Detection of Presence of Life (DePLife) Prototype

Operational Field Assessment Report

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FOREWORD

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EXECUTIVE SUMMARY

On October 18, 2022, the Department of Homeland Security (DHS) Science and Technology Directorate's (S&T) National Urban Security Technology Laboratory (NUSTL) conducted an operational field assessment (OFA) of MaXentric's Detection of the Presence of Life (DePLife) prototype at the MaXentric facility in La Jolla, CA. The OFA consisted of nine law enforcement and first responder evaluators deploying three identical prototypes. Research and development of the prototypes was funded and managed by DHS S&T's Office of Mission and Capability Support (MCS).

The DePLife is a radar-based system that distinguishes between living and non-living objects behind walls and determines the number of people present. The prototype included radio frequency (RF) transceivers, digital processers, antenna arrays, and data storage devices for operational evaluation. Specialized algorithms and software controlled the radar system; detected, tracked, and interpreted movements over time as people; and helped visualize the locations of the people detected. A remote user interface displayed radar returns and detections. The prototype system was hands-free during operation, remote operated via a mobile phone user interface, and able to detect one or more lifeforms. The solution is expected to be integrated with commonly used first responder equipment and is not meant to burden the operator with unusual or complicated attachments.

During the OFA, evaluators operated three prototype radars in three different scenarios: two indoor scenarios with interior walls and one outdoor scenario against an exterior wall. Prototypes were at a technology readiness level (TRL) of 6, which denotes a successful prototype or representative model tested in a relevant environment. Additional development efforts are required to achieve a mature, commercially available product.

Throughout the OFA, evaluators provided feedback on the strengths and weaknesses of the system. The evaluators expressed a need for this capability and provided several use cases, but indicated a preference for a more accurate and precise device to determine or approximate the number of lifeforms. Evaluators agreed that the DePLife prototype was able to detect people through walls and that it was easy to set up, use, and interpret the radar display. However, the accuracy and false positives greatly reduced the evaluators' confidence in using the output results to form a solid conclusion. Missed detections and false positives occurred, which lowered the evaluators' confidence in the device. The evaluators agreed that the prototype device was easy to use and deploy, lightweight and mobile, and had an adequate field of view (FOV) for operational use.

Evaluators suggested the following improvements to the DePLife system:

- Add ability to attach the device to a robot for remote deployment and operation.
- Improve software algorithms to increase accuracy and precision and to reduce false positives.
- Ruggedize the device.
- Add ability to distribute and transmit radar output/feed to multiple users (i.e., multiple phones or tablets).
- Add ability to combine the output from more than one radar onto one screen.

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1.0 INTRODUCTION

A technology that detects the presence of life (people) through building walls and displays their location and movement would be a game-changing tool for SWAT teams, giving them valuable situational awareness before breaching a room. Similarly, this technology would be invaluable to law enforcement officers searching for kidnapping or human trafficking victims.

The Department of Homeland Security Science and Technology Directorate (DHS S&T) awarded a contract to MaXentric Technologies, LLC (MaXentric) to develop three radar sensor Detection of the Presence of Life (DePLife) prototypes. The prototypes include radio frequency (RF) transceivers, digital processers, antenna arrays, and data storage devices as well as customized software that controls the radar system, distinguishes wall parameters, and shows the location of the people detected. A remote user interface was developed that displays radar returns and detections. The prototype can be operated hands-free or remotely to detect one or more lifeforms and to alert the operator. The solution is expected to be integrated with commonly used first responder equipment and not burden the operator with unusual or complicated attachments.

On October 18, 2022, the National Urban Security Technology Laboratory (NUSTL) conducted an operational field assessment (OFA) of the MaXentric radar prototype solution to determine whether select system requirements were met and to obtain user feedback. Nine law enforcement professionals and first responders served as evaluators. This report describes the OFA activities performed, the results from those activities, and the evaluators' feedback.

1.1 PURPOSE

The purpose of the OFA was to assess the capabilities and usability of the DePLife prototype in a realistic operational environment.

1.2 OBJECTIVE

The OFA was designed to complete the following tasks:

- Assess the capabilities of the DePLife prototype.
- Assess the usability and functionality of the DePLife prototype and how intuitive it is to operate.
- Provide feedback to the DHS S&T program manager and to the developer (MaXentric).

1.3 REQUIREMENTS

Table 1-1 summarizes the requirements that the DePLife prototype was expected to meet and the ways those requirements were tested during the OFA.

Test requirements were derived from the Statement of Work, which identifies critical capabilities for functionality. The requirements in this matrix were reviewed and validated by the DHS S&T Office of Mission and Capability Support (MCS) program manager.

Table 1-1 DePLife Requirements and Activities Matrix

No.	Requirement	Assessment Method(s)
Detection Capabilities		
1	Detect the presence of life and number of people and determine whether the people are moving or stationary (upright or laying down) and if they are detectable through standard construction walls (interior)	• Evaluators were asked to deploy the DePLife prototype in multiple scenarios and determine whether there were people in a room on the other side of the wall, how many people were present, and whether the people were stationary or moving. • Reflectors (walls, furniture, etc.) were used to obscure people from the device. • NUSTL developed a test matrix to systematically determine the maximum number of people that the DePLife prototype detects in different scenarios. • Additionally, the NUSTL team determined limitations by adding stationary objects like furniture and appliances and moving objects like fans.
2	Detect people at a distance from the prototype radar	Evaluators deployed the DePLife prototype and determined if they could detect and locate people at various distances and at an angular field of view from the prototype radar. They determined where people were located and distributed in the room.
System Attributes		
3	Deployment time is acceptable for operational use	• NUSTL data collectors recorded the deployment time for each trial. • Deployment included the following tasks: unpack, assemble the radar, perform checkout, mount the radar to the tripod, verify the mount assembly, select a wall, move the radar assembly to the wall, select a site on the wall for initial radar placement, place the radar, activate the user interface (UI), and verify the UI is connected to the radar. • Data collectors determined an average and a range of deployment times.
4	Usability is acceptable for operational use	• NUSTL data collectors recorded feedback from the evaluators on the deployability and usability of the DePLife prototype. • Data collectors asked the evaluators questions on the graphical user interface (GUI), form and fit, set up/deployability, and their ability to understand the prototype's output. • Evaluators determined whether the prototype required one user or two users to operate.
5	Ability to switch between covert and overt alerts	• Evaluators determined ability to switch by operating in the prototype's two different modes: silent alert (covert) and audible alert (overt). • Data collectors asked the evaluators if the covert and overt functionality existed and whether it was easy to use and intuitive (i.e., does it meet end-user expectations? Or is it confusing and hard to use?) • All alert modes were provided through the UI app. Users had the ability to operate in either overt or covert alert mode.
6	The system has wireless communication capabilities	Evaluators and data collectors tested the ability to wirelessly share data output with Android tablets, determined the distance from the radar at which the tablets operated properly, and tested the ability to record and store data for after-engagement action reviews.

1.4 OFA EVALUATION QUESTIONNAIRE

DHS S&T NUSTL created a questionnaire to assess the capabilities and functionalities of the DePLife prototype. The NUSTL data collectors used the questionnaire to interview the evaluators and obtain feedback and comments on the prototype system during and after training (Table 1-2) and during and after deployment and operations (Table 1-3).

The evaluators answered whether they strongly agreed, agreed, were neutral, disagreed, or strongly disagreed with the statements in the questionnaire and were given the opportunity to elaborate on their answer and provide additional feedback.

Table 1-2 Questionnaire for Training

Correlated Requirement from Table 1-1	Statement to Evaluator
4	1. The system hardware was easy and intuitive to deploy and set up
4	2. The size and weight of the system hardware made it easy to handle while deploying and setting it up
4	3. The system software (including control software and radar display interface) was easy and intuitive to deploy and set up
6	4. I was able to connect the radar hardware wirelessly to the mobile device
3	5. I was confident in my ability to properly position the device
3	6. I was properly trained in how the first responders' body can interfere with radar feedback

Table 1-3 Questionnaire for Deployment and Operations (Interior and Exterior)

Correlated Requirement from Table 1-1	Statement to Evaluator
1	1. I was able to detect people through exterior walls and easily interpret the radar display, including number, location, position (standing, laying down, moving), speed of target (if moving), and validity of targets (real target or interference)
1	2. The way the identification level of confidence was shown on the display was adequate
2	3. The detection range and field of view (FOV) of the radar was acceptable for operational usage
3	4. The time to deploy the system (hardware and software) was acceptable for operational usage
3	5. I was confident in my ability to properly position the device
4	6. The system could be easily deployed and set up
4	7. The radar hardware was easy and intuitive to operate
4	8. The system software (including control software and radar display interface) was easy and intuitive to set up and use
4	9. I had a full understanding of when to move the radar to avoid reflectors and blockage
2	10. I can interpret from the device's display where reflectors (walls, furniture, etc.) are located
1	11. I did not observe any false positives during the testing
1	12. I did not observe any missed detections during the testing
5	13. Switching between overt and covert alerting modes was easy
5	14. I was able to successfully receive, interpret, acknowledge, and/or resolve overt alert notifications
5	15. I was able to successfully receive, interpret, acknowledge, and/or resolve covert alert notifications
6	16. I was able to connect the radar hardware wirelessly to the mobile device
6	17. It was easy to record and store data for after-action reviews

Correlated Requirement from Table 1-1	Statement to Evaluator
6	18. The content and amount of data that can be recorded is acceptable for my agency's usage

1.5 SYSTEM DESCRIPTION

DHS S&T collaborated with MaXentric to design and fabricate a sensor-radar prototype to detect the presence of life behind building walls. The DePLife device can provide a real-time, through-walls radar scene indicating when people are present and their respective locations up to 30 feet from the radar source.

The principal technology operating is an 8GHz ultra-wideband (UWB) multiple-input and multiple-output (MIMO) radar based on the X4 UWB System-on-Chip (SoC) developed by Novelda, Inc. with one transmitting channel and four receiving channels. The channels are set up in a time duplexing method, in which there are four radar SoCs on the antenna board with the first channel set to transmit and receive and the last three channels set to only receive. The antenna board is connected to a controller baseboard with an i.MX RT1060 Crossover MCU for internal processing. This baseboard acts as a standalone Wi-Fi access point streaming a unique Wi-Fi service set identifier.

To deploy the device, the system is attached to a tripod and leaned against the wall of interest (see Figure 1-1). Users stand 3–5 feet away from the radar unit when operating it. Users control the radar by connecting a tablet or phone application to the radar Wi-Fi, at which point the radar will start streaming results on the screen.

Figure 1-1 DePLife prototype deployed

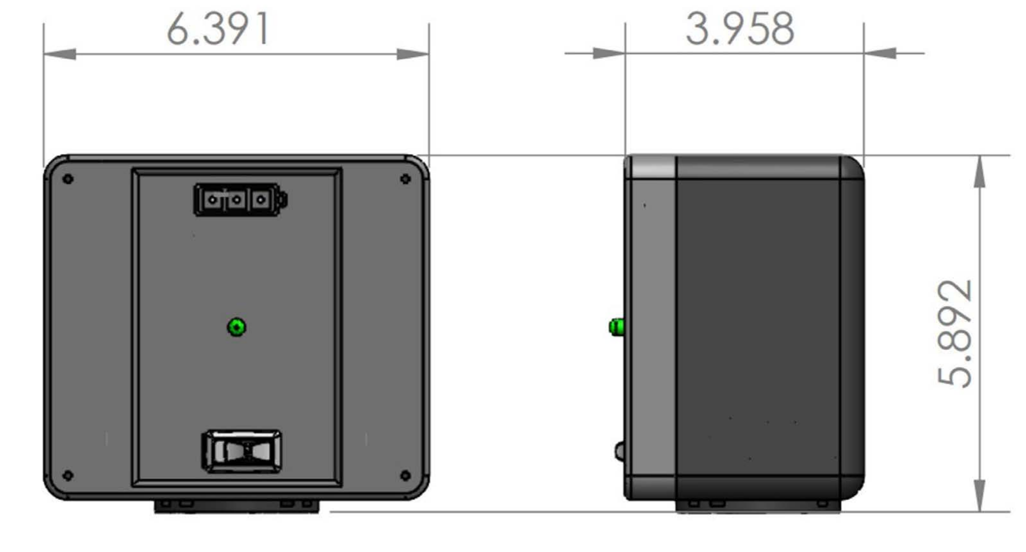


Figure 1-2 DePLife prototype dimensions

The prototype's dimensions are 6.39" x 3.96" x 5.89" and its weight is 2.1 lb. (Figure 1-2).

The software application shows a two-dimensional (2D), birds-eye view relative to the radar's location. The suggested setting shows a real-time, motion-filtered colormap that highlights moving targets in the scene and has icons overlayed on top that indicate the presence and location of moving or stationary people.

The user has the option to swap between the following visualizations:

- Motion-filtered: real-time—a real-time, motion-filtered colormap that highlights moving targets within the scene.

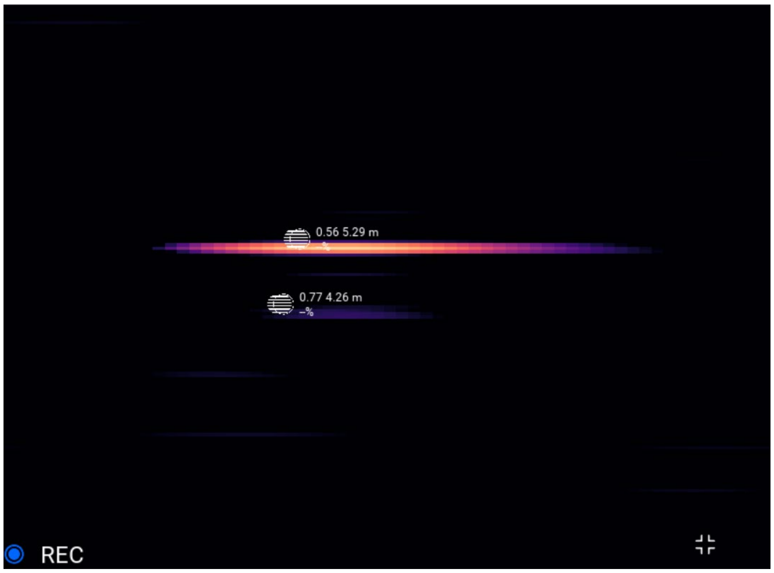


Figure 1-3 UI for the Motion-filtered: real-time visualization

- Motion-filtered: 10s—a 10-second, motion-filtered colormap highlighting stationary or weaker targets from the scene. Because this setting requires 10 seconds of data to build a sufficient image, if someone walks through the room, the data will smear for 10 seconds until the data block resets.

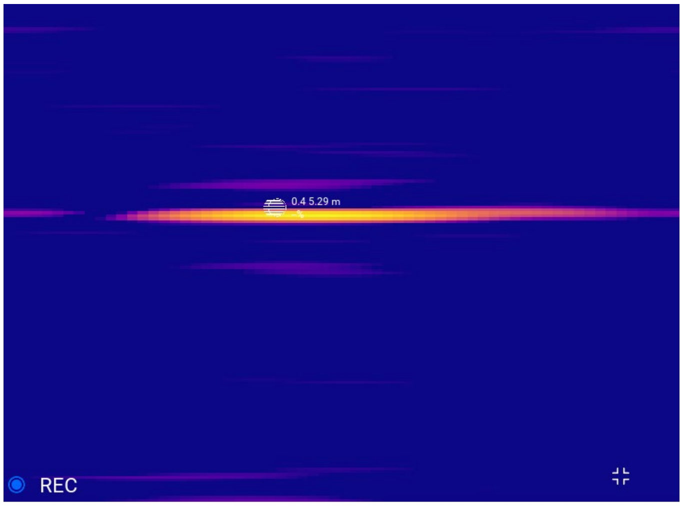


Figure 1-4 UI for the Motion-filtered: 10s visualization

- Unfiltered: reflectors—a real-time, nonfiltered colormap of the radar results. This highlights the locations of strong reflectors in the scene such as walls, furniture, or other clutter. This display is very useful for identifying the layout of rooms and for helping the user find good radar placement for the device.

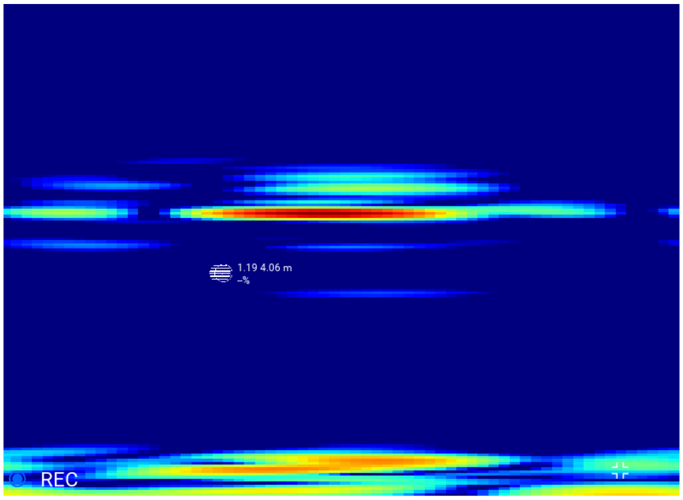


Figure 1-5 UI for the Unfiltered: reflectors visualization

- Blank—a black screen that shows only icons without a colormap.

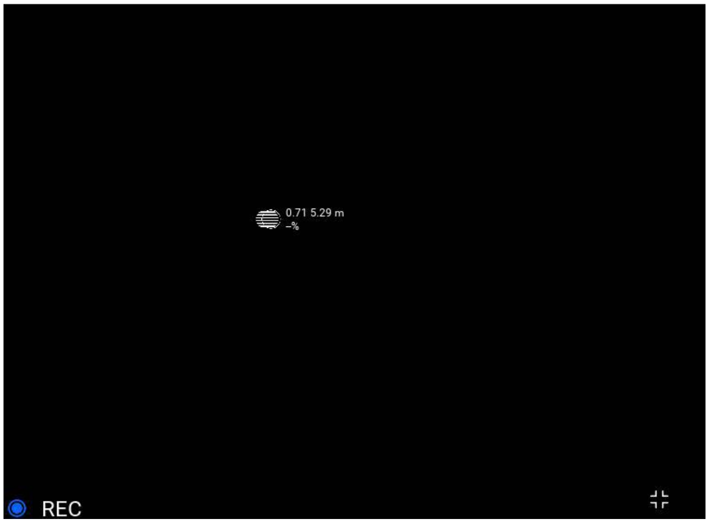


Figure 1-6 UI for the Blank visualization

In each of these visualizations, the icons can be enabled or disabled. The icons are based on internally developed algorithms that evaluate various length data blocks.

2.0 OPERATIONAL FIELD ASSESSMENT DESIGN

2.1 EVENT DESIGN AND EXECUTION

On October 18, 2022, NUSTL conducted an OFA of the DePLife radar prototype to assess the technology's ability to detect through walls the presence, location, and movement of human life in a building. For this OFA, nine end users from the law enforcement and first responder communities served as evaluators and assessed the capability and usability of the prototype radar system in test trials. During these trials, the evaluators addressed the requirements listed in Table 1-1.

The evaluators were grouped into three teams of three. Each team performed parallel activities using the three available prototypes. Each team rotated through three stations (two indoor and one outdoor). For each activity, evaluators conducted tasks working together or taking turns. OFA data collectors from NUSTL shadowed each evaluator team to record the evaluators' observations and collect user feedback after each activity using a questionnaire. In the room on the other side of the wall from the deployed radar prototype, people were configured in different spatial positions to determine where in space the prototype was able to detect them. These people also performed various movements (e.g., standing, walking, sitting, laying down, and waving arms). A comprehensive test matrix was constructed to vary the number of people, spatial positions, and level of activity to ascertain the capability and limitations of the prototype.

The evaluators were trained with the DePLife prototype before the deployment and operational scenarios. The evaluators transported the device case, removed a prototype from the case, mounted it on a stand (bipod or tripod), powered it on, wirelessly connected the radar to a tablet device, configured the system to a desirable setting, and operated the system at a distance from the radar.

In predetermined trials (Table 2-1), the evaluators deployed the radar device on a wall and determined whether people could be detected, how many people were present, and where in 2D space the people were located for each trial. Trials A through D in Table 2-1 were performed only once at the two interior stations and were designed to get an initial idea of the FOV of the radar system at each station, while trials 1 through 10 where repeated by each team and were intended to include multiple variables associated with the use of the system. In the room where the detectable people were positioned (on the other side of the wall from where the radar device was deployed), the arrangement of people and objects and the movements each person completed were modified for each trial according to the test matrix. The evaluators verbalized the system interpretation to the data collectors while performing the trials.

For the outdoor scenarios, evaluators deployed the device on an exterior wall. The evaluators determined whether people could be detected, how many people were present, and where in 2D space the people were located.

Table 2-1 Indoor and Outdoor Station Test Matrix

Trial	Interior Station 1	Interior Station 2	Exterior Station
A	1 person, walking along radar line of sight (LOS) at 0° angle	1 person, walking along radar LOS at 0° angle	No test trial defined for exterior station
B	1 person walking along radar LOS at 45° angle	1 person walking along radar LOS at 45° angle	No test trial defined for exterior station
C	1 person walking along radar LOS at 90° angle	1 person walking along radar LOS at 90° angle	No test trial defined for exterior station
D	1 person walking in 6' diameter circle at 0° angle at max range from radar LOS, 1 person walking in 6' diameter circle at 45° angle at max range from radar LOS	1 person walking in 6' diameter circle at 0° angle at max range from radar LOS, 1 person walking in 6' diameter circle at 45° angle at max range from radar LOS	No test trial defined for exterior station
1	No one in room	1 person standing at three-quarter max range and 0° angle from radar LOS, 1 person sitting at one-quarter max range and 0° angle from radar LOS, 1 person running parallel to wall at one-half max range	Test trial was not assessed
2	1 person standing still, 0° angle from radar LOS at three-quarter max range	1 person standing at three-quarter max range and 0° angle from radar LOS, 1 person sitting at one-quarter max range and 0° angle from radar LOS, 1 person laying on floor at one-half max range and 45° angle from radar LOS	No one in room
3	1 person walking parallel to wall at three-quarter max range	1 person sitting at three-quarter max range and 45° angle from radar LOS, 1 person lying on floor at one-half max range and 45° angle from radar LOS, 1 person laying on floor at one-quarter max range and 0° angle from radar LOS	1 person entering building, walking the full length of lab bench in both directions
4	1 reflector stationary at three-quarter max range and 0° angle from radar LOS, 1 person walking parallel to wall and behind reflector at three-quarter max range	1 person standing at three-quarter max range and 45° angle from radar LOS, 1 person standing at one-quarter max range and 90° angle from radar LOS, 1 person walking in circle at one-half max range and 0° angle from radar LOS	2 people sitting at opposite sides of lab bench on end nearest to the exit
5	1 reflector stationary at three-quarter max range and 0° angle from radar LOS	1 person laying at three-quarter max range and 45° angle from radar LOS, 1 person laying on floor at one-quarter max range and 90° angle from radar LOS, 1 person walking in circle at one-half max range and 0° angle from radar LOS	Test trial was not assessed

Trial	Interior Station 1	Interior Station 2	Exterior Station
6	1 reflector stationary at three-quarter max range and 0° angle from radar LOS, 1 person standing at three-quarter max range behind reflector and 0° angle from radar LOS, 1 person sitting at one-half max range and 45° angle from radar LOS	1 person standing at three-quarter max range and 0° angle from radar LOS, 1 person standing at one-half max range and 0° angle from radar LOS, 1 person standing at one-quarter max range and 0° angle from radar LOS	1 person standing in back corner of lab space
7	1 person standing 0° angle from radar LOS at three-quarter max range, 1 person sitting at one-half max range and 45° angle from radar LOS, 1 reflector stationary at wall just in front of radar	1 person laying on floor at three-quarter max range and 0° angle from radar LOS, 1 person laying on floor at one-half max range and 0° angle from radar LOS, 1 person laying on floor at one-quarter max range and 0° angle from radar LOS, 1 fan spinning at one-quarter max range and 45° angle from radar LOS	1 person standing on far side of the wall beyond exit
8	1 person standing at three-quarter max range and 0° angle from radar LOS, 1 person walking along radar LOS at 45° angle	1 person walking parallel to wall at one-quarter max range, 1 person walking parallel to wall at one-halft max range, 1 person walking parallel to wall at three-quarter max range, 1 fan spinning at one-quarter max range and 45° angle from radar LOS	1 person walking from back corner of lab space nearest the exit to the far side of the wall behind the exit and back
9	1 person laying on floor at three-quarter max range and 0° angle from radar LOS, 1 person crawling along radar LOS at 45° angle	No people in room, 1 fan spinning at one-quarter max range and 45° angle from radar LOS	Test trial was not assessed
10	1 person walking along radar LOS at 0° angle, 1 person walking parallel to wall at one-half max range	1 person walking along radar LOS at 0° angle, 1 person walking between far left side of room and near right side, 1 person walking parallel to wall at one-quarter max range	Test trial was not assessed
Notes: LOS is an imaginary straight line between the viewer (radar) and subject of interest, or their relative direction. The radar's maximum range was specified by the developer.			

Following the assessment, the OFA team held a group discussion to solicit additional feedback from the evaluators and review key observations made during the scenarios. Observers from DHS provided comments for additional discussion during this group debriefing.

2.2 PARTICIPANTS

Table 2-2 lists the OFA participants. The list includes nine law enforcement officers and first responders who served as evaluators to test and provide feedback on the DePLife prototype.

Table 2-2 Participant Roles and Organizations

Role	Organization	Location
Evaluator 1	Los Angeles Police Department (LAPD)	Los Angeles, CA
Evaluator 2	Story County Sheriff's Office	Nevada, IA
Evaluator 3	Los Angeles City Fire Department	Los Angeles, CA
Evaluator 4	Las Vegas Metro PD	Las Vegas, NV
Evaluator 5	DHS CBP Border Patrol	Tucson, AZ
Evaluator 6	Adams County Sheriff's Office	Natchez, MS
Evaluator 7	Cass County Law Enforcement Center	Omaha, NE
Evaluator 8	Dona Ana County Sheriff's Department	Las Cruces, NM
Evaluator 9	DHS Homeland Security Investigations–Los Angeles	Los Angeles, CA
Program Manager	DHS S&T MCS	Washington, DC
OFA Lead and Data Collectors	DHS NUSTL	New York, NY
Technology Developer	MaXentric Technologies	La Jolla, CA

2.3 TEST VENUE LAYOUT

The test venue was the MaXentric office building located in La Jolla, California. The facility had an indoor meeting room, several indoor workspaces, and an outdoor area. The meeting room was used for presentations, training, and group discussions. Two indoor areas and one outdoor area were used for testing. The layouts of these areas are shown in Figures 2-1 and 2-2 on the next page. The prototype radars were deployed in two rooms in the office building and one location outside. The interior walls were typical drywall and wooden stud construction and the exterior wall was a standard stucco wall with insulation. In Figure 2-1, the radar is situated against the wall in Room B, detecting the presence and movements of people in Room A. In Figure 2-2, the radar is situated against the wall in Room E, detecting the presence and movements of people in Room F. In Figure 2-3, illustrates the outdoor scenario, where the radar is situated against the outside wall, detecting the presence and movements of people in the hallway, lab space, and office room.

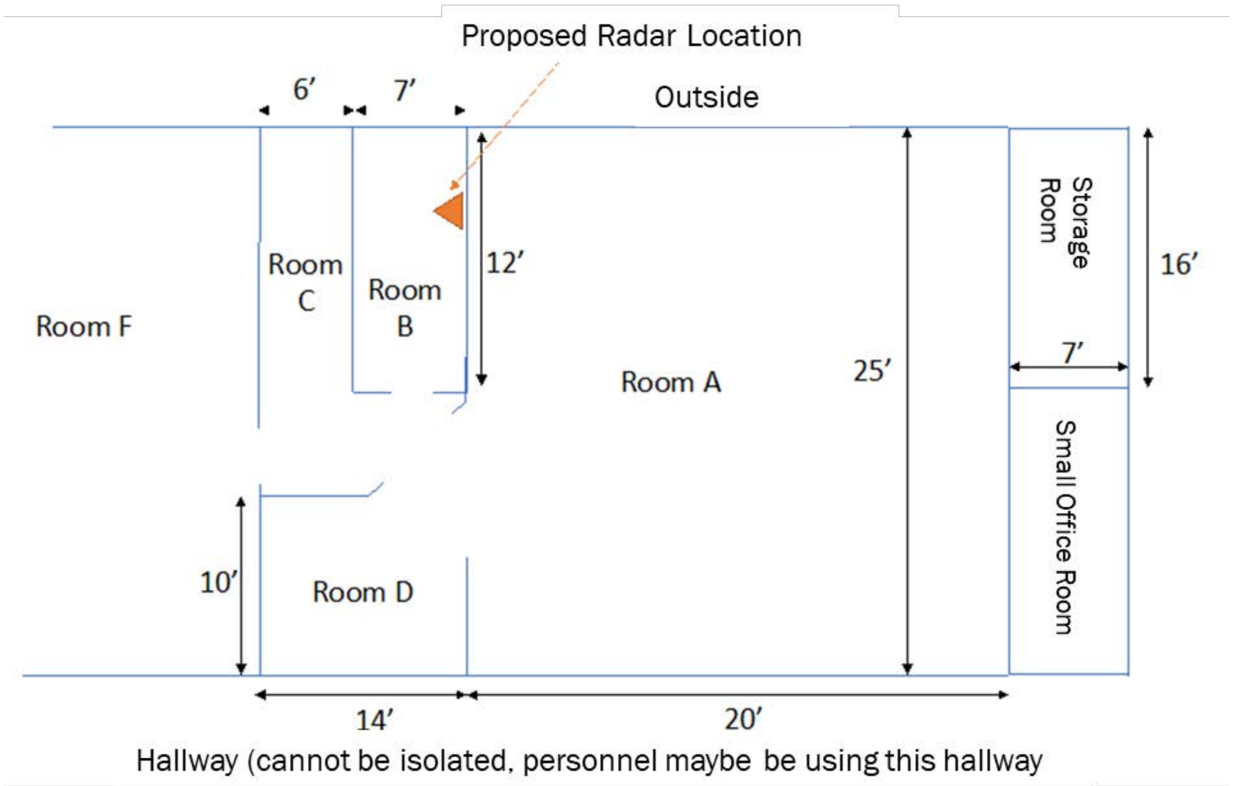


Figure 2-1 Layout of Interior Station 1

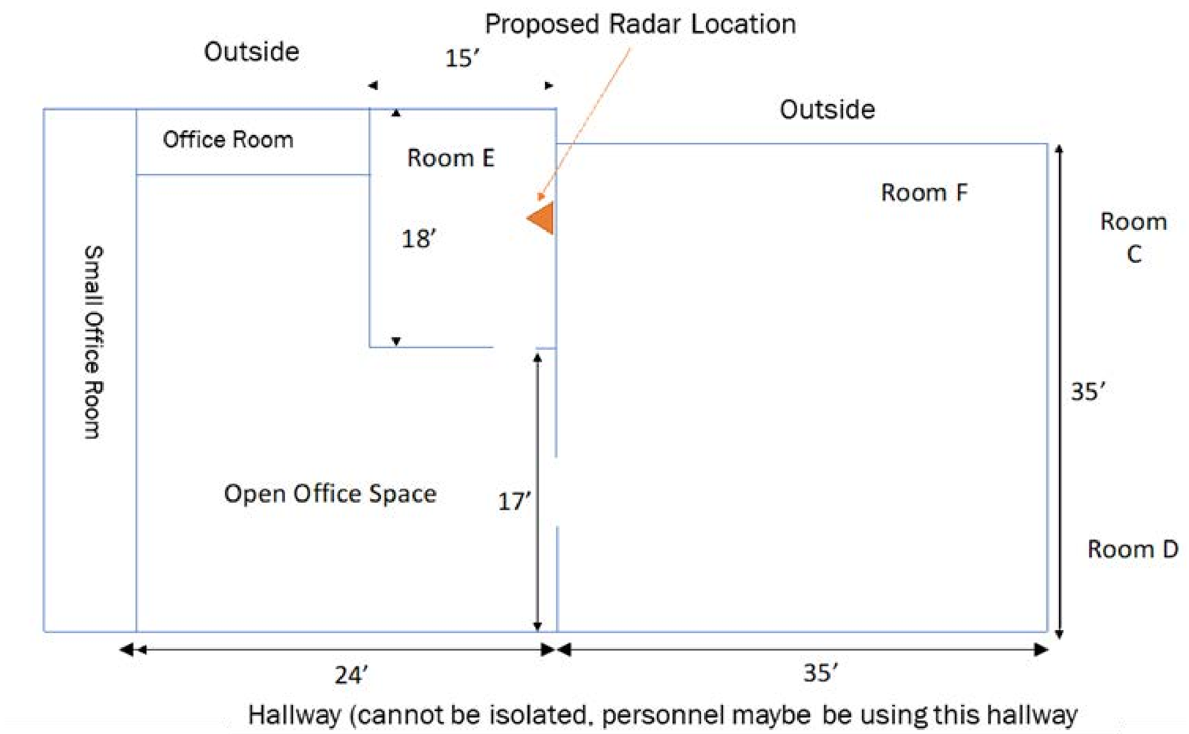


Figure 2-2 Layout of Interior Station 2

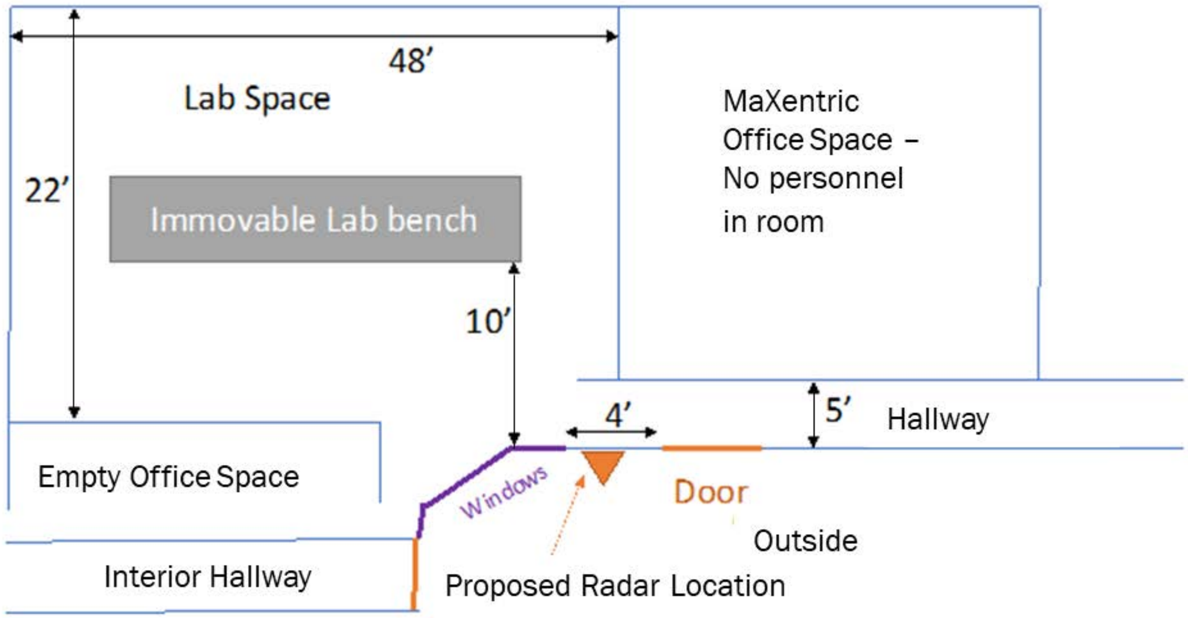


Figure 2-3 Layout of Exterior Station

3.0 RESULTS

This section contains results from the questionnaire and additional evaluator feedback from one-on-one interviews and group discussions. Questionnaire responses relate directly to the training and deployment, detection capabilities, and system requirements listed in Section 1.3. The one-on-one interviews and group discussions allowed evaluators to provide generalized feedback on the DePLife prototype and to elaborate on any feedback given during administration of the questionnaire by NUSTL OFA team.

3.1 REQUIREMENTS FOR DETECTION CAPABILITIES

The two requirements for the prototype detection capabilities listed in Table 1-1 are: (1) *detect the presence of life and number of people and determine whether the people are moving or stationary (upright or laying down) and if they are detectable through standard construction walls,* and (2) *detect people at a distance from the prototype radar*. The following subsections provide a summary of the evaluators' feedback with respect to each of these requirements.

3.1.1 DETECT THE PRESENCE OF LIFEFORMS

When asked if they were able to detect lifeforms through walls and easily interpret the radar display, six evaluators agreed that they were successfully able to perform this or were neutral about this across all three activity stations. One of the three evaluators that disagreed after using the prototype at the exterior station mentioned that the radar system produced a very low level of accuracy.

At interior station 1, evaluators could successfully detect people only about 60% of the time. This was attributed to the presence of several glass windows on the far wall of the room that the test subjects were in, which acted as radar reflectors. The developer stated that reading the radar display would be much easier in a residential building with fewer interior glass windows. Evaluators mentioned that it would also be easier to interpret the display if they already knew the layout of the room. One evaluator said they could not detect targets that were laying down or crawling, but they could detect targets who were walking or running.

At interior station 2, evaluators continued to cite reflective surfaces like windows as sources of radar signal interference. Many evaluators noted that the radar could more easily detect moving targets such as an oscillating fan. However, the system software often misinterpreted the fan as a person.

At the exterior station, evaluators found it much harder to detect targets, but one evaluator mentioned that interpreting the radar display became easier as they got more experience using the system.

When asked if the identification confidence level display was adequate, most evaluators strongly agreed or agreed it was adequate. One evaluator disagreed it was adequate and three responded with neutral at interior station 1, two evaluators disagreed and one responded with neutral at interior station 2, and one evaluator disagreed and one strongly disagreed at the exterior station. These evaluators noted that the system occasionally indicated 100% confidence for invalid targets.

In general, the evaluators mentioned that the percentage labels on targets were easy to read and could help distinguish between valid and invalid targets. However, the evaluators also mentioned that operators should not rely on confidence levels as they gain more experience using the system.

One evaluator mentioned that the labeling was very useful if there is only a single target in the room. Another evaluator mentioned that font size should be adjustable for better readability in the field.

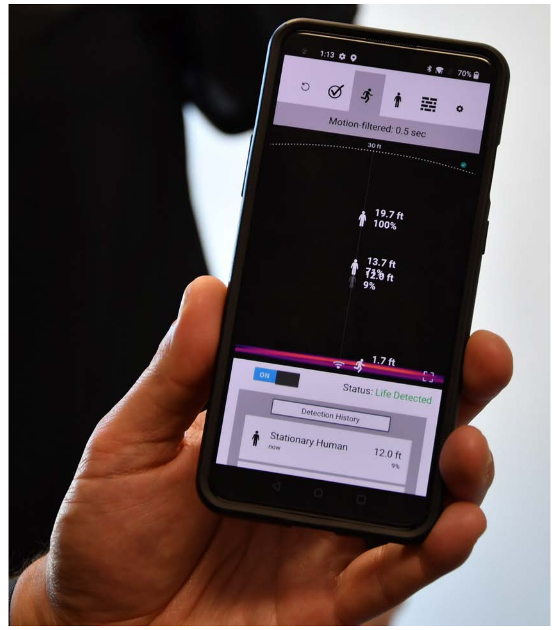
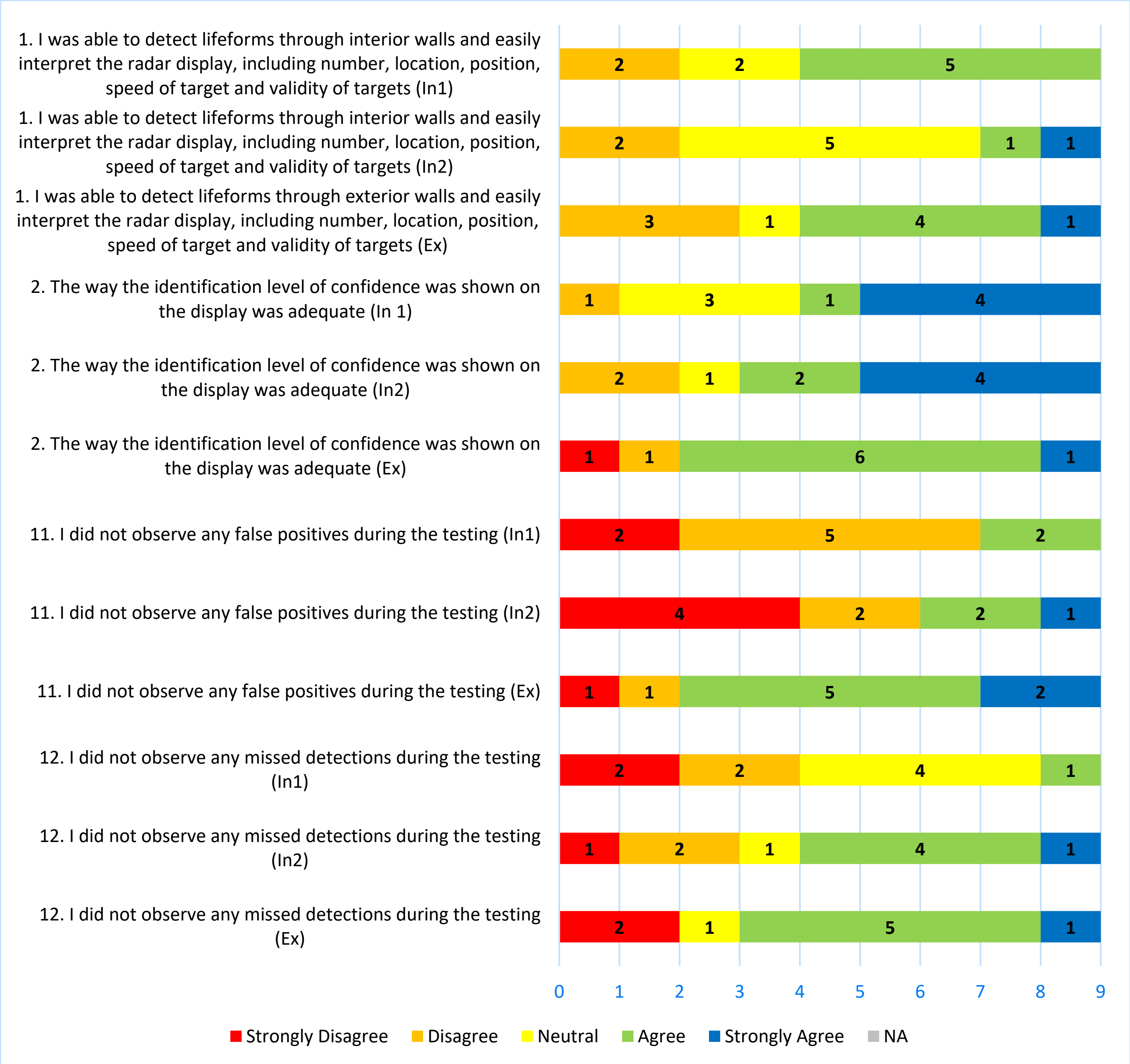


Figure 3-1 Multiple targets detected with varying confidence levels

Responses from evaluators were varied across the three stations when asked if they did not observe false positives. At interior station 1, two evaluators agreed they did not observe false positives while seven evaluators disagreed or strongly disagreed; these evaluators noted that the windows in the room functioned as radar reflectors that interfered with the system operation. At interior station 2, three evaluators agreed or strongly agreed with the statement while six disagreed or strongly disagreed. Evaluators who disagreed noted that the fan at this station was a false positive. One of these evaluators mentioned they would rather experience false positives than false negatives (or missed detections). A different evaluator noted that any false positives could be a reflection of an invalid target or multiple reflections from a valid target. At the exterior station, seven evaluators agreed or strongly agreed they did not observe false positives while two disagreed or strongly disagreed. The evaluators who disagreed noted the same false positive but did not attribute it to anything. One evaluator who agreed noted that while there was a valid detection, the location was incorrect.

When asked if they did not observe any missed detections, opinions varied among the evaluators and across the three stations. At interior station 1, only one evaluator agreed, four were neutral, and four disagreed or strongly disagreed. Two of the evaluators who disagreed noted that the missed detection was a result of the test design but did not mention the location or position of the person. At interior station 2, five evaluators agreed or strongly agreed with the statement, one was neutral, and three disagreed or strongly disagreed. The three evaluators who disagreed noted a missed detection when a person was laying down and another missed detection caused by radar shadowing (the three people were positioned in a row behind each other). At the exterior station, six evaluators agreed or strongly agreed, one was neutral, and two strongly disagreed. The two who strongly disagreed noted a missed detection but did not attribute it to anything. The one who was neutral noted that an I-beam in the wall produced a radar shadowing effect.

Table 3-1 DePLife Questionnaire Results: Requirement 1



Notes:

NA—Not answered. Indicates that an evaluator did not provide a response because it was not applicable, not assessed, or not answered due to oversight.

In1, In2, and Ex indicate evaluators responded to the statement at Interior Station 1, Interior Station 2, and the Exterior Station, respectively.

3.1.2 DETECT LIFEFORMS AT DISTANCES

When asked if the detection range and FOV of the radar were acceptable for operational usage, most evaluators agreed or strongly agreed. Two evaluators disagreed while using the system at the exterior station, citing a maximum detection range of only 8 feet and a minimum of 3 feet.

One evaluator at the exterior station who agreed noted that the setup of the room limited the maximum range of the radar. This evaluator also noted that radar reflectors such as windows at the interior stations would limit the maximum range. A separate evaluator mentioned that the range was adequate for operational use at a single-family residence and another evaluator stated the system's range and FOV were similar to other products.

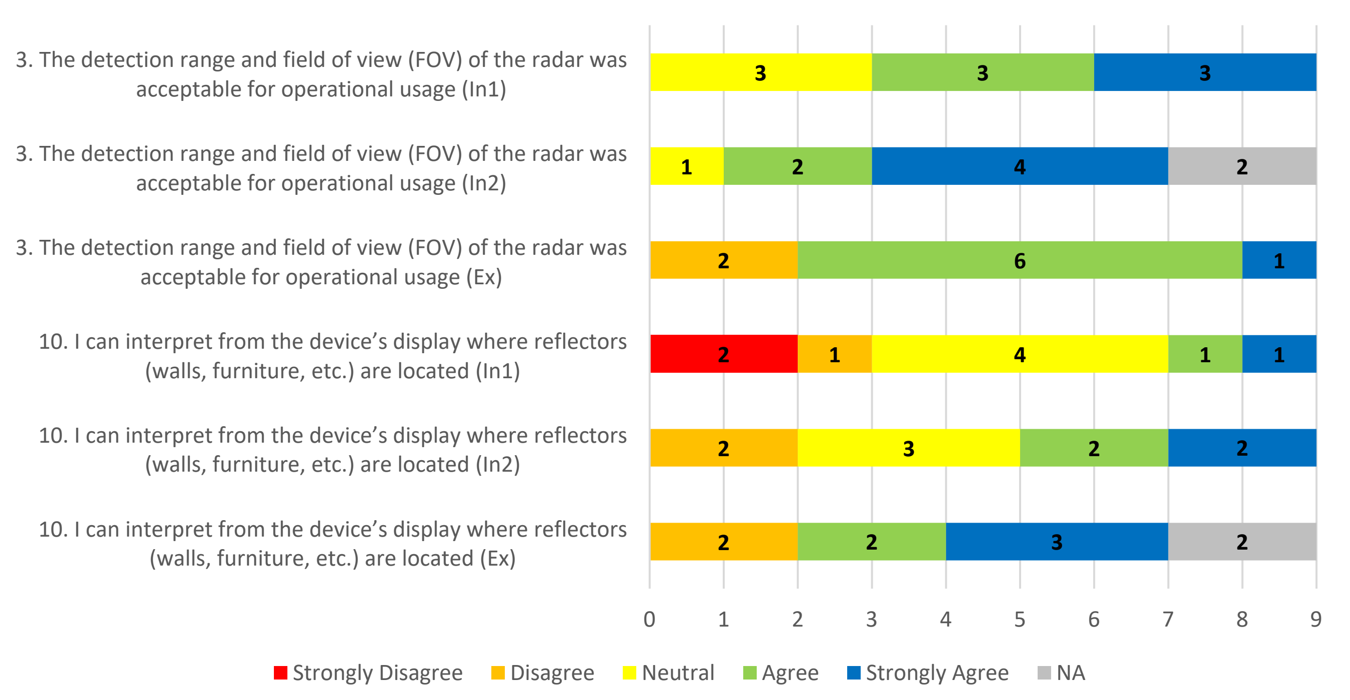
Figure 3-2 Multiple targets detected at range of up to 27 feet

Most evaluators agreed, strongly agreed, or were neutral that they were able to identify the location of radar reflectors by interpreting the device's display. There were two or three evaluators who disagreed or strongly disagreed at each of the stations.

Evaluators who disagreed noted they could not distinguish between inanimate reflectors and valid human targets. One of these evaluators mentioned that users would need to know the layout of the room to do so. Other evaluators mentioned that they would be better able to distinguish between reflectors and valid targets after gaining more experience with the system, even if there was no awareness of the room layout. This would be a matter of being able to distinguish the behavior of moving targets and stationary targets.

At the exterior station, one of the evaluators who disagreed mentioned the system was, however, able to identify a construction beam in the exterior wall.

Table 3-2 DePLife Questionnaire Results: Requirement 2



Notes:

NA—Not answered. Indicates that an evaluator did not provide a response because it was not applicable, not assessed, or not answered due to oversight.

In1, In2, and Ex indicate evaluators responded to the statement at Interior Station 1, Interior Station 2, and the Exterior Station, respectively.

3.2 REQUIREMENTS FOR SYSTEM ATTRIBUTES

The four requirements for the system attributes listed in Table 1-1 are: (1) *Deployment time is acceptable for operational use, (2) Usability is acceptable for operational use, (3) Ability to switch between covert and overt alerts, and (4) The system has wireless communication capabilities*. The following subsections provide a summary of the specific feedback that was given by the evaluators during the OFA with respect to each of these requirements.

3.2.1 OPERATIONAL DEPLOYMENT TIME

When asked if the time to deploy the system (hardware and software) was acceptable for operational use, most of the evaluators strongly agreed across all three activity stations. Deployment includes the following tasks: unpackage, assemble the radar, check that the system is operating properly, mount the radar to the tripod, verify the mount assembly, select a wall, move the radar assembly to the wall, select a site on the wall for initial radar placement, place the radar, activate the UI, and verify that the UI is properly connected to the radar. Most responders felt the system was straightforward and easy to set up and deploy. The average time to deploy was approximately five minutes the first time, then dropped to two or three minutes as the evaluators developed more familiarity with the system and procedure.

Two of the evaluators responded neutrally to the statement for the exterior station, saying the system was good for nonemergency uses but they would not use it during emergency or time-sensitive situations. One evaluator said that for operational use the system should be ready to go out of the box.

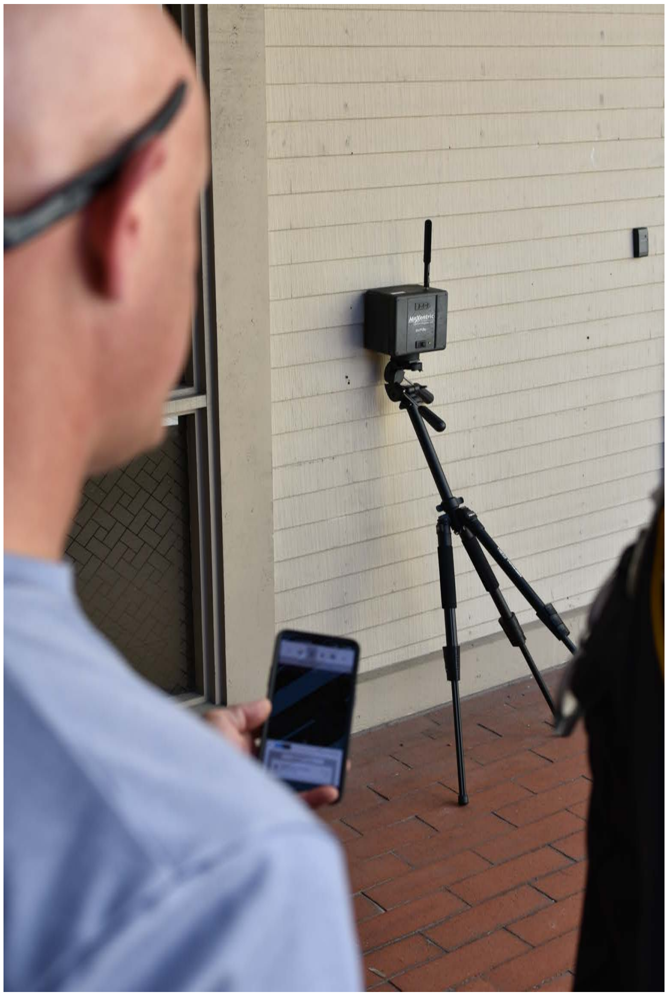
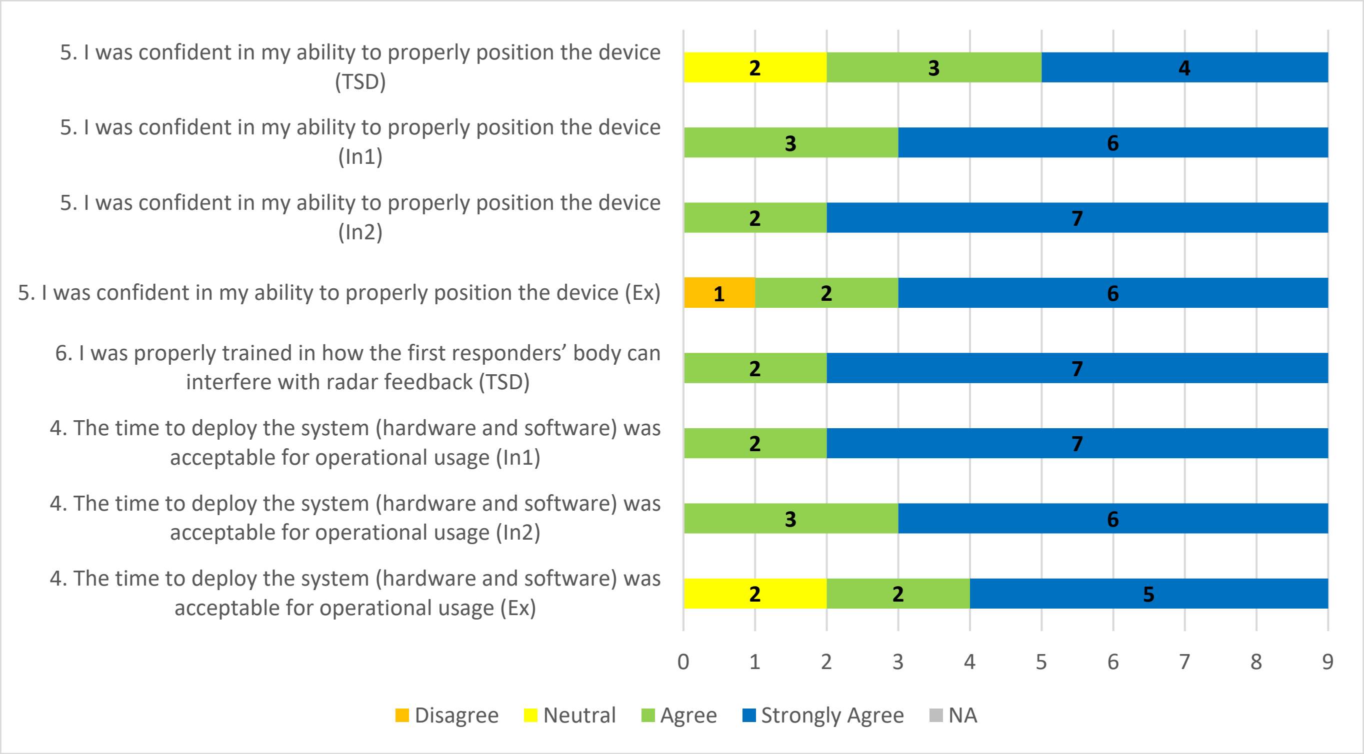


Figure 3-3 Device deployed with tripod against exterior wall

Most evaluators either strongly agreed or agreed with the statement, “I was confident in my ability to properly position the device,” following the training and set up/deployment activity as well as testing the prototype at the three activity stations. Evaluators felt the set up was intuitive, the tripod was easy to set up, and the training was helpful. A few evaluators wanted more guidance on where to position the device in rooms with very high ceilings. Two evaluators responded neutrally to the statement during the training activity, stating that there were too many variables to consider. They changed their response to strongly agree after gaining experience at the three activity stations. A few of the evaluators liked the way the system alerted them when the device was incorrectly positioned and the notification when there was an obstruction. Other evaluators felt confirmation of proper positioning would be helpful. For the exterior station, one of the evaluators disagreed with the statement, saying that he could not position the device to detect the person he knew was present. Other evaluators stated that the indicators from the system were helpful in optimally positioning the device at the exterior station. All the evaluators felt they were properly trained in how a first responder’s body can interfere with radar feedback, with seven saying they strongly agree and two saying they agree. Evaluators felt that effective training on this issue would improve successful deployment of the device.

Table 3-3 DePLife Questionnaire Results: Requirement 3



Note:

NA—Not answered. Indicates that an evaluator did not provide a response either because it was not applicable, not assessed, or not answered due to oversight.

TSD, In1, In2, and Ex indicate evaluators responded to the statement during Training on Set up and Deployment (TSD), at Interior Station 1, at Interior Station 2, and at Exterior Station, respectively.

3.2.2 ACCEPTABLE USABILITY FOR OPERATIONAL USE

Most evaluators strongly agreed or agreed that the system could be easily deployed, saying it was simple, easy, and quick and that the system was lightweight and portable. At the exterior station, one evaluator responded neutrally, saying that the tripod can take time to set up. Two recommended using an adhesive glue as a mounting option to avoid slippage. An evaluator suggested replacing the tripod mount with a Picatinny rail or Arca-Swiss rail because the radar fell off the mount at one point during this OFA.

All the evaluators generally agreed with the statement that the system hardware was easy and intuitive to deploy, with seven strongly agreeing and two agreeing when asked during set up at the three stations. They felt it was easy, intuitive, and straightforward. One evaluator said that while the tripod was easy to use, a bipod may be easier for some people. Evaluators also noted it would be nice, but not necessary, to have the hardware attached together in some way.

All the evaluators either agreed or strongly agreed that the size and weight of the system made it easy to deploy and set up, with six agreeing and three strongly agreeing. Most evaluators were pleased with the weight of the system, even expressing surprise at how light it was. They also felt the size and footprint were good for this type of technology. However, one evaluator felt the device was too cumbersome to handle in a tactical environment.

During training and setup, all evaluators agreed that the system software was easy to deploy and set up, with seven agreeing and two strongly agreeing.

Most evaluators strongly agreed that the system software was easy and intuitive to set up and use at all three activity stations. They stated it was straightforward but somewhat dependent on the user's familiarity with Android devices. One evaluator would like to have had some kind of indication when the Wi-Fi was disconnected during use. Another noted it was obvious that the software was designed to be simple and stated that once they started interpreting data, the data tabs became useful for discernment.

Almost all the evaluators strongly agreed or agreed that they fully understood when to move the radar to avoid reflectors and blockage. Evaluators liked that the software gave a clear indication when the device needed to be moved to avoid an obstruction. A few felt that it was clear when there was a blockage but liked the message from the system for validation. One evaluator suggested adding a stud finder to aid in positioning the device on the wall. At interior station 2, one user said he lowered the radar when a person was crawling, which improved the data, but it would have been difficult to make this decision if one was already on a target. One user received an obstruction alert and then was able to move the radar away from a steel column to use the system.

Figure 3-4 Evaluator attaching device to tripod

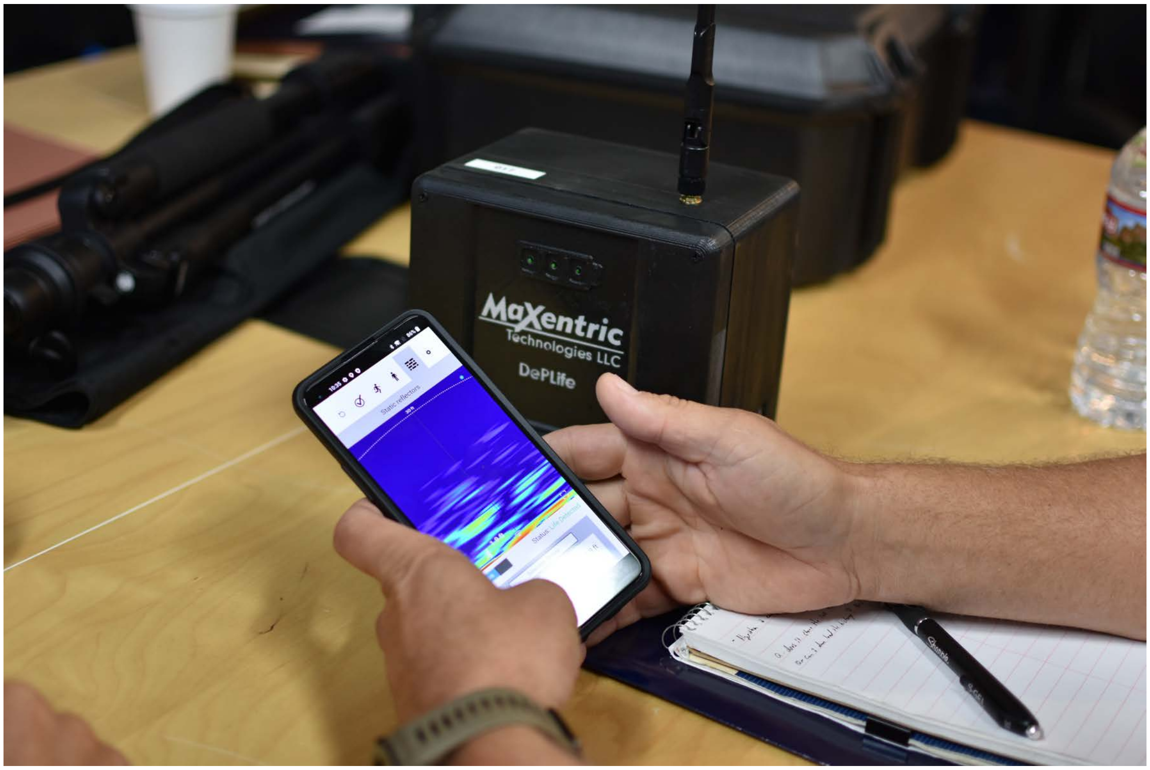
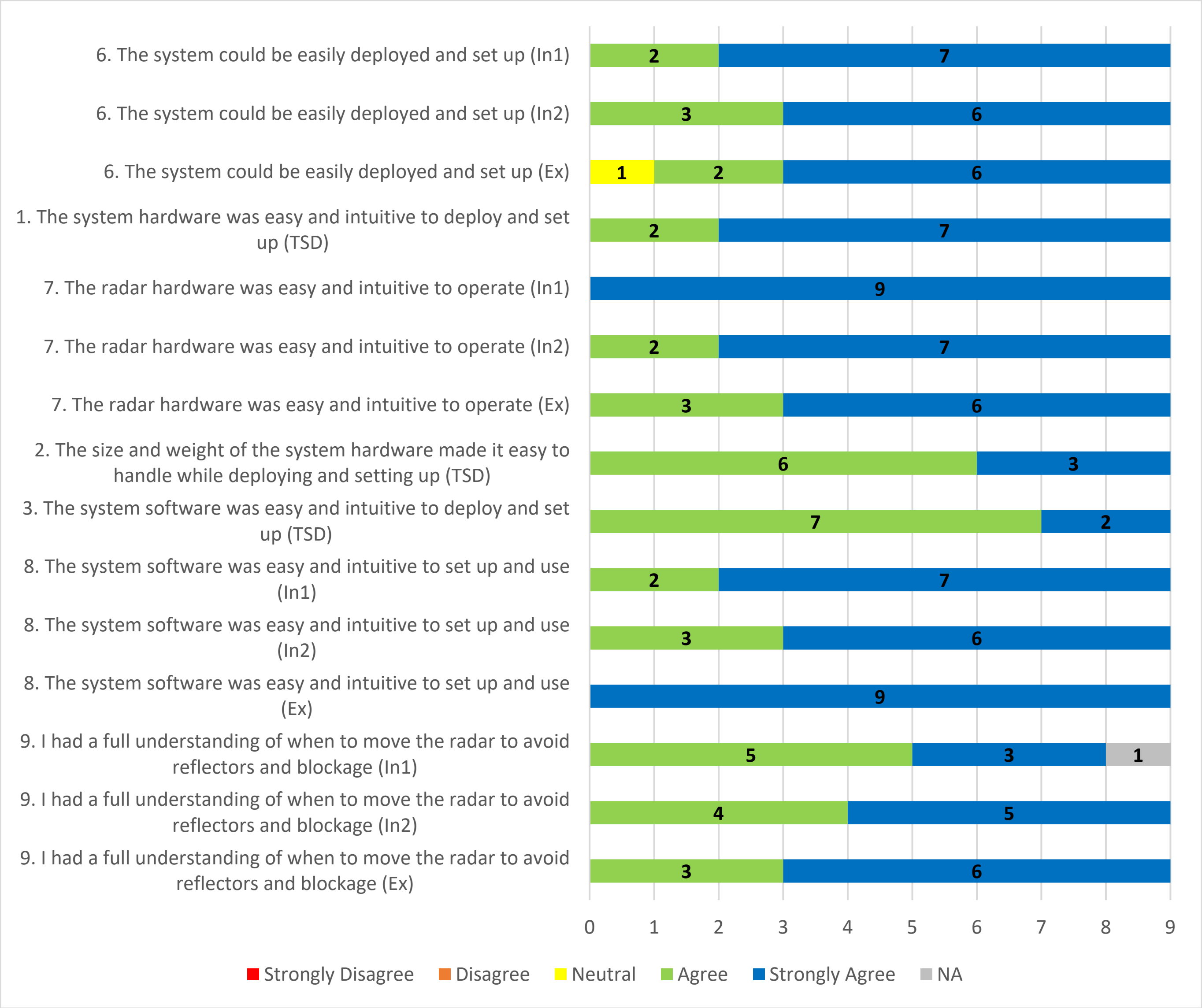


Figure 3-5 Display showing location of static reflectors to help position radar using the Unfiltered: reflectors visualization

Table 3-4 DePLife Questionnaire Results: Requirement 4



Note:

NA—Not answered. Indicates that an evaluator did not provide a response either because it was not applicable, not assessed, or not answered due to oversight.

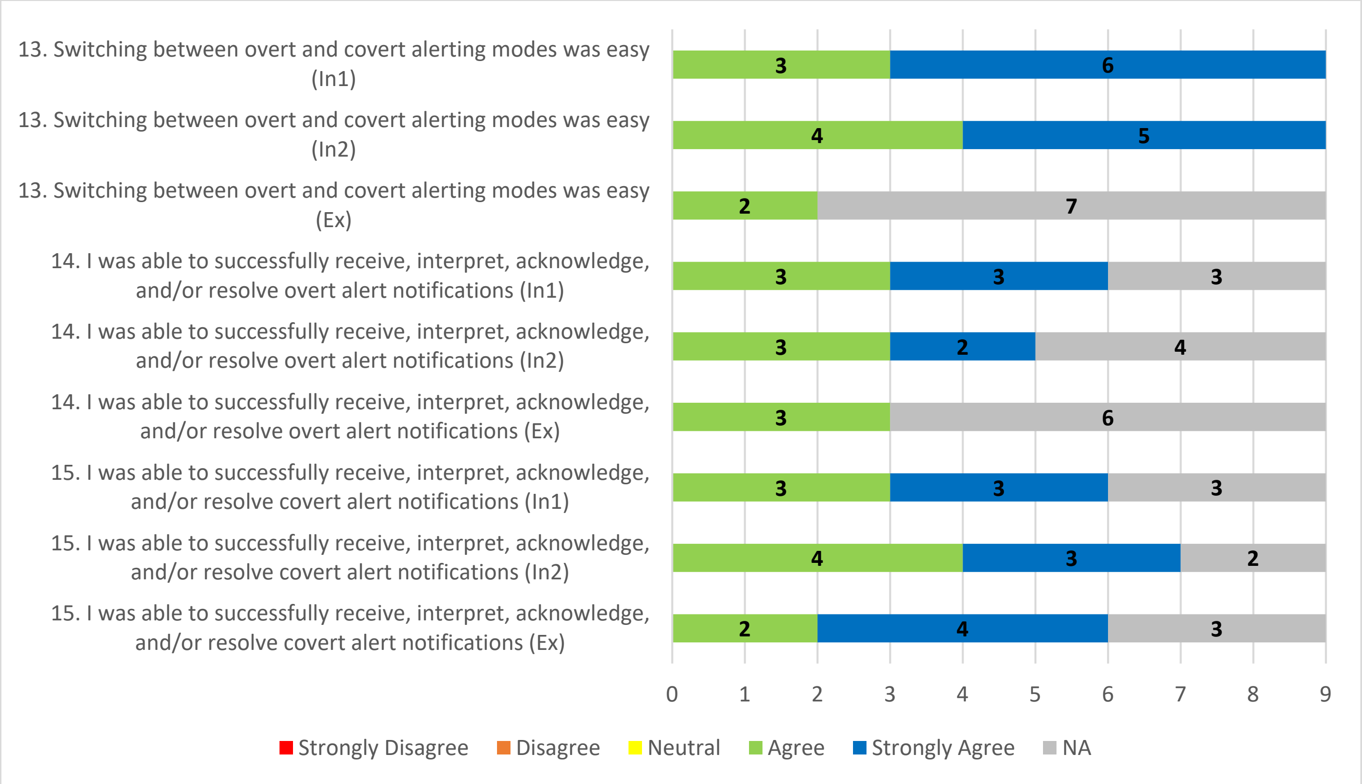
TSD, In1, In2, and Ex indicate evaluators responded to the statement during Training on Setup and Deployment, at Interior Station 1, at Interior Station 2, and at the Exterior Station, respectively.

3.2.3 COVERT AND OVERT ALERT ABILITY

The evaluators assessed the system's ability to alert both covertly and overtly. Overall, the evaluators agreed that the system provided the capability to: (1) switch between covert and overt modes, and (2) receive, interpret, acknowledge, and resolve both covert and overt alert notifications.

After using the system in each mode, some evaluators preferred the covert mode, while others preferred the overt mode. Some evaluators commented that the process to switch between covert and overt mode only required a simple change in a setting and there isn't a reason to use overt notifications unless someone can't monitor the screen, so they would likely leave the device on silent mode (covert). Others liked having overt alerts (beeping) since it can reduce user fatigue and help validate the display but felt that there should be a way to turn off the beeping sound without switching modes. One evaluator suggested that the system could be used with headphones.

Table 3-5 DePLife Questionnaire Results: Requirement 5



Note:

NA—"Not answered". Indicates that an evaluator did not provide a response either because it was not applicable, not assessed, or not answered due to oversight.

TSD, In1, In2, and Ex indicate the question was asked during Training Setup and Deployment, at Interior Station 1, at Interior Station 2, and at the Exterior Station, respectively.

3.2.4 WIRELESS COMMUNICATION CAPABILITY

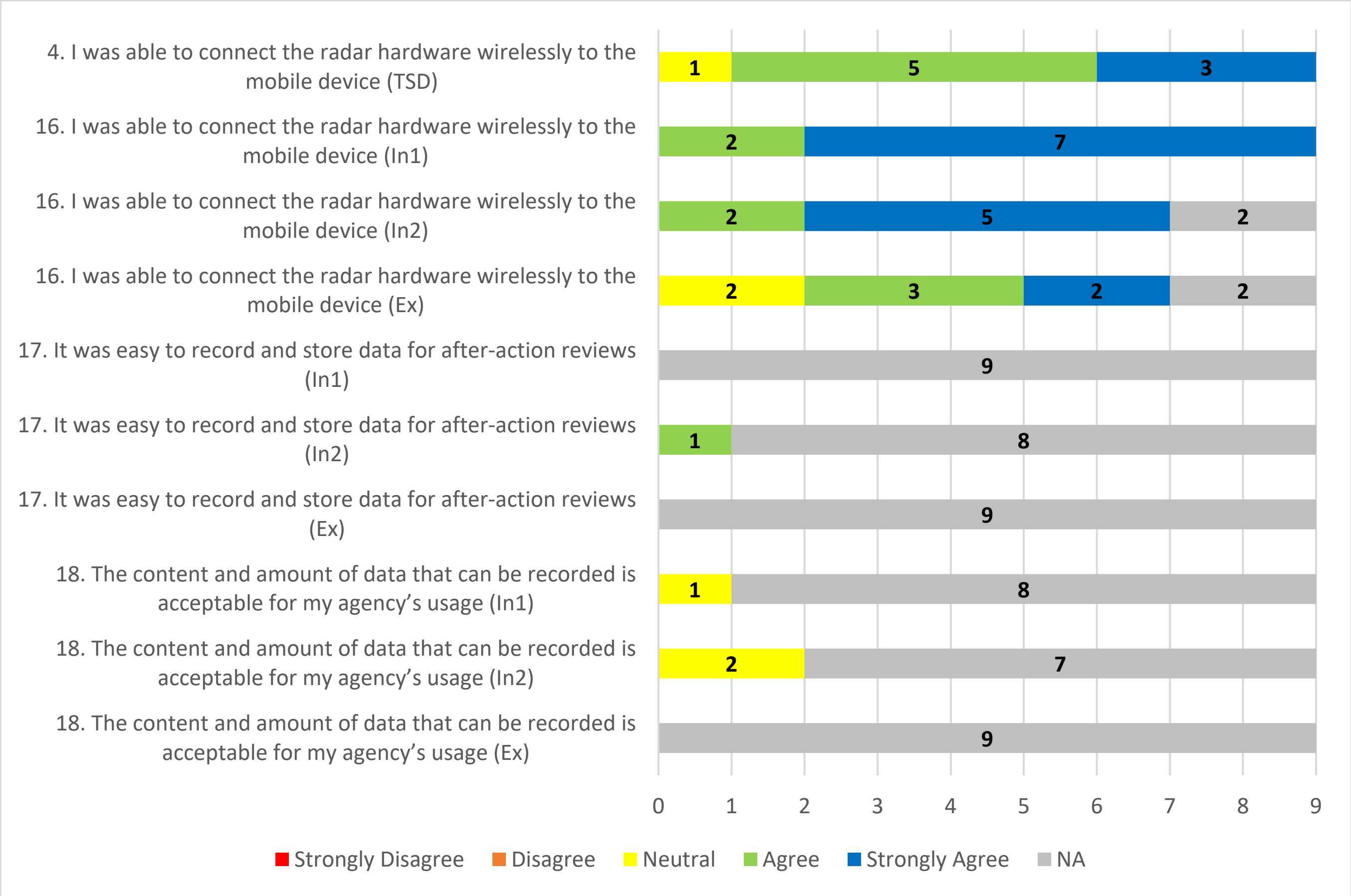
During the OFA activities, the evaluators assessed the prototype's wireless communication capability. Most evaluators strongly agreed they were able to connect the radar hardware wirelessly to the mobile device. The evaluators followed up with additional feedback that connecting the radar and the Android phone was generally easy and became effortless with user familiarity. One set of evaluators indicated there were issues encountered with maintaining a connection between the radar and the phone and the connection dropped three times; the system consistently disconnected when the battery was low. This issue was resolved once a new battery for the radar system was installed.. Additional feedback from the evaluators included that they would prefer the device automatically connect to Wi-Fi when rebooted versus having to disconnect and reconnect manually.

A related observation was that the Wi-Fi disconnects when the app is closed on the phone and doesn't reconnect automatically when you open it up again.

During the training activity, most evaluators felt the wireless communication operation was simple, but some evaluators noted that Wi-Fi would sometimes cut out during setup and the connection between the mobile app and the radar did not automatically reconnect. Instead, users had to manually reconnect to the device's Wi-Fi network through the phone's settings menu. The focus of evaluating the wireless capability was the ability of the radar to connect to the mobile phone and remain connected. Most of the evaluators during the OFA did not have the opportunity to review and evaluate the acceptability of the stored data logs, leading to several "Not Answered" results for questions 17 and 18. The stored data capability was addressed in the group discussion after completion of the OFA activities.

Additionally, the OFA assessment team was able to determine that the Wi-Fi range with perfect line of sight was approximately 100 feet.

Table 3-6 DePLife Questionnaire Results: Requirement 6



Note:

NA—Not answered. indicates that an evaluator did not provide a response either because it was not applicable, not assessed, or not answered due to oversight.

TSD, In1, In2, and Ex indicate evaluators responded to the statement during Training Setup and Deployment, at Interior Station 1, at Interior Station 2, and at Exterior Station, respectively.

3.3 GROUP DISCUSSION

After the assessment activities were completed, the evaluators were gathered to obtain additional followup feedback on the DePLife system. This section covers output from this group discussion, which included the evaluators' answers to additional operational questions from the OFA team and the evaluators' overall assessment of the system.

The first question was, *"What was your overall impression of the DePLife system?"* One evaluator shared that the system was easy to maneuver but had some false alarms and missed detections, noting that, for SWAT applications, the system needs to be perfect. Another evaluator said the deployment kit is easy to use and the app is user-friendly, but there is a limitation of radar technology for this use case where the number or location of targets is not always accurate. A third evaluator noted the technology was impressive and easy to use but added that sometimes it was deceiving and not as perfect as it needs to be. They added that the number of people present needs to be portrayed more accurately and this outcome could get better with more system familiarity. The evaluator felt that while there are limitations with radar for this application, the system did provide some information that would help make tactical decisions.

The second question posed was, *"In what applications would you use it?"* Evaluators said it would be useful for warrant service, barricade situations, and cases where an adjacent apartment or hotel room is available. They also stated it could be useful in a SWAT hostage situation, determining where to place explosive wall charges, for welfare checks (such as with elderly care or a suicidal person), and for accountability purposes in cases of litigation.

The third question posed was, *"What changes would you recommend and why?"* Evaluators recommended providing a means to mount the radar to a robot claw, adding a stud finder to help avoid blockages, making the prototype more rugged for vibration and shock resilience, and enabling each radar unit to communicate to multiple phones simultaneously. Other evaluator recommendations included making a sustaining connection between the UI and the radar (possibly through a hardwired connection) and providing larger detection logs.

The final question posed was, *"Is the DePLife system something you would actively use if it was available to you? Why or why not?"* One evaluator commented, "Yes, in the right situations such as warrant service or barricade/suicide scenarios. Could be useful for litigation purposes." The evaluator responses were overwhelmingly affirmative and reiterated the applications noted above as reasons it would be useful. They also noted it's easy to tell if there's a person in the building.

3.3.1 OVERALL PERFORMANCE AND ASSESSMENT

At the OFA, MaXentric's DePLife system was assessed to be at a TRL of 6 by NUSTL, which denotes a successful prototype tested in a relevant environment. Further development is required to mature the technology to a final commercial form.

Overall, evaluators found the DePLife system to be intuitive and easy to use. Evaluators indicated they were able to detect people through walls and easily interpret the radar display throughout the different stations. The evaluators had difficulties and found inconsistencies with the ability to determine the exact number and location of people in a room. They indicated the detection range and FOV of the radar were acceptable for operational usage.

Evaluators also indicated that interpreting the radar output became easier as they got more experience over the hours they used the system. The evaluators' opinions were nearly evenly mixed on whether false positives were an issue. The evaluators stated that the percentage confidence labels on potential targets helped distinguish between valid and invalid targets, thus reducing false positives.

For the statement, "I did not observe any missed detections during the testing" (false negative), most evaluators agreed or were neutral. Three evaluators noted that missed detections occurred when a person was laying down and in cases with radar shadowing, which occurred when two or more people were lined up behind each other. Additionally, all the evaluators strongly agreed or agreed that they had a full understanding of when to move the radar to avoid reflectors and blockages. The evaluators liked the feature that provided a notice to move the radar to avoid a blockage, reflector, or any type of obstruction.

Most evaluators strongly agreed that the time to deploy the system (hardware and software) was acceptable for operational use. The average time to deploy the system was initially estimated to be about five minutes but was reduced to two or three minutes after users became more familiar with the deployment procedure. The evaluators indicated that the system was lightweight and mobile.

Other features such as covert and overt alerts and wireless connectivity were deemed acceptable by the evaluators.

3.3.2 OPPORTUNITIES FOR IMPROVEMENT

Throughout the OFA, the evaluators identified several ways the prototype could be improved. These findings may be helpful to further refine the DePLife system.

Evaluators suggested the following improvements to the DePLife prototype:

- Add the ability to attach the DePLife device to a robot for remote deployment and operation. This standoff capability option will provide safety and cover to the operator.
- A high level of confidence in the system output results is important. Improve software algorithms to increase accuracy and precision and to reduce false alarms.
- The DePLife device is a prototype, not in its final commercial form. Ruggedize and harden the commercial version for physical handling and the operational environment.
- Add a capability to distribute and transmit radar output/feed to multiple users (i.e., multiple phones or tablets). This feature will support command and control, coordination of different intelligence, and execution of responder personnel movement in different locations.
- Add a capability to combine the output from more than one radar onto one device screen, potentially increasing accuracy and confidence.
- Reconnect the mobile phone/app with the radar automatically when restarting the radar or app. Add an option for hardwiring the connection. Add an indication or notification when the Wi-Fi connection is lost.
- Improve on-screen data log by adding up to 8 hours of data storage.
- Increase font size on the display.
- Add a stud finder to help avoid reflectors and blockages when positioning the device.
- Upgrade the tripod mount to a Picatinny rail or an Arca-Swiss rail for a more secure connection between the radar and the tripod.
- Make the device ready for operation immediately after it is taken out of the box.
- Supply adhesive to the prototype to improve attachment to the wall.
- Configure the hardware such that it all connects together.
- Provide an indication of Wi-Fi connection status.

4.0 CONCLUSION

On October 18, 2022, DHS S&T NUSTL conducted an OFA of the DePLife prototype radar in a realistic operational environment. The DePLife is a radar-based system that primarily detects people behind walls by determining the number and tracking the location of the detected people. During the OFA, the prototype system was remotely operated via a mobile phone UI. Once finalized, the solution is expected to be integrated with commonly used first responder equipment, must not burden the operator with unusual or complicated attachments, and must be able to detect single and multiple lifeforms through walls and alert the operator. The NUSTL OFA test team evaluated the DePLife system to be at a TRL of 6. Additional development efforts are required to achieve a mature, commercially available product.

Evaluators agreed the DePLife prototype was able to detect people through walls and that it was easy to set up, use, and interpret the radar display. However, the accuracy and false positives greatly reduced the evaluators' confidence in using the output results to form a solid conclusion. A few evaluators wanted 100% confidence in the device's results for use in SWAT situations. The evaluators recommended the system technology and algorithms be developed further to increase detection accuracy, especially of stationary subjects, and reduce false detections. The evaluators also determined that the DePLife radar FOV and detection distance capabilities were acceptable for operational use.

The prototype was assessed for deployment time and ease of use. The evaluators determined the device was quick to deploy and easy to operate and that they could interpret the results from the user interface. Evaluators evaluated the system's ability to switch between covert and overt modes as acceptable.

The evaluators also suggested improvements to the device such as adding a capability to attach it to a robot, increasing its detection accuracy, decreasing false alarms, ruggedizing it, distributing its output to multiple user's mobile phones, combining outputs from multiple radars, and automatically reconnecting the device with the mobile phone/app when the Wi-Fi connection is lost.