APPENDIX D – NMSU TEST PLAN MISSION

New Mexico State University
Unmanned Aircraft Systems Test Site
(NMSU UASTS)

NMSU UASTS
A46 Visual Observer Assessment Test Plan

May 9, 2022

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1 Introduction

This document provides the test plan for New Mexico State University (NMSU) Unmanned Aircraft Systems Test Site's (UASTS') effort in A11L.UAS.88–A46-001– Validation of Visual Operation Standards for Small UAS (sUAS): Separation Requirements and Testing. Details on the participants, locations, and test cards being flown for NMSU UASTS tests are identified within the document.

1.1 Project Overview

The FAA's proposed small UAS rules suggest the use of dedicated Visual Observers (VO) to help aid the Remote Pilot in Command (RPIC) in See And Avoid (SAA). The Alliance for System Safety of UAS through Research Excellence (ASSURE) A46 research task aims to address gaps in knowledge in an attempt to quantify VO/Remote Pilot (RP) performance, identify potential visual detection limitations, and inform safety training standards for Visual Line of Sight (VLOS) and Extended Visual Line of Sight (EVLOS) operations with the use of VOs. To address the gaps in knowledge and key concerns regarding VO/RP capabilities as they relate to 14 CFR Part 107 operations, the ASSURE A46 research team conducted a literature review to identify the current state of research on VO/RP visual acquisition and avoidance of potential collision hazards.

The literature review has identified a number of findings and gaps. The information captured in the literature review has been used for planning simulations, tests, demonstrations, and/or analysis needed to assess VO/RP performance and validate related standards. There are questions on the accuracy of detection of intruder aircraft whether manned or another sUAS, by the VO and the RPIC. New Mexico State University (NMSU), Kansas State University (KSU), Wichita State University (WSU), and Mississippi State University (MSU) are investigating methods to determine the accuracy to identify VO/RPIC performance considerations for visual detection and avoidance of conventional aircraft; explore capacity for VOs and RPIC to use visual references for avoidance; identify challenges associated with VO/RPIC communications; explore capacity for the RPIC to give way to manned aircraft. The research will provide the Federal Aviation Administration (FAA) agnostic information to help assess safe UAS operations when using VOs. A flight test methodology has been developed to test the VO capabilities of through a series of encounters flown with manned aircraft.

1.2 Scope of Testing

This effort establishes a test the methodology for the investigation of VO capabilities by looking at the types of operations, defined collected data parameters, and defined data processing required for validation. As noted, the literature review identified a number of findings and gaps. There are more elements in the findings and gaps that can be adequately addressed with the testing and within the scope of this research. The research team has reviewed these findings and gaps, coupled with FAA provided inputs/emphasis during Technical Interchange Meetings, and debated the merits of all of the potential testing elements. Five specific research questions were proposed that will be addressed through this testing.

1. What is the visual detection time for a ground-based VO?

2. At what point does the VO 1) see the intruder aircraft, 2) alert the RPIC, and 3) suggest an avoidance maneuver?
3. How does the distance/angular distance and/or associated portion of the Field of View between the VO and the intruder aircraft affect the probability of detection?
4. How do ambient light levels affect detection performance?
5. What can be done to improve VO performance? (answer anecdotally using input)

The NMSU UASTS is planning to execute an equivalent of up to 10 days of flights. Each flight set will have multiple encounters profiles. Each profile will be flown a minimum of one time each with subsequent days providing for additional reruns of the desired flight paths. This will allow the most data to be collected each event.

The A46 team has researched Detect and Avoid approaches in previous flight testing. This includes unmanned to manned intruder encounters and unmanned to unmanned encounters that have been completed with safe separation distances. A46 team members have also tested VO performance with various encounter scenarios. The A46 testing will use lessons learned during the previous flight tests to ensure safe separation during all phases of flight and for best data collection practices.

2 Test Architecture

The VO testing will follow a set of sequential steps to ensure safety and compliance. The general steps are as follows:

- Before the mission
  - Internal Review Board (IRB) approval from university (VO's are human test subjects)
  - Informed consent by the VO test participants
  - Submission of questionnaire (demographic information, experience, issues, etc.)
  - Perceptual testing (hearing screening and visual acuity testing)
  - VO training (common set of baseline materials)
  - Subject number assignment (for data collection and anonymity preservation)
- Mission Day (repeat multiple days with multiple subjects)
  - Escort to VO station
  - Practice trial (if required)
  - Main trials and data collection
- Debrief
- Data collection and storage

All subjects will receive the same VO Training Baseline before testing. These materials are in development now and will be available before any flight testing and data collection is completed. The literature review provided a broad view of various VO training approaches and materials. These were focused on the entire process conducted by different organizations/groups. Training materials were broad and generally included the following:

- Knowledge elements
- VO specific elements
- Operational elements

A nominal graphical representation of the testing is shown in Figure 1. Working from the center out, the green circle shows the location of the VO test subjects. Multiple groups of VO's will be located in a central area, but not within auditory range of each other. Multiple groups will be used so that each encounter can produce multiple data points and observations. It is envisioned that three to six VO's will take part in each test. Each VO will be located with a RPIC.

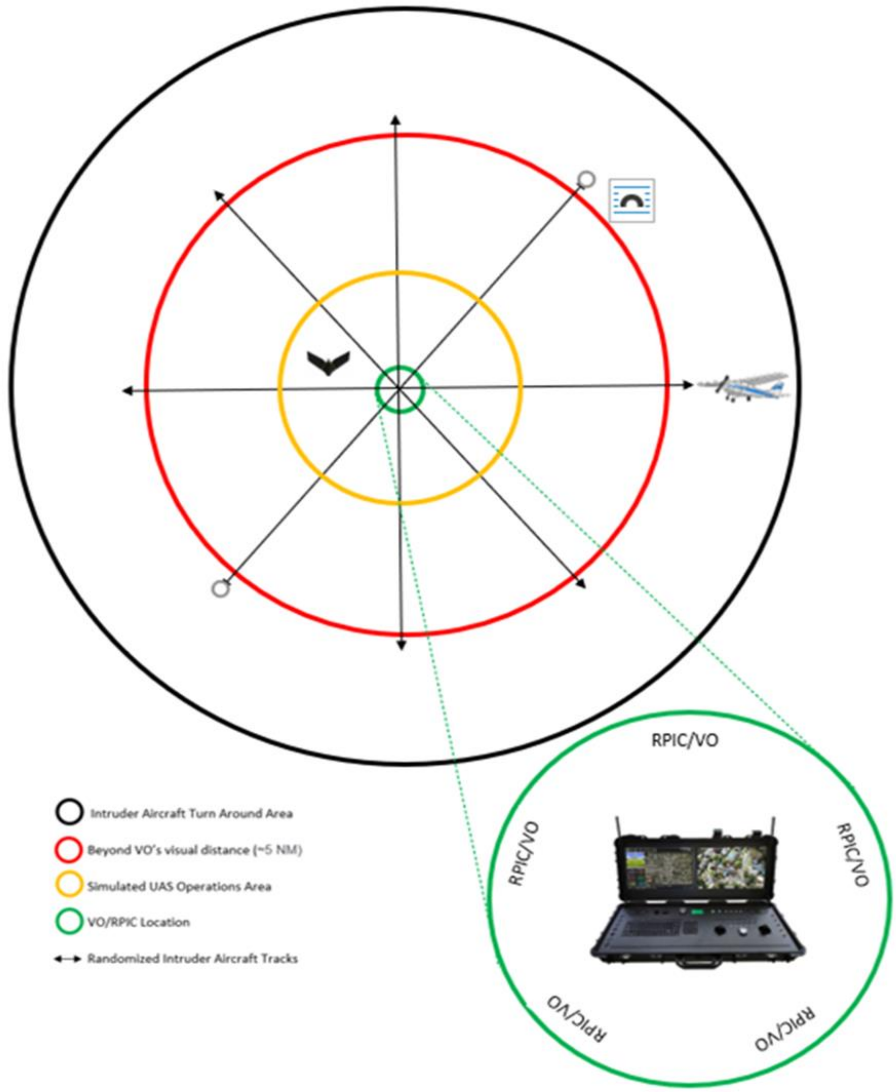


Figure 1. Nominal testing geometry.

The yellow circle in Figure 1 represents the simulated sUAS operations area. The red circle is five miles in diameter. This represents a distance beyond the visual range of the VO's. The team set this as the distance that each encounter will be set up and provide the start times/locations for each run. Areas outside of this five-mile range will be used for aircraft re-setup for the following runs. It should be noted that the five-mile range is an arbitrary line and past flight testing has shown that the intruder aircraft may not be able to be seen at two to three miles out. The further this distance, the longer the runs will take and the fewer tests will be able to be completed in a day. This test "start line" of five miles will be reviewed as part of the testing to see if it can be made smaller to increase the number of tests completed.

Intruder aircraft will cross at either 500 or 700 feet Above Ground Level (AGL), simulating a crossing encounters of a sUAS flying at 200 ft AGL or at 400 ft AGL (respectively). Safe separation is supposed to be at least 250 ft vertical separation. All aircraft encounters will maintain a simulated separation of at least 300'with the simulated sUAS at all times. Previous DAA system testing has shown that if actual manned versus unmanned encounters were to take place (instead of simulated sUAS operations), then flights should be completed with 350 ft to 400 ft target vertical separations to ensure that the testing maintains well clear. This additional distance in separation accounts for multiple uncertainties in both the flight profiles of the sUAS and manned aircraft as well as the data logging systems.

Position data of the Intruder Aircraft (and sUAS if they are flown) will be collected via the onboard aircraft flight recorders, and with Global Positioning System (GPS) loggers that will record both horizontal and vertical position data in similar formats. This will reduce the time to post process the data for the final report. The GPS loggers are QStarz BT-1000XT. These loggers can record data at one second intervals. This data will be used to validate position report from the VO group being tested. Testing encounter geometries are presented in a later section of this plan.

2.1 Deployed Assets

The NMSU UASTS will deploy the assets shown in Table 1 onsite to support the flight-testing.

Table 1. Available NMSU-UASTS Asset Descriptions.

Asset	Category	Description
ADS-B Receivers	Sensor: ADS-B	Multiple local ADS-B receivers will be deployed. Sensors will provide data on cooperative aircraft in the region.
echoUAT Transceiver	ADS-B Out	The echoUAT is a Class B1S ADS-B UAT transmitter coupled with a dual-link 1090MHZ / UAT receiver for Experimental and Light Sport Aircraft. An integrated Wi-Fi system transmits traffic and weather to popular Electronic Flight Bag (EFB) applications on iOS and Android.
Qstarz GPS Logger	Data Collection	BT-Q1000XT is a new age for the GPS Travel Recorder. Q1000XT is capable of recording up to 40 days, which is very reliable and powerful for long trip arrangement. Can log up to 400,000 waypoints in 3D space (Lat, Long, and Alt) – two per aircraft
Vertex Standard Crew Communications	Communications	Vertex Standard Radio allows two-way radio users to take radio communication to greater distances.
VHF Communications	Communications	A VHF Radios will be used in the NMSU UASTS manned aircraft for communications with the

		surrogate UAS (Spyder LSA) and the intruder Aircraft (CTLS LSA) and any local manned aircraft as needed.

3 Aircraft and Support Equipment

The NMSU UASTS will utilize as an intruder a Flight Design CTLS owned and operated by NMSU. The aircraft information card is provided below.

Flight Design CTLS

The Flight Design CTLS is a 2 seater Light Sport Aircraft designed around the FAA LSA regulation. It is all composite construction and uses a Rotax 90HP engine. The CTLS will serve as the intruder aircraft during the flights at NMSU.

Wing Span	28 ft 8 in	**Cruise Speed**	80-90 knots
Maximum Takeoff Weight	1,600 lb	**UAS Operator**	NMSU
Fuel Capacity	34 US gal		

A potential secondary backup intruder will be a Flight Star E-LSA. The Flight Star E-LSA is a small 2-seater ultralight.

FlightStar SCII Spyder

The FlightStar SCII Spyder is a 2 seat ultra-light class aircraft registered with an Experimental Airworthiness for Reaseach and Development.

Wing Span	32 ft	**Cruise Speed**	60-75 mph
Maximum Takeoff Weight	950 lbs	**Operator**	NMSU
Endurance	2 hrs	**GCS Type**	N/A
Line of Sight Range	300 nm	**Autopilot**	N/A

Support Equipment

There are a number of separate items needed to support these tests that are unique to tests temseleves and to the collection of data from human test subjects. Many of these are covered in the VO test data collection documentation. Included are the following:

- Light meter (TBD, only one for test area)
- Ambient noise meter (TBD, only one for test area)

- Audio (TBD)
- Video (TBD)

4 Flight Locations

Manned aircraft will takeoff from Las Cruces International Airport (KLRU). The test area is ~18 Nautical Miles (NM) Northeast of Las Cruces International Airport. Generally, most of the flight maneuvers will take place away from the airport as to minimize the impact with general aviation operations. The area is sparsely populated and all maneuvering of the manned aircraft will be performed at or above 500 ft AGL. If a sUAS is used for any of the optional testing, all maneuvering for the unmanned aircraft will be performed at or below 400’ AGL. To maintain a level of safety the manned aircraft involved in the operation, aircraft will have ADS- B in/out installed so that all pilots will have a high level of situational awareness and will allow for smoother setup for test encounters.

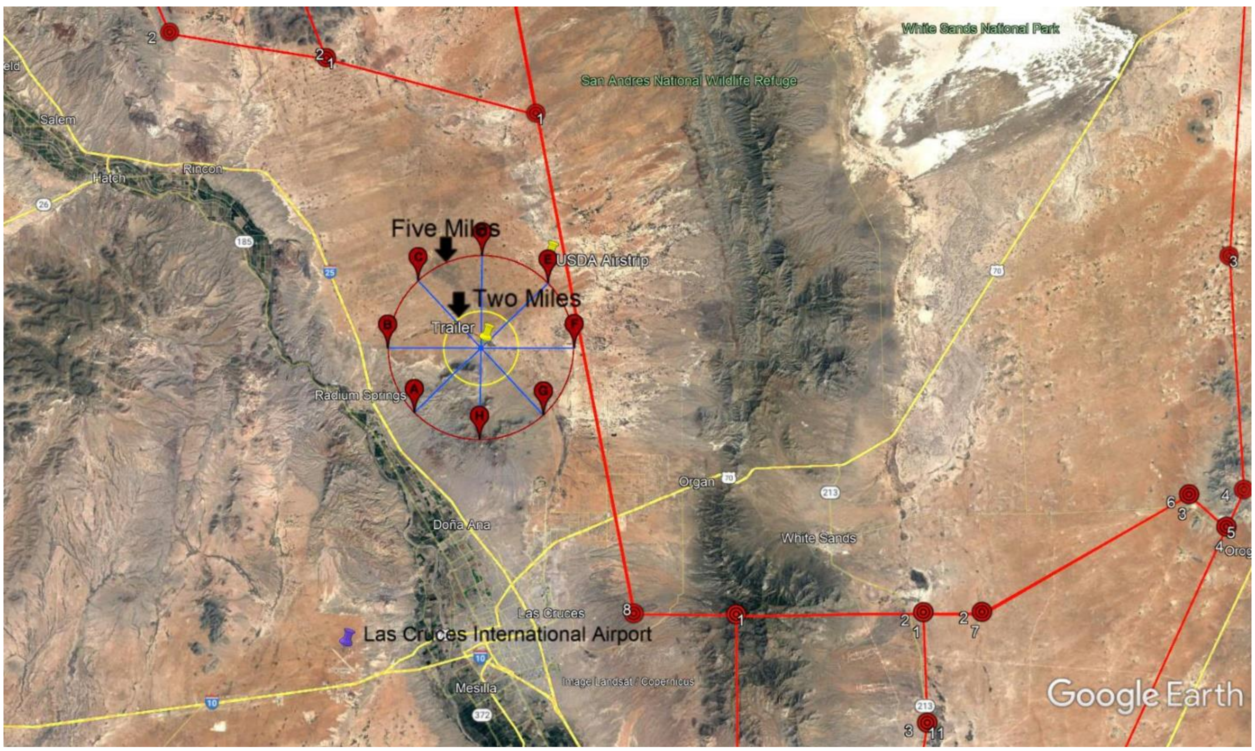


Figure 2. Wide view of NMSU testing area.

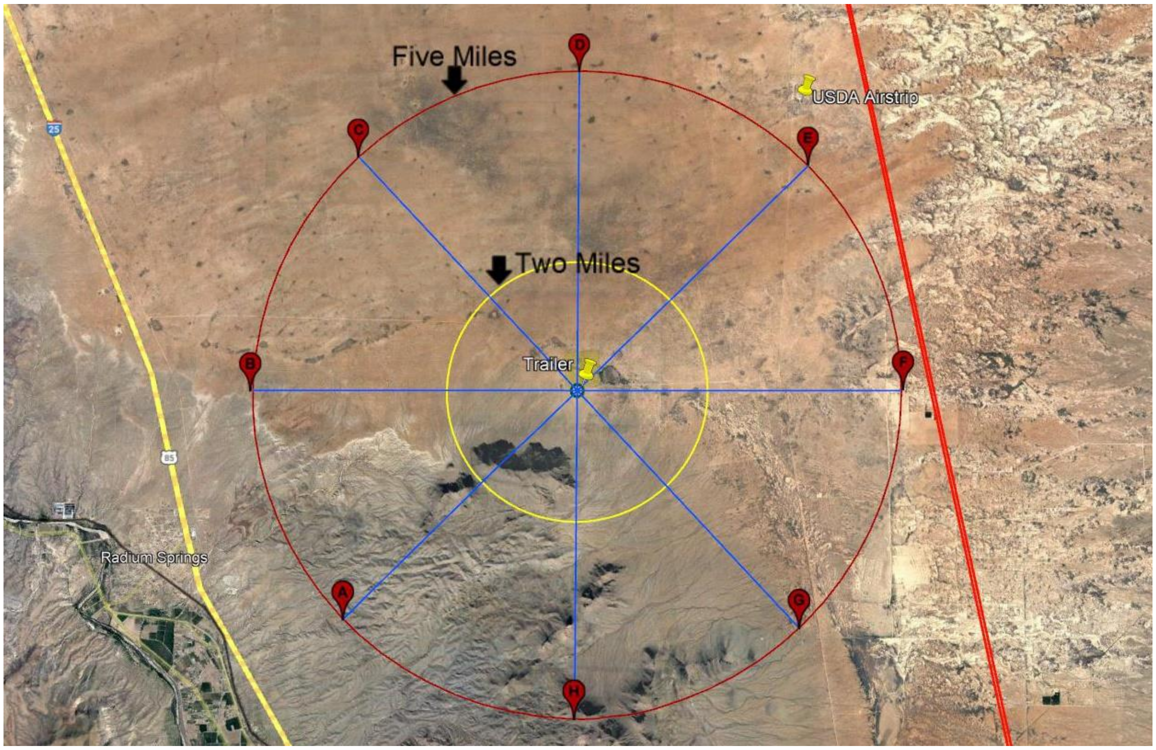
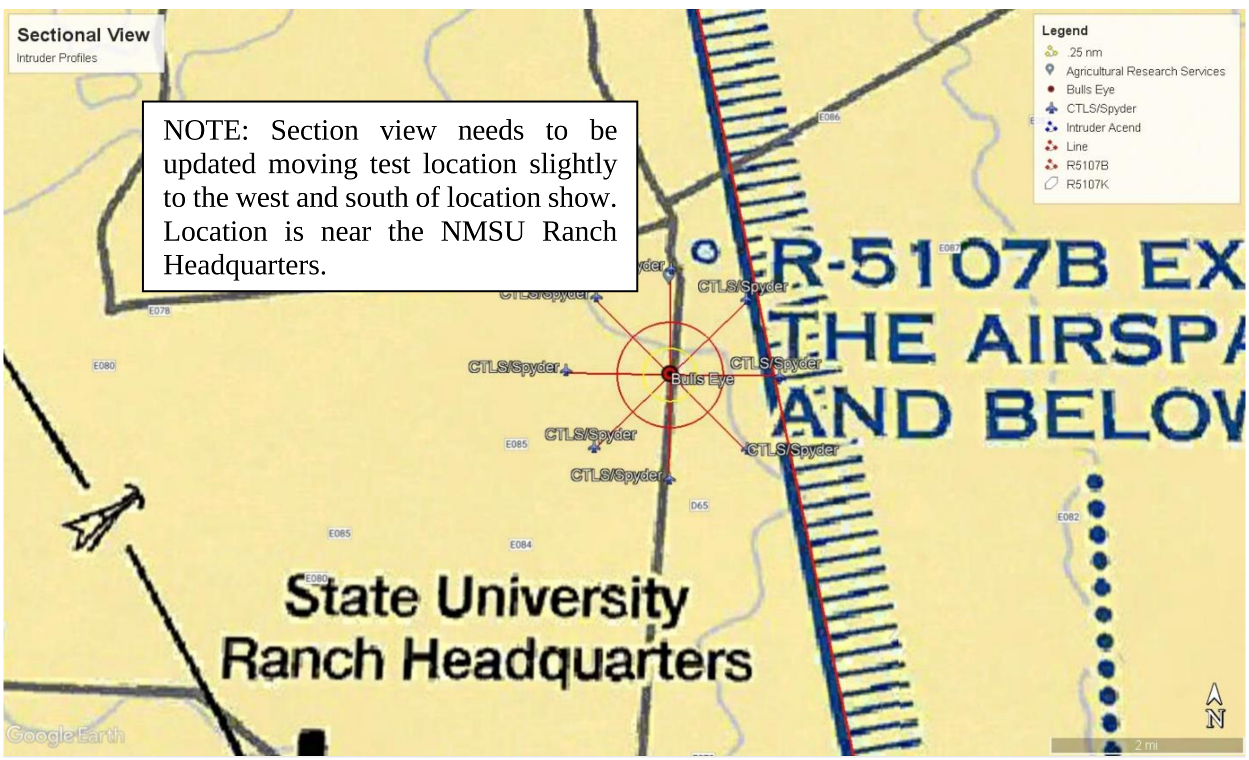


Figure 3. Birds eye view of the operational location for the NMSU A46 Event.



NOTE: Section view needs to be updated moving test location slightly to the west and south of location show. Location is near the NMSU Ranch Headquarters.

Figure 4. Sectional view of the operational location for NMSU A18 Event.

The VO location is at the NMSU College Ranch. Las Cruces is due south of the testing area. The Las Cruces International Airport is south and slightly west of the testing area. The solid red border lines represent the edges of White Sands Missile Range's restricted airspace.

5 Encounter Geometries

The encounter geometries provided are what is referred to as "wagon wheel" crossings. The encounters are laid out around the compass rose centered on the location where the VO's will be situated. Encounters will start at a distance beyond visual line of sight of the VOs. Nominally for these tests, this has been set at five miles. This will mark the start of the encounters. The Intruder will come from one of the depicted start points. The UAS will fly various patterns within a .25 NM radius of the bulls-eye. The intruder will then exit this location by aligning along the defined exit vector. The exit direction is aligned to minimize the flight time outside the five-mile diameter ring. Each subsequent intruder crossing will be along a different "spoke of the wheel". Dedicated visual observers will be posted on the ground and in the manned aircraft to help ensure See and Avoid will be maintained safely.

For more details on each encounter, please see the associated test cards. There are six dedicated test cards for this testing. They cover three sets of approaches/encounters with the intruder at 500 ft AGL and 700 ft AGL. It is hoped that each test card can be completed per day.

6 Success Criteria

The following is a list of criteria that if met will be considered a successful flight demonstration event.

- Determine if test methodology allows for VOs to identify and relay well clear during encounters.
- Determine if the test methodology allows for proper testing of the VO see and avoid.

Test Card	Test Card Description	Number of encounters
1	Compass rose encounters, configuration 1 – 500 ft	24
2	Compass rose encounters, configuration 2 – 500 ft	16
3	Compass rose encounters, configuration 3 – 500 ft	16
4	Compass rose encounters, configuration 1 – 700 ft	24
5	Compass rose encounters, configuration 2 – 700 ft	16
6	Compass rose encounters, configuration 3 – 700 ft	16
	Potential for additional repeats of the test cards	-
	Total Encounters	112

Patterns may be repeated for additional encounters. Encounters have been planned to maximize the randomness of encounters of the intruder aircraft. Additional test cards have been generated in case a sUAS flight is desired instead of a simulated sUAS. The sUAS flight patterns include Box, Linear, Mapping, and Orbit flight patterns at two different altitudes

7 Participants and Roles

The NMSU UASTS will work to accomplish the goals and objectives of the Visual Observer testing of ASSURE A46.There are three different sets of participants required for these flights.

First are the personnel related to the actual flight execution. Second are the personnel related to the VO handling and data collection. Third are the test subjects who will be the VOs.

7.1 NMSU UASTS ASSURE A46 Visual Observer Test Participants

Table 2 provides a list of the partners associated with Event 1 A46 flight tests in New Mexico. The following subsections provide overview of each partner and their role.

Table 2: NMSU UASTS ASSURE A46 Event 1 Test Flight Partners

Partner	**Role**
NMSU UASTS	Flight Coordinator, Manned Aircraft Provider, sUAS pilots
NMSU	VO Test Director and staff
NMSU	Student / Visual Observers / Test Subjects

7.1.1 NMSU UASTS

The NMSU UASTS will provide a Mission Commander (MC). The MC will be the primary person leading the execution of these tests and will oversee operations. The MC will ensure that flights adhere to NMSU UASTS Standards and Policy. NMSU UASTS will provide the FAA Certificated Pilots. The manned pilots will fly according to all FAA Regulations during all encounters. NMSU will provide Part 107 sUAS pilots to act as the RPICS for the simulated flights, and as needed if these optional tests are desired. The sUAS pilots will simulate/perform normal flight operations in accordance to the test plan. The NMSU UASTS will also provide ground personnel for logistics, setup, and coordination.

For flight safety the NMSU UASTSwill also provide visual observers for the overall flight portions of the testing. There will be two types of NMSU VOs, airborne and ground, to assist pilots with see and avoid.

Optional personnel may support using a Fortem Radar. This will be used during testing to provide an additional control point. This will also provide an additional level of safety to the operation. NMSU UASTS will provide a conference room/space as needed for daily briefings and debriefings for the flight testing. Some personnel may have dual roles.

7.1.2 Visual Observer Test Director and Staff

NMSU will provide personnel to oversee the VO test subjects. The VO Test Director will ensure that the "human factors" elements of the testing are addressed including the VO data collection and oversight.

7.1.3 Visual Observer Test Subject

NMSU will provide personnel to use as VO test subjects. The VOs will be evaluated based on test criteria during flight operations.

8 Schedule

8.1 General Flight Day

Table 3. General flight Schedule.

Start	End	
8:00:00 AM	8:30:00 AM	Pilot Brief
8:30:00 AM	9:00:00 AM	
9:00:00 AM	9:30:00 AM	Take-off Manned Aircraft
9:30:00 AM	10:00:00 AM	Flight Test
10:00:00 AM	10:30:00 AM	
10:30:00 AM	11:00:00 AM	
11:00:00 AM	11:30:00 AM	
11:30:00 AM	12:00:00 PM	
12:00:00 PM	12:30:00 PM	Landing Manned Aircraft
12:30:00 PM	1:00:00 PM	Break
1:00:00 PM	1:30:00 PM	
1:30:00 PM	2:00:00 PM	Take-off Manned Aircraft
2:00:00 PM	2:30:00 PM	Flight Test
2:30:00 PM	3:00:00 PM	
3:00:00 PM	3:30:00 PM	Landing Manned Aircraft

It is estimated that with the aircraft speed, it will take 10 to 12 minutes per each run including the 10-mile traverse (ref. 5-mile radius circle) and then repositioning for the next leg. With the flight times shown in Table 4, this would represent between 18 and 21 encounters per full flight day. Some or all of each test may not be completed within this period. There may be efficiencies in the schedule that increase the number of encounters and some elements may take longer than expected. The overall flight plan execution will be reviewed after each flight day to assess efficiencies to gather the most data possible. The flight days and times may vary depending on the weather and complexity of the encounters. The plan will be to conduct operations over several days to fulfill the planned number of encounters. Flight days may also not be sequential.

9 Data Management Plan

Data will be collected and aggregated in a variety of locations during live events. This data will then be mined post flight to perform proper analysis and generate results by the NMSU team. Some of these may change between the time of this plan development and the flight execution. The NMSU UASTS will ensure the proper data is collected.

The following subsections provide more detail on the data collection methods/locations.

9.1 Metadata Spreadsheet

Prior to flight each day, the Mission Commander will collect general information on the day. This information will include weather and planned encounters.

The spreadsheet will collect the following data points.

- Pilots of Intruder
- Pilots of UAV
- Weather Conditions
- Take-off and landing times
- Comments from flight including lessons learned

Date (dd/mm/yy)				Index#

Form 2
Flight Data
FAA UAS Test Site

Data collector:		Proponent:	
Flight Objective:			
Crew Information			
UAV Surrogate (Spyder SCII)			
Pilot in Command		Airborne VO	
Aircraft N number			
Intruder Aircraft (CTLS)			
Pilot in Command		Airborne VO	
Aircraft N number			
Comments:			
Weather			
Time of observation		Source	
Wind speed in knots		Temperature in Celcius(°C)	
Wind direction (deg)			
Ceiling (ft)	unlimited	Barometric pressure reading	
Visibility (miles)	unlimited	Density altitude (ft)	

Figure 5. Example of Flight Report.

9.2 Test Card Data

Test cards for all encounters define the step by step planning. The required start times, calls, and any associated remarks will be recorded in the test cards.

9.3 Flight Data

Flight data will be collected continuously throughout the experiment from takeoff to landing. All of the flight data will be time-synced. This will include the GPS coordinates and flight data of the intruder and of simulated UAS.

9.4 VO Data and Other Test Data

Other data will be collected continuously throughout the experiment including light levels and ambient noise levels. Again, all of the flight data will be time-synced via GPS or radio mark calls. A separate set of data collection information related to the VO's will be generated. This will include the required audio and video to capture the VO's detections.

10 Flight Day Communications Plan

Flight day communications can be broken down into two separate elements. First are the communications required for the safe aircraft operations that will provide for the proper testing environment. Second are the communications required for the test subject VO coordination and data collection.

The flight operations will be overseen and organized the NMSU UASTS Director in conjunction with MCs for each flight crew. Each flight crew will be assigned NMSU UASTS Pilot and Visual Observer. The PIC for each aircraft will have direct communication with each other to coordinate each encounter. Flight crews will have direct communications with the flight Airborne and Ground Visual Observers (mission VOs and not test subject VOs). The MC/PIC will also ensure that each flight crew adheres to the flight plan requirements and monitor conformance.

Each day will begin with a briefing to cover plans and safety information for the day's activities. This flight briefing will occur at the NMSU College Ranch. The Manned PIC will be called on the phone to participate.

Communications between pilots will be accomplished in several ways. Primary flight operation communications will be accomplished via dedicated aviation VHF air band radios using an internal frequency of 123.2. In addition, cell phones will be used as auxiliary mean of communication as required. VHF air band radio will be used to communicate to local air traffic as required.

With the Visual Observers and RPIC in close proximity to each other, the VO will communicate to the RPIC verbally to alert real hazards during flights.

The VO test subjects and coordination will be via the Visual Observer Test Coordinator and staff. They will provide specific testing directions and instructions in accordance with the human subject data collection plans. The test VOs will use the brick radios on a separate channel so that the data can be recorded.