Handheld Rocket Tracker
Group #16 Project Proposal

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Introduction:

Problem:

For rocket platforms of any size, recovery is a major issue. With the amount of physical hardware costs typically involved with a rocket, recovery and reuse of these resources is an ever increasingly important task. Therefore, systems are needed to be able to recover a rocket. Two cases arise. One, when the rocket is fully intact and can be directly reused. Two, when the rocket suffers a catastrophic failure. Here, some system of tracking the major components is needed so engineering teams can retrieve the surviving physical components to analyze in order to pinpoint the error that occurred to cause the failure.

This isn't a new issue in amateur rocketry, and many solutions have already been developed to address this problem. Radio beacons, altimeters, and similar handheld devices have been created, however they all suffer from being clunky, unintuitive, or expensive. Affordable solutions such as radio beacons don't send out their exact location, and are tracked by following the strength of their signal [1], which only gives the general direction of the beacon. Altimeters send out their exact location, but are costly ($380+) and often require a laptop to receive their position [2], which is inconvenient to carry during a search. A few handheld trackers exist, however they are costly ($475+), difficult to reconfigure, and unintuitive [3].

Solution:

Our system aims to tackle several of the issues with current trackers on the market. We'll be implementing a 2-part tracking system consisting of a tracking beacon ("beacon"), which will be placed on the rocket, as well as a handheld tracking device ("tracker"). The beacon will transmit its GPS location to the handheld tracker. Once received, the tracker will compare its current location with the beacon's transmission, and guide the user towards the beacon. This will be done by displaying a compass needle, which points in the direction of the rocket. Ideally, this solution will be more intuitive, more affordable, and more enjoyable to use.

High Level Requirements:

1. Successfully transmit positional and state data from the beacon to the handheld tracker, and handheld tracker should successfully transmit commands to the handheld beach.
2. The user should be able to switch the frequency of both the beacon and the handheld tracker via the handheld tracker device.
3. Accurately show the distance from the beacon within 5 meters, and point the user in the correct direction of the beacon within 2 degrees. This information should be shown via the screen in the User Interface, and behave similar to a compass, however pointing towards the beacon instead of pointing North.

Visual Aid:

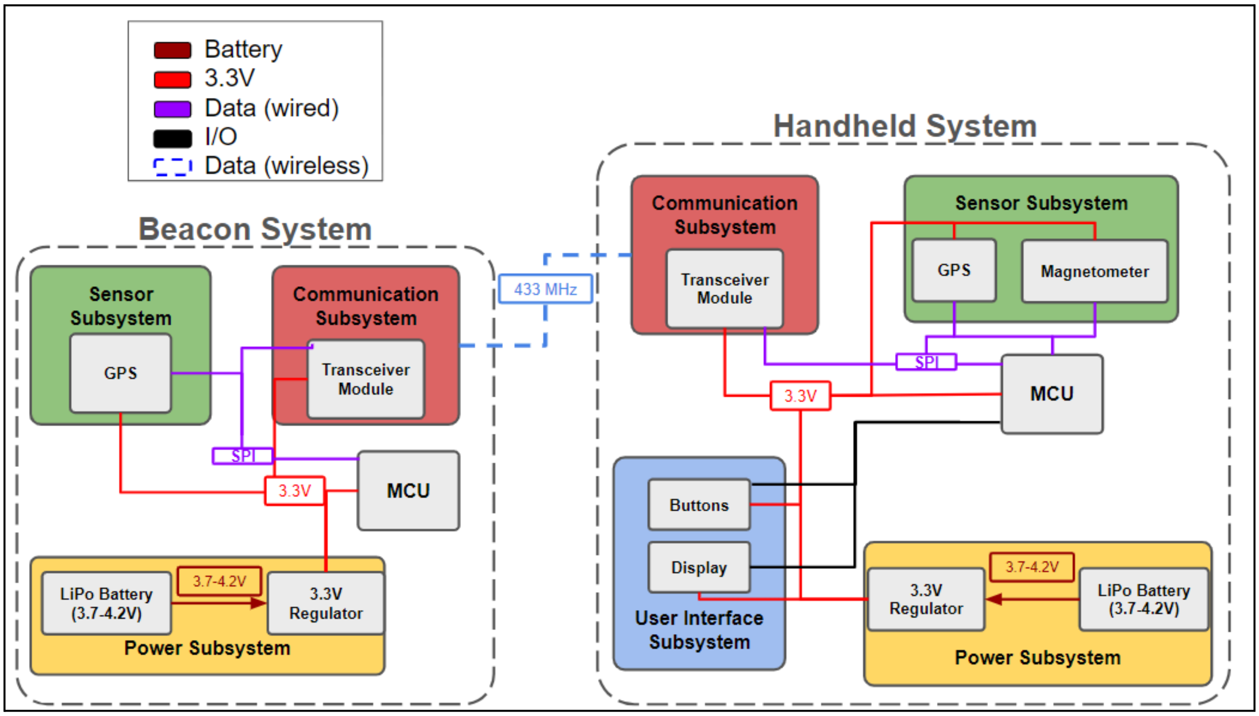

Figure 1: Block Diagram

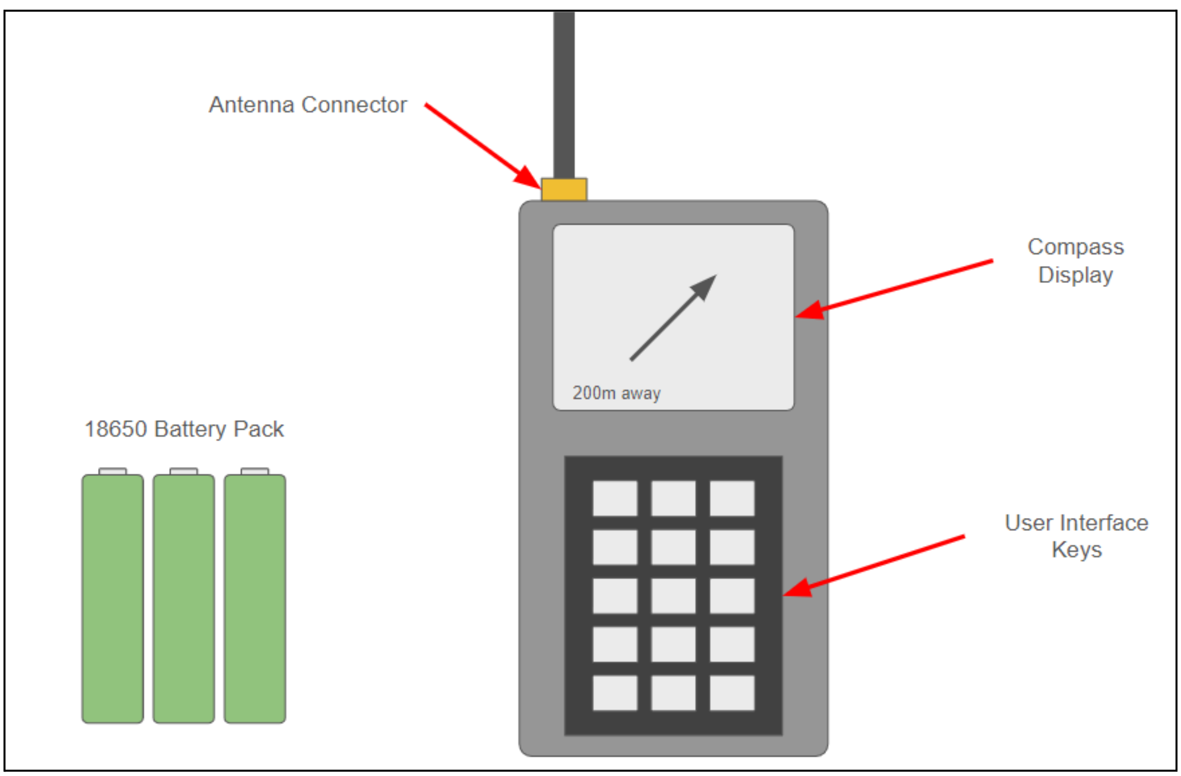

Figure 2: Handheld Tracker Concept Design

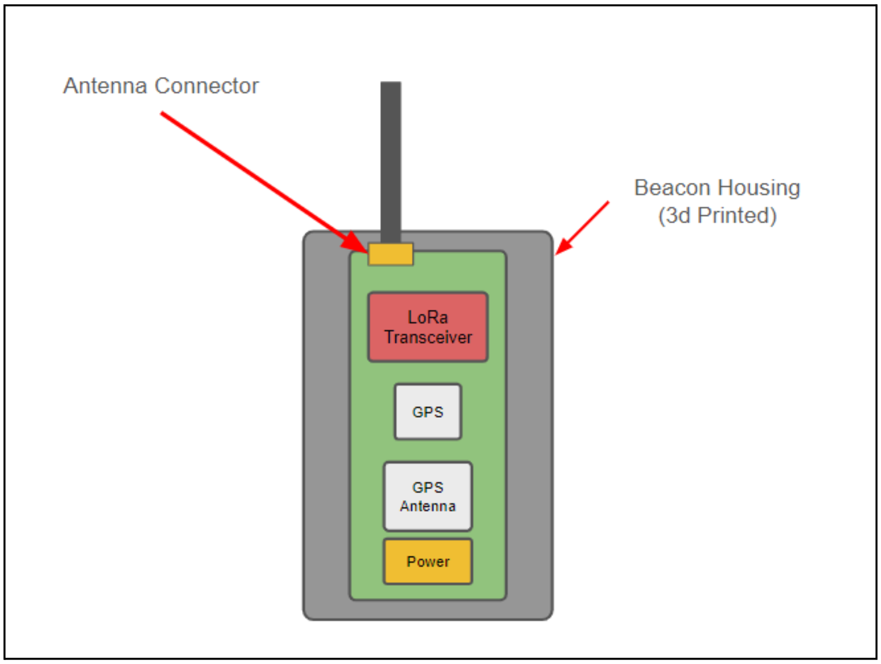

Figure 3: Beacon Concept Design

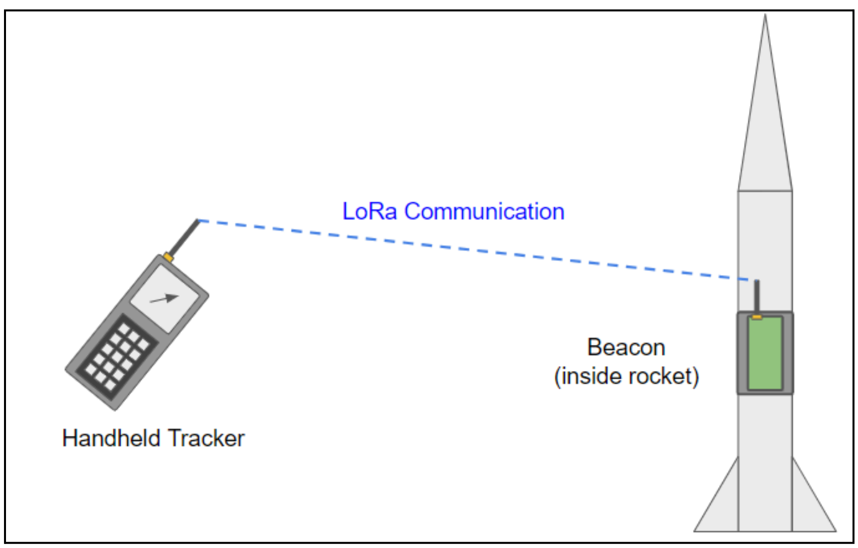

Figure 4: General Overview Diagram

Design:

MCU:

We'll be using an Atmega2560 at the center of this project. The MCU will connect to the sensors and transmitter over I2C, and general IO for the user interface (buttons and display). On the beacon side, the MCU will receive positional data from the GPS, and transmit it to the tracker. The tracker will compare its own location & heading (see Sensor Subsystem (tracker)) to the received beacon location, and calculate the distance & direction from the user. It will tell the display (User Interface) which direction to point the arrow to guide the user to the beacon.

Requirements:

- The MCU must successfully receive positional and directional heading data via I2C from the Sensor Subsystem.
- Upon user input, both the tracker and beacon must be able to change to the desired frequency (complying with LoRa spec of 433.05MHz - 434.79MHz).
- The User Interface Subsystem must display accurate heading and distance to guide the user to the beacon. Accuracy must be within 10-15 meters (accuracy of GPS readings), and the arrow must point within 5 degrees of actual heading.

Communication Subsystem (both devices):

Both the beacon and the tracker will have 433Mhz LoRa transmitters. Range varies with antenna, so field testing will be required to determine the exact range of our device. These will receive data over the I2C bus from the MCU, and transmit to/from each device. The beacon will transmit data packets containing its GPS location, which will be received by the tracker. If the user wants to change frequencies, the tracker will send a data packet containing the desired frequency to the beacon, and both devices will switch to said frequency. Confirmation packets will be sent from each device to confirm a successful switch.

Requirements:

- Antennas used should be capable of transmitting at 433 MHz.
- Antennas should be capable of transmitting over a minimum range of 0.5 miles (or available space on UIUC campus quad). Maximum range of transmission would need to be obtained via field testing.

Power Subsystem (both devices):

The Power Subsystem is slightly different for the two devices. We have chosen to power the two of them to be powered by 18650 batteries. The 18650 batteries were chosen for their rechargeability and ease of access to us. The tracker, which has higher power consumption (due to the screen) will have 2-3 18650 batteries in parallel. The beacon on the other hand will only have 1-2 of these batteries. These batteries would be fed into a 3.3 V linear voltage regulator, which is sent to the rest of the system.

Requirements:

- The Power Delivery Subsystem must take a variable input (3.7V-4.2V) from the LiPo battery pack and consistently regulate down to 3.3V. This 3.3V must be sent out to all corresponding electronics, including everything in the Sensor, Communication, and User Interface subsystems.
- The power supply for the two of these systems would be fed into a 3.3 V linear voltage regulator. The regulator would need to be operable between −55°C and +150°C, as to not trigger thermal shutdown [5].

User Interface (tracker):

The user will directly interact with 2 main components on the tracker: the visual display and the input keys. The visual display will be used to display a "compass", which points in the direction of the beacon's location, as well as the beacon's distance from the user. The input keys will be used to navigate a basic menu on the display (compass display, or frequency change). The user may change the frequency by entering the desired channel on the keys.

Requirements:

- The User Interface Subsystem must display accurate heading and distance to guide the user to the beacon. Accuracy must be within 10-15 meters (accuracy of GPS readings), and the arrow must point within 5 degrees of actual heading.
- When pressed, the input keys should generate interrupts and control the user-interface accordingly

Sensor Subsystem (tracker):

The tracker has a GPS module and a magnetometer. The GPS module requires its own antenna for communicating with satellites (for receiving location). Location calculations are all handled inside the GPS module. The magnetometer will be used to determine the heading (cardinal directions) of the user. When the device is held with the back parallel to the ground (like how you would hold a compass), the magnetometer will be able to read the magnetic field of the earth (knowing which direction is North). The GPS location and heading of the user will be sent to the MCU via the I2C bus. Combining this data with the received GPS location from the beacon will allow us to find the beacon in reference to the user's location & heading.

The beacon only has a GPS module. The GPS module requires its own antenna for communicating with satellites (for receiving location). Location calculations are all handled inside the GPS module. This data is sent to the MCU via the I2C bus.

Requirements:

- The sensor subsystem should be able to get accurate GPS coordinates within 5 meters, and heading accuracy within 2°.

Tolerance Analysis:

A main area of risk within this project is the proper function of the RF components. Specifically the proper communication of the transmitters/GPS. The range and accuracy are paramount. This fact will be discussed further under ethics contexts. The Adafruit transceiver datasheet currently lists 12 miles and 1 mile of range based on attached antenna and wire [4]. This component should therefore give us the range of signal transmission we need to establish connections for locating the rocket or debris. Beyond the transceiver we also have a need for reliable GPS and antennas. For the SAM-M8Q Sparkfun GPS we are currently considering 2.5m Horizontal Accuracy, with 26s cold first fix time [6]. These datasheet stats show that the system should be able to locate the rocket or debris fairly accurately with short connection time when first activated. These times and ranges will be tested extensively when the system is built to verify the datasheet claims.

These datasheet values, if accurate, show that we should be able to build an accurate and reliable tracking system. The GPS's built in antenna and magnetometer give it extra reliability as student work connecting these components will not risk connection breakdown over wire or circuit board.

Another main area of risk is the voltage regulator. As we require all major components to operate at 3.3V, failure of the regulator, in this case our chosen buck converter, will result in a total failure of the overall system. Thus, reliability is paramount. Power dissipation of the converter can first be found by the following equation.

$$P_d = i_{out} * (V_{in} - V_{out})$$

Here our output current is equal to roughly 125mA at minimum and up to 600 mA at maximum based on converter datasheet specs [8]. Our desired output voltage is 3.3V. Our input voltage could be between 3.5V to 4.2V. This results in a minimum power dissipation of 0.025W with min voltage difference and min current draw, and a maximum of 0.54W with max voltage difference and max current draw.

$$\mathrm{T_j} = \mathrm{i_{out}}(\mathrm{v_{in}} - \mathrm{v_{out}})(\Theta_{\mathrm{jc}} + \Theta_{\mathrm{ca}}) + \mathrm{T_a}$$

Furthermore, we can use the above equation to estimate junction temperature. From the buck converter datasheet, junction to ambient thermal resistance is listed as 130 Celsius/Watt [8].

$$\theta_{jc} + \theta_{ca} = 130$$

At 60 celsius ambient temperature, the junction temperature would rise to 63.25 Celsius at minimum and 130.2 Celsius at maximum temperature.

$$63.25C = 0.0025W * 130C/W + 60C$$
$$130.2C = 0.54W * 130C/W + 60C$$

We should not reach much more operating current than what is minimally required. Estimating a twice than needed current draw of roughly 250mA, we get power dissipation of at most 0.225W with 4.2 to 3.3 volt drop. Using this we find we have a junction temperature of 89.25 Celsius at 60 Celcius ambient. This represents a temperature rise of only 29.25C in an extreme environment given what we can assume to be an above average current draw.

$$89.25C = 0.225W * 130C/W + 60C$$

The datasheet also states the converter is 500 mW draw at ambient 60 celsius. This is a temperature near the high end of typical environments. Given this information, we can see that the buck converter can handle most high ambient heat environments as well as significant current draw from the actual board. It is not, however, impervious. Significant current draw or ambient heat can cause damage to the buck convertor. Thus design choices within the rest of the board must be monitored for minimizing current draw when possible to lighten power dissipation on the buck converter.

Ethics and Safety:

Our project aims to improve on the affordability and usability of current trackers on the market. Our project operates on 433 MHz, which is used by many household devices. Hence, by testing our project in open fields, we wish to minimize the amount of interference caused, which falls under IEEE's Code of Ethics Section 1.1 by aiming to " hold paramount safety, health, welfare of the public" [7].

Furthermore, other ethical and safety issues with this system come primarily with the tracking portion of our project itself. It could be potentially used for malicious purposes by certain people. We do not advocate for the misuse of our project's tracking capabilities. By ensuring that our tracker requires a line of sight between the tracker and the beacon, along with a minimal mile radius requirement to operate the software, we aim to minimize the potential malpractices that our project can be used for. This falls under IEEE's Code of Ethics Section 1.1 by aiming "to strive to comply with ethical design and sustainable development practices, to protect the privacy of others, and to disclose promptly factors that might endanger the public or the environment" [7].

References

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[2] I. Apogee Components, "Rocket locators : Apogee rockets, model rocketry excitement starts here," Model Rockets & How-To Rocketry Information, https://www.apogeerockets.com/Electronics_Payloads/Rocket_Locators (accessed Feb. 8, 2024).

[3] I. Apogee Components, "Rocket locators : Apogee rockets, model rocketry excitement starts here," Model Rockets & How-To Rocketry Information, https://www.apogeerockets.com/Electronics_Payloads/Rocket_Locators (accessed Feb. 8, 2024).

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[6] M. #167436, Greggler, M. #873985, and M. #985133, "SparkFun GPS breakout - chip antenna, Sam-M8Q (Qwiic)," GPS-15210 - SparkFun Electronics, https://www.sparkfun.com/products/15210 (accessed Feb. 8, 2024).

[7] IEEE, "IEEE Code of Ethics," *ieee.org*, Jun. 2020. https://www.ieee.org/about/corporate/governance/p7-8.html (accessed Feb. 8, 2024).

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