

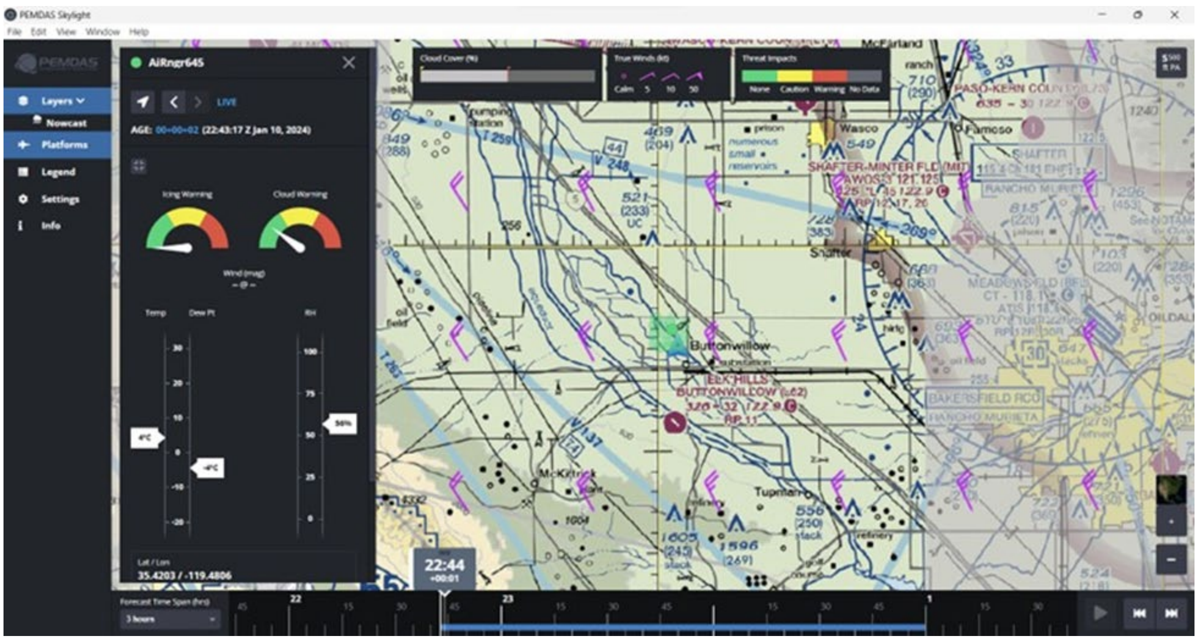


Figure 37 Skylight FAA Sectional Map Background

5. Conclusion and Future Work

The day-time flight tests met all objectives outlined in the statement of work along with the test plan approved prior to flight. The technical team successfully completed and tested the integration of aircraft flight control system pressure and winds with sensor data and validated the connection of the ASAPS sensor with the EINC. Once the daytime tests were completed, the team moved forward with the nighttime flights which were successfully completed in April and June 2024.

A. Data Collection and Display Conclusions

The initial four sorties flown in December provided functional checks to ensure the AiRanger / ASAPS / EINC systems met the data collection and display criteria for the entire suite. Specific relevant analysis points (which were outlined in the pre-mission test plan) are shown here along with the outcome for each test. The answer to each question is “Yes.”

1. [**SUCCESSFUL**] Does the ASAPS system measure and record all the environmental parameters required for operation of the system warnings and to provide critical weather data to the EINC system?

   AATI Feedback:

   Yes, the Atmospheric Sensing and Prediction System (ASAPS) measures and records all the necessary environmental parameters required for the safe operation of the system. It monitors key factors such as temperature, pressure, relative humidity, and dew point, providing essential real-time data. Additionally, ASAPS is equipped with sensors that detect potential weather threats like clouds and icing conditions, issuing warnings to the Remote Pilot in Command (RPIC) for proactive safety measures. The data collected by ASAPS is crucial for the Environmental Intelligence NOWcast (EINC) forecast software. EINC uses this data to generate accurate, real-time weather forecasts, helping the RPIC anticipate and plan for changing weather conditions. This integration ensures comprehensive environmental monitoring, early weather threat warnings, and critical weather data provision for safe and efficient flight operations.

2. [**SUCCESSFUL**] Is the ASAPS data able to be data-linked directly to the AiRanger GCS and display warnings on the PEMDAS provided Skylight system?

   AATI Feedback:

   Yes, the ASAPS data is data-linked to the EINC through the AiRanger Ground Control Station (GCS). This capability allows for the efficient transmission of environmental data and warnings, which are then displayed on the PEMDAS-provided Skylight system in the GCS. This integration ensures the Remote Pilot in Command (RPIC) receives real-time alerts and critical weather information, enhancing situational awareness and providing safe and efficient flight operations.

3. [**SUCCESSFUL**] Can ASAPS data be directly linked via the internet to the EINC system?

   AATI Feedback:

   Yes, ASAPS data is directly linked from the GCS via the internet to the Environmental Intelligence NOWcast (EINC) system.

4. [**SUCCESSFUL**] Can EINC forecast be directly linked via the internet to the AiRanger GCS?

   AATI Feedback:

   Yes, the EINC forecast can be directly linked via the internet to the AiRanger Ground Control Station (GCS).

5. [**SUCCESSFUL**] Is all data recordable for post-flight analysis on the AiRanger GCS computers and does the data (and collection rate) match between the onboard recording of data and the data collected at the GCS?

   AATI Feedback:

   Yes, all data is recordable for post-flight analysis on the AiRanger Ground Control Station (GCS) computers. The data and collection rate are synchronized between the onboard recording system and the GCS, ensuring consistency and accuracy for comprehensive post-flight analysis.

Conclusion 1: **As demonstrated during the conduct of the flights, the methods followed in section 3, and the results in section 4, PEMDAS environmental intelligence systems successfully meets all data collection and display criteria to support AiRanger BVLOS operations.**

B. Flight Objective Conclusions

Objectives applied to preparation and execution of the test flights. A brief summary of the specifics supporting the rating of "successful" for each objective is provided.

Objective 1

[**SUCCESSFUL**] Establish an EINC "window" over the proposed test site. This 3D volume of airspace over a given region is the area of increased resolution and fidelity characterization of environmental conditions attained by the big data analytics of the EINC system.

Specifics: The EINC domains were developed and used for all test sorties and are shown in *Exhibit 4*.

Objective 2

[**SUCCESSFUL**] Devise flight test points to assess how the AiRanger can collect the necessary atmospheric information using ASAPS to support proper decision products for night BVLOS flights. This may include a series of climbs and descents through the earth's atmospheric boundary layer (ABL) to more properly assess moisture. This knowledge is relevant to the formation of clouds and the inversion layer.

Specifics: A specific set of maneuvers was designed and outlined in a flight test card shown in section 3. These maneuvers in the flight profile addressed ASAPS installation error corrections, compression error corrections, and sensor lag error corrections.

Objective 3

[**SUCCESSFUL**] Perform EINC modeling and error correction on an appropriate weather model for this test (e.g., the Weather Research and Forecasting Model). This correction process includes ingesting various weather observations and information to include ASAPS data from the flight test points, processing this in the cloud and outputting high resolution, real-time weather decision products for evaluation.

Specifics: ASAPS data was linked from the AiRanger aircraft to the GCS. The data was then forwarded using the ASAPS System Administration Software (ASA) located on the GCS computer to the PEMDAS EINC instance running in the cloud. Data was assimilated into the EINC model and used for future forecasts and then re-routed back to the GCS for display for the pilot on Skylight. Most of the test flights involved favorable weather. One example where clouds were encountered was on the 10th of June and ASAPS provided the pilots with the warnings of those clouds. EINC forecast a consistent cloud forecast during that same period as detailed in section 4.

Objective 4

[**SUCCESSFUL**] Visualize the EINC information on the PEMDAS Skylight software installed in the Ground Control Station (GCS).

Specifics: EINC clouds and wind forecasts were able to be visualized on the Skylight display in the AiRanger GCS. ASAPS data and warning levels were also able to be visualized by the pilots.

Objective 5

[**SUCCESSFUL**] Support enroute flight navigation of the AiRanger with real-time EINC and ASAPS decision products.

Specifics: Throughout the testing period, both ASAPS and EINC warned the pilots of impending weather threats. Examples of these events occurred on 14-15 Jan and 10 Jun. The data collected and warnings provided are outlined in section 4.

Objective 6

[**SUCCESSFUL**] Perform validation on the EINC output to verify accuracy and fidelity.

Specifics: As outlined in the test plan, sufficient accuracy, and collection methods across a forecast resolution cell of the EINC software were important to overall system performance. Specifically, the performance of the pilot warnings of threats based on in situ measurements and the characterization of the atmosphere were important to provide sufficient resolution cell measurements to accurately predict conditions for use in the EINC system. As shown in the results of the cloud warnings on 14-15 Jan and 10 Jun, ASAPS provided warnings for pilots which were validated by the AiRanger tail camera.

Objective 7

[**SUCCESSFUL**] Conduct user feedback sessions to understand the usefulness of the ASAPS/EINC decision information for flight navigation and operational display.

Specifics: AATI pilots provided feedback on the details of operating PEMDAS systems (section 4.3), as well as an overall assessment of their added value (section 5.3).

Conclusion 2: **Via successful accomplishment of all flight objectives, PEMDAS and AATI have proven that the environmental intelligence systems ASAPS, EINC, and Skylight are mission suitable for AiRanger BVLOS operations.**

C. AATI Contributions: AATI RPIC Summary and Observation

This is a summary of the flights from the perspective of AATI's AiRanger Remote Pilot in Command (RPIC).

During the daytime flights using the PEMDAS sensor system, the AiRanger RPIC was able to identify numerous real-time atmospheric conditions. These flights aimed to investigate how the ASAPS and EINC decision products enhance BVLOS UAS day and night operations, collecting real-time and localized weather data. Some of the data provided to the RPIC are real-time icing and cloud indications and warnings, near real-time weather situational awareness within a designated operating area, wind speed and direction, icing at various altitudes, clouds at-and-below altitudes enabling BVLOS operations, and designated threat areas to avoid based on select environmental threats.

All the data listed were provided via the Skylight interface and allowed the RPIC to make accurate in-the-moment aeronautical decisions to ensure a safe flight of the AiRanger. Additionally, it increased the situational awareness of the RPIC of the conditions the UAS was flying toward, through and around. During each flight, the sensor booted up and connected as expected through the UAS' Commercial Mobile Radio Service (CMRS) link, better known as (LTE). However, due to the higher altitudes of the data collection profile of 4500 ft AGL, the CMRS Link would periodically lose coverage and pause the real-time data to be transferred from the sensor to the GCS, lasting from ~10 sec to ~1:00 minute.

ASAPS was a useful tool for mission situational awareness and improved safety during the flight. During nighttime flights, the sensor was incredibly beneficial in advising the RPIC of any unsafe or changing atmospheric flight conditions.

D. Future Work Recommendations

1) As the flight tests met all objectives outlined in the Statement of Work and the test plan approved by the FAA prior to flight and have demonstrated significant added value and safety, the project team recommends moving forward with the combination of ASAPS, EINC, and Skylight systems to support AATI's AiRanger UAS BVLOS flight operations.
2) Expand the weather envelope over which the PEMDAS system is tested and validated.
3) Proceed with development of the Conop and Safety case required to support a SAC-EC COA with 49 CFR 91.113(b) including both day and night VMC operations.

Appendix A: FAA 7711-1 2023-CSA-415-SAC

DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

CERTIFICATE OF WAIVER OR AUTHORIZATION

ISSUED TO

American Aerospace Technologies, Inc.

14 Union Hill, Suite 100
Conshohocken, PA 19428

This certificate is issued for the operations specifically described hereinafter. No person shall conduct any operation pursuant to the authority of this certificate except in accordance with the standard and special provisions contained in this certificate, and such other requirements of the Federal Aviation Regulations not specifically waived by this certificate.

OPERATIONS AUTHORIZED

Operation of the Resolute Eagle (aka AiRanger) Unmanned Aircraft Systems (UAS), in Class E and G airspace, at or below 5,000' above ground level (AGL) in the vicinity of Williston, North Dakota (KXWA), under the jurisdiction of Salt Lake City, Minneapolis Air Route Traffic Control Center (ARTCC) and Minot Air Force Base (AFB) Radar Approach Control (RAPCON). See Attachments.

LIST OF WAIVED REGULATIONS BY SECTION AND TITLE

N/A

STANDARD PROVISIONS

1. A copy of the application made for this certificate shall be attached and become a part hereof.
2. This certificate shall be presented for inspection upon the request of any authorized representative of the Federal Aviation Administration, or of any State or municipal official charged with the duty of enforcing local laws or regulations.
3. The holder of this certificate shall be responsible for the strict observance of the terms and provisions contained herein.
4. This certificate is nontransferable.

Note-This certificate constitutes a waiver of those Federal rules or regulations specifically referred to above. It does not constitute a waiver of any State law or local ordinance.

SPECIAL PROVISIONS

Special Provisions are set forth and attached.

This certificate of Waiver or Authorization (COA) for Special Airworthiness Certificate – Experimental Category is **effective for a period of two years from the date of signature** and is subject to cancellation at any time upon notice by the Administrator or his/her authorized representative.

BY DIRECTION OF THE ADMINISTRATOR

STEVEN T PHILLIPS

Digitally signed by STEVEN T PHILLIPS
Date: 2024.01.16 07:50:45 -06'00'

FAA Central Service Area
(Region)

Steven Phillips
(Signature)

Tactical Operations Team Manager (A), AJV-C23
(Title)

FAA Form 7711-1 (7-74)

STANDARD PROVISIONS

A. General.

1. The approval of this certificate of Waiver or Authorization (COA) for Special Airworthiness Certificate- Experimental Category is effective only with a signed and dated Operating Limitations Document and a Special Airworthiness Certificate (FAA Form 8130-7).

2. This authorization may be canceled at any time by the Administrator, the person authorized to grant the authorization, or the representative designated to monitor a specific operation. As a general rule, this authorization may be canceled when it is no longer required, there is an abuse of its provisions, or when unforeseen safety factors develop. Failure to comply with the authorization is cause for cancellation. The proponent will receive written notice of cancellation.

3. Frequency spectrum approval is independent of the COA process and requires the proponent to obtain certification and frequency assignments (licenses) from the National Telecommunications and Information Administration (NTIA) (47 CFR Part 300) or Federal Communications Commission (47 CFR Part 2, Subpart J and 47 CFR Part 87, Subpart D) and frequency licenses (47 CFR Part 87) when applicable for the control link, ATC radios, transponders, detect and avoid systems, and navigation systems used to support this COA. Equipment licensed under 47 CFR Part 5 (Experimental) or 47 CFR Part 15 (Radio Frequency Devices) does not provide the protection necessary for NAS operations.

B. Safety of Flight.

1. The Operator or delegated representative is responsible for halting or canceling activity in the COA area if, at any time, the safety of persons or property on the ground or in the air is in jeopardy, or if there is a failure to comply with the terms or conditions of this authorization.

2. See-and-Avoid

   Unmanned aircraft have no on-board pilot to perform see-and-avoid responsibilities; therefore, when operating in the National Airspace System provisions must be made to provide an alternate means of compliance to 14 CFR §91.113.

   a. Any crew member responsible for performing see-and-avoid requirements for the UA must have and maintain instantaneous communication with the PIC.

   b. Visual observers must be used at all times except in Class A airspace, active restricted areas, and warning areas designated for aviation activities or as authorized in the Special Provisions. Observers may either be ground-based or airborne in a chase plane.

      (1) Visual Observers:

         (a) Must be able to communicate clearly to the pilot any instructions required to remain clear of conflicting traffic, using standard phraseology as listed in the Aeronautical Information Manual when practical.

         (b) The PIC is responsible to ensure visual observers are able to see the aircraft and the surrounding airspace throughout the entire flight, and

(c) The PIC is responsible to ensure visual observers are able to provide the PIC with the UA's flight path, and proximity to all aviation activities and other hazards (e.g., terrain, weather, structures) sufficiently to exercise effective control of the UA to:

- Comply with 14 CFR § 91.111, §91.113 and § 91.115, and
- Prevent the UA from creating a collision hazard, and
- Comply with all conditions of this COA.

(2) Chase Aircraft:

(a) If the chase aircraft is operating more than 1 mile laterally or longitudinally and/or more than 100 feet vertically of the unmanned aircraft, the chase aircraft PIC will advise the controlling ATC facility.

(b) Must remain at a safe distance from the UA to ensure collision avoidance if a malfunction occurs.

(c) Must remain close enough to the UA to provide visual detection of any conflicting aircraft and advise the PIC of the situation.

(d) Must remain within radio control range of the UA to maintain appropriate signal coverage for flight control or activation of the Flight Termination System, for all operations when the UA is being flown by a pilot in the chase aircraft.

(e) May be required to have communication with appropriate ATC facilities based on the operator's application or mission profile.

(f) Must maintain 5 statute miles in-flight visibility restrictions.

(g) Pilot/observer:

- Will not concurrently perform either observer or UAS pilot duties along with chase pilot duties unless otherwise authorized.
- Must maintain direct voice communication with the UAS pilot.

(h) Pilots operating as a formation flight will immediately notify ATC if they are using a nonstandard formation.

(i) Operations will not be conducted in instrument meteorological conditions (IMC).

(j) Operations will be thoroughly planned and briefed.

(k) During a lost link situation, the pilot must be notified immediately along with ATC. The chase pilot will report to ATC that the UA is performing lost link procedures as planned or if deviations are occurring.

(l) Pilot will ensure safe separation with the UA, and immediately notify ATC and the UA PIC during loss of visual contact with the UA by both the chase pilot and observer, when such contact cannot be promptly reestablished. The UA PIC will either execute lost link procedures to facilitate a rejoin, recover the UA, or terminate the flight as appropriate.

3. Coordination Requirements.

   a. A distance (D) NOTAM must be issued when unmanned aircraft operations are being conducted. This requirement may be accomplished by contacting the NOTAM Flight Service Station at 1-877-4-US-NTMS (1-877-487-6867) not more than 72 hours in advance, but not less than 24 hours prior to the operation, unless otherwise authorized as a special provision. The issuing agency will require the:

      (1) Name and address of the pilot filing the NOTAM request.

      (2) Location, altitude, or operating area.

      (3) Time and nature of the activity.

   b. Proponent filing and the issuance of the required distance (D) NOTAM at least 24 hours prior to commencing operations, will serve as advance notification for the FAA air traffic control facility(s) under this authorization.

   c. Proponent must cancel the NOTAM when UAS operations are complete for the day or cancelled.

   d. Pilot/operator must also review NOTAMs (real-time) for all operating areas prior to commencing UAS flight operations, if this reveals another proponent will be operating in intersecting airspace, the proponent must resolve the confliction.

   e. Proponent will coordinate UAS operations and NOTAM information with all airport managers when unmanned aircraft operation will be conducted within five nautical miles of any airport.

   f. Coordination and de-confliction between Military Training Routes (MTRs) and Special Use Airspace (SUA) is the operator's responsibility. When identifying an operational area, the operator must evaluate whether an MTR or SUA will be affected. In the event the UAS operational area overlaps an MTR or SUA, the operator will contact the scheduling agency as soon as practicable in advance to coordinate and de-conflict. Approval from the scheduling agency is required for regulatory SUA, but not for MTR's and non-regulatory SUA. If no response to coordination efforts, the operator must exercise extreme caution and remain vigilant of all MTRs and/ or non-regulatory SUAs. Scheduling agencies for MTRs are listed in the Area Planning AP/1B Military Planning Routes North and South America. If unable to gain access to AP/1B, contact the FAA at email address mailto: 9-AJV-115-UASOrganization@faa.gov with the IR/VR routes affected and the FAA will provide the scheduling agency information. Scheduling agencies for SUAs are listed in the FAA JO 7400.10.

AIR TRAFFIC CONTROL SPECIAL PROVISIONS

A. Coordination Requirements.

1. **For all operations, the UAS operator must contact Salt Lake City ARTCC** no later than 30 minutes prior to beginning operations and no later than 15 minutes after termination of operations at **801-320-2562**. Expect a beacon code assignment from ATC.

2. For operations in the Minneapolis ARTCC area, the UAS operator must contact **Minot AFB RAPCON** no later than 30 minutes prior to beginning operations and no later than 15 minutes after termination of operations at **601-385-6199**.

3. Additional coordination is not required, however, if necessary, the UAS operator can also contact **Minneapolis ARTCC** at **651-463-5584 / 5580.**

B. Communication Requirements.

1. No ATC communications required.

2. For operations in the vicinity of Williston Basin International Airport, the UAS operator must monitor the KXWA CTAF frequency, 122.8.

C. Flight Planning Requirements.

It is the operator's responsibility for obtaining authorization from the appropriate authority for any operations that that may result in launching and/or landing from lands or waters administered by a Federal, State or Public agency (e.g., National Parks, State Parks, Wilderness Area, and Wildlife Refuge, etc.).

D. Procedural Requirements.

Operations must be conducted under VMC and are not authorized without visual observance.

E. :Lost Link/Emergency/Contingency Procedures.

1. Lost Link Procedures:

   In the event of a lost link, the UAS pilot must immediately comply with the following provisions:

   a. The unmanned aircraft will remain within the NOTAM'd Operations Area.

   b. If a lost link occurs, the aircraft will land automatically at designated landing zone in multirotor configuration.

   c. Lost link orbit points will not coincide with the centerline of published airways.

   d. Lost link programmed procedures will avoid unexpected tum-around and/or altitude changes and will provide sufficient time to communicate and coordinate with ATC.

   e. Lost link orbit points shall not coincide with the centerline of Victor airways.

   f. Lost Link programmed procedures must de-conflict from unmanned operations within the operating area.

2. Loss of Sight with the UA:

   If a visual observer loses sight of the unmanned aircraft (UA), notify the pilot-in-command immediately. If the UA is visually reacquired promptly, the mission may continue. If not, the UA must follow lost link procedures as stated in the COA or immediately terminate the flight.

3. Lost Communications:

   If a visual observer and PIC loses communication, the pilot-in-command of the UA must initiate and follow lost link procedures as stated in the COA or immediately terminate the flight.

4. Emergency Procedures:

   a. The PIC must immediately notify the appropriate ATC facility(ies).

   b. The PIC will state pilot intentions, and provide the following:

      (1) The nature of the emergency

      (2) UAS last know position, altitude, and direction of flight

      (3) Maximum remaining flight time

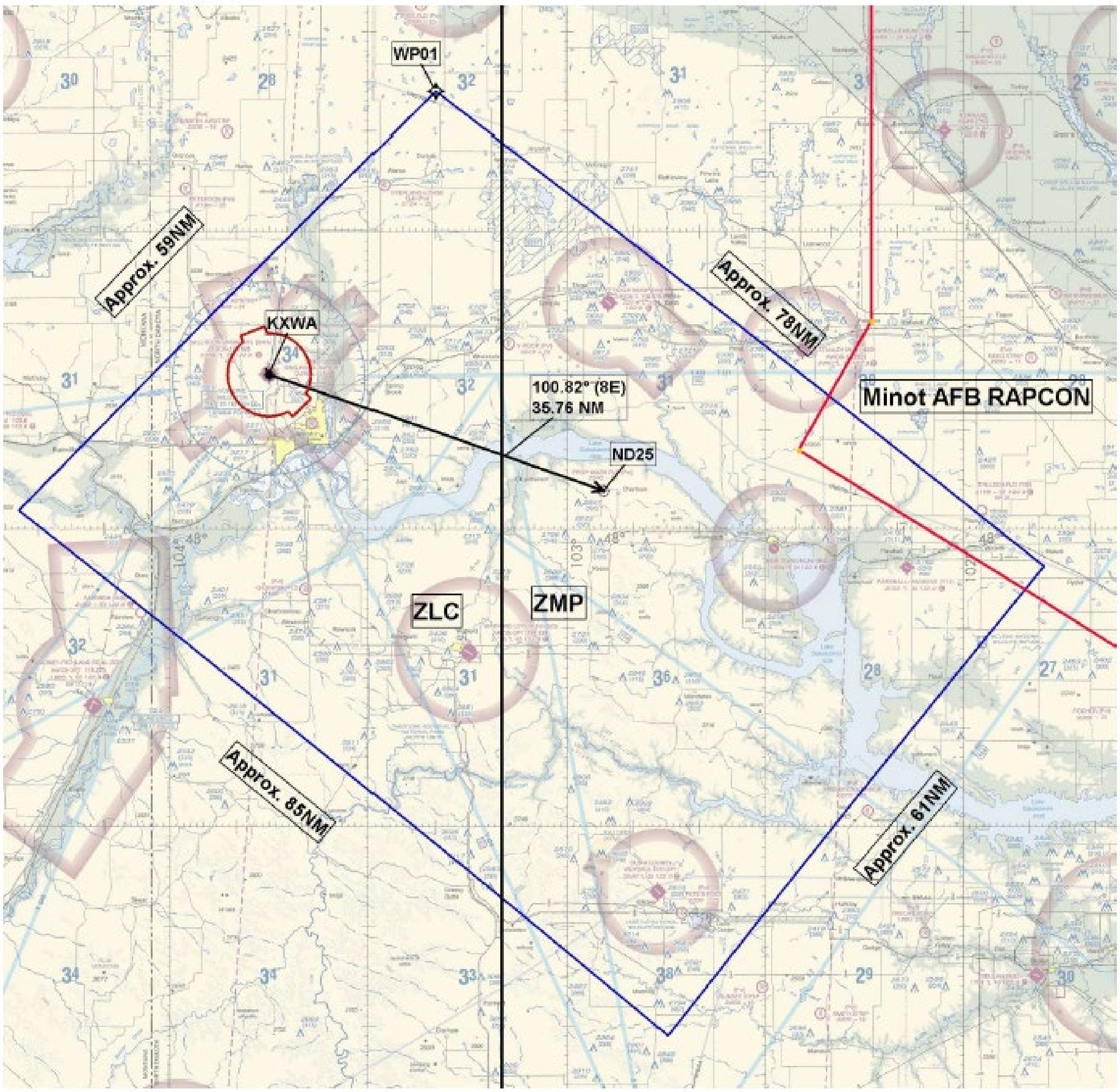
AUTHORIZATION

This Certificate of Waiver or Authorization does not, in itself, waive any Title 14 Code of Federal Regulations not specifically stated, nor any state law or local ordinance. Should the proposed operation conflict with any state law or local ordinance, or require permission of local authorities or property owners, it is the responsibility of the proponent to resolve the matter. This COA does not authorize flight within Temporary Flight Restrictions, Special Flight Rule Areas, regulatory Special Use Airspace or the Washington DC Federal Restricted Zone (FRZ) without pre-approval. The proponent is hereby authorized to operate the Unmanned Aircraft System in the NAS within the areas defined in the Operations Authorized section of the cover page.

Attachment 1-1

Operational Area

Class E & G Airspace At/Below 5,000' AGL



Attachment 1-2

Beginning at WP01, thence clockwise:

N	48 °	43 '	57.00 "	W	103 °	20 '	0.00 "
N	47 °	56 '	19.00 "	W	101 °	47 '	47.00 "
N	47 °	9 '	0.00 "	W	102 °	44 '	48.00 "
N	48 °	1 '	56.00 "	W	104 °	22 '	56.00 "

Appendix B: SAC-EAC – 8130-7: N642RE

UNITED STATES OF AMERICA
DEPARTMENT OF TRANSPORTATION-FEDERAL AVIATION ADMINISTRATION
SPECIAL AIRWORTHINESS CERTIFICATE

CATEGORY/DESIGNATION	Experimental		
PURPOSE	Research and Development / Showing Compliance with Regulations		
MANU-FACTURER	NAME N/A		
	ADDRESS N/A		
FLIGHT	FROM N/A		
	TO N/A		
N N642RE	MODEL AiRanger	SERIAL NO. 19-002	
BUILDER American Aerospace Technologies Inc		DATE OF ISSUANCE	29 Apr 2024

Unless sooner surrendered, suspended, revoked, or the termination date of **28 Apr 2025**, this airworthiness certificate is effective under the conditions prescribed in 14 CFR, Part 21, Section 21.181 or 21.217.

SIGNATURE OF FAA REPRESENTATIVE	DESIGNATION OR OFFICE NO.
Kurt Krumlauf	430409773

This airworthiness certificate is issued under the authority of Title 49 United States Code 44704 and Title 14 Code of Federal Regulations. Any alteration, misuse or reproduction for a fraudulent purpose of this certificate may be punishable by certificate revocation, fine, and / or imprisonment. THIS PORTION OF THE CERTIFICATE MUST BE DISPLAYED IN THE AIRCRAFT PER THE APPLICABLE REGULATIONS.

-- Conditions and Limitations --

The following operating limitations are applicable to operations in the National Airspace System (NAS):

1. This aircraft does not meet the airworthiness standards of Annex 8 to the Convention on International Civil Aviation. Operations in airspace outside of the United States will require the permission of the applicable foreign authority. That permission must be carried aboard the aircraft together with this U.S. airworthiness certificate and, upon request, be made available to an FAA inspector or the applicable foreign authority in the country of operation. Operations may be further restricted by the applicable foreign authority. This may include not allowing use of an airport, requiring specific routing, and restricting flight over specific areas. The operator must comply with any additional limitation prescribed by the applicable foreign authority when operating in its airspace. (add)

2. The AiRanger (Resolute Eagle) Unmanned Aircraft (UA), control station, and communication equipment comprise the UAS. (1)(.34)

3. No person may operate this UAS for other than the purpose of Research and Development (R&D), and Show Compliance as specified on the front of the FAA Form 8130-7, Special Airworthiness Certificate. These operating limitations do not provide any relief from any applicable law or regulation. This aircraft must be operated in accordance with the applicable regulations and the additional limitations prescribed herein. Note that a clearance from air traffic control (ATC) is not authorization for a pilot to deviate from any rule, regulation, operating limitation, or minimum altitude, or to conduct unsafe operation of the aircraft. If ATC issues a clearance that would cause a pilot to deviate from a rule, regulation, or operating limitation, or in the pilot's opinion, would place the aircraft in jeopardy, it is the pilot's responsibility to request an amended clearance. These operating limitations are a part of FAA Form 8130-7, and are to be located at the Ground Control Station (GCS) while operating the UAS, and must be available to the pilot in command (PIC) of the aircraft. (2)(.34)

4. The airworthiness certificate, aircraft registration certificate, aircraft manuals, and FAA Form 7711-1, Certificate of Waiver or Authorization (COA), must be located at the control station. (3)(.34)

5. When changing between operating purposes, the operator must determine that the UAS is in a condition for safe operation and appropriate for the operational purpose intended. A record entry will be made in the maintenance records to document the operational purpose change and that the UAS is in a condition for safe operation. (5)(.34)

6. This UAS must be operated in accordance with the applicable air traffic and general operating rules of 14 CFR part 91, and all additional limitations herein prescribed. (6)(.34)

7. No person may operate this UAS to carry persons or property for compensation or hire. (7)(.34)

8. Each UA must be controlled by only one control station at a time. A control station may not be used to operate multiple UA. (8)(.34)

9. UA flight operations must be conducted in visual meteorological conditions (VMC), **day only, at Elk Hills-Buttonwillow CA (L62) and Woodbine Municipal Airport NJ (KOBI)** designated flight areas as provided in the FAA Form 7711-1. (9 Modified)(.34)

10. UA flight operations must be conducted in VMC, **day and/or night**, **at Williston Basin International Airport North Dakota (KXWA)** designated flight area as provided in the FAA Form 7711-1. (10 Modified)(.34)

11. UA flight operations must be conducted within visual line of sight of the PIC or visual observer. (11)(.34)

12. Flight over a densely populated area or in a congested airway is prohibited. (12)(.34)

13. All flight operations must remain within the lateral and vertical boundaries of the designated flight area as provided in the FAA Form 7711-1. (13)(.34)

14. UA flight in RVSM-designated airspace is prohibited. (17)(.34)

15. The UA is prohibited from aerobatic flight, that is, an intentional maneuver involving an abrupt change in the UA's attitude, an abnormal acceleration, or other flight action not necessary for normal flight. (19)(.34)

16. The UA is prohibited from formation flight as a wingman, that is, flight by reference to another aircraft. (20)(.34)

17. This UA must not be used for towing, including, but not limited to, gliders, banners, targets, or electronic receivers or transmitters. (21)(.34)

18. UA flight operations may not involve carrying hazardous material, as defined in Title 49 of the Code of Federal Regulations (49 CFR) 171.8, or the dropping of any objects or external stores. (22)(.34)

19. No weapons may be added to the UA.(23)(.34)

20. Any incident or accident, or any flight operation that transgresses the lateral or vertical boundaries of a flight test area, restricted airspace, or other operational boundary, must be reported within 24 hours to the UAS Policy Team (AJV-P22). AJV-P22 can be notified via email at 9-AJV-115-UASOrganization@faa.gov. If this is an emergency, contact the local law enforcement or call the customer service number at the geographic FAA National Engagement and Regional Administration office. Contact information for these regional offices can be found at https://www.faa.gov/about/office_org/headquarters_offices/arc/. Accidents and incidents must be reported to the National Transportation Safety Board (NTSB) per instructions contained on the NTSB web site. Further flight operations must not be conducted until AFS-830 provides authorization to resume operations. (26)(.34)

21. Visual observers (VO) must assist the PIC in not allowing the UA to operate beyond the visual line of sight limit. VOs must be able to see the aircraft and the surrounding airspace sufficiently to assist the PIC with determining the UA's proximity to all aviation activities and other hazards, and prevent the UA from creating a collision hazard. The VO must assist the PIC with exercising effective control of the UA and with complying with §§ 91.111 and 91.113. The VO must also inform the PIC before losing sufficient visual contact with the UA or a previously sighted collision hazard. (27)(.34)

22. All crew positions must maintain two-way communications with each other during all operations. If unable to maintain two-way communication, the PIC will expeditiously return the UA to its base of operations while remaining within the flight area and conclude the flight operation. (28)(.34)

23. In the event of a transponder failure on the UA, the UA must conclude all flight operations and expeditiously return to its base of operations. If a chase aircraft is used and equipped with an operable transponder, the mission may continue with proper coordination with air traffic control (ATC). (29)(.34)

24. When filing a flight plan, the experimental nature of this UA must be listed in the remarks section. The pilot will notify the control tower of the experimental nature of the UA when operating the UA into or out of airports with operating control towers. (30)(.34)

25. This UA must be marked with its U.S. nationality and registration marks pursuant to 14 CFR part 45. (31)(.34)

26. This UA must display the word EXPERIMENTAL pursuant to § 45.23 or an alternative marking approval issued pursuant to § 45.22(d) by the FAA's Policy and Innovation Division (AIR-600). (33)(.34)

27. The UAS manufacturer and their representatives may perform the maintenance and inspections required by these operating limitations. Representatives of a manufacturer must have written authorization from the manufacturer. The use of FAA certificated maintenance providers is encouraged, which may include repair stations, holders of mechanic and repairman certificates, and other persons working under the supervision of these mechanics and repairman. An FAA certificated maintenance provider performing maintenance and/or inspection on UAS that are not applicable to 14 CFR part 43 requirements, § 43.1(b)(1), does not constitute at this time the exercising of certificate holder privileges.(36)(.34)

28. Application to amend these operating limitations must be made to the geographically responsible FSDO or Certificate Management Section (CMS). (41)(.34)

29. When an aircraft's home base is changed or there is a transfer of ownership, the owner will submit a new

program letter to the geographically responsible FSDO within 30 days. (42)(.34)

30. This special airworthiness certificate is not in effect during public aircraft operations (PAO). Concurrent public/civil operations are not permitted. The FAA makes the distinction between the authorized flights for the purposes described in the program letter and PAO. Before operating this aircraft under this special airworthiness certificate following a PAO, the aircraft must be returned, via an approved method, to the condition and configuration appropriate for civil operations. The aircraft records and entries must clearly differentiate between a civil flight, pursuant to this certificate, and any other flights. When PAO are concluded, an entry will be made in the aircraft records to document that the aircraft has been returned to the civil aircraft configuration and is in a condition for safe operation. (44)(.34)

31. 14 CFR 47.45 requires that the FAA Aircraft Registry be notified within 30 days of any change in the aircraft registrant's address. Such notification is to be made by submitting Aeronautical Center Form 8050-1, Aircraft Registration Application, to the FAA Aircraft Registration Branch (AFS-750) in Oklahoma City, Oklahoma. (46)(.34)

32. Immediately after the certificate is issued, the applicant must forward a copy of the program letter, special airworthiness certificate, operating limitations, and FAA Form 7711-1 to the attention of: FAA Headquarters, Unmanned Aircraft Systems, Policy team, AJV-P22 at the email address 9-AJV-115-UASOrganization@faa.gov, or via fax at (202) 267-8249. (48)(.34)

33. This special airworthiness certificate is not in effect during aircraft operations conducted under 49 U.S.C. § 44807 exemption. Before operating this aircraft under this special airworthiness certificate following a 49 U.S.C. § 44807 aircraft operation, the aircraft must be returned, via an approved method, to the condition and configuration appropriate for operations under the special airworthiness certificate. The aircraft records and record entries must clearly differentiate between any flights for which this certificate was required and any other flights. When 49 U.S.C. § 44807 aircraft operations are concluded, an entry will be made in the aircraft records to document that the aircraft has been returned to the aircraft configuration appropriate for operations in accordance with this special airworthiness certificate and is in a condition for safe operation. (45) (.34) (Modified)

--------------------END-------------------- KK

Appendix C: ASAPS Measurements Summary

December 2023 and January 2024 flights were conducted in California. Summaries of the flight times, sortie parameters, and ASAPS data collected (over 900,000 in situ measurements) during these flights are shown in *Exhibit C1* and *Exhibit C2*.

AATI AiRanger December Flight Summary				
	08 DEC	09 DEC	10 DEC	11 DEC
Start Times (UTC)	19:45:41	19:07:12	17:07:30	22:24:23
End Times (UTC)	21:17:49	21:23:28	19:24:49	(12 DEC) 00:21:19
Collection Durations	1:32	2:16	02:17	1:57
Maximum Altitude (ft MSL)	2795	4920	4799	4794
Number of ASAPS Measurements Collected (1Hz)	5600	8320	8410	7520

Exhibit C1. December 2023 Flight Summary - CA

AATI AiRanger January Flight Summary					
	9 JAN	10 JAN	13 JAN	14 JAN	15 JAN
Start Times (UTC)	22:29	22:21	18:13 19:57 21:19	18:15 19:39 21:24	18:47 21:49
End Times (UTC)	00:44	(11 JAN) 00:15	19:56 21:13 22:23	19:33 21:18 22:34	19:44 23:10
Collection Durations	02:15	01:54	01:43 01:16 01:04	01:18 01:39 01:10	00:57 01:21
Maximum Altitude (ft MSL)	4798	4788	4810	4797	4801
Number of ASAPS Measurements Collected (1Hz)	8,100	10,304	10,600 7910 6909	7567 8768 6482	1000 1570

Exhibit C2. January 2024 Flight Summary - CA

A single flight was flown on 2 May 2024 in Williston, ND. This flight was scheduled to be a “chase aircraft” checkout flight for local pilots followed by a weather collection flight. Due to increasing crosswinds encountered at the airfield, the sortie was terminated early immediately following the checkout of one of the chase pilots and no weather collection flight was conducted (though ASAPS data were recorded).

Flights were again conducted in Williston, ND from 7-11 June 2024. The flight on the 7 Jun was a daytime flight which included flight down-range as well as ASAPS collection test points. The other flight days included both day and night operations (takeoff during daylight and landing at night). The flight on 11 Jun included two weather collection events plus a flight down-range with the chase aircraft. ASAPS observations were assimilated into the EINC model during each of these flights. Details of each flight are listed in the flight summary, *Exhibit C3*.

	AATI AiRanger May - June Flight Summary					
	2 MAY	**7 JUN**	**8 JUN**	**9 JUN**	**10 JUN**	**11 JUN**
Start Times (UTC)	14:46	20:02 22:59	(09 Jun) 01:45 (09 Jun) 03:14 (09 Jun) 04:28	(10 Jun) 00:48 (10 Jun) 02:13 (10 Jun) 03:26 (10 Jun) 04:37	(11 Jun) 01:31 (11 Jun) 02:18 (11 Jun) 02:51 (11 Jun) 03:42	(12 Jun) 01:41 (12 Jun) 03:12 (12 Jun) 04:03
End Times (UTC)	15:47	22:58 (08 Jun) 00:19	(09 Jun) 03:14 (09 Jun) 04:27 (09 Jun) 05:26	(10 Jun) 02:12 (10 Jun) 03:25 (10 Jun) 04:36 (10 Jun) 05:55	(11 Jun) 02:17 (11 Jun) 02:50 (11 Jun) 03:41 (11 Jun) 04:43	(12 Jun) 03:11 (12 Jun) 04:02 (12 Jun) 04:54
Collection Durations	01:01	02:56 01:20	01:29 01:14 00:58	01:24 01:12 01:12 01:18	00:46 00:32 00:50 01:01	01:30 00:50 00:47
Maximum Altitude (ft MSL)	3842	5233 7021	7022 7018 7023	7021 7020 7018 7019	6510 6015 7012 7021	7020 4519 7013
Number of ASAPS Measurements Collected (1Hz)	3666	10566 4782	5303 4381 3459	5042 4334 4202 4689	2766 1979 3057 3650	5409 3054 3052

Exhibit C3. May-June 2024 Flight Summary - ND

Appendix D: Technology Overview

AATI employed the following technology test articles to support this project:

The AiRanger™ BVLOS UAS, selected for this Program, is a Group 3, long-endurance UAS. (*Exhibit D1*). AATI boasts a fully equipped UAS manufacturing facility to design, assemble, test, and deploy its commercial mission ready systems. AATI can rapidly integrate the UAS to meet customer requirements for specialized payloads and use cases.

Wingspan:	18.6 ft (5.6 m)
Endurance:	12+ hours (configuration dependent)
Service Ceiling:	12,000 ft (4,572 m)
Speed:	100 kts / 65 kts / 55 kts
Payload Power:	600 W
Maximum Weight:	220 lbs (99.8 kg)
Max. Payload Wt:	54 lbs (25 kg) (payloads and fuel)
Range:	750 nm (1200 km) (SATCOM)
FAA Approvals	44807 Exemption and 91.113(b) Waiver
Safety Mgmt	In place and audited

Exhibit D1: AiRanger Aircraft Vehicle

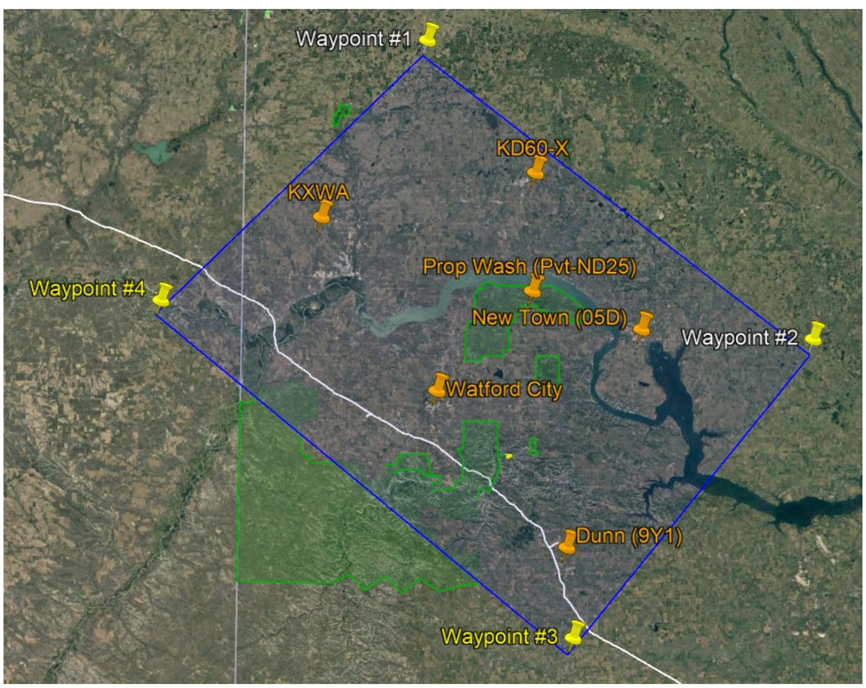


Exhibit D2: Area of Operation (Williston, ND)

With a maximum payload capacity of 75 pounds (including fuel), the AiRanger is a field proven fixed-wing UAS with an 18-foot wingspan, 12-hour endurance and 750-mile range. It has completed over 220 successful flights (>500 hours), mostly on pipeline corridors and over upstream production fields.

The aircraft is capable of patrolling at 70 pipelines miles/hour and upstream fields at the rate of 28 square miles per hour. It is undergoing TC review with the FAA and is approved for flight operations in Western North Dakota over a 6,650 square mile area to 5,000’ AGL.

It is the first in AATI aircraft manufacturing history to receive a 91.113(b) waiver enabling BVLOS flight operations without chase aircraft or ground observers.[11]

The AiRanger has an active TC application[12] under review by the FAA for BVLOS Pipeline Patrol Operations in the National Airspace (NAS) nationwide and has achieved a Special Experimental Authorization for BVLOS operations without chase aircraft in the San Joaquin Valley, CA (confidential). Flights out of the Williston Basin International Airport (KXWA) (See Exhibit D2) commenced in April 2024. In June, AATI conducted research flights for the FAA out of KXWA to develop the safety case for BVLOS night operations.

PEMDAS employed the following technology test articles to support AATI.

Atmospheric Sensing and Prediction System (ASAPS®). ASAPS is comprised of a sensor package, controller, and propriety algorithms to calculate environmental warnings. ASAPS measures and calculates environmental parameters including temperature, pressure, relative humidity, and dew point to provide a standalone warning of weather threats such as clouds and icing. ASAPS data are also used to update weather models (like EINC) with real-time in situ measurements of critical atmospheric parameters.

For this test, PEMDAS installed a specially developed ASAPS sensor configuration on the right wingtip of the AiRanger aircraft as shown in *Exhibit D3*.

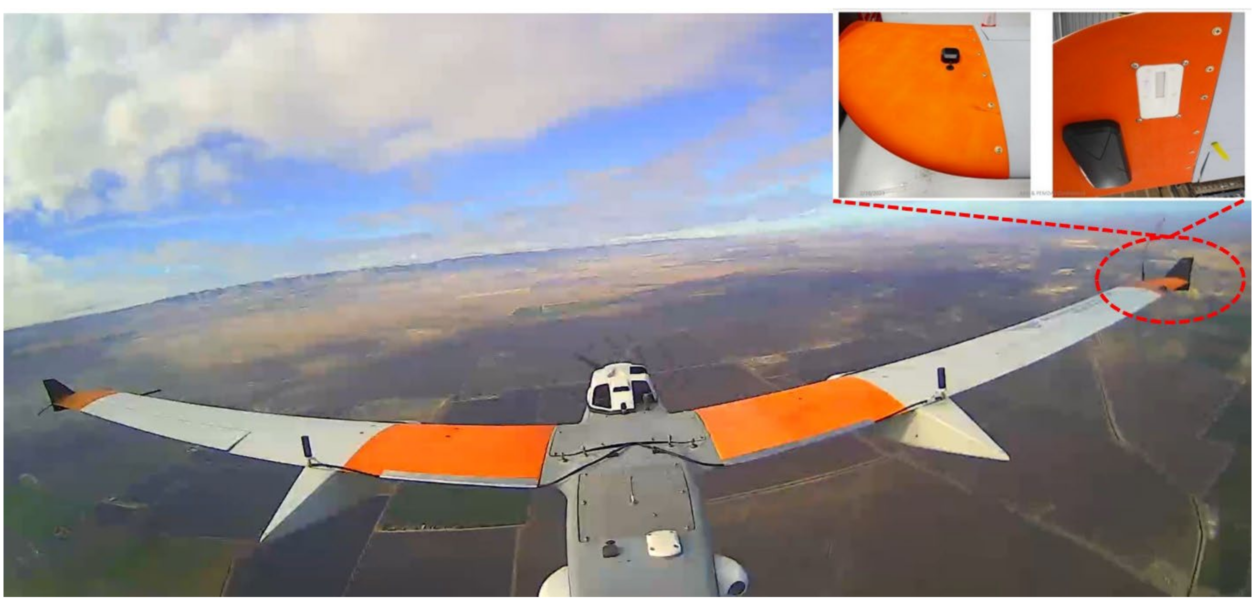


Exhibit D3. ASAPS Installed on AiRanger's Right Wingtip

Environmental Intelligence NOWcasting (EINC). The PEMDAS EINC system employs a U.S. government approved weather model, then ingests traditional and non-traditional weather data from a multitude of sources, such as ASAPS, to improve the weather model fidelity. EINC then generates near real-time, high-resolution forecasts of specific weather parameters such as clouds, icing and winds aloft for display to UAS operators to improve mission safety and execution. This includes the ASAPS/EINC

[11] 2024-WSA-418-SAC: Operation of the AiRanger UAS in Class E and G airspace at or below 8,000 feet MSL; under the jurisdiction of Bakersfield (BFL) Terminal Radar Approach Control (TRACON), Lemoore Approach Control (NLC), Los Angeles (ZLA) Air Route Traffic Control Center (ARTCC), and Oakland ARTCC (ZOA).
[12] TC17190LA-A

capability to provide for cloud-free line-of-sight operations, and threat polygons designating recommended areas of avoidance that contain select environmental threats. For these tests EINC software was hosted on a cloud server.

Skylight. The PEMDAS-developed Skylight visualization system displays ASAPS and EINC information using configurable options as selected by the user interface (UI). These visualizations include weather forecasts from the EINC system for clouds, icing, and winds as well as historical weather satellite and radar information. Additionally, Skylight can display observation data such as Meteorological Aerodrome Reports (METARs) and ASAPS in situ measurements along with ASAPS weather warnings for clouds and icing.

Exhibit D4 provides an example of Skylight with EINC and ASAPS warning displays, showing how the test articles work synergistically. This example shows the flight path of the AiRanger operating VFR below a cloud deck at 13,000' that also shows forecast icing. The ASAPS warnings displayed show the increased potential for clouds as the aircraft operates underneath the weather. While the flights intentionally were conducted at altitudes and within weather guidelines specified in the test plan (and thus did not encounter icing), this example demonstrates the capability of Skylight to show weather at any user selected altitude for situational awareness (SA) while still showing current aircraft/ASAPS altitude and weather threat level. An alternate mode allows the threat overlay and aircraft altitudes to sync automatically. More information on Skylight, ASAPS, and EINC can be found in the respective user manuals delivered to AATI.

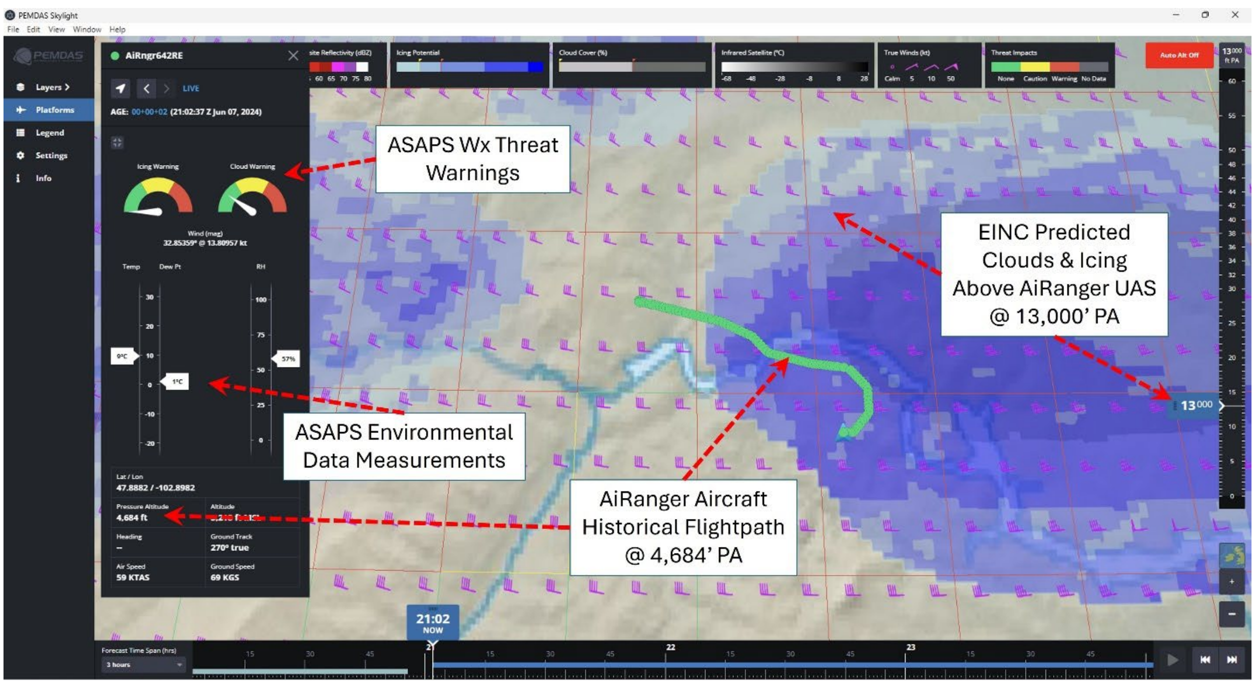


Exhibit D4. PEMDAS ASAPS/EINC Data Display on Skylight

Funding Sources

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References

A. Periodicals – N/A

B. *Books - N/A*

C. *Proceedings - N/A*

D. *Reports, Theses, and Individual Papers*

[1] Interim Flight Test Report for PEMDAS Atmospheric Sensing and Prediction System (ASAPS) Integrated on the American Aerospace Technologies, INC. AiRanger UAS, dated 28 January 2024 - Prepared by Brian P. Patterson, Flight Test Engineer, brian.patterson@pemdastech.com

[2] Final Test Report for PEMDAS Atmospheric Sensing and Prediction System (ASAPS) and Environmental Intelligence NOWcasting Software Integrated with the American Aerospace Technologies, Inc. AiRanger UAS, dated 30 June 2024 - Prepared by Brian P. Patterson, Flight Test Engineer, brian.patterson@pemdastech.com

E. Electronic Publications - N/A

F. Computer Software

[3] Real-time Cloud Potential and Real-Time Icing Potential software

[4] ASAPS sensor and controller RTOS and communication and data protocol software

[5] NOWcasting system encompassing the Mission Area Sensor Streaming (MASS); Dynamic Rapid Update Model (DRUM); Fused Representation of Environment (FIRE)

G. Patents

[6] Patent 9,363,462: System and Method for Simultaneous Display of Multiple Geo-Tagged Videos of a Particular Geographic Location

[7] Patent 8,577,518: Airborne Right-of-Way Autonomous Imager (AiRWAI)

[8] Patent 8,494,760: Airborne Widefield Airspace Imaging and Monitoring (WAIM)

[9] Intelligent Ground-Based Pipeline Monitoring Sensor Network - Patent pending

[10] Airborne Internet of Things Gateway - Patent pending

H. Private Communications and Websites

[11] Footnote 6: American Aerospace Technologies, Inc. website: https://americanaerospace.com/

[12] Footnote 8: Vantis Network website: https://www.vantisuas.com/news/article/american-aerospace-technologies-inc-announces-first-flight-on-vantis

I. Unpublished Papers and Books - N/A