Elaboration on Table D: UAS Design Specifications

# Introduction

Different public safety consumers of maps care about different map quality measures, such as coverage, density, global accuracy, local accuracy, topological accuracy, free space reporting, and the symbolic segmentation and representation of planes and other objects. These measures can be competing; thus, given limited time and resources, a mapping system may be optimized towards some of these at the expense of others. In this document, we aim to provide guidance for a technically actionable interpretation of the overall challenge goal to help teams better understand the aspects of map quality that will be rewarded in this competition.

This elaboration is not yet final, and feedback regarding points of clarification is welcomed by August 11, 2023.

## The Public Safety Scenario

The Challenge Requirements and Objectives reflect the needs of public safety personnel who seek to move themselves and their equipment through the mapped space, searching for people and objects of interest in an indoor, constrained environment. A map user in this scenario cares a lot about understanding the layout of the space, where they can move, and where important objects may be located. In contrast to, say, an engineer or someone deploying breaching equipment, they find map quality measures such as the degree to which absolute local and global accuracy are achieved to be less critical. For example, they are ***not*** looking to measure the minuscule displacement of beams or to know precisely within a millimeter what is on the other side of a wall. The following required capabilities reflect this specific public safety user’s point of view.

# Required and Additional Preferred Capabilities

## Indoor 3D Map Deliverable

### Map delivery time

The 3D map shall be streamed in (near) real-time while the UAS moves through the indoor, constrained environment where access to the Internet may not be reliable nor guaranteed. The ideal scenario is to have the best map possible at any given time. The final streamed map can be submitted instantly at the end of the mission, with zero post-processing time, maximizing their points for processing time. Alternatively, up to 30 minutes after the mission is allowed to download and process the data from the UAS or use a remote data processing facility to produce a better map. However, the points for processing time will decrease proportionally to the time taken for post-processing, down to zero if the maximum allowed time is used.

### Map file format

In order to facilitate the scoring of the maps for the competition, the map shall be delivered in a format that satisfies the following criteria.

* Is viewable on a PC or Mac, running the latest version of Windows or MacOS, with “mid-range gaming” levels of hardware (e.g., a mid-range gaming laptop).
* Allows the user to view the map rendered from arbitrary 3D perspectives (e.g., “Bird’s-eye” or “3rd person” views), in addition to locations along the UAS path.
* Allows the user to measure the distances between points on the map.
* Allows the user to export rendered images and “slices” from the map (as one might do to generate 2D maps).
* Either natively saves maps in or implements the export of at least one of the following open formats, including any additional information that the teams may have extracted and wish to demonstrate, such as objects of interest, segmented planes, UAS path, and so on (some of these formats may not be suitable depending on what additional information teams extract).
  + ISO Standard (X3D) format.
  + Pointcloud Library (PCD) format.
  + Polygon (PLY) format.
  + Wavefront (OBJ) format with associated textures.
  + Open Geospatial Consortium Indoor Mapping Data (IMDF) format.
  + Teams may also nominate an open file format for inclusion with a justification.

Teams shall provide the map in a format that satisfies these criteria and a map viewer (e.g., freely available open-source or commercial software). Teams that elect to use their proprietary software to fulfill these requirements must provide the competition organizers with a royalty-free license that any competition organization personnel may use for the duration of the competition. Teams that elect to use commercial software to fulfill these requirements must include it in the bill of materials (BOM) with at least six months of subscription or license and provide Challenge Administrators access to the software (any additional licenses allocated for Challenge Administrators may be excluded from the BOM).

### Surface Gaps

This scenario values topological accuracy over local or global dimensional accuracy. This means it is more important to trace a path through the map and be confident in the relative location and size of the gaps, doorways, hallways, and rooms that may be navigated. As a guide, we assume a person can fit through a 1x1 ft gap. Thus, surfaces in the environment, such as walls, floors, and ceilings, that do not actually have such gaps should appear on the map without gaps or holes greater than 1x1 ft, so users understand that they cannot pass through. Similarly, any actual gap in surfaces in the environment greater than 1x1 ft (such as a window or a doorway) should appear as such in the map, without stray points or surfaces that may imply that the gap is blocked, so users understand that they can pass through. Such gaps in maps that do not exist in the real world, or such gaps that exist in the real world that do not exist in the map, will incur a penalty relative to the number and size of the gaps.

### Object Detection

The map should be of sufficient density and local consistency for the public safety user to identify two types of objects of interest readily. The first will be rectangular prisms of varying sizes in the environment consistent with where tripping obstacles might be of concern. The second will be sets of standardized objects placed randomly (note: additional descriptions of the standardized objects will be provided later). Teams will not be told the location or number of these objects in advance. According to [Johnson's criteria](https://www.osti.gov/biblio/1222446/), the map must have at least 2x2 data points (e.g., points of a point cloud) on at least 1 face of the rectangular prism or the standardized object to be considered to have detected the object. Partial credit is awarded if the detected object is not included in the 3D mapping data but is shown using other means (e.g., texture mapping). Environmental lighting may vary from bright to unlit.

### Dimensional Error

Dimensional accuracy is measured in relative terms. The public safety user cares that a hole that looks 2 ft wide is within an inch or so, affecting their decision to bring equipment through. In contrast, they only are interested that a hallway that is 100 ft long is reported within around 5 ft of this measurement. In this competition, a dimensional error is evaluated based on a combination of the percentage error in the Euclidean distances between the mapped locations of objects of interest and the percentage error in the mapped dimensions of significant doorways in the environment.

## 3D Map Progress Rendering (also see Map delivery time)

Time is of the essence when it comes to building maps for public safety applications. Thus a draft map needs to be generated and shown to the public safety user in approximately real-time (i.e., no more than 10 seconds of latency), on the understanding that re-traversals and loop closure may cause the map to update or "jump" from time to time.

## Map Data Acquisition Speed

It is also important to be able to map an area at an operational pace. For a given target map quality, mapping speed depends on environmental complexity due to occlusions. For this evaluation, teams should be able to map simple, approximately piecewise linear, textured parts of the test environment, such as an office building hallway with office doors closed and simple furniture, such as cabinets, against the walls, to their usual level of map quality according to the mentioned capability requirements, at a rate of at least 2 ft/sec.

## Human Detection

Humans are particularly important objects of interest. The system should enable the detection of stationary human mannequins with typical skin colors. The humans may or may not be fully visible (e.g., only a limb may be visible). The humans may or may not have thermal signatures. Environmental lighting may vary from bright to unlit. Detection by the human operator is required, and automatic detection is ideal. Teams should be careful to avoid false positives.

## Real-Time Video

Although the primary focus of this competition is 3D mapping, real-time video is still important for situational awareness and live inspection. The requirement of live video at a resolution of 640x480 pixels at 10 fps is a guide to an acceptable lower bound. It is unlikely that systems such as conventional analog video transmitters will meet this capability requirement. Teams will be judged on how suitable their video feed is for giving the remote operator both situational awareness of the environment and the ability to inspect objects, such as trip hazards and hazmat placards, as the UAS flies through the environment.

The specifications allow teams to make design decisions that trade off the field of view, acuity on target, image resolution, frame rate, image compression, how fast the UAS flies, how close it needs to get to objects to inspect them, and so on. We welcome using novel camera configurations, including systems that present composite information from multiple and omnidirectional cameras. Teams may elect to use separate cameras for this live video feed or cameras that are also used for mapping.

Additional Preferred Capability: Blue/Green UAS Capable

The intent for including this requirement as an additional preferred capability is to encourage teams to consider building their UAS for public safety agencies who have been impacted by their state policies that limit procurement of UAS manufactured or built with foreign parts from foreign countries impacting U.S. national security. The current federal government policy affects the Department of Defense and the military’s ability to procure UAS from some foreign entities. It has started to impact procurement in state and local public safety agencies adopting these policies. This challenge will bring awareness to public safety agencies' obstacles and encourage UAS builders to build towards this evolving policy. You can learn more from the [Defense Innovation Unit (DIU) summary](https://www.diu.mil/blue-uas-policy) or [congressional bill](https://www.congress.gov/bill/117th-congress/house-bill/7776/text) for the National Defense Authorization Act (NDAA) for Fiscal Year 2023. AUVSI recently began to assist in this topic by creating a commercial certification (e.g., non-military) and labeling it Green UAS. For teams seeking an industry certification of Blue or Green UAS, this challenge is not an authorized certification program.

Since the Blue/Green UAS capability is not required to participate in this challenge, those teams that choose to be scored on this capability can improve their base score throughout the challenge. The impact on the overall team score in the Stage 3 Live Test is minimal. However, teams will be able to win a “Best-in-Class Blue or Green UAS Capable” prize award of $10,000 and an invitation to Stage 4.1. The prize is based on maximizing the number of Blue/Green UAS components or having the least amount of parts manufactured from a "covered foreign country," meaning the People's Republic of China, the Russian Federation, the Islamic Republic of Iran, and the Democratic People's Republic of Korea, as well as “covered unmanned aircraft system companies.” Covered companies include Da-Jiang Innovations and those companies on the Consolidated Screening List https://www.trade.gov/consolidated-screening-list.

Teams may be unaware that their UAS contains components in their solution with an origin from a “covered” foreign country or UAS company, so this additional preferred requirement can only be claimed if teams provide a web link to the part proving its location of origin, a certificate of origin (COO), or other relevant documentation. Additionally, building or assembling your UAS in the U.S. does not make it a Blue/Green UAS if NDAA-compliant companies do not make the main components. This requires teams to look for compliant components such as electronic speed controllers, transmitters, video transmission systems, etc., versus non-compliant chips. For example, a UAS assembled in the United States with components manufactured in the People's Republic of China would not meet compliance specifications.