Final Project Proposal (Bomb Detection Bot)

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Problem Statement / Narrative:

The bomb detection and diffusion bot aims to mitigate soldiers and police officers from risking their lives in unnecessary situations. Bomb sniffing dogs are used to help soldiers and police officers detect bombs and other dangerous substances. Canines have a much better sense of smell than humans, so they are a valuable asset to both militaries and police departments [5]. Bomb sniffing dogs are in short supply due to high demand and many tests the dogs have to pass; they require many weeks of training and need to be continually retested to ensure they are successful [4]. While soldiers, officers, and dogs who are specialized in bomb detection and diffusion may be incredibly skilled in what they do, wouldn't it be better to lose a robot than a life? The bomb diffusion bot would allow an entire area to be cleared and risk no lives, even those whose job it is to diffuse the bomb.

The bomb diffusion bot is driven manually and allows those same specialized and skilled individuals, who would otherwise risk their lives, to instead utilize their knowledge and skillset from the sidelines. With the utilization of the Cybot bomb detection radar GUI, the driver of the bot will be able to view detected objects in view between zero and one hundred and eighty degrees. The GUI will also provide information about the distance from the object as well as the angle the object is at relative to the front of the bot. Additionally information about the distance between objects detected will be output to the terminal, this way, the driver will be able to determine if the bot can fit between the two objects projected in front of it. The GUI is critical to the usability of the bot and allows users to better understand the environment around them without the aid of sight.

A variety of obstacles are accounted for within the programming of the bot. When encountering shorter obstacles like barbed wire or possibly a sidewalk curb, the Cybot is programmed to automatically move backwards a set amount of five centimeters. Additionally, the bot will notify the driver when it is done moving with the sound of three beeps. This, in addition to a prompt for user input in terms of driver functionality, will notify the user that Cybot has completed this command. In the case of taller obstacles, like a car tire or rubble, the bot will simply detect the object with the GUI and the driver will be tasked to move and avoid the obstacle. The bot is also programmed to detect cliffs, or possible potholes, and will back up immediately and act similarly to the short object detection in that it will back up five centimeters and beep once the operation is complete.

A bot of this nature will allow professionals to utilize their skills for a longer period of time without the requirement of risking their lives. This bot would be perfect for military or police use. Because it is able to do the most high risk elements of bomb diffusion it will provide the opportunity to save all lives [10].

Project objectives:

1. Our robot will use the open interface capabilities of the Cybot platform and our GUI for bot movement, boundary detection, collision detection, and producing audio cues
2. Our bot will use interrupts on the Cybot platform for the sound sensor and general system timing
3. Our bot will use WiFi-UART of the Cybot for general communication between the GUI and the bot receiving commands and sending data
4. Our bot will use the ADC conversion of the Cybot for analyzing and interpreting data from the infrared sensor
5. Our bot will use the input capture capabilities of the Cybot for time-sensitive tasks, including analyzing sound sensor data
6. Our bot will use pulse wave generation capabilities of the Cybot for operating the servo motor allowing it to scan and move the sensors.
7. Our robot will use a graphical user interface to present data collected from the Cybot to the user.

Research:

Department of Homeland Security:

Person-Borne Improvised Explosive Devices (PBIED) Canine Initiative

- Started in 2012 between Department of Homeland Security Science and Technology and University of Maryland Police Department
- Used to understand strengths and weaknesses of canines trained to detect explosives carried by people in large crowds
- Explosives devices are a growing threat to the United States
- Dogs have a much better sense of smell than humans and can be trained to detect the smell of explosives

US department of justice:

Ion mobility spectrometry (IMS)

- Technology study for explosive detection
- Can aid investigators at bomb scenes for faster testing
- Explosive residue can be collected with a special attachment to a vacuum found in a household
- Collection of trace physical evidence transferred to hands or surfaces through contact or residue after a blast

Pacific Northwest National Laboratory:

Ion Chemistry technique

- Detects explosive vapors, dangerous chemicals, and illegal drugs
- Replacement for sniffer dogs

- Higher accuracy compared to other technologies
- Can be detected in seconds
- This technology works by sucking air into a narrow metal tube where the sample collides with chemical ions on its way to a mass spectrometer which detects the desired ions based on charge and mass.

Explosives trace detection:

- chemical and spectroscopic techniques to screen passengers, baggage, and cargo for small amounts of explosives

US Department of Homeland Security:

Canine explosive detection teams

- Highly trained detection dog and law enforcement handler
- Conduct searches near building exteriors, parking lots, vehicles, packages, and people near federal buildings
- Immediate response to bomb threats and unattended packages for minimal disruptions
- Trained to detect explosives in moving people or objects
- Dogs and handlers required to complete 10 week training program and participate in multiple training exercises throughout the year to maintain proficiency

Bureau of Alcohol, Tobacco, Firearms and Explosives:

Accelerant and Explosives Detection Canines

- Dogs trained to detect explosives, residue from explosives, and evidence following a blast in a 10 week program
- Producing a tool to help law enforcement
- Odor recognition through food and praise reward conditioning
- Provides canine teams to select foreign countries to assist them in fighting terrorism
- Exposes canines to five basic explosive groups to detect widest range of commercial or improvised explosive

NPR:

Bomb Sniffing Dogs are in Short Supply Across the U.S.

- Dogs have been used by police, Department of Homeland Security, and Transportation Security Administration for decades to detect possible bomb threats
- Dogs used in stadiums and airports
- U.S. imports 80% - 90% of its bomb sniffing dogs from Europe
- Cindy Otto, executive director of PennVet Working Dog Center at University of Pennsylvania sites one of the major reasons for the shortage of working dogs is importing them from other countries because the U.S. doesn't control the type, health, or early training of the dogs

- The pandemic and supply chain issues have further increased the problem
- Greater demand for these dogs as more countries are realizing their benefits
- American Kennel Club says dogs need early training and socialization to be able to succeed as bomb sniffing dogs

United States Army:

Dogs noses key to security regarding detection of explosives in Afghanistan

- Dogs must have traits of obedience, loyalty, and discipline, and they have to be certified
- Common dogs used as bomb sniffers are German Shephards and German Malinois
- Dogs improve mission effectiveness and reduce casualties due to explosives

United States Bomb Data Center:

Explosive Incidents Report

- Examines the total number of explosives related incidents reported in the Bomb Arson Tracking System in 2019

Empathy map:

Government/Military (used primarily out of country):

Do: ● Demonstrate use and needs required out of the robot in terms of possible environmental obstacles ● Possible obstacles: walls, furniture, rubble, barbed wire, miscellaneous metal objects strewn about, uneven terrain ● Usability: needs to have long range wireless connection capability	Think: ● Could be useful when visual contact is lost → this bot would be able to navigate terrain without visual aid effectively ● Accuracy would be incredibly important ● Easy of use, would allow driver to navigate quickly ● Needs to be as foolproof as possible
Say: ● Reliability in detecting and diffusing the bomb in a reasonable amount of time ● Navigating the environment in a careful manner, disturbing as little as possible → aiming to not disrupt any other potential threats ● Navigation without visuals was a concern in terms of accuracy	Feel: ● Could solve many problems in terms of possible bomb threats ● Possibly prevent a person and/or canine and handler from risking their lives to detect, navigate, and diffuse a bomb ● Could be utilized and developed further for other uses like communication with an armed individual, etc

Police/Security/Airport (used primarily in country):

Do: ● Demonstrate requirements in terms of possible obstacles in the environment ● Possible obstacles: curbside avoidance, vehicle avoidance, possible trash avoidance ● Usability: needs to have strong enough connection that it can be run from outside of the environment	Think: ● Could possibly save life of the person who would be sent in to diffuse the bomb ● Could mean that no one would have to be in range of bomb threat ● Should be as accurate as possible in order to successfully diffuse threat
Say: ● Reliably navigate environments with mostly flat terrain and a few obstacles and possible potholes ● Move efficiently through the area towards bomb ● Avoid stray objects encountered and move around bumps/curbs	Feel: ● Could be used in a national security scenario like a possible bomb threat or hostile situation ● Would prevent police or special operations teams from having to enter a dangerous area unnecessarily ● Further development would be useful in hostage negotiations by adding communication elements

Point of view statements:

Potential users such as soldiers and police officers may say:

- "I need a way to quickly detect and diffuse explosives in order to reduce casualties"
- "I need a way to quickly navigate an area and avoid obstacles in order to locate explosives"
- "I need a way to accurately detect explosives, so people carrying them are caught quickly and innocent bystanders are safe and don't experience disruptions"

Prototype:

Demonstration narrative:

The bomb detection robot is tasked to identify and navigate terrain to get to the bomb. There are tall objects, short objects, and a hole in the room/environment. The robot is to complete the task before the bomb goes off. It only has 20 minutes to complete the task.

Table 1: Mapping Test Field Elements to Application Narrative

Basic Objects and Other Elements	Description of how Test Field Elements Map to Application Map
Tall objects	Trees, large stones, tables, chairs, antennas, miscellaneous objects
Short objects	Rocks, curbs, rubble, barbed wire, miscellaneous object
Holes	Dirt holes, potholes
Out of bounds	Outside of the designated test field. The only exception of what is not considered out of bounds is when the robot completes its task. The out of bounds would signify the walls of a room of a house or a space outdoors
Destination zone	4 pillars that represent the ‘bomb’

User-centered Sketch:

① Moving through rough terrain

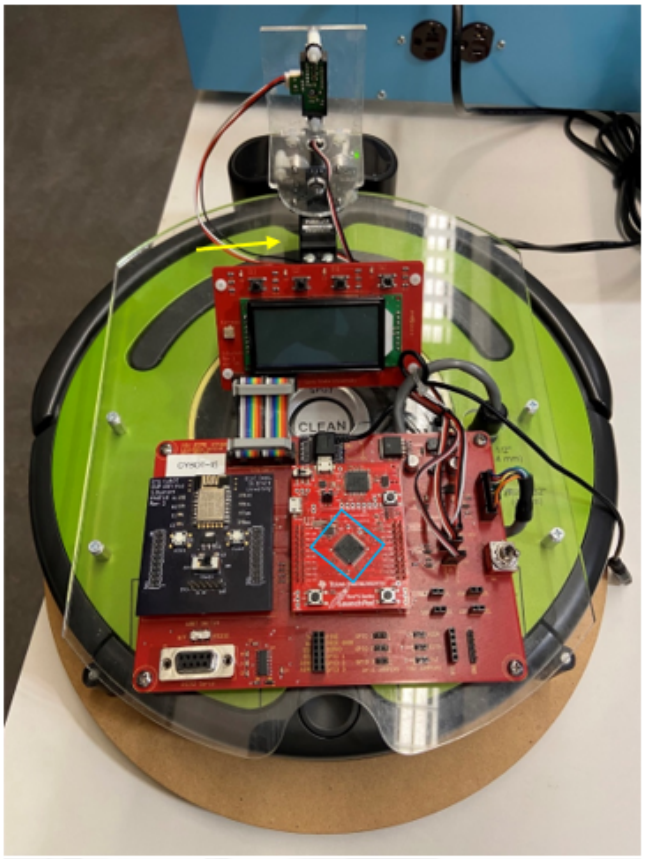
② Bumped the wire

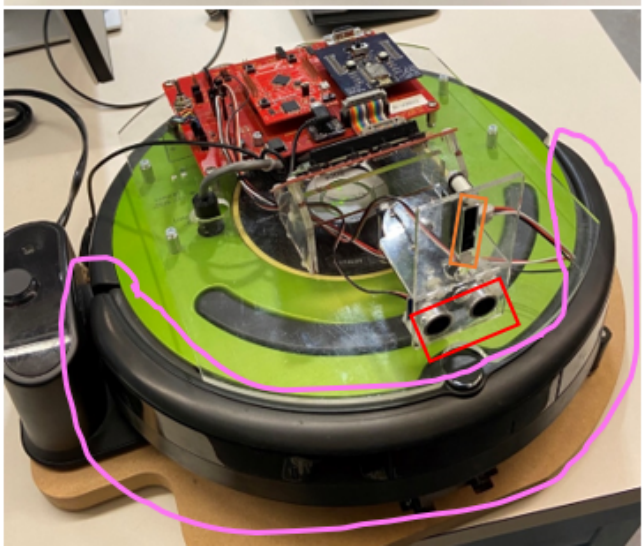
③ Detected an antenna

④ Detected a hill / small bump

⑤ Detected a cliff/hole

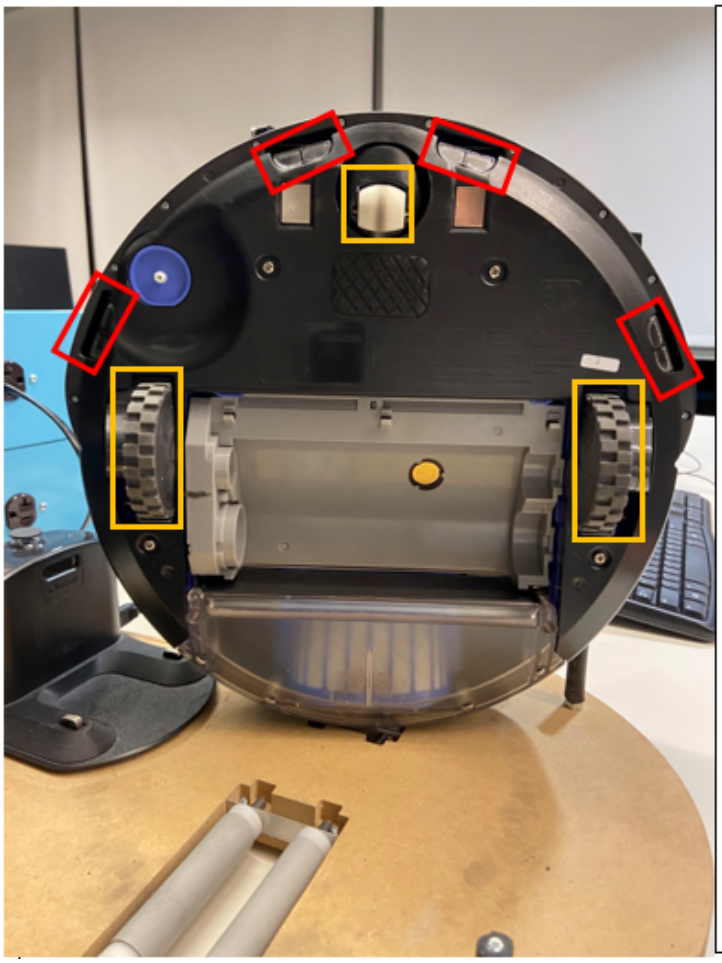
Technical-Centered Sketch:





Key Features-

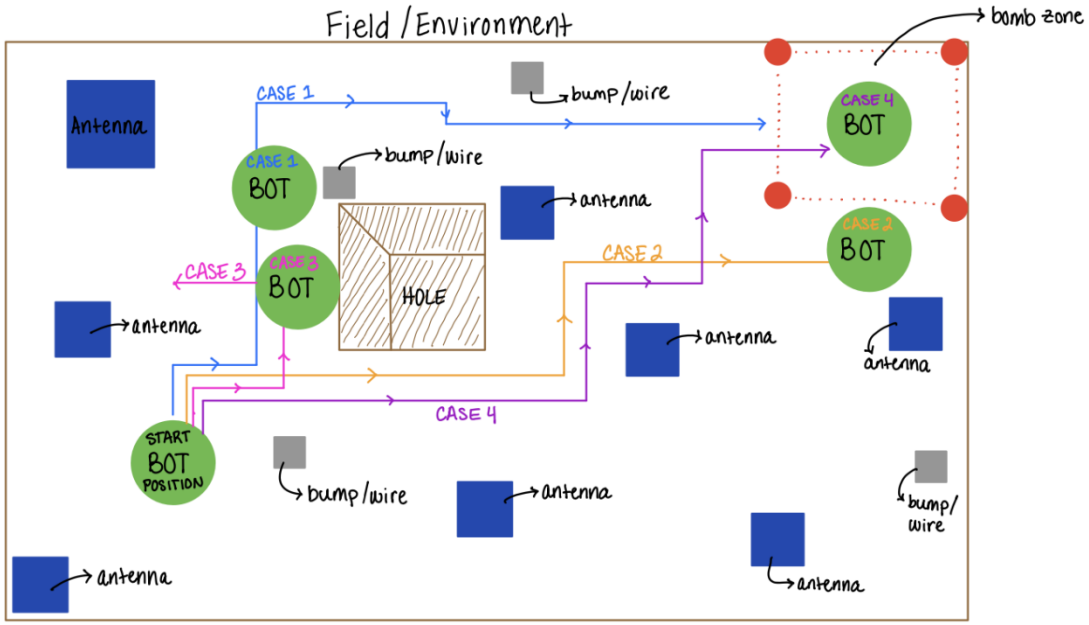
- TM4C123GH6PM Microcontroller-
  - Enables the bot's base capabilities
- Speakers (internal)-
  - Used to create sound
- Servo Motor-
  - Allows movement of sound and infrared sensors
- Left and Right bump sensors-
  - Allows bump detection
- Infrared Sensor-
  - Allows infrared detection
- Sound Sensor-
  - Allows sound detection



Key Features-

- Wheels-
  - Allow movement
- Cliff sensors-
  - Allow cliff and boundary detection

Test Field Sketch:



1. The Cybot will first scan the area in front of it before it starts to move. Case 1 shows the Cybot bumping a short object that could not be detected by the IR sensor. If the right bumper of the Cybot bumped the short object,we would manually drive backward 5 cm with a car reverse sound effect (beeping), turn 90 degrees counterclockwise, drive forward 5 cm, turn 90 degrees clockwise, and drive forward 10 cm. Once it has passed the short object, we will turn 90 degrees clockwise, drive forward 5 cm, turn 90 degrees counterclockwise, and keep driving forward until it reaches 30 cm away from its previous location. Vice versa.
2. We will manually drive the Cybot and scan every time it moves 30 cm because the accuracy range of the IR sensor is within 50 cm.
3. Case 2, when the IR sensor of the Cybot detects an object (tall & skinny or tall & thick), it will drive forward until it reaches 5 cm away from the object. If the object was scanned over or exactly at 90 degrees by the IR sensor, we will make the Cybot turn 90 degrees clockwise, drive forward 5 cm, turn 90 degrees counterclockwise, and drive forward 10 cm. Once it passes the object, we will then turn 90 degrees counterclockwise, drive forward 5 cm, turn 90 degrees clockwise, and continue driving forward until it reaches 30 cm away from its previous location. Vice versa.
4. We will continue to drive the Cybot until the final destination of the bomb is met and diffused. The Cybot will send data back to a radar-based GUI that will keep track of the

angle and distance of objects detected. The GUI will also calculate the distance between objects if two or more objects are detected to determine if the Cybot can fit between those objects. When it encounters an obstacle in its path, it will move backwards and allow the driver to move around the object. If the Cybot encounters the edge of the environment it will automatically move backwards 5 cm and alert the user that the edge of the environment was detected. Additionally, it will make a beeping noise to notify the user that it is backing up.

5. Case 3, when the Cybot detects a hole with the cliff sensor underneath, it will go backward 5 cm with the backward sound effect. It will have front and side sensors located at the bottom of the bot to determine if a cliff is either in front or to the left of the Cybot. It will notify the user that a cliff was detected and the approximate direction the cliff is relative to the bot; front, left, or right.
6. Case 4, assumes the Cybot has done its task. It will then play a song and send a 'victory' message to the driver.

Functional Requirements Map:

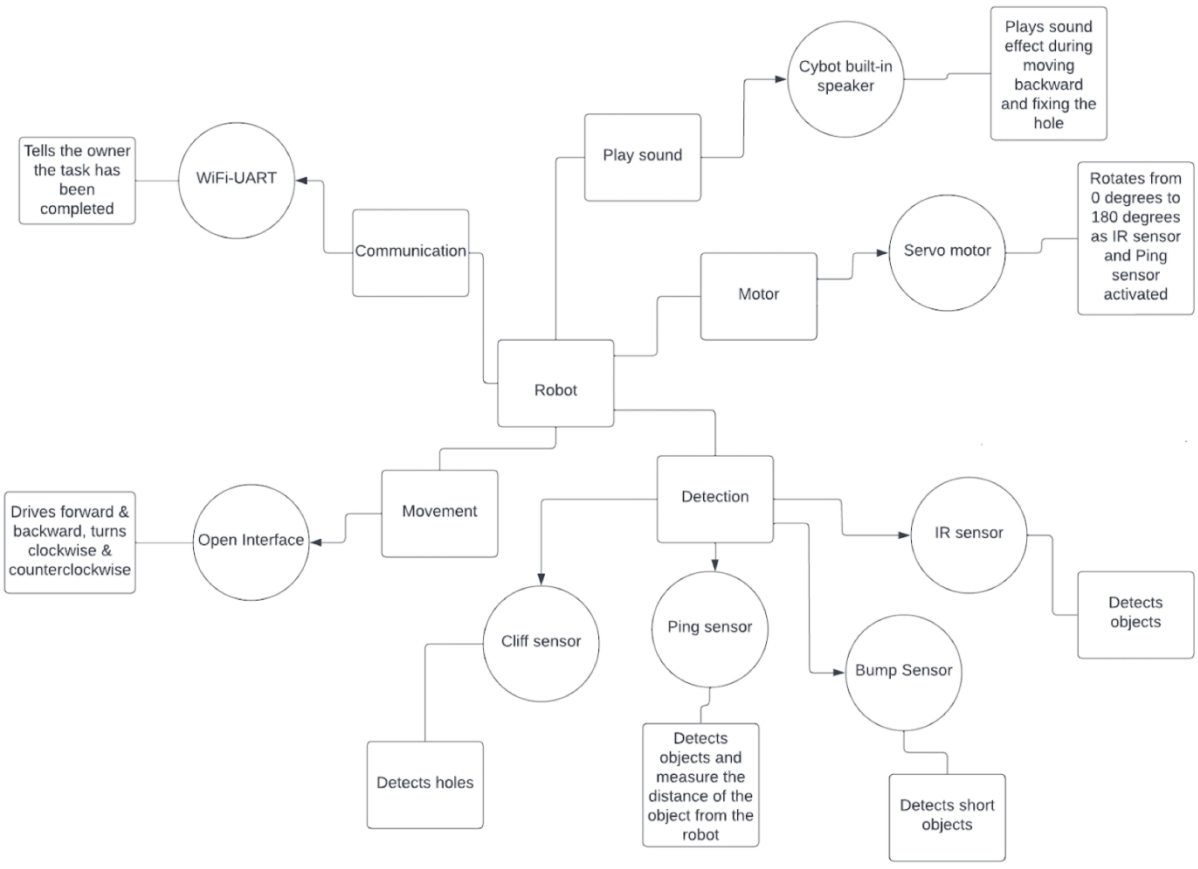


Table 2: Base Functionality

Base Functionality	Mapping to Application Narrative
Cybot Communication	The robot needs to receive a command from the user and send a notification to the user when it has completed its task through WiFi-UART/GUI.
Cybot Movement	The robot needs to be able to be manually driven.
Object Detection	The robot needs to detect the objects so the driver can avoid them.
Object Avoidance	The driver of the bot needs to have an understanding of the bot's movement so that he/she can maneuver the bot appropriately.
Boundary Adherence	The robot needs to avoid driving out of the area. The robot will sense when it is about to leave the area and relay the information to the driver.
Arrival at Destination (Completion of goal)	The robot and driver needs to be able to identify the difference between the objects sizes. This way the driver will be able to confidently identify the “bomb.” (4 small pillars)
User Interface	The robot needs Cybot capabilities and a GUI
Application Specific Functionality	
Play Sound	The robot needs to play sounds to alert the surrounding living things that it is reversing. It is to avoid the surrounding living things getting hurt. The bot will also play a sound when it has completed its objective.

Table 3: Cybot Capabilities

Base Capabilities Types	Default Usage	Project Usage
Open Interface	Robot Movement	Robot Movement,, Play Sound
Interrupts	Ping Sensor	Ping Sensor
WiFi-UART/GUI	Cybot Communications	Cybot Communications
Analog to Digital Conversion	Infrared Sensor	Infrared Sensor
Input Capture	Ping Sensor	Ping Sensor
Pulse Wave Generation (PWM)	Servo Motor	Servo Motor

Collaboration:

Ella: Research, Empathy Map, Works Cited
Emily: Point of View statements, System View
Kai: Demonstration Narrative, User Centered Sketch, Test Field Sketch, Functional Requirements Map, Table 1: Mapping Test Field Elements to Application Narrative, Table 2: Base Functionality, Table 3: Cybot Capabilities
Wesley: Problem Statement/Narrative, Project Objectives, Technical Centered Sketch, Works Cited
The team: Documented Collaboration

Upon a group brainstorming session, among a lot of ideas we decided on going with the bomb detection and diffusion bot. We tried to create a scenario where we could use Cybot capabilities we had already used in the lab and ones we had not yet. We decided we liked the idea of adding further upon our simple mission code we had already worked so hard on in past labs but our new goal is to perfect it to do a final mission in this project. Using the research we had done on bomb detection and diffusion we knew we needed to be able to identify and navigate to the ‘bomb’. It needed to be easy to use. We also found our primary consumer would have to be military focused. Finally, to end our little group brainstorming session we decided on a final plan for how the bot should function and what functionalities it would utilize.

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