


Blue Unmanned Aircraft Systems for First Responders in a Rural Environment

Assessment Report

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FOREWORD

The National Urban Security Technology Laboratory (NUSTL) is a federal laboratory within the U.S. Department of Homeland Security (DHS) Science and Technology Directorate. Located in New York City, NUSTL is the only national laboratory focused exclusively on supporting the capabilities of federal, state, local, tribal, and territorial responders to address the homeland security mission. The laboratory assists responders with the use of technology to prevent, protect against, mitigate, respond to, and recover from homeland security threats and incidents. NUSTL provides expertise on a wide range of subject areas, including chemical, biological, radiological, nuclear, and explosive detection, personal protective equipment, and tools for emergency response and recovery.

NUSTL manages the System Assessment and Validation for Emergency Responders (SAVER®) program, which provides information on commercially available equipment to assist response organizations in equipment selection and procurement. SAVER publications provide information on equipment that falls under the categories listed in the DHS Authorized Equipment List (AEL), focusing primarily on two main questions for the responder community: "What equipment is available?" and "How does it perform?" The SAVER program works with responders to conduct objective, practitioner-relevant, operationally oriented assessments and validations of commercially available emergency response equipment. Having the right tools provides a safer work environment for responders and a safer community for those they serve.

NUSTL is responsible for all SAVER activities, including selecting and prioritizing program topics, developing SAVER publications, and coordinating with other organizations to leverage appropriate subject matter expertise. In conjunction with DAGER Technology, NUSTL conducted an assessment of select Unmanned Aircraft Systems on the Department of Defense's Blue Cleared List. This equipment falls under the AEL reference number 03OE-07-SUAS, titled "System, Small Unmanned Aircraft."

SAVER reports are available at www.dhs.gov/science-and-technology/saver.

Visit the NUSTL website at www.dhs.gov/science-and-technology/national-urban-security-technology-laboratory, or contact the lab at NUSTL@hq.dhs.gov.

U.S. Department of Homeland Security

SAVER

System Assessment and Validation for Emergency Responders ®

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EXECUTIVE SUMMARY

Over the past decade, first responders have begun integrating small, unmanned aircraft systems (UAS) as a resource for a variety of operational needs. UAS provide first responders with an aerial view of their environment and can be outfitted with various sensors tailored to address different applications. UAS, often referred to as "drones," are used by first responders in support of public safety activities such as search and rescue, firefighting, and post-incident reconstruction.

From June 24 through 28, 2024, the Systems Assessment and Validation for Emergency Responders (SAVER) program conducted an operational assessment of Blue Unmanned Aircraft Systems. The assessment took place at Texas A&M's Engineering Extension Service (TEEX) in College Station, Texas.

Nine first responders from various jurisdictions with at least three years of piloting UAS served as evaluators for this assessment. Evaluators assessed four products – the Ascent AeroSystems Spirit, Parrot Drones ANAFI USA GOV, Skydio X2D, and Teal Drones Teal 2 – during four operational scenarios. Products were assessed against 13 evaluation criteria on a scale from 1 to 5, where 1 means the product met none of their expectations and 5 means it exceeded expectations.

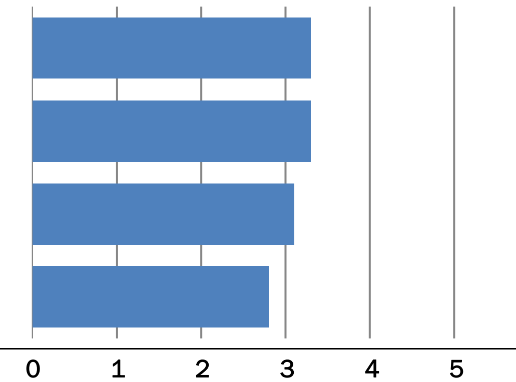
Evaluators concluded that three of the products met most of their expectations during day operations with the Parrot ANAFI USA GOV and Ascent AeroSystems Spirit both scoring the highest with a 3.3. Three products met most of the evaluators' expectations during night operations with the Teal 2 and Ascent AeroSystems Spirit both scoring the highest with a 3.2. The below tables present the overall scores as well as the category scores for each product, listed in order from highest to lowest overall score.

The purpose of this assessment report is to provide emergency responders with information that will guide their agencies in making operational and procurement decisions. Emergency responder agencies should consider overall capabilities, technical specifications, and limitations of Blue UAS in relation to their agency's operational needs when making equipment selections.

Agencies should also consider impacts associated with integrating equipment into their power and information technology infrastructure, data management, concept of operations, and required maintenance.

Overall Day Operation Scores Summary Table

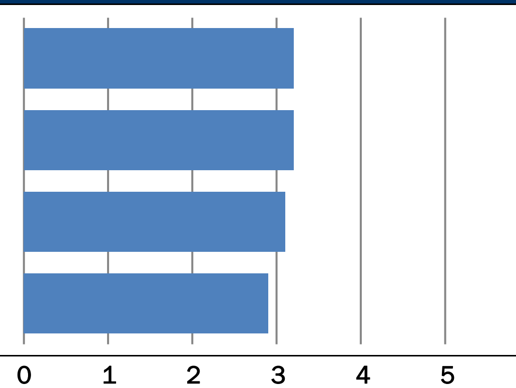
Manufacturer and Product	Overall Score	Overall	Capability	Usability	Deployability
Parrot Drones, ANAFI USA GOV		3.3	2.9	3.1	4.2
Ascent AeroSystems, Spirit		3.3	3.3	3.5	3.0
Skydio, X2D		3.1	3.1	2.8	3.3
Teal Drones, Teal 2		2.8	2.6	2.9	3.0



Key: 1 (least favorable) to 5 (most favorable)

Overall Night Operation Scores Summary Table

Manufacturer and Product	Overall Score	Overall	Capability	Usability	Deployability
Teal Drones, Teal 2		3.2	3.2	3.2	3.5
Ascent AeroSystems, Spirit		3.2	3.3	3.1	3.1
Skydio, X2D		3.1	3.0	3.1	3.4
Parrot Drones, ANAFI USA GOV		2.9	2.5	3.1	3.8



Key: 1 (least favorable) to 5 (most favorable)

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1.0 INTRODUCTION

Over the past decade, first responders have begun integrating small, unmanned aircraft systems (UAS) as a resource for a variety of operational needs. UAS provide first responders with an aerial view of their environment and can be outfitted with various sensors tailored to address different applications. UAS, often referred to as "drones," are used by first responders in support of public safety activities such as search and rescue, firefighting, and post-incident reconstruction. This equipment falls under the AEL reference number 03OE-07-SUAS titled "System, Small Unmanned Aircraft."

In June 2024, the System Assessment and Validation for Emergency Responders (SAVER) program assessed four Blue Unmanned Aircraft Systems (or Blue UAS)[1] at Texas A&M's Engineering Extension Service (TEEX) in College Station, Texas. The purpose of the assessment was to obtain information on Blue UAS that will be useful emergency responders in making operational and procurement decisions. The assessment activities and the 13 criteria against which the systems were evaluated were based on recommendations gathered from a focus group of emergency responders with operational experience flying UAS conducted in November 2023. The "Blue Unmanned Aircraft Systems for First Responders Focus Group Report" can be found on the SAVER website at www.dhs.gov/science-and-technology/saver/blue-uas-first-responders.

1.1 Participant Information

Nine emergency responders assessed the Blue UAS following procedures developed by NUSTL and DAGER. Evaluators were selected for the assessment based on their respective geographic location, responder discipline, and professional experience, as well as their UAS operational experience. Each participant's professional information is listed in Table 1-1.

Table 1-1 Evaluators' Professional Backgrounds

Evaluator Discipline	Years of Experience Piloting UAS	State
Law Enforcement	7	Colorado
Fire Service	10	Florida
Fire Service	3	New York
Law Enforcement	9	Michigan
Fire Service	10	Oklahoma
Law Enforcement	4	Oregon
Law Enforcement	9	Texas
Law Enforcement	14	Virginia
Law Enforcement	4	Virginia

[1] The Blue UAS Cleared List or "Blue List" is a list of United States and ally-manufactured UAS vetted by the Defense Innovation Unit (DIU) to be policy approved by the DoD. (Section 848 of the National Defense Authorization Act (NDAA) for Fiscal Year 2020 prohibits the use of UAS or any related services or equipment from certain foreign entities.) All UAS on the Blue List are NDAA-compliant and have undergone cybersecurity testing by DIU or their contractors. Each device on the Blue List is granted authority to operate (ATO) from the DIU.

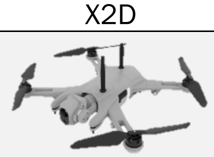
1.2 Assessed Products

Four Blue UAS were selected and procured for the assessment based on market research and recommendations from the focus group. Product selection criteria identified specifications, attributes, or characteristics a product should possess to be considered for the assessment. The assessment team established the following product requirements when determining the scope of products for the assessment:

- Included on the Blue List (at the time of purchasing for the assessment)
- Battery powered
- Single-person deployable
- Vertical take-off/landing
- Electro-optical and infrared (EO/IR) sensors
- Live video feed

Based on market research and the focus group's recommendations, four products from four manufacturers were included in the assessment. In addition to the overall selection criteria, UAS also had to be able to be procured and delivered in time for the assessment. The products selected for assessment and their key specifications are shown in Table 1-2.

Table 1-2 Assessed Products' Key Specifications

Product	Weight (lb)	Dimensions (in)	Max Flight Time* (min)	Payload	Cost†
 Ascent AeroSystems Spirit	7.8	12 x 4.2 x 25.5	53	NightHawk2-UZ EO/IR 1280x720	$56,196
 Parrot Drones ANAFI USA GOV	1.1	11.1 x 14.7 x 3.2	32	EO 4k, IR 320x256	$13,965
 Skydio X2D	3	26.1 x 22.4 x 8.3	35	EO 4k, IR 320x256	$21,889
 Teal Drones Teal 2	2.75	17 x 19 x 3	30	Hadron Payload EO 4k, IR 640x512	$15,074

Note: The specifications in this table represent the equipment as assessed.
* Reported by manufacturer
† GSA pricing for models/packages procured for this assessment rounded to the nearest whole dollar

2.0 EVALUATION CRITERIA

The SAVER focus groups used four of the SAVER assessment categories to help participants identify 18 evaluation criteria. The four SAVER assessment categories used are:

- **Capability** criteria relate to product features or functions needed to perform responder relevant tasks
- **Deployability** criteria relate to preparing to use the product, including transport, set up, training, and operational/deployment restrictions
- **Maintainability** criteria relate to the routine maintenance, storage, calibration, and minor repairs performed by responders, as well as included warranty terms, duration, and coverage
- **Usability** criteria relate to ergonomics and the relative ease of use when performing responder relevant tasks

The focus group participants assessed the importance of the evaluation criteria by assigning weights. These criteria were ranked on a scale of 1 to 5, with 1 denoting minor importance (meaning that meeting this criterion or having this feature might have a minimal impact on the evaluators' decision to buy the product), and 5 indicating the highest importance (signifying that the evaluators would not consider purchasing a product that doesn't meet their expectations for this criterion or lacks this feature).

Table 2-1 presents the evaluation criteria and their associated weights aligned under the applicable SAVER categories as determined by the focus group. Evaluation criteria are defined in Appendix A.

Five criteria identified by the focus group – automated mapping, automated flight modes, external spotlight, operability with gloves, and hot swappable GCS battery – are not included in Table 2-1 as they were not assessed. None of the products had an external spotlight as an approved payload on their authority to operate, nor did they offer their GCS with hot swappable batteries[2] therefore these criteria could not be assessed. Sufficient time was not available to conduct automated mapping. Evaluators preferred that automated flight modes available per platform be reported rather than rating them based on their experiences flying; they also indicated they would not operate a GCS with full finger gloves, therefore scores for these criteria were not factored into the overall scores.

This resulted in the drones being assessed operationally against 13 criteria.

[2] Evaluators expressed they wanted the ability to hot swap batteries.

Table 2-1 Evaluation Criteria

SAVER CATEGORIES			
Capability	**Deployability**	**Usability**	**Maintainability**
Evaluation Criteria			
Camera's Visual Acuity Weight: 5	Time to Redeploy Weight: 5	Ease of Use Weight: 4	In-House Maintenance Weight: 3
Flight Duration Weight: 5	Deployability Weight: 4	Ground Control Station (GCS) Interface Weight: 4	
Command and Control Link Quality Weight:5	Portability Weight: 4	GCS Legibility Weight: 4	
Latency Weight: 5		Customizable Safety Features Weight: 3	
		Covertness Weight: 2	

3.0 ASSESSMENT METHODOLOGY

Each product was operationally assessed by the evaluator pilots working in teams. Data collectors observed each team of evaluators as they completed the assessment activities. All flight activities were overseen by the DHS S&T Project Joint Unmanned Systems Testing in Collaborative Environments (JUSTICE) and Mississippi State University (MSU). These activities were documented via photo and video support from U.S Army Combat Capabilities Development Command (DEVCOM).

3.1 Scenarios

3.1.1 Familiarization

Evaluators familiarized themselves with the basic use of the products. This session began in a classroom at the TEEX Brayton Fire Training Field, where SMEs from MSU provided training. The evaluators removed the UAS from their storage cases, powered up the UAV and the GCS, and navigated through menu options to become familiar with the controller. Additionally, they had access to reference materials.

Figure 3-1 MSU trainer leading a familiarization session on the Ascent AeroSystems Spirit

The session continued at an outdoor location where the evaluators received hands-on training. Evaluators flew the UAS through a predetermined course to become familiar with the platform.

Evaluation criteria assessed during this scenario (listed in descending order of criteria weight) included the following:

- Camera's Visual Acuity
- Command and Control Link Quality
- Latency
- Ease of Use
- GCS Interface
- GCS Legibility

3.1.2 Post Incident Damage Assessment

Figure 3-2 Evaluator using the Teal 2 to locate a victim in a rubble pile

This scenario simulated a daytime disaster relief operation. Evaluators transported the UAS to a launch site using vendor-supplied storage cases, set up and deployed the UAS. Evaluators launched the UAS and flew over rubble piles and stabilized collapsed buildings where simulated smoke, “victims” (manikins), vehicles, and debris were present. They used the video feed from the UAS to inspect the infrastructure for damage and attempt to locate victims. Once the victims were found, evaluators shared location information, accessible ground routes to the victims, and any potential hazards to on-the-ground personnel. Evaluators also flew to a location approximately 500 feet from the rubble piles and launch point and observed drums marked with hazmat labels, which they attempted to read with the camera. After completing these tasks, evaluators landed the UAS at a predetermined safe location.

Evaluation criteria assessed during this scenario (listed in descending order of criteria weight) included the following:

- Camera's Visual Acuity
- Flight Duration
- Command and Control Link Quality
- Latency
- Ease of Use
- GCS Interface
- GCS Legibility
- Customizable Safety Features

3.1.3 Situational Awareness

Evaluators performed a daytime operation to gather and provide intelligence and situational awareness to public safety personnel. Using vendor-supplied storage cases, evaluators transported the UAS to a launch site in an open parking lot, set up, and deployed the UAS. They launched the UAS and flew them over an outdoor area with multiple vehicles and buildings of varying heights, in both shaded and unshaded areas. Evaluators used the live video feed from the UAS to assess a simulated hostage/entrapment situation (using manikins) and identify items (mock firearms and license plates) from various distances and locations in different lighting conditions (i.e., shaded/unshaded). After completing these tasks, evaluators landed the UAS at a predetermined safe location to perform a swap of the aircrafts' batteries. Then they redeployed the UAS and continued to gather information using the live video feed.

Figure 3-3 Skydio X2D being used to collect information during the situational awareness scenario

Evaluation criteria assessed during this scenario (listed in descending order of criteria weight) included the following:

- Camera's Visual Acuity
- Flight Duration
- Command and Control Link Quality
- Latency
- Time to Redeploy
- Deployability
- Portability
- Ease of Use
- GCS Interface
- GCS Legibility

3.1.4 Night Operations

This scenario began at dusk (low-light conditions) and continued into the night (no light conditions) at outdoor locations at RELLIS. These locations included austere areas with various natural terrain features such as bodies of water (a pond and river), sand pits and wooded areas as well as man-made structures. Evaluators transported the UAS to a launch site using vendor-supplied storage cases, set up, and deployed the UAS. They then launched the UAS and attempted to locate individuals (manikins wearing heated vests) in rugged terrain that featured a variety of natural terrains and man-made structures. Once the individuals have been located with the UAS, the evaluators shared location details and information for situational awareness. Evaluators also assessed visual acuity by searching for and reading mock license plates in low light and night conditions. After completing these tasks, evaluators landed the UAS at a predetermined safe location with red landing lights designating each touchdown zone.

Figure 3-4 Evaluator preparing the ANAFI USA GOV for launch during night operations

Evaluation criteria assessed during this scenario (listed in descending order of criteria weight) included the following:

- Camera's Visual Acuity
- Flight Duration
- Command and Control Link Quality
- Latency
- Deployability
- Portability
- Ease of Use
- GCS Interface
- GCS Legibility
- Customizable Safety Features
- Covertness

3.1.5 Other Considerations

After each UAS completed its last scenario, evaluators reviewed and conducted manufacturer prescribed routine maintenance, such as examining the airframe, swapping batteries, and changing propellers. The evaluation criterion assessed during this activity was "In-House Maintenance," which was scored individually under SAVER's Maintainability category. Results for this can be found within each product section. Additionally, outdoor temperatures during day operations were exceeding 90 degrees during flights.

3.1.5.1 Automated Flight Modes

Each manufacturer may use different names for flight modes when referring to a capability of their small UAS (sUAS) in flight. To simplify the discussion of capabilities across platforms, this report uses following terminology, tailored towards sUAS that vertically take off and land, to encompass the underlying functions of each flight mode in a standardized manner across each platform.

- Position hold: In position hold, the UAS maintains its location in all three dimensions, latitude, longitude, and altitude. UAS may utilize any available sensor, including those used for obstacle avoidance. Typical UAS achieve position hold primarily with the inertial measurement unit (IMU), barometer, and GNSS but may combine obstacle avoidance sensors to assist with more precise relative positioning.
- Attitude hold: In attitude hold, the UAS controls its pitch, roll, and yaw using an IMU but does not fuse this information with absolute positioning sources such as GNSS to correct for drift in position and altitude.
- Altitude hold: In altitude hold, the UAS utilizes sensors such as GNSS and barometers to hold altitude but not position.
- Manual: In manual modes the remote pilot directs inputs to the desired orientation of the UAS and the system reacts by holding the last known orientation without providing corrective inputs to the attitude, position, or altitude.
- Return to home (RTH): The UAS utilizes GNSS information or dead reckoning[3] to return to user designated home point or the original launch point.

[3] Dead reckoning (or "DR") is navigation solely by means of computations based on time, airspeed, distance, and direction. The products derived from these variables, when adjusted by wind speed and velocity, are heading and GS. The predicted heading takes the aircraft along the intended path and the GS establishes the time to arrive at each checkpoint and the destination. More information on dead reckoning can be found in Chapter 16, "Navigation," *Federal Aviation Administration Pilot's Handbook of Aeronautic Knowledge*, 2023. p.16-13.

- Three-dimensional (3D) obstacle avoidance: In 3D obstacle avoidance modes, the UAS is capable of navigating in 3D space via onboard sensors that sense the surrounding environment absent the use of positioning from GNSS. UAS may still use GNSS for corrections when available.
- Other obstacle avoidance: The UAS utilizes sensors such as radar altimeters for automatic takeoff and landing or obstacle avoidance using forward/rearward looking sensors in one or two axes.

Table 3-1 Automated Flight Modes by Platform

Navigation Mode *(Manufacturer Terminology)*	Teal 2	Anafi USA GOV	Spirit	Skydio X2D
Position Hold	✓ (*Position*)	✓ (*Auto*)	✓	✓ (*GPS*)
Attitude Hold	✓ (*Altitude*)	✓ (*Auto*)	✓ (*Altitude Hold/Loiter*)	✓ (*GPS/Alt*)
Altitude Hold	✓ (*Altitude*)	✓ (*Auto*)	✓ (*Altitude Hold/Loiter*)	✓ (*GPS/Alt*)
Manual	✓ (*Manual*)	--	✓ (*Manual/AltHold*)	—
Return to Home	✓ (*Return to Home*)	✓ (*Return to Home*)	✓ (*Return to Land*)	✓ (*Return to Home*)
3D Obstacle Avoidance	—	—	—	✓
Other Obstacle Avoidance	✓*	✓*	—	✓**

-- Indicates that the system does not have that automated flight mode
* Takeoff and landing
** Skydio offers obstacle avoidance with multiple distance options for day operations and an obstacle avoidance mode specifically for night operation.

3.1.5.2 Automated Mapping

Similar to automated flight modes, manufacturers may name their mapping modes with their own unique naming conventions. This report uses the following categories to standardize automated mapping capabilities across the platforms.

- Area based mapping: The UAS collects data in a NADIR (90 degrees below the aircraft) orientation and typically follows a "lawn mower" pattern with set forward and side laps sufficient for the data to be stitched together in post processing.
- Circular/orbit mapping: The UAS collects data on an object in the center of its orbit by collecting with the sensor pointed inwards on the object.
- Corridor mapping: The UAS collects data in a straight line flying from waypoint to waypoint in a linear manner.
- Free mapping: The UAS collects data in any manner the user chooses via manually adjusting the UAS speed, capture speed, altitude, forward/side lap and more.

- Other: Custom features designated as mapping features that do not fit into the above categories.

Table 3-2 Automated Mapping Modes by Platform

Mapping Mode	Teal 2	Anafi USA GOV	Spirit	Skydio X2D
Area Mapping	✓	✓	✓	✓
Circular/Orbit Mapping	✓	✓	✓	–
Corridor Mapping	✓	✓	✓	–
Free Mapping	✓	✓	✓	–
– indicates that the system does not have that automated mapping mode				

3.2 Data Gathering and Analysis

After each operational scenario, data collectors used a questionnaire to record the evaluators' scores for each product according to the evaluation criteria listed in Section 2.0. The questionnaire included specific questions for each criterion that the data collectors read to the evaluators. Evaluators then scored the criteria using the following 1 to 5 scale:

1: The product **meets none** of my expectations for this criterion.

2: The product **meets some** of my expectations for this criterion.

3: The product **meets most** of my expectations for this criterion.

4: The product **meets all** my expectations for this criterion.

5: The product **exceeds** my expectations for this criterion.

Once assessment activities were completed, evaluators were provided an opportunity to review their criteria ratings and comments for all products and to make adjustments, if desired. Then the average overall assessment scores were calculated for each product using the formulas in Appendix B.

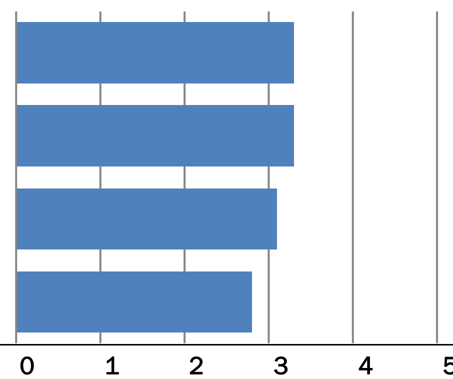
Data collectors also captured comments on advantages and disadvantages as well as general comments regarding the assessed products and on the assessment process. The evaluators' comments are summarized in this assessment report.

4.0 ASSESSMENT RESULTS

Overall day operation scores for Blue UAS ranged from 2.8 to 3.3. Overall night operation scores ranged from 3.2 to 2.9. Assessment results are presented in Tables 4-1 through Table 4-3, while additional details and evaluator comments on each product are provided in Sections 4.1 through 4.4.

Table 4-1 and Table 4-2 present the overall scores based on operating environment, as well as the SAVER category scores for each product. The products are listed by overall score from high to low. Calculation of the overall score uses the average score for each criterion, prior to rounding. When products have the same overall score, they are listed in order by the highest capability score. Criteria definitions are provided in Appendix A.

Table 4-1 Overall Day Operation Results

Manufacturer and Product	Overall Score	Overall	Capability	Usability	Deployability
Parrot Drones, ANAFI USA GOV		3.3	2.9	3.1	4.2
Ascent AeroSystems, Spirit		3.3	3.3	3.5	3.0
Skydio, X2D		3.1	3.1	2.8	3.3
Teal Drones, Teal 2		2.8	2.6	2.9	3.0

Key: 1 (least favorable) to 5 (most favorable)

Table 4-2 Overall Night Operation Results

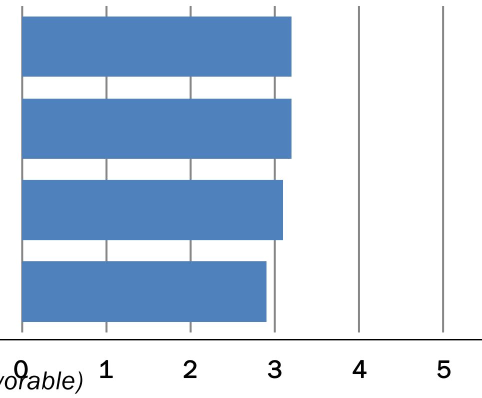
Manufacturer and Product	Overall Score	Overall	Capability	Usability	Deployability
Teal Drones, Teal 2		3.2	3.2	3.2	3.5
Ascent AeroSystems, Spirit		3.2	3.3	3.1	3.1
Skydio, X2D		3.1	3.0	3.1	3.4
Parrot Drones, ANAFI USA GOV		2.9	2.5	3.1	3.8
Key: 1 (least favorable) to 5 (most favorable)					

Table 4-3 presents the average evaluation criteria scores the products received from the evaluators for each evaluation criterion. The darker the shade of blue denotes the higher the rating.

Table 4-3 SAVER Scorecard: Evaluation Criteria Ratings

SAVER Assessment Criteria		Manufacturers/Products							
		Spirit Night	Spirit Day	Anafi Night	Anafi Day	Skydio Night	Skydio Day	Teal 2 Night	Teal 2 Day
Capability	Camera's Visual Acuity	3.7	3.4	2.1	3.3	2.1	2.8	2.9	2.3
Capability	Flight Duration	2.7	2.6	3.4	3.4	3.6	3.7	3.4	2.2
Capability	Command and Control Link Quality	3.2	3.4	2.6	2.8	2.9	2.6	2.8	2.3
Capability	Latency	3.8	3.6	1.9	2	3.4	3.2	3.6	3.3
Deployability	Time to Redeploy	N/A	3.1	N/A	4.3	N/A	2.9	N/A	3.4
Deployability	Deployability	2.8	2.9	3.2	3.7	2.6	2.9	2.9	1.6
Deployability	Portability	3.3	3.1	4.3	4.4	4.3	4.3	4.1	3.9
Usability	Ease of Use	2.4	3.2	2.7	3.8	2.3	3	3	2.7
Usability	GCS Interface	3.4	3.6	2.9	3.4	2.6	2.4	2.8	2.6
Usability	GCS Legibility	4	3.7	3.7	1.8	4.1	2.7	3.8	3.2
Usability	Customizable Safety Features	2.6	3.4	3.6	3.3	2.8	3.1	3.6	3
Usability	Covertness	2.6	N/A	2.2	N/A	4.3	N/A	2.4	N/A
Maintain-ability	In-House Maintenance	2.4		2.8		2.7		3.7	

Note: blank (white) cells represent criteria that were not assessed during respective operations (day/night).

SAVER Scorecard Key:	This product _____________ of my expectations for this criterion				
	meets none	meets some	meets most	meets all	exceeds all

4.1 Ascent AeroSystems, Spirit

The Ascent AeroSystems Spirit (Figure 4-1) is a coaxial unmanned aircraft with multiple configuration options. The Spirit can be flown with one or two 12S 44.4V lithium ion (Li-ion) batteries; for the assessment it was mostly flown with one battery. The airframe is sealed to protect against dust and moisture, with an ingress protection rating of IP56, and has an operating temperature range of −40°F to +130°F. The Spirit uses the Navigator Tab3 GCS and can perform autonomous flights. The Spirit was tested with a NextVision Nighthawk2-UZ EO/IR camera that features 40x EO zoom (20x optical, 2x digital) and 4x digital IR zoom. Both cameras have a resolution of 1280 x 720 pixels. Other camera options are also available, including the NextVision Raptor, NextVision DragonEye2, and Gremsy ZIO. The Spirit's dimensions are 12.0 x 4.2 in.; with the blades fully extended the tip-to-tip diameter is 25.5 in. The Spirit weighs about 7.8 lb. with one battery and the Nighthawk2-UZ camera payload. The product includes a storage case that holds the Spirit UAV, Navigator Tab3 GCS, three batteries, a charger, and one set of four propellers. As configured for this test with the Nighthawk2-UZ, the Spirit cost $56,196

Figure 4-1 Ascent AeroSystems Spirit

The Ascent AeroSystems Spirit received an overall assessment score of 3.3 for daytime operations and 3.2 for night operations. Evaluator comments provided throughout the assessment are reported below, grouped by SAVER category. In each category, the criteria are listed according to their order of importance as assigned by the Blue UAS focus group.

4.1.1 Capability

The Ascent AeroSystems Spirit received a capability score of 3.3 for both day and night operations. Evaluator feedback on evaluation criteria related to this SAVER category included:

- **Camera's Visual Acuity:** Four evaluators indicated that the Spirit met all of their expectations for the camera's visual acuity during daytime operations, while five evaluators said it met most of their expectations. Six evaluators praised the 40x zoom capability, noting the image clarity and highlighting that there was no loss of resolution at higher magnifications (Figure 4-2). Three evaluators appreciated the camera's ability to track a target or perform a search for people or vehicles. Five evaluators found the auto exposure feature of the camera occasionally washed out the images. Additionally, they would have preferred a manual adjustment.

Figure 4-2 Evaluator reading a license plate on the Spirit GCS

The Spirit received the highest score across all platforms for camera visual acuity during night operations. All evaluators indicated it met all or most of their expectations, which was attributed to the thermal camera's image detail and zoom clarity. One evaluator however disliked the inability to change the camera exposure as it made it hard to see details in the image, while another evaluator noted the low amount of IR palate choices.

- **Flight Duration:** The manufacturer specifications claim the Spirit's flight duration with a full (6.5 lb) payload is approximately 16 minutes with one battery and 32 minutes with two batteries. Actual flight times ranged between 15–25 minutes as configured with one battery for the assessment flights, across day and night operations. One flight was conducted with the two battery configuration, resulting in a flight time just under 32 minutes. For daytime operations, all evaluators indicated that this met most or some of their expectations. For night operations, five evaluators indicated that it met some of their expectations, two indicated that it met most, and two felt that it met all of their expectations. Evaluators appreciated the ability to extend the flight time by affixing an additional battery, but noted battery configuration would be dependent on the operation at hand. Using the additional battery to extend flight time results is a tradeoff of having less overall battery time than single batteries. Three evaluators stated that given the larger size of the batteries, they expected longer flight times.
- **Command and control link quality:** All the evaluators indicted the command and control link quality met all or most of their expectations during both daytime and nighttime operations. Evaluators did not observe any issues connecting the GCS to the drone at startup. Three evaluators stated that they lost connection to the Spirit during daytime operations; no lost connections were observed during night operations, however.
- **Latency:** The highest scored criterion for Spirit – during both daytime and night operations – is for latency, as all evaluators indicated that the UAS met all or most of their expectations for this criterion. Two evaluators indicated that the camera responded very quickly to inputs. One evaluator experienced reaction delays for both flight command and camera inputs, while another stated that the gimbal adjustment was jumpy and lacked refinement.
- **Automated Flight Modes:** The Spirit offers position hold, altitude hold/loiter, manual/alt hold, and return-to-home (RTH) modes. Three evaluators indicated that the RTH feature worked well. Three evaluators also programmed an autonomous flight path and stated that the drone performed it well. Five evaluators were impressed by the Spirit's ability to track objects and to perform automated searches for people or vehicles.

4.1.2 Usability

The Ascent AeroSystems Spirit received a usability score of 3.5 for daytime operations and 3.1 for night operations. Evaluator feedback on evaluation criteria related to this SAVER category included:

Figure 4-3 Spirit UAS in flight during daytime operations

- **Ease of Use:** For daytime operations, three evaluators indicated that the Spirit met all of their expectations regarding the ease of using the system, while five stated it met most expectations and one said it met some. Three of the evaluators stated the GUI was easy and intuitive to use. Two evaluators noted the location of controls makes it very difficult to maneuver the camera while the drone is moving. One evaluator stated it was difficult to determine the orientation of the Spirit while it's flying due to its coaxial and vertical configuration (see Figure 4-3).

  Regarding night operations, four evaluators indicated that the Spirit met most of their expectations, while five stated it met some. Three evaluators reported it was difficult to determine the Spirit's orientation while flying at night. Additionally, two evaluators stated it was difficult to fly and land the Spirit at night, partly due to challenges in determining the drone's orientation due to its configuration.

- **GCS Interface:** All evaluators found the GCS interface met all or most of their expectations during both daytime and nighttime operations. Overall, they liked the feel of the controller and the location of buttons, but three evaluators noted that the camera controls are right below the altitude control joystick (Figure 4-4); this made it very difficult to maneuver the camera while the drone is in motion. One evaluator noted that there is no indication of the zoom magnification or gimbal angle on the screen. Additionally, two evaluators reported that the emergency shut-off switch is located close to the record button and looks similar, which could cause issues when flying at night.

Figure 4-4 Spirit GCS with altitude and camera controls circled

- **GCS Legibility:** The Spirit scored the highest across all platforms for GCS legibility in daylight, as all evaluators indicated that the drone met all or most of their expectations for this criterion. Two evaluators reported that the GCS screen was legible even in direct sunlight, and the auto brightness adjustment feature worked well. For night operations, all evaluators stated that the Spirit met all their expectations for GCS legibility. Six evaluators cited good screen brightness. One evaluator suggested that it would be an improvement if the hard buttons on the controller were backlit.

- **Customizable Safety Features:** For daytime operations, five evaluators indicated that the Spirit met all of their expectations for customizable safety features, while three evaluators stated that it met most, and one evaluator reported that it met some. Notable safety features include the ability to set a geofence radius and an altitude limit, and the ability to override RTH mode. Two evaluators indicated that the safety features were easy to set, easy to review and functioned well. Four evaluators noted the Spirit lacks an obstacle avoidance feature and suggested including one could improve usability for first responder operations.

  Feedback varied regarding Spirit's safety features during night operations. One evaluator stated that it met all of their expectations, four reported it met most, three indicated it met some, and one stated it met none. One evaluator noted the lack of anti-collision lights. Another noted the drone lacks an auto-land feature, which could result in a hard touchdown and possible damage

- **Covertness:** During night operations, five evaluators reported the Spirit met most of their expectations for covertness, while four evaluators stated it met some. Six evaluators felt the drone was loud compared to the other drones assessed, and two evaluators said the large size and cylindrical shape made the Spirit stand out in the sky. One evaluator reported that the lighting was fairly dim, but four evaluators noted that the strobe lights could not be turned off (Figure 4-5), which is a disadvantage for covertness.

Figure 4-5 Spirit UAS in flight in low light conditions

4.1.3 Deployability

The Ascent AeroSystems Spirit received a deployability score of 3.0 for daytime operations and 3.1 for night operations. Evaluator feedback on evaluation criteria related to this SAVER category included:

- **Time to Redeploy:** This criterion was only evaluated during daytime operations. Three evaluators indicated that the Spirit met all of their expectations for time to redeploy, while four reported that it met most and two said it met some. Three evaluators indicated that changing the battery after landing was fairly quick and simple, averaging just over four minutes to accomplish. Four evaluators noted that the startup checklist had to be repeated after a battery change, which increased the time the UAS was on the ground. Two evaluators said that too many parts had to be reassembled after a battery change and there were too many steps involved in redeploying the drone (i.e., disassembly, reassembly with charged battery, reconnect GCS to drone, complete checklist, launch).

- **Deployability:** For daytime operations, two evaluators reported that the Spirit met all of their expectations for deployability, while four indicated that it met most and three felt that it met some. Five evaluators reported that the drone required a lot of assembly and software setup prior to launch which was time consuming, however two evaluators noted that the assembly process was easy to perform (see Figure 4-6).

  Regarding night operations, seven evaluators indicated that the Spirit met most of their expectations, while two evaluators stated that it met some. Most evaluators stated that the drone was difficult to assemble at night because of the number of parts involved. Three evaluators felt that there are too many steps involved in assembling the drone and setting up the UAS, which was challenging in low and no light environments. Two evaluators indicated that two people were needed to complete the assembly process efficiently.

Figure 4-6 Evaluator assembling the Spirit during daytime operations

- **Portability:** The majority of evaluators found the portability of the Spirit met all or most of their expectations across daytime and nighttime operations, while one evaluator said it met some. All of the evaluators stated that the storage case (Figure 4-7) is larger and heavier than most UAS cases, which will result in it taking up more space to store. However, two of the evaluators still felt that the case was easily portable despite the larger size. One evaluator indicated that the case is well made.

Figure 4-7 Spirit Storage Case

4.1.4 Maintainability

The Ascent AeroSystems Spirit received a maintainability score of 2.4. Evaluator feedback on the evaluation criterion related to this SAVER category included:

- **In-House Maintenance:** Five evaluators reported that the Spirit met most of their expectations, while three indicated that it met some, and one reported that it met none. Four evaluators noted that insufficient directional marking on the blades that could result in their being mounted backwards. Two evaluators expressed concern about the propellers' sensitivity to imbalance and the overall complexity of maintenance. Two evaluators stated that a set of propellers is too expensive ($299 for a set of four).

4.2 Parrot Drones, Parrot ANAFI USA GOV

The Parrot ANAFI USA GOV is a quadrotor UAS with an integrated EO/IR payload containing two EO cameras (one 21 MP telephoto and the other 21 MP wide angle), and a 320- x 256-pixel IR camera. The telephoto lens provides 5x zoom from the wide angle, with all other zoom being digital. The FLIR Boson LWIR micro-bolometer sensor is rated at 20 Hz with a thermal sensitivity of 0.05ºC. Other notable features include the ability to blend the EO and IR feeds, and the ability to stream from the controller to a computer with RTP-compatible video players. The airframe has an ingress protection rating of 53 and has an operating temperature range of −33°F to +122°F. The ANAFI weighs approximately 500 grams with a flight time of up to 32 minutes. The product comes with a carrying case, the ANAFI USA GOV aircraft, Parrot Skycontroller 3 GCS, three batteries with a charger, and various spare parts including propellers and USB-C cables. For the product inclusive all the equipment described above, NUSTL paid $13,965.

Figure 4-8 Parrot ANAFI USA GOV

Image Credit: Parrot Drones

The Parrot ANAFI USA GOV received an overall assessment score of 3.3 for daytime operations and a 2.9 for night operations. Evaluator comments provided throughout the assessment are reported below, grouped by SAVER category.

4.2.1 Capability

The Parrot ANAFI USA GOV received a capability score of 2.9 for day operations and 2.5 for night operations. Evaluator feedback on evaluation criteria related to this SAVER category included:

- **Camera's Visual Acuity:** For daytime operations, the ANAFI UAS GOV received a score of 3.3, which aligns with the overall sentiment that the EO camera met all or most of the evaluators' expectations. One evaluator appreciated the overlap with thermal images, and others found the EO camera's capabilities solid. The digital zoom function (32x) was helpful until it impacted the imagery, making them(blurry and/or pixelated. Additionally, evaluators noted that the camera did not handle scenes with high and low contrast objects well and when it did transition from light to dark environments (e.g., darkened areas to tree lines), it was slow. The IR camera was found mostly unusable during daytime operations due to limited thermal sensitivity.

Figure 4-9 Evaluators locating a casualty during daytime operations on the ANAFI USA GOV GCS (Skycontroller 3)

Evaluators had mixed feedback on the camera's visual acuity during night operations, ranging from its meeting most expectations to meeting none. Approximately half of the evaluators stated the RGB was usable in low light conditions with some adjustments in the camera settings. Still, they noted it provided noisy image, especially at higher altitudes, making it unlikely to meet their needs. The remaining evaluators found the RGB camera unusable at night. All evaluators found the IR camera lacked sufficient resolution for use at night, and the zoom unhelpful since it was purely digital. Two evaluators adjusted the isotherm settings, which assisted them in identifying thermal objects by enhancing their thermal contrast with color palettes. They considered this adjustability positive feature, but also noted that adjusting the isotherms took time to navigate through the menus.

Figure 4-10 Evaluators locating a mock casualty during night operations with the ANAFI USA GOV

- **Flight duration:** The ANAFI UAS GOV manufacturer specifications list its flight duration at approximately 32 minutes. All evaluators indicated this met all or most of their expectations. Some of the evaluators who stated it met most of their expectations attributed this to the actual flight duration during both day and night operations being approximately 25 minutes. For the first responder mission set, the evaluators stated flight times closer to 45 minutes would be ideal.
- **Command and control link quality:** The majority of evaluators found the ANAFI UAS GOV met most or some of their expectations. They cited issues with the command and control link quality during both day and night operations in the form of latency issues, slow reacting settings, limited range, and unreliability of the UAS to connect to the GCS on a cold start.[4]
- **Latency:** During both day and night operations all evaluators noted latency issues between the UAS and GCS that impacted camera controls, zoom abilities and overall flight operations; therefore, evaluators were split on whether it met some or none of their expectations. One evaluator noted the latency issues worsened with additional UAS in the area or when the GCS was near a handheld radio. Evaluators also expressed concern that the lag could cause interference with law enforcement operations (e.g., loss of a subject in a pursuit) which made it unacceptable.
- **Automated Flight Modes:** The ANAFI USA GOV offers position hold, attitude hold, and altitude hold – all of which are referred to as "auto" s – as well as return to home. Evaluators tested the RTH behavior of the UAS during flight and found that in one instance the aircraft hovered instead. When the UAS did RTH, one evaluator found that control stick inputs cancel the return and suggested it would be better to have a warning pop up to prevent accidental cancellation. One evaluator tested the automatic takeoff and landing function and stated that it worked well. During night operations some evaluators found the ANAFI USA GOV drifted in high winds, and, in a typical position hold, the UAS drifted between 3–5 feet vertically.

[4] One of the Anafi USA GOV UAS had hardware fault that caused the GCS to lose binding with the aircraft, requiring the RF modem to be reset via the built in button on the back of the GCS. It was returned for repairs after the assessment.

4.2.2 Usability

The Parrot ANAFI USA GOV received a usability score of 3.1 for day operations and 3.1 for night operations. Evaluator feedback on evaluation criteria related to this SAVER category included:

Figure 4-11 Aerial view of the ANAFI USA GOV, with the battery (circled in yellow) attached

- **Ease of Use:** For daytime operations, seven evaluators responded that the ANAFI USA GOV met all of their expectations relative to the ease of use of the system, while two stated it met most of their expectations. Evaluators found the set up and operation quick and simple even with no prior experience with the product: propeller arms were easy to position and lock for takeoff, batteries were located in a convenient location for access (Figure 4-11), content on the display (including a "center point") was ideal, and settings could be easily changed on the controller. One evaluator noted that they also appreciated that the system does not require maintenance or pairing before launch with the ANAFI USA GOV. Evaluators identified some features that were not easy to use, however: they cited the Wi-Fi dependent process for incorporating maps along with the process of setting up mapping features. Feedback varied on the size of the GCS, as some evaluators found it sufficient and appreciated the ability to operate it with one hand, if necessary, while others stated it was slightly larger than they would prefer. One evaluator noted that the GCS joysticks should be configurable. Another evaluator noted it would be helpful to make the lens cover color red so that it would be easier to recognize when it's on and be harder to lose.
  Nighttime operations scores varied with three evaluators saying the ANAFI USA GOV either exceeded, met all or most of their expectations. Meanwhile six said it met some, which they attributed to the drone itself being easy to use but the GCS not being sufficient for night operations. Evaluators noted that the GCS was more difficult and much slower to operate in darkness since the controls and buttons are challenging to find and see without external light or the buttons being backlit. The drone also lacks its own navigation lighting, so it would require a separate lighting payload for night flights and to comply with some FAA regulations; these attributes were deemed as negatives.
- **GCS Interface:** Overall, evaluators found the ANAFI USA GOV's GCS controls conveniently located and intuitive to use after a brief period of initial use. They noted the switches and toggles were convenient to use during both day and night operations. For the daytime operations, four evaluators responded that the ANAFI USA GOV met all their expectations of the GCS interface of the system, while five stated it met most. Some evaluators experienced difficulty locating menus and adjusting settings, for example locating the menu for changing flight modes. They also noted that improvements such as decreasing the sensitivity of the slide bar for the altitude limit feature and adding a mechanism to precisely set the altitude could enhance usability. Additionally, the adaptive brightness sensor built into the tablet is covered by the controller hardware and therefore does not function. Adjusting screen brightness requires users to exit the ANAFI software to access the tablet's settings, which evaluators considered a disadvantage.

During nighttime operations, eight evaluators stated the ANAFI USA GOV met most of their expectations, and one stated it met some. One evaluator appreciated the thermal palette buttons on the GCS that allows operators to use a single button to change the thermal palette, a common task, without navigating menus via the touch screen. One evaluator encountered an issue with the size of the thermal image on the GCS – a small image overlaid on the RGB image (shown in Figure 4-12) – and they couldn't determine how to increase the relative size. Another evaluator appreciated the exposure hot button on the GCS although it is not user programmable.

Figure 4-12 Infrared image overlaid on the RGB image

- **GCS Legibility:** During daytime operations, one evaluator indicated that the ANAFI's GCS legibility met most of their expectations, while five stated it met some of their expectations and three said it met none of their expectations. During daytime operations scoring, most evaluators stated that they could not use the controller while wearing sunglasses, that viewing the screen in direct sunlight was nearly impossible (since it makes the screen appear faded), and that it is very difficult to see the display over someone's shoulder (Figure 4-13). Evaluators noted in order to see the screen without glare and shadows they needed to position the GCS in a specific manner. One evaluator could not see when the battery status indicator turned yellow, even when they used the GCS in the shade. Evaluators found that adjusting the screen brightness did not resolve all issues encountered with the display in sunlight.

Figure 4-13 View of the ANAFI GCS during daylight operations

During nighttime operations the legibility was much clearer. GCS legibility of the ANAFI USA GOV during nighttime operations, exceeded the expectations of three evaluators and met most of the expectations of six. They did, however, encounter some issues with viewing the display at night. One evaluator observed that the display would switch back and forth between color and thermal imagery without any input from the operators on the GCS. They also mentioned that when they changed the display themselves, they encountered latency. Another evaluator stated that they would have like to have a EO inset when viewing the IR camera.

- **Customizable Safety Features:** Overall, evaluators scored customizable safety features similarly for daytime and nighttime operations. All evaluators found the ANAFI USA GOV met all or most of their expectations. Evaluators appreciated having the capability to manually land the drone, and the option to set an altitude threshold. One evaluator appreciated it having a way for operators to override return to home mode but would have preferred that canceling RTH require a long press since it could be accidentally hit. Another evaluator encountered an issue with the drone returning to the launch zone without any warning; they did not know if or how they could cancel the automated return. A different evaluator reported his experience that touching the controls while the drone was flying in any of the automated modes disabled the automated features. Additionally, the ANAFI USA GOV doesn't have obstacle avoidance nor anti-collision beacons or navigation lights, which are features that would benefit first responder operations.
- **Covertness:** Four evaluators responded that the ANAFI USA GOV's covertness during nighttime operations met most of their expectations, while three stated it met some of their expectations, and two said it met none. All evaluators considered the sound from the drone too loud for covert use. One evaluator noted that at 350 feet in the air the sound was still very evident. Another evaluator mentioned that if they increased altitude, it would mitigate the sound but would also result in degradation of imagery due to the particular capabilities of the cameras and digital zoom. No lights are included with the ANAFI USA GOV, which is a benefit for covertness, however, evaluators felt having lights for night flights that could be controlled from the GCS would be ideal.

4.2.3 Deployability

The Parrot ANAFI USA GOV received a deployability score of 4.2 for day operations and 3.8 for night operations. Evaluator feedback on evaluation criteria related to this SAVER category included:

- **Time to Redeploy:** All evaluators agreed that the time to redeploy the ANAFI UAS GOV exceeded or met their expectations.
- **Deployability:** The majority of evaluators found the ANAFI UAS GOV exceeded, met all or met most of their expectations across day and night operations as it was easy to remove from the case and intuitive to configure for flight. However, during daytime operations, two evaluators experienced the GCS and aircraft failing to pair out of the case, which resulted in them stating this met some or none of their expectations based on the unreliability of connecting. One evaluator found the GCS tablet's cold boot time of up to three minutes too long for first responder operational needs. Two evaluators expressed concern over the fragility of the battery connectors, which were exhibiting stress fractures after limited use during the assessment. Three evaluators noted the requirement to attach the control sticks, which were sometimes loose, to the GCS could be problematic during night operations and the sticks could be lost more easily in low to no light conditions.

Figure 4-14 An evaluator removing the ANAFI USA GOV from the case to prepare for launch

- **Portability:** All evaluators found the ANAFI USA GOV exceeded or met their expectations for being easy to transport, based on the small size and low weight of the case. The case is 17 x 13 x 7 in. and weights 11.9 lb. with the UAS in it. One evaluator appreciated that the case could hold three batteries, which would sustain continuous operations.

4.2.4 Maintainability

The Parrot ANAFI USA GOV received a maintainability score of 2.8. Evaluator feedback on the evaluation criterion related to this SAVER category included:

- **In-House Maintenance:** Seven evaluators responded that the ANAFI USA GOV met most of their expectations relative to maintainability of the system, while two stated it met some because of the limited maintenance that can be performed in an operational environment.

4.3 Skydio, Skydio X2D

The Skydio X2D (Figure 4-15) is a quadrotor UAS with an integrated EO/IR payload that includes a 12.3MP Sony IMX577 EO camera and a FLIR 320 x 256 pixel IR sensor. It is also equipped with six navigation cameras to provide 360-degree obstacle avoidance. It weighs 2.9 lb. The GCS uses the Skydio enterprise application and Q Ground Control. It is available with 5 GHz, 1.8 GHz and multiband radios. The airframe has an operating temperature range of 14°F to 109°F. The Skydio X2D in the tested configuration included the vehicle, EO/IR camera payload, Skydio Enterprise Controller, three Li-ion batteries, a dual charger, spare propeller blades set, soft and hard cases, 2 256GB pre-installed SD cards. The unit tested used the 5 GHz radio. This configuration and a Skydio Autonomy Enterprise perpetual license with one year of maintenance and support costs $21,889.

Figure 4-15 Skydio X2D

Image Credit: Skydio

The Skydio X2D received an overall assessment score of 3.1 for both daytime and nighttime operations. Evaluator comments provided throughout the assessment are reported below, grouped by SAVER category. In each category, the criteria are listed according to their order of importance as assigned by Blue UAS focus group.

4.3.1 Capability

The Skydio X2D received a capability score of 3.1 for daytime operations and a 3.0 for nighttime operations. Evaluator feedback on evaluation criteria related to this SAVER category included:

- **Camera's Visual Acuity:** During daytime operations, the majority of evaluators indicated the Skydio X2D met all or most of their expectations for the camera's visual acuity. Three evaluators found the Skydio X2D met some expectations, noting the optical zoom resulted in pixelated images that required users to fly closer to items/areas to get clearer views. Additionally, evaluators wished the camera had a wider field of view without zooming.

Figure 4-16 Skydio X2D EO camera

  During nighttime operations, one evaluator stated that the X2D met most of their expectation, while eight evaluators indicated it met some. Feedback was consistent with that received during daytime operations, including the system's being insufficient for search operations due to the low quality, grainy images from the thermal camera (the 320 x 256 sensor) and the pixelation of images when zooming. Evaluators also found the palettes available for IR were not sufficient for identifying objects, noting that having an option for certain temperatures at a different contrast would be valuable.

- **Flight Duration:** The Skydio X2D had similar flight duration ratings for both day and nighttime operations. During daytime operations, evaluators indicated the Skydio X2D met all or most of their expectations for flight duration, noting that the batteries performed well for the size of the aircraft. They also noted that it was easy to track remaining power levels through the battery indicator; The battery indicator displays the remaining battery charge percentage and uses various colors to display battery capacity for nominal flight as well as the capacity needed to safely return and land. During nighttime operations, five evaluators indicated the Skydio X2D met all their expectations and four indicated it met most of theirs. Those choosing "most expectations" attributed their rating to their expectation for flight duration to be longer when the drone was operated in cooler temperatures. The X2D flight duration was consistent across daytime operations and evening operations, despite temperature differences, at approximately 35 minutes.

Figure 4-17 Skydio X2D Command and Control (battery life indicator circled)

- **Command and Control Link Quality:** During daytime operations, five evaluators indicated the Skydio X2D's command and control link quality met only some of their expectations, noting the operator must follow the aircraft with the directional antenna, and that they experienced interference when two Skydio X2D's were operated close to each other. One evaluator experienced a lost link during a flight. The remaining evaluators indicated the Skydio X2D met all or most of their expectations. Evaluators had mixed feedback during nighttime operations. Two evaluators indicated the X2D met all their expectations, as it responded to all inputs; four evaluators indicated it met most expectations; and three indicated it met some expectations, due to connection issues while flying the X2D directly above the pilot even when no other aircraft were flying in surrounding areas.
- **Latency:** During daytime operations, four evaluators indicated the Skydio X2D met all expectations regarding signal latency. Three evaluators indicated it met most expectations, noting some delay in the control input catching up to the drone's movement as well as a delay in parts of the image updating. The remaining two evaluators indicated the Skydio X2D met some expectations regarding signal latency, noting the latency prevented the aircraft from operating smoothly (i.e., flight movements were jerky).

  During nighttime operations, six evaluators indicated the X2D met all expectations, noting no discernible latency issues. One evaluator indicated it met most expectations, noting only minor latency issues, and two evaluators indicated the X2D met some of their expectations, as the aircraft could not descend and fly forward at the same time, instead it did these maneuvers separately as if going down steps.
- **Automated Flight Modes:** The Skydio X2D offers position holds of GPS, GPS/Alt and, return to home. All are available with configurable3D obstacle avoidance. Some evaluators noted the "Orbit," and "Tap-to-Fly" features were nice, and the "Tracked Target" feature worked well. Another evaluator found the automated flight modes very useful.

4.3.2 Usability

The Skydio X2D received a usability score of 2.8 for daytime operations and 3.1 for nighttime operations. Evaluator feedback on evaluation criteria related to this SAVER category included:

- **Ease of Use:** The Skydio X2D showed very consistent results during day operation; all evaluators indicated it met most expectations, with one evaluator highlighting the magnet-based battery system as a benefit. They noted that operating the aircraft was easy and straight forward. however, the optical zoom control is located on the opposite side of the GCS from other platforms, which could cause confusion. Additionally, they noted the aircraft needed a flat and consistent deployment area to launch/land, which could be challenging during some response operations. Evaluators also reported the screen dimming when the outside temperature was/the GCS got hot, which made the display challenging to use.

Figure 4-18 An evaluator preparing the Skydio X2D UAS for launch

During nighttime operations, the majority of evaluators indicated that Skydio X2D met some expectations for ease of use; they found deploying the aircraft at night required a lot of steps, including manually calibrating the aircraft by waving it in a specific pattern. These steps required a relatively lengthy and unpredictable amount of time, causing a delay in aircraft deployment. They also noted that using automatic landing modes is necessary because twice, the aircraft flipped over during a manual landing, causing damage to the aircraft. The remaining three evaluators indicated the Skydio X2D met most expectations, which they attributed to difficulty seeing if the arms are locked and the need to adjust the brightness of the screen prior to flight. They noted the aircraft was easy to use but required additional time to perform a magnetometer calibration when switching to GPS night flight mode.

- **GCS Interface:** The majority of evaluators found the GCS interface met most or some of their expectations during both daytime and nighttime operations. One evaluator highlighted that the joysticks are well positioned, the physical buttons are decent for day operations, and the back of antenna has an overview of button bindings, which they appreciated. However, evaluators noted they had difficulty navigating the menus to get to various control settings (which required extended time off active flight) and noted the lack of a center reference point on the camera. During night operations the lack of any back-lighting of the controller buttons made it challenging to change settings via the buttons; this was particularly true when their night vision had been compromised by looking at a bright screen. Additionally, the GCS is 10.75 x 5.25 x 3.0 in. and weighs approximately 2.5 lb., which some evaluators deemed too large and found ergonomically difficult to operate. They also inadvertently hit buttons when holding it with one hand.

Figure 4-19 Skydio GCS, overview of button bindings circled

- **GCS Legibility:** Evaluators had mixed feedback on legibility during daytime operations. One evaluator indicated the legibility of Skydio's X2D met all of their expectations, five indicated it met most, two indicated it met some, and one indicated it met none. Feedback included that the screen was bright enough when used in the shade, but could be difficult to see in direct sunlight, especially once the screen dimmed after heating up (from exposure to direct sunlight/in response to outdoor temperatures). Evaluators also noted that the screen was hard to see when wearing polarized sunglasses, both in shade and direct sunlight.

  During nighttime operations the legibility of the Skydio X2D's GCS exceeded expectations for three evaluators, and met all expectations of four additional evaluators. They noted the brightness was acceptable for use at night and had no issues seeing the screen. Two evaluators indicated that the GCS legibility met some expectations, noting some of the characters on the were too small and that the "hard buttons" on the controller were hard to see next to the brightly lit screen because they are not backlit.

- **Customizable Safety Features:** Evaluators had mixed feedback on this criterion during daytime operations. Three evaluators indicated the Skydio X2D's customizable safety features met some expectations, noting it has no option for manually landing the aircraft and the lack options available for lost link like configuration of return to home altitudes and locations, evaluators found the Skydio defaults to a default return to home behavior instead. Three additional evaluators indicated it met most expectations, commenting they would like the option to change the home point while in flight and that the slide-controller made it difficult to set an exact maximum altitude. Two evaluators indicated it met all expectations, as the max altitude was tested and the X2D exceeded it by only five feet while they had a lost link during flight. However, the system worked, and the pilot was able to regain control. An evaluator indicated the Skydio X2D's customizable safety features exceeded expectations, noting that many of the X2D's capabilities are unique among Blue UAS.

  During nighttime operations, one evaluator indicated the Skydio X2D met all expectations, five evaluators indicated it met most expectations and three indicated it met some expectations. They noted changing to night mode was easy, the aircraft lights could be turned off/on easily while in flight and that the altitude limit was only able to be exceeded by four to five feet. They also noted that obstacle avoidance turns off when in night mode, which could and did lead to abrupt landings during the assessment.
- **Covertness:** Nearly all evaluators indicated the covertness of the Skydio X2D exceeded or met all of their expectations. They appreciated features that gave the pilot's the ability to turn on/off the visible lights or change to IR lighting while in flight and the aircraft's low noise signature.

4.3.3 Deployability

The Skydio X2D received a deployability score of 3.3 for daytime operations and 3.4 for nighttime operations. Evaluator feedback on evaluation criteria related to this SAVER category included:

- **Time to Redeploy:** Evaluators had mixed feedback on the X2D's time to redeploy. Four evaluators indicated it met all expectations, one said it met most, three reported it met some and one stated it met none. This lowest rating was attributed to the UAS' internal calibration taking approximately two minutes and thirty seconds after a battery change, which the evaluator noted, was too long of a wait to get the aircraft back in the air.

- **Deployability:** During daytime operations, eight evaluators indicated the X2D's deployability met most expectations, while one indicated it met some expectations. Evaluators noted deployment was negatively impacted by the time needed to connect/recalibrate the aircraft and the requirement to log in with a passcode. They also commented that the arm clamp used to lock the arms into position could be confusing. They noted, too, that failing to space out the rotors prior to flight could cause an imbalance and excessive vibrations on start-up. Results varied during nighttime operations, with one evaluator indicating the Skydio X2D's deployability met all expectations and four indicating it met most. These evaluators commented that while the system required extra calibration steps at night, those were easy to accomplish and the delay the extra steps caused was acceptable. Similar to comments during day operations, they noted that properly locking the arms in place may be an issue at night. Of the remaining four evaluators, three indicated the Skydio X2D met some expectations, and one indicated it met no expectations. These evaluators deemed the time required to setup and calibrate the system excessive and a detriment to first responder operations.

Figure 4-20 Evaluators configuring the and rotors of the Skydio X2D to prepare for takeoff

- **Portability:** All evaluators found the portability of the X2D exceeded or met all of their expectations during both daytime and nighttime operations. They particularly noted the case's small, lightweight, well-shaped design could easily fit into a patrol car.

4.3.4 Maintainability

The Skydio X2D received an overall maintainability score of 2.7. Evaluator feedback on the evaluation criterion related to this SAVER category included:

- **In-House Maintenance:** Six of the evaluators indicated the Skydio X2D's in-house maintenance met most of their expectations, while the three indicated it met some. The evaluators did not like that changing props requires handling a tool and small screws. They did however highlight that all required tools were provided and the items most prone to damage are fixable by the operator.

4.4 Teal Drones, Teal 2

The Teal 2 is a quadrotor UAS with an integrated EO/IR payload (Figure 4-31) has a listed weight of 2.75 lb. and comes equipped with an integrated dual axis EO/IR gimbal with a Hadron 16MP EO and 640x512 IR payload. The airframe has an ingress protection rating of 53, and an operating temperature range of −32°F to +110°F. The GCS is compatible with Teal Q Ground Control, Tomahawk Robotics Kinesis, and the ATAK UAS Tool software. The Teal 2 as assessed included the vehicle, EO/IR camera payload, Teal Air Controller, two battery/charger kits (each kit includes one charger and two batteries), Teal 2 Tactical Case, a field repair kits containing tools, two rotor arms, one set of propellers, micro-SD card, quick start guide, transport case, and a one-year warranty at the price of $15,074.

Figure 4-21 Teal 2

Image Credit: Teal Drones

The Teal 2 received an overall assessment score of 2.8 for daytime operations and 3.2 for nighttime operations. Evaluator comments provided throughout the assessment are reported below, grouped by SAVER category. In each category, the criteria are listed according to their order of importance as assigned by Blue UAS focus group.

4.4.1 Capability

The Teal 2 received a capability score of 2.6 for daytime operations and 3.2 for nighttime operations. Evaluator feedback on evaluation criteria related to this SAVER category included:

- **Camera's Visual Acuity:** Three evaluators indicated the Teal 2 met most of their expectations for the camera visual acuity during daytime operations, while six evaluators felt it met only some of their expectations . One evaluator noted that with a line of sight to aircraft, the video image on the controller showed heavy pixelation and latency; when the EO camera was on auto-exposure, the image appeared to be overexposed in bright sunlight. All evaluators stated they had trouble reading staged hazmat labels and license plates on the controller when using the EO camera. They also had trouble with the camera zoom, which is incremental and not proportional to the controller input; the steps between each zoom level on the camera zoom mechanism were too drastic, making it difficult to make fine adjustments to the controller image. One evaluator commented that incremental zoom would be sufficient on a stationary object but would be difficult to use on a moving target. Several of the evaluators found the IR camera on the Teal 2 useful, even during hot, bright, afternoon conditions, that were near the top of the operating range for the system.

Figure 4-22 Teal 2 using EO camera during daylight operations

During nighttime operations, the Teal 2 met most of their expectations for the camera's visual acuity for eight evaluators, while one evaluator it met only some. One evaluator commented that the Teal 2 RGB camera is not very sensitive in low light conditions and very grainy at dusk. Other evaluators commented that the zoom of the RGB and thermal are not linked together making transition between the cameras difficult, especially when trying to locate an object. Evaluators found the Teal 2 thermal camera acceptable from a distance, but observed grainy and pixelated imagery when zoomed in (see Figure 4-23), which would prevent them from being able to work at a higher altitude. Similarly, to the EO camera's zoom functionality, evaluators found the Teal 2 IR camera incremental zoom to not be sufficient for their operations. Two evaluators received "waiting for video" errors that delayed operations. Several evaluators also experienced issues with the IR camera color palette; one commented that only some palettes were usable due to poor color differentiation limiting the operator's ability to discern details between objects. One evaluator noted that the gimbal sits too low to the ground, which made landing difficult using the camera. Another evaluator also did not like how low the gimbal sits to the ground and that it maintains a downward-looking position during landing. The opens the lens up to the risk of getting hit with debris during landing. This evaluator further commented it would be nice to have feet on the Teal 2.

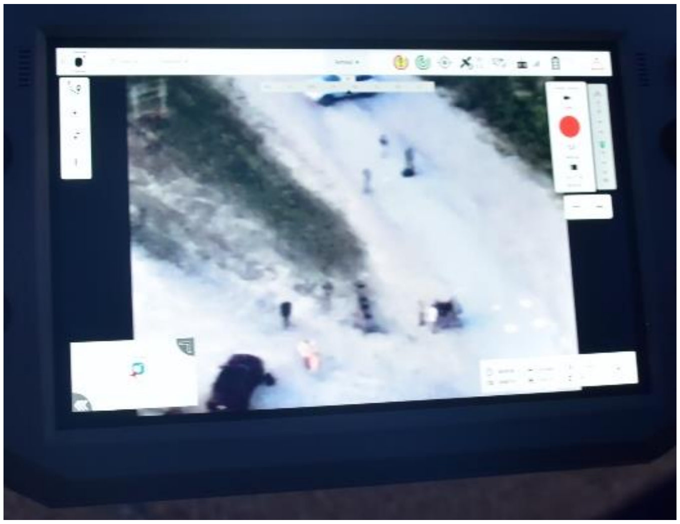


Figure 4-23 Teal 2 thermal image zoomed in

- **Flight Duration:** Flight duration scores for daytime and nighttime operations for the Teal 2 were varied. During daytime operations, the majority of evaluators indicated the Teal 2 met some or none of their expectations for flight duration, however, two said it met all. The seven evaluators that found the Teal 2 met none or some of their expectations had difficulties with the Teal 2 overheating in the Texas summer afternoon (outdoor temperatures exceeding 90 degrees during use), which abbreviated their flight times. A high temperature warning (shown in Figure 4-24) would alert the pilot. These evaluators experienced approximately 15 to 20 minutes of flying time when the expected flight time is claimed to be approximately 30 minutes based on manufacturer specifications.

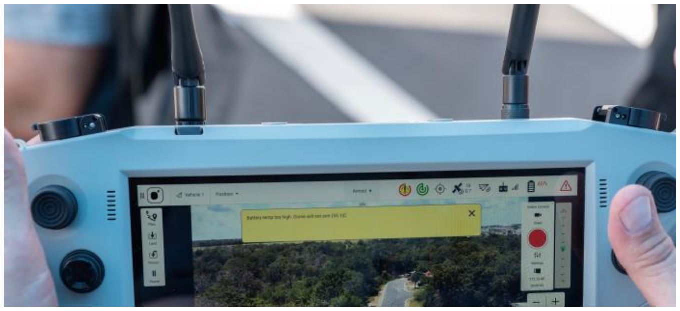


Figure 4-24 Teal 2 High Temperature Warning

The Teal 2 better met the evaluators' expectations for flight duration during night operations, where all evaluators found the Teal 2 to exceed, meet all or meet most of their expectations for flight duration. The evaluator who indicated the Teal 2 exceeded expectations attributed this to the flight time they experienced – nearly 25 minutes – as well as the ability to easily change the batteries in the field. They added that the cost of batteries at $1,000 for two batteries and a charger makes it reasonable to have a sufficient number of spares on hand to support operations.

- **Command and Control Link Quality:** During daytime operations, six evaluators indicated the TEAL 2's command and control link quality met some of their expectations, noting that the system continuously had issues with the GCS properly pairing and syncing with the aircraft causing delays up to 15 minutes before the UAS was ready to take off. Three evaluators indicated it met most of their expectations as two of these evaluators experienced some aircraft movement without controller input and drift in the camera. One evaluator experienced the zoom/video feed freezing during flight; the Teal 2 had to be landed and the entire system reset to recover functionality.

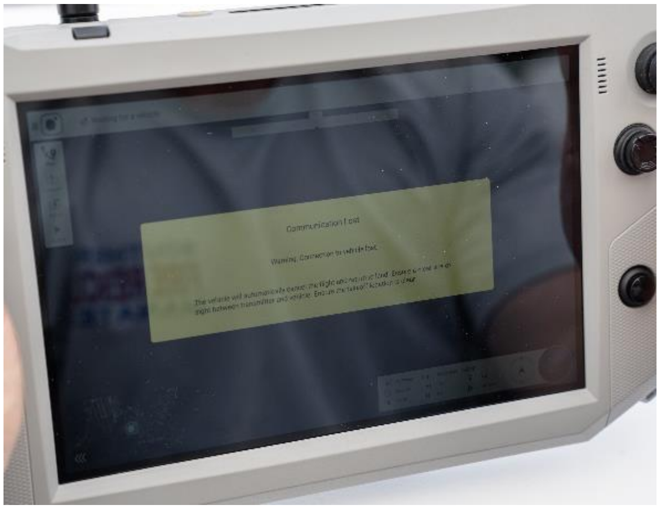


Figure 4-25 Pairing Teal 2

Evaluators had mixed feedback regarding command and control link quality during night operations. Three evaluators indicated the Teal 2 met all of their expectations; two evaluators indicated it met most of their expectations; three evaluators found it met some; and one evaluator said it met none. The evaluator who said it met none of their expectations attributed that his difficulties trying to establish a GPS link and waiting for the remote ID warning to resolve. Two evaluators experienced signal issues during flight.

- **Latency:** The Teal 2 met most or all of the expectations of all evaluators during day operations. Three evaluators indicated the Teal 2 met all their expectations for latency, however they experienced some instances of video failure (Figure 4-26) and pixilation, as well as lag in response to commands.

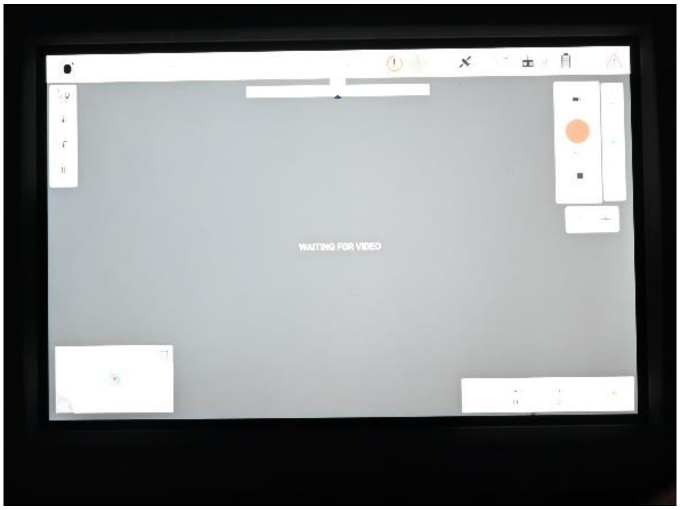


Figure 4-26 Teal 2 Image Freeze

Latency issues were less pronounced during nighttime operations; the flight controls were very responsive to movement inputs and evaluators experienced minimal delays with video transmission. One evaluator who experienced repeated latency issues noted the controller image would disappear and reappear and that the video lagged after movement inputs; as a result, the Teal 2 met only some of their expectations.

- **Automated Flight Modes:** The Teal 2 offers "position hold," "altitude" that covers both attitude and altitude hold, "return to home," and manual flight options. One evaluator highlighted the accuracy of the RTH feature, the geofence, and the ceiling settings. Two evaluators noted that the automated flight modes were sufficient, but that Teal 2 is missing a couple of software options that allow more advanced automated flight modes.

4.4.2 Usability

The Teal 2 received a usability score of 2.9 for daytime operations and 3.2 for nighttime operations. Evaluator feedback on evaluation criteria related to this SAVER category included:

- **Ease of Use:** Difficulties evaluators experienced pairing the Teal 2 with the GCS greatly affected to the scoring. Evaluators found the Teal 2 quick and easy to set up, and intuitive to use once the devices were paired. The Teal 2 controller has two joysticks for the controlling the drone at the top of the GCS on the left and right sides and two camera control joysticks below those (circled in Figure 4-27). Some evaluators noted the rubberized joysticks were comfortable and easy to manipulate, while others found them stiff. However, the majority of evaluators found it difficult to navigate using the GCS – particularly when flying by touch as they would inadvertently use the camera joysticks in lieu of the flight control joysticks, and vice versa. Evaluators found the menus were in an ideal location, but blocked screen views.

Figure 4-27 Joystick locations

  The GCS weighs approximately 3.7 lb., and measures 13.75 x 7.5 in, which some evaluators deemed too large and heavy, and therefore difficult to operate one handed. The configuration and location of the controls, as well as the incremental zoom and gimbal adjustment were not ideal for the evaluator's operations.

  One evaluator expressed concern about the "manual disarm" (propeller stop) button, specifically, about potential accidental disarms in flight. They explained they would prefer an automated disarm sequence if the UAS senses no movement due to contact with the ground or a laser/radar/camera altimeter to measure touching down. One evaluator noted that how low the gimbal sits to the ground made landing using the camera difficult. Another evaluator also did not like how low the gimbal sits to the ground and that it stays in a downward-looking position during landing; the lens was hit by debris kicked up during that evaluator's landing.

- **GCS Interface:** Overall, the GCS interface scored similarly for daytime and nighttime operations. Evaluators found the interface intuitive to use and appreciated that the GCS was operable via touchscreen, and liked the summary screen, options menu, the ability to type in values into the settings. Nonetheless, evaluators stated the location of the camera controls underneath the control joysticks left them unable to fly the drone and control the camera at the same time, which is typically how they would operate a UAS system. Evaluators also had trouble navigating through settings, for example, the "settings adjustment" pop up menu was so large that it covered most of the screen. Evaluators identified additional disadvantages including their needing to use two different applications to operate the drone; the incremental zoom not being smooth; and the screen not having enough resolution, nor IR color palettes/patterns to provide distinctions between temperatures (thus limiting their ability to discern details between objects); and the gimbal's control being located on the back of the GCS.

Figure 4-28 Evaluator using the Teal 2 GCS during the damage assessment scenario

  Evaluators had mixed feedback on the joysticks. While some evaluators found them comfortable and easy to use, others noted their positions were inappropriate and one found themselves repeatedly using the wrong joysticks since there were multiple (see Figure 4-28). Evaluators noted that it would have been beneficial for night operations if the GCS controls had been back-lit.

- **GCS Legibility:** Four evaluators indicated the legibility of the Teal 2's GCS met all expectations during daytime operations, and two indicated it met most expectations. These evaluators found the GCS screen size appropriate for their operations and appreciated the ability to set the brightness and see the screen during bright summer days. The GCS legibility met some of the expectations of two evaluators who attributed their score to screen glare in the sunlight, and the screen was also not bright enough in daylight. Some evaluators had difficulty finding the screen brightness settings in the GCS menu.

  During nighttime operations, the GCS legibility met all or most of all nine evaluators' expectations. One evaluator noted that the screen was so bright that others could look over his shoulder and see the screen.

- **Customizable Safety Features:** Overall, evaluators appreciated the Teal 2's number of customizable safety features. During daylight and night operations, the majority of evaluators were able to easily adjust the safety settings, even while flying the drone, and found the visual and audible safety warnings, geofencing, RTH, and ceiling settings beneficial to operations. One evaluator commented that the visual and audible alerts ensured awareness of the safety warning. The evaluators found the geofencing easy to set up and effective in keeping the drone in the assigned area. They also found value in the ability to command the Teal 2 out of an RTH procedure. While evaluators appreciated the Teal 2's safety features, particularly the ability to set a launch height, they expressed concern for having to set them all in advance; this resulted in extending the timeline to launch and the inability to change the home point.

Evaluators suggested the inclusion of obstacle avoidance, anti-collision lighting, and a light to be activated upon landing would enhance the usability of the Teal 2.

- **Covertness:** Four evaluators found that the covertness of the Teal 2 during nighttime operations met most expectations; the system met some expectations of the five others. The majority of evaluators found the noise produced by the drone louder than they would want for covert operations, as they could still hear the UAS at 350 feet above ground level and 600 feet away. Evaluators gave mixed feedback on the UAS external strobes: three said they were acceptable, while two would have preferred an option to disable the lights to enhance covertness.

4.4.3 Deployability

The Teal 2 received a deployability score of 3.0 for daytime operations and 3.5 for nighttime operations. Evaluator feedback on evaluation criteria related to this SAVER category included:

- **Time to Redeploy:** Four evaluators indicated the TEAL 2's time to redeploy met all expectations and noted that the redeployment time was sufficient for their needs. The other five evaluators indicated that the Teal 2 redeployment time met most expectations. These evaluators did not like having to recalibrate and reconnect the drone after every battery change and felt that the time (roughly 150–180 seconds) was too long for their needs.
- **Deployability:** During daytime operations, two evaluators indicated the Teal 2 deployability met most expectations and one indicated it met some expectations. The other six evaluators said the Teal 2 met none of their expectations and attributed this to the complexity and unreliability of the Teal 2 start-up and pairing sequence. Evaluators expressed concerned by the inconsistency of pairing the Teal 2 with the GCS and the amount of time it took to troubleshoot the issue when the drone failed to pair. All evaluators stated concerns surrounding the complexity and unreliability of connecting the GCS to the aircraft.

Figure 4-29 Evaluator pairing the Teal 2 for deployment

Three primary issues were identified during the assessment

1) Needing to navigate multiple applications on the GCS to connect to the aircraft

2) Unreliability of connecting to the aircraft as the GCS and aircraft would connect sometimes connect readily, other times connected after 5–15 minutes, and sometimes not connect at all, which required the manufacturer to reset or modify the radio parameters inside a configuration menu that is only accessible when the system is connected over an internet connection with Teal unlocking it.

3) Remote ID integration in the Teal 2 would not allow the aircraft to arm for takeoff, which resulted in numerous delays throughout the assessment. Even when the aircraft would report 15 or more satellites, the GCS would report the position was not established as fixed for Remote ID.

The evaluators also did not like the amount of time it took to navigate Teal 2's pre-flight checklist and the two separate power buttons on the GCS.

- **Portability:** Nearly all evaluators found the portability of the Teal 2 for daytime operations met all their expectations. During nighttime operations, the system's portability exceeded the expectations of two evaluators, met all expectations of six evaluators, and met most expectations of one evaluator. Based on the size and weight of the transport case, evaluators found that it could easily fit into a response vehicle. One evaluator appreciated that the case had a handle on the top as well as the side. Some evaluators also appreciated the camouflaged secondary case to carry the drone (Figure 4-30) noting it would be particularly useful when needing to navigate to and launch a drone from scenes in challenging environments (e.g., uneven terrain or obstacles).

Figure 4-30 Teal 2 Transport Case

4.4.4 Maintainability

The Teal 2 received an overall maintainability score of 3.7. Evaluator feedback on the evaluation criterion related to this SAVER category included:

- **In-House Maintenance:** Six evaluators indicated the Teal 2's in-house maintenance met all their expectations, while the remaining three indicated it met most expectations. Evaluators appreciated that the only field maintenance needed for the Teal 2 is replacing the propellers and arms, and that the system comes with four replacement props and two replacement arms. Evaluators found the Teal 2 propellors very easy to replace and appreciated that they are designed to fit into place only on the correct arms.

5.0 SUMMARY

Table 5-1 summarizes the advantages and disadvantages of each product as identified by the evaluators. Individual responder agencies that intend to purchase Blue UAS should carefully research the capabilities and features of available technologies or equipment to identify the product best suited to their operational needs. Agencies should also consider impacts associated with integrating equipment into their power and information technology infrastructure, data management, concept of operations, and required maintenance.

Table 5-1 Advantages and Disadvantages

<table>
<tr><th colspan="2">Manufacturer/Product</th><th>Advantages</th><th>Disadvantages</th></tr>
<tr><td colspan="2">
Ascent AeroSystems
Spirit</td><td rowspan="2">• Large zoom capability, EO 40x (20x optical + 2x digital), IR 4x digital
• High resolution IR camera (1280 x 720) allows for gathering clear imagery
• Low latency experienced between GCS and aircraft
• Capable of performing autonomous flights
• Camera can track objects and perform automated searches for people or vehicles
• Option to outfit with two batteries to extend operational time</td><td rowspan="2">• Location of controls makes it difficult to maneuver the camera while the drone is in motion
• Requires multi-step assembly and software setup that is time consuming and delays deployment
• Assembly is particularly challenging during night operations
• Difficult to determine orientation of the aircraft while in flight, which makes it particularly challenging to fly at night
• Storage case is large and heavy</td></tr>
<tr><td>Cost: $56,196</td><td>Overall Score Day/Night: 3.3/3.2</td></tr>
</table>

Manufacturer/Product	Advantages	Disadvantages
 Parrot Drones ANAFI USA GOV **Cost: $13,965** **Overall Score: Day/Night: 3.3/2.9**	• Quick and simple set up and operation • Easy to position and lock in propeller arms for flight • Batteries on the aircraft are easily accessible • Very portable due to small size	• EO camera does not handle scenes with high and low contrast objects well • EO camera is slow to transition between bright and dark scenes • IR camera has limited resolution and no optical zoom • Occasional high latency between aircraft and GCS, especially when multiple UAS operating in the same area • GCS buttons are not backlit of • No built-in navigation lights or anti-collision beacons for night operation • Tablet on GCS takes up to three minutes to boot
 Skydio X2D **Cost: $21,889** **Overall Score Day/Night: 3.1/3.1**	• Customizable safety features • Ability to turn off the visible lights is beneficial for covertness • Portable, lightweight, and easy to fit in a vehicle • Magnet-based battery system • Sufficient battery life • Graphical overview of GCS buttons affixed to antenna casing for quick reference	• IR camera has limited resolution and no optical zoom • Occasional interference experienced when multiple UAS operating in close proximity • Directional antenna needs to face aircraft for best link quality • Deploying at night requires manually calibrating by waving in a specific pattern and can take an unpredictable amount of time, causing a delay in aircraft deployment. • GCS buttons are not backlit of • GCS screen dims automatically in high heat • Propellers' proximity to the ground results in striking the landing surface if it is not flat

<table>
<tr><th colspan="2">Manufacturer/Product</th><th>Advantages</th><th>Disadvantages</th></tr>
<tr><td colspan="2">
Teal Drones
Teal 2</td><td rowspan="2">• Intuitive GCS interface
• Brightness of GCS screen easily adjustable
• Backlit GCS buttons
• Easy propeller replacement
• Geofencing and ceiling settings available
• Sufficient battery life during nighttime operations
• Secondary, streamlined transport pouch for UAV</td><td rowspan="2">• Significant delays pairing controller to GCS
• Camera control zooms in increments, not continuously
• EO camera images overexposure and details were difficult to interpret
• Significant degradation of battery during daytime operations in high temperatures
• Camera is controlled by a second set of joysticks that make it challenging to operate while flying</td></tr>
<tr><td>Cost: $15,074</td><td>Overall Score Day/Night: 2.8/3.2</td></tr>
</table>

6.0 ACKNOWLEDGEMENTS

NUSTL thanks the assessment evaluators for their valuable time and expertise. Their insights and recommendations will assist responder agencies making procurement decisions and guide the planning and execution of future SAVER projects. The lab also extends its appreciation to Boulder (Colorado) Police Department, Clackamas County (Oregon) Sheriff's Office, Fire Department City of New York (New York), Michigan State Police, Norfolk (Virginia) Police Department, Southern Manatee (Florida) Fire Department, Texas Department of Public Safety, Tulsa (Oklahoma) Fire Department, and Virginia State Police for allowing the evaluators to participate in this SAVER assessment. Great appreciation is also extended to DEVCOM, DHS S&T's Project JUSTICE, Mississippi State University, and TEEX for being integral to event execution.

APPENDIX A. EVALUATION CRITERIA DEFINITIONS

Capability

Camera's Visual Acuity refers to the subjective clarity of the image produced by the camera.

Flight Duration refers to the approximate time of flight considered suitable for a first responder's operational needs based on varied conditions (perching, weather, such as wind).

Command and Control Link Quality refers to the reliability of the radio frequency data link between the ground control station and the UAS. This includes the ability to stream live video from the UAS, and share the feed, through complex environments with minimal interference.

Latency refers to the amount of time between the moment data is captured by the UAS and the moment it is received by the ground control station.

Automated Mapping refers to the capability of a UAS to be programmed to execute a mapping mission with parameters provided by the operator.

Automated Flight Modes refers to non-manual capabilities, such as an orbit or position hold, that assist the operator during flight.

Deployability

Time to Redeploy refers to the amount of time it takes to change the UAS battery (or batteries) and return to flight.

Deployability refers to the ease of and the amount of time it takes to remove the UAS from its case in addition to its boot up and configuration time prior to take off.

Portability refers to the ease with which the UAS can be transported from one location to another. This includes the size, weight and shape of the carrying case(s).

Usability

Ease of Use refers to the intuitiveness of setting up and deploying and operating the UAS.

GCS Interface refers to the ease of use of the GCS, including the intuitiveness and human factors integration of the graphical user interface (GUI), configuration adjustments, menu navigation, control buttons, joystick, etc.

GCS Legibility refers to the visibility of the screen in various lighting conditions, considering Nit of brightness[5] and if it's backlit.

Customizable Safety Features refers to the ability to manually override safety features, such as "hover," "land" and "return to home" in order to achieve mission goals.

Covertness refers to the amount of light and sound being emitted by the UAS during flight.

External Spotlight refers to the ability to carry and the ease of using a light source during low- or no-light operations.

Operability of GCS with Gloves refers to the ease with which the GCS can be used while wearing gloves.

[5] A unit of measurement that refers to the amount of light emitted from an object.

Hot Swappable GCS Battery refers to the ability to change the battery for the GCS without losing power.

Maintainability

In-House Maintenance refers to inspections and component replacements (e.g., propellers, landing gear) that can be performed by technicians, without specialized tools and within the user's agency or department, rather than having to be returned to the vendor for maintenance.

APPENDIX B. ASSESSMENT SCORING FORMULA

Overall assessment scores for each product were calculated by multiplying the average criterion rating by the criterion weight assigned by the focus group, thus resulting in a weighted criterion rating. The sum of the weighted criterion scores was then divided by the sum of the weights for each criterion across all SAVER categories as seen in the formula and example below:

Overall Score Formula

$$\frac{\sum(Average\ Criterion\ Rating \times Criterion\ Weight)}{\sum(Criterion\ Weights)} = \begin{matrix} Overall \\ Score \end{matrix}$$

Overall Score Example [vi]

$$\frac{(4.3 \times 4) + (5 \times 4) + (4 \times 3) + (4.5 \times 3) + (4.5 \times 3)}{4 + 4 + 3 + 3 + 3} = 4.5$$

[vi] Examples are for illustration purposes only. Formulas vary depending on the number of criteria and categories assessed