First Responder Robotic Operations System Test (FRROST) Small Unmanned Aircraft Systems for Search and Rescue

Focus Group Report

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The cover photo and images included herein were provided by the National Urban Security Technology Laboratory.

FOREWORD

The U.S. Department of Homeland Security (DHS), Science and Technology Directorate (S&T), initiated a program to better understand small unmanned aircraft systems (sUAS) in the context of first responder missions. This program will study public perception of sUAS use, identify first responder priority use cases, and conduct experiments and exercises. One component of this program is the First Responder Robotic Operations System Test (FRROST).

The National Urban Security Technology Laboratory (NUSTL) through FRROST will assess commercially available sUAS under realistic field conditions according to priority use cases identified by the First Responder Resource Group (FRRG). The FFRG is an all-volunteer working group made up of first responders from all major disciplines and regions of the country that helps DHS S&T maintain focus on the top-priority needs of responders in the field. Following the model established by the DHS S&T System Assessment and Validation for Emergency Responders (SAVER) Program, FRROST will conduct focus groups and assessments of sUAS in the context of the use cases identified by FRRG. NUSTL will coordinate these efforts with the National Institute of Standards and Technology (NIST) and DHS S&T Office of Mission & Capability Support.

The purpose of FRROST is to identify the needs and requirements of first responders when using sUAS in specific use cases; to assess commercially available sUAS, sensors, and their interoperability with remote users; to validate NIST standard development efforts; and to create knowledge products to aid responders making purchasing decisions.

For more information on S&T NUSTL, visit the DHS S&T NUSTL home page (http://www.dhs.gov/science-and-technology/national-urban-security-technology-laboratory).

For more information on the S&T Office of Mission & Capability Support, visit the DHS S&T Office of Mission & Capability Support home page (http://www.dhs.gov/science-and-technology/office-mission-and-capability-support).

For more information on NUSTL's SAVER Program, visit the DHS S&T SAVER home page (http://www.dhs.gov/science-and-technology/SAVER).

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EXECUTIVE SUMMARY

Small unmanned aircraft systems (sUAS)—systems whose gross take-off weight is less than 55 pounds[i]—offer tremendous potential for emergency responders supporting public safety missions. Due to advances in technology over the last decade, sUAS have become more affordable, technically capable, and easier to fly. As such, sUAS can carry out public safety missions at a fraction of the cost of a manned aerial response, while keeping responders out of personal danger. These systems also offer opportunities to perform missions impossible for manned vehicles, such as exploring inside buildings or tunnels.

To assess commercially available sUAS for public safety missions, the U.S. Department of Homeland Security (DHS), Science and Technology Directorate (S&T) established the First Responder Robotic Operations System Test (FRROST). Using its System Assessment and Validation for Emergency Responders (SAVER) Program as a model, the National Urban Security Technology Laboratory (NUSTL), in coordination with the National Institute of Standards and Technology (NIST), will conduct the first FRROST assessment of sUAS for search and rescue missions.

As part of the assessment process, NUSTL convened a focus group on June 29, 2018, at the Homeland Security Acquisition Institute in Washington, D.C. The primary objectives of the focus group were to recommend evaluation criteria, product selection criteria, products, and possible scenarios for the assessment of sUAS. Nine emergency responders from various jurisdictions—each with experience using sUAS during search and rescue operations—participated in the focus group.

Focus group participants identified 73 evaluation criteria by which the sUAS could be assessed. They grouped these criteria into five categories (affordability, capability, deployability, maintainability, and usability) and concluded that capability and deployability were the most important categories, followed by usability, maintainability and affordability, respectively.

The focus group also assigned a weight for each criterion's level of importance and identified 22 criteria of utmost importance, i.e., they would not purchase a sUAS that did not meet their expectations for that criteria. Those that were considered of utmost importance included capabilities related to the camera, flight time, automated flight functions, ease of use, and reliability.

Focus group participants outlined two possible operational scenarios for conducting the assessment: a lost hiker and post-disaster search and rescue events in both daytime and nighttime conditions. Finally, the focus group made suggestions as to products they would like to see evaluated for search and rescue missions. They suggested 11 sUAS models with associated sensors that span a wide range of sUAS sizes and retail prices.

Focus group recommendations documented in this report will directly guide the planning of the FRROST assessment of sUAS for search and rescue applications.

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[i] 115th Congress. (2018, October 4). *Federal Aviation Administration (FAA) Reauthorization Act of 2018, Pub. L.* Retrieved from www.congress.gov/115/bills/hr302/BILLS-115hr302enr.pdf

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1.0 INTRODUCTION

Small unmanned aircraft systems (sUAS)—systems whose gross take-off weight is less than 55 pounds—offer tremendous potential for emergency responders supporting public safety missions. Due to advances in technology over the last decade, sUAS have become more affordable, technically capable, and easier to fly. As such, sUAS can carry out public safety missions at a fraction of the cost of a manned aerial response, while keeping responders out of personal danger. These systems also offer opportunities to perform missions impossible for manned vehicles, such as exploring inside buildings or tunnels.

To assess commercially available sUAS for public safety missions, the U.S. Department of Homeland Security (DHS), Science and Technology Directorate (S&T) established the First Responder Robotic Operations System Test (FRROST). FRROST will assess commercially available sUAS under field conditions according to priority use cases identified by the First Responder Resource Group (FRRG). The first use case to be assessed will be search and rescue.

Using its System Assessment and Validation for Emergency Responders (SAVER) Program as a model, the National Urban Security Technology Laboratory (NUSTL), in coordination with the National Institute of Standards and Technology (NIST), will conduct the first FRROST assessment of sUAS. The FRROST assessment will be conducted at the Combined Arms Collective Training Facility at Camp Shelby Joint Forces Training Center near Hattiesburg, Mississippi. Emergency responders participating in the assessment as evaluators will receive familiarization training on each sUAS model prior to the assessment. This training and the assessment scenarios will incorporate elements of the NIST sUAS Standard Test Methods Program.

As part of the assessment process, NUSTL convened a focus group on June 29, 2018, at the Homeland Security Acquisition Institute in Washington, D.C. The primary objectives of the focus group were to recommend evaluation criteria, product selection criteria, products, and possible scenarios for the assessment of sUAS. Nine emergency responders with experience using sUAS during search and rescue operations, along with representatives from the Federal Aviation Administration (FAA), Federal Emergency Management Agency (FEMA), and the National Association of Search and Rescue (NASAR), participated in the focus group.

1.1 Participant Information

Nine emergency responders from various jurisdictions with experience using sUAS during search and rescue operations participated in the focus group. Practitioner information is listed in Table 1-1.

Table 1-1 Focus Group Participant Demographics

Practitioner	Flight Time Experience	State
Firefighter/Remote Pilot	>350 hours	Virginia
Firefighter/Paramedic/Remote Pilot	~150 hours	California
Firefighter/Remote Pilot	~100 hours	California
Police Officer/Remote Pilot	~100 hours	Virginia
Emergency Manager/Remote Pilot	~70 hours	Kansas
Firefighter/Remote Pilot	~30 hours	California
Firefighter/Emergency Manager/Remote Pilot	~30 hours	Virginia
Engineer/Paramedic/Remote Pilot	~20 hours	California
Police Officer/Remote Pilot	~20 hours	California

2.0 FOCUS GROUP OVERVIEW

The focus group began with introductions and an overview of the FRROST and SAVER Programs by the NUSTL facilitator. A representative from the U.S. Army Combat Capabilities Development Command (CCDC) Armaments Center (formerly known as the Armament Research Development and Engineering Center (ARDEC)) gave a brief summary of sUAS technologies. A representative from NIST discussed the NIST sUAS Standard Test Methods—a suite of standard methods that can be used to quantify the capabilities of remotely operated response robots (including aerial systems) for responder training and applications[ii].

The NUSTL facilitator outlined the goals of the focus group.

1. To identify evaluation criteria for assessing sUAS for search and rescue missions
2. To categorize and prioritize the evaluation criteria and categories
3. To recommend product selection criteria and specific sUAS for evaluation during the assessment
4. To propose operational scenarios for the sUAS assessment

Initially, the group sought to further define the search and rescue concept. Participants stated their priorities and choice of equipment would change depending on the specific scenario. For example, in a situation where a responder may have to hike to a launch point, the size and weight of an sUAS would be considered more important than in a situation where the launch location is accessible by vehicle. A focus group participant stated that ideally, responders would own a variety of smaller and larger sUAS for different applications. Another focus group participant mentioned that because some agencies use sUAS assets for divergent missions, they may not purchase an sUAS that is most suited to search and rescue. Ultimately, it was agreed, that for the purpose of this focus group, responders should assume the sUAS may have to be carried into a remote launch location with no vehicle access or grid electrical power.

[ii] ASTM International Standards Committee on Homeland Security Applications; Response Robots (E54.09).

3.0 EVALUATION CRITERIA

Focus group participants were asked to identify criteria for sUAS that may be important to consider when making acquisition or operational decisions. These criteria form the basis for evaluating sUAS during the FRROST assessment. Then, participants grouped the evaluation criteria into five categories (typical of the SAVER Program):

- **Affordability** criteria relate to the total cost of ownership over the life of the product. This includes purchase price, training costs, warranty costs, recurring costs and maintenance costs.
- **Capability** criteria relate to product features or functions needed to perform one or more responder relevant tasks.
- **Deployability** criteria relate to preparing to use the product, including transport, setup, training and operational/deployment restrictions.
- **Maintainability** criteria relate to the routine maintenance 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 one or more responder relevant tasks.

First, the focus group identified 73 evaluation criteria and concluded capability and deployability were the most important categories, followed by usability, maintainability and affordability, respectively.

Next, focus group participants assigned a weight for each criterion's level of importance on a 1 to 5 scale, where 5 is considered to be a feature of utmost importance and 1 is of minor importance[iii]. The assessment categories were then weighted on a percent scale summing to 100 percent.

The affordability category was given a weight of 0 percent, because participants declined to consider evaluating cost as part of the FRROST assessment. Table 3-1 presents the category weights, evaluation criteria, and evaluation criteria weights.

[iii] Focus group participants were asked to assign weights to criteria according to the following guidance:
5: Criteria are of utmost importance, meaning *I would never consider purchasing a product that does not meet my expectations of this criterion.*
4: Criteria are very important, meaning *I would be hesitant to purchase a product that does not meet my expectations of this criterion.*
3: Criteria are important, meaning *meeting my expectations of this criterion would strongly influence my decision to purchase this product.*
2: Criteria are somewhat important, meaning *meeting my expectations of this criterion would slightly influence my decision to purchase this product.*
1: Criteria are of minor importance, meaning o*ther things being equal, meeting this criterion may influence my decision to purchase this product.*

Table 3-1 Evaluation Criteria

CATEGORIES				
Capability	**Deployability**	**Usability**	**Maintainability**	**Affordability**
Overall Weight 30%	Overall Weight 30%	Overall Weight 25%	Overall Weight 15%	Overall Weight 0%
Evaluation Criteria				
Onboard Camera/ Video Recording Weight: 5	Flight Time Weight: 5	Ease of Use Weight: 5	Hardware Reliability Weight: 5	Initial Platform Cost Weight: 5
Video Quality Weight: 5	Ease of Flight Operations Weight: 5	Fault Condition Behavior Weight: 5	Communications Reliability Weight: 5	Battery Price Weight: 5
Omnidirectional Pan/Tilt Capability Weight: 5	Return Home Capability Weight: 5	Visual Warnings Weight: 5	Hot-Swappable Batteries Weight: 5	Payload/Options Costs Weight: 5
Live View Capability Weight: 5	Autoland Capability Weight: 5	Anti-Glare Screen Weight: 5	Service Center Ease of Access Weight: 5	Replacement Props/Parts Costs Weight: 4
Intelligent Flight Modes Weight: 5	Cache Packaging Weight: 4	Intuitive GUI Weight: 4	Battery Recharge Time Weight: 4	Cost to Service System Weight: 3
Precision Hold while Hovering Weight: 5	Time to Deploy Weight: 4	Reconfigurable Alerts Weight: 3	Vehicle Battery Charger Capacity Weight: 4	Support Equipment Costs Weight: 2
Range from Controller Weight: 5	Collision Avoidance Weight: 4	Controller Ergonomics Weight: 3	Ease of Battery Replacement Weight: 4	Liability Insurance Cost Weight: 1
Zoomable Lens Weight: 4	Ability to Disable Collision Avoidance Weight: 4	Controller Use with Gloves Weight: 2	In-House Maintenance Weight: 4	
Swappable Camera Packs Weight: 4	Number of Batteries for Continuous Ops Weight: 4		Replacement Parts Availability Weight: 4	
Remote Video Streaming Weight: 4	Ingress Protection Rating Weight: 4		Proprietary Field Service Tools Weight: 4	
Non-Proprietary Recording Media Weight: 4	Downrange Dwell Time Weight: 3		Warranty Weight: 3	

CATEGORIES				
Capability	**Deployability**	**Usability**	**Maintainability**	**Affordability**
Overall Weight 30%	Overall Weight 30%	Overall Weight 25%	Overall Weight 15%	Overall Weight 0%
Evaluation Criteria				
Programmable from Tablet Weight: 4	Unlock No-Fly Zones Capability Weight: 3			
Ability to Download Maps Offline Weight: 4	Radio Frequency Interference Weight: 3			
Capability to Use Third Party Software Weight: 4	Controller Batteries' Charge Time Weight: 3			
Thermal Imaging Weight: 4	Self-Heating Batteries Weight: 3			
Maximum Speed Weight: 4	Size Weight: 3			
Capability to Carry Strobe Light Weight: 4	Temperature Range Weight: 3			
Dual Optical/IR Camera Weight: 3	Manual Frequency Change Capability Weight: 2			
Ability to Use Multiple Controllers Weight: 3	Operating Frequencies Weight: 2			
Wireless Video Relay Weight: 3	DOD Approved Weight: 1			
Precision Movement through Waypoints Weight: 3				
Ability to Save Pre-Programmed Flights Weight: 3				

CATEGORIES				
Capability	**Deployability**	**Usability**	**Maintainability**	**Affordability**
Overall Weight 30%	Overall Weight 30%	Overall Weight 25%	Overall Weight 15%	Overall Weight 0%
Evaluation Criteria				
Onboard Recording of Aircraft Telemetry Weight: 3				
Payload Capacity Weight: 3				
Wind Tolerance Weight: 3				
Ability to Extract Telemetry Logs Weight: 2				
First Person View Capability Weight: 2				

3.1 CAPABILITY

Twenty seven capability criteria were identified and defined by the focus group.

Onboard Camera/Video Recording refers to the ability of the system to record and store camera/video data onboard the aircraft. Focus group participants noted that the video stored onboard will be higher quality than streamed video. In the event of a lost link, streamed video will be lost, but onboard video can still be retrieved and reviewed.

Video Quality refers to the quality of live video, streaming video, and onboard retrievable video. Focus group participants indicated that onboard video should, at a minimum, be high definition.

Omnidirectional Pan/Tilt Capability refers to the ability of the camera platform to pan and tilt in all directions. Focus group participants indicated a preference for a camera platform with a 3-axis gimbal.

Live View Capability refers to the ability of a remote pilot to switch between a map view and live video when employing waypoint navigation.

Intelligent Flight Modes refers to sUAS flight modes that assist a remote pilot in simultaneously piloting the aircraft and capturing still or video images, while protecting the sUAS and the pilot.

Precision Hold while Hovering refers to a feature of the sUAS that, when selected, automatically controls the throttle to maintain the current altitude.

Range from Controller refers to the distance the aircraft can travel from the controller. Note that, in addition to technological limits, this distance is limited by FAA regulations.

Zoomable Lens refers to the zooming capability of the sUAS camera. Camera options may be limited by the aircraft payload capacity. Focus group participants preferred a camera with a 30x optical zoom at a minimum.

Swappable Camera Packs refers to the ability to swap out the sUAS camera payload, and the effect this will have on the system. Focus group participants pointed out that swapping payloads affects battery life.

Remote Video Streaming refers to the availability of a video output option on the sUAS controller that allows remote streaming of video—over the internet, for example to a command center.

Non-Proprietary Recording Media refers to the type of recording media employed by the sUAS. Focus group participants preferred non-proprietary Secure Digital (SD) cards, so that they would not have to rely on proprietary software to view recorded video.

Programmable from Tablet refers to the ability to use a tablet to program a search-pattern flight plan with Global Positioning System (GPS) coordinates. Focus group participants preferred automated flight made possible through the use of GPS coordinates.

Ability to Download Maps Offline refers to a feature of the sUAS that allows remote pilots to pre-program flight plans and use them in areas with low or no internet connectivity.

Capability to Use Third Party Software refers to the ability of an sUAS to integrate with third party software, for example, mapping software used by other agencies. The use of proprietary software would prevent the integration of software with other agencies.

Thermal Imaging refers to the thermal imaging capability of the sUAS sensor package. Focus group participants noted that the usefulness of thermal imaging during search and rescue operations can be dependent on the environment; it can be quite beneficial in open areas with little to no tree cover, but is less so in dense forests.

Maximum Speed refers to the maximum speed at which an sUAS can travel, while maintaining stability and control.

Capability to Carry Strobe Light refers to the capability of the sUAS to carry a high-intensity strobe light that could be visible at a minimum of 3 miles away for nighttime operations.

Dual Optical/IR Camera refers to an sUAS featuring optical and infrared (IR) sensors. Focus group participants noted that while available, dual cameras are not a common feature. It was also pointed out that, while not required, some agencies find it beneficial to employ a subject matter expert to operate the camera while a remote pilot flies the sUAS; this may be a necessity for dual cameras as they can be complicated to operate.

Ability to Use Multiple Controllers refers to the ability to use two controllers to control one sUAS. Focus group participants noted that one controller would be used to control the aircraft and the other controller would be used to control the camera.

Wireless Video Relay refers to the manner in which video is relayed from the sUAS controller to a larger video monitor, allowing for a greater number of individuals on-scene to view the video output from the camera without interfering with the remote pilot's operation of the aircraft.

Precision Movement through Waypoints refers to the ability of an sUAS to navigate through GPS waypoints with precise three-dimensional positioning (longitude, latitude, altitude).

Ability to Save Pre-Programmed Flights refers to the ability of the sUAS to save pre-programmed flight data for common areas where the systems may be frequently deployed.

Onboard Recording of Aircraft Telemetry refers to the ability of the sUAS to record telemetry data on the aircraft. Focus group participants explained that the sUAS controller may not capture all of the telemetry data of the aircraft if its range from the controller is exceeded. Should this occur, the data can be retrieved from the aircraft's internal memory.

Payload Capacity refers to the amount of weight an sUAS aircraft can carry. Focus group participants mentioned that sUAS used for search and rescue operations should be able to carry payloads of up to 5 pounds as they may be used to deliver items such as life jackets or first aid kits to those in need.

Wind Tolerance refers to the wind force that the sUAS can tolerate while remaining stable enough to perform as needed during search and rescue operations.

Ability to Extract Telemetry Logs refers to the ability of a remote pilot to extract telemetry logs from sUAS components in the field at the end of flights. Focus group participants noted that some sUAS components must be returned to the manufacturer—who may be located overseas—in order to extract telemetry data. Participants preferred the ability to extract data themselves in the field.

First Person View Capability refers to a feature that allows the remote pilot to fly the sUAS from the driver's or pilot's point of view. This capability is facilitated by a sensor on the platform looking ahead, and not through the camera payload. Focus group participants remarked that remote pilots must maintain a visual line of site with the sUAS, and testing this capability may require a Part 107 waiver.

3.2 Deployability

Twenty deployability criteria were identified and defined by the focus group.

Flight Time refers to the amount of time an sUAS can remain airborne during a search and rescue operation. The longer an sUAS can remain airborne during an operation, the greater the benefit to personnel on the ground.

Ease of Flight Operations refers to how easy it is for a remote pilot to control the sUAS—in terms of stability and maneuverability—during flight operations.

Return Home Capability refers to the capability of the sUAS to return home to where the controller is or to a pre-programmed location in the event of a lost link or other communication or system issue. Focus group participants indicated that this feature is of utmost importance.

Autoland Capability refers to the capability of the sUAS to safely autoland in the event of loss of aircraft control or other system issue. Focus group participants indicated that this feature is of utmost importance.

Cache Packaging refers to the size, weight, and portability of the sUAS and its associated sensors and batteries as packed for transport to a search and rescue mission. Focus group participants stated that the cache should be man-portable and contain enough batteries for 4 hours of continuous operation.

Time to Deploy refers to the amount of time it takes a remote pilot to unpack, setup, and launch the sUAS.

Collision Avoidance refers to the sUAS being equipped with avoidance sensors to detect obstacles in its path, such as branches or walls. Focus group participants noted that sUAS will need to be able to detect obstacles in front of, behind, above, and below the system. The sUAS may also be equipped with lights, beyond orientation lights, that enable individuals in the area to see and avoid the sUAS.

Ability to Disable Collision Avoidance refers to the ability of a remote pilot to disable the collision avoidance feature of an sUAS. During search and rescue operations, it may be desirable to move closer to an object of interest than the collision avoidance feature would allow.

Number of Batteries for Continuous Operations refers to the number of batteries necessary to power an sUAS continuously during an operational period. Focus group participants indicated that this criteria is important in both situations where electrical power is and is not available. When no power for recharging sUAS batteries is available, remote pilots need enough fully charged batteries on hand to power the sUAS for the duration of the operational period. Where electrical power is available, multiple batteries are still required to account for the fact that battery recharge times are greater than battery life during flights.

Ingress Protection Rating refers to the ingress protection rating, or IP rating, of the sUAS. Focus group participants indicated that any sUAS they purchased would need an IP rating of 43 at a minimum and be resistant to water spray. It was also noted that some sUAS models are not capable of flying in rain, while others are, but may not be covered under warranty if they are damaged as a result of water intrusion.

Downrange Dwell Time refers to the length of time—limited by battery life—that the sUAS can remain in place (landed) with sensors and communications powered on and operational (e.g., in situations where a landed sUAS continues to transmit as rescuers attempt to reach the area).

Unlock No-Fly Zones Capability refers to the ability to rapidly unlock no-fly zones—which inhibit sUAS flight—that have been programmed by the manufacturer to comply with FAA flight restriction guidance. These no-fly zones may surround permanent structures such as airports or may be set up temporarily for emergency situations such as forest fires. Responders that may need to enter no fly zones around certain critical infrastructure during search and rescue missions should coordinate with the FAA, local law enforcement, and the sUAS manufacturer.

Radio Frequency Interference refers to the manner in which an sUAS behaves when experiencing radio frequency interference. This interference may be caused by other sUAS operating in the area, land-based vehicles or robots on the scene, or high-powered radio stations.

Controller Batteries' Charge Time refers to the amount of time it takes to recharge the batteries in the sUAS controller using shore power or a vehicle charger.

Self-Heating Batteries refers to the ability to use self-heating batteries to power an sUAS. Self-heating batteries allow for rapid charging despite low temperatures that may be found in the field during a response, and help prevent power fluctuation. Focus group participants also expressed interest in the power fluctuations of these batteries at the top and bottom of their operating temperature range.

Size refers to the size of the sUAS platform as deployed. Focus group participants noted that there are specific tasks relative to search and rescue (e.g., trail running, searching large areas, delivering payloads, etc.) that lend themselves to sUAS of varying sizes.

Temperature Range refers to the operational and storage temperature ranges of an sUAS. Focus group participants preferred wide temperature ranges.

Manual Frequency Change Capability refers to the ability of a remote pilot to manually change the radio frequency on which an sUAS operates. During search and rescue operations, there are likely to be multiple public safety sUAS operating in the same area.

Operating Frequencies refers to the radio frequencies used for command and control and video streaming. Responders expressed a preference for sUAS that operate on unlicensed spectrum.

DOD Approved refers to whether the U.S. Department of Defense, or DOD, has approved the sUAS for use on military installations or by military personnel. Focus group participants mentioned that DOD approval is not necessary for civilian or public safety use, though some agencies may want to comply with DOD regulations.

In addition to the deployability criteria listed above, focus group participants expressed an interest in identifying the communications protocol used by the sUAS selected for assessment (such as Ocusync or Lightbridge for DJI products). The type of communications link will be noted in the assessment report, but will not be scored during the assessment.

3.3 Usability

Eight usability criteria were identified and defined by the focus group.

Ease of Use refers to the amount of time required, and the ease with which, a remote pilot can learn to operate the sUAS, its controller, and the camera or sensor package.

Fault Condition Behavior refers to the manner in which the sUAS responds to lost communication links, ceiling overruns, or loss of the motor or power. While sUAS should land safely in the event of a lost link, it may not be possible to safely land an sUAS in the event of a power or motor loss. Instead of testing these behaviors, it was suggested that information about fault condition behaviors be obtained from the manufacturer.

Visual Warnings refers to the visual warning indicators displayed on the sUAS controller. These warning indicators may indicate lost links, onboard conditions, low battery, high winds, etc. These indicators allow remote pilots to make operational decisions regarding the sUAS.

Anti-Glare Screen refers to the ability of a remote pilot to view the sUAS controller screen in direct sunlight.

Intuitive GUI refers to the sUAS controller's graphical user interface, or GUI, and how intuitive the remote pilot finds the layout of the controls on the interface.

Reconfigurable Alerts refers to the ability of a remote pilot to program their own warning indicators based on the operational conditions on scene, like a strong head wind. Reconfigurable, customizable alerts help increase a remote pilot's situational awareness.

Controller Ergonomics refers to the number of physical buttons present on the sUAS controller and how intuitive their placement is.

Controller Use with Gloves refers to the ease with which a remote pilot can use the controller, specifically when wearing gloves. It was noted that evaluators will be asked to bring their regular duty gloves to the assessment to test this criterion.

3.4 Maintainability

Eleven maintainability criteria were identified and defined by the focus group.

Hardware Reliability refers to the reliability of the sUAS. Focus group participants were interested in determining the number of malfunctions during 50 battery cycles.

Communications Reliability refers to the reliability of sUAS software and firmware, as well as radio links and data links. Focus group participants noted that failures of software, firmware, or radio/data links can be identified through an analysis of sUAS data log files.

Hot-Swappable Batteries refers to the ability to change batteries in the sUAS without powering the system down, with the goal of reducing system down-time. This criteria encompasses the amount of time it takes for the system to be operational after the batteries are swapped out.

Service Center Ease of Access refers to the ease with which sUAS can be serviced by the manufacturer, and whether the system needs to be shipped overseas for maintenance. Focus group participants explained that the sUAS currently on the market have no phased maintenance schedules, and they need to determine how to manage system maintenance over time: Which maintenance procedures can be performed by the public safety agency? Which procedures must be performed by the manufacturer's service center?

Battery Recharge Time refers to the amount of time it takes to recharge sUAS batteries when charging them in a series, and what happens to intelligent batteries over time. Focus group participants pointed out that the manner in which batteries are charged can affect the amount of time they hold their charge and their lifespan.

Vehicle Battery Charger Capacity refers to the capacity of a vehicle charger to recharge batteries. Vehicle chargers are used frequently in the field and they have limited power in comparison to grid power. Focus group participants were interested in the number of batteries that could be charged at one time in a vehicle charger and the amount of time it takes to fully charge them.

Ease of Battery Replacement refers to the ease with which batteries can be replaced in the field during search and rescue operations. Factors include the amount of time it takes to change the battery, the number of tools required, and whether the tools are proprietary.

In-House Maintenance refers to the number of sUAS components that can be maintained by the public safety agency and the number of components that must be maintained by the manufacturer.

Replacement Parts Availability refers to the availability, and ease with which, consumable replacement parts for the sUAS can be obtained by a public safety agency.

Proprietary Field Service Tools refers to the whether or not proprietary field service tools are required to access the sUAS. Focus group participants preferred sUAS that do not require the use of proprietary tools.

Warranty refers to the terms of the warranty provided by the manufacturer of the sUAS.

In addition to the maintainability criteria listed above, focus group participants expressed an interest in how easy it is to research—and how much information is publically available on—maintenance costs associated with the sUAS selected for assessment. The ease with which systems can be researched will be noted in the assessment report, but will not be scored during the assessment.

3.5 Affordability

Seven affordability criteria were identified and defined by the focus group.

Initial Platform Cost refers to the initial cost of the sUAS platform.

Battery Price refers to the cost of the batteries and associated chargers used to power the sUAS. Batteries are essential to the operation of sUAS, require charging and periodic replacement, and are likely to be purchased in multiple quantities to ensure that spares are on hand to facilitate continuous operation while in the field. It was noted that the cost of batteries for sUAS can greatly increase an agency's investment over time.

Payload/Options Costs refers to the cost of sensor payloads and other options that are not included with the initial sUAS platform. Depending on the sophistication of the sensors, camera, or other payload options, these items may cost significantly more than the sUAS platform.

Replacement Props/Parts Costs refers to the costs of replacement propellers and consumable parts that a public safety agency would purchase to maintain the sUAS. It was noted that the cost of consumables for sUAS can greatly increase an agency's investment over time.

Cost to Service System refers to the cost of a public safety agency routinely servicing the system to ensure that it is ready to be deployed when needed. Focus group participants noted that the systems currently on the market do not have service plans, and agencies view this as a risk.

Support Equipment Costs refers to the cost of support equipment that is needed to operate the sUAS in the field during search and rescue operations. This equipment may include a laptop, tablet, generator, etc.

Liability Insurance Cost refers to the cost of insurance that a public safety agency may purchase for liability risks from sUAS operations.

Although focus group participants provided and weighed affordability criteria, they articulated these criteria should not be part of the operational evaluation. Rather, information on affordability criteria will be listed in the final report.

4.0 EVALUATION CRITERIA ASSESSMENT METHODS

Focus group evaluation criteria will be assessed operationally or according to vendor-provided specifications. In an operational assessment, evaluators assess criteria based on their hands-on experience using the product. In a specification assessment, evaluators assess criteria based on information provided by the vendor. A specification assessment may be used for criteria such as payload capacity, where evaluators provide feedback on the vendor-provided specification, rather than by testing the sUAS with increasing weight payloads. In some cases, criteria may be assessed both operationally and according to vendor-provided specifications. The FRROST assessment plan will identify how each criteria will be assessed.

For criteria focus group participants declined to evaluate, evaluators will not score those criteria at the assessment; however, information on those criteria will be provided in the assessment report.

5.0 ASSESSMENT SCENARIO RECOMMENDATIONS

The focus group recommended two search and rescue scenarios in which sUAS could be assessed using the evaluation criteria recommended. It was suggested that both scenarios could be performed under daylight conditions and repeated at night, for a total of four scenarios.

5.1 Lost Hiker (Daytime/Nighttime) Scenario

Evaluators will use each sUAS model to simulate search and rescue operations typical of a lost hiker response. The sUAS will be deployed to assist search teams on the ground. Focus group participants noted that it is common to employ multiple sUAS during operations. It is also common to have more than one operator (a pilot and a visual observer) controlling the sUAS.

Standard search patterns include parallel track, creeping line, square, and track line. These patterns are mission driven, and flight patterns would likely be determined by the remote pilot once on scene.

This scenario will be performed under daylight conditions and repeated after nightfall.

5.2 Post Disaster (Daytime/Nighttime) Scenario

Following a natural disaster, public safety agencies may need to engage in search and rescue operations. These operations would begin with initial reconnaissance to identify the high impact area(s) and determine the scope of the operation, followed by a cursory primary search and a more thorough secondary search.

Once the secondary search is complete, it was suggested that the sUAS assume an over watch posture, hovering over the scene until the battery is depleted. At this point, the scenario could be indexed or the battery could be swapped.

This scenario will be performed under daylight conditions and repeated after nightfall.

6.0 PRODUCT SELECTION RECOMMENDATIONS

The focus group participants noted that none of the commercial sUAS currently on the market were designed specifically for public safety missions. For the most part, they are not hardened or water resistant. As such, it is important to assess the capabilities and limitations of such systems under conditions present during search and rescue operations.

In discussing the sUAS models currently on the market, focus group participants identified some product selection criteria that may influence their decision to purchase one of these systems for the purpose of conducting search and rescue operations, including length of flight time, multiple camera platforms, payload capacity, and UL certification.

While discussing specific products for assessment, focus group participants expressed an interest in evaluating the capabilities and limitations of a number of sUAS from different manufacturers that span a wide range of sizes and price points. Focus group participants expressed an interest in seeing how lower priced models may compare to more expensive models. Participants noted that various manufacturers' sensors could be paired with each sUAS model leading to multiple combinations of systems. It was decided that for this assessment, the sUAS manufacturers' standard sensors, particularly the optical and/or infrared cameras, would be assessed. Table 6-1 presents the products recommended for assessment by the focus group; sUAS specifications and price range have been added using information from various sources including vendor websites. The final list of sUAS for evaluation will be determined during assessment planning.

Table 6-1 Product Selection Recommendations

sUAS	Specifications	Price Range
Aeryon SkyRanger R60 with HDZoom 30 and EO/IR MK-II	Quadcopter 23.6 x 23.6 x 11.8 in. 5.3 lbs. (without payload)	>$100,000
Aibot X6	Hexacopter 41 x 38 x 15 in. 7.5 lbs.	$25,000 - $50,000
Autel Robotics EVO	Quadcopter 13.3-in. diagonal 1.9 lbs.	$1,000 - $2,000
Autel Robotics X-Star Premium	Quadcopter 13.8-in. diagonal 3.1 lbs.	<$1,000
DJI Matrice 210 with HD+IR	Quadcopter 34.9 x 34.6 x 14.9 in. 10 lbs.	$25,000 - $50,000
DJI Mavic Pro	Quadcopter 13.2-in. diagonal 1.64 lbs. (including gimbal cover)	<$1,000
DJI Phantom 4 Pro + 2.0	Quadcopter 13.8-in. diagonal 3 lbs. with battery	$1,000 - $2,000
Intel Falcon 8+ with IR	V-form Octocopter 30 x 32 x 6.3 in. 2.65 lbs. (empty)	$25,000 - $50,000
Parrot Bebop-Pro 3D	Quadcopter 15 x 3.5 x 12.9 in. 1.1 lbs.	<$1,000
UAV America Eagle XF with EO/IR dual sensor	Quadcopter 43.5 in. dia. x 19.5 in. 13.5 lbs. (empty)	$25,000 - $50,000
Yuneec H520	Hexacopter 20.5 x 18 x 11.6 in. 3.6 lbs. with battery	$2,000 - $10,000

7.0 FUTURE ACTIONS

The focus group recommendations documented in this report will be used to guide the development of the FRROST sUAS assessment plan and the selection of products to assess. The FRROST sUAS assessment will occur at Combined Arms Collective Training Facility at Camp Shelby Joint Forces Training Center near Hattiesburg, Mississippi. Once the assessment is complete, the results will be published in an assessment report.

8.0 ACKNOWLEDGEMENTS

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