ATARAXIA

# Final Project Report

## SAFE-T


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# Introduction

The product currently under development by Ataraxia is the SAR (Search and Rescue) Assisting Frequency-modulating Electronic Transceiver - known professionally as SAFE-T, for short. This device is essentially a handheld beacon that will assist NASA with Lunar Search and Rescue operations by transmitting position, navigation, and time (PNT) information to the appropriate parties.

The Ataraxia team consists of Gabrielle Quemada, Falak Fahim, Peyton Goodman, and Vatsal Modgil, who are all senior engineering students at Texas A&M. Dr. Joseph Morgan is the faculty advisor overseeing the project, which is sponsored by Matt Leonard, the President of T STAR. The beacon prototype is being designed at the request of NASA, to be further developed by the Lunar Search and Rescue program to be used by astronauts in 2024.

## Background and Rationale

The background of SAFE-T stems from NASA's plan to return to the moon under the Artemis missions in 2024. With the Artemis program, NASA will establish a sustained presence on the Moon, opening more of the lunar surface to exploration than ever before. Currently, there is no adequate means of cislunar and lunar surface distress tracking coupled with a notification system, which will be a key element of safe exploration. Thus, the need for a mobile beacon arises.

The intention is for SAFE-T to serve this purpose, as well as be capable of attaching to the Gandalf Staff - another project under development by several other ETID Capstone teams. The Gandalf Staff will be utilized in the upcoming years as a handheld extra-vehicular activity tool capable of lighting and remote imaging, and Ataraxia providing an automated distress tracking and notification system for the staff will only benefit the safety of lunar surface users.

## Problem Statement

As space-faring nations continue to explore the lunar surface, unique terrain and lighting challenges will present themselves. Much like the maritime industry, there will be a need for a distress tracking and notification system. NASA and T STAR require a prototype for the wireless local area network (wLAN) portion of a handheld beacon that will assist Lunar Search and Rescue (SAR) operations in locating astronauts by relaying Position, Navigation, and Time (PNT) data to rescue parties.

To meet these requirements, Ataraxia will provide a handheld beacon that will assist NASA's Lunar Search and Rescue development by recording the device's PNT data and transmitting it to a base station through the 802.11n protocol (wireless Local Area Network). The device will have an attachment capability (either to an EVA suit or a Gandalf Staff), a battery life comparable to the time span of a Lunar trek, and an easily operable user interface. The device's user will be able to send and receive messages with the base station, as well as indicate an emergency. The device's emergency mode will be triggerable via manual input or the detection of an abnormal simulated heart rate.

## Concept of Operation

SAFE-T is a handheld beacon controlled by four easily accessible buttons (up, down, select, emergency) and has a menu to access various functionalities such as sending preformatted messages or indicating an emergency.  SAFE-T shall also transmit messages containing PNT information while not actively being handled, and shall have its emergency mode triggerable via physical input or the detection of an abnormal simulated heart rate.  All messages shall be sent to a Gandalf Staff.


Figure 1. 3D Design

The Gandalf Staff is a handheld extra-vehicular activity tool capable of lighting and remote imaging that many astronauts will carry with them on future missions. SAFE-T should be capable of attaching to the staff or an EVA suit so that it can accurately relay the user's PNT information as well as be easily accessible for communication during a mission.

In order to operate the device, the user simply needs to have the beacon on their person or in a desired location and it will record and transmit PNT data - which includes but is not limited to: latitude, longitude, altitude, and time. This data is displayed on the device's screen, along with a menu of selectable preformatted messages that can be sent from the device. SAFE-T will communicate via the 802.11n protocol and TCP with a base station in order to send PNT data as well as the user's heart rate data. It is imperative that the device triggers emergency mode if an abnormal heart rate is detected so that it can signal to the base station that there is a health crisis and the user needs assistance.

## Functional Requirements

This section highlights the functional requirements of the project - the functions the device must be capable of performing - divided into five categories: enclosure, power, user interface, command and data handling, and communications.

### Enclosure

The enclosure shall have housing that secures all components and contains the internal circuitry, buttons, and an HDMI display, and likewise protect these at-risk components from Regolith (lunar dust). The device shall be capable of attaching to the Gandalf Staff or an EVA suit, and have a means of pressure ventilation.

### Power

The system will be powered via a rechargeable battery that allows it to operate for 12 hours for lunar operations, and have a power switch. The system shall have power monitoring, distribution, and regulation capabilities.

## User Interface

The system will have a backlit display that displays PNT data on-screen, as well as messages for a base station/receiver. The buttons and power switch will not be easily pressed/flipped inadvertently.

## Command and Data Handling

The system shall locally store data, and operate with a Lunar Standard Time (LST) clock. The device will simulate a heart rate to be transmitted and its emergency mode will be entered upon triggering conditions, such as the detection of an abnormal heart rate, or manual input.

## Communications

All messages shall not be encrypted and will include an identifier unique to the beacon. A GNSS/GPS shall be used for PNT information, which will be sent out at incremental time values dependent on the device's mode (nominal or emergency). The device shall communicate with the Gandalf Staff via TCP over an 802.11n protocol.

## Conceptual Block Diagram

The conceptual block diagram below indicates the components of the system. The device's electronic components consist of a Raspberry Pi Zero W, a 5" HDMI screen, a power monitor, and a gps receiver from Adafruit - all powered by a 7.4V Lithium ion battery. SAFE-T shall distribute and regulate the battery such that all of the components receive voltages specified by their respective data sheets. The battery's status will also be monitored and reported to the Raspberry Pi in order to make the user aware of the expected battery life remaining given the current level of charge. The screen will be run by an OS (Raspbian Pi OS 3.0), as well as the GPS. For the sake of this project all communications will be done with a singular Gandalf Staff hosting a physical router and Jetson Nano through which communications will take place.

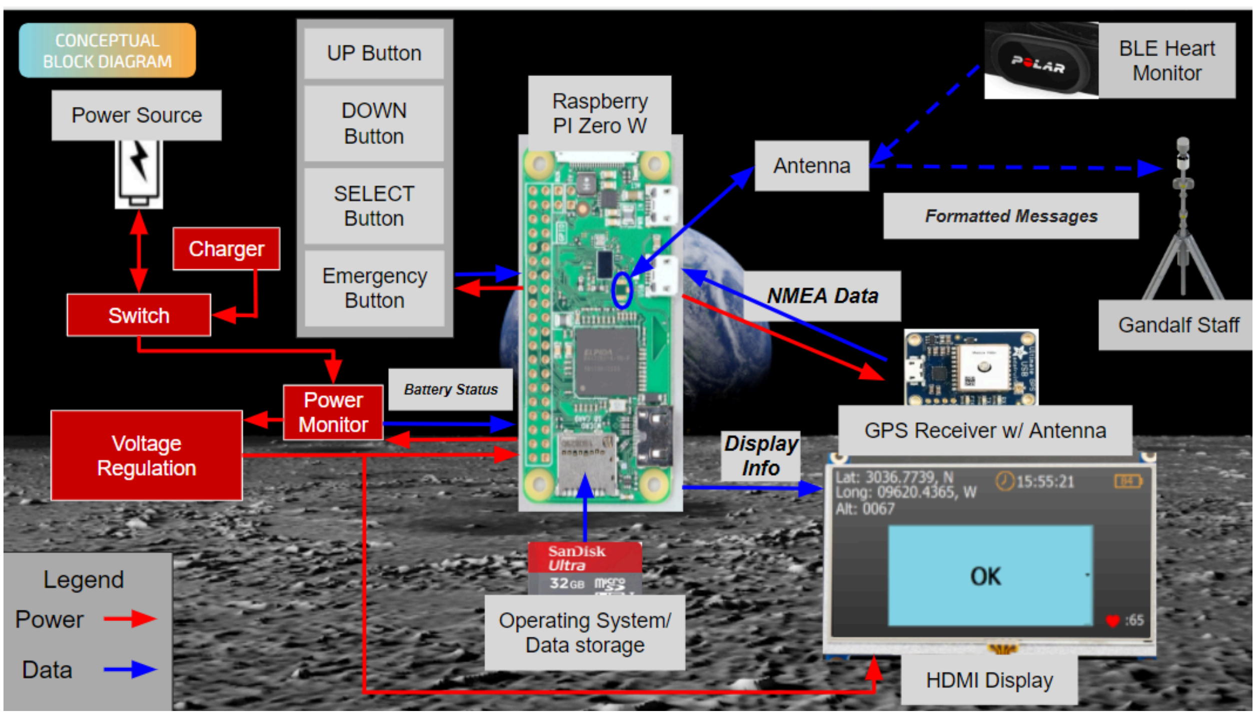



Figure 2. Conceptual Block Diagram

The general operation of the device is such that it is controlled by four mechanical buttons utilized to traverse ('up' and 'down') an onscreen menu of preformatted messages, send ('select') the displayed message, or enter 'emergency' mode. The buttons will be placed on the front and top faces so as to mimic the handfeel that many portable gaming systems exhibit.

The Graphical User Interface (GUI), as seen in Figure 3, was designed with the help of the PyQt5 platform, which is "a Python binding for Qt v5", which in turn is a "set of cross-platform C++ libraries that implement high-level APIs for accessing many aspects of modern desktop and mobile systems. These include location and positioning services, multimedia, NFC and Bluetooth connectivity, a Chromium based web browser, as well as traditional UI development". For this project's purposes PyQt5 is being utilized for the UI development features in its 'PyQt5 Designer' application.

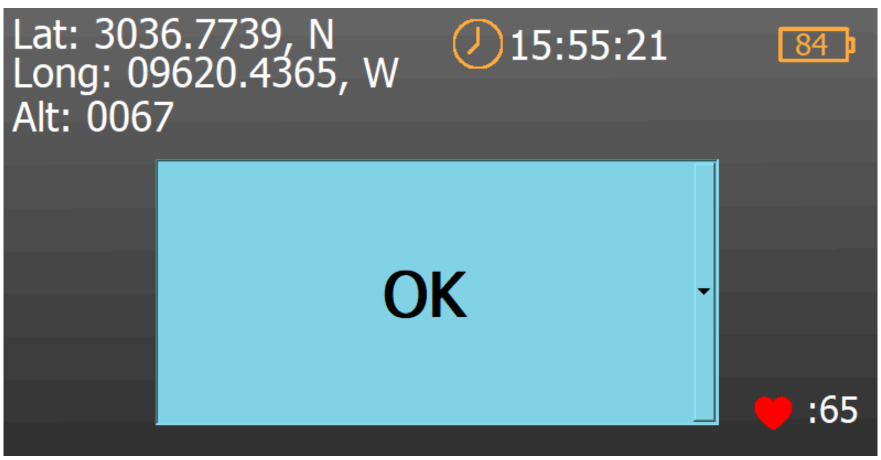



Figure 3. User Interface

# Performance Specifications

This section describes SAFE-T's performance specifications, which are quantifiable, testable, and measurable values that expand upon each functional requirement. Each category matches those mentioned in the previous section: enclosure, power, user interface, command and data handling, and communications.

## Enclosure

The enclosure will have the minimum dimensions of 6.5" x 3.25" x 2.5", in order to account for the components housed inside, which will not be able to dangerously move around when SAFE-T is moved or tilted. The enclosure will have corners with a minimum of 0.05 inch corner radii. The enclosure will protect against damage from particles sized 10 microns and larger.

## Power

The battery powering the system will be 7.4V and internally rechargeable, replaceable, and removable, with a battery life of at least 12 hours. The power switch shall only be easily operable in a shortsleeve environment - that is, not easy to inadvertently be operable in an EVA environment. The system will be able to provide acceptable voltages to components according to their data sheets, such as: 3.3V to the power monitor and buttons, and 5V to the HDMI display, pin header, and GPS receiver. To fulfill the system's power monitoring requirement, SAFE-T will display battery status.

## User Interface

The position, navigation, and time (PNT) information displayed on the device's screen will include latitude, longitude, altitude, and Lunar Standard Time (LST). The messages displayed on screen will be preformatted, and will be 'packaged' with the collected peripheral data (location, heart rate, etc.) to include an indication of the device's emergency mode being triggered. The display will have a luminosity of at least 200 Lumens to ensure readability of the on-screen information. There are a total of four buttons on the device, and each will have a minimum diameter of 0.75 inches, with a same-face separation of a minimum of 1 inch. The emergency button on the device shall be red.

### Command and Data Handling

The system will have a memory storage capacity of 64GB, and operate on a LST clock - which is equivalent to UTC time found in the NMEA messages that the GPS receives from satellites. The device's emergency mode will be triggered either through manual input, or the detection of an abnormal heart rate - for the purposes of this device, a value outside of the nominal range of 60-160bpm.

### Communications

The identifier unique to the beacon is set to be (hex) 07E6 (as per the customer's recommendation). The system will use a GNSS/GPS for PNT information, with processes defined in the Cospas-Sarsat T.018 - Issue 1, Revision 4. PNT information will be sent out once every 15 minutes in nominal mode. While in emergency mode the device will send it out every 15 seconds for the first 30 minutes, and every 60 seconds after the 30 minute mark has been passed without issue. The system will send messages to the Jetson Nano on the Gandalf Staff via the 802.11n network.

## Functional Block Diagram

This section contains a functional block diagram that shows how each component will be connected in the system, as well as a more detailed version showing this same concept pin for pin.

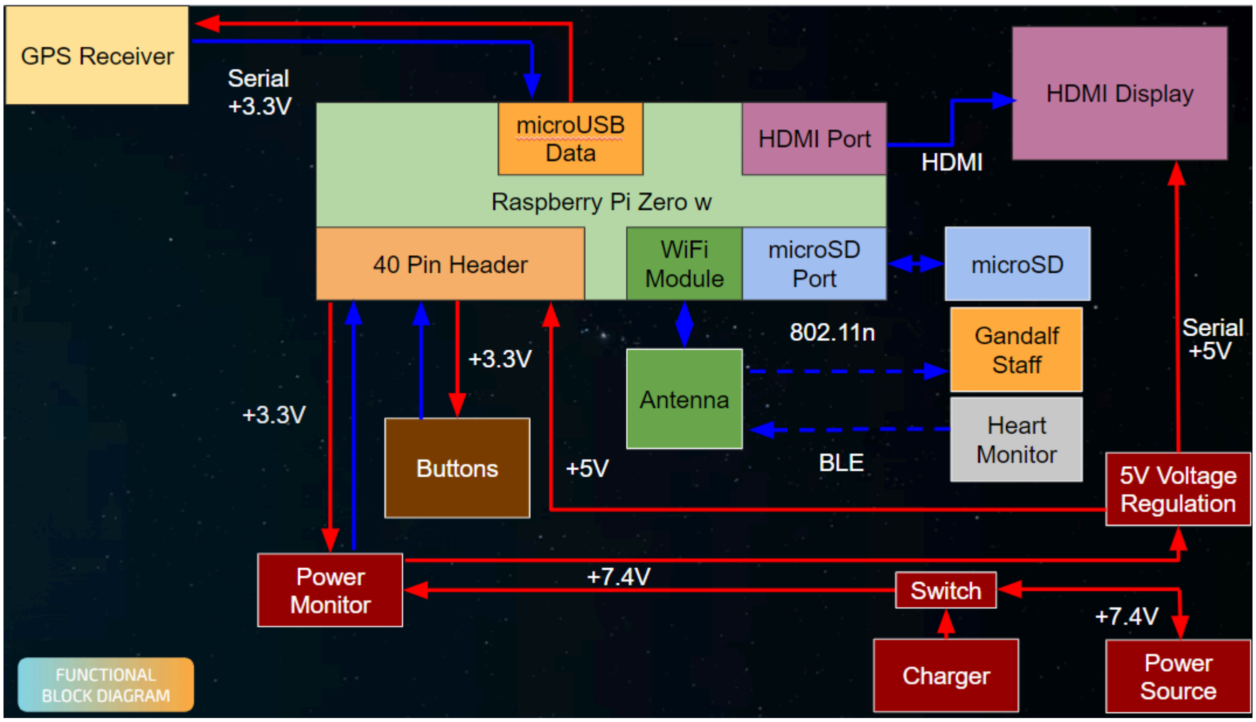



Figure 4. Functional Block Diagram

The battery will be providing 7.4V to the 5V voltage regulator. The Power Monitor will receive its power from the 3.3V pin on the 40-pin header on the Raspberry Pi and be used to monitor the battery. The power monitor will connect through an I2C connection for both the source clock and source data on the 40-pin header. The voltage regulator will provide 5V to the HDMI display and the 5V power pins of the Raspberry Pi. The Raspberry Pi will connect to the GPS module through a micro-usb connection and the display through HDMI connection. An SD card will host the OS system and store the data logs.

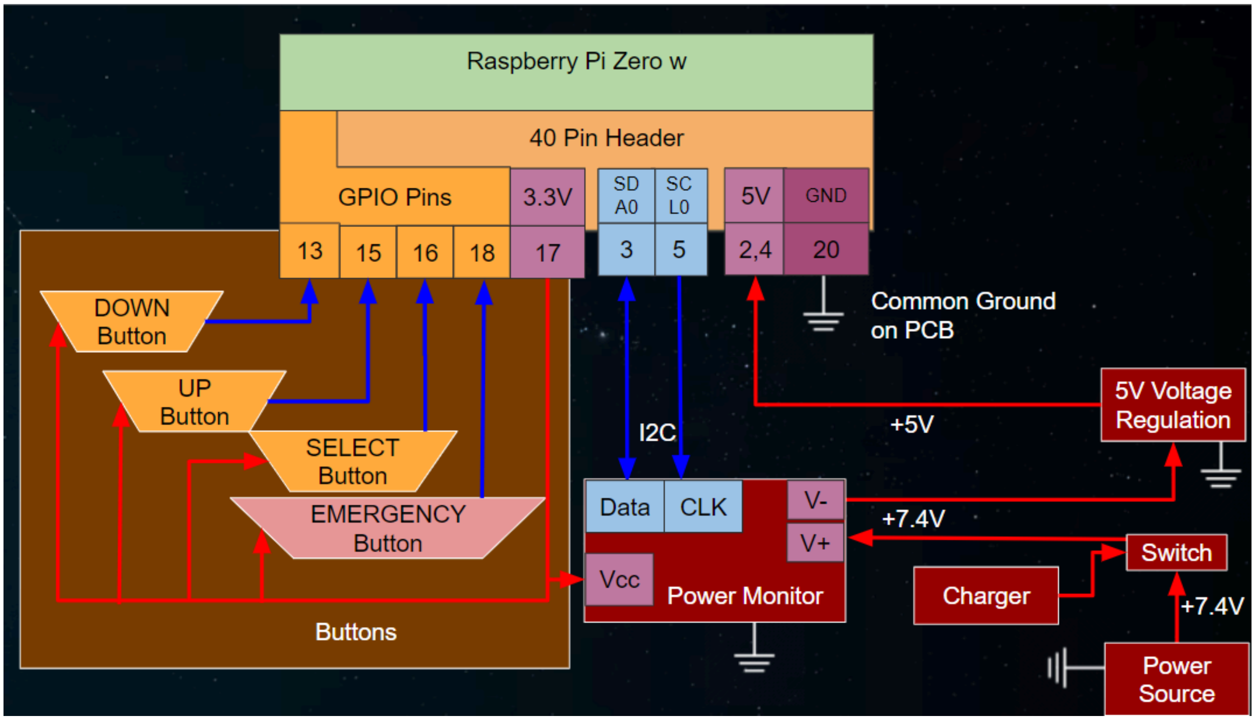



Figure 5. Functional Block Diagram - Pin Diagram

Figure 5 shows a more detailed view of the specific pins being utilized on the Raspberry Pi. The 5V from the voltage regulator connects to pin 2 to provide power to the Raspberry Pi. The power monitor will connect to pin 3 to send source data and pin 5 to send source clock. The “Down” button, “Up” button, “Select” button, and “Emergency” button will be connected to pins 13, 15, 16, and 18 respectively. These buttons will receive 3.3V from pin 17. Everything on the PCB will be commonly ground, pin 20 is an example of the ground pins available on the pin header.

## Alpha Schematic

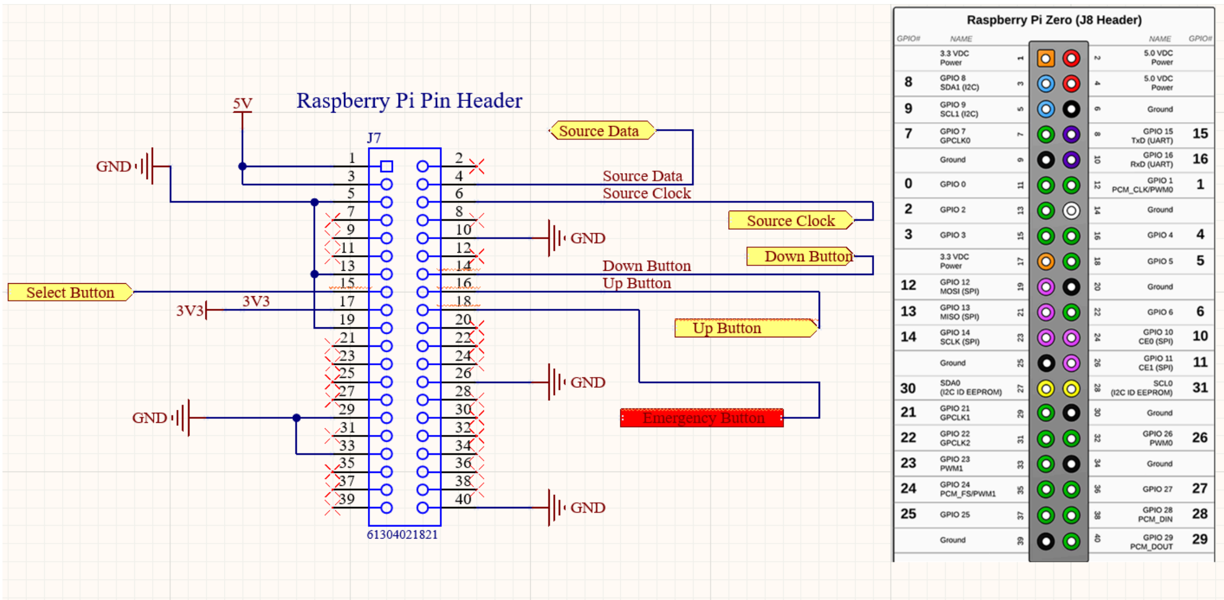



Figure 6. Raspberry Pi Pin Header Schematic

A simple 2 by 20 female pin header connector will be utilized to securely connect to the Raspberry Pi. The 5 volts from the voltage regulator will be applied to pin 1 and 3 on the header thus providing power to pin 2 and 4 on the Raspberry Pi.

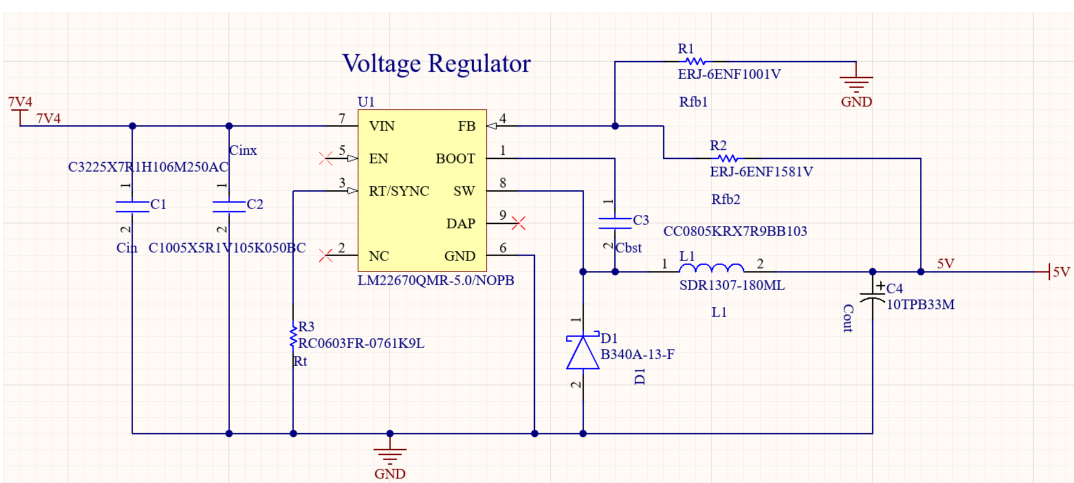
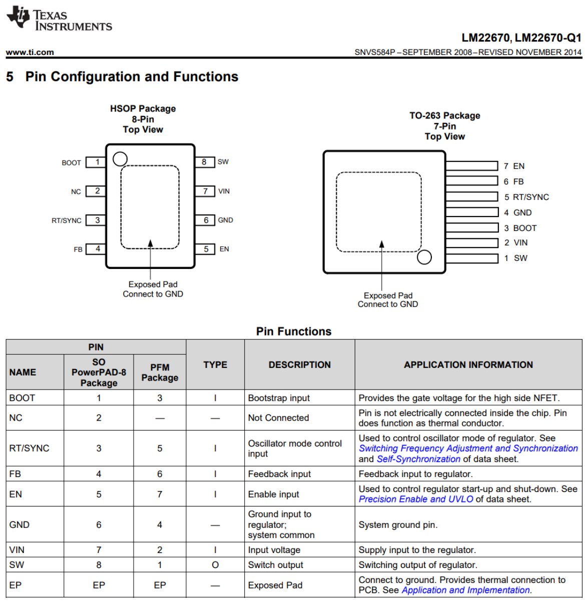



Figure 7. Voltage Regulator Schematic



TEXAS INSTRUMENTS

www.ti.com

LM22670, LM22670-Q1

SNVS584P – SEPTEMBER 2008 – REVISED NOVEMBER 2014

5 Pin Configuration and Functions



Pin Functions

| PIN | | | TYPE | DESCRIPTION | APPLICATION INFORMATION |
|---|---|---|---|---|---|
| NAME | SO PowerPAD-8 Package | PFM Package | | | |
| BOOT | 1 | 3 | I | Bootstrap input | Provides the gate voltage for the high side NFET. |
| NC | 2 | — | — | Not Connected | Pin is not electrically connected inside the chip. Pin does function as thermal conductor. |
| RT/SYNC | 3 | 5 | I | Oscillator mode control input | Used to control oscillator mode of regulator. See *Switching Frequency Adjustment and Synchronization* and *Self-Synchronization* of data sheet. |
| FB | 4 | 6 | I | Feedback input | Feedback input to regulator. |
| EN | 5 | 7 | I | Enable input | Used to control regulator start-up and shut-down. See *Precision Enable and UVLO* of data sheet. |
| GND | 6 | 4 | — | Ground input to regulator; system common | System ground pin. |
| VIN | 7 | 2 | I | Input voltage | Supply input to the regulator. |
| SW | 8 | 1 | O | Switch output | Switching output of regulator. |
| EP | EP | EP | — | Exposed Pad | Connect to ground. Provides thermal connection to PCB. See *Application and Implementation*. |

Figure 8. Voltage Regulator LM22670

The LM22670QMR Voltage regulator (shown in Figure 8) was chosen because it is a simple switch step-down regulator which has a wide input voltage range of 4.5 volts to 42 volts. The LM226700QMR will take the 7.4 volts into pin 7 from the battery and provide 5 volts to the rest of the system.

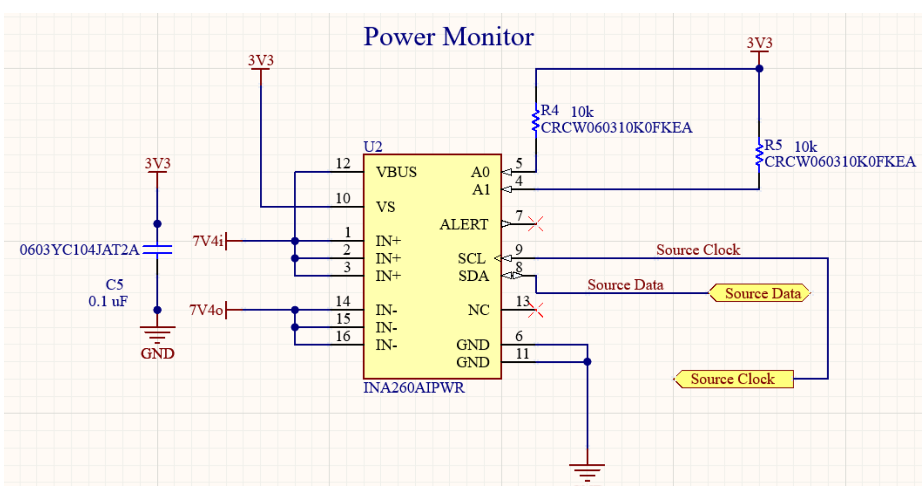


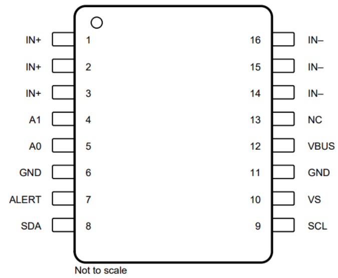

Figure 9. Power Monitor Schematic

INA260
SBOS656C – JULY 2016 – REVISED DECEMBER 2016 www.ti.com

TEXAS INSTRUMENTS

## 6 Pin Configuration and Functions

**PW Package**
**16-Pin TSSOP**
**Top View**




**Pin Functions**

| PIN | | I/O | DESCRIPTION |
|---|---|---|---|
| NAME | NO. | | |
| A0 | 5 | Digital input | Address pin. Connect to GND, SCL, SDA, or VS. Table 2 shows pin settings and corresponding addresses. |
| A1 | 4 | Digital input | Address pin. Connect to GND, SCL, SDA, or VS. Table 2 shows pin settings and corresponding addresses. |
| ALERT | 7 | Digital output | Multi-functional alert, open-drain output. |
| GND | 6, 11 | Analog | Ground pin for both analog and digital circuits. |
| IN+ | 1, 2, 3 | Analog input | Connect to supply for high side current sensing or to load ground for low side sensing. |
| IN– | 14, 15, 16 | Analog input | Connect to load for high side current sensing or to board ground for low side sensing. |
| NC | 13 | — | No internal connection. Can be grounded or left floating. |
| SCL | 9 | Digital input | Serial bus clock line input. |
| SDA | 8 | Digital I/O | Serial bus data line, open-drain input/output. |
| VBUS | 12 | Analog input | Bus voltage monitor input. |
| VS | 10 | Analog | Power supply input, connect a 2.7 V to 5.5 V supply to this pin. |

Figure 10. Power Monitor INA260

The INA260 power monitor is the power monitoring device being utilized to monitor the power consumption of SAFE-T. This will take its voltage from the 3.3 volts on the Raspberry Pi into the Vin pin (pin 10), and monitor the 7.4 volts from the battery subsequently passing on the source clock (pin 9) and source data (pin 8) to pins 3 and 5 on the Raspberry Pi respectively.

As for the GPIO Button connectors research is being done on how to represent the inputs of the buttons on the Altium schematic capture. For testing the board there will be simple two by one pin headers connected to the appropriate pins so that the test engineer can simply access these signals when needed.

## Software

The digital logic controlling the operation of SAFE-T can logically be broken into two parts: one for the general operation of the system, and one for the traversing of the menu and interacting with the mechanical buttons.

For the general operation logic, SAFE-T initializes its home screen display and will try to connect to all of the data-collecting peripherals (heart monitor, GPS, etc.). Once successfully initialized, nominal (normal) mode is entered and a series of checks occur.

In nominal mode SAFE-T awaits its mechanical buttons to be pressed by the user and will log and record any and all data it has at the given 15 minute interval rate (emergency mode differs). This 15 minute period does not 'freeze' the device and prevent any interactions, it just simply denotes that the 'automatic' transmission of messages can only occur at set intervals. This establishes a 'breadcrumb trail' of information that rescue parties can use to search for potentially lost, unconscious, or disabled crew members.

As for emergency mode, SAFE-T will send 'SOS' messages at two specific time intervals depending on the time since activation of emergency mode: once every fifteen seconds during the first thirty minutes of an emergency, and once every minute after the first thirty minutes of an emergency.

During this time, the beacon will still continue to operate in a 'nominal' mode setting, however every communication it makes will have its 'Message Priority' message field set to indicate that emergency mode has been triggered. According to Ataraxia's customer, a method to disable emergency mode manually is not required for such an early-staged prototype.

Figure 11 summarizes the process described above.

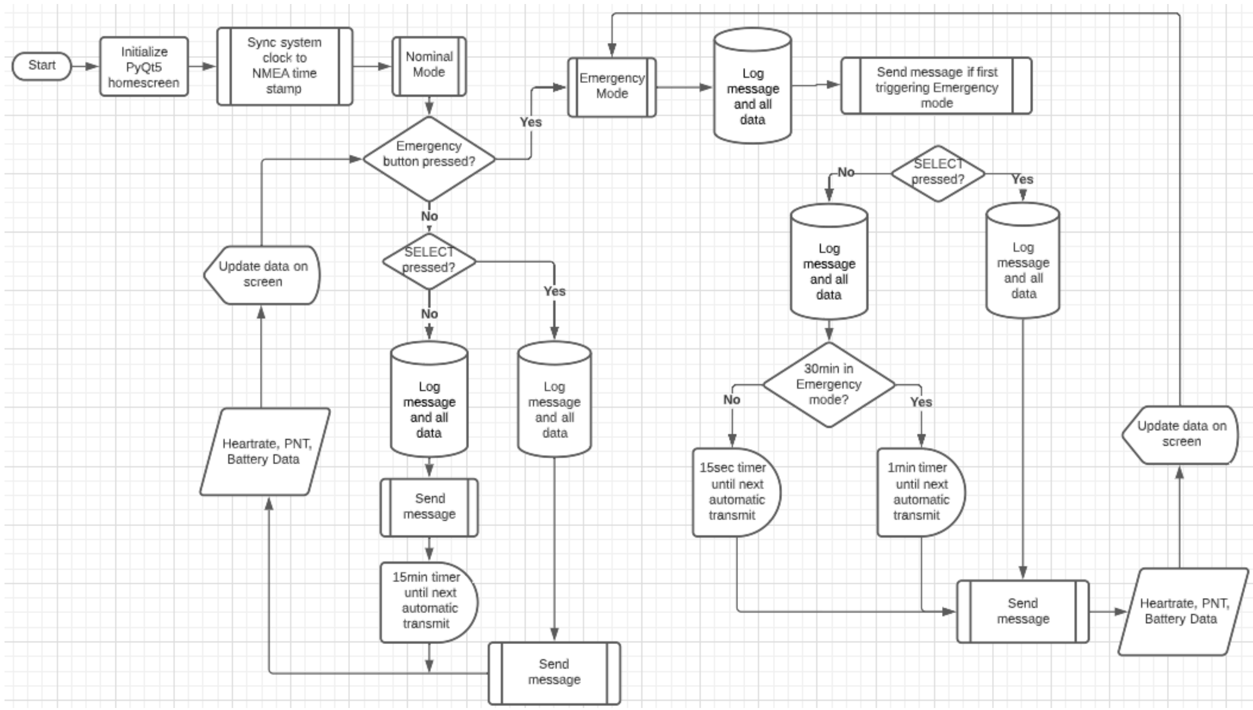



Figure 11. Flowchart - Main Operation

The next portion of the digital logic behind SAFE-T's operation is the logic behind sending messages by interacting with the onscreen menu of preformatted messages, as illustrated in Figure 12.

The currently selected message on the screen is adjusted by the user pressing either the 'up' or 'down' buttons on the front face of the enclosure - which causes an internal variable representing an index to be updated and compared to 'protective logic'. This protective logic prevents the user from accessing the zero-th index (the 'SOS' text), and also prevents the user from accessing indexes that do not exist. The 'SOS' text selection-prevention is different from the idea of preventing 'index errors' of indexes that are too large in the way that the 'SOS' text is in fact accessible, but only when the emergency button is pressed.

Once a message is highlighted/displayed on the screen, a check is made to determine if the 'select' button has been pressed. If the 'select' button is pressed, SAFE-T will log any and all data it has access to and attempt to transmit a message over the 802.11n protocol to a nearby Gandalf Staff. SAFE-T will only transmit messages if the 'select' button is pressed, allowing the user to freely navigate the menu of messages without accidentally sending an erroneous transmission.

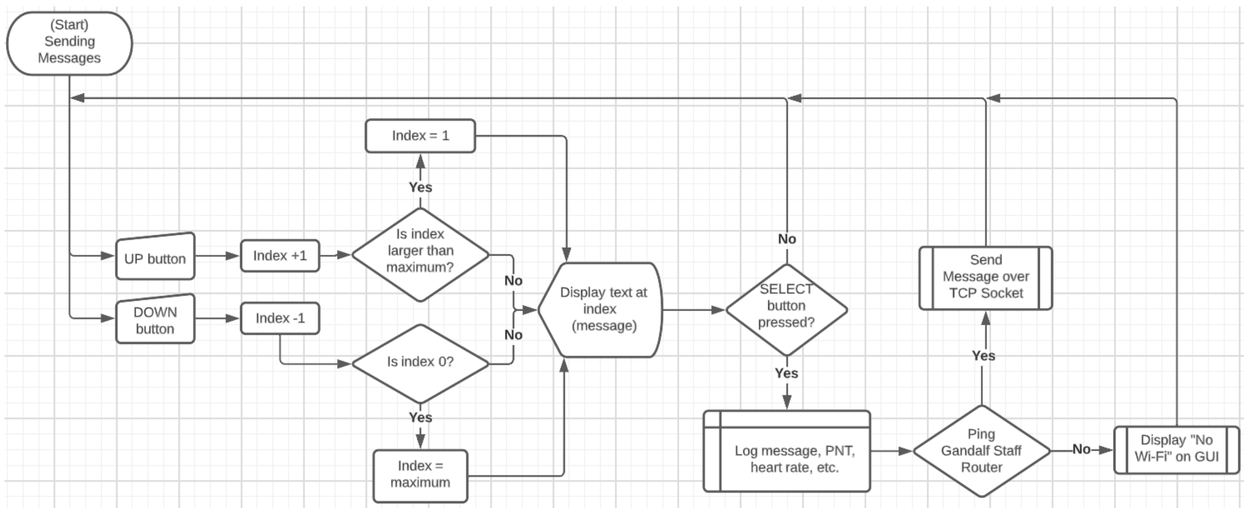



Figure 12. Flowchart - Message Sending

As for the method of SAFE-T internally storing data, it will utilize its onboard microSD card as a file system for not only its OS, but also file I/O and memory. The chosen method of logging data is with a (.csv) file. The file contains a column header indicating various information fields for things such as whether or not emergency mode has been triggered, the time, the message itself, the heart rate, latitude, longitude, etc.. By analyzing these logs, entire treks, missions, and even 'stories' can be inferred from the gathered information, with the following figure as an example of a story. In this scenario (ignoring the artificial heart rate values) an excavation/science crew member acknowledges receiving a message and agrees to stay where they are before attempting to begin their mining work in the lunar south pole region, but they soon send out an SOS message indicating an emergency. From the message log, it is clear and easy to follow that the crew member indicated an emergency due to a suit issue (low pressure) and declared that they were 'on the way' (OTW) back to the lander in order to correct the issue. The (.csv) file's labels and order of data presentation are not finalized, but serve to depict what a fully developed data logging system might look like. (Despite not being finalized, the data collected was generated using currently existing code, with the heart rate, latitude, and longitude values being simulated).

| MsgType | Time | Message | Msg Bits | HeartRt | Lat. | Long. |
|---|---|---|---|---|---|---|
| 1 | 16:57:56 | OK | 0b1 | 70 | 30.618 | -96.336 |
| 1 | 16:57:58 | MSG RECEIVED | 0b11 | 68 | 30.617 | -96.335 |
| 1 | 16:58:00 | STAYING PUT | 0b1011 | 70 | 30.614 | -96.333 |
| 0 | 16:58:03 | SOS | 0b0 | 70 | 30.611 | -96.332 |
| 0 | 16:58:06 | SUIT ISSUE | 0b100 | 67 | 30.613 | -96.333 |
| 0 | 16:58:10 | SUIT PRESS LO | 0b1001 | 69 | 30.614 | -96.334 |
| 0 | 16:58:14 | OTW TO LANDER | 0b1100 | 66 | 30.613 | -96.332 |
| 0 | 16:58:18 | SOS | 0b0 | 70 | 30.612 | -96.336 |

Figure 13. Example Data Log Analysis

*NOTE: The Figure above utilizes an old version of the message logs, but is more 'user friendly' and easier to understand than the official, final rendition.*

## Responsibilities and Schedule

Outlined in this section are the project's Work Breakdown Structure, Responsibility Assignment Matrix, Gantt Chart, and Network Diagram.

## Work Breakdown Structure

Figure 14 depicts the main categories required for the completion of this prototype.

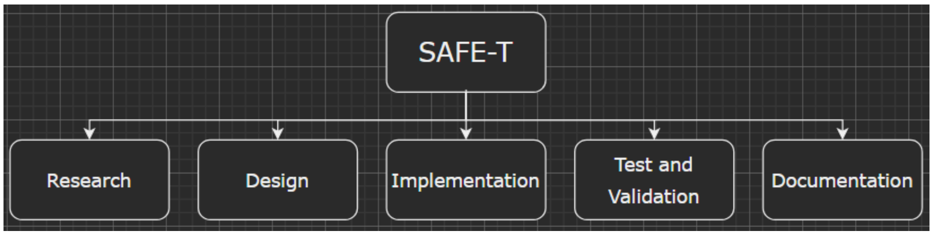



Figure 14. WBS Level 1

The first of the five sub-projects is Research, which is shown in more detail in Figure 15. The research sub-project is divided into four categories: Acquire/Purchase (of components), Software, Hardware, and Network/Integration, with each category housing its respective subjects for team members to look into.

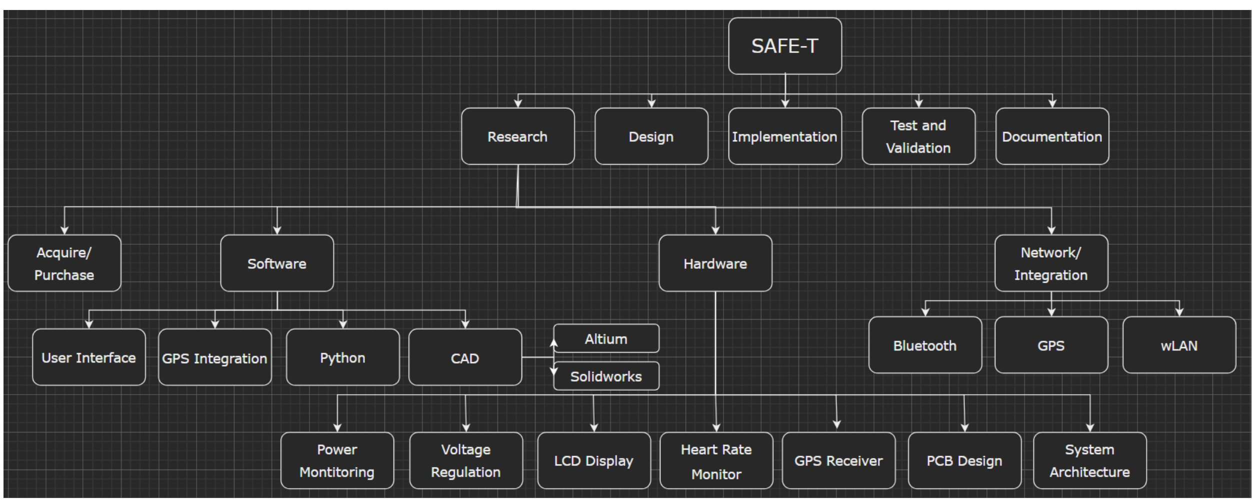



Figure 15. Research Sub-Project

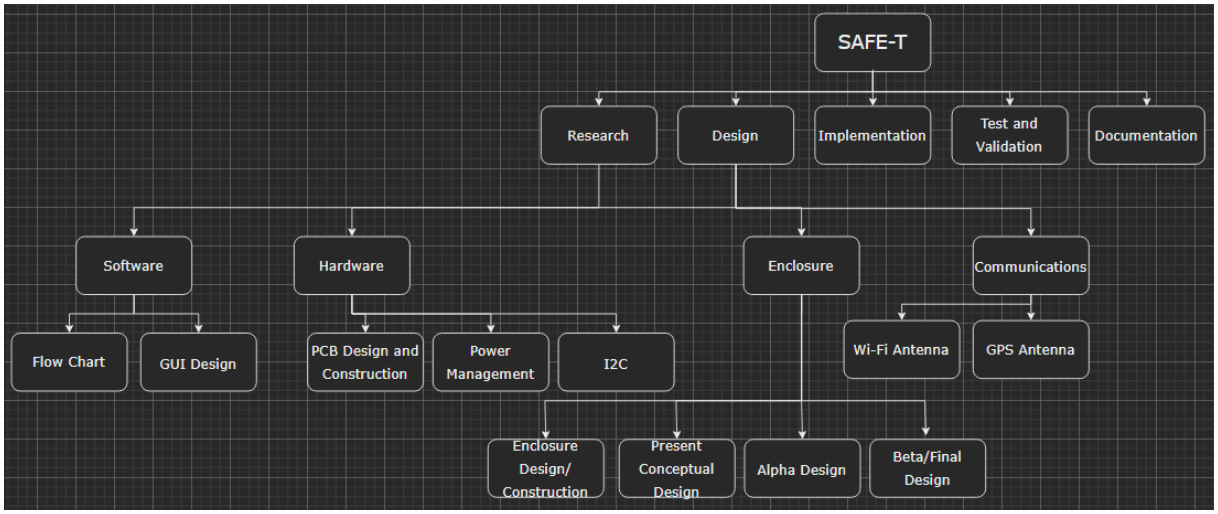



Figure 16. Design Sub-Project

Next is the Design sub-project, which is broken down into four categories: Software, Hardware, Enclosure, and Communications. This section of the WBS is dedicated to all aspects of the device's design - the user interface, the PCB that will contain all components, the enclosure that will house the components, and the communications devices that allow the device to interact with a base station.

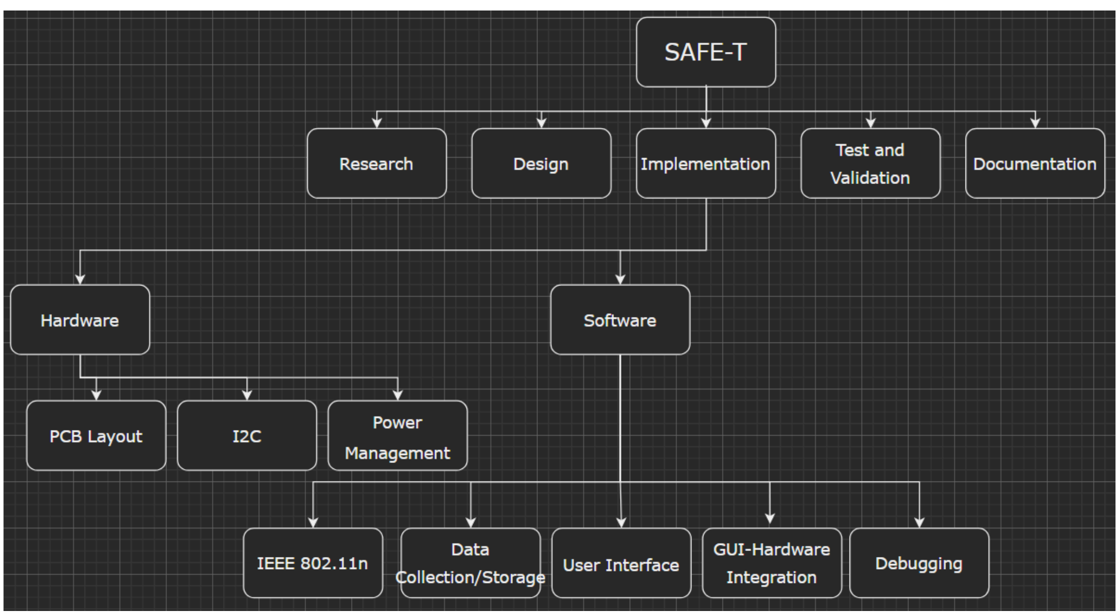



Figure 17. Implementation Sub-Project

The Implementation section of the WBS deals with hardware and software, and the components that make both of these categories up. The software development and integration between the prototype and necessary software make up the bulk of this section, however implementing the correct configuration of hardware and ensuring all connections are stable is just as important.

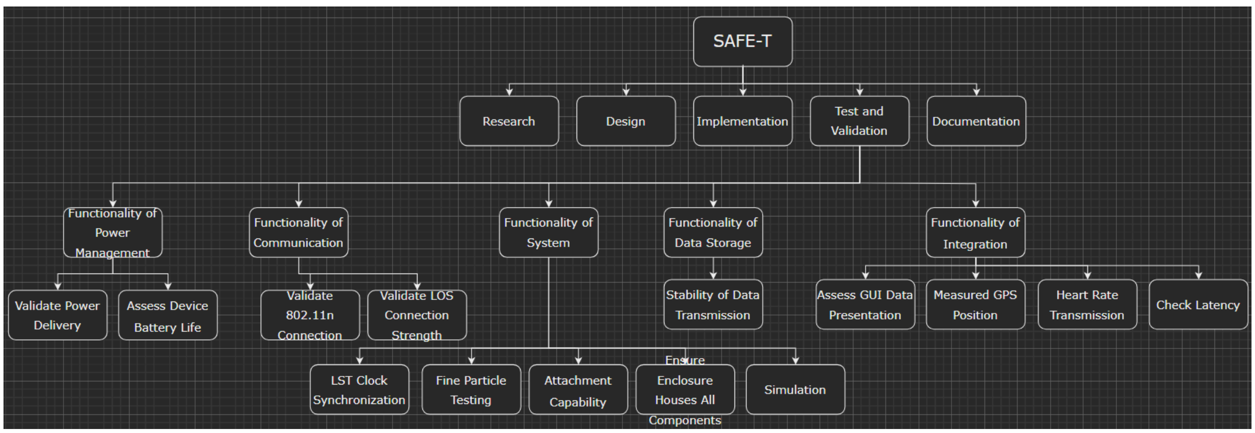



Figure 18. Test and Validation Sub-Project

As shown in Figure 18, after implementation comes the testing and validation period of the project. There are five major categories for the test engineer to validate, beginning with the functionality of the system's power management (ensuring all components receive adequate sources), that enables the whole device to function properly. The time must be correctly synchronized, the enclosure must withstand fine particles and be able to attach to an EVA suit or Gandalf Staff. Next, communication: verifying that the device can communicate with a base station through the Gandalf Staff with the correct environment. The successful integration of components such as GPS and heart rate is also integral to the project, as they are the main pieces in the software development.

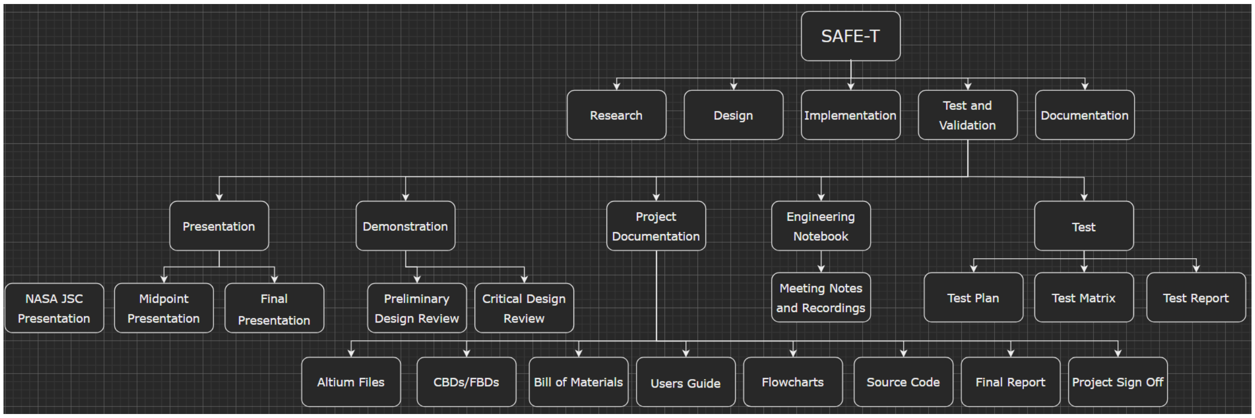



Figure 19. Documentation Sub-Project

The Documentation sub-project closes out the WBS. This section of the WBS will take place over the entire course of the project, start to finish. This includes meetings with advisors, checkpoints, hardware and software documentation, as well as thorough test documentation.

## Responsibility Assignment Matrix

The following figures show the full Assignment Matrix for this project. The matrix illustrates a detailed breakdown of each Ataraxia team member's responsibilities, expanding upon the information shown in the WBS.

The 'p', 'r', and 's' letters beneath each Ataraxia member's name represents their responsibilities for that specific task. The letters indicate which tasks are a member's primary responsibility, secondary responsibility, or responsibility to review, respectively.

| WBS # | Task | Gabrielle | Falak | Peyton | Vatsal |
|---|---|---|---|---|---|
| 1 | Research | | | | |
| 1.1 | Acquire/Purchase | p | r | s | |
| 1.2 | Software | | | | |
| 1.2.1 | User Interface | s | | p | r |
| 1.2.2 | GPS Integration | | r | p | s |
| 1.2.3 | Python | s | | p | r |
| 1.2.4 | CAD | | | | |
| 1.2.4.1 | Altium | s | p | | r |
| 1.2.4.2 | Solidworks | | p | s | r |
| 1.3 | Hardware | | | | |
| 1.3.1 | Power Monitoring | r | p | | s |
| 1.3.2 | Voltage Regulation | r | p | | s |
| 1.3.3 | LCD Display | r | p | s | |
| 1.3.4 | Heart Rate Monitor | r | | p | s |
| 1.3.5 | GPS Receiver | r | | p | s |
| 1.3.6 | PCB Design | s | p | | |
| 1.3.7 | System Architecture | s | p | | |
| 1.4 | Network/Integration | | | | |
| 1.4.1 | Bluetooth | r | | p | s |
| 1.4.2 | GPS | r | | p | s |
| 1.4.3 | wLAN | r | | p | s |

Figure 20. Assignment Matrix - Research

| WBS # | Task | Gabrielle | Falak | Peyton | Vatsal |
|---|---|---|---|---|---|
| 2 | Design | | | | |
| 2.1 | Software | | | | |
| 2.1.1 | Software Flow Chart | s | | p | r |
| 2.1.2 | GUI Design | s | | p | r |
| 2.2 | Hardware | | | | |
| 2.2.1 | PCB Design/Construction | r | p | | s |
| 2.2.2 | Power Management | r | p | | s |
| 2.2.3 | I2C | r | p | | s |
| 2.3 | Enclosure | | | | |
| 2.3.1 | Enclosure Design/Construction | s | p | | r |
| 2.3.2 | Present Conceptual Design | s | p | | r |
| 2.3.3 | Alpha Design | s | p | | r |
| 2.3.4 | Beta/Final Design | s | p | | r |
| 2.4 | Communications | | | | |
| 2.4.1 | Wi-Fi Antenna | | p | s | r |
| 2.4.2 | GPS Antenna | | p | s | r |

Figure 21. Assignment Matrix - Design

| WBS # | Task | Gabrielle | Falak | Peyton | Vatsal |
|---|---|---|---|---|---|
| 3 | Implementation | | | | |
| 3.1 | Hardware | | | | |
| 3.1.1 | PCB Layout | s | p | | r |
| 3.1.2 | I2C | r | p | | s |
| 3.1.3 | Power Management | r | p | | s |
| 3.2 | Software | | | | |
| 3.2.1 | IEEE 802.11n | r | | p | s |
| 3.2.2 | Data Collection/Storage | r | | p | s |
| 3.2.3 | User Interface | s | | p | |
| 3.2.4 | GUI-Hardware Integration | r | s | p | |
| 3.2.5 | Debugging | r | | p | s |

Figure 22. Assignment Matrix - Implementation

| WBS # | Task | Gabrielle | Falak | Peyton | Vatsal |
|---|---|---|---|---|---|
| 4 | Test and Validation | | | | |
| 4.1 | Functionality of Data Storage | | | | |
| 4.1.1 | Review Stability of Data Transmission | r | | s | p |
| 4.2 | Functionality of Power Management | | | | |
| 4.2.1 | Validate Power Delivery | r | s | | p |
| 4.2.2 | Assess Device Battery Life | r | s | | p |
| 4.3 | Functionality of Communication | | | | |
| 4.3.1 | Validate 802.11n Connection | r | | s | p |
| 4.3.2 | Validate LOS Connection Strength | r | s | | p |
| 4.4 | Functionality of System | | | | |
| 4.4.1 | Lunar Standard Clock Synchronization | r | | s | p |
| 4.4.2 | Fine Particle Testing | r | s | | p |
| 4.4.3 | Attachment Capability | r | s | | p |
| 4.4.4 | Ensure Enclosure Houses All Components | r | s | | p |
| 4.4.5 | Simulation | s | | r | p |
| 4.5 | Functionality of GPS, Bluetooth Integration | | | | |
| 4.5.1 | Assess GUI Data Presentation | r | | s | p |
| 4.5.2 | Validate Measured GPS Position | r | | s | p |
| 4.5.3 | Heart Rate Transmission | r | | s | p |
| 4.5.4 | Check Latency | r | | s | p |

Figure 23. Assignment Matrix - Test and Validation

| WBS # | Task | Gabrielle | Falak | Peyton | Vatsal |
|---|---|---|---|---|---|
| 5 | Documentation | | | | |
| 5.1 | Presentation | | | | |
| 5.1.1 | NASA JSC Director Presentation | p | r | r | s |
| 5.1.2 | Midpoint Presentation | p | r | r | s |
| 5.1.3 | Final Presentation | p | r | r | s |
| 5.2 | Demonstration | | | | |
| 5.2.1 | Preliminary Design Review | p | s | r | r |
| 5.2.2 | Critical Design Review | p | s | r | r |
| 5.3 | Project Documentation | | | | |
| 5.3.1 | CBDs/FBDs | p | r | r | s |
| 5.3.2 | Bill of Materials | p | r | r | s |
| 5.3.3 | Users Guide | p | r | r | s |
| 5.3.4 | Program Flowcharts | s | | p | r |
| 5.3.5 | Source Code | s | | p | r |
| 5.3.6 | Altium Files | s | p | | r |
| 5.3.7 | Final Report | p | r | r | s |
| 5.3.8 | Project Sign Off | p | r | r | s |
| 5.4 | Engineering Notebook | | | | |
| 5.4.1 | Meeting Notes/Recordings | p | r | r | s |
| 5.5 | Test | | | | |
| 5.5.1 | Test Plan | s | r | r | p |
| 5.5.2 | Test Matrix | s | r | r | p |
| 5.5.3 | Test Report | s | r | r | p |

Figure 24. Assignment Matrix - Documentation

Figure 25 shows the breakdown of the project - the number of packages per topic and overall, as well as the amount of labor hours going into the entire project.

| Topic | Packages | Hours |
|---|---|---|
| Research | 16 | 158 |
| Design | 11 | 156 |
| Implementation | 8 | 104 |
| Test/Validation | 14 | 178 |
| Documentation | 17 | 330 |
| Total | 66 | 926 |

Figure 25. Work Packages and Hours

| Number of Assigned Work Packages Per Person | | | | |
|---|---|---|---|---|
| | Gabrielle | Falak | Peyton | Vatsal |
| Primary | 12 | 20 | 17 | 17 |
| Secondary | 20 | 9 | 12 | 25 |
| Review | 30 | 14 | 15 | 18 |
| Total | 62 | 43 | 44 | 60 |
| **Total Hours Per Person** | | | | |
| Hours | 251.46 | 191.4 | 161.04 | 260.7 |

Figure 26. Work Packages and Hours Per Person

Lastly, Figure 26 shows the amount of work packages and hours expected of each Ataraxia team member. As of the publication of this document, the expected total working hours is 864.6.

## Gantt Chart

Figure 27 illustrates the project's planned schedule for the duration of the 2021-2022 academic year.

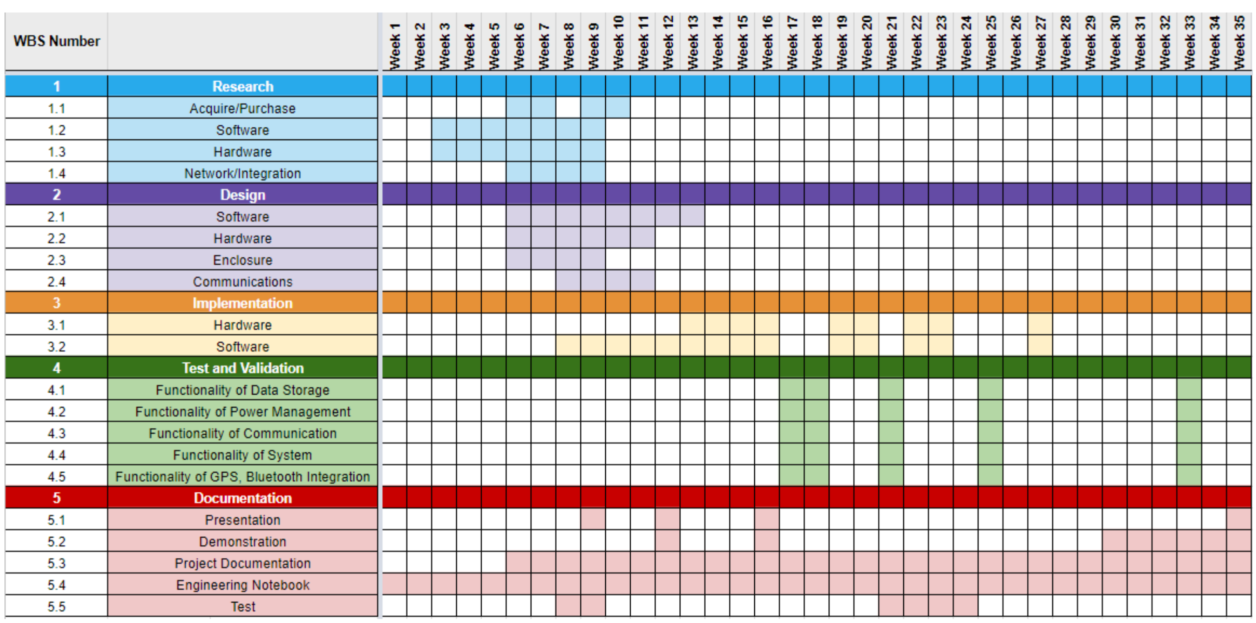



Figure 27. Gantt Chart for Fall 2021 - Spring 2022

The Gantt Chart establishes the general idea and timeframe of how each section of the WBS will be completed throughout the academic year.

## Network Diagram

The figure below shows the Network Diagram in its entirety, with a given key for each phase. The main takeaway is observing the critical path (red line).

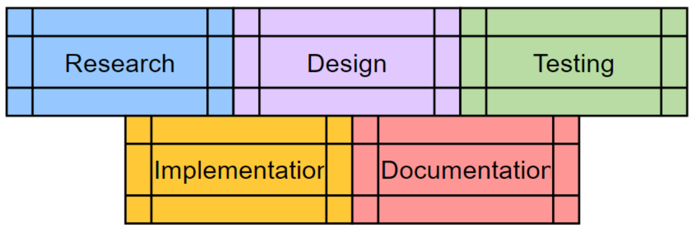



Figure 28. Network Diagram Key

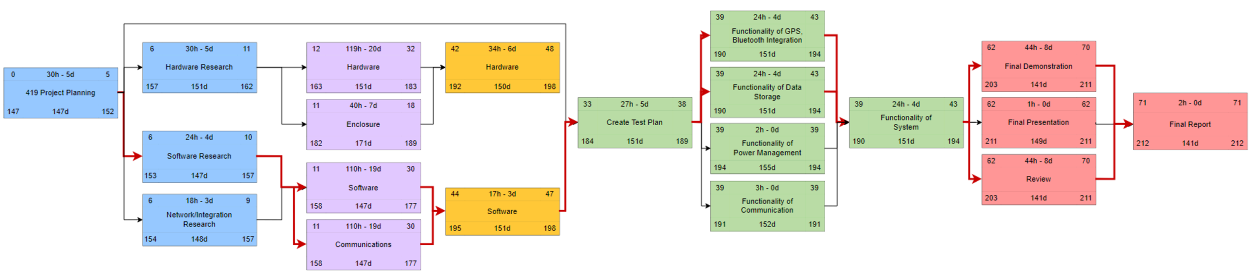



Figure 29. Network Diagram

There are five distinct phases of the Network Diagram - research, design, implementation, testing, and documentation. They should look familiar, as the project schedule is structured around these categories (also seen in WBS and Gantt Chart). The diagram begins with the essential research, moves into the design process of necessary subjects of each research category, and then sees the implementation take place in both the hardware and software of the device. After a test plan is drafted, the testing phase begins, involving all necessary components needed to fulfill the project's functional requirements. Concluding the diagram is the documentation phase, which includes the final presentation, demonstration, and report.

## Risk Response Plan and Risk Assessment Matrix

The Risk Assessment Matrix below depicts the major risks of the project, and expands upon the likelihood and impact of each one.

| Ataraxia Risk Matrix | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Risk #** | **Risk** | **Impact** | **Likelihood of Occurrence** | **Degree of Impact** | **Action on Trigger** | **Responsibility** | **Response Plan** |
| 1 | Project will go over budget | System will lack necessary components | M | M | Bill of Materials exceeds budget at any time | Gabrielle | Request additional finances from customer |
| 2 | Project will go over schedule | Ataraxia cannot deliver the prototype in time for deadline or graduation | L | H | SAFE-T is not complete by the 35th week | Gabrielle | Ensure team is on track with all work packages, re-assign responsibilities as needed |
| 3 | Increase in project scope | Project will require more direct cost/labor hours or time to complete | M | H | Customer or technical advisor changes scope | Gabrielle | Work with advisors and customer to ensure project scope is clearly defined |
| 4 | Customized software has integration problem | System not working, no information recorded or transmitted | L | H | System is unable to receive or send information | Peyton | Develop system with compatible programming |
| 5 | TSTAR does not deliver or create a Lunar Standard Time | Beacon will be unable to use the customer's requested time | L | M | TSTAR is unable to create LST | Peyton | Work with advisors and customer to determine a different clock for the device |
| 6 | TSTAR cannot create a compatible 802.11n network | Beacon will be unable to connect to the Gandalf Staff | L | M | TSTAR is unable to develop 802.11n for the project | Peyton | Work with advisors and customer to determine an alternate connection to the Gandalf Staff |
| 7 | Unexpected delays in shipping | Components will be received behind schedule | H | M | Shipping company experiences delays | Gabrielle | Order parts from reliable vendors and place orders ahead of schedule |
| 8 | Performance Specification is not met during Test & Validation phase | Ataraxia will not live up to specifications declared in the project proposal | L | H | Test fails during Test and Validation phase | Vatsal | Validate components as they are received and construct a thorough test plan |
| 9 | PCB Hardware Failure | New board will need to be ordered | M | M | PCB fails during preliminary testing | Falak | Order a replacement board |
| 10 | Loss of team member or technical advisor | Schedule will be delayed | L | H | Notice by said member of advisor of absence | Gabrielle | Re-assign responsiblities to remain on schedule |

Table 1. Risk Assessment Matrix

The risks with the highest degree of impact are whether the project goes over schedule or increases in scope, as well as if the customized software has integration problems with components. The risk with the greatest importance is whether the prototype meets all functional requirements by the specified end date of the project, so as to not disappoint customers as well as be able to have contributed to the progress of safe lunar exploration. Many risks associated with the completion of the project are easily fixable, as the team is dedicated to ensuring the prototype functions as promised. The Raspberry Pi Zero W, which is one of the main components being used for the development of SAFE-T, is a very flexible device for whatever idea a user has to program it. It has various solutions for connectivity and programming, and because the PCB will be custom-made by Ataraxia's hardware engineer, the risks should still be considered, but should not be a huge concern.

The issues out of Ataraxia's hands are whether T STAR can create a Lunar Standard Time and compatible 802.11n network for the device, however if either of these situations occur, there are alternatives - such as connecting the device to wi-fi, or using another time zone associated with lunar events.

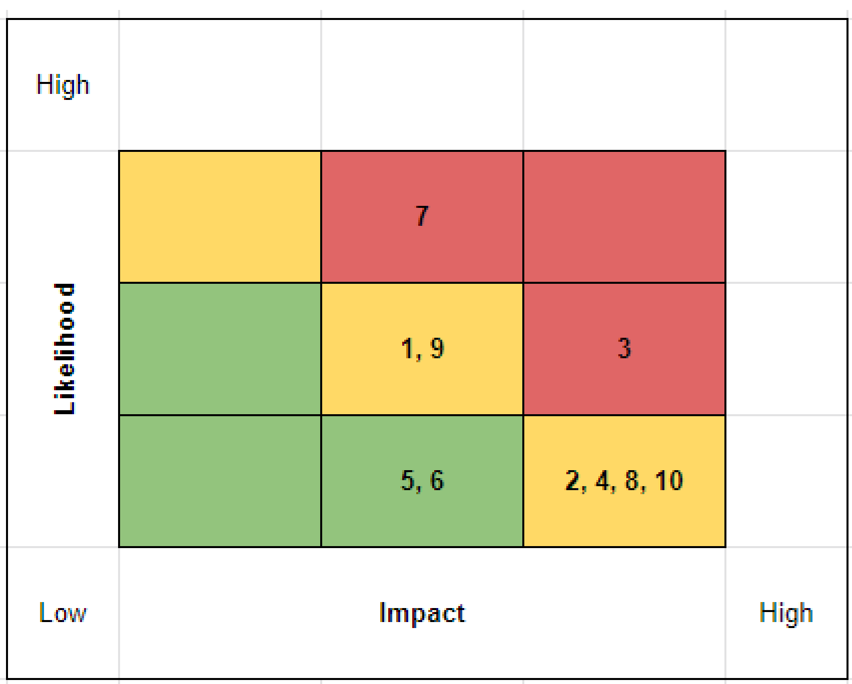



Figure 30. Graphical Risk Matrix

The graphical risk matrix shown above illustrates the likelihood and impact of each risk shown in Figure 30.

# Test Matrix

| Functional requirement→<br>Test↓ | Power Management | GPS Position Accuracy | 802.11n Connection | EVA-Operable capability | Bluetooth Integration | Real-Time Data Acquisition | Fine Particle Durability |
|---|---|---|---|---|---|---|---|
| Battery outputs 7.4V | | | | | | | |
| 5V Voltage Regulator | | | | | | | |
| Simulate Irregular Heart Rate | | | | | | | |
| Use device for 12 hour period | | | | | | | |
| Place talcum powder on device | | | | | | | |
| Handle device with EVA glove | | | | | | | |
| Walk around with GPS | | | | | | | |
| Send message to Gandalf Staff | | | | | | | |

Table 2. Test Matrix

Testing of individual components, as well as hardware and software systems as a whole, is essential in order to have a working system. The testing process determines how effective our hardware and software integration is. Ataraxia will do a series of electrical tests on each component to check the component's power data and operation. Furthermore, the construction of our own power management system via our PCB must function perfectly in order for the entire system to be precisely verified.

## Power Management

Testing the power management will verify that the SAFE-T device has the ability to monitor and control power to individual components in the enclosure. In order to conduct this test, a power budget will be set up to regulate the maximum power each component pulls from the battery. By employing a single sub-experiment, Ataraxia will be able to establish that the SAFE-T device is correctly regulating and controlling the power that it is drawing.

### 802.11n Network

Testing the network will verify that the 802.11n protocol, implemented in the SAFE-T device, has the ability to communicate with the Gandalf Staff wirelessly. This test will be conducted by using a TCP connection to ensure that any dropped packages trigger the entire message to be resent. If the data is not transferred correctly the test will fail. It is important to verify that the beacon is receiving data from the base station.

### PCB

The printed circuit board (PCB) will go through alpha, beta, and final testing in order to gather data on how efficient the PCB is. This test will also assist in pinpointing areas of improvement. By using the power of Webench, multimeter and providing power to the board, the test will ensure each pin receives the right voltage. Test voltage at each point will be taken from the GPIO buttons and voltage regulator. It is important to ensure that the GPIO (general purpose input/output) pins are receiving 3.3 V from the raspberry pi. The voltage regulator needs to be tested to ensure that it is pulling 7.4 V and discharging 5V. The PCB is the system's heart, supplying the electricity required for each component's proper operation. These tests have been implemented to the design of the circuit board to increase the chances of success.

### Bluetooth Integration

Testing the connection and strength of the bluetooth integration will verify the ability for the SAFE-T device to communicate and obtain data from the H10 heart rate monitor. This test will be conducted by using multiple bluetooth signal strength meter applications on an android device (connected to SAFE-T) to determine the devices signal range and strength. Successful Transmission of data from the heart rate monitor to the bluetooth module will pass the test.

## GPS

The capacity for the user to find the SAFE-T gadget at any moment is a crucial feature of the concept. The Adafruit Ultimate GPS module will be tested for the ability to output accurate NMEA data to the Raspberry Pi. Conducting the test will require bringing out the SAFE-T device out onto a field during a clear starry night and cross referencing the outputted longitude and latitude data with the true positioning of the device.

## EVA Operable Capability

Testing the ability to operate the SAFE-T device with an EVA glove will require administering a physical inspection of all functions on the device with an EVA glove on. Mr. Cody Kelly, the deputy of national affairs within NASA's search and rescue mission once, will be providing Ataraxia with an EVA glove from a previous Apollo mission in order to conduct this physical test. It is important to ensure that in this test the user will be able grip the device comfortably, press all buttons, and clip the carabiner while wearing an EVA suit.

## Fine Particle Durability

Fine particle durability can be tested through the process of placing talcum powder on the device. The enclosure is required to protect against damage from particles sized 10 microns and larger, which means these particles should not get through to the housed components. The beacon should be able to operate correctly even if the enclosure comes in contact with these particles. This test will be considered successful if after the powder comes in contact with the enclosure, and is then removed, that the device is still functioning properly.

## Broader Impact and Technical Contribution

The successful creation of this novel device, SAFE-T, will provide a method of automated cislunar and lunar distress tracking and notification, something that is currently lacking in lunar search and rescue operations. The device will be able to transmit its PNT data (such as latitude, longitude, and the time of said events), as well as read a simulated heart rate to determine whether or not its emergency mode should be activated. SAFE-T will also be able to send and receive messages with a base station through a Gandalf Staff. This prototype will be invaluable to NASA when the Artemis missions begin, as well as other space agencies that have any interest in procuring safe lunar exploration.

As it stands, the device could be commercialized due to the fact that the prototype is able to work on Earth as well as the moon (to the best of its abilities), while it will be further developed for the lunar surface specifically after completion. However, because the prototype is meant for space exploration, interested parties would most likely be majority government agencies and space-related companies.

The device will be in high demand, given that it provides a key element of safe lunar search and rescue operations, which will become more popular the closer NASA gets to launching the Artemis missions in 2024.

# Costing

The table below shows the costs of some materials shown in the conceptual block diagram and functional block diagram. The rest of the bill of materials can be found within the Ataraxia Google Drive in the 'Project Documentation' folder - otherwise including it in this report would take multiple pages and be largely incoherent as a result. As of 1/May/2022 the cost spent over the duration of the project is $1,866.67, leaving the team $633.33 under budget.

| Item | Quantity | Unit Price | Price |
|---|---|---|---|
| HDMI 5" 800x480 Display Backpack - With Resistive Touchscreen | 1 | $74.95 | **$74.95** |
| Raspberry Pi Zero WH (Zero W with Headers) | 2 | $14.00 | **$28.00** |
| iKits Short Micro USB Cable Nylon Braided High Speed Durable Sync and Charge Cord Compatible with 4K TV Sticks, S7, HTC, LG. | 2 | $9.99 | **$19.98** |
| CableCreation 2-Pack Micro USB Male to Male OTG Cable Compatible with DJI Spark and Mavic, PS4, Android Phone and Ta | 2 | $9.99 | **$19.98** |
| Duttek Mini HDMI to Standard HDMI Cable, HDMI to Mini HDMI Cable, Ultra-Thin UP Angled 90 Degree Mini HDMI Male to HDMI M | 2 | $12.58 | **$25.16** |
| SanDisk 64GB ULTRA microSDXC Card Class 10 (SDSDQUA-064G-A11A) | 2 | $11.20 | **$22.40** |
| Adafruit Ultimate GPS with USB - 66 channel w/10 Hz updates | 2 | $29.95 | **$59.90** |
| 2.4GHz Mini Flexible WiFi Antenna with uFL Connector - 100mm | 4 | $2.50 | **$10.00** |
| Highfine 2 x 2.4GHz 6dBi Indoor Omni-Directional WiFi Antenna 802.11n/b/g RP-SMA Female Connector | 1 | $8.59 | **$8.59** |
| uxcell GPS Active Antenna 90-Degree SMA Male Plug 28dB Aerial Connector Cable Magnetic Mount 0.1 Meter | 1 | $11.49 | **$11.49** |
| DZS Elec 2pcs RG316 Wire Jumper 15cm SMA Male to SMA Male with Connecting Line RF Coaxial Coax Cable Antenna Extender | 1 | $7.49 | **$7.49** |
| POLAR H10 Heart Rate Monitor Chest Strap - ANT + Bluetooth | 1 | $79.90 | **$79.90** |
| uFL SMT Antenna Connector | 4 | $0.75 | **$3.00** |
| CR1220 12mm Diameter - 3V Lithium Coin Cell Battery - CR1220 | 4 | $0.95 | **$3.80** |
| SMA to uFL/u.FL/IPX/IPEX RF Adapter Cable | 2 | $3.95 | **$7.90** |

Table 3. Parts list

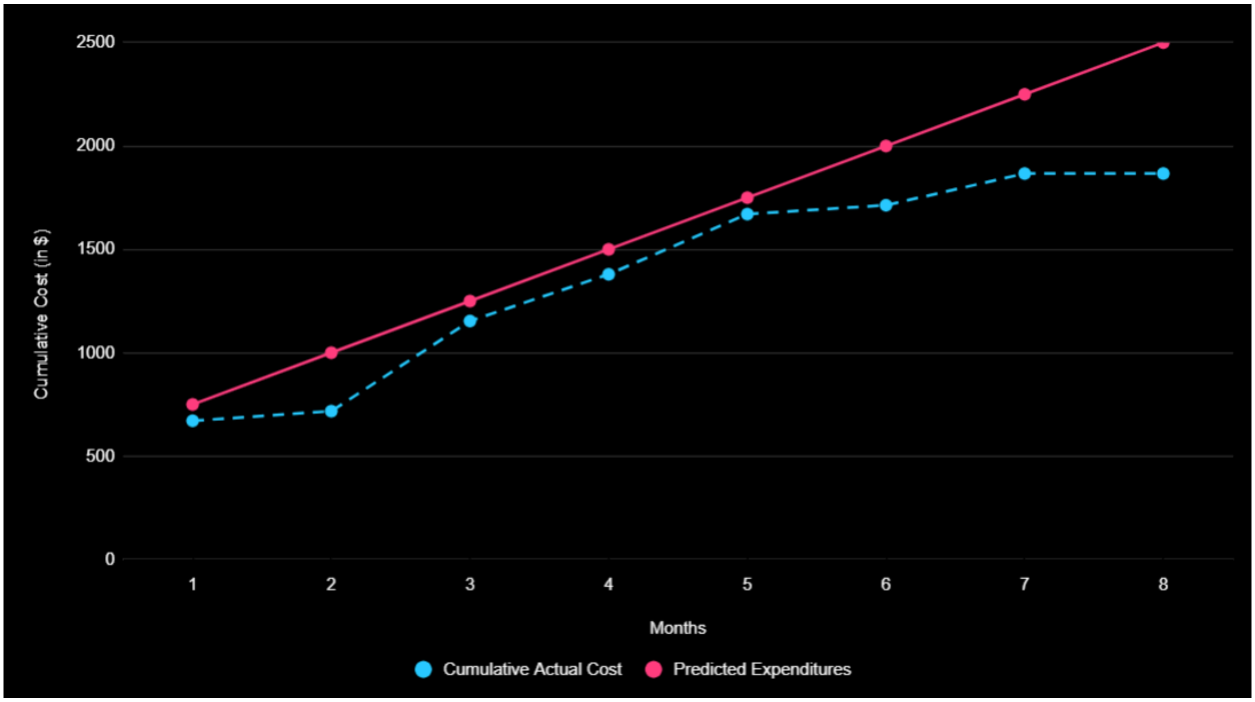



Figure 31. Cumulative vs. Budgeted Cost (in $)

The figure above illustrates the cumulative actual cost versus the predicted expenditures, with accurate spending up to November. The rest of the cumulative actual cost is an estimate based on how development has gone so far.

Overall, the estimated unit cost of the device is **$500-$650,** with around **$1,500-1,800** leftover to cover unexpected costs. The total estimated development cost of the prototype will be **$1,900-$2,300.** These values differ from the actual unit costs for a SAFE-T unit - which is estimated at roughly $425 for a single unit. The unit cost of SAFE-T's decreases when creating multiple units, and the unit cost for constructing four SAFE-T's is roughly $380.

## Conclusion

Ataraxia will use incorporated hardware, software, and mechanical solutions to deliver a prototype for the wireless local area network (wLAN) portion of a beacon that will assist Lunar Search and Rescue operations. The successful completion of this project will represent an important milestone for safe cislunar and lunar exploration. As a handheld beacon, SAFE-T will be able to attach to an EVA suit or Gandalf Staff, as well as be able to last for the duration of a standard lunar trek. The device will be capable of automated tracking of position, navigation, and time (PNT) data, notification of said data, and communication between the device and a base station. A user's heart rate will be recorded and monitored for any abnormalities, and the device will have an emergency mode triggerable via manual input or the detection of an abnormal heart rate. Given that NASA plans to return to the moon in 2024, having a functioning device to further lunar search and rescue operations will be crucial for the future of space exploration.