March 16, 2022
Dr. Mike Hegedus
School of Engineering Science
Simon Fraser University
Burnaby, BC, V5A 1S6

RE: ENSC 405/440 Design Specification for Key Assist

Dear Dr. Mike Hegedus:

The design specification is enclosed below for WiCCSafe's KeyAssist system as part of ENSC 405W/440. Our company's goal is to create a reliable communication system that aids in protecting students and faculty by creating a safer environment on university campuses for all. This document will make design decisions based on specified user requirements.

KeyAssist will utilize wireless technology to locate and send alert signals to campus security from the end-users. Our solution provides feedback to the user about the status of the distress signals to ensure that communication with campus security was successful. Our primary goal in the enclosed document is to design a system that carefully analyzes consumers' needs for the KeyAssist system, and categorizes them clearly in the form of system design decisions. The document will explore general end-user design specifications, system design specifications, design alternatives, and a test plan for our system.

Our team would like to thank the Engineering department for taking the time to read through our requirement specifications document. If you have any additional questions, please feel free to reach out to me via email: hbergero@sfu.ca

Sincerely,

Hannah Bergeron
CCO
WiCC SAFE

WiCC SAFE

Design Specification:

Key Assist

Company #10

CCO:	Hannah Bergeron
CTO for Software:	Valeriya Svichkar
CFO:	Paola Moreno
CTO for Hardware:	Marychelle Bitoon
CTO for Hardware:	Jerry Fu
CTO for Software:	Peter Zhang

2022/03/16

Abstract

The design specification document serves to outline the decisions made for the initial design of the keyAssist system. The KeyAssist system consists of personal safety devices (PSDs) which allow students to communicate distress to a main interface at campus security headquarters. The design decisions outlined in this document are broken down into subcategories such as Personal Safety Device (PSD) design and general system design, where the choices in software, technology and physical design are addressed. An introduction and system overview will outline the main components of the KeyAssist system, and provide background information to the reader.

Table of Contents

List of Tables

List of Figures

Version History

Version #	Revision Date	Revised by	Revision Reason
1	2021-03-16	Marychelle Bitoon Hannah Bergeron Valeriya Svichkar Paola Moreno Jerry Fu Peter Zhang	Initial revision

Approval

Print Name	Hannah Bergeron
Role	CCO
Signature	
Date Signed	2021-03-16

Glossary

The following table includes a list of terms used throughout the document.

Term	Definition
End user	The end user of the personal safety device (i.e.college/university students).
PSD	Personal Safety Device (PSD) signed out by the end user (i.e. WristAssist).
Main Transceiver	Main transceiver refers to the transceiver located at campus security headquarters which receives all distress signals and sends feedback signals.

Table 1 - Definition of the common terms used throughout the document

1.0 Introduction

KeyAssist is a small and compact device that provides students with a discreet method of alerting campus security of potentially dangerous situations. Students will be able to sign out these devices from sign-out stations located throughout campus, guaranteeing accessibility to any students who are concerned for their personal safety. This device will help students communicate their level of distress to campus security along with their location and identification information. Campus security will have a user interface that will receive and process any incoming signals from devices across campus. The information they receive will allow them to efficiently locate, track and personally respond to users in distress.

KeyAssist contains two main systems, the campus security system and the end-user system. The campus security system includes a LoRa transceiver module, a user interface module, and a backend server. The user interface will present the student's information as well as the latest GPS coordinate points from which the distress signal is transmitted to help achieve an accurate and swift response from campus security.

This document discusses the design specification details of our project to meet the proof-of-concept requirements.

1.1 Background

Violence and harassment have long been issues in college/university settings, and the subject has been extremely prevalent in past years due to factors such as the presence of social media platforms. As an example, women in the United States aged 18-24 are at a risk three times higher than that of the average woman to be victims of sexual violence [1]. Similarly, men aged 18-24 who are enrolled in college/university are 78% more likely than the average man to be victims of sexual violence [1]. Given this risk, the common solutions for students' personal safety are often outdated and don't offer effective options in the event of dangerous situations. A survey conducted in the United States by ADT found that in 2021, programs such as SafeWalk were only utilised by 17% of college/university students, while 82% of students reported feeling concerned for their personal safety [2]. These statistics contribute to a feeling of unease by students on campuses and indicate the presence of an expanding market for personal safety solutions.

KeyAssist's main goal is to create a comprehensive solution to the issue of personal safety on campus by providing a product that prioritises the needs and requirements of consumers. Continuously aiming to uphold the client's expectations and deliver a dependable product is the highest priority. WiccSafe believes that innovation in technology is the stepping stone to a brighter and safer future, and KeyAssist is just the beginning.

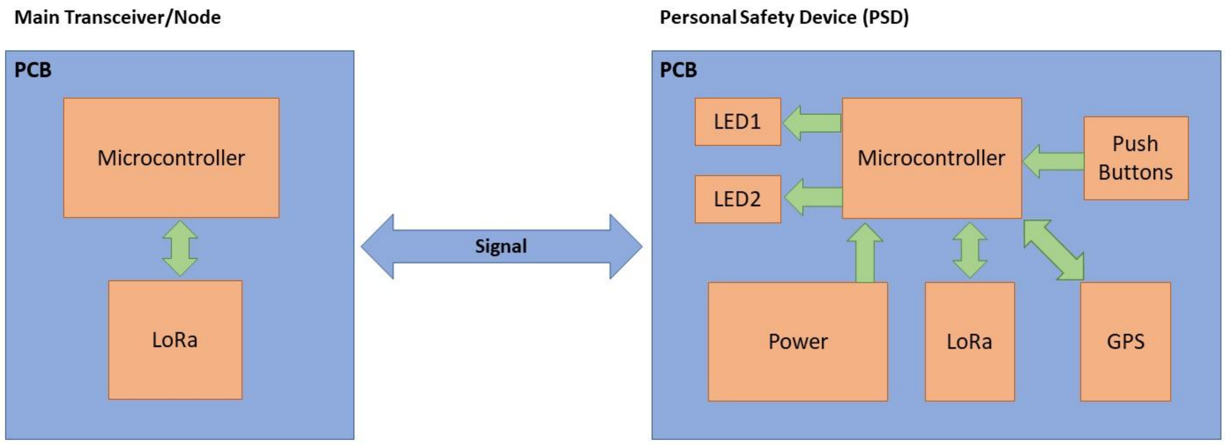

Figure 1: Block diagram for our system's overview

1.2 Expected Challenges

There are a few different types of challenges that can occur during the development of the KeyAssist system. The first challenge that might occur corresponds to the limited documentation available for LoRa since it is a fairly new technology. Additionally, the imperfect nature of the implementation environment could affect the signal range of the LoRa nodes.

GPS functionality can also cause challenges since it can be hard to get a GPS fix in some environments. Evidently, the PSD needs to get a GPS fix as quickly as possible so that the end user can depend on the PSD to assist them in case of an emergency. Likely, different GPS modules will need to be purchased and tested to verify that the ideal GPS module is being used for this application.

These challenges are likely to present themselves during the alpha and beta testing phases.

1.3 Design Classification

The table below lists and explains the design phases which are associated with each design decision in the following document.

ID	Classification	Explanation
A	Alpha	Details design decisions applicable to the proof-of-concept phase (i.e. ENSC 405W)
B	Beta	Details design decisions applicable to the engineering prototype phase (i.e. ENSC 440)
P	Production	Details design decisions applicable to the production phase

Table 2 - Design Phase Classification

2.0 PSD Design

In the following sections, the design of the Personal Safety Devices (PSDs) will be detailed in terms of chosen technology/hardware, physical design, and logic design.

2.1 Overall Design

The Overall design of the (PSD) is detailed below where it is demonstrated how and why each individual component was chosen. Each PSD unit will contain a microcontroller to communicate signals between the internal components. The Light-Emitting Diode (LED) will provide direct feedback to the end user, using multiple colours to communicate different information about the PSD System at any given time. The PSD will be able to receive Global Positioning System (GPS) signals through the GPS module which will receive and triangulate the location of the user in real time. The overall design will be powered by a battery controlled by the power module, which will also handle device recharging and report battery health to the microcontroller.

All PSD components will be fitted onto a custom Printed Circuit Board (PCB) to integrate all the modules together. This design will allow the product to fit comfortably within the PSD housing unit as shown in figure 4 and will offer more customization possibilities. The basic PCB diagram is shown in figure 3.

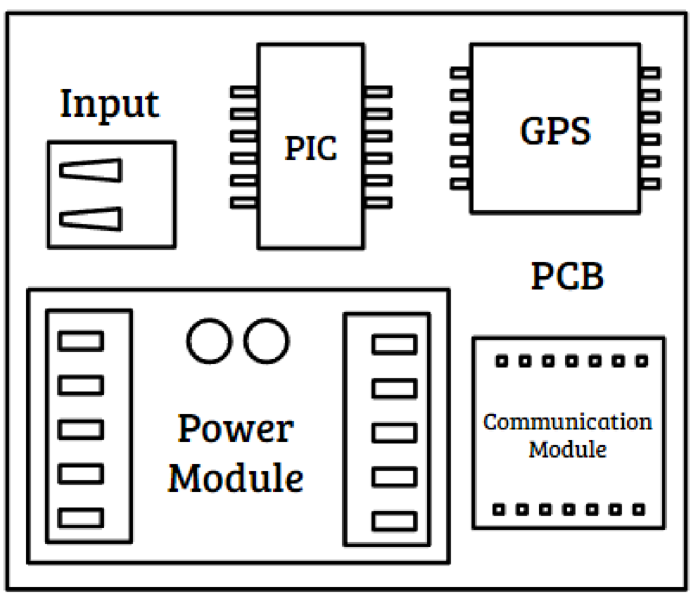

Figure 2: High-level overview of the PCB design

2.2 Microcontroller

In the Alpha phase, the PSD will be programmed and tested with the arduino UNO board with the ATmega328P 8 bit microcontroller [3]. This will enable quick feature testing of components and fast integration.

During the beta phase, the PSD will utilise a Peripheral Interface Controller (PIC). The PSD design will feature the PIC16f15244 chip [4]. This is an 8 bit microcontroller featuring 35 digital I/Os, which would allow for all components to be connected. The PIC's programming would be done using Embedded C or assembly programming language. The program can be loaded at an additional cost during purchase, or it can be tested with a development board and an in circuit debugger to monitor the IO of the PIC chip [6]. The PIC chip will also provide adequate size for the casing of the PSD (262mm by 79mm) [7]. Without an external uart bridge to program or flash storage, this unit will be easy to integrate on the PCB.

Power consumption for PIC microcontroller (*low power, Sleep*) :
$P = V * I = 3V * 600nA = 1.8\mu W$

Power consumption for PIC microcontroller (*low power operation, 32kHz*) :
$P = V * I = 3V * 48\mu A = 144\mu W$

Power consumption for PIC microcontroller (*low power operation, 4MHz*) :
$P = V * I = 3V * 1mA = 3mW$

2.3 GPS Module

The following design decisions regarding the GPS functionality of KeyAssist helped in determining the modules being considered for use with the PSDs. These decisions are derived primarily from the requirements specifications.

Design Identifier/ Justification	Design Decision	Linked Requirement
DD - 2.3.1 - A	GPS module must update coordinates at a rate of no less than 5 seconds.	**Req 3.1.8**
Justification	Campus security should be able to easily observe the change in the end user's location in real time.	
DD - 2.3.2 - A	GPS module must be capable of triangulating the end user's location with an accuracy of at least 10 metres.	**Req 3.2.8** **Req 3.1.6**

Justification	Campus security requires sufficient accuracy while locating an end user in distress. For a given outdoor implementation environment, 10 metres is determined to be sufficient.	
DD - 2.3.3 - B	The PSD will take less than 1 minute to boot up and get a GPS fix.	**Req 3.2.22**
Justification	The PSD needs to be reliable and ready to use during an emergency as quickly as possible after a cold fix.	

Table 3 - GPS module design decisions

For the alpha phase, the GPS module that will be used is the L80 GPS (base on MTK MT3339). This is incorporated into the LoRa/GPS Shield and satisfies the required location precision and accuracy. It also allows for a short start-up time since the EASY™ calculates and predicts orbits automatically by using the data stored in the RAM (up to 3 days of data). This technology allows for a cold start of <15s, a warm start of <5s, and a hot start of <1s. In conclusion, when signal levels are low, the GPS module is able to tackle this issue with this feature. Without this EASY™ feature, a cold start can take up to 35s. Additionally, there is an AlwaysLocate™ technology incorporated in the chosen GPS that will be able to achieve a balance between position accuracy and power consumption depending on the surrounding motion and environment [8].

For the beta phase, the prototype will include a GPS that can update coordinates in the required time and will be capable of providing an accurate location point of at least 10 metres. While also factoring in the power consumption and various features, the GPS module chosen will be the best option for the system design. The associated power consumption for this module is:

Power consumption for GPS Module (*Power Acquisition*) :

$$P = V * I = 2.9V * 0.025A = 0.0725W$$

Power consumption for GPS Module (*Power Tracking*):

$$P = V * I = 2.7V * 0.020A = 0.054W$$

2.4 LED

The following section outlines the design considerations for the LEDs in the PSD.

Design	Design Decision	Linked

Identifier/ Justification		Requirement
DD - 2.4.1 - B	The PSD will include one tri-colour LED and one bi-colour LED that can indicate the status of the distress signal and the battery to the end user.	**Req 3.2.14**
Justification	End users must have a visual indicator on the PSD to know the status of the distress signal and device. By knowing the status, the end user can make an informed decision on what actions to take.	

Table 4 - LED module design decisions

The two LEDs will be set on the PIC that will be connected to our PCB. By using a common cathode RGB, a HIGH signal or VCC will be sent to the red, green, blue pins to change it to the specific LED indication listed (Table 14) 3 specific resistors that will be connected to the RGB pins and will be used to limit current in order to output red, green, and yellow [9][10]. The LED will be bright enough for the user to see and will change in real time. The associated power consumption for this module is:

Power consumption small indicator LED (*Maximum*):
$P = V * I = 3.3V * 0.020A = 0.066W$ [11]

Power consumption small indicator LED (*Minimum*):
$P = V * I = 3.3V * 0.002A = 0.0066W$ [11]

2.5 LoRa Module

Design considerations for the LoRa technology are outlined in this section.

Design Identifier/ Justification	Design Decision	Linked Requirement
DD - 2.5.1 - A	LoRa transceiver modules will be implemented in the PSDs and the nodes as the communication module.	**Req 3.1.9** **Req 3.2.2**
Justification	LoRa transceivers modules allow for wireless 2-way communication between campus security, the meshed nodes and the PSDs. This 2-way communication subsequently allows for end users to receive feedback about their distress signals.	
DD - 2.5.2 - A	LoRa module will be able to communicate at least 5 kB of data every 5 seconds.	**Req 3.2.7** **Req 3.1.6**

Justification	PSD/LoRa nodes will need to relay every 5 seconds at most: the unique ID of the PSD, the emergency level, and the user's location coordinates. 5 kB of data is determined to be sufficient for this amount of information.

Table 5 - LoRa module design decisions

The LoRa module that is being used in the PSD design will work cohesively with the GPS module in order to provide real-time tracking coordinates to campus end security. LoRa has been chosen since it provides data communication over a long range while also consuming low power. For the alpha phase, the LoRa/GPS Shield that is composed of a LoRa/GPS Shield motherboard and Lora BEE will be used with an arduino uno to demonstrate the proof of concept. For the LoRa part, the SX1276/SX1278 transceiver is able to provide two-way communication to satisfy the required feedback needed to be transferred to both campus security and user. The chosen LoRa module can provide a throughput of 50Kbps which is sufficient to satisfy the required kB of data needed to be sent [12],[13]. For the beta phase, a SX1276/SX1278 LoRa transceiver will be incorporated into the final PSD design (Figure 3). LoRa is able to maintain lower power consumption due to its ability to shift to sleep mode when not in use.The associated power consumption for this module is:

Power consumption for LoRa end device (Peak current):
$P = V * I = 3.3V * 32mA = 0.1056W$

Power consumption for LoRa end device (Sleep current):
$P = V * I = 3.3V * 1\mu A = 3.3\mu W = 0.0000033W$

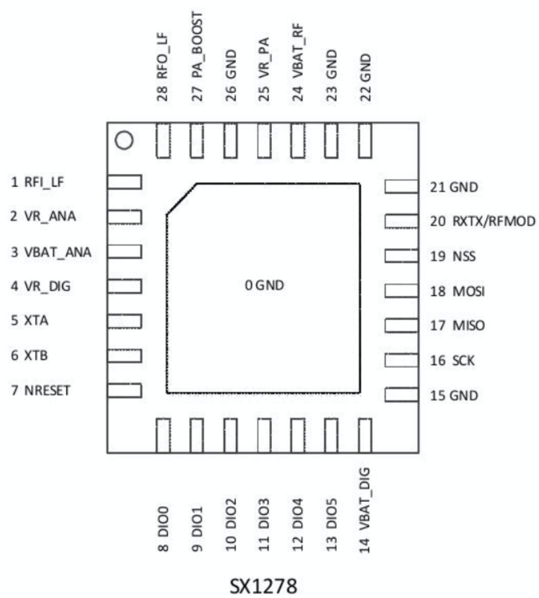

Figure 3: SX1278 transceiver overview [15]

2.6 Power Module

Design Identifier/ Justification	Design Decision	Linked Requirement
DD - 2.6.1 - B	The rechargeable power module will be able to reasonably supply power to the PSD components for ~6 hours.	**Req 3.2.5** **Req 3.2.6**
Justification	Students should be able to reasonably utilise the device in a standard sign-out period without having to recharge the battery. A reasonable timespan by definition for this project is an 'ON' time of ~6 hours.	

Table 6 - Power module design decisions

For the alpha phase, the arduino uno will need 5V to operate and that will be provided through a USB port connected to a computer. This also ensures that there is enough power to supply the LoRa/GPS Shield motherboard. For the beta phase, the power supply would need to satisfy the PIC's operating voltage of 1.8V - 5.5V [14]. With that in mind, the power module that is chosen will fulfil the required watts needed to power up all the modules listed below while not surpassing the max input voltage. The chosen power module will be a rechargeable power supply mounted on the PCB in order to minimise the size dimensions of the device. The module will then be charged by using a USB port that will be incorporated in the PCB design. This satisfies the requirement that the PSD can supply enough power for 6 hours and will also be easy enough to recharge. The circuit that will be encoded on the PCB will enable a low battery detector and stable voltage input and output.

2.7 Physical Design

The physical design of the KeyAssist PSD is determined primarily from the requirements specifications. The design decisions made below are linked to their respective requirements to justify the decisions made. The CAD drawing below outlines the physical appearance of the device, along with the dimension specifications that are addressed in the following section.

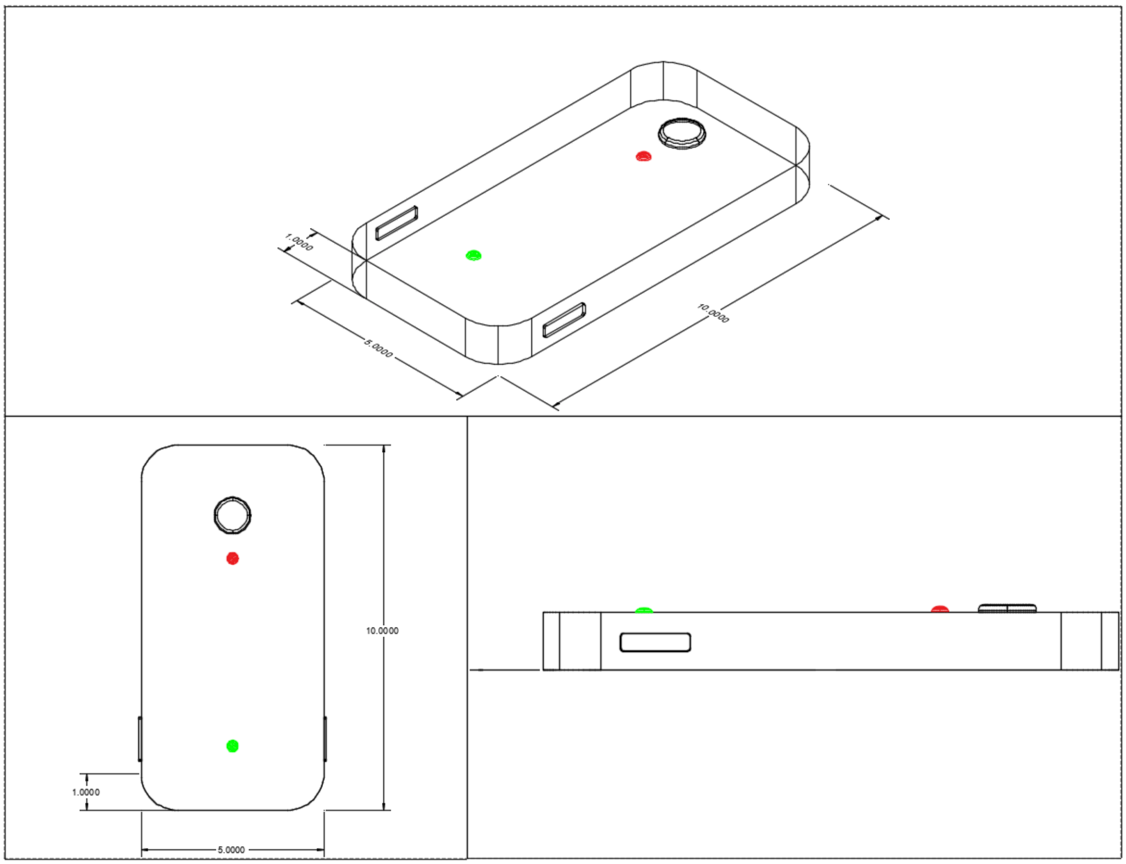

Figure 4: KeyAssist CAD (units = cm)

Design Identifier/ Justification	Design Decision	Linked Requirement
DD - 2.7.1 - B	To allow the end user to send distress signals to campus security, two push buttons will be placed on either side of the PSD.	**Req 3.1.2** **Req 3.2.9**
Justification	Push buttons are chosen to provide the end user with intuitive functionality, while keeping the device discreet.	
DD - 2.7.2 - B	The dimensions of the PSD will not exceed 10.0 cm x 5.0 cm x 1.0 cm (see figure 4).	**Req 3.2.1**
Justification	Dimensions are chosen to allow the end users to easily hold and operate the device in one hand. Subsequently, due to the size specification, end users will be able to easily depress both push buttons on either side of the device simultaneously.	
DD - 2.7.3 - P	PSD will include a keychain extension.	**Req 3.2.3**
Justification	Keychain functionality allows the end user to attach the PSD to their keys in order for it to be on hand and discreetly accessed at any time.	
DD - 2.7.4 - P	PSD will be outfitted with an outer casing of seamless silicone.	**Req 3.2.4** **Req 3.4.3** **Req 3.4.4**
Justification	The silicone casing will prevent water from affecting the device's functionality, and will allow an end user to operate it in various weather conditions. The outer casing will also serve to extend the life of the PSD, resulting in less replacements and overall waste in the life cycle of the system.	
DD - 2.7.5 - B	PSD casing will be made from eco-friendly 3D filament.	**Req 3.4.3**
Justification	Choice of casing material will affect the sustainability of the device.	

Table 7 - Physical design decisions

2.8 Logic Design

The general logic of the PSDs is best visualised in the state diagram below.

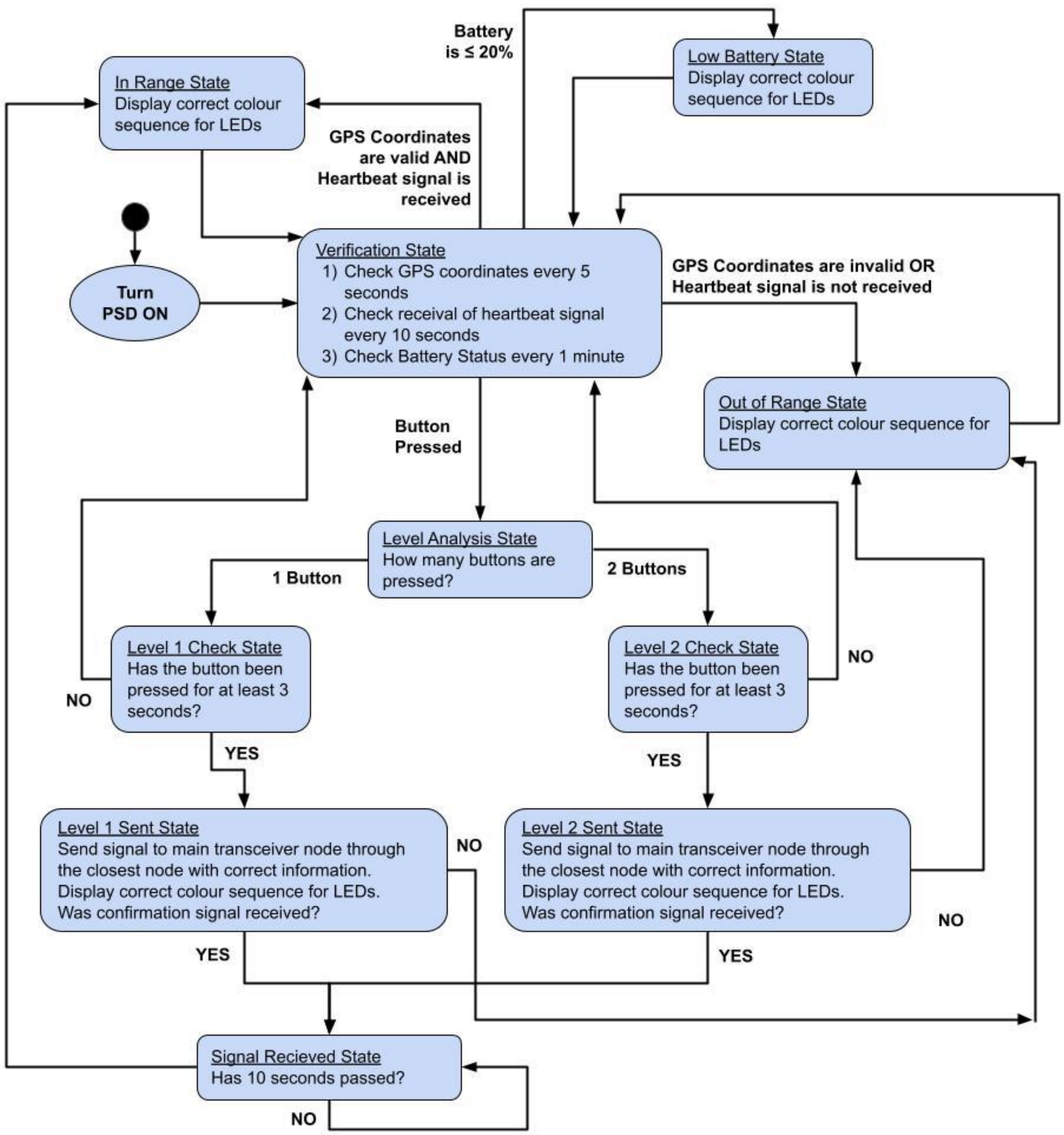

Figure 5: PSD State Diagram

2.9 End User Interaction Design

LEDs have been chosen as the physical indicator of the device's feedback state, and push buttons as the physical means of sending a signal. Design decisions detailing their functionality are found below.

Design Identifier/ Justification	Description	Linked Requirement
DD - 2.9.1 - B	The signal status LED (LED1) will use distinct colour sequences to represent the different statuses for a distress signal and for the range of the PSD. Refer to figure 5 for the flowchart for LED1.	**Req 3.2.15** **Req 3.2.16** **Req 3.2.18** **Req 3.2.19**
Justification	End user must have a visual indicator to indicate if their distress signal was sent, received, and the level of emergency of the sent signal (level 1 or level 2). The end user must also be made aware if they are out of range of the coverage area and/or if the PSD does not have a GPS fix. An LED will be used to keep the PSD discreet.	
DD - 2.9.2 - B	The PSD will have a second LED (LED2) located adjacent to the power button that will display unique colour sequences to indicate if the PSD has a low battery, is fully charged, and if the PSD is ON/OFF. Refer to figure 6 for the flowchart for LED2.	**Req 3.2.21** **Req 3.2.23**
Justification	The end user should know if the PSD is ON/OFF and/or if the battery level of the PSD is too low. The LED indicates if the PSD has low battery in case the end user needs to charge the PSD during the sign out period.	
DD - 2.9.3 - B	The two push buttons on the PSD will have two distinct depression sequences for sending a level 1 or a level 2 emergency. A level 1 distress signal will be sent when one of the two buttons is pressed for > 3 secs. A level 2 distress signal will be sent when both buttons are pressed simultaneously for > 3 secs.	**Req 3.2.10** **Req 3.2.11**
Justification	The push button sequences for both emergency distress level signals should be easy for the end user to distinguish and remember both sequences. In this case, level 1 = 1 button pressed, level 2 = 2 buttons pressed.	

Table 8 - End-user Interface Design Decisions

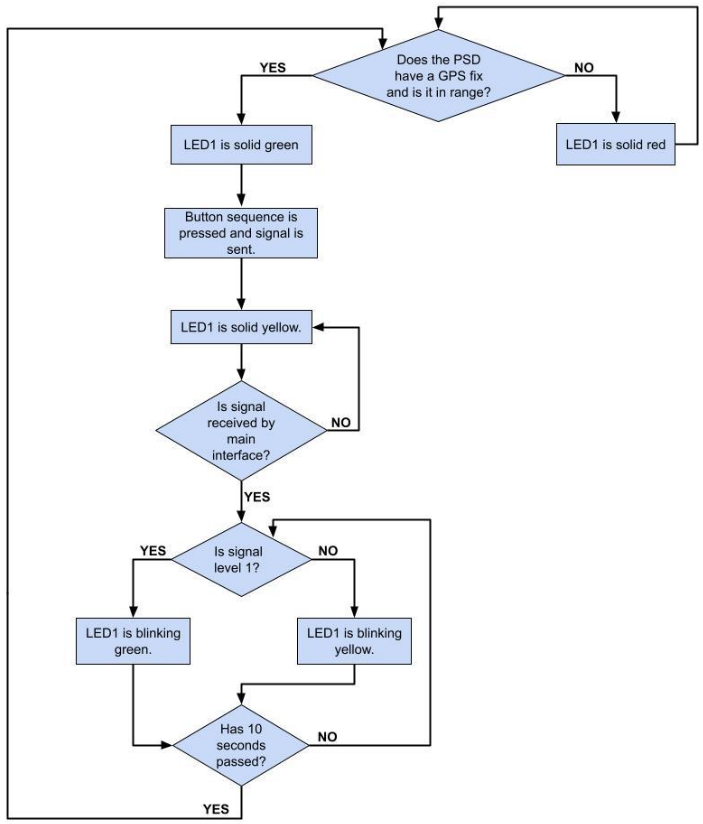

Figure 6: Flowchart for the colour sequence for LED1

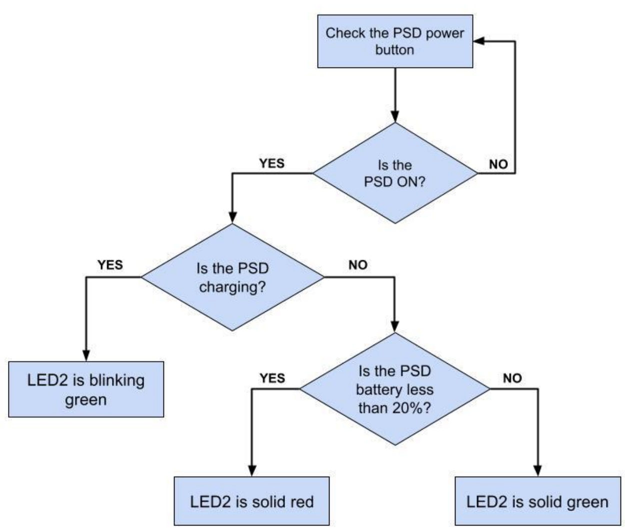

Figure 7: Flowchart for the colour sequence for LED2

3.0 System Design

The KeyAssist system will consist of multiple nodes that will be strategically placed around the implementation environment to create a mesh network. Each node will contain a LoRa transceiver that will be able to send a received signal from a PSD to the main transceiver located at campus security headquarters. The following design decisions address this functionality.

Design Identifier/ Justification	Description	Linked Requirement
DD - 3.0.1 - P	LoRa nodes will be positioned throughout the implementation environment in a mesh system in order to receive and pass along distress signals from all areas of the defined coverage area to campus security's user interface.	**3.1.10**
Justification	End users must be able to send a distress signal from all parts of the coverage area defined by the university. Strategically positioning LoRa nodes around the defined coverage area will allow students to utilise the system without reliance on any external factors such as cell phones, cellular service, etc. In this way, the system will be able to eliminate any dead zones that the university has identified as concerning.	
DD - 3.0.2 - P	The mesh network will be self-healing in that it will be able to update the available routes to the main transceiver.	**N/A**
Justification	If a node goes out of service, the mesh network should be able to continue to send signals to the main transceiver if an alternate route is available. The mesh network will be able to determine a new route to the main transceiver by using the remaining available nodes.	
DD - 3.0.3 - B	The nodes in the mesh network will determine the shortest route to the main transceiver and subsequently send a signal using the predetermined route.	**3.1.7**
Justification	End users sending a distress signal from a PSD will require the quickest response possible from campus security. A mesh network will allow a quick signal transfer along nodes as it can determine the shortest route to the main transceiver.	
DD - 3.0.4 - P	LoRa nodes will be positioned throughout the implementation environment with sufficient overlap in node coverage.	**3.1.10**

Justification	To ensure that a path to the main transceiver from each node always exists, there should be no gaps in node coverage. This overlap should also compensate for any fluctuation in node signal radius caused by minor changes in the implementation environment.	
DD - 3.0.5 - B	All nodes will contain heartbeat functionality, i.e. will output a heartbeat signal at an interval of 10 seconds to all PSDs within node signal range.	**N/A**
Justification	Heartbeat signals will be essential in determining whether the PSDs are in range of a node. Subsequently, this range information will be indicated to the end user through the feedback LED.	

Table 9 - System Design Decisions

For the alpha phase, the KeyAssist system will consist of the main transceiver and a PSD. In this phase, the network will demonstrate that a signal containing the specified information can be sent between a node and a PSD and vice versa. For the beta phase, the KeyAssist system will consist of three nodes (including the main transceiver) and a PSD. The nodes will create a mesh network that will be able to determine the quickest route to the main transceiver when a PSD sends a distress signal. Lastly, for the production phase, the KeyAssist system will contain enough nodes to cover the full coverage area defined by the university. Similar to the beta phase, the nodes will create a mesh network that can determine the quickest route to the main transceiver for a distress signal.

3.1 User interface for Campus Security

Design considerations for campus security's user interface are outlined in this section.

Design Identifier/ Justification	Description	Linked Requirement
DD - 3.1.1 - A	From the information in the distress signal, campus security's software will determine the user's name, student ID, photo, and phone number from the device's unique ID and populate the correct fields in the user interface.	**3.3.4** **3.3.5**
Justification	Campus security requires this information be presented in order to accurately respond to the distress signal.	
DD - 3.1.2 - B	Campus security's user interface will show the end user's	**3.3.6**

	three latest coordinate points on a map for the duration of the distress signal.	
Justification	Campus security should have an indication of the direction of the end user's movements. Only three locations will be shown so as not to overpopulate the map and keep the information relevant and easy to interpret.	

Table 10 - Campus Security User Interface Design Decisions

For the alpha phase, the user interface for campus security will display the received distress signals on a log, extract the location of the PSD and the end user's personal information. For the beta phase, campus security's user interface will display all necessary information in a manner similar to the graphical representations of the user interface in Appendix C.

3.2 Sign out Stations

End users will be able to sign out a PSD from sign out stations located around campus. The design considerations for the PSD sign out stations are outlined in this section.

Design Identifier/ Justification	**Description**	**Linked Requirement**
DD - 3.2.1 - A	The end user's personal information (name, phone number, student ID, and photo) will be linked to the PSD's unique ID during the sign out process for identification purposes during a distress signal event.	**3.1.5**
Justification	For security purposes, the end user's personal information needs to be linked to the PSD's unique ID. When a distress signal is received, campus security will be able to view the end users personal information to help them when looking for the end user during an emergency.	

Table 11 - Sign out Station Design Decisions

There will only be one PSD prototype during the beta and alpha phases thus the sign out stations will be implemented during the production phase.

4.0 Backend Server

We will be using MongoDB as the backend database of our services. MongoDB uses a document database system, which is more advantageous to utilise than traditional RDBMS (relational database management system) for the scope of our design. The reason for this is that the KeyAssist system focuses more on the data of each entry as time progresses and the relationship between the entries can be disregarded. MongoDB is more user-friendly and readable [16]. This will provide more freedom in the development stage as well as in maintenance and operations. MongoDB can also support a large number of reads and writes which is helpful if there is a sudden increase of end-users, making our system more scalable [17]. The information stored can also be distributed to many smaller lower-spec computers which can lower the cost of our system and increase accessibility for the clients [16]. The minor inconsistency in comparison with RDBMS is not critical as our expected daily user quantity is low. The students' information will be collected at the sign out stations located around the campus, and that information will then be stored on our backend server until they return their devices.

5.0 Wireless communication protocol

LoRaWAN has been chosen as the transmission/communication protocol due to its versatile attributes. LoRaWAN's protocol algorithm is simple in that it lessens the hardware complexity, thus reducing the cost of the device [18]. Since LoRaWAN uses unlicensed frequency bands, there is no cost for network usage. LoRaWAN also has good area coverage paired with low power consumption, allowing devices to transmit at low power settings [19]. Additionally, since the PSDs are required to be portable and the battery life needs to be sufficient for long periods of time, LoRaWAN meets all the requirements. Further, the low power consumption aspect of LoRaWAN decreases the battery capacity necessary for the end-user devices, potentially increasing the device's space for the allocations of other components or decreasing the size of the device which allows for more portability. The last attribute of LoRaWAN that is advantageous is that it is open-sourced, which allows for easier development and therefore is a fitting solution to our devices [18].

6.0 Conclusion

KeyAssist is designed to be a personal safety device that is inclusive to all students by offering an updated and affordable solution that can help improve safety on campus.The KeyAssist end user interface is designed to be intuitive and user-friendly to minimise the operation difficulty of our device in the case of emergencies. The KeyAssist system delivers a functional and convenient solution by providing a design solution that tackles the user requirements. The KeyAssist system's design decisions were chosen with the concept of integration with the existing campus security system to minimise the cost and improve the efficiency of our system.

At the proof of concept stage, the prototype presented will showcase the functionality of the data transfer between LoRa nodes and the accuracy of the GPS coordinates. It will provide enough data to show the range of the module and the precision of the location received. For the final prototype stage, the prototype presented will be a PSD as shown in figure 4. The final design will also showcase a mesh network of around 2-3 nodes (including the main transceiver).

6.1 References

[1] “Campus Sexual Violence: Statistics | RAINN,” Rainn.org, 2000. [Online]. Available: https://www.rainn.org/statistics/campus-sexual-violence. [Accessed Mar. 16, 2022].

[2] “Research Finds 82 Percent of American College Students are Concerned About Their Personal Safety | ADT Inc.,” news.adt.com. [Online]. Available: https://news.adt.com/news-releases/news-release-details/research-finds-82-percent-american-college-students-are. [Accessed Mar. 16, 2022].

[3] “Arduino Uno Rev3,” Arduino Online Shop. [Online]. Available: http://store-usa.arduino.cc/products/arduino-uno-rev3 [Accessed Mar. 16, 2022].

[4] “PIC16F15244 | Microchip Technology.” [Online]. Available: https://www.microchip.com/en-us/product/PIC16F15244#document-table [Accessed Mar. 16, 2022].

[5] “PIC16F152XX Family Product Brief,” p. 19, 2019. [Online]. Available: https://ww1.microchip.com/downloads/en/DeviceDoc/40002140A.pdf. [Accessed Mar. 16, 2022].

[6] “MPLAB® PICkit™ 4 In-Circuit Debugger | Microchip Technology.” [Online]. Available: https://www.microchip.com/en-us/development-tool/PG164140 [Accessed Mar. 16, 2022].

[7] “20-Lead Plastic Dual In-line 400 mil Body” microchips, 2017. [Online]. Available: http://ww1.microchip.com/downloads/en/DeviceDoc/20L_PIDIP_300_mil_P_C04-019B.pdf [Accessed Mar. 16, 2022].

[8] “GPS-only L80,” Quectel. [Online]. Available: https://www.quectel.com/product/gps-only-l80 [Accessed Mar. 16, 2022].

[9] “Tri-colour LED - Circuit Creator - PICAXE,” picaxe.com. [Online]. Available: https://picaxe.com/circuit-creator/light-and-lcd-outputs/tri-colour-led/ [Accessed Mar. 16, 2022].

[10] Microcontrollers Lab, “RGB LED interfacing with pic microcontroller - Multi color LED,” Microcontrollers Lab, May 02, 2018. [Online]. Available: https://microcontrollerslab.com/rgb-led-interfacing-pic/. [Accessed Mar. 16, 2022].

[11] J. Hamblen, “Using RGB LEDs | Mbed,” Mbed.com, Aug. 28, 2020. [Online]. Available: https://os.mbed.com/users/4180_1/notebook/rgb-leds/. [Accessed Mar. 16, 2022].

[12] “Lora/GPS Shield - Wiki for Dragino Project,” wiki.dragino.com. [Online]. Available: https://wiki.dragino.com/index.php?title=Lora/GPS_Shield#LEDs [accessed Mar. 16, 2022].

[13] “LoRa,” Wikipedia, Aug. 28, 2020. [Online]. Available: https://en.wikipedia.org/wiki/LoRa. [Accessed: Mar. 16, 2022].

[14] “LORAWAN ® AND NB-IOT: COMPETITORS OR COMPLEMENTARY?” [Online]. Available: https://lora-alliance.org/wp-content/uploads/2020/11/cr-lora-102_lorawanr_and_nb-iot.pdf. [Accessed: Mar. 16, 2022].

[15] [Online]. Available: https://semtech.my.salesforce.com/sfc/p/#E0000000JelG/a/2R0000001Rc1/QnUuV9TviODKUgt_rpBIPz.EZA_PNK7Rpi8HA5..Sbo [Accessed Mar. 16, 2022].

[16] Wikipedia Contributors, “MongoDB,” Wikipedia, Oct. 31, 2019. [Online]. Available: https://en.wikipedia.org/wiki/MongoDB [Accessed Mar. 16, 2022].
[17] “The most popular database for modern apps,” MongoDB, 2019. [Online]. Available: https://www.mongodb.com/ [Accessed Mar. 16, 2022].
[18] “What Is LoRaWAN? Long Range Wide Area Networks Explained,” www.emnify.com. [Online]. Available: https://www.emnify.com/iot-glossary/lorawan [Accessed Mar. 17, 2022].
[19] D. A. Norman, *The design of everyday things*, Revised and Expanded edition. New York, New York: Basic Books, 2013.“Expert Advice: What You Need to Know about Testing,” *GPS World*, May 01, 2012. [accessed Mar. 04, 2022]
[20] P. KINNEY, “IEEE SA - IEEE 802.15.4-2003,” *SA Main Site*. [Online]. Available: https://standards.ieee.org/ieee/802.15.4/3388/ [accessed Mar. 04, 2022].
[21] “IEEE SA - IEEE 145-2013,” SA Main Site, Mar. 06, 2014. [Online]. Available: https://standards.ieee.org/ieee/145/4705/ [accessed Mar. 04, 2022].
[22] “IEEE SA - IEEE 802.11-2007,” SA Main Site, Jun. 12, 2007. [Online]. Available: https://standards.ieee.org/ieee/802.11/3605/. [accessed Mar. 04, 2022].
[23] “IEEE SA - IEEE/ISO/IEC 8802-15-6-2017,” SA Main Site, Oct. 15, 2017. [Online]. Available: https://standards.ieee.org/ieee/8802-15-6/10017/. [accessed Mar. 04, 2022].
[24] “IEEE SA - IEEE 802.15.4-2020,” SA Main Site, Jul. 03, 2020. [Online]. Available: https://standards.ieee.org/ieee/802.15.4/7029/ [accessed Mar. 04, 2022].
[25] “IEEE SA - IEEE 1625-2004,” SA Main Site, May 28, 2004. [Online]. Available: https://standards.ieee.org/ieee/1625/3567/ [accessed Mar. 04, 2022]
[26] “IEEE SA - IEEE 802.15.1-2002,” SA Main Site, Jun. 14, 2002. [Online]. Available: https://standards.ieee.org/ieee/802.15.1/1180/ [accessed Mar. 04, 2022]
[27] “IEC 62133-2:2017 | IEC Webstore | lithium, li-ion, rural electrification, energy storage, battery, energy efficiency, smart city, power bank, powerbank,” webstore.iec.ch, Feb. 07, 2017. [Online]. Available: https://webstore.iec.ch/publication/32662 [accessed Mar. 04, 2022]
[28] ISO, “ISO 14040:2006,” ISO, Jul. 2006. [Online]. Available: https://www.iso.org/standard/37456.html. [accessed Mar. 04, 2022]
[29] W. William, “IEEE SA - IEEE 1363.3-2013,” SA Main Site. [Online]. Available: https://standards.ieee.org/ieee/1363.3/3822/ [accessed Mar. 04, 2022].
[30] “Low-power wide-area network,” Wikipedia, Aug. 25, 2021. [Online]. Available: https://en.wikipedia.org/wiki/Low-power_wide-area_network [Accessed Mar. 16, 2022].
[31] “Analog and Mixed-Signal Semiconductors | Semtech,” www.semtech.com. [Online]. Available: http://semtech.com [Accessed Mar. 16, 2022].
[32] “Zigbee Protocol - an overview | ScienceDirect Topics,” Sciencedirect.com, 2014. [Online]. Available: https://www.sciencedirect.com/topics/engineering/zigbee-protocol. [Accessed Mar. 16, 2022].
[33] “Buyers Guide To GNSS & GPS Systems Learning Center Tiger Supplies,” [Online]. Available: www.tigersupplies.com. https://www.tigersupplies.com/LC/Buyers-Guide-To-GNSS-and-GPS-Systems-.aspx [Accessed Mar. 17, 2022].

[34] “Eco-friendly 3D filament guide - what are the possibilities and innovations,” Aniwaa, Aug. 05, 2021. [Online]. Available: https://www.aniwaa.com/guide/am-materials/eco-friendly-3d-filament/. [Accessed Mar. 16, 2022].
[35] “Ultimate 3D Printing Material Properties Table,” Simplify3d.com, Mar. 29, 2019. [Online]. Available: https://www.simplify3d.com/support/materials-guide/properties-table/. [Accessed Mar. 16, 2022].
[36] “Test plan,” Wikipedia, Nov. 17, 2021. [Online]. Available: https://en.m.wikipedia.org/wiki/Test_plan [Accessed Mar. 16, 2022].
[37] CellMapper, “Freedom Mobile (formerly wind) (Canada) cell tower map,” CellMapper. [Online]. Available: https://www.cellmapper.net/map?MCC=302&MNC=490&type=LTE&latitude=49.27645201512482&longitude=-122.92117587024056&zoom=14.469136021500342. [Accessed: 16-Mar-2022].

7.0 Appendix A: Design Alternatives

7.1 GPS

The deciding factor for our GPS module was the location precision and accuracy as well as how well it can be incorporated with the LoRa mesh system. There were a couple modules that were analysed and the main comparison that was made was either using GPS or GNSS [33]. When selecting the best GPS/GNSS module, accuracy, availability, first fix time, and reliability were the four main components to analyse for each module [33]. L80 GPS patch is ideal for portable devices for its low power and compact design. This is already incorporated into the LoRa/GPS Shield and can work cohesively with the protocol. For the beta phase, there are going to be several modules tested and compared against one another in order to pick the best one for the KeyAssist system. GPS modules like NEO-6M module, Grove GPS (Air530), etc. are one of the many choices that are comparable, however, the most important aspect of the GPS module is that it needs to be able to work with the LoRa module in transferring data to a LoRa node.

An alternative to an internal GPS module is to connect our phone to the PSD through a bluetooth module and acquire the coordinates from the cellphone location services. By doing this, the fix time is lessened and it opens up the option to utilise a user's cellular service. This would ensure that there is a failsafe implemented in the design. However, the choice to have an internal GPS module on the PSD itself is a better option since there would have to be an added requirement that the end user would need to have a cellphone.

7.2 Wireless Communication

For our method of wireless communication, LoRa is an ideal solution because it will provide a solution to the problem of not needing to rely on cell phones. With LoRa modules, the KeyAssist system will be able to use less nodes than a Zigbee network since the range of LoRa is 5 km in urban areas and 15 km in rural areas [30]. Zigbee has a much shorter range of 10-100 m [32], which will require a much denser mesh network.

Another alternative is to connect the PSD to the end user's phone and use the phone's cell service to send a distress signal to campus security. This method is not practical as there are many cellular service dead zones around campus and distress signals will not be sent when the PSD is used in these areas [26]. This constraint does not allow the KeyAssist system to satisfy a major requirement (Req 3.1.10) about providing coverage to areas of concern specified by the university. Additionally, these cellular dead zones can change depending on the cellular service provider of the end user's phone. This method is reliant on the end user's cell phone and assumes that they have a functional and charged cell phone at all times. Clearly, this is a major assumption to make and is not inclusive to all the students.

7.3 Microcontroller

There are a few advantages to using the PIC chip family chips. This chip will allow the entire PSD to consume less power. With the provided eXtreme Low Power (XLP) feature from this board, the chip will consume less than 600nA (3V) during sleep to 48µA (3V) at 32 kHz operation frequency. Another feature of the PIC chip would be the integrated programmability. Unlike an Arduino or ESP32, a PIC chip can be programmed internally without the use of an external flash storage for the program. Additionally, this chip would cost <$1.00 USD at bulk purchase, compared to other options such as esp32 or arduino, which would often cost >$5.00.

7.4 Casing

The casing of the PSD must be chosen to minimise the damage done to the environment and increase its sustainability in order to fulfil requirement 3.4.3. However, the PSD must also be reasonably priced according to requirement 3.2.27. Due to these two requirements, for the Beta phase of development, 3D printing will be the most cost efficient source of casing. In terms of material, ABS and PLA are two of the most popular choices for 3D printing. However, PLA is biodegradable, unlike ABS [34], and it provides a more stiff and printable material [35]. For these reasons, PLA is the best choice for the PSD casing.

8.0 Appendix B: Test Plan

8.1 Introduction

This appendix will include the acceptance test plan provided in the requirements specification document, as well as a test plan for the alpha phase and beta phase. The alpha phase will require design verification test cases, which will assess the progress of the initial stages of development [36]. The beta phase will have manufacturing test cases that will evaluate the performance verification and quality control of the product during later stages of development [36]. The user interface test cases will be excluded from this appendix, due to their inclusion in the User Interface Design Appendix.

8.2 Acceptance Test Plan

By the end of ENSC 405W, WiCCSafe will present the following proof of concept deliverables:

- A user interface to monitor the system and communicate with a personal safety device
- A wireless personal safety device that can communicate the following to a remote user interface:
    - Personal safety device's location resolved to an accuracy of 10 metres
    - Two levels of distress signals
    - End user's information

8.3 Design Verification Test

The following test cases will list the specific phase A requirements covered, and the team responsible for performing said test [36]. At the alpha phase, we will have two main teams: node team and PSD team. The node team will build and develop the algorithm that controls the behaviour of the main transceiver node and the nodes that make up the mesh system. The PSD team will be in charge of building the PSD and controlling its behaviour in response to events.

Test Coverage	**Test Methods**	**Test Responsibilities**
Req 3.1.1	*Test Case:* Send a distress signal from the PSD. *Expected Results*: Verify the sent signal is received by the main transceiver node.	Node Team
Req 3.2.7	*Test Case:* Send a distress signal from the PSD.	PSD/Node Team

	Expected Results: Verify main transceiver node receives the following information: - Location of the PSD - Emergency Level (Low, High) - PSD's unique identifier	
Req 3.2.8	*Test Case:* Send a distress signal from the PSD. *Expected Results*: Verify GPS location is within 10 metres of PSD by displaying coordinates on a map in real time.	PSD Team
Req 3.2.14	*Test Case:* Send a distress signal from the PSD while in range. *Expected Results*: Verify a confirmation signal was triggered to send from the campus end node when the distress signal was received.	Node Team
Req 3.2.14	*Test Case:* Send a distress signal from the PSD. *Expected Results*: Verify the PSD receives the confirmation signal that was sent from the main transceiver node.	PSD Team

Table 12 - Test cases for design verification of PSD and main transceiver

8.4 Manufacturing Test

The following test cases will list the specific phase B requirements covered, and the team responsible for performing said test. At the beta phase, we will have two main teams: Campus Security team and PSD team. The Campus Security team will handle the behaviour of the nodes, as well as create the user interface for campus security. The PSD team maintains the same responsibilities as in phase A.

Test Coverage	**Test Methods**	**Test Responsibilities**
Req 3.1.2	*Test Case:* Mechanically manipulate the PSD according to the PSD state chart in Fig. 5 to send two different levels of distress. *Expected Results*: Verify the accurate signals of distress are received by the main transceiver node.	PSD Team
Req 3.1.3	*Test Case:* Navigate to campus security's user interface after a distress signal was sent from the PSD. *Expected Results*: The user interface receives an alert indicating a distress signal was sent.	Campus Security Team
Req 3.1.7	*Test Case:* Send a distress signal from the PSD. *Expected Results*: Verify the signal is received by the campus security's user interface	Campus Security Team

Req 3.1.8	*Test Case:* Send a distress signal from the PSD. *Expected Results*: Verify the PSD sends coordinates to the main transceiver node every 5 seconds.	PSD Team
Req 3.2.9	*Test Case:* Depress the buttons on the PSD according to the PSD state chart in Fig. 5 to send two different levels of distress. *Expected Results*: Verify the correct levels of distress are triggered.	PSD Team
Req 3.2.18	*Test Case:* Turn nodes ON. *Expected Results*: Verify every node sends a heartbeat signal at an interval of 10 seconds.	Campus Security Team
Req 3.2.18	*Test Case:* Turn PSD ON while in range. *Expected Results*: Verify the PSD receives the node's heartbeat signal.	PSD Team
Req 3.2.18	*Test Case:* Turn PSD ON while out of range. *Expected Results*: Verify the PSD is set to "out of range" mode when it does not receive a heartbeat signal within 10 seconds.	PSD Team
Req 3.2.19	*Test Case:* Turn PSD ON while indoors and away from windows. *Expected Results*: Verify the PSD is set to "out of range" mode when it does not receive valid GPS coordinates while checking every 5 seconds.	PSD Team
Req 3.2.21	*Test Case:* Allow PSD battery to drain to 20%. *Expected Results*: Verify the PSD is set to "low battery" mode.	PSD Team
Req 3.2.23	*Test Case:* Turn PSD ON and OFF using the power button. *Expected Results*: Verify the PSD is successfully turned ON and OFF.	PSD Team

Table 13 - Test cases for manufacturing verification of PSD and subsystems

Appendix C: User Interface Appearance Appendix

1.0 Introduction and Background

KeyAssist is a small and compact device that provides students with a discreet method of alerting campus security of potentially dangerous situations. Students will be able to sign out these devices from sign-out stations located throughout campus, guaranteeing accessibility to any students who are concerned for their personal safety. This device will help students communicate their level of distress to campus security along with their location and identification information. Campus security will have a user interface that will receive and process any incoming signals from devices across campus. The information they receive will allow them to efficiently locate, track and personally respond to users in distress. The purpose of this appendix is to provide an overview of the user interface's design process. It will outline the design decisions that were made and the corresponding justifications according to certain guidelines that ensure an effective user interface. The scope of this document includes user analysis, technical analysis, safety and sustainability, engineering standards along with empirical usability and analysis testing.

The KeyAssist system requires multiple hardware and software interfaces to operate fully. A brief description of each interface that will be discussed in this document is provided below to provide context for the user interface analysis.

1.0.1 End User PSD Interface (Hardware)

The End User Personal Safety Device (PSD) interface refers to the hardware on the physical PSD that the end user interacts with in order to communicate with campus security. The PSD will be equipped with push buttons which when depressed in a certain sequence send a distress signal to campus security with a distress level identification. Additionally, a power button on the front of the PSD will be used to power on and off the device. Finally, two Light Emitting Diodes (LEDs) will be placed on the PSD to communicate feedback to the user.

1.0.2 End User PSD Sign Out Interface

The PSD sign out interface is created for the sign out stations located around campus. This interface is designed for the end users to interact with when they sign out a PSD. This interface will contain all functionality necessary to allow the end users to sign out/return/renew a PSD, attach their student information, as well as any information necessary to operate the PSD.

1.0.3 End User KeyAssist Website Interface

The KeyAssist website interface is designed to improve the end user experience by offering another method of accessing instructions and sign out information regarding the PSD. The website will include instructions for the PSD, a map that shows where the sign out stations are located, a section for information on-campus security, a section to renew the sign out period for the PSD, and a section to report a problem with the PSD.

1.0.4 Campus Security Interface

The interface for campus security refers to the software that campus security will use to respond to any distress signals from an end user with a PSD. This interface will track and distinguish all received distress signals, and will display the necessary information associated with the PSD.

2.0 User Analysis

2.1 End User Analysis

End users of KeyAssist require little to no prior experience with any technology or product to utilize the device in an easy and efficient manner. End users must be able to press a combination of two buttons in a specific sequence to signal for assistance from campus security. In terms of physical abilities, end users must have the dexterity to press two buttons simultaneously with minimal force. Additionally, the end users must be able to perceive the colours of the LEDs to interpret the PSD's feedback, and read the device's instructions.

2.2 Campus Security User Analysis

Once the system is implemented on campus, campus security will be responsible for the ongoing operation of the system, and for the appropriate response to any received signals. All personnel with access to the campus security user interface will need to be appropriately trained in the system's operation. Users must have appropriate login credentials to ensure that the end user's personal information is secure. Campus security personnel should be given a system orientation to explain the user interface's functionality which will be described in more detail below. Physically, the security personnel must have the ability to use a regular desktop computer.

3.0 Graphical Presentation

3.1 Personal Safety Device

The following images are the design of our user end devices illustrated using SolidWorks. The first image is the overall illustration of the device, showing the position as well as the relative size of the LEDs and the buttons. The second image indicates the critical components of our device and provides short descriptions of its purpose. The power button controls the activation and the deactivation of our device. The emergency signalling buttons are used to transmit different levels of emergency signals to campus security. With various input combinations, the emergency level will vary. LED 1 reflects the emergency signal's transmission status as well as the service range of the device, while LED 2 shows the battery status of the device (see Table 14 for more details).

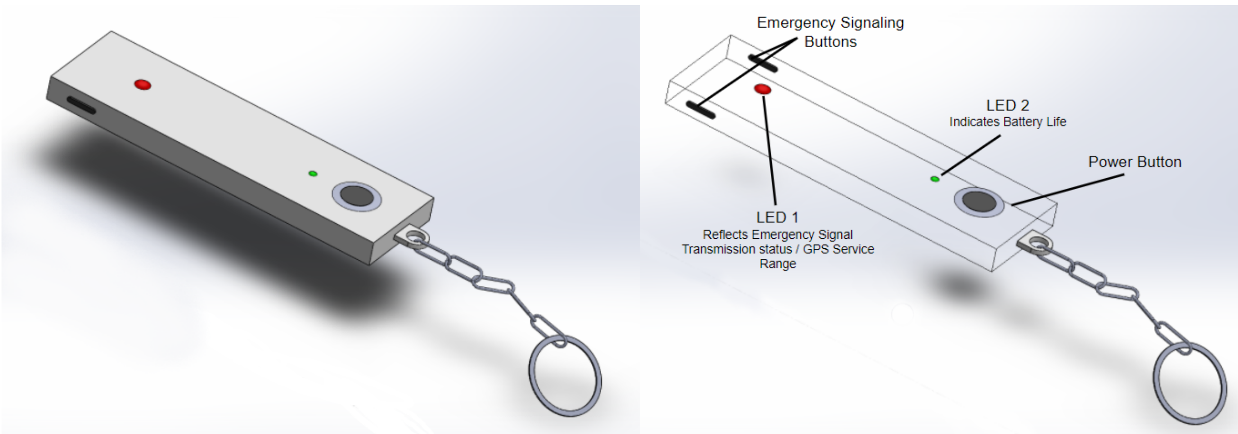

Figure 8: Illustration of the device in SolidWorks with component descriptions

3.2 End User Website

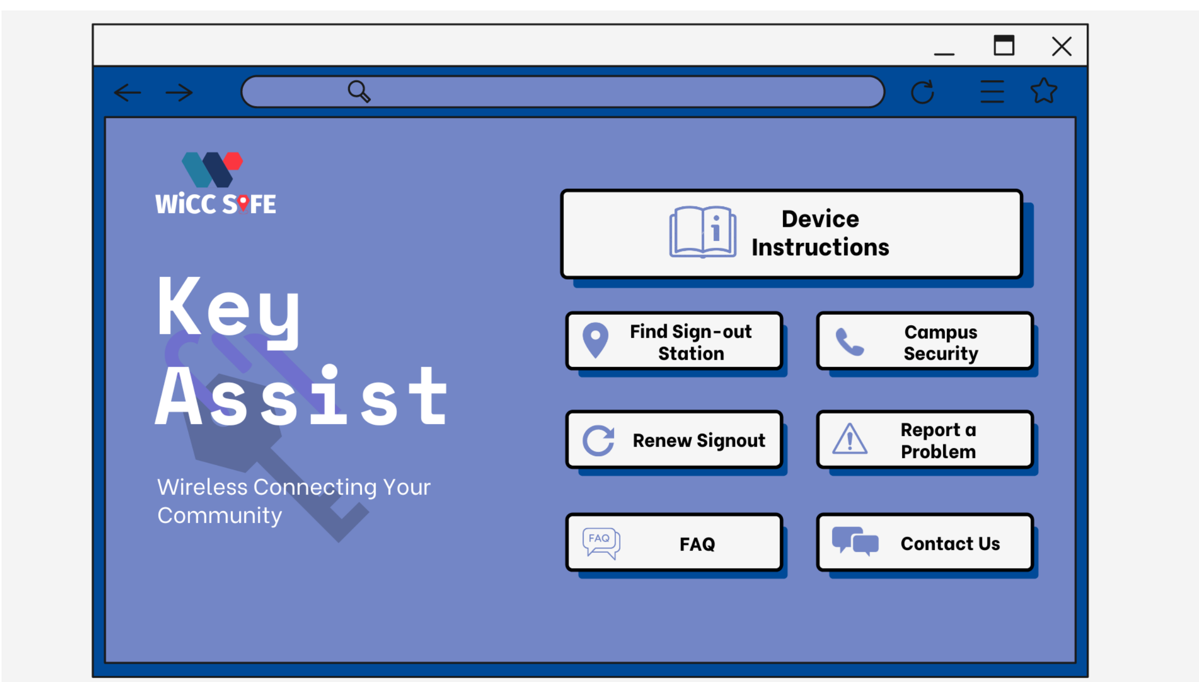

Figure 9: Illustration of the End User KeyAssist Website

3.3 End User PSD Signout Interface

Figure 10: Illustration of the End User PSD Signout Interface

3.4 Campus Security Interface

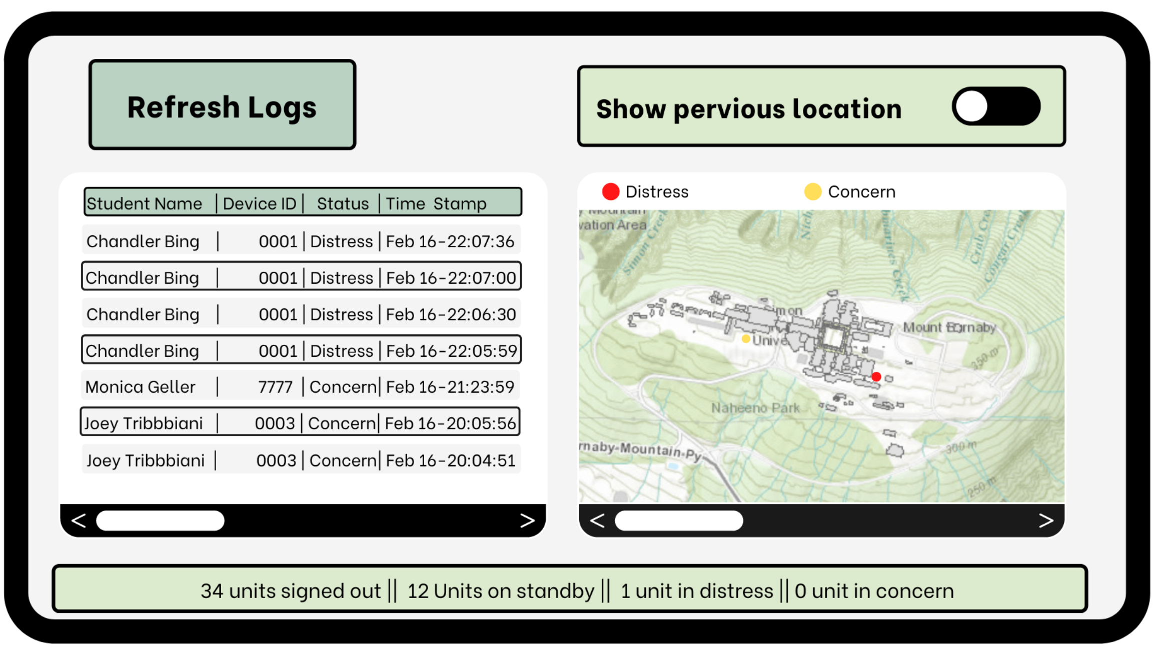

Figure 11: Illustration of the Campus Security Interface (1)

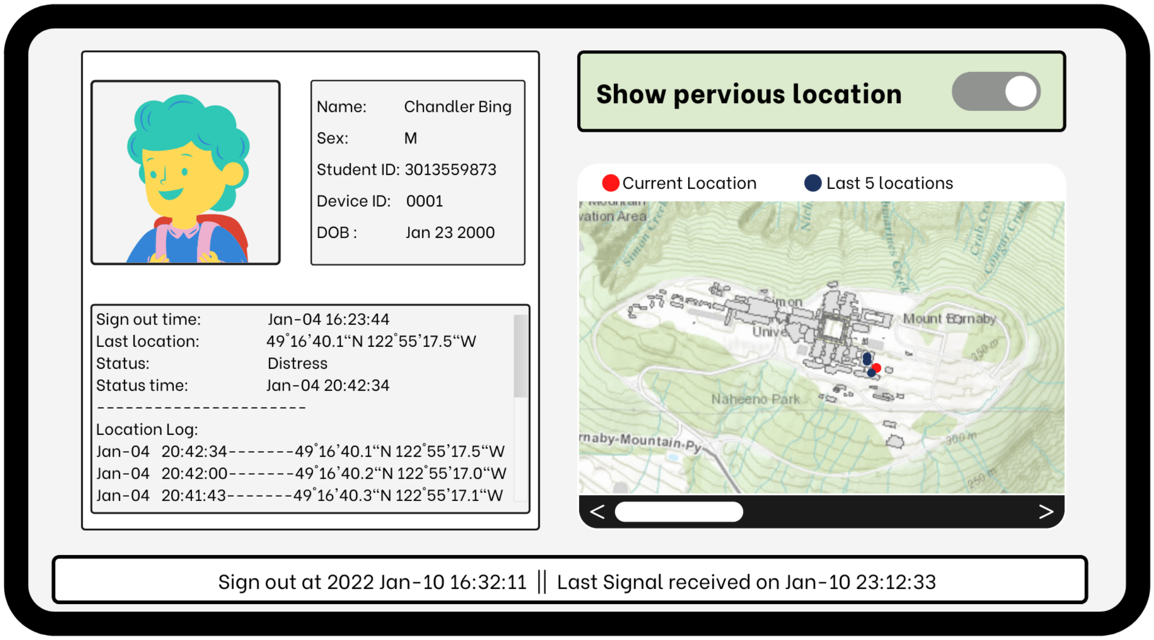

Figure 12: Illustration of the Campus Security Interface (2)

4.0 Technical Analysis

This section outlines the Seven Elements of UI Interaction: Discoverability, feedback, conceptual models, affordances, signifiers, mappings, constraints from Don Norman’s book “The Design of Everyday Things” [19].

4.1 Discoverability

The PSD will include a power button that is distinctive and easy to locate, with a unique identifier (power symbol). Two separate pushbuttons located on either side of the PSD will be provided for alerting security (see figure 8), with two unique sequences for different emergency levels. These sequences will be intuitive and easy to remember in a state of panic. A QR code will be placed on the back of the PSD for the end user to access, which will direct them to a designated website. The website will contain clear and concise instructions on how to use the device, which sequences signifies certain emergency levels, and a map of the range that the KeyAssist product reaches. The current state of the device will be indicated to the user via a Light Emitting Diode (LED), which is described further in section 4.2.

Campus security’s user interface will be able to present all received distress signals from multiple PSDs. The user interface will have a colour-coded system to distinguish between inactive and active distress signals. A log that contains all previously received distress signals will be available for later reference and/or any data analysis/reporting needs. Additionally, security personnel will be able to easily navigate to a separate page showing the location of each distress signal on a map, and the end user's personal information previously linked to the PSD (student number, student ID, phone number, and the status level of the distress signal).

4.2 Feedback

For the KeyAssist product, end user feedback is defined as the indication to the end user of the status of the physical PSD, as well as the status of the distress signal. These indications are essential to the safety of the user and will in turn help dictate the necessary steps they should take to ensure their distress signal is received by campus security. The end user feedback is communicated via two LEDs located on the front of the PSD. The colour of LED 1 located near the end of the PSD (see figure 8) will indicate the status of the device detailed in table 1 below. As LED 1 indicates multiple states, a state hierarchy will be implemented to ensure that the most important state is communicated to the end user at any given time. LED 2 will be placed directly adjacent to the power button, which will indicate the battery status as described in table 1. To make it easily accessible for the user, the PSD will have brief instructions about the LED colour code printed on the back.

	Colour of LED	**State of PSD**
LED 1	OFF	OFF
	Solid Red	Out of Range
	Green	ON and in range
	Constant Yellow	Signal Sent
	Blinking Green after Constant Yellow	Signal Received (Low-level emergency)
	Blinking Yellow after Constant Yellow	Signal Received (High-level emergency)
LED 2	OFF	OFF
	Solid Red	Battery Low (Less than 20%)
	Solid Green	Battery Charged
	Blinking Green	Battery Charging

Table 14 - LED behaviour in response to the state of PSD

4.3 Conceptual Models

The conceptual model for this system is similar to those for personal emergency response systems like Life Alert. The end user of KeyAssist will be provided with a device tutorial during the signout process that will allow the end user to visualize and understand the conceptual model. The user interface for campus security has a similar conceptual model as home emergency alert systems since assistance needs to be dispatched when a distress signal is received by an end user pressing a button. Campus security will be provided with a tutorial to further help understand and communicate the system's conceptual model.

4.4 Affordances

The KeyAssist device allows users to send distress signals to campus security if they feel unsafe by pressing a sequence of push buttons. This functionality can be misused by anyone with ulterior motives, as all students have access to the PSDs. It should be recognized that it is possible that an end user decides to abuse the PSD by sending distress signals without feeling at all unsafe, thus wasting valuable campus security resources. Moreover, any user could physically abuse the PSD by breaking it and/or stealing it from the university. In order to mitigate these possible circumstances, the user will be warned upon signout of the PSD that there are monetary consequences to abusing the technology that can be configured by the university. As all PSDs are linked to a student's personal information, these fines can be directly associated with an end user's school fees at the university's discretion.

4.5 Signifiers

In order for the user to easily identify the purpose of each button, an indicator of each button's functionality will be printed on the PSD. The power button will have the universal power symbol printed on it for easy identification. Furthermore, a brief description of the LED colour code will be available on the back of the PSD, along with a scannable QR code that takes the end user directly to the user interface website. On the campus security user interface, the colour will be employed to separate active and inactive distress signals, as well as to easily distinguish the level of distress of each active signal on the map.

4.6 Mappings

To provide a user-friendly device, the buttons will be strategically placed to minimize confusion for the end user. The emergency signalling buttons will be identical and placed on either side of the device to indicate that both buttons must be pressed simultaneously. The power button will be placed far from the emergency signalling buttons and will be labelled with the universal power button symbol to make the operation clear to the end user.

4.7 Constraints

A physical constraint imposed on the KeyAssist PSD is the limit of two buttons available for the user to press, so as to make the sequences as simple as possible for the end user while minimizing the opportunity for accidental distress signals (explained further in section 6.4.1). End users are offered only two distress signal levels to communicate to campus security as a semantic constraint. This constraint limits the number of sequences the end user needs to remember, and limits confusion. Finally, the area of PSD coverage is constrained to the university to ensure campus security's jurisdiction is maintained.

5.0 Sustainability/Safety

The KeyAssist system saves and manages the end users personal information and it is a priority to keep this data confidential. The location services on the PSD are potentially threatening to the end user if this data is not properly protected and it can result in dangerous circumstances. Therefore, the system is responsible to ensure that the end user's personal sensitive information is safe and securely stored. Furthermore, taking sustainability into account, the casing for the PSD will be chosen to minimize the possible environmental damage and maximize the lifespan of the device.

6.0 Empirical Usability Testing

6.1 Testing for End-User

1. Were you able to sign out a keyAssist easily?
2. How intuitive was it to use the device?
3. Were you able to depress the buttons without unnecessary force?
4. Was the device comfortable to hold/operate?
5. Were the push buttons easy to depress simultaneously?
6. How easy was it to recall the push button sequences for the different emergency levels?
7. Was the keychain aspect of KeyAssist convenient for portability?
8. Were the LED lights helpful in indicating the status of the keyAssist?
9. Were the LED colour meanings intuitive and easy to recall?
10. Were there sufficient instructions available on the device to understand its operation?
11. Is this device preferable to other safety programs on campus?
12. Would you use this device again? If not, please specify why.
13. What was your first impression of the keyAssist?

6.2 Website User-Friendly Questions

1. Is the website easy to navigate?
2. Is all the important information clearly displayed on the website?
3. Were you able to access the website from the QR code?
4. Was the QR code on the KeyAssist device a helpful shortcut to the website?
5. Is there another feature that you would like to see on our website? If yes, please specify.

6.3 Testing for Campus Security

1. Is the interface easy to navigate and understand?

2. Does the software provide an intuitive representation of an end user's location?
3. Does the end user's map location update at a high enough rate for a response?
4. Is it easy to differentiate between active and inactive distress signals?
5. Is it intuitive to determine the date and time of both active and inactive distress signals?
6. Is the map easy to navigate (ex. zoom in/out, change views, etc.)?
7. Is the user's information displayed on the interface sufficient for the operator to respond to the distress signal?
8. Is the alert for new signals sufficient in notifying the operator?
9. Is the alert for system maintenance/issues sufficient in notifying the operator?
10. Is there another feature not currently implemented that would aid an operator? If yes, please specify.

6.4 Potential Errors

6.4.1 PSD Errors

Using the PSD, there is a risk that the user doesn't remember the sequence of the push buttons in a situation of panic, or confuses the sequences. To mitigate that risk, the sequences will be as simple and easy to remember as possible as well as unique. Further, there is a risk that the user depresses the buttons in one of the defined sequences by accident. To limit this risk, the sequences require simultaneous depression of two push buttons, located on opposite sides of the PSD so that it is unlikely that both buttons be depressed unintentionally. Another risk would be the end user interpreting the LED feedback in an incorrect manner. To limit user confusion, instructions will be readily available via a tutorial at the signout stations, and concisely printed on the back of the PSD.

6.4.2 Campus End Errors

Campus security needs to be able to accurately respond to a distress signal by using the information provided to them on the campus security interface. For this reason, it is imperative that the interface clearly communicates the information required for the response team. As an operator of the system, a risk is that a distress signal is overlooked by an operator. To ensure that an operator is clearly notified of a distress signal, a pop-up will appear on screen, accompanied by an alert sound. The pop-up window and alert sound will continue until a user manually addresses the distress signal. Another possible issue is the GPS tracking of the end user, as there is always a possibility that an end user's location coordinates are not able to be sent, or are not updated properly. In this case, the user's last known location will be available on the screen along with a timestamp and a log of previously received locations. Finally, as this is a system with many moving parts, it is possible that elements of the system fail, or require maintenance. A pop-up window will appear on the campus security user interface indicating the element of the system that is down, along with maintenance instructions and/or contact information of a system installation representative.

7.0 Analytical Usability Testing

During the development phase of the KeyAssist, WiCCSafe's engineers will complete quality assurance testing on the PSD and campus security user interfaces. The test cases will address the essential functionalities of the product, in order to focus on the most important requirements.

7.1 Testing with End User Device (PSD) (step by step instructions)

Test Case	Expected Results
Power ON/OFF the PSD using the power button.	PSD powers ON and status/power LED outputs constant green light. PSD powers OFF and status/power LED is OFF.
Press designated button sequence for low level emergency.	Signal is sent with identification of low level emergency status.
Verify the PSD signal status for low level emergency.	If signal is received: ● Status LED outputs blinking green light after constant yellow If signal is sent but not yet responded to: ● Status LED outputs constant yellow light
Press designated button sequence for high level emergency.	Signal is sent with identification of high level emergency status.
Verify the PSD signal status for high level emergency.	If signal is received: ● Status LED outputs blinking yellow light after constant yellow If signal is sent but not yet responded to: ● Status LED outputs constant yellow light
Move PSD out of range.	Status LED outputs constant red.
PSD is low battery.	Power LED outputs constant red.
Plug in and charge PSD.	PSD is charging and power LED outputs blinking green light

Table 15 - PSD Test Cases

7.2 Testing with Campus Security Interface

Test Case	Expected Results
Signal is received	Interface generates pop-up and alert sound. The interface displays the new signal received with "active" colour coding and is recorded in the log.

Verify that the correct information is received from a distress signal	Interface displays (see figure 4): ● End user's location is shown accurately on the map (within 10 metres of the PSD's location) ● Distress signal status level ● Student ID ● Device ID
Select one distress signal from the signal log	Interface displays (see figure 5): ● End user's location shown accurately on the map (within 10 metres of the PSD's location) ● Distress signal status level ● Student ID ● Device ID ● Location Log

Table 15 - Campus Security Interface Test Cases

8.0 Engineering Standards

The following table outlines the important engineering standards that apply to KeyAssist's user interfaces as well as the functional aspects associated with it.

Engineering Standard	Description
IEEE 802.15.4-2003	Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for Low Rate Wireless Personal Area Networks (WPAN).[20]
IEEE 145-2013	Definitions for antennas and for systems that incorporate an antenna as a component of the system are established in this standard.[21]
IEEE 802.11-2007	Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications[22]
IEEE IEC 8802-15-6-2017	Short-range, wireless communications in the vicinity of, or inside, a human body (but not limited to humans) are specified in this standard.[23]
IEEE 802.15.4	The physical layer (PHY) and medium access control (MAC) sublayer specifications for low-data-rate wireless connectivity with fixed, portable, and moving devices with no battery or very limited battery consumption requirements are defined in this standard. [24]
IEEE 1625-2004	Standard on design analysis for qualification, quality, and reliability of rechargeable battery systems for portable computing. [25]
IEEE 802.15.1-2002	IEEE Standard for Telecommunications and Information Exchange Between Systems.[26]
IEC 62133-2:2017	IEC Cells and batteries containing non-acid electrolytes - Safety requirements for portable sealed secondary cells[27]
ISO - ISO 14040:2006	ISO Environmental management — Life cycle assessment — Principles and framework.[28]
IEEE 1363.3-2013	Engineering Standard on encryption for data transmission [29]

Table 16 - Engineering Standards

9.0 Conclusion

KeyAssist is a device designed to protect the safety of students on campus by offering a simple, affordable, and reliable solution. The KeyAssist user interface is designed to be intuitive and user-friendly to minimize the operation difficulty of our device in emergencies.

The KeyAssist system is constructed with the concept of integration with the existing campus security system to minimize the cost and improve the efficiency of our system. Our device will be built following the engineering standards of Canada and considers its safety and sustainability, providing a safe and reliable product for the students while reducing the possible stress our product could cause to the environment.