FINAL REPORT
FOR
DAA SENSOR MODEL VALIDATION FLIGHT TEST

April 20, 2022

Contract No. 697DCK-21-C-00235

Prepared By:

GENERAL ATOMICS AERONAUTICAL SYSTEMS, INC. (GA-ASI)
14200 Kirkham Way
Poway, California 92064

FINAL REPORT
FOR
DAA SENSOR MODEL VALIDATION FLIGHT TEST

APPROVAL

PREPARED BY: David Marcus — Digitally signed by David Marcus Date: 2022.04.27 13:02:57 -07'00'

David Marcus DATE
Program Manager
GA-ASI

APPROVED BY: Wayne Lu — Digitally signed by Wayne Lu Date: 2022.04.27 13:08:33 -07'00'

Wayne Lu DATE
Project Engineer
GA-ASI

APPROVED BY: Digitally signed by Joseph Wimbrow Date: 2022.04.27 13:33:43 -07'00'

Joseph Wimbrow DATE
Chief Engineer
GA-ASI

FINAL REPORT
FOR
DAA SENSOR MODEL VALIDATION FLIGHT TEST

Revision History

Revision	Date	Description
Rev A	04/20/2022	Initial release [66273]

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. EXECUTIVE SUMMARY

This report is the final report associated with contract 697DCK-21-C00235 between the Federal Aviation Administration (FAA) and General Atomics Aeronautical Systems, Inc. for "Development of Non-System Specific Technology to Integrate Unmanned Aircraft Systems (UAS) into the National Airspace System (NAS): Detect and Avoid Capability" hereafter referred to as the "Sensor Model Validation project." The purpose of this report is to review all the activity on the Sensor Model Validation project, summarize the conclusions from the sensor model analysis report, and report on lessons learned that may have a positive impact on similar projects in the future.

In general, the Sensor Model Validation project achieved all its objectives. GA-ASI was able to plan and execute a flight test (with the help of the Northern Plains UAS Test Site, NPUASTS) that demonstrated UAS operations in various encounters between a GA-ASI remotely piloted test aircraft (N190TC/YBC01) and a crewed intruder aircraft (N231EX). The team collected sensor data (ATAR, ADS-B, and Active Surveillance) as well as GPS data showing the true position of each aircraft in the encounter. This data has been used to validate the assumptions built into the sensor models and show correlation between actual flight test conditions and simulated conditions.

2. INTRODUCTION

One of the greatest technical challenges for Uncrewed Aircraft Systems (UAS) to fly in civilian airspace is fulfilling the current "See and Avoid" requirements (14CFR §91.113). A Detect and Avoid (DAA) system certified to TSO-C211 (DAA systems) fulfills this requirement, yet its application in the National Airspace System (NAS) is still in its infancy. For example, UAS operators complying with the current revision of RTCA/DO-365 do not have the authority to conduct loiter operations in Class E airspace and are, thus, limited to transit (point-to-point) flights only. Phase 2 of RTCA's SC-228 resolves this limitation by introducing extended operations in Class E airspace, expanded operations in the terminal environment, and includes requirements for ACAS Xu-based DAA systems (RTCA/DO-365 Revision B).

GA-ASI has over 30 years of experience designing, developing, operating, and certifying Uncrewed Aircraft Systems (UAS). This project utilized GA-ASI's extensive experience in flight testing of prototype DAA systems, obtaining the first civil operational approvals for airborne- and ground-based DAA, and strong support of RTCA (and worldwide) committees for DAA and related standards.

GA-ASI was awarded a contract with the FAA in September of 2021 and extending through April 2022. The objective of this contract was to test the assumptions used to develop the Detect and Avoid (DAA) sensor models via flight test. GA-ASI performed a series of flight tests with DAA sensors (ADS-B, ATAR, Active Surveillance) to collect data for later analysis against existing sensor models. The flight test series was designed to evaluate the sensors themselves as well as the expanded operating environments allowed in RTCA/DO-365 Revision B.

GA-ASI successfully executed the flight test series in January of 2022 in Grand Forks, North Dakota. The flight tests were performed using a GA-ASI SkyGuardian® UAS equipped with GA-ASI's prototype DAA system. Flight test details and results are provided in the Flight Test Results Report, ASI-22882. The flight tests were performed in partnership with the Northern Plains UAS Test Site (NPUASTS) who provided test planning and execution support as well as the intruder aircraft. A summary of the NPUASTS effort is also included in ASI-22882.

Following the completion of the flight test and as the final major task of the contract, GA-ASI performed an analysis to validate the assumptions pertaining to DAA modelling and simulation, in particular the assumptions made for sensor modelling. This analysis is documented in the DAA Sensor Model Validation Data Analysis Report, ASI-23043. Each of the DAA sensors (ADS-B, ATAR, Active Surveillance) performs differently and has a set of assumptions that is used when simulating the errors generated by each sensor. The analysis compares the results data from the flight test to the sensor models to assess accuracy and make recommendations regarding their use in the future.

3. REFERENCED DOCUMENTS

The documents provided in Table 2-1 below represent all the documentation deliverables associated with the Detect and Avoid Sensor Model Validation project. All the documents have been released and submitted for customer review.

Table 3-1 Reference Document List

Document Number	Reference Document Title	Revision	Release Date	SOW Task
ASI-22498	FAA Detect and Avoid Sensor Model Validation Flight Test Plan and Flight Test Procedures	A	12/16/2021	2.1, 2.4
ASI-22882	FAA Detect and Avoid Sensor Model Validation Flight Test Report	A	03/17/2022	4
ASI-23043	FAA Detect and Avoid Sensor Model Validation Data Analysis Report for BAA Call 2 FAA DAA Sensor Flight Test	A	*	5.2
ASI-23126	Final Report for DAA Sensor Model Validation Flight Test and Analysis	A	04/20/2022	6.1

*ASI-23043 was not yet released at the writing of this report

4. PARTNERSHIPS

This project would not have been successful without the support of strong relationships between GA-ASI and its partners.

The State of North Dakota's Northern Plains UAS Test Site (NPUASTS) is one of seven FAA approved UAS test sites formed through the FAA Other Transaction Agreement (OTA). NPUASTS supported the flight test effort in the form of reviewing test plans, supported test execution, provided a crewed intruder aircraft for scripted encounters, and generated a test report of flight test activity and data.

Unmannned Applications Institute, International (UAI) is a research and applications institute created to advance the uncrewed systems industry in North Dakota and the region. UAI is a subcontracted partner to the NPUASTS for these efforts. UAI provided the pilots and Mooney aircraft to perform the crewed flight encounter profiles in the test scenarios.

Honeywell Aerospace partnered with GA-ASI on previous DAA-related projects. Honeywell provided the TCAS unit used for this flight test (including the sensor tracker software), as well as engineering and data analysis support.

5. ACTIVITY SUMMARY

This section of the report summarizes the activities performed throughout the project. GA-ASI provides references to deliverables generated at each stage that provide much more detail regarding test planning and procedures, test execution, and data analysis.

5.1 TEST PLANNING

During the proposal process, GA-ASI had already developed a flight test setup to ensure the encounters could be performed safely and the data could be accurately collected. An overview of this setup is shown in Figure 4-1 below. In this setup, the remotely piloted test aircraft (SkyGuardian™) performs scripted encounters with an intruder aircraft. The remotely piloted test aircraft has a DAA system onboard with the key sensors being tested (Active Surveillance, ADS-B, and ATAR). The intruder aircraft also is configured with similar sensors (Active Surveillance and ADS-B) so it can appear as a cooperative intruder to the DAA system. Both aircraft are equipped with a GPS to collect "truth tracks" showing actual position.

The ground system architecture serves as flight control of the remotely piloted aircraft as well as a backup data recorder. The Ground Control Station (GCS) presents the DAA data via the Conflict Prediction and Display Software (CPDS). The CPDS software takes the traffic information from the aircraft, analyzes the data for intrusions to Remain Well Clear of ownship, and presents that information to the Pilot in Command (PIC).

An additional feature of the setup used for this testing was the Ground-Based Sense and Avoid (GBSAA) available at GA-ASI's Flight Test and Training Center (FTTC) in Grand Forks, North Dakota. The GBSAA system is a ground-based radar providing track information to an Electronic Observer stationed in the GCS. Should an unexpected intruder appear during the scripted encounters, the Electronic Observer will be able to advise the PIC of the situation. This also provides another backup data source for the encounters.

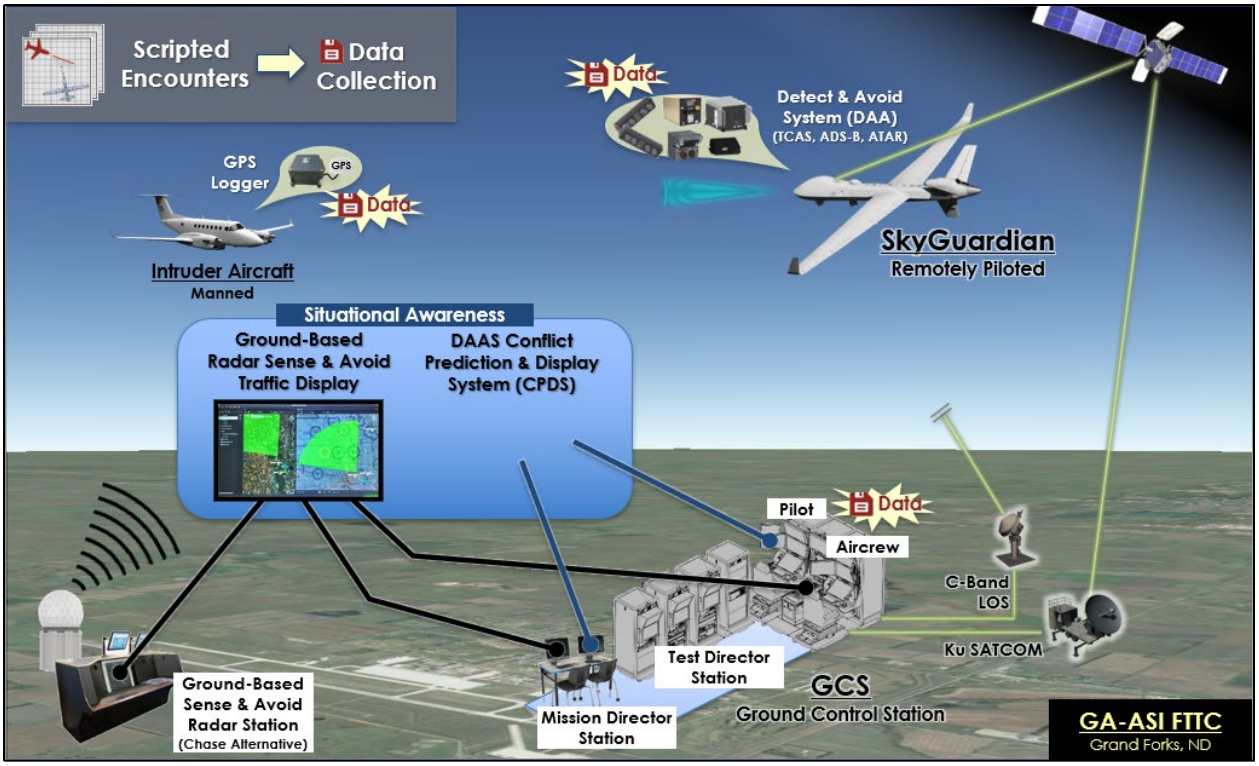

Figure 5-1 Flight Test Setup Overview

With the test setup in mind, the test planning process focused on developing the set of encounters that could best meet the objective of the project (to test the assumptions of the DAA sensor models). In particular, GA-ASI opted to focus on encounters that tested in three areas: (1) Air-to-Air Radar Field of Regard (ATAR FOR), (2) Terminal Area, and (3) Extended Operations. First, this flight test presented a strong opportunity to build a more robust data set of flight testing to compare against simulations of ATAR FOR. ATAR FOR is depicted Figure 4-2 as a distribution of detection range based on the radial distance from the nose of the aircraft. In addition, revision A of the DAA MOPS (RTCA/DO-365) adds clearance to fly in the Terminal Area as well as perform Extended Operations in Class E airspace. Again, this flight test project adds to the data used to develop the safety case for Terminal Area/Extended Operations approval.

In total 20 unique encounters were developed as part of the Test Planning phase of the project: 10 encounters associated with testing horizontal Field of Regard (FOR) performance, 4 encounters associated with testing vertical FOR, 4 encounters to test the Terminal Area performance, and 2 encounters to test Extended Operations performance.

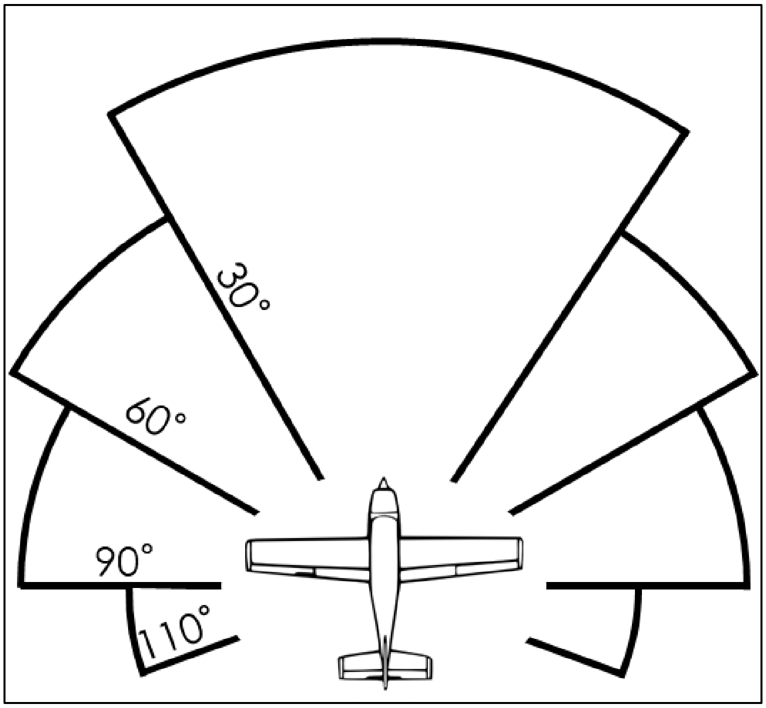

Figure 5-2 ATAR FOR Graphical Depiction (Horizontal)

5.2 TEST PROCEDURES/FLIGHT CLEARANCE

ASI-22498, “FAA Detect and Avoid Sensor Model Validation Flight Test Plan and Flight Test Procedures,” provides details of how, where, and with what equipment the flight test would be performed to collect sufficient data for validating the Detect and Avoid Sensor Models. Procedures for executing each test encounter, maintaining safety at all times, maintaining communications (among the GA-ASI test aircraft, the piloted aircraft, and the ground control station), and “knock-it-off” conditions are all included in the document. Regarding facilities, testing was performed at both the Gray Butte, California Flight Operations Facility (FOF) and the Grand Forks, North Dakota Flight Test and Training Center (FTTC).

Testing was conducted using a prototype MQ-9B/SkyGuardian™ aircraft with DAA equipment installed and a piloted aircraft acting as the intruder aircraft during all planned encounters. The aircraft was commanded and controlled with a Block 30 Ground Control Station (GCS) installed with a Conflict Prediction and Display System (CPDS).

Regarding data collection, TCAS and CPDS velocity and positioning data will be recorded from the sensors installed on the SkyGuardian aircraft for use in validating the sensor mode. Furthermore, Global Positioning System (GPS) equipment was installed in the SkyGuardian and intruder aircraft as a truth source for GPS data. Standard data logs recorded from Aircraft Enhanced GPS/INS (EGI) data in the aircraft also provided the team with data to be used in validating the sensor models.

The number of test flights was expected to be 4 flights out of the FTTC facility in Grand Forks, ND. Upon further review with the test pilots and intruder aircraft and in consideration for how long each maneuver took to complete, the encounters were actually completed within 2 flights.

The final stage in flight test preparation was development of flight test cards that show encounter-specific procedures. This includes specific latitude/longitude/airspeed for each stage of the encounter, radio calls, “knock-it-off” procedures, and a chart visualizing the maneuver. The pilots of both aircraft used this to perform each encounter. An example of the flight test card from Encounter 3 is provided in Figure 4-3 below. GA-ASI successfully completed flight test cards for each encounter in advance of performing the flight test.

Event: Encounter 3: Field of View 3

Test Pt No:

Initial Conditions & Config:
ALT: 8,000 ft MSL
Ground Speed: 110 Kts
ILLA: 8000 ft MSL
Maneuver Mode - Advisory
SAAP - On/Transmitting
CPDS - On/Recording

Tolerance: ALT +/- 200 ft   Timing: SP ± 15 sec

Limits: Aircraft G limit > -1 < 3 G

Link & Video Config:
KU - CL and RL
LOS - UL and DL

Aircraft Config:
Gear: UP
Wt: A/R
CG: A/R
Stall Protect: A/R

Hold Modes
ALT: A/R
A/S: A/R
HDG: A/R

Steps:

1 Toggle applicable Loggers (SAAP, DRR/IQ, CPDS)

2 (TD) Announce Scenario -*"NINETY NINE - Scenario - [Title]"*

3 (UAV + INT) Aircraft proceed to Start Point location and altitude.

4 (UAV + INT) Aircrew announce holding when nearby start point.
- *"[Call Sign] Standing By"*

5 (TD) Announce Start Time (~2min) - *"COMEX [Time]"*

6 (UAV + INT) Make adjustments as needed to cross Start Point at COMEX time.

7 (UAV + INT) Announce passing Start Point.
- *"[Call Sign] Action"*

8 (UAV + INT) Announce when crossing final point.
- *"[Call Sign] - CROSSING FINAL"*

9 (TD) Announce Scenario Complete - *"NINTEY NINE FINEX Scenario"*

Log GMT

Notes:

Emergency Mission	WP1 - Maintain altitude, fly northeast
Upon KIO	UAV turn right, INT turn right

F3 - Intruder 3.5 nm to SW at same altitude

Ownship Info	Label	Latitude	Longitude	Maneuver	Altitude start (ft)	Heading	GS (kgs)	Time to (m:s)	Turn Rate (deg/s)	Climb rate (ft/min)
Leg 1	GF1	48°30'00.00"	-97°30'00.00"	Fly Heading	8000	315	110	-	-	-
CPA -	O3-1	48°33'31.21"	-97°35'17.80"		8000	315	110	0:02:44	0.0	0
CPA	O3	48°34'13.97"	-97°36'22.14"		8000	315	110	0:03:17	0.0	0
End Point	GF24	48°38'22.76"	-97°42'36.48"		8000	315	110	0:06:33	0.0	0
Intruder Info	**Label**	**Latitude**	**Longitude**	**Maneuver**	**Altitude start (ft)**	**Heading**	**GS (kgs)**	**Time to (m:s)**	**Turn Rate (deg/s)**	**Climb rate (ft/min)**
Leg 1	GF5	48°35'56.21"	-97°46'35.38"	Fly Heading	8000	135	110	-	-	-
CPA -	I3-1	48°32'25.00"	-97°41'17.59"		8000	135	110	0:02:44	0.0	0
CPA	I3	48°31'42.24"	-97°40'13.25"		8000	135	110	0:03:17	0.0	0
End Point	GF28	48°27'33.45"	-97°33'58.91"		8000	135	110	0:06:33	0.0	0

Closest App.	
HMD (ft)	21874
VMD (ft)	0

Figure 5-3 Example Flight Test Card for Encounter 3

In addition to preparing detailed procedures for performing the flight test, GA-ASI follows internal procedures for “safety of flight” approval prior to testing. This process includes review of an internal Aircraft Flight Approval document as well as the Flight Test Plan and Procedures document. Subject Matter Experts review the risk associated with performing the test encounters in the proposed configuration to determine if it is acceptable or if additional mitigations are required to ensure safety. This flight safety review was performed successfully in January 2022 in advance of the first test flight.

GA-ASI also works closely with the FAA for aircraft and airspace authorization. The testing was performed with a prototype SkyGuardian™ aircraft (tail number N190TC, serial number YBC01) configured with a DAA system. The aircraft was approved for research and development flights via the Special Airworthiness Certificate – Experimental Certificate (SAC-EC) process (8130.34D). Figure 4-3 shows a copy of the certificate from the FAA. To perform the flight tests, GA-ASI took advantage of existing Certificates of Waiver/Authorization (COAs) approved for the test aircraft. Flight operations were performed in two locations (Gray Butte, California and Grand Forks, North Dakota). For initial checkout flights and the transit flight from Gray Butte to Grand Forks, GA-ASI utilized the 2021-WSA-101-SAC-REV1 COA for approval. Operations were performed with a chase plane for "see and avoid" mitigation. For the flight testing at the FTTC facility in Grand Forks, GA-ASI utilized the 2021-CSA-97-SAC (Rev 3) COA for approval (an image of operating areas from this COA is provided in Figure 5-5). Operations were performed with the GBSAA and an Electronic Observer for "see and avoid" mitigation.

UNITED STATES OF AMERICA DEPARTMENT OF TRANSPORTATION-FEDERAL AVIATION ADMINISTRATION **SPECIAL AIRWORTHINESS CERTIFICATE**		
CATEGORY/DESIGNATION Experimental		
PURPOSE Market Survey,Crew Training,Research and Development		
MANU-FACTURER	NAME N/A	
	ADDRESS N/A	
FLIGHT	FROM N/A	
	TO N/A	
N190TC	MODEL UBC97000-1	SERIAL NO. YBC01
BUILDER GENERAL ATOMICS AERO SYSTEMS		DATE OF ISSUANCE 22/Jul/2021
Unless sooner surrendered, suspended, revoked, or the termination date of 21/Jul/2022, this airworthiness certificate is effective under the conditions prescribed in 14 CFR, Part 21, Section 21.181 or 21.217.		
SIGNATURE OF FAA REPRESENTATIVE Adrian Oscar Rivera Digitally signed by Adrian Oscar Rivera Date: 2021.07.27 06:36:49 -07'00'		DESIGNATION OR OFFICE NO. AFG-VNY-FSDO-01
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 the certificate revocation, fine and / or imprisonment. THIS PORTION OF THE CERTIFICATE MUST BE DISPLAYED IN THE AIRCRAFT PER THE APPLICABLE REGULATIONS.		

Figure 5-4 Experimental Certificate (Copy) for N190TC/YBC01

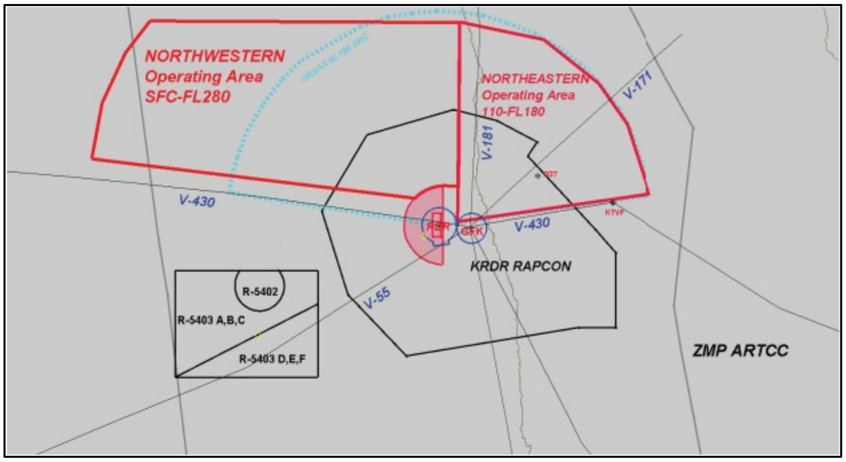

Figure 5-5 Operating COA for Flight Test Encounters at FTTC

5.3 TEST EXECUTION AND DATA COLLECTION

ASI-22882, “FAA Detect and Avoid Sensor Model Validation Flight Test Report,” provides details of how the testing was performed and what data was gathered during testing. The report includes a visualization of each encounter based on latitude and longitude data. In addition, there is a review of each sortie with comments from the Test Director, Project Engineer, and Test Pilots. This document also includes the test results report of the Northern Plains UAS Test Site.

Testing started when the GA-ASI project team took control of the test aircraft, YBC01 (N190TC). Initial work to integrate the GPS device was performed at the GA-ASI Gray Butte, California Flight Operations Facility. A system verification flight performed on January 13, 2022, confirmed functionality of the systems (DAA, GPS, etc.) critical to performing the flight test campaign. Upon completion of the verification flight and approval from the project team to proceed, the aircraft transited from the Gray Butte, California facility to the Flight Test and Training Center in Grand Forks, North Dakota on January 14.

The flight test encounters were performed across two sorties over January 24-25, 2022. During each flight, the GA-ASI Test Director called out each encounter to be performed, captured initial data (start time, etc.) and coordinated activity with the Flight Test Pilot and Intruder Test Pilot. Upon completion of each encounter, the Test Director captured any notes/feedback from the crew and coordinated to initiate the next encounter. In a few encounters, the pilots called a “knock-it-off” condition because changes in initial conditions including loss of visual of the test aircraft from the intruder aircraft or changes in prevailing winds that affected aircraft position. These details are included in ASI-22882 as well as a review of aircraft configuration, ADS-B sensor validity, and test feedback from the pilots.

Regarding data collection, velocity, and position data, captured from the sensors installed on the SkyGuardian aircraft, was recorded by the TCAS unit and the SAAP computer on the aircraft, and the CPDS software in the Ground Control Station (GCS). Furthermore, aircraft position data (“truth tracks”) were provided by the Global Positioning System (GPS) on the SkyGuardian aircraft and an additional GPS on the intruder aircraft.

Standard data logs recorded from the Embedded GPS/INS (EGI) data in the aircraft were also provided to the analysis team to be used in validating the sensor models.

A summary of the flight test campaign (all encounters superimposed) is shown in Figure 5-6. For comparison, a track of the ADS-B data capture (from the publicly available source FlightAware) for the intruder aircraft during the first sortie is shown in Figure 5-7.

Following the flights, project engineers processed the data and confirmed its integrity before calling the end to the data collection phase of this test effort. The sensor data collected from these flights was passed to GA-ASI Engineering for analysis and sensor model validation. The final data analysis report is presented in ASI-23043.

Upon completion of this phase of the flight test, the aircraft was flown back to its base of operations from FTTC in Grand Forks, North Dakota, to FOF in Gray Butte, California. After the return flight was completed, the aircraft was handed off to another project team for the following project. A summary of the flights is provided in Table 2 below.

#	Flight Name	Objective	Airspace	Flight Duration (hrs)	Encounters Attempted	Encounters Completed
1	System Verification Flight	DAA system checkout flight	FOF (GB)	3		
2	Transit Flight	Transit to FTTC	FOF(GB)-FTTC	8		
4	DAA Flight Test Day 1 (Jan 24th)	DAA Flight Tests	FTTC	2.9	8	7
5	DAA Flight Test Day 2 (Jan 25th)	DAA Flight Tests	FTTC	6.2	20	13
7	Transit Flight	Transit to FOF (GB)	FTTC-FOF (GB)	7.5		

Table 5-1 Summary of Flight Test Campaign

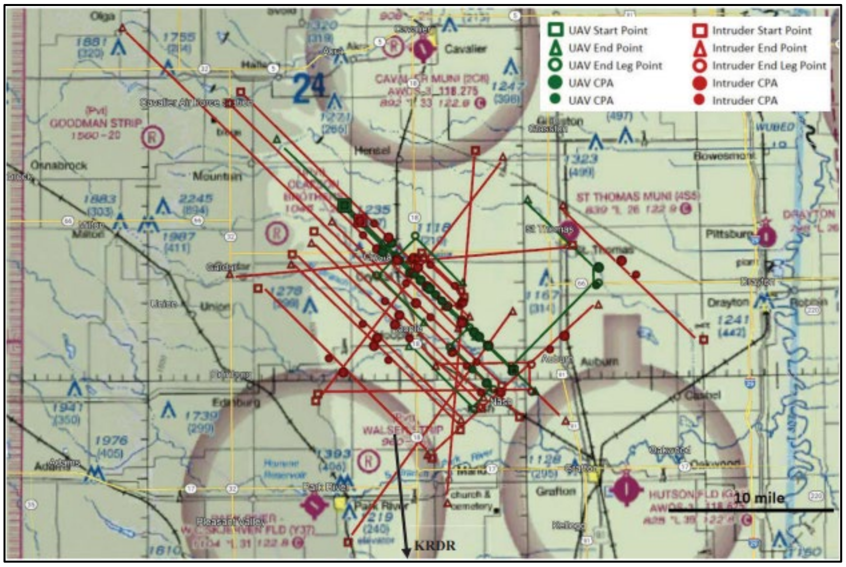

Figure 5-6 Summary View of Test Encounters

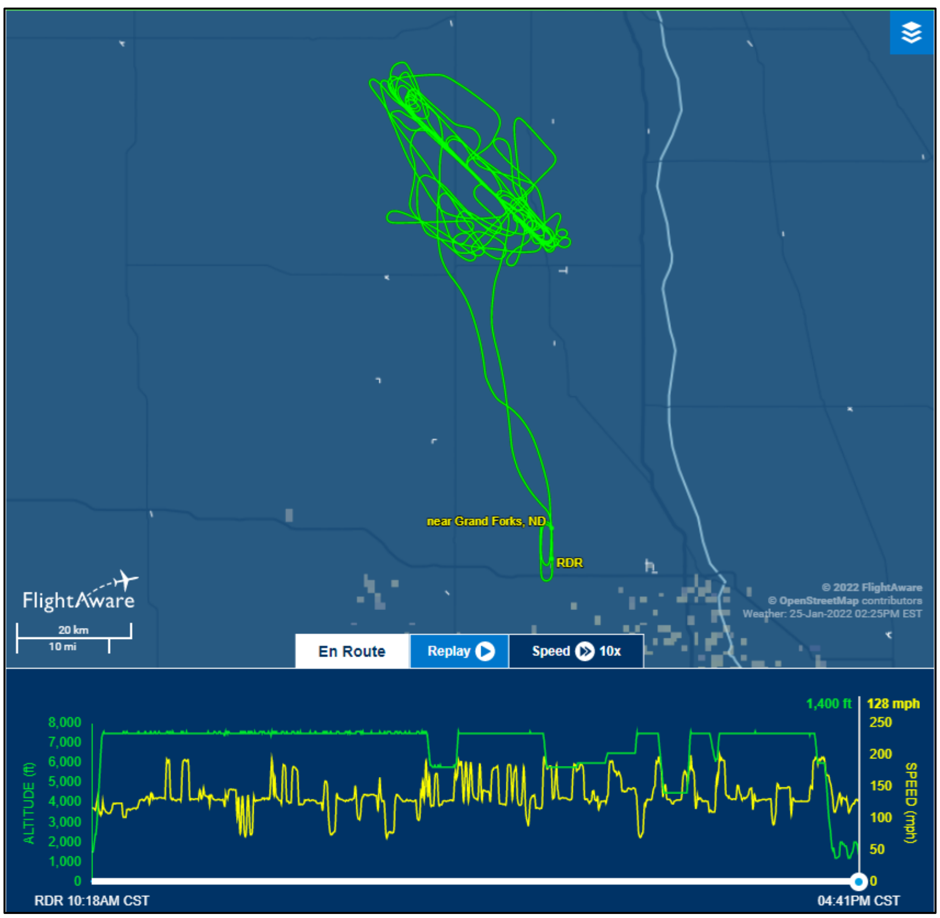

Figure 5-7 ADS-B Data Capture for N231EX During 1st Sortie

5.4 SENSOR MODEL ANALYSIS

ASI-23043, "FAA Detect and Avoid Sensor Model Validation Data Analysis Report," provides details of the data analysis and conclusions associated with the sensor model validation. At a high level, the data analysis was performed using the method pictured in Figure 5-8 below.

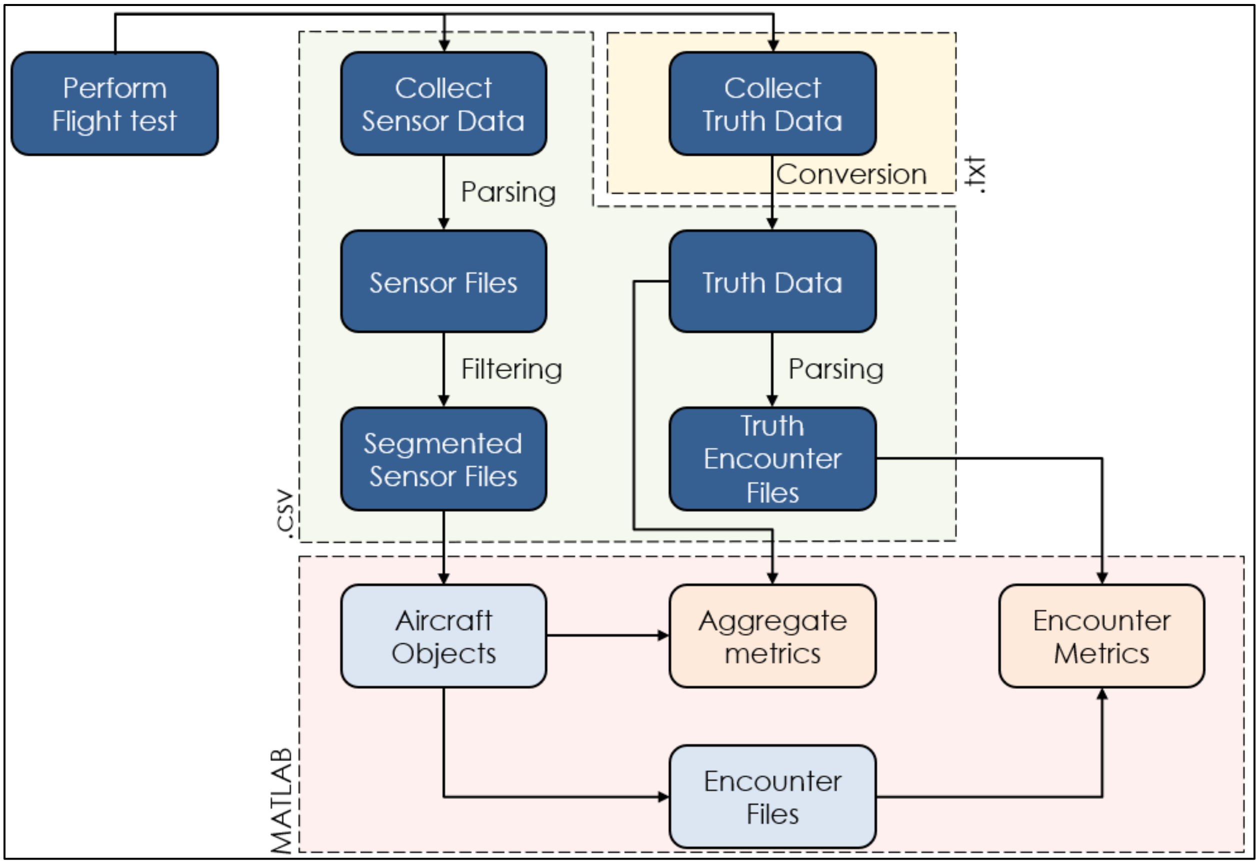

Figure 5-8 Sensor Model Analysis Methodology

The first step in the process was to capture the data from the flight test both from the DAA sensors and the GPS capturing truth data. This data needed to be parsed into data sets for each encounter, filtered to separate data associated with each sensor, and translated to ensure the orientation of each sensor is in the same reference frame. In particular, the ATAR measures relative measurements in the ownship body frame, ownship attitude information is needed to calculate the relative azimuth and elevation of the intruder. Also, the truth position data from the GPS units is measured in latitude and longitude. Since both Active Surveillance and ATAR use a relative reference frame, it is necessary to convert the truth position from latitude and longitude to a comparable format.

In addition to the parsing, filtering, and translating steps, the data must finally be extrapolated to a common time and converted to common units for comparison. For example, the ATAR measurements are interpolated to the nearest whole second, so that the Time of Applicability (TOA) of the ATAR data and the truth measurements align exactly. In addition, each sensor has a base unit (i.e., meters for ADS-B position and feet for Active Surveillance range), so the data comparisons were converted to like units.

After completing these steps, the comparison between sensor data and truth data was simply subtraction. This generated a data set of encounter metrics with errors for each of the individual sensors. The encounter metrics are then compared to the same expected error for each of the sensor models. In so doing, it is possible to determine if the error assumptions in the sensor models match the calculated error from actual data. In addition, the ATAR sensor data was analyzed further against the Field of Regard (FOR) assumptions of ATAR performance. These analyses were compiled for each sensor and recommendations made (see Section 6) to incorporate the results into the sensor models in the future.

6. SUMMARY OF FINDINGS

The data analysis identified some opportunities to improve the existing sensor models based on flight testing. The details of these recommendations are provided throughout ASI-23043. A summary of these findings is below:

1. ATAR: Correlation between range error to intruder range
    a. Observation: the standard deviation of range error at 0-1 nautical mile from ownship deviates from the standard deviation at other ranges
    b. Recommendation: discussion on how ATAR model can reflect this behavior or drop tracks at close range
2. ATAR: Correlation between azimuth error and intruder range
    a. Observation: the ATAR performs similarly for all ranges with the exception of close intruder range
    b. Recommendation: discussion on how ATAR model can reflect this behavior or drop tracks at close range
3. ADS-B: Probability of reception
    a. Observation: the calculated probability of reception for ADS-B was below the modeled value
    b. Recommendation: discuss reducing the probability of reception for lower-SWaP aircraft (like the GA-ASI SkyGuardian) to 75% for ADS-B
4. Active Surveillance: Measured RMS range error
    a. Observation: although the measured mean range error is consistent with the Active Surveillance model, the measured RMS range error exceeds the model
    b. Recommendation: investigate the causes of this error; signs point to overcompensation of latency. If this error is representative, discuss updating the model to reflect measured performance
5. Altitude Error (applies to both ADS-B and Active Surveillance): Standard deviation of calculated error
    a. Observation: the calculated error in the standard deviation of corrected data for measured altitude (82 feet) exceeds the standard deviation of simulated data (65 feet)
    b. Recommendation: discuss potential resolutions for altitude modeling with RTCA Special Committee SC-228 (committee on "Minimum Performance Standards for Unmanned Aircraft Systems")

7. FUTURE OUTLOOK

7.1 LESSONS LEARNED

There is always opportunity to assess performance and identify opportunities to improve on future projects. GA-ASI has identified a few lessons learned that would benefit performance the next time this type of project is completed.

The first lesson is to try to increase the time from contract award to executing flight test. In this project, there was approximately 4 months of lead time to perform test planning, generate test procedures, and prepare the aircraft to execute the test. One challenge was awarding a purchase order to Northern Plains UAS Test Site for their support. Some of the logistics that would normally have been included in the planning stage were not able to be completed due to the shorter schedule. In addition, GA-ASI would have had an opportunity to perform a Systems Integration Lab (SIL) test of the exact flight test configuration to avoid delays once the aircraft became available.

Another lesson learned was to develop a formal communication plan for flight test. For security reasons, normal operations for GA-ASI's remotely piloted vehicles occurs exclusively in the Ground Control Station (GCS). In this project, there were observers from NPUASTS in the GCS as well as at an offsite facility monitoring the test. Unfortunately, only radio traffic and the DAA traffic display were available offsite making it difficult to maintain situational awareness of the testing. The recommendation would be to incorporate communications planning during the test planning phase and to install the capability for broadcasting more situational data to outside observers.

7.2 CONCLUSIONS AND RECOMMENDATIONS FOR UAS IN THE NAS

As noted above, the purpose of this project was to perform real-world flight testing to confirm assumptions associated with safety assessments for technology (i.e., Detect and Avoid) required for operations of Uncrewed Aircraft Systems (UAS) in the National Airspace System (NAS). In review of the tasks, analyses, and documents completed, GA-ASI concludes that the project was completed successfully. The flight testing was completed as planned and captured sufficient data from the DAA sensors for later analysis. The sensor model analysis was also successful in assessing performance of the sensors in real-world conditions relative to models and making recommendations on how best to adjust the models based on this new data.

Beyond the technical recommendations provided in the analysis report (ASI-23043), the broader recommendation is to provide the results of this data collection to SC-228 for review and discussion. Even further, this project has shown the value of performing even a small flight test (20 encounters as opposed to 1 million) as a means of verifying digital models of a technology like Detect and Avoid. The recommendation would be to continue to execute these projects with UAS operators like GA-ASI.

8. LIST OF ACRONYMS

The following is an alphabetical listing of acronyms used in this document.

ADS-B	Automatic Dependent Surveillance-Broadcast
ATAR	Air-to-Air Radar
BAA	Broad Agency Announcement
CFR	Code of Federal Regulations
DAA	Detect and Avoid
dGPS	Differential Global Positioning System
FAA	Federal Aviation Administration
FOR	Field of Regard
GA-ASI	General Atomics Aeronautical Systems, Inc.
GCS	Ground Control Station
ICAO	International Civil Aviation Organization
MOPS	Minimum Operation Performance Standard
NAS	National Aerospace System
NPUASTS	Northern Plains UAS Test Site
RWC	Remain Well Clear
SAAP	Sense and Avoid Processor
TCAS	Traffic Collision Avoidance System
TSO	Technical Standard Order
UAS	Uncrewed Aircraft System