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Project: LEGION (Linked Emergency Gear, Inter-Operative Network)

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1. PROBLEM DEFINITION

1.1. OBJECTIVE

This project performs in-depth research, consultation, and exploration to engineer, design, and develop a system that would assist first responders in assessing and responding to active threat scenarios. In the design challenge document, the team was specifically requested to design their system to assist first responders in locating "hide-in-place" victims involved in the event. Design criteria from the challenge document states typical emergency locations may include but are not limited to, educational buildings, offices, shopping centers, and multi-room facilities.

This system will address the increased frequency of active threat scenarios such as shootings, bombings, and natural disasters. This system was designed specifically to help first responders to locate "hide-in-place" victims and hostiles in each of these situations. This system also assists emergency responder leadership in locating and identifying first responders at the scene of the active threat, or those nearby. This would allow first responder leadership to react to a wide variety of different active threat scenarios more effectively.

Feedback from local Subject Matter Experts (SME) directed the development of the final system. Based on SME feedback, the team designed and prototyped a system consisting of different edge devices that would implement an internet of things (IoT) platform for the first responders to use in active threat scenarios. The final design implements edge devices currently used by first responders to enhance familiarity and improve functionality.

1.2. FUNDAMENTAL ASSUMPTIONS

The team made the below fundamental design assumptions based off of feedback they received from the SMEs the team interviewed. Justification for each assumption is provided below the assumption.

1.2.1. The system will be functional in any active threat environment. I.e. the system shall be resistant to water, dirt, dust, mud, sand, impact, and electrical discharge.

The team's SMEs wanted the wearable system to be resilient to the elements due to the fact that the weather/environment at any given active threat scenario can range from mild to extreme. Protecting the computer/electrical components of the system is crucial in having functioning equipment throughout any active threat.

1.2.2. The system devices shall maximize user-friendliness and intuition to promote adoption and use among first responders.

The team's SMEs unanimously expressed that if the system were too complicated to use, that it would be a waste of their limited time during active threat events. They all wanted the devices to maximize ease of use.

1.2.3. The design must minimize size and weight without compromising performance.

The team's SMEs shared the opinion that if the system was too heavy or large, that their responders would not use it during time restricting events. They would more likely use larger equipment during long term threat scenarios such as natural disaster rescue. During rapidly developing events, such as shootings or bombings, they would likely not use the equipment.

1.2.4. The system devices must operate for a duration of at least three hours.

Per SME feedback, most active threat scenarios are resolved within three hours. The team decided, with approval of the SMEs, that having a system with an operational life of three hours would be sufficient for the majority of active threat scenarios.

1.2.5. Due to application limitations, pre-Installed systems are not desirable.

The SMEs voiced that not all establishments that active threat scenarios occur in have pre-installed systems. They requested that the system design be independent of any pre-installed equipment.

1.3. ENGINEERING REQUIREMENTS

The following requirements are sourced and updated from the Capstone Design Requirements Contract [1].

1.3.1. The system shall assist in identifying individuals and their role in an active threat environment

Source: The design challenge places emphasis on locating individuals in an active threat. Identifying the role of each individual in an active threat enables first responder leadership to better react to the emergency. Furthermore, the problem statement expresses the need for the system to assist in identifying individuals as victims or hostiles.

Verification Fulfillment: The system was used by a team member in a simulated situation searching a building using the LEGION responder gear. The footage from the sensors was successfully streamed to both the responder and central command, allowing both to use the sensor streams to locate and identify persons.

1.3.2. The system shall assist in identifying the condition of affected individuals.

Source: The problem statement declares the need to determine the victims' medical condition.

Verification Fulfillment: The system was tested with an unarmed responder dropping pin locations on the map using their wrist-mounted terminal. Using the terminal, they indicated the location, number, and triage status of the victims at each location. Additionally, central command was able to remotely edit the locations with the victim count and triage status.

1.3.3. The system shall report the location of persons in the active threat environment within 30 ft and the number of persons within the reported location.

Source: The problem statement declares the team shall build a prototype system to locate personnel during an Active Threat event.

Verification Fulfillment: The system was tested by dropping pins on the last known GPS location of the unarmed responder. This proved accurate to less than 30 ft in optimal conditions. Responders could clarify inaccurate GPS data using verbal descriptions.

1.3.4. Training time shall be 30 minutes or less.

Source: Initial competition requirements stated the team would train first responders to use the system in the project demonstration. Reducing the required training time also promotes the system's ease of use.

Verification Fulfillment: The system, along with the graphical user interfaces (GUIs), was designed for simplicity. The system was iterated several times based on this feedback to improve ease of use.

1.3.5. Deployment time shall be less than one minute.

Source: The SME interviews showed the necessity of quick deployment. In an active threat scenario, the first responders must resolve the situation and attend to victims as quickly as possible. Any device with prolonged deployment will likely not be used.

Verification Fulfillment: System activation was timed from devices being shut down to getting functional data streaming. Assuming the IoT platform and MiFi's were already active, the system starts up in approximately thirty seconds.

1.3.6. Time to use shall be less than 10 seconds per interaction.

Source: The SME interviews showed that if any device hinders first responders in an active threat, the first responders would not use the system. The biggest hindrance in using the device would be the time per interaction with the device (load times, feedback times, etc.).

Verification Fulfillment: The system streamed image data from the armed responders automatically and required no interaction from the armed responders. The medical responder was able to add a simple location in less than ten seconds. Each GUI used large buttons to improve navigation and reduce interaction time.

1.3.7. Any personal device shall not impede the mobility of a responder or the use of their hands.

Source: The SMEs stated that any personal device which requires the constant use of hands would hinder responder performance.

Verification Fulfillment: The responder gear consists of a sensor suite mounted on a tactical vest along with a wrist-mounted terminal. An AFRL judge stated, after a visual inspection of the system, that the responder gear would not interfere with the actions of a first responder.

1.3.8. All devices shall weigh less than five pounds.

Source: Through SME interviews, the team determined that any system heavier than five pounds would become a hindrance to the first responders.

Verification Fulfillment: Not including standard issue equipment (MiFi, tactical vest, and radio), the AFRL judges weighed the armed responder system to be less than four pounds.

1.3.9. Any personal device shall operate for a minimum of three hours.

Source: Through SME interviews, the team determined that any personal device the first responder would use needed to operate for a minimum of three hours, which is the average operation length of active threat scenarios.

Verification Fulfillment: The devices were tested using an external power source while streaming data. Testing confirmed that all devices lasted over three hours.

1.3.10. The system shall have an operational range of one mile.

Source: SMEs informed the team that typical active threat scenarios that are not natural disasters are contained within a one-mile radius. Current active threat response efforts include establishing a headquarters location where first responders gather. This location is typically within a mile of the active threat event.

Verification Fulfillment: The system connects each first responder using an internet connection. As such, there is no inherent range to the current implementation. The system range is only limited by cell signal range and internet access.

1.3.11. The system shall enhance communication between first responders and central command.

Source: Several SMEs stated the major problem in responding to emergencies is inadequate communication. The team determined that their system should enhance two-way communication between first responders and central command. First responders currently have audio communication via radio handsets, the system should enhance, not obstruct, that existing communication.

Verification Fulfillment: The system was tested with responder sensor data being successfully transmitted to a central command and central command successfully broadcasting footage to the "team" channel which responders could access on their wrist-mounted terminals.

1.3.12. The system should be modular to allow implementation with various platforms and sensors.

Source: Through SME interviews, the team determined the system should communicate with and integrate current systems used by first responders. The system should also allow for future device integration as technology advances.

Verification Fulfillment: The system implemented MiFi routers currently used by Logan City Police. The responder gear was built for integration on common tactical vests which responders use. The architecture of the IoT platform allows for new sensors to be added with minimal effort.

1.3.13. Edge devices should be able to connect to the internet.

Source: The AFRL problem statement indicates the system should be able to provide real-time situational awareness to first responders. This situational awareness will be enhanced through the use of online data processing/streaming.

Verification Fulfillment: All data during tests and competition was transmitted via the internet using MiFi cell routers.

1.3.14. Interface development should be simplified or include development tools.

Source: This project has two intended outcomes per the problem statement. The first is a satisfactory performance during competition exercises. The second outcome is future adoption by real first responders. Simplified interface development promotes long-term adoption of the system.

Verification Fulfillment: The selected IoT platform, ThingWorx, is designed to be user-friendly. PTC, the company that creates ThingWorx, also provides extensive support and creates tutorials. New users benefitting from this support can start using ThingWorx within two to three days of full-time training, allowing them to modify the platform and adapt it for different applications.

1.3.15. Edge devices will allow adequate data transfer to stream video.

Source: The provided problem statement indicates the system must assist in identifying personnel. For this reason, the devices must be capable of transmitting the data required to identify individuals in active threats.

Verification Fulfillment: This was tested by having central command clearly identify persons (by name) remotely through the data transmitted by armed responders.

1.4. GOALS

1.4.1. The system should use disposable batteries to power edge devices.

Source: Corporal Harvey requested the edge devices operate with disposable batteries. This is because first responders replace the batteries in their devices while traveling to active threat scenarios. This ensures the device will function.

Discussion: This goal was accomplished by powering the Raspberry Pis with AA batteries and a UBEC voltage dropper. AA batteries were selected to meet Requirement 1.3.9.

1.4.2. The system should include thermal video streaming.

Source: Logan City Police and USU Police requested having a thermal camera in the system. Law enforcement currently uses thermal imaging cameras to search for fleeing suspects. They also stated it would benefit in finding “hide-in-place" individuals involved in active threat scenarios.

Discussion: Thermal image streaming was achieved by using a SparkFun FLIR lepton radiometric dev kit in conjunction with the PureThermal2 break-out board. The PureThermal2 break-out board allowed the thermal camera to be recognized by the Raspberry Pi as a webcam. Image processing uses the "fswebcam" Raspberry Pi software.

1.4.3. The system should allow for strategic placement of body cameras in active threat events.

Source: Logan City Police would like to place body cameras in strategic locations throughout a facility during active threats. This gives first responders an additional set of eyes that would provide for more coverage of the area and surveillance for first responders.

Discussion: The WIFI range of the Verizon MiFi's purchased for the system allowed first responders to stream images within a range of 50 ft. Future development could include a stronger router to increase the distance between the responder and the placed camera.

2. SYSTEM OVERVIEW

The system the USU AFRL team designed was based completely on SME feedback. Early feedback indicated that communication during scenarios was problematic and needed improvement. The team designed a system to enhance communication between first responders and leadership located at central command. Specifically, the system enhances central commands ability to see where the first responders are in the field and see what the responders see in the active threat scenario.

2.1. PHYSICAL DESCRIPTION

The system has multiple parts that connect the responders to central command. First responders carry a mobile router in a pocket on their vest. These routers send data from three types of cameras to an IoT platform. These cameras include a body camera, a borescope, and a thermal camera. The body camera mounts to the front of the responder's vest (according to current police practice). The borescope mounts in either a pocket or pouch that can be positioned anywhere on the vest per first responder preference. LEGION also includes a thermal camera to improve responder visibility and mounts in a pocket on the responder's vest.

Responders view the IoT platform using wrist-mounted cell phones. An off-the-shelf case and mounting system is used for the phone. The mounting system attaches to the forearm of the first responder and is adaptable to the needs of different departments (law enforcement, medical, search and rescue, etc.). Figure 1 shows a 3D model of the final physical system the team created.

Figure 1: CAD representation of the physical system.

2.2. HOW IT WORKS

The system enhances communication between first responders by collecting all the data from the first responder and forwarding it to central command. Officials at central command can then distribute the information to other responders. Each component of this system has Wi-Fi connection capabilities. The router on the first responder transmits data from all the responder's devices to an IoT platform for central command. Unarmed responders have a similar setup, but their equipment excludes the three cameras. The unarmed responders will digitally record and mark the location, triage status, and additional comments of victims found in the active threat scenario. This information will be sent to the IoT network, and central command will have immediate access to the information.

3. HARDWARE

This section overviews all the different subsystems comprising the system. The subsystems include network connectivity, data collection, user interface, and power.

3.1. NETWORK CONNECTIVITY

Each first responder will carry a mobile router to connect to the internet. The router will transmit and receive data from central command. This system uses two different routers: the MiFi 8800L and the Cradlepoint IBR900.

Personal Hotspot:

The MiFi 8800L was chosen because it is currently in use by Logan City Police. The router will be carried individually by each responder. The router will connect the first responder to the IoT platform. This will allow the responder to receive data from central command via the IoT. The router has a max data transfer capability of 867Mbps, can connect up to 15 different devices, and has a 50 ft range. It also has a built-in battery that will last for a total of 24 hours [2].

Central Command Router:

The team uses a Cradlepoint IBR900 router to connect central command to the IoT platform. This connection will allow central command to receive info from the devices of all the responders in the field and distribute image data to the armed responders. Corporal Harvey requested a rugged router capable of connecting an entire military unit. This router was selected for central command because it was designed with first responder grade security features, adheres to military ruggedization standards (MIL-STD-810G), and can connect up to 128 devices [3]. Figure 2 shows both of the selected routers.

Figure 2: MiFi and Cradlepoint routers

3.2. DATA COLLECTION

Several different data types stream to the IoT platform to enhance intra-team communication. One data type is GPS data to report personnel and victim locations. The remaining sensors collect image data to identify people's roles in active threats and reduce radio communication. The image sensors include a body camera, a borescope, and a thermal camera. Raspberry Pi computers collect the data from each of the sensors and transmit the data to the IoT platform.

The data gathering and sending are achieved by python scripts running on Raspberry Pis. Each data type (GPS, borescope image, thermal, body cam) has a dedicated python script with a similar architecture detailed in Fig. 3. A command prompt to run these scripts is placed in the rc.local file of the Raspberry Pi which causes the Raspberry Pi to execute the script on startup. This allows the sensor to start streaming to the IoT platform when the Raspberry Pi is powered without any user input.

```
While (Raspberry Pi is on)
  Retrieve data from sensor
  Convert data to JSON format
  Confirm internet connection
    Update Thing property via JSON PUT request
  Wait for the platform to update
```

Figure 3: Python script pseudocode for sensors

The Python scripts have several levels of exception handling because any error that is not handled when the script runs from the rc.local file on start-up will terminate the script. The main function in the scripts has a loop which tests for an internet connection before calling the function to send the data (via Json PUT request). In the PUT request function, code for PUT request error handling will also catch any error associated with sending the data. This allows the sensors to be powered before the routers and stream data successfully once an internet connection is established. This exception handling also allows the router to lose internet connection due to poor cell signal and start streaming automatically once the cell signal allows for an internet connection.

The GPS requires a background process to run called GPS Daemon (gpsd) in order for a Python script to retrieve location data. Gpsd acts as a driver for the GPS on a Raspberry Pi and needs to be configured to "listen" to a specific port of the Raspberry Pi. Gpsd is configured to select this port on startup which allows the GPS to stream data automatically when the Raspberry Pi is powered.

Body Camera:

Many police departments currently outfit each of their officers with body cameras. Collecting live data from each officer's body camera will better inform the police chiefs of rapidly developing situations. Initial feedback from USU and Logan City Police requested implementing professional body cameras currently on the market (WatchGuard and Axon). Proprietary restrictions required the team to implement a custom body camera (see Fig. 4).

Figure 4: The body camera consisted of a Raspberry Pi computer with the Camera Module V2

The custom body camera is composed of a Camera Module V2 interfacing with a Raspberry Pi 3 model B+ through the Raspberry Pi's camera port. A Python script using the "raspicam" library allows image capture and transmission. The Raspberry Pi, camera, external power, and peripherals are contained in a single 3D printed box.

GPS:

SME feedback and initial requirements requested the system collect personnel location. A GPS module allows central command to know the location of the responders and enables responders to report the locations of victims. The system uses the Adafruit Ultimate GPS Breakout Board shown in Fig. 5. The GPS module connects to the same Raspberry Pi as the custom body camera and fits within a shared housing.

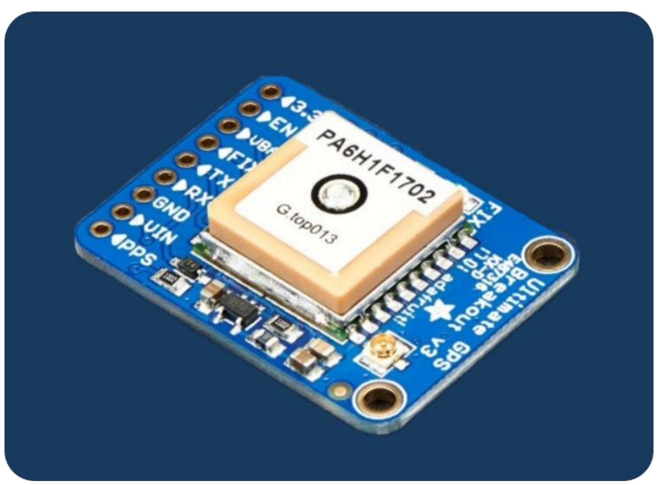


Figure 5: Adafruit Ultimate GPS Breakout Board

The GPS module provides three-meters accuracy outdoors with an unobstructed view of the sky [4]. Indoor location accuracy is lower than outdoor accuracy and varies depending on a variety of factors.

These factors include building composition, building height, and location within the building. When asked if this was a problem, Captain Budge stated it is sufficient to know whether or not his officers are in a particular building; further information can be communicated via radio. Testing showed the GPS module keeps a fix while inside a building provided it was within two-meters of a window or exterior door.

An optional pill battery mounted to the underside of the breakout board powers the GPS module. With the pill battery, the GPS will find a fix 2 - 15 seconds after the module is power cycled. Without the battery, the module receives power from the Raspberry Pi and requires 5 - 15 minutes to obtain a fix. The module updates at a rate between 1 -10 Hz. The battery mount is displayed in Fig. 6.

Figure 6: Optional pill battery emplacement for the GPS module

The GPS module interfaces with the Raspberry Pi through the UART connectors, which are a subset of pin connectors available on the Raspberry Pi's GPIO interface. This mounting scheme allows the GPS to interface with the Raspberry Pi while not exceeding the dimensions of the housing. The UART interface is shown in Fig. 7.

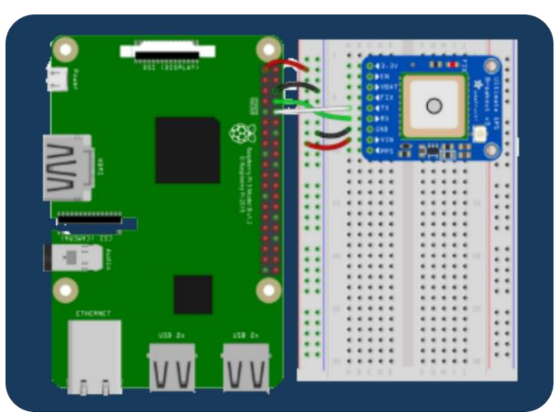


Figure 7: UART interface between Raspberry Pi and the GPS module

Borescope:

Corporal Harvey requested incorporating a borescope into the system. Other SMEs voiced that it would aid responders by allowing them looking around corners when hunting for shooters, looking under doors, and searching through rubble to find victims. The team chose to use a Depstech USB borescope since it could plug directly into the Raspberry Pi (see Fig. 8). This type of borescope connects to the Raspberry Pi computer and streams pictures to the IoT server.

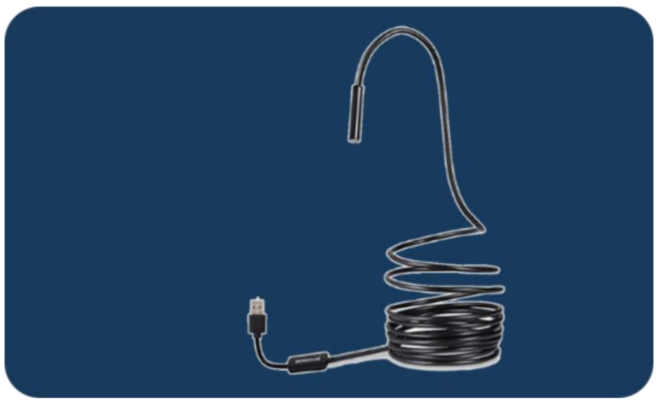


Figure 8: Depstech borescope used in the system

Thermal Camera:

Following the advice of Captain Budge, the team incorporated a thermal imaging camera into the system. Captain Budge mentioned the usefulness of having a thermal camera in finding hidden individuals. While the thermal camera can't actually see through materials that an individual would be hiding behind, it can detect left-over infrared footprints and assist the first responder in locating the individual.

The team used SparkFun's FLIR Radiometric Lepton Imaging Module (see Fig. 9) installed in the PureThermal 2 Lepton Smart Board (see Fig. 10). This setup effectively interfaces with the Raspberry Pi via USB and facilitates image transmission. An open source image processing software for Raspberry Pi's called "fswebcam" takes and stores the images from the module.

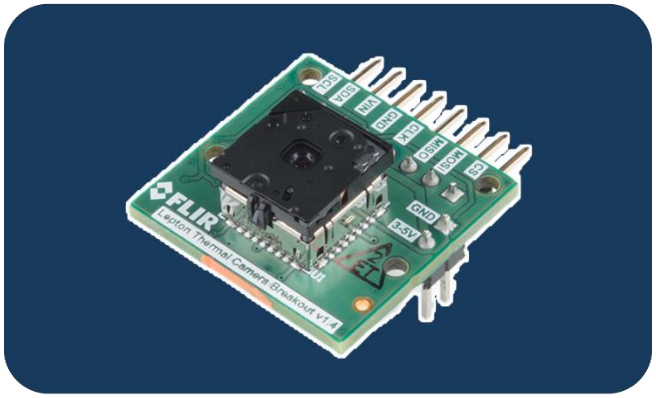


Figure 9: FLIR radiometric Lepton imaging module

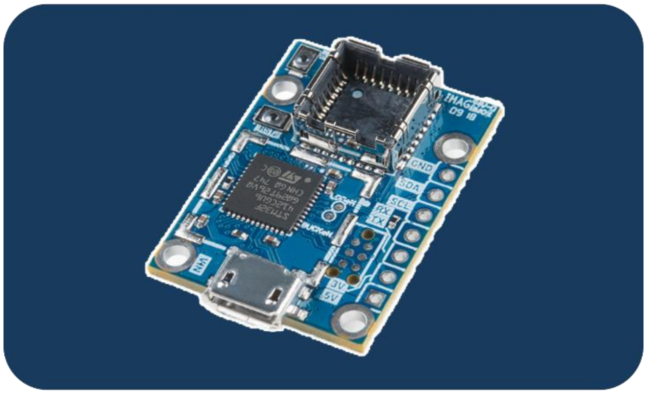


Figure 10: PureThermal 2 Lepton smartboard

3.3. USER INTERFACE

Phone:

The team made the decision to use a cellular phone as the user interface for the system because it would be an off-the-shelf option, has a built-in battery, and easily connects to the internet. Per SME request, the team chose the Samsung Galaxy S9 (see Fig. 11). SMEs preferred the Galaxy S9 over other phone options due to ideal screen size, familiarity with the Android operating system, and common usage among SMEs.

Figure 11: Samsung Galaxy S9 in Juggernaut phone case

Phone mounting system:

The team found an online company (Juggernaut phone cases) that manufactures military-grade cellphone mounts (see Fig. 12). When the team presented this to the SMEs as a potential mounting option, it was met with great enthusiasm. SMEs enjoyed the quick attach/detach ability provided by the BOA chord fastening system, as well as the flexibility to adapt to different forearm sizes of first responders. They also were impressed with the ability that a first responder would have in modifying the positioning of the mount as the situation required. SMEs provided the example of a first responder wearing the phone on their non-dominant arm to engage threats with a handgun, but that the first responder could switch the mount to their dominant arm if they used a shotgun or rifle.

Figure 12: Juggernaut armband with BOA cord fastener

3.4. POWER

SME feedback stated that power for the system should be easy to access and use disposable batteries. Multiple SMEs stated that they prefer AA batteries because they are used in current field devices. Using the same batteries that SMEs use in their current equipment is ideal because the first responders would not have to purchase or carry additional power units for active threat scenarios. Based on team testing, the battery pack (see Fig. 13) powers each device for a minimum of three hours and satisfies Requirement 1.3.9. The battery pack holds 6 AA batteries and connects to a UBEC board to convert the 9 V nominal output of the battery pack to the 5 V used by the Raspberry Pi. The battery pack powers the Raspberry Pi via the 5 V and ground pin connectors on the Raspberry Pi GPIO interface.

Figure 13: AA battery pack with UBEC volt dropper

4. THINGWORX PLATFORM

ThingWorx is the software subsystem of the team's first responder design project. ThingWorx is an IoT platform originally developed by PTC to analyze manufacturing data in smart factories. Because of this, the platform can receive information from a variety of data sources that are then accessed, processed, shared, and presented to other devices and users.

SMEs requested the system have built-in network security if video feed was going to be streamed from the first responder to central command. ThingWorx is designed with a focus on secure network communication. Software security features include role-based access controls, encrypted WebSocket channels, and multilevel authentication between the edge devices and the cloud. Additionally, each server hosted by PTC resides in secure data centers to protect the physical integrity of the system [5]. The team also chose to use ThingWorx due to the platform's ability to integrate with mobile edge devices i.e. Raspberry Pi computers. PTC developed ThingWorx to readily accept data from a variety of edge devices. Logan City Police and Cache County Sheriffs requested a platform to integrate their existing systems and technologies, which is possible due to the flexibility provided by ThingWorx. ThingWorx also has multiple built-in tools to help with GUI development and design that made presenting the data on the first responder's cell phone interface more organized. Ease of use in platform development and customization will promote platform adoption in future development.

4.1. FUNCTIONALITY:

The team created a system to enable communication between three functional groups: Armed Personnel, Unarmed Personnel, and Central Command.

4.1.1. Unarmed Personnel:

Unarmed personnel identify and evacuate victims in emergency situations. The system gathers GPS data from all personnel throughout the event. When personnel locate victims, the system allows the user to catalog the number of victims in the area (categorized by a TRIAGE counter), input location information, and indicate the location with a pin on the virtual map. The GUI for medical personnel includes a map, screens to input victim information, and the ability to view reported victim data.

4.1.2. Armed Personnel:

In hostile emergencies, such as an active shooter, military or police personnel may take a combative role. Combative officers search the emergency area to eliminate threats. The system gathers video streams and GPS data from these officers. The system displays a map of the emergency and a video stream of interest when desired by central command.

4.1.3. Central Command:

Central command dispatches personnel to the emergency, coordinates the efforts of responding units, and facilitates information sharing between personnel. The system collects data from the different responders and displays this data to a central command to enable more informed decision making. The GUI for central command includes a map of the emergency, a personnel roster that includes personal information on the responders, data on located victims, and the ability to share a video stream of interest to the team.

4.2. SOFTWARE STRUCTURE:

ThingWorx simplifies object-oriented software development for IoT applications. Class instances in ThingWorx are called *Things*. Data members, which store each Thing, in ThingWorx are called *Properties*. In our system, the Raspberry Pis update Thing properties using JSON PUT requests. Member functions, which are executable code snippets, are called *Services.* In ThingWorx, users can use ThingTemplates to enable class inheritance and simplify Thing creation.

The platform uses templates to create each instance of armed responders, unarmed responders, and victim locations. The responder templates include personal information of each responder, their role, and location. Armed responders also have additional properties to store their camera data. The victim location Things record location, name, location description, and TRIAGE counts. A single Thing called reportedLocation facilitates data sharing between the other things. Appendix D provides a summary of all the implemented Things, their properties, and services.

4.3. MASHUPS (USER INTERFACES):

ThingWorx implements GUIs using “mashups”. A *mashup* is a program in ThingWorx to integrate and display platform information to the user. Mashups are the web page each user sees when they access the platform. This section discusses each mashup used in LEGION.

4.3.1. Unarmed Responders:

4.3.1.1. MedicalResponderBase:

Function: Home GUI for the unarmed responders.

Description:

The left portion of the UI displays the active emergency map with icons indicating all responder and victim locations. The right portion of the screen shows a more detailed list of the reported victim locations. The list displays the location name, GPS coordinates, and a number of victims at that location categorized by TRIAGE status. In the bottom right of the UI are two buttons to edit and create victim locations. Figure 14 shows the medicalResponderBase UI.

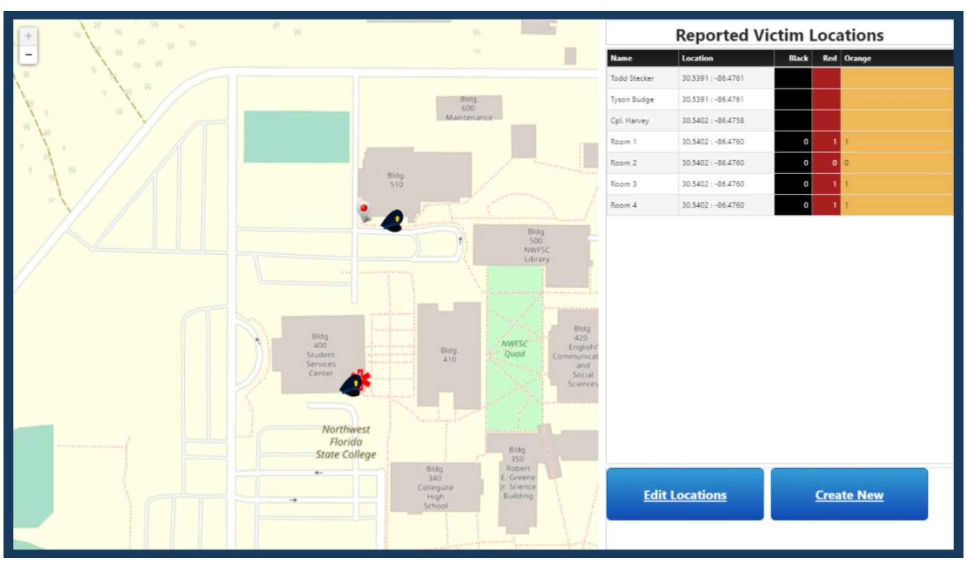


Figure 14: Base screen for the unarmed responders’ GUI.

4.3.1.2. ListVictimLocations:

Function: Display and edit reported victim locations.

Description:

The top section of this UI provides a drop-down list for the unarmed responder to select the victim location they wish to edit. Next to the drop-down list is a text entry box to edit the name of the location. The middle section of the UI contains three numeric sliders to update the number of victims at the selected location by TRIAGE status. The bottom section of the UI contains a text entry area to add information about the location. Finally, a submit button gives the user feedback when clicked to inform the user the changes have been saved. The unarmed responders return to the base screen by clicking the exit bubble at the top-right of the window. Figure 15 shows the listVictimLocations UI.

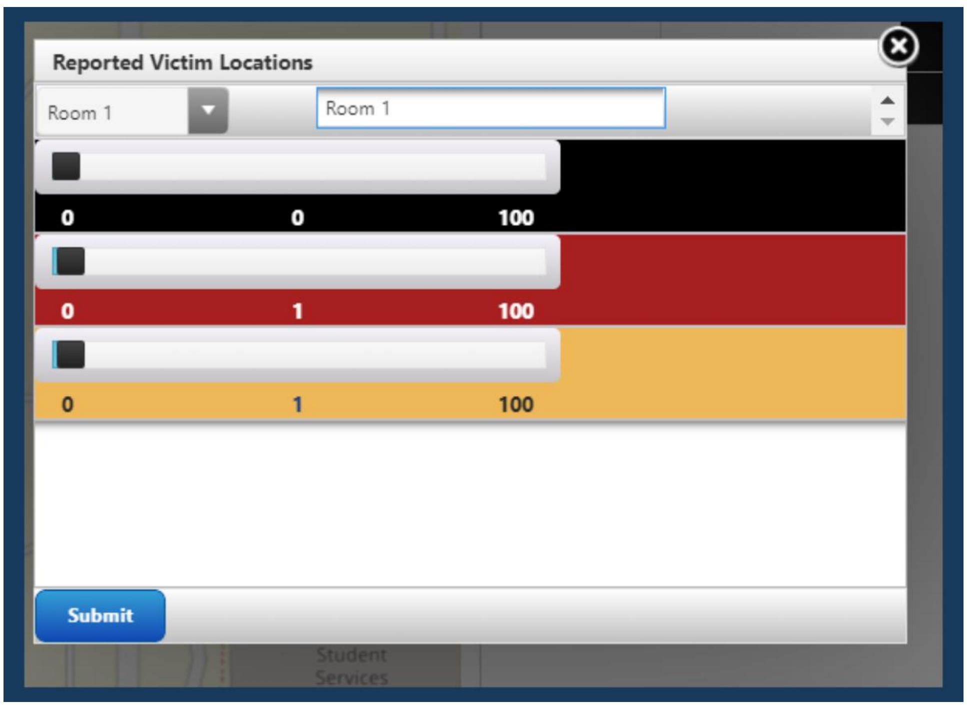


Figure 15: Add/Edit victim location screen

4.3.1.3. AddVictimLocation:

Function: Create new victim location using responder input

Description:

The addVictimLocation UI is nearly identical to the listVictimLocation UI. The only difference is the add location UI does not have the drop-down to select other locations. Additionally, the location name defaults to "New Location #", where "#" is the current number of reported locations. Pressing the exit bubble at the top-right of the window returns the user to the medicalResponderBase UI. When creating a new location, unarmed responders need only open this UI and close it. Closing the UI will send the responder's GPS location as the victim location. The unarmed responders can edit any property of the location or communicate the location information to central command. Figure 15 shows the listVictimLocations UI that is nearly identical to the addVictimLocation UI.

4.3.2. Armed Responders

4.3.2.1. ArmedResponderBaseMashup:

Function: Home GUI for the armed responders.

Description:

The left portion of the UI displays the active emergency map with icons indicating all responder and victim locations. The right portion shows the video stream of interest. Armed responders select the video stream of interest using large tabs above the video feed. The UI was designed to maximize button size at the request of Cpt. Budge, USU Police, and Cpl. Harvey. Using these tabs, the armed responders can view the footage from their body camera, their borescope, their thermal camera, or a video feed of interest from central command. Figure 16 shows the armedResponderBaseMashup UI.

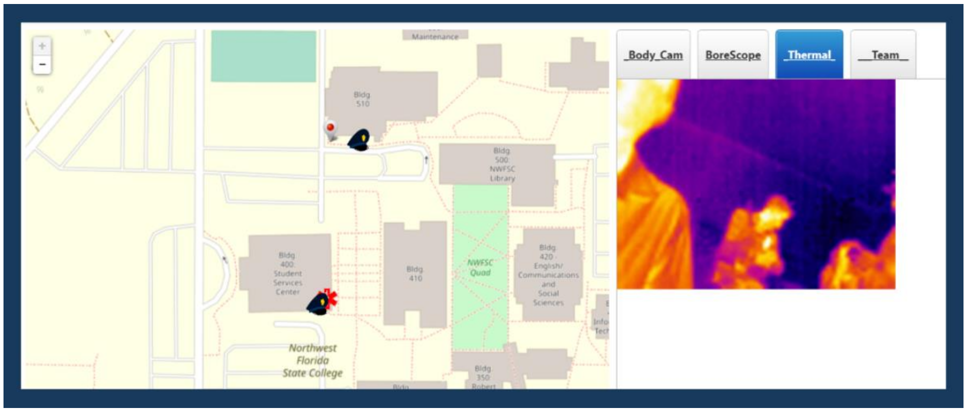


Figure 16: Armed responder screen with the thermal stream selected

4.3.3. Central Command

4.3.3.1. CommandResponderMashup:

Function: Base screen for central command.

Description:

Across the top of this UI is a customizable logo of the command organization. The current implementation shows the College of Engineering logo. The left portion of the UI displays the active emergency map with icons indicating all responder and victim locations. The bottom-right corner of the screen shows a streamed image from a responder camera selected by central command. The top-right corner contains three sub-windows that can be selected by a set of three tabs.

The first tab, as shown in Figure 17, shows the “Responders” sub-window. This sub-window provides buttons to view detailed information about each responder. The bottom section of this sub-window displays a list of all the armed responders and their streaming cameras. Next to the available video streams is a large button to broadcast the selected video stream to all the active armed responders.

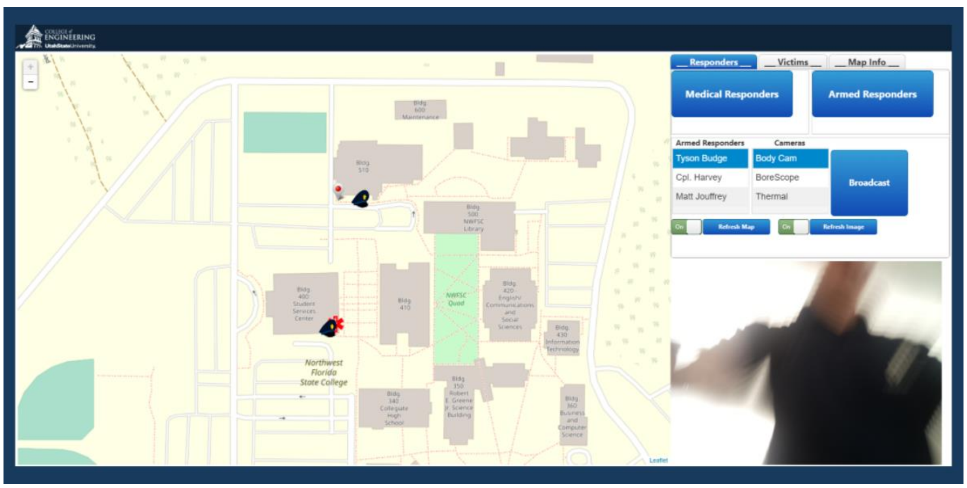


Figure 17: Central command base showing camera and responder information

The next tab selects the "Victims” sub-window. This sub-window displays the listVictimLocation UI described in 4.3.1.2. Using this window, central command can edit the locations provided by the medical first responders. “John Doe”, the EMT SME, mentioned he would disregard any tool that slowed him down in an emergency. Allowing central command to update the victim location information enables the medical responders to treat victims with minimal interference from this system, thus satisfying Requirement 1.3.6. Figure 18 shows this sub-window.

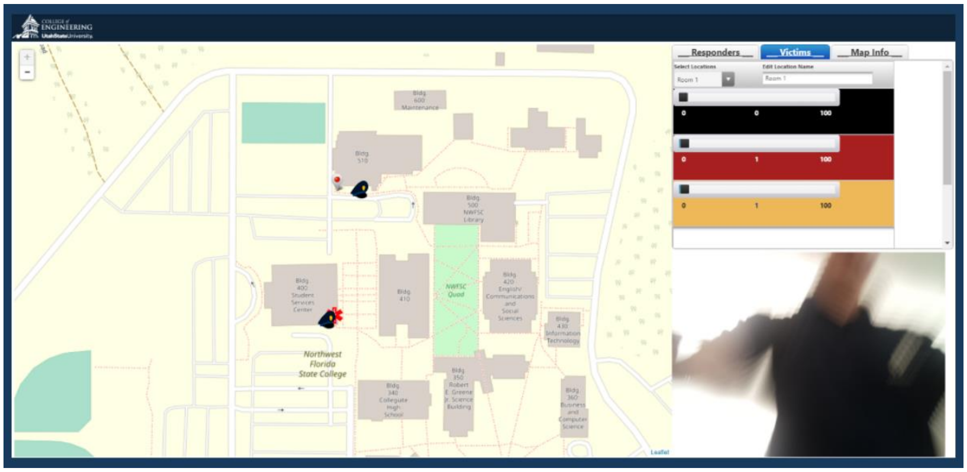


Figure 18: Central command base showing the edit victim locations tab

The final tab shows the "Map Info" sub-window. This sub-window shows the same list of detailed locations provided in the medicalResponderBase UI described in 4.3.1.1. This map information enables the responder leadership to facilitate resource allocation. With this list of victim locations, leadership can readily identify the locations of interest in hostile threat situations, natural disaster recovery, or any other wide-spread emergency. Figure 19 shows this sub-window.

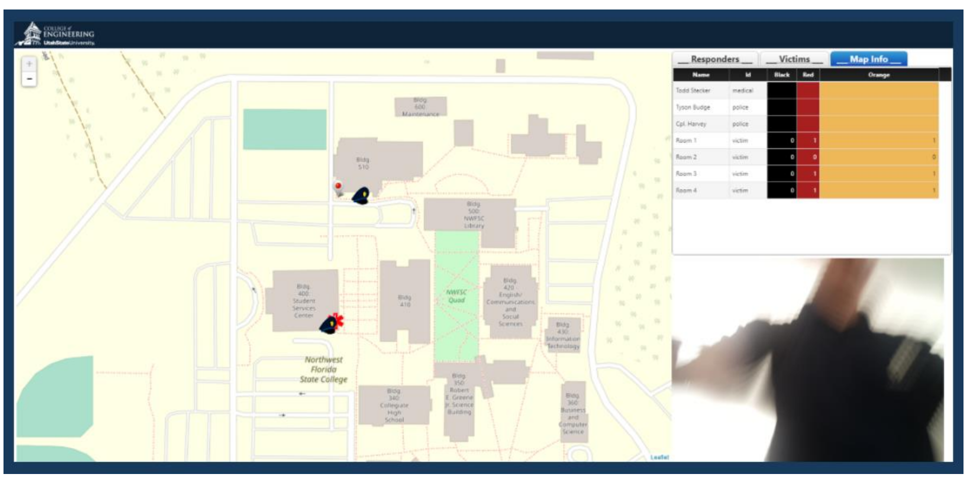


Figure 19: Central command base showing the map information tab

4.3.3.2. ListMedicalPersonInfo:

Function: View unarmed responder roster and their information

Description:

Pressing the "Medical Responders" button in Fig. 16 accesses this UI to provide detailed information about each active medical responder. Central command can select each medical responder from the drop-down list at the top-left of the window. Emergency response organizations could customize the information they provide for their personnel. For this general application, the UI reports the responders' name, organization, identification number, relevant training, phone number, age, and gender (see Fig. 20). Pressing the exit bubble at the top-right of the window returns the user to the commandResponderMashup UI.

Figure 20: Personal information display for the first responders

4.3.3.3. ListPersonInfoMashup:

Function: GUI to view the armed responder roster and their information

Description:

Pressing the "Armed Responders" button in Fig. 20 accesses this UI. This mashup is identical in function and appearance to the listMedicalPersonInfo UI outlined in 4.3.3.2.

5. ANCILLARY TOPICS

5.1. ENVIRONMENTAL AND SOCIETAL IMPACT

The environmental impact of the system design is minimal. The major functionality of the system is dependent on software, which has little to no impact on the environment. The most negative impact that the system would have on the environment would be contributed from the disposable batteries. Adhering to proper disposal practices will minimize the impact of these batteries.

Potential societal impacts would be beneficial in more quickly assessing and reacting to active threat scenarios. Improving communication between central command and first responders would allow leadership to better assign tasks to responders. The potential of having streaming cameras from the first responders engaged in the active threat would also allow central command to have a better understanding of how the event is unfolding in real time. Sharing victim location data will allow leadership to better orchestrate medical responders in administering first-aid.

5.2. SAFETY

Safety risks are also minimum with the current design. None of the components of the system utilize any hazardous materials that would affect the health of the user. All the system edge devices have a small SWAP (size, weight, and power) characteristic, so the devices are safely carried with minimal additional strain on the first responder.

5.3. LESSONS LEARNED

The team learned about networking technologies throughout the course of this project. From SME feedback, the team decided to take a less-than-expected (and less-than-mechanical) route to design the system to meet the problem statement requirements.

If the team were to do this project again, they would spread out the research and studying of the capabilities of ThingWorx. Throughout the course of the project, there was only one main student who invested the time into researching the networking/IoT software that the team used for their system. Due to this, the development time was hindered. Had the team spread it out more evenly, the final system could have had more functionality.

Another thing that the team would have done differently is created a team with more disciplinary backgrounds. Everyone on the team was declared a mechanical engineering major, with only two members that were minoring in computer science. If the team had more diverse backgrounds, software development could have been assigned to members that were better qualified to design them.

5.4. RECOMMENDED FUTURE WORK

Future development for this system is essentially boundless. Without knowing exactly what technologies will become available in the future, the team has pinpointed several possible developmental focuses that could be integrated into the system in the near-future.

5.4.1. First Responder Sensor Development

The first recommendation is conducting more thorough edge device research and design. The team obtained satisfactory performance from their edge devices built using Raspberry Pis. Improving the system may include developing custom sensors or cooperating with professional companies to integrate their sensors. These improvements will add greater functionality, improved performance, and greater data security.

5.4.2. Live Social Media Data Feeds

Throughout the course of the project, the team interacted with Todd Stecker, a PTC employee, who showed potential applications of the ThingWorx platform and helped integrate the edge devices. One of the ThingWorx capabilities he showed the team was the ability to import data from social media feeds. Using keywords, ThingWorx can pull live data from about developing emergencies from social media databases. First responders could use this additional information to increase situational awareness and improve communication with the public.

5.4.3. Dynamic Google Maps Overlays

Another beneficial ThingWorx feature that Todd showed the team was the ability to create interactive Google Maps overlays. This would require pre-existing access to facility floorplans or geographical data. Once obtained, overlays can be created on a Google Maps view within ThingWorx. These overlays could provide the first responders with geographical information about the event e.g. rooms with victims/threats, areas of concern, safe areas.

5.4.4. First Responder Database Integration

First responders currently collect and store data in a variety of software platforms. Many police departments use Spillman to record body camera footage and collect information from 911 calls. Fire departments and county emergency managers use geographic information databases to track damage from natural disasters. Importing data from these databases will increase the information available to the first responders and improve user familiarity with the platform.

6. REFERENCES

[1] USU AFRL Team, “Requirements Document”

[2] Verizon, “User guide. MiFi 8800L”, https://ss7.vzw.com/is/content/VerizonWireless/Devices/Verizon/Jetpack%20MiFi%208800L/User%20Manual/verizon-jetpack-mifi-8800l-um.pdf

[3] Cradlepoint,” ruggedized long distance mobile router”, https://cradlepoint.com/sites/default/files/upload-file/ibr900-spec-sheet-032019v2.pdf

[4] Adafruit Industries, “*Adafruit Ultimate GPS Breakout - 66 channel w/10 Hz updates -Version 3,”* https://www.adafruit.com/product/746

[5] ThingWorx, “Providing Secure Connected Products,” https://tpg-twxdevzone.s3.amazonaws.com/files/media/security/ThingWorx%20Security%20Whitepaper.pdf.

Appendix A
Attached References

[Reference 1] AFRL Problem Statement Rev 0

Air Force Research Laboratory's (AFRL) Center for Rapid Innovation (CRI)

2019 University Design Challenge (UDC) and Service Academy Challenge (SAC)

Problem Statement: ***Mobile Active Threat Emergency System (MATES)***

This Senior Capstone Design project during the UDC/SAC is to perform in-depth research, consultation, and exploration to engineer, design, and build a prototype system to locate personnel during an Active Threat (shooting, stabbing, bomb, hostage taking) event in an educational, office, shopping, or multi-room facility and integrate data streams (information coming to the command center) to provide First Responders with real-time info. It is assumed a threat causes personnel to "shelter-in-place" and often these personnel are unable to receive or send communications and unaware if the threat is active, contained, or eliminated; injured or captive personnel may be unable to communicate with outside, rescue, or other personnel; and finally, integrate information from on-site, radio, telephone, and miscellaneous data sources into a usable First Responder tool.

According to the Federal Bureau of Investigation (FBI), there were 250 Active Shooter incidents in the United States from 2000-2017. Of these 250 incidents, 52 of them or 20.8% were at Educational Institutions. According to the FBI, an "active shooter is an individual actively engaged in killing or attempting to kill people in a populated area." The United States Department of Homeland Security defines an active shooter as "an individual actively engaged in killing or attempting to kill people in a confined and populated area; in most cases, active shooters use firearms, and there is no pattern or method to their selection of victims. Most incidents occur at locations in which the killers find little impediment in pressing their attack. Locations are generally described as soft targets, that is, they carry limited security measures to protect members of the public."

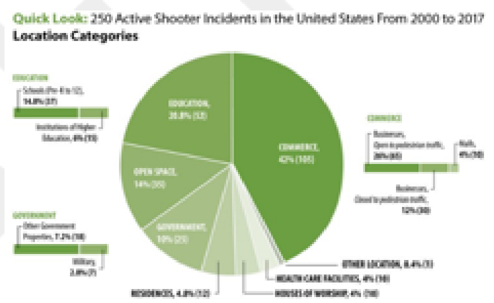


Figure 1: *The above pie chart shows a statistical breakdown of the location categories where the 250 active shooter incidents took place in the U.S. from 2000 to 2017. Those location categories include: areas of commerce, 105 incidents or 42 percent; educational environments, 52 incidents or 21 percent; government property, 25 incidents or 10 percent; open spaces, 35 incidents or 14 percent; residences, 12 incidents or 5 percent; houses of worship, ten incidents or 4 percent; and health care facilities, ten incidents or 4 percent. https://www.fbi.gov/about/partnerships/office-of-partner-engagement/active-shooter-incidents-graphics*

Due to the rapid and dynamic nature of active threats and their propensity to occur against soft targets and unarmed persons, First Responders must be trained and prepared to address these incidents by recognizing characteristics associated with past attackers, maintaining situational awareness, developing countermeasures, and integrate all methods of communication sources for immediate use. Additionally, First Responders must determine which personnel are hostages and which is the threat(s), as well as, who requires medical care and specialized extrication.

In any situation, the "operator" (military, police, first responder) wants a device which works as advertised, has a small SWAP (size, weight, and power requirement), requires little to no training, and is easy to use. Consider flexibility of uses, the durability of the device, weather conditions, portability and probability of use over other methods.

Your team is <u>required</u> to meet and interview at least five Subject Matter Experts (SMEs) from different departments, groups, or areas. For instance, interviewing five campus police officers does not count. Consider police, military, first responders, security guards, school resource officers, and so forth. Bonus points for interviewing personnel involved with a real active threat or active shooter incident or a professional trained to teach and instruct active shooter events. Additionally, concept drawings are required during your PDR telecons and photographs are required during your CDR telecon <u>and</u> video proof of your device during testing is required in your in-person briefing to the judges. Your final design <u>must</u> be operational and undergo at least one test prior to attending the event.

The University Design Challenge culminates in a Concept of Design briefing and Ground Demonstration of the student designs. The final demonstration includes three phases, conducted in sequence. First, present a thorough and in-depth presentation to the judges and SMEs in attendance. This briefing includes your research, reasoning, and engineering. Second, deploy your device into a "normal building environment " and determine which rooms, offices, closets, and so forth have humans either hiding or captive, and attempt to determine which of any of the personnel are the active threat. Third, perform a similar search as above, however, in an outdoor environment through collapsed building material (such after an explosion), sand, dirt, tunnels, caves, vehicles, trailers, and so forth.

Scoring your Locator Device is based on Size, Weight, Performance, Ease of Operation, Reusability, Innovation, Creativity, Engineering, Research, SME interviews, Participation, Presentation, and Judge's Comments.

If successful, your device may be included in your University or Military Academy's First Responder Tactics, Techniques, and Procedures (TTPs). Your device may save the lives of your classmates, professors, administrators, and others at your school. Quite possibly, your system may be implemented in institutions, business, government, and commerce building across the world.

Program Manager, Mr. Mike Lazalier, michael.lazalier.1@us.af.mil, Arnold Engineering Dev Complex
Asst. Program Manager, Mr. Mickey Wright, wrightm@rallypointmanagement.com, Rally Point Management

Appendix B
Bill of Materials

The team has included a list of all the components to their system, combined with the cost per component budget of the system. The team determined that it would be beneficial to break down the cost of the system into two parts: cost of components that were assumed to already be in the possession of the First-Responders, and cost of the components that were unique to the system. The team also determined to simplify the build of materials and budget by listing the cost and components for a single First-Responder. To find the cost of outfitting an entire team one would simply multiply the total by the appropriate number of responders needing to be outfitted.

Existing First-Responder Equipment		
Component	Price	Vendor
Flak vest	$ 38.99	Amazon.com
Jetpack 8800L Mifi (with 1 month unlimited data)	$ 270.00	Verizon
Retevis Radio handsets	$ 149.99	Amazon.com
HP Spectre Laptop (For Central Command)	$ 1,499.98	BestBuy
Cradlepoint Router (for Central Command)	Donated	Cradlepoint
Total cost of assumed existing equipment	$ 1,958.96	

First Responder Interface		
Component	Price	Vendor
Samsung Galaxy S9	$ 728.99	BestBuy
Juggernaut phone case & armband	$ 149.23	Juggernautcase.com

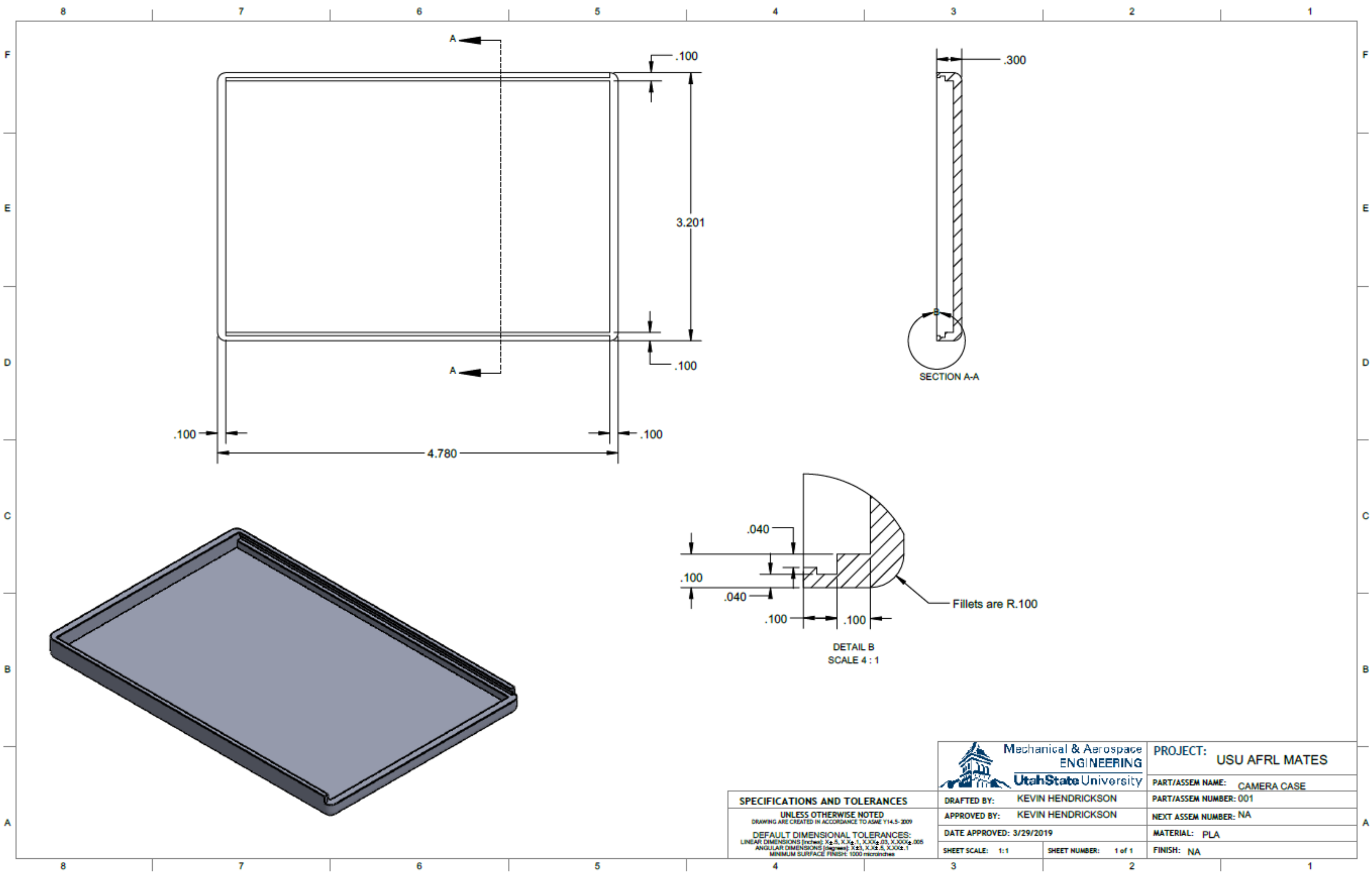
Body camera		
Component	Price	Vendor
Raspberry Pi 3b+ starter kit	$ 79.99	Amazon.com
UBEC receiver servo	$ 8.99	Amazon.com
4AA Battery Pack	$ 10.99	Amazon.com
4AA Duracell Batteries	$ 2.00	Amazon.com
3D printed Case	$ 5.00	USU Library
Raspberry Pi camera	$ 29.95	Sparkfun.com
Raspberry Pi GPS module	$ 39.95	Adafruit.com
CR1220 coin cell battery	$ 2.99	Interstate Battery

Borescope Camera		
Component	Price	Vendor
Raspberry Pi 3b+ starter kit	$ 79.99	Amazon.com
UBEC receiver servo	$ 8.99	Amazon.com
4AA Battery Pack	$ 10.99	Amazon.com
4AA Duracell Batteries	$ 2.00	Amazon.com
3D printed Case	$ 5.00	USU Library
Depstech USB Borescope	$ 21.99	Amazon.com

FLIR Thermal Camera		
Component	Price	Vendor
Raspberry Pi 3b+ starter kit	$ 79.99	Amazon.com
UBEC receiver servo	$ 8.99	Amazon.com
4AA Battery Pack	$ 10.99	Amazon.com
4AA Duracell Batteries	$ 2.00	Amazon.com
3D printed Case	$ 5.00	USU Library
Flir Thermal Cam (w/ Purethermal2 breakout board)	$ 339.49	Sparkfun.com
FLIR USB data cord (1m)	$ 3.95	Sparkfun.com

Software Development		
ThingWorx IoT Software	Donated	ThingWorx.com
(Typical cost is about $4,000 for a ThingWorx license)		
Total system cost for one First-Responder	$ 1,637.45	

Appendix C
Drawing Package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UtahState University
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PART/ASSEM NUMBER: 001
NEXT ASSEM NUMBER: NA
MATERIAL: PLA
FINISH: NA
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APPROVED BY: KEVIN HENDRICKSON
DATE APPROVED: 3/29/2019
SHEET SCALE: 1:1
SHEET NUMBER: 1 of 1
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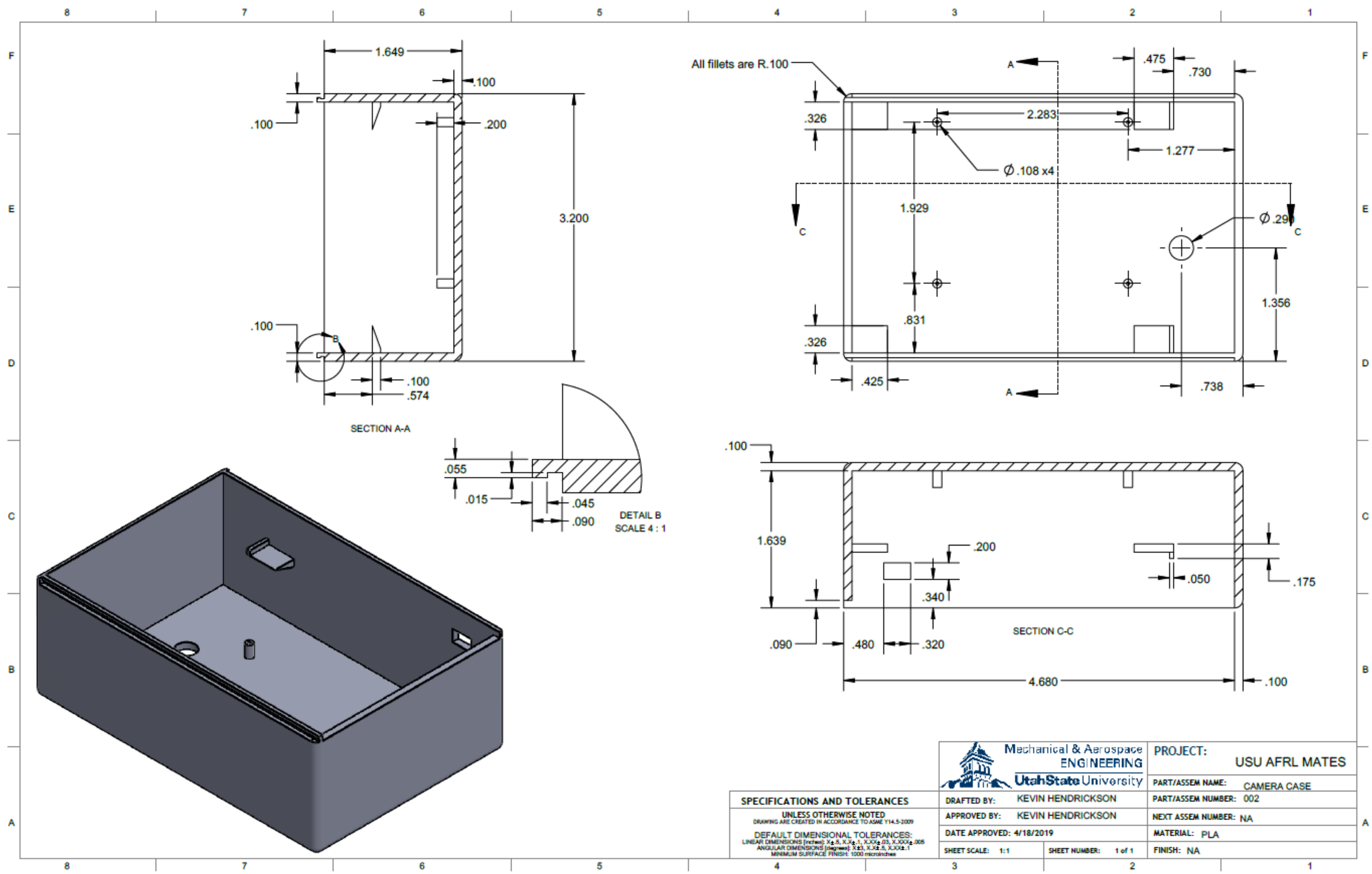
ANGULAR DIMENSIONS (degrees): X±3, X.X±.5, X.XX±.1
MINIMUM SURFACE FINISH: 1000 microinches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UtahState University
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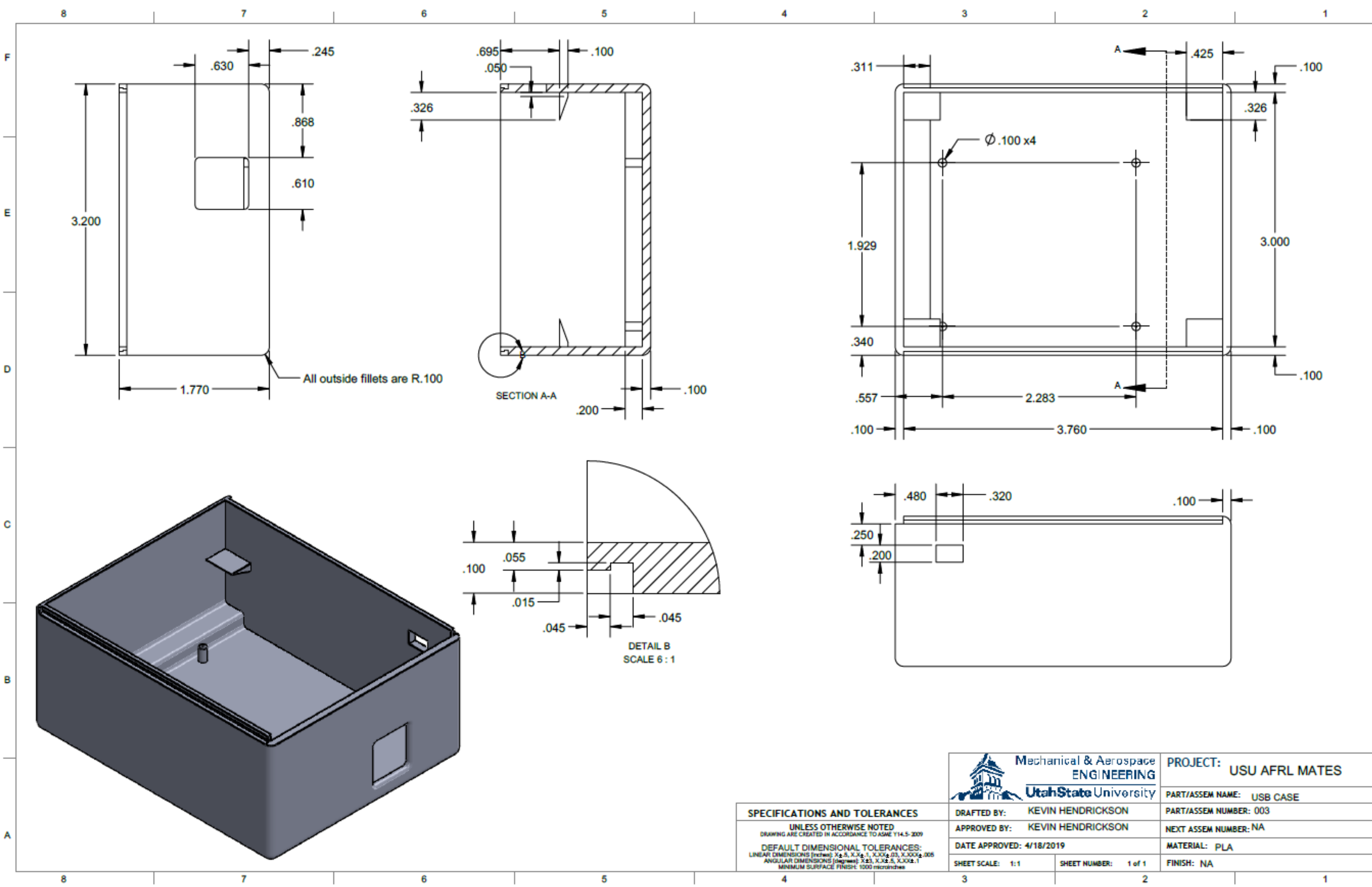
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UtahState University
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DRAFTED BY: KEVIN HENDRICKSON
APPROVED BY: KEVIN HENDRICKSON
DATE APPROVED: 4/18/2019
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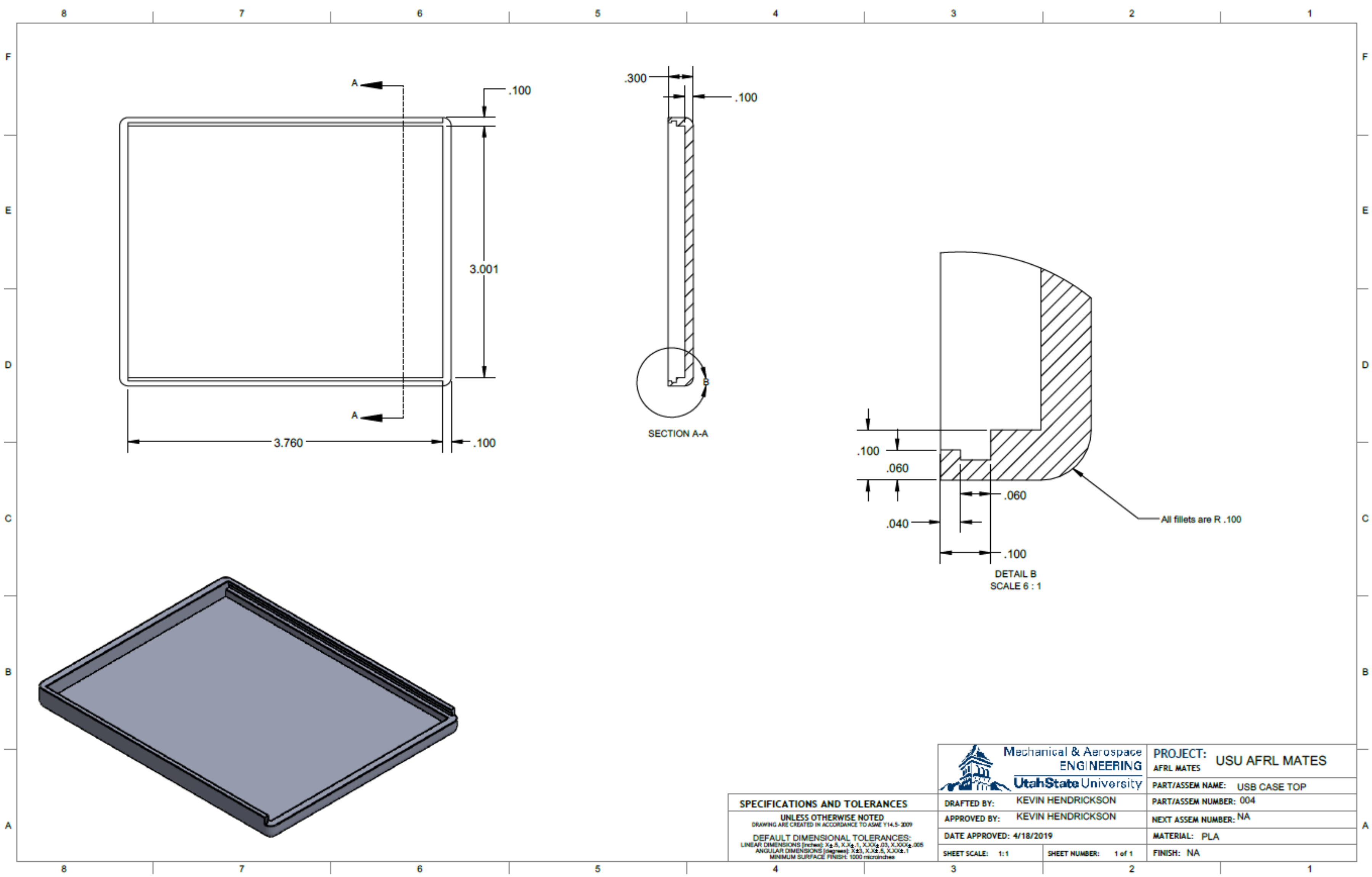
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UtahState University
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Appendix D
ThingWorx Implementation

Templates:

ResponderTemplate:

Inherits: None

Properties:

- **PersonInfo:** Data structure to store personal/contact information of responders
- **Id:** Responder name
- **Location:** GPS coordinate location

Services:

- **SetPersonInfo:** Function to edit the personInfo property
- **UpdateMyLocation:** Use incoming GPS signal to update responder location

VictimLocation:

Inherits: None

Properties:

- **PlaceDescription:** Details about each victim location.
- **Id:** Location title
- **Location:** Location GPS coordinates
- **Black:** Number of victims under triage black condition
- **Red:** Number of victims under triage red condition
- **Orange:** Number of victims under triage orange condition

Services:

- **ReturnVictimLocationDataShape:** Collect location information for display on the map widgets

ArmedResponderTemplate:

Inherits: responderTemplate

Properties:

- **BoreImage:** Borescope image stream
- **ThermalImage:** FLIR camera image stream
- **Video:** Body camera image stream
- **CamList:** Data structure to store all camera streams

Services:

- **GetArmedResponderLocationData:** Collect data for transmission to central command mashup
- **GetLocation:** Return responder's location to accessing entities
- **SetCams:** Update the CamList property

Implementing Things:

- ArmedResponder1
- ArmedResponder2
- ArmedResponder3

MedicalResponderTemplate:

Inherits: responderTemplate

Properties: See responderTemplate properties

Services:

- **CreateNewVictimLocationWithInputs:** Use the responder's location and input from the mashup to create a new victim location
- **GetMedicalResponderLocationData:** Collect data for transmission to central command mashup

Implementing Things:

- medicalResponder1
- medicalResponder2
- medicalResponder3

Other Things:

ReportedLocation: Collect all responder and victim information for the mashup

Inherits: None

Properties:

- **AllLocations:** Data structure to report all responders and victim locations. Used to populate the list widgets
- **NumTotalLocations:** The total number of reported locations
- **ArmedResponders:** List of all active armedResponders
- **BroadcastThing:** Indicator of which armed responder's video stream is being broadcasted
- **BroadcastCam:** Which camera from the BroadcastThing is being broadcasted
- **BroadcastImage:** Property storage of the image being broadcasted
- **MedicalResponderLocations:** Storage entity for all active medical responders
- **ResponderLocations:** List of all active responder locations
- **NumResponders:** The number of active first responders
- **VictimLocations:** List of all reported victim locations
- **NumVictimLocations:** Total number of reported victim locations

Services:

- **GetArmedResponderLocations:** Update the armedResponders property
- **GetLocations:** Update the victim locations property
- **GetMedicalResponderLocations:** Update the medcalResponders property
- **GetResponderLocations:** Update the responderLocations property
- **SetAllLocations:** Update the allLocations property
- **SetBroadcastImage:** Enable video stream broadcast from the command mashup

Appendix E
Professional References

	Company	*Discipline*	*Location*

<u>CMSgt (retired) Mickey Wright</u>

WrightM@rallypointmanagement.com	*Rally Point Management*	*USAF BA*	*Ft. Walton Bch*

"CMSgt (retired) Mickey Wright spent 30 years in the USAF as a Combat Controller. As part of the most highly decorated USAF unit since the Vietnam War, Mr. Wright served at the Squadron, Group, Wing, and Command level.

His first assignment after technical training was the 1st Special Operations Wing Combat Control Team at Hurlburt Field, Florida and his last assignment in the USAF was as Superintendent of the Special Tactics Training Squadron (STTS). As the STTS, Mr. Wright provided leadership and management to the over 400 joint service and interagency cadre and students integral to sustaining global Special Tactics Battlefield Airman and Joint Terminal Attack Control qualifications. Since his USAF retirement, Mr. Wright is employed by Rally Point Management as a special operations subject matter exert focusing on advanced technologies, capabilities development, and technology integration. In this capacity, Mr. Wright supports government laboratories, academia, and industry. Mr. Wright sits on the Board of Directors of the Air Commando Foundation and the Combat Control Foundation. Mr. Wright despises excuses, time wasters, slackers, and braggarts. Finally, Mr. Wright is a cantankerous old guy, and he usually calms down with an iced or hot coffee spiked with sugar-free vanilla syrup. "

<u>Mr. Mike Lazalier</u> - *931-454-4815*

michael.lazalier.1@us.af.mil	*USAF*	*ME/AE*	*AEDC/Arnold AFB*

Mr. Lazalier is a mechanical engineer with over 18 years of mechanical engineering experience. He's spent those 18 years working in Air Force ground test facilities that simulate real-world flight conditions from sea-level to exo-atmosperic from subsonic to hypersonic speeds developing and testing various weapons systems for the USAF. Mr. Lazalier is now the Technical Advisor for all ground test facilities at AEDC ensuring the health and veracity of all test capabilities of the complex. He's been involved with the University Design Challenge since 2014 (PM of 2017 and 2018 challenges).

<u>Mr. Steve Hulls</u>

hulls@rallypointmanagement.com	*Rally Point Management*	*AT/SWAT*	*Ft. Walton Bch*

Mr. Hulls is a retired Sergeant from the Fort Walton Beach Police Department with 20-years of experience. He has extensive experience as SWAT for 15 years and 4 years as Team Leader. Mr. Hulls is a FDLE Certified Instructor, Firearms Instructor, Certified Armorer on multiple firearm platforms, and an Active Shooter Instructor for 18+ years. Mr. Hulls has developed and implemented Annual Active Shooter training and curriculum. He is currently contracted with RPM as SME for UDC 2019.

	Company	*Discipline*	*Location*

Mr. Josh Osborne

joshua.osborne.4@us.af.mil	*USAF*	*ME/AE*	*AEDC/Arnold AFB*

Mr. Osborne is a mechanical engineer with 10 years of practical engineering experience. Mr. Osborne is prior Air Force National Guard, but currently works as an Air Force civilian. As a civilian he has functioned as a project manager, test data analyst, test engineer, test manager, and senior engineer for test capabilities integration associated to the following areas: turbine and scramjet engine ground testing, aerodynamic transonic and hypersonic ground testing, and instrumentation and diagnostics technology development. He's been involved with the University Design Challenge since 2013 (PM of 2015 and 2016 challenges). He is an amicable gentleman that attempts to counterbalance cantankerous old guys via girly coffee drinks or with just a plain old snickers candy bar.

Mr. Devon Parker

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Mr. Parker has 22 years of engineering experience. He's spent the last 15 years of his career at Arnold Air Force Base where he's served as the lead test engineer of the largest turbine engine test facility in the US, Deputy Director of the Aeropropulsion Test Branch at AEDC, and currently the Branch Chief for Test Capabilities Integration at AEDC tasked with ensuring every ground test facility operated by the USAF is capable of meeting future test requirements. Devon has been involved with the AFRL University Challenge for the last 7 years. He was the PM from October 2011 through May 2014 before transitioning to a support role and design judge.

Mr. Wallace Patterson

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Mr. Patterson has 32 years of experience as a civilian in the Air Force acquisition system including basic research, exploratory research, advanced development, and other programs such advanced solar cells for the satellites, supply chain management tools, artificial intelligence for white collar automation, hardened materials, novel biomaterials, biomimetics, biosensors, and the microbiome of the USAF aircraft and infrastructure. Mr Patterson is the senior program manager for the Biological Materials & Processes Research Team for the Air Force Research Laboratory's Materials and Manufacturing Directorate (AFRL/RX). He is the RX Lead for the Personnel Recovery Service Core Function and a charter member of the Junior Force Warfighter Operations in RX Leadership Group. Mr Patterson is a former officer in the United States Navy Reserve, Naval Sea Systems Command and holds B.S. in Systems Engineering. He has firearms and basic life support instructor certifications and recently had a main chute malfunction while skydiving.

	Company	*Discipline*	*Location*

Dr. Brett Bolan

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Dr. Brett Bolan, is a Chemical and Materials Engineer with over 28 years of service as an Air Force civilian working in the Air Force Research Laboratory's System Support Division providing time critical Materials & Processing expertise in Adhesives & Composites (composite processing, adhesives and bonding, M&P and equipment development/evaluation and on-aircraft bonded repairs). Prior to working for the AF, he spent 6 years on active duty as an Army Chemical Officer then transferred to the AF Reserves where among other things he was the PM for the Service Academy Challenge for two years. He retired as a Colonel.

Mr. Bryan Sanbongi

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Mr. Sanbongi's educational background includes a BS degree in Mechanical Engineering and Materials Science, and an MS in Aviation Safety focused on aviation security. Mr. Sanbongi's 35+ year career has included conducting aircraft failure analysis for the Air Force including accident and fire damage investigations, developing aviation and environmental safety coursework and related technology at the FAA schoolhouse in Oklahoma City, leading technology development at AFRL that has transitioned new capabilities for turbine engine inspection and person-borne 'suicide vest' IED detection, and currently focuses on customer engagement and tech development supporting the special operations (SO) and global Intelligence, surveillance and surveillance (ISR) communities. Mr Sanbongi has judged and supported AFRL engineering design competitions since 2009 and, previously, SAE Mini Baja and Supermileage competitions.

Acknowledgments

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