Proceedings of the INMM & ESARDA Joint Virtual Annual Meeting
August 23-26 & August 30-September 1, 2021

Title: **Process to Down-Select a Counter-Unmanned Aircraft System for Testing and Evaluation**

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Abstract:
Recent security events involving unmanned aircraft systems (UAS) have left many nuclear regulatory bodies and facility operators wondering if they should implement counter-UAS (CUAS) technologies. Many regulators and operators are, therefore, beginning to assess the risk and potential impact of UAS threats on site security and operations to determine whether implementing CUAS technology or products is warranted. If the risk of UAS incursion is determined to be unacceptable, the challenge of determining which CUAS technologies/capabilities to select and implement can seem overwhelming. In addition, understanding how to evaluate product specifications and claims made by manufacturers through defined testing is essential to the proper selection of capabilities that meet site/facility and regulatory requirements.

The process of incorporating CUAS technologies/capabilities into existing security systems includes critical steps to ensure optimal system performance. These critical steps include: developing CUAS requirements based on site/facility requirements (such as expense or mitigation limitations), performing a CUAS market survey, down-selecting CUAS based on requirements, defining test or evaluation criteria, developing test location requirements while considering important test location characteristics, and down-selecting a test location based on requirements. This process will provide a sound purchase justification for a CUAS that meets site/facility needs.

This paper will explain the steps of the down-selection process as well as lay out testing and evaluation considerations that support implementation of a CUAS that is appropriate for the needs of the site/facility. This process is based on a methodology that has been applied to the down-selection and testing of CUAS for high security applications.

1. INTRODUCTION

The potential for using an unmanned aircraft system (UAS) as a delivery platform or for facility surveillance for malicious intent at critical infrastructure is a security concern. As a result, the commercial sector is marketing a variety of UAS detection, assessment, and neutralization systems (i.e., counter-UAS [CUAS]), to mitigate the threat of UAS incursion. As UAS capabilities develop, so to do CUAS capabilities and options. To aid in the implementation of these systems, this work focuses on the process of CUAS selection so that the protection needs of critical infrastructure or material in transport are appropriately addressed. Regardless of the systems selected as candidates, the down-selection process culminates in testing and evaluation (T&E) to verify that systems meet protection and operational requirements of the facility or use case prior to purchase and implementation.

2. CUAS REQUIREMENTS AND DOWN-SELECTION PROCESS

Identifying and Developing CUAS Selection Requirements

A critical first step in selecting an appropriate CUAS for implementation is to identify and develop (i.e., document) CUAS requirements that are specific to the facility or use case. The main purpose for developing these requirements is not only to identify CUAS that best fulfill implementation needs but also to ensure a direct link and easy comparison of T&E results between technologies. CUAS requirements are commonly not well defined but can be derived from existing requirement documents (e.g., Design Basis Threat), risk assessments, and site- or operational-specific conditions. From these, one can evaluate what parameters must be met by the CUAS. Examples of CUAS requirements include: sensing and tracking range, sensing technology, assessment range, mitigation type and range (if mitigation is authorized), integration or interface constraints, operational environment, and cost.[1]

Perform Market Survey and Down Select Available CUAS Based on Requirements

Following the identification and development of CUAS selection requirements, the next step in the process is to perform a CUAS market survey. Utilizing multiple sources allows for the comparison and evaluation CUAS across the entire market and will help gain a full understanding of the available market and capability options. Because the market is evolving quickly to keep up with UAS capabilities, care should be taken to obtain recent market information. Saving the survey results in a spreadsheet with fields that capture comparative information such as sensing technology, assessment range, mitigation method, and cost may be helpful. After completing the market survey, perform a down-selection process to eliminate CUAS that do not meet requirements. If the number of CUAS candidates remaining is high after the down-selection process, CUAS requirements will need to be refined and the down-selection process performed again until a workable number of CUAS candidates remain. See Figure 1 below for an overview of the CUAS down-selection process:

[1] Sensing range, assessment range, and mitigation range is the point at which a CUAS first notices something is in the airspace, identifies the object in the airspace as a UAS, and stops the forward progress or mission of the UAS, respectively.

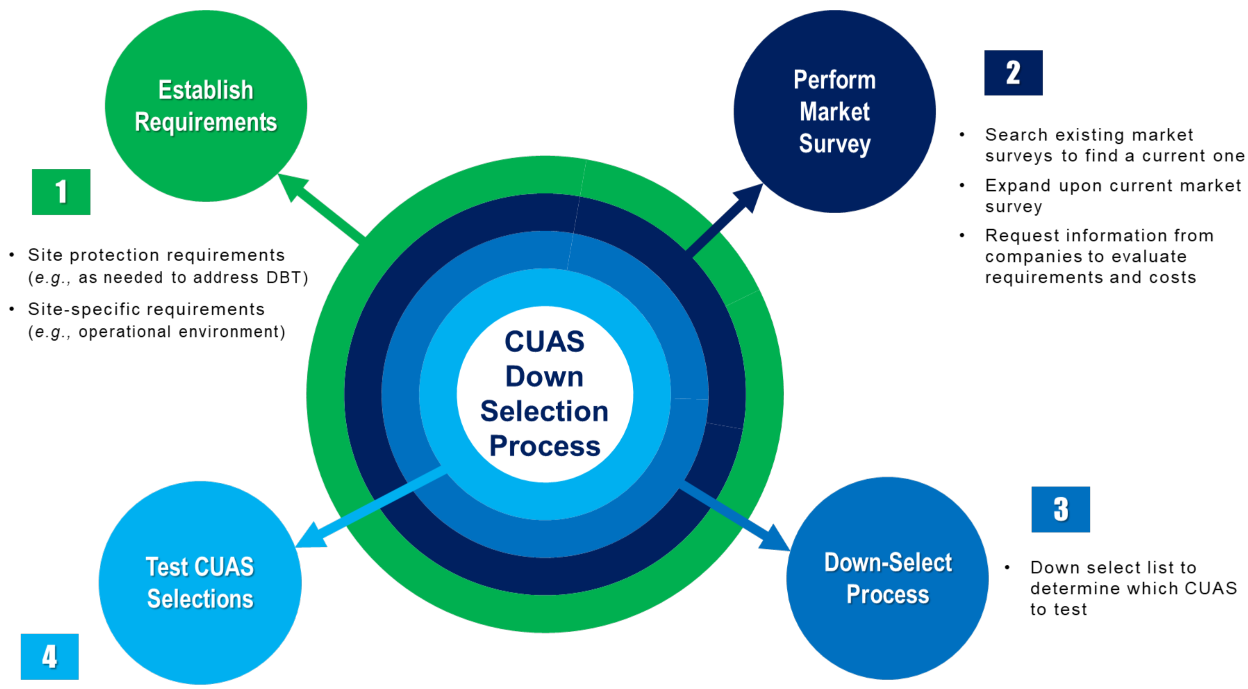

Figure 1. *CUAS Down-Selection Process Overview*

3. TEST LOCATION REQUIREMENTS AND DOWN-SELECTION PROCESS

Identifying and Developing Test Location Requirements

It is important to understand that actual system performance may differ from that advertised by the CUAS manufacturer, as the operational environment varies from ideal conditions. Therefore, once CUAS(s) have been selected based on the facility-/use-parameters, the next step in the down-selection process is to conduct T&E of the selected system(s). To accomplish this, a proper test location must be identified, and requirements for the test location should also be developed to ensure that the location characteristics allow for full T&E of the CUAS's performance capabilities. These test location requirements assist in test site selection if multiple options exist. Example test location requirements that should be considered include: available flight area, flight altitude limits, geographical environment mimics the implementation location as much as possible, airspace class (some classes of airspace require difficult to obtain approvals and have strict rules for UAS flights), accessibility, availability of power, safety and health requirements/approvals, operational times, and associated costs. Utilizing these test location requirements, the next step in the process is to identify the location(s) that meet these requirements.

4. TEST LOCATION APPROVALS

Before beginning any T&E, ensure that all flight and safety approvals have been put in place in accordance with the regulatory entities policy and regulations. Approvals required at most test locations for the operation of UAS and CUAS may include: airspace operations, radio frequency transmission, personnel and equipment access, and picture or video capture. Obtaining all needed approvals can involve several stakeholders and can take up to a year to complete.

5. TEST, ANALYZE DATA, AND MAKE FINAL CUAS SELECTION FOR IMPLEMENTATION

Test

The goal of testing is to ensure that each CUAS candidate meets the operational and facility/site requirements that were previously identified and to provide a meaningful, justifiable way to compare each CUAS in order make a final selection. Testing procedures should focus on standardized, repeatable tests, therefore. As an example, a standard fixed UAS platform (type) and UAS flight path, as shown in Figure 2 below, should be used. This way, tests can be reproduced, and test results more easily compared for each CUAS evaluated.

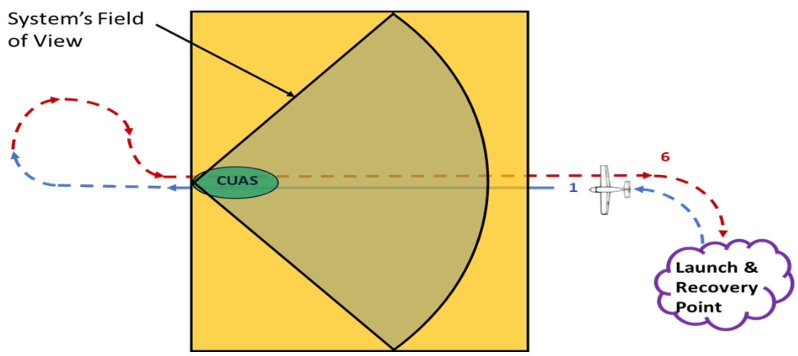

Figure 2. ***Standardized/Repeatable Test UAS Flight Path***

In addition, specialized testing should be conducted if time allows in order to analyze the performance of the CUAS under site-specific scenarios and to learn more about the tested CUAS. Examples of specialized flight tests include: sensing and mitigation limits of CUAS operation effectiveness, additional UAS platforms not included in standardized/repeatable tests, no-notice UAS incursions, and unique approach vectors. An example of a UAS flight path for specialized tests is shown in Figure 3 below.

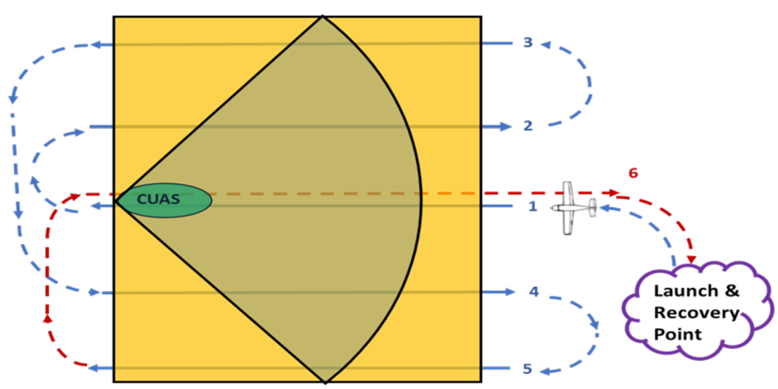

Figure 3. ***Example Specialized Test UAS Flight Paths***

Utilizing standard and specialized tests will provide data that can be used to calculate important performance metrics about the CUAS under test. Common performance metrics include: probability of sensing (P_S), probability of assessment (P_A), probability of detection (P_D), probability of neutralization (P_N), sensing point (SP), assessment point (AP), detection point (DP), neutralization point (NP), and nuisance alarm rate and false alarm rate (NAR/FAR). Figure 4 shows a notional example of a UAS incursion and CUAS performance metric volumes:

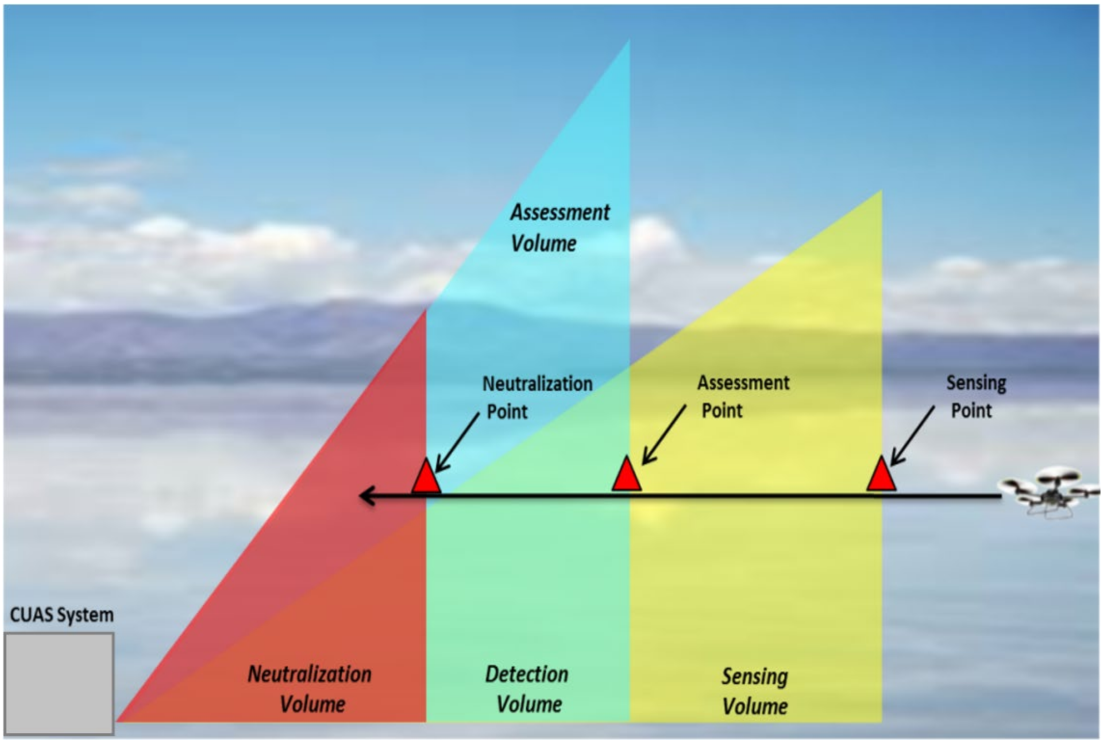

Figure 4. ***Illustration showing CUAS performance metrics volumes.***

Sensing characterizes the capability of a sensor to react to a UAS stimulus and initiate an alarm. The following sensing metrics are used to evaluate each component of the CUAS technology. Probability of Sense (P_S) is the probability associated with the capability of the sensor to detect the presence of a UAS. Sensing Point (SP) is the location at which the UAS is sensed by the CUAS. The SP is characterized by coordinates referenced from the CUAS location. [1]

Assessment characterizes the CUAS capability to determine the cause of an alarm, specifically, whether the alarm was caused by a UAS. Depending on the CUAS technology, assessment may or may not require the presence of a human operator. For example, assessment may require an operator to study an image provided by a camera to determine if an alarm is caused by a bird or a UAS. If an alarm is associated with detection of a specific communications protocol, then assessment may not require human interaction. The performance metrics used to quantify the effectiveness of a CUAS's assessment ability are Probability of Assessment (P_A) which is the probability associated with the CUAS's capability to determine whether the alarm was caused by a UAS or some other stimulus such as weather or wildlife and Assessment Point (AP) which is the location at which accurate assessment occurs. The AP is characterized by coordinates referenced from the sensor location. [1]

Detection. Probability of detection is the product of P_S and P_A. Detection is dependent on the capability of the sensor's performance to declare an alarm during an adversary intrusion and the capability to accurately assess the cause of the alarm. The performance metrics used to quantify the effectiveness of a CUAS's detection ability are Probability of Detection (P_D) which is the probability of the CUAS to sense and assess the presence of a UAS and Detection Point (DP) which is the location at which the UAS is detected by the CUAS. The DP is characterized by coordinates referenced from the CUAS location. [1]

Neutralization is defined as the capability to direct the UAS away from a location or to stop its forward progress. The neutralization performance of a CUAS is evaluated using metrics based on probability and location. Probability of Neutralization (P_N) is the probability associated with the capability of the CUAS system to direct the UAS away from a location or to stop its forward progress. Neutralization Point (NP) is the location where the UAS is effectively neutralized, meaning the UAS is no longer under the control of the original pilot. Ideally at this point, the UAS is now flown/controlled by the CUAS to a specific location where the response force can appropriately address the threat. If the CUAS technology does not have the capability to fly the UAS to a specific set of coordinates, the NP is where the UAS's forward progress is halted by the CUAS, and the UAS is forced to land or return to its takeoff location. The NP is characterized by coordinates referenced from the sensor location. [1]

NAR/FAR. CUAS nuisance alarm rates (NAR) is an alarm reported by the sensor that was assessed to be caused by some stimulus other than a threat (e.g., birds or inclement weather). The NAR represents the number of nuisance alarms created per day. A high NAR overwhelms the ability of the alarm monitoring staff to assess the cause of every alarm. CUAS false alarm rates (FAR) is an alarm reported by the sensor for which the system was unable to determine a cause. FAR represents the number of false alarms created per day. False alarms are recorded whenever UAS are not being flown and an alarm is generated by the CUAS. [1]

Analyze Data

The amount of data collected will be dependent on many factors, such as length of testing and data outputs from CUAS and UAS. Once the test data is analyzed, it is helpful to display the data using a graphic to simplify the CUAS performance data and provide a simple means of comparing systems. An example of this type of graphic is a star chart, as shown in Figure 4 below. This notional chart shows CUAS desired performance along with results from best- and worst-case data.

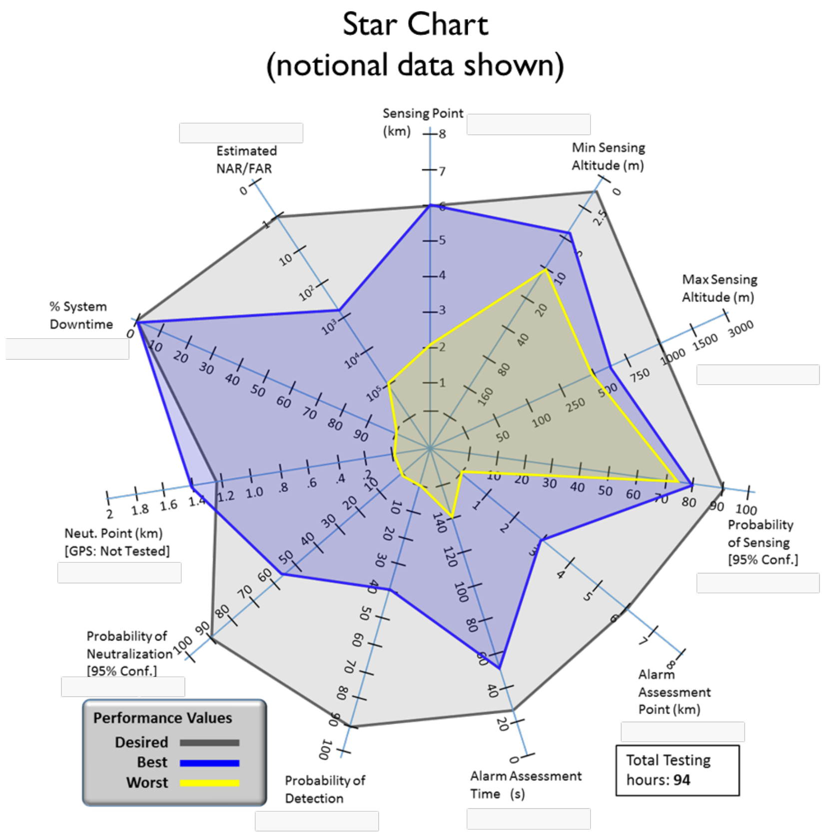

Figure 4. CUAS Performance Data Star Chart

Final CUAS Selection for Implementation

The final step in this process is to conduct a post-test comparative review to decide whether the CUASs met all requirements and, if not, whether unmet requirements are tolerable. Other questions may need to be considered as well. Is the CUAS cost appropriate for the level of risk reduction? How easy was it to work with CUAS manufacturer? What level of operator training is required? Is the system adaptable or sustainable to accommodate improvements needed to address evolving UAS technology? Using this recommended down-selection process will allow for an educated, justifiable CUAS selection that meets facility/use case needs.

REFERENCES

[1] Russell, John, et al. *Development Of Metrics And Requirements To Enable Down-Selection And Evaluation Of Commercial Counter-Unmanned Aircraft Systems Products*.

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