Guardian

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***Abstract*—The Guardian project focuses on creating advanced safety tech jewelry that empowers users with both physical and online security options. The ring and necklace system is designed to be discreetly activated by users in situations where they feel unsafe or threatened, offering a seamless and unobtrusive way to access advanced safety features for both physical and online security. It features an integrated emergency SOS system for immediate physical assistance and a smart system to detect and alert users about unsafe Wi-Fi or Bluetooth connections. Uniquely, it allows users to customize their safety preferences, choosing which security features to activate at any given time, ensuring a personalized balance between physical and digital protection, all within a stylish and functional design.**

***Index Terms*—RFID, passive, ESP32, geo-fence, PCB, MCU**

1 INTRODUCTION

Our goal is to develop a discreet safety device that provides immediate response in threatening situations, regardless of mobile device availability. Recognizing the importance of discretion, especially in scenarios where phone access may be unsafe or hindered, our device offers one-hand activation through a pendant-ring design, supplemented with additional trigger options for quick and easy use. It incorporates emergency alert features that facilitate direct communication with emergency services via a dedicated app or as a standalone function. Furthermore, our device boasts smart features including GPS tracking, voice detection capabilities, and separation alerts to enhance its effectiveness in emergency situations. With a target demographic of young adults, particularly middle and high school as well as university students, we aim to address the safety concerns prevalent among this age group. From an engineering standpoint, our project aligns with the core areas of Electrical and Computer Engineering (ECE), focusing on software systems and circuit design to ensure seamless integration and reliable performance of our safety device.

Our project addresses public health, safety, and welfare by providing a jewelry system that doubles as a safety device. It enables users to discreetly contact authorities or emergency contacts when facing physical harm or dangerous situations, thereby enhancing their sense of security without drawing unwanted attention. By mitigating risks efficiently and quietly, the device promotes a safer environment for individuals to navigate their daily lives without fear. In terms of social factors, we prioritize cultural sensitivity by ensuring our jewelry conforms to cultural norms regarding wearables, including multilingual support for diverse linguistic backgrounds. Additionally, accessibility and usability are key considerations, with features designed to accommodate individuals with varying levels of technological proficiency. Compliance with regulations and privacy restrictions across different regions is paramount, given the diverse rule sets present in various jurisdictions. Moreover, from an economic standpoint, we aim to make the jewelry cost-effective, particularly targeting a younger demographic with limited spending power, thereby ensuring accessibility to a wider user base.

2 USE-CASE REQUIREMENTS

Reliable communication from ring and pendant: Establishing a robust and dependable communication link from the ring to the pendant is paramount for user safety. In times of distress, our innovative system ensures that users need not worry about repeatedly pressing the button to activate the SOS protocol. This streamlined process enhances efficiency and guarantees a swift response when every second counts.Moreover, our advanced technology incorporates a failsafe mechanism to address the occurrence of false alarms. Users have the ability to promptly and reliably veto any false alert within a specified timeframe directly through the intuitive app interface. This added layer of control not only minimizes the chances of unnecessary interventions but also empowers users with the confidence that our system is designed to be accurate and trustworthy 99.5 percent of the time. This commitment to reliability underscores our dedication to providing a seamless and secure experience, prioritizing user peace of mind in every aspect of our innovative communication system. Latency with triggers: Efficient trigger response is vital for user safety, especially in emergency situations. When any triggers are activated, our pendant ensures a rapid vibration within 5 seconds, achieving an impressive 99 percent reliability. This quick response time is crucial, not only for notifying the user promptly but also for allowing them enough time to veto in case of a false alarm. This emphasis on low latency is fundamental to the swift execution of the SOS protocol during moments of distress. Power conservation: In our pursuit of user convenience, our device is designed to require charging no more than once a day. It boasts an impressive standby time of over 24 hours, ensuring readiness even during periods of inactivity. Additionally, with voice recognition active, the device can last a minimum of

6 hours, striking a balance between efficiency and longevity for a seamless user experience.

Voice activation: Voice activation is a prominent feature of our system, offering a user-friendly experience in diverse settings. In quiet environments, it reliably triggers over 90 percent of the time when the user's chosen phrase is spoken. Additionally, even in noisy surroundings, our voice activation remains effective, operating successfully over 50 percent of the time. This adaptability ensures a seamless and reliable experience, catering to users' needs across various scenarios.

Usability without phone: In instances where the pendant encounters difficulty establishing a connection with the user's phone, our intelligent system is programmed to initiate a series of strategic actions to ensure continued safety and communication. When faced with this situation, the pendant takes a proactive approach by deactivating the Bluetooth module. Simultaneously, it activates the cellular module, allowing the pendant to seamlessly transition to an alternative mode of communication.

In this switched mode, the pendant goes beyond its primary function and takes on the responsibility of reaching out to the user's emergency contacts and pre-selected emergency services. This dynamic feature ensures that, even in challenging connectivity scenarios, the user's safety remains paramount. By leveraging cellular technology, the pendant extends its reach and proactively communicates crucial information to those designated contacts and services, creating an added layer of security and reassurance for the user in unexpected situations.

Accessibility: In the thoughtful design of our device, we've taken into consideration the ergonomic needs of our target demographic, specifically individuals aged 12 to 24. Recognizing the significance of user comfort and accessibility, our device is meticulously crafted to ensure that the average person within this age group can effortlessly engage with its functionality.The button on the device is strategically positioned to align with the natural range of motion of the thumb, allowing for a comfortable and intuitive pressing experience.

Customization: Empowering users with a personalized touch, our device allows customization of the voice activation trigger phrase, duration, and the number of button presses needed to initiate protocols. Users can fine-tune their experience by adjusting settings for false alarms, GPS tracking location, and vibration sensitivity directly within the companion app. These personalized configurations seamlessly integrate into device use with an impressive 95 percent reliability, ensuring your preferences are accurately reflected in every interaction.

Connectivity: The pendant connects to your phone within a generous 30-meter range, offering flexibility in movement. Meanwhile, the ring communicates seamlessly with the pendant within a close range of up to one meter. This dual-range connectivity ensures a reliable and efficient user experience for various scenarios.

3 ARCHITECTURE AND/OR PRINCIPLE OF OPERATION

Our product will consist of three primary subsystems: the ring, the pendant, and the Phone/companion app within the phone. The High level component view is shown in Fig 1. Additionally the system composition and interactions are outlined in Figure 2. Our overall design has 4 different triggers to activate our system which notifies the user's Emergency Contacts and notifies Emergency Services, either via the user's phone (if a bluetooth connection is available) or through the cellular module in the pendant itself. We will go into these three subsystems in more detail below.

3.1 A: Pendant

The Pendant consists of many components all on a customized PCB. The first component is the ESP32 (tinyPICO) microcontroller. We chose this microcontroller for its small size and it's built in bluetooth capability. All triggers that get activated pass through the ESP32, from there we either check if we still have an established connection with our phone via bluetooth. If we do then we use our phone to send an emergency SOS and location to our emergency contacts and the police. Otherwise we tell our cellular module to send the information itself.

The next component on the PCB is a unidirectional microphone. This microphone will be facing the user's mouth so words spoken can be transmitted in the direction of the mic without noise coming in from other directions. The microphone is part of one our triggers, the audio trigger. The user will have set up a "trigger word" to say when they are in an unsafe position.

Another component on the device is the Vibration ERM Motor. If any of our triggers that interact with the Pendant are enabled, the ESP32 will trigger a vibration of the motor. This vibration is meant to be felt by the user wearing the pendant, to let them know a trigger was activated. If the user accidentally triggered the device, then there is a button located near the center of the pendant that the user can press to cancel the SOS process (they must do so within 10 seconds of the vibration.

As mentioned earlier, the pendant, if no bluetooth connection with the phone is present, should be able to send the SOS signal from the pendant itself. Thus, we have included both a Cellular Module with a SIM card on the chip as well as a cellular antenna to send the SOS.

We will also have a UHF Long Range RFID Reader Module on the pendant, along with an RFID antenna. This Reader model is in interaction with our Ring (which will be explained in the next section). The Reader Module will be expecting a certain frequency, if it no longer detects it the RFID Reader will trigger and alert the ESP32.

For all these components we will be powered by an 11.1 V battery as the ESP32 can be run on 3.3 V, the omnidirectional mic 1.5 V, the Vibration Buzzer 3 V and the cellular chip with sim uses 3V.

3.2 B: Ring

The Ring is comprised of Two Components. The first component is the UHF RFID Tag. This tag works with the UHF Long Range RFID reader module on the pendant and is sending a frequency to the reader. The RFID tag is connected to a button (2mm diameter). While the button is off, the RFID will emit a frequency. However when the button gets pressed, the circuit will be shorted and the no frequency will be present. When the Reader detects the lack of frequency, this acts as the trigger. The ring will be encased in a material that won't cause interference with the RFID Technology such as plastic.

3.3 C: Companion App

The jewelry device will come with a app downloadable onto the users phone. This app will be developed using Flutter and the goal is to be compatible with iOS and Android. In this app the user will first pair the phone to the pendant via Bluetooth. They will then set their 3 emergency contacts. This information will get transmitted to the pendant in order to send the SOS signal. They will also then have the opportunity to set preferences for the different triggers. For example, for the ring we can customize how long the button has to be pressed to signal a trigger, or for the geo-fence, what area we want to set the geo-fence around, and for the audio trigger, what safe word the device should detect.

The geo-fence trigger will be a trigger built into the phone, and will use the GPS already integrated into the device. To implement this we will use the geofencing package as part of flutter. If the user exits this pre-defined radius the phone gets alerted and sends an emergency message directly through the app.

The audio trigger will be one of the triggers dependent on having a phone connection. The microphone on the pendant will be actively listening and parsing words. If it captures the trigger word, it will start the SOS process. On the phone, we will use a library like PyAudio in order to capture the much audio and choose an open source speech to text service such as DeepSpeech or the SpeechRecognition module in python.

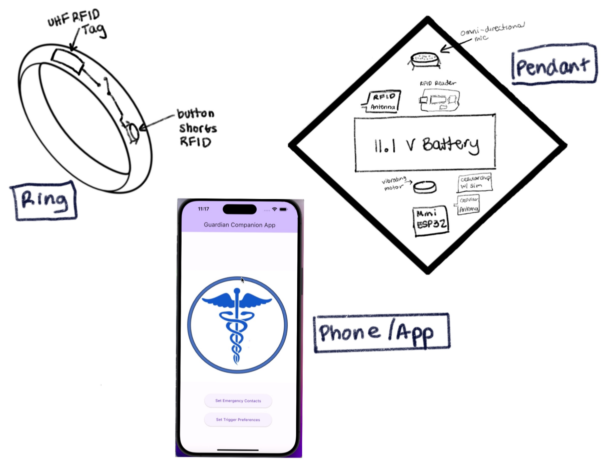

Figure 1: High-Level System View

4 DESIGN REQUIREMENTS

Size and weight: Our pendant is designed to be lightweight, not exceeding 2 pounds. The button, with a minimum diameter of 2mm, ensures easy and precise activation. The compact pendant, measuring no more than 6x6 inches, guarantees a discreet and unobtrusive addition to your daily wear.

Durability: Our ring's button is built to last, offering reliable functionality for up to 10,000 presses. The hardware is equally robust, capable of enduring up to 5,000 connection cycles. This durability ensures a prolonged and dependable user experience.

Battery less Ring: Our ring effortlessly connects to the pendant without electricity, thanks to RFID technology. This efficient communication system ensures a reliable link between the two components without the need for a traditional power source.

Offline compabilibility: To increase utility in a wider variety of situations, voice detection and GPS functionality will operate seamlessly, independent of the necessity for cellular data.

Latency: Communication from ring to pendant, and pendant to phone should not take more than .5 seconds . Furthermore, the pendant will switch to cellular when it is incapable of connecting to the phone within 1 second.

5 DESIGN TRADE STUDIES

5.1 Battery Sizes/Charging

In determining the battery for our project, we encountered several trade-offs. Originally, we aimed for a compact battery akin to a coin cell to adhere to our size constraints. However, considering the array of components housed within our pendant and the requisite power draw, this option proved impractical. We anticipate requiring

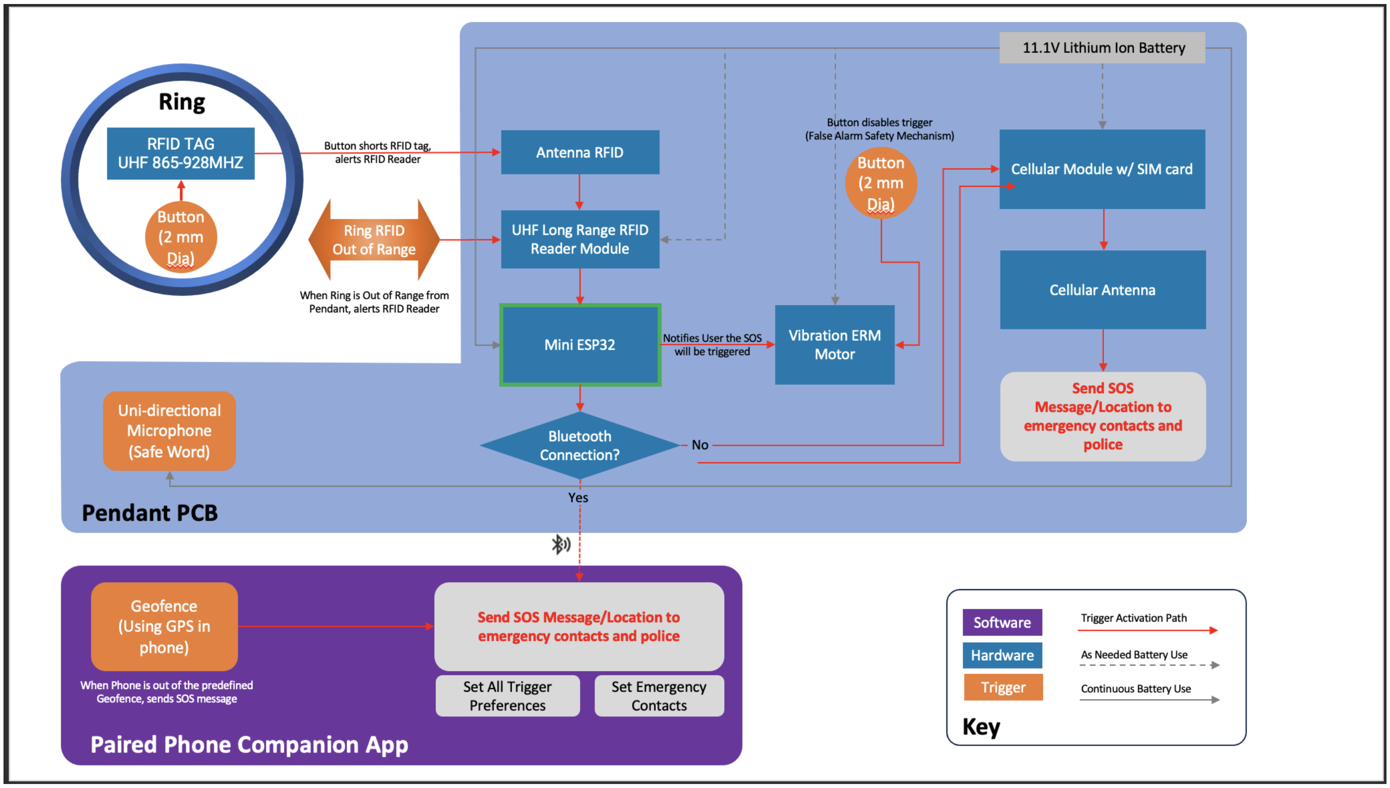

Figure 2: Block Diagram

approximately 11 volts(2.7 in x 2.17in) to power all components adequately. Another pivotal consideration was whether to opt for re-chargeability or not. If we decided to make our battery non-rechargable we would have a significant reduction in battery size, but from a consumer perspective it would be much more convenient to simply recharge the battery on the pendant. Being able to recharge would provide a higher sense of comfort for the user. It's much safer to have a battery with a predictable use time than to have a regular battery and the inability to know when the battery will run out. Thus we feel this convenience and safety perspective outweighs the size.

5.2 PCB vs Breadboard

Initially, opting for readily deployable microcontroller boards like the Nucleo or Arduino boards might seem convenient. However, we deliberately chose to design a custom PCB. This decision was driven by our willingness to prioritize aesthetics and wearability over the challenges in development. Also, with all the additional components we are incorporating this will help compact our design and make it "cleaner". However, while we will work on the custom PCB we will also be simultaneously using a breadboard to connect and test different parts of the design to remain on time. If the PCB is unable to work we will present the breadboard version as a proof of concept.

5.3 Ring to Pendant Connection

We had many different considerations when choosing how we wanted to connect the ring and the pendant. The biggest constraint we had in our different options was being able to fit whatever components necessary into our ring while maintaining a ring thickness or around 8mm. With our button on the ring, we considered using a bluetooth connection between the ring and pendant. However, this would require some sort of bluetooth chip on the ring as well as a battery to power it. These to components would put us well over our size constraints and make the connection too complex. To compromise we decided to come up with a solution that involved a passive RFID communication between the ring and the pendant(This will be explained further in the system implementation(section 6)). This solution means that no battery is necessary on the ring and the only components needed are a RFID tag and a button to short the transmitted signal. The next decision we had to make with this was whether we wanted UHF, HF, or LF RFID. Below Table 1 describes the different frequency ranges and it's corresponding read ranges.[4] If we take into account that the average female height in America is around 5 foot 4 (1.61 meters)[2] and the average male height in America is 5 foot 9 (1.79 meters)[3], and accounting for the fact that the average wingspan is around 1 inch added to the person's height (0.0254 m) The average length in meters from a person's (male or female) chest to

Table 1: RFID Frequency Types

Description	Frequency Range	Read Range
UHF	300 MHz - 3 GHz	$\leq$ 12m
HF	3-30 MHz	10 cm -1 m
LF	30 KHz-300 KHz	$\leq$ 10cm

finger would be:

$$(((1.61 + 2.79)/2)/2) + 0.0254 = 1.254\text{m} \quad (1)$$

Given this information, we determined that UHF would be the ideal RFID Range. However if we are unable to find UHF, we will present the prototype using HF as a proof of concept.

6 SYSTEM IMPLEMENTATION

6.1 Subsystem A

Our first subsystem is Ring-Pendant. This is the hardware/software communication between ring RFID and Pendant. More specifically, the ring generates an UHF RFID signal with its embedded RFID passive transmitter within the ring. The passive transmitter consistently sends the signal. The ring also include a button, and when the button is pressed, the transmitted signal is shorted. The pendant on the other hand, which is the receiver is non-passive, and periodiaclly polling the RFID signal. When the pendant RFID receiver processes that the signal has died, it knows that a button has been pressed. Once this button has been pressed and the pendant has received the press, its data and information goes first into Subsystem B and then if Subsystem B is unable to connect in 10 seconds, it immediately connects to Subsystem C and goes through that process.

6.2 Subsystem B

The second subsystem is the communication between Pendant and Mobile App. After the pendant receives a button press in subsystem A, Subsystem B first checks for communication between the mobile app. It does this by sending a Bluetooth ping and ensuring a proper acknowledgement bit is responded. Once it knows that connection is stable it begins parsing. If the ACK bit is not received, subsystem B defers to subsystem C which then continues with its operation. To Parse the information, system B parses with the MCU (ESP) and serializes the information. After confirming connection with SDP, system B also receives any subsequent button presses (depending on number of presses it could be different triggers, discussed in other section). With this information serialized into a transmittable service (TCP) the pendant uses the MCU as its own bluetooth communicator (ESP) and sends the information to the mobile app. As discussed in the companion app section, the app then parses the received information and properly conducts the correct triggers and information.

6.3 Subsystem C

The third subsystem is the communication between Pendant and Cellular. This system only connects after system B is unable to create a Bluetooth connection to the companion app. When permission to transmit is granted from system B, system C receives the same button presses as B and parses them in the MCU as well. After parsing the information in the MCU (ESP) into a serialized form that the cellular process can handle. This transmission information includes stored data in the pendant including contacts, emergency phone numbers, and more. Based on the triggers provided by the ring or elsewhere, the proper call/text information is serialized and sent to the cellular chip. The pendant then transmits this with GPIO from the MCU to the cellular chip. The cellular chip which already has an e-sim card, allows for the chip to instantly transmit data. This is then properly parsed and sent via the according method using the cellular antenna.

7 TEST & VALIDATION

7.1 Tests for Design Specification A

Subsystem A: Ring→Pendant. The objective the testing of this subsystem is to ensure that it meets all our design specifications as well as our user requirements that we have aligned. In order to test the RFID connection there will be various tests set.

7.1.1 Testing Types:

1. Connectivity. This test will verify that RFID communication between ring and pendant is handled properly and the pendant is able to receives the constant signal from different arm lengths and various blockers (clothing etc).

2. Button press Triggers. This will test if the shorting of the button at different lengths will also be properly receives. This is paired with the connectivity test as it requires understand the RFID max transmit distance.

3. Durability tests. This will test the durability of the ring subsystem within subsystem A, as well as the overall pendant subsystem. This testing will be conducted with various situations like device strength at drop distances as well as the longevity of the button and overall designs of the ring material and pendant shell casing.

7.1.2 Testing Verification:

For each type of test, the Use-Case requirements will be a base-line for testing. For example, the connectivity relates to our use-case of ensuring versatility of users as not everyone is the same height, various clothing choices and any personal objects from other devices and jewelry that could cause interference with our signal. For button press triggers this will be hitting the button at different time intervals, quick repetitive presses, slow presses and more. For durability this will include water-resistance, ability to work after being dropped and more.

7.1.3 Testing Validation:

For each test, the validation will differ. For some it will be if the communication is successful, if it is not we will test and learn, as in we will test as we create and ensure that if something is not meeting out use-case requirements that we either review the use-case and see if its plausible and if it is why our system is unable to pass the current test. For connectivity tests validation will be if the process was successful. For edge-case testing the validation will be ensuring that our system is able to handle various forms of communications, interrupts and processing issues as our project is a safety device, and it cannot just fail and then do nothing, it must be able to transmit in dangerous situations.

7.2 Tests for Design Specification B

Subsystem B: Pendant → App. The objective the testing of this subsystem is to ensure that it meets all our design specifications as well as our user requirements that we have aligned. In order to test the data processing aspect of subsystem B and the Bluetooth connection there will be various tests set.

7.2.1 Testing Types:

1. Connectivity. This test will verify that Bluetooth communication between pendant and app is handled properly and the pendant is able to quickly poll for the mobile device nearby, and if it is not to handover access to subsystem C.

2. Data Serialization and Processing. This will test if handling subsystem A's data is properly analyzed and reported. This will go hand in hand with subsystem A's communication and connectivity tests. By testing alongside with subsystem A, we will be able to see and test harder edge cases such as receiving multiple button presses from close to max transmission distance.

7.2.2 Testing Verification & Validation

For Each test the verification and validation of each test for subsystem B will involve ensuring that in each different case and edge-case that the correct information is being transmitted. This means that MCU communication, Bluetooth transmission from pendant and Bluetooth receiving from the mobile phone must work within all the use-case requirements.

7.3 Tests for Design Specification C

Subsystem B: Pendant → App. The objective the testing of this subsystem is to ensure that it meets all our design specifications as well as our user requirements that we have aligned. In order to test the data processing aspect of subsystem B and the Bluetooth connection there will be various tests set.

7.3.1 Testing Types:

1. Connectivity. This test will verify that Cellular communication between pendant and cellular towers are handled properly and the pendant is able to quickly poll for the subsystem B, and if it is not to handover access to this subsystem.

2. Data Serialization and Processing. After ensuring that process power handover is properly activated after polling system B, we will then test similar to system B where we test the handling of subsystem A's data and that it is properly analyzed and reported so that subsystem C can transmit to cell towers with the correct information. This will require ensuring data is stored. We will then ensure that the proper transmission occurs.

7.3.2 Testing Verification & Validation

For each test the verification and validation of each test for subsystem C will involve ensuring that in each different case and edge-case that the correct information is being transmitted. This means that MCU communication and data parsing works exactly as intended, that cellular transmission from pendant and cell towers works as intended with proper data parsing. This will be tested in various forms by taking the mobile phone to a distance to ensure power handover takes place. Data processing and transmission will be tested as we test our triggers.

8 PROJECT MANAGEMENT

8.1 Schedule

We are prioritizing constructing the PCB for our project and ring connectivity with pendant first. After that, we will work on other triggers and app customization. The schedule is shown in Fig. 4.

8.2 Team Member Responsibilities

Anika's tasks are centered around the app, including the front-end, connection with pendant, and customization options. Olivia will implement the cellular module, connectivity of the pendant with the phone, jewelry design, and designing the PCB. Bradley will work on the gps, voice, assembly of hardware, and connection with ring and pendant.

8.3 Bill of Materials and Budget

A table with our Bill of Materials can be found on Page 8.

8.4 Risk Mitigation Plans

Noise reduction for voice detection: To enhance voice detection in louder environments, we've opted for a unidirectional microphone. Our strategy includes integrating the Whisper library for transcription purposes, with plans for thorough experimentation on alternative options should Whisper not yield the desired results. This deliberate choice in technology reflects our commitment to ensuring optimal performance in various acoustic settings while maintaining a flexible and adaptive approach to transcription solutions.

Battery life: Given the multitude of triggers, sustaining the battery until it meets usage requirements poses a challenge. In response, we're exploring innovative solutions, such as implementing lower voltage components and optimizing the connection between the ring and the battery. Additionally, we're empowering users by allowing them to selectively activate voice detection, offering a more personalized approach rather than keeping it consistently active. These strategic adjustments reflect our commitment to maximizing battery life while preserving the functionality and user experience of the device.

Lots of false alarms: Anticipating the varied ways users may interact with the device, we acknowledge the possibility of multiple button presses or common phrases triggering false alarms. To address this, our focus is on enhancing accessibility and reliability for users to effortlessly veto these occurrences. During the onboarding process within the app, users will have the opportunity to set preferences, ensuring a user-friendly experience in managing and minimizing false alarms. Striking a careful balance, we aim to provide a reasonable window for users to veto a false alarm without compromising the swift initiation of the emergency protocol. This thoughtful approach reflects our commitment to user empowerment, ensuring that the device adapts seamlessly to individual preferences while maintaining the efficiency and effectiveness of emergency response protocols.

9 RELATED WORK

There are a number of similar products out there in the market similar to what we are proposing to implement. Some of them include InvisiaWear, and Safelet. InvisaWear offers a range of safety jewelry including necklaces, bracelets, and keychains equipped with hidden panic buttons that can discreetly alert emergency contacts or 911 dispatchers.[1] Safelet offers a smart bracelet designed for personal safety, featuring a dual-button design that allows users to send alerts with their GPS location to a list of emergency contacts.[5] Where our product Guardian comes in: It is a combination of these two products, but with additional features beyond a single button as well as the addition of a ring as an easy-to-access-with-one-hand component.

10 SUMMARY

Our project focuses on developing a discreet safety device for young adults, offering swift response in emergencies regardless of mobile device availability. With one-hand activation through a pendant-ring design, supplemented by voice detection and GPS tracking, users can trigger immediate assistance. The device ensures direct communication with emergency services and by prioritizing accessibility and compliance with regulations, we aim for cost-effectiveness to reach a wide user base. By providing a jewelry system doubling as a safety device, we empower users to discreetly contact authorities, promoting a safer environment without drawing unwanted attention

Glossary of , Acronyms

- UHF –Ultra High Frequency
- HF – High Frequency
- LF – Low Frequency
- PCB - Printed Circuit Board
- RFID - Radio Frequency Identification

References

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[5] Safelet. “Safelet”. In: (2024). URL: https://safelet.co.nz/.

1	Item	Link	Manufacturer	Price	Units
2	DIGIKEY				
3	*Vibration buzzer*	VZ43FM1B8230001L Vybron	Vybronics Inc	2.64	3
4	UHF RFID TAG	LXMS21NCMH-230 Murata E	Murata Electronics	$8	3
5	ESP32	https://www.digikey.com/en/p	Espressif Systems	$26	2
6	Mini ESP32	https://www.digikey.com/en/p	Adafruit Industries LLC	$15	1
7	CELL w/ SIM!	https://www.digikey.com/en/p	u-blox	$46	1
8	1.5V unidirectional mic	AUM-5047L-3-R PUI Audio, I	**PUI Audio, Inc.**	1.72	1
9	Antenna RFID (HF)	1462360051 Molex | RF and	Molex	$0.84	1
10	Antenna Cellular	1004795 KYOCERA AVX | R	**KYOCERA AVX**	$3.22	1
11	Lithium Battery (comes with charger)	BL2600C1865003S1PGMG	GlobTek, Inc.	$56.72	1
12	HF rfid tag	441170538-0107101 SAG | F	SAG	$2.07	1
13					
14	ALI EXPRESS	Arduino R200 Chip Small UH	shenzhen invelion		
15	UHF receiver			60.21	1
16					
17	Amazon				
18	Button switch set	QTEATAK 240 Pcs 24 Value	QTEATAK	14.99	1
19					
20		Total		$270	

Figure 3: A full-page view of the Bill of Materials

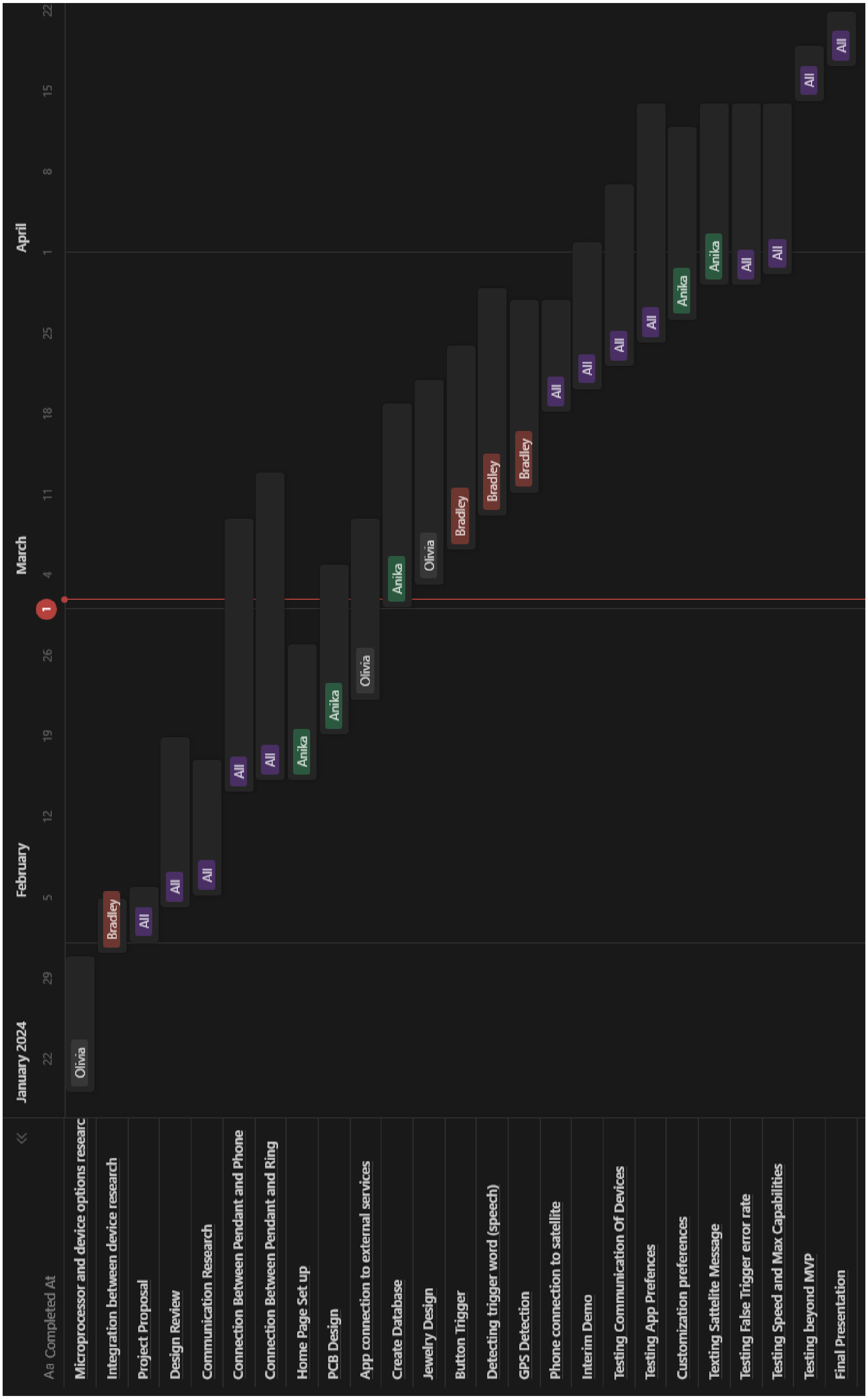

Figure 4: Gantt Chart