Senior Design Project:
Notre Dame Rocketry Club Deployable Rover
High Level Design

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1. Introduction

This team will participate in the NASA student launch program, which is a multidisciplinary research-based competition. Students participating in the launch program design a rocket with several payloads to achieve objectives that are set forth by NASA. This year, NASA allowed the groups to choose between one of three payloads: target detection, which involved differentiating between three targets of different color; a deployable rover, which involved remotely deploying a rover from the body of the rocket that would move autonomously until it reached a point that was at least five feet from any part of the rocket; the final option was reaching landing coordinates via triangulation, in which teams would design an optical range finding system to determine the landing coordinates within a grid. The rocket team determined that the scoring payload for this year's team would be the deployable rover. The senior design team's main goal is to design the electrical systems for this rover, in addition to designing the ground station that the rocket team would use to communicate pertinent flight information with the rocket.

2. Problem Statement and Proposed Solution

The requirements provided by NASA for the deployable rover determined the problem description for this project. First, the rover must be a custom design that will deploy from the internal structure of the launch vehicle. Second, the rover must be deployed from the rocket using a trigger that is remotely activated by the team upon the rocket's landing. Third, the rover must autonomously move at least 5 feet in any direction from the launch vehicle once it has been deployed. Finally, the rover must deploy a set of foldable solar cell panels once it has reached its final destination.

The rover will be deployed from the rocket using black powder to eject the nose cone and then retracting the studs that hold the rover in place. This will be accomplished using the LoRA modem network to remotely deploy the rocket and set the nose cone charge. The rover will then read the Bluetooth beacons in each of the sections of the rocket to ascertain its exact position relative to the rest of the rocket. It will move autonomously using the LiDAR sensor for object avoidance. The solar cells will be deployable using a servo motor controlled by the PIC microcontroller, The servo will operate a rack-and pinion system, which will extend a post on either side of the rocket, expanding the folded solar panel array.

3. System Requirements

Control Requirements

The embedded intelligence must be capable of providing navigation and object avoidance for the rover. It must also be able to communicate the rover's location and the rocket's flight trajectory information to a base station. Finally, it must be able to determine when the rover is at least five feet away from the rocket and then deploy the folding solar panels.

Power Requirements:

The Power Control System is the subsystem that powers the rover. It needs to provide enough voltage and current to drive the four motors and the microcontroller. The motors selected have a max voltage rating of 8 V. The microcontroller requires a voltage between 3.3 and 5 V. All the sensors used have similar voltage ranges. The LiDAR sensor requires 5 V, the Gyroscope and Accelerometer needs between 1.9 to 3.6 V, the GPS module requires 3.3 V, the Altimeter needs between 1.6 and 3.6 V, and the LoRa requires 3.3 V. Ideally, the battery should be able to power the rover for several hours so that multiple recharges are not necessary.

In addition to supplying the necessary power, this subsystem also has to fit other design requirements such as size, weight, durability, and safety. The system should also be transportable, so batteries are an obvious choice. The battery system should be compact, lightweight, and robust enough to withstand vibrations and pressure from the rocket launch.

The batteries tentatively selected are IMREN batteries that are based on IMR chemistry. IMREN batteries come in many voltage and amp-hour options that seem to satisfy the power and voltage needs for the rover. They are also cheap, lightweight, and have excellent reviews. However, more testing needs to be done before the battery selection is finalized.

Mechanical Requirements:

The rover's weight and size requirements come from the team designing the rocket since the rover has to interface with the payload compartment. The weight limit tentatively allotted for the rover is 7 lb. The rover must also fit within the payload compartment of the rocket, which is a tube 7 inches in diameter and 11 inches long. The track system design concept for securing the rover is depicted in Figure 1 below.

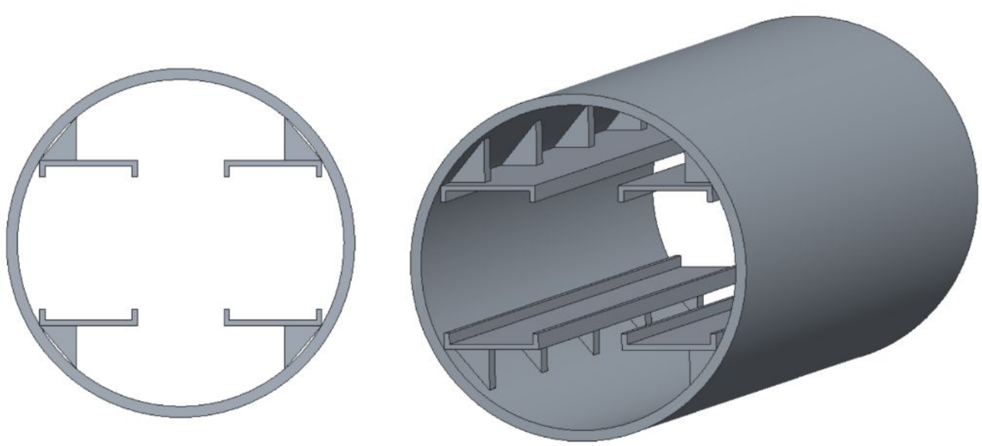

Fig 1. A CAD model of the track system design concept for securing the rover to the rocket.

User Interface Requirements:
The main user interface is with the ground station. The ground station needs to provide easy access to the rocket's current flight trajectory as well as the location and status of the rover.

4. System Block Diagram

4.1 Overall System

Figure 2 below shows a block diagram of the overall system. The arrows indicate the direction of communication between interacting systems.

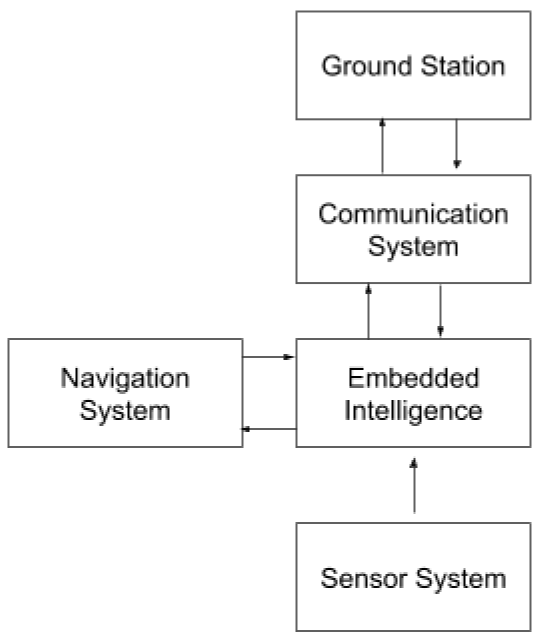

Fig 2. The overall system block diagram

4.2 Subsystem and Interface Requirements

Sensor System Requirements
The orientation of the rover needs to be determined upon landing. A gyroscope will be used for this. The height of the rocket needs to be determined in real time. This will be done with an altimeter. All the sensors used must be physically robust enough to withstand the vibrations and stress from the launch and landing.

Navigation System Requirements
The navigation system needs to include object avoidance in order to avoid both obstacles native to the environment as well as other parts of the rocket. The LiDAR will be used for object avoidance. Bluetooth modules will be used as beacons in the main sections of the rocket so that the rover can move away from the sections of the rocket.

Embedded Intelligence Requirements
The PIC32 microcontroller is the heart of the embedded intelligence system. The software for the PIC must be robust. The microcontroller will interface with all the other subsystems. For navigation, it will take the information from the LiDAR sensor to compute the direction that the rover must travel in order to avoid obstacles. The microcontroller will also use the Bluetooth beacons in the rocket to determine the location of the rocket parts in order for the rover to move farther away from the rocket parts. The microcontroller will interface with the LoRa module to communicate with the base station.

The diagram shown in Figure 3 below depicts how the microcontroller will interface with the sensors. The arrows indicate the direction of communication.

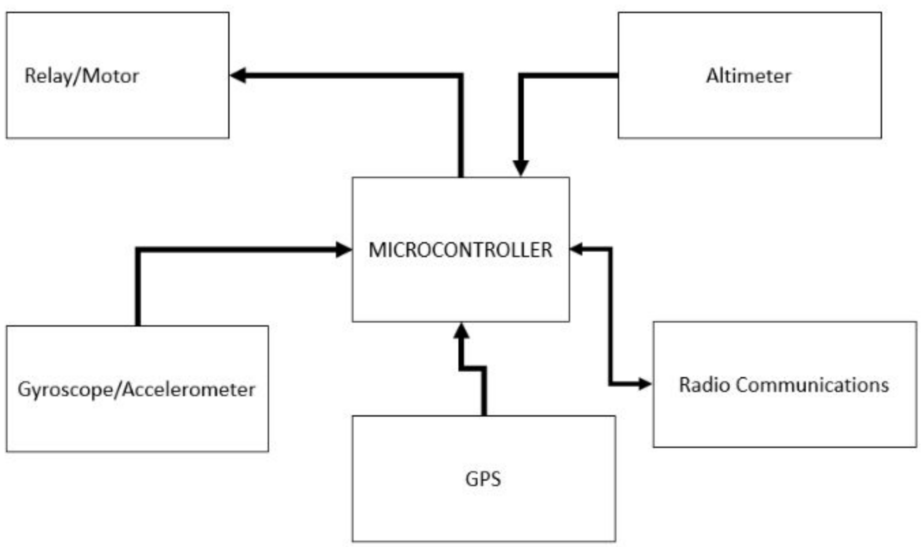

Fig 3. Block diagram for the Embedded Intelligence Subsystem

Communication System Requirements
The communication system must transmit information between the microcontroller on the rover and the base station. The communication system has to be robust in handling interference since various other teams will also be using similar frequencies for communication.

4.3 Future Enhancement Requirements

The initial release of our product is the only foreseeable release. Therefore, all of the requirements specified by NASA must be met in the first version. However, for pedagogical reasons, it might be interesting to equip the rover with a camera and transmit images to the base station. This would mimic the functionality found on existing rovers and make the rover more useful for scientific endeavors. A future design might also take care to see that the deployable solar panels are large enough to power the rover fully. This would make the rover entirely self-sufficient on foreign terrain.

5. High Level Design Decisions

Table 1. Justification for High Level Design Decisions Regarding System Requirements

Requirement	Part Name	Justification
Gyroscope	GYROSCOPE/ACCELEROMETER LSM9DS1	Capable of withstanding the acceleration based on last year’s flight profile
Altimeter	Altimeter 1 MPL3115A2	Capable of measuring expected altitude
LiDAR	LIDAR-LITE V3	Easy I2C interface, small and lightweight
Bluetooth	JDY-08 BLE Bluetooth	Easily configurable and default usage is for bluetooth beacons. It is also one of the cheapest options available.
Microcontroller	PIC32 MX795	Has the necessary number of pins needed to interface with all sensors. Large program memory.
Radio communication	RN2903_LORA_MODULE	Chirp Spread Spectrum technology makes it robust against interference. Encoding process gives it over air resiliency.
GPS	FGPMMOPA6H GPS Standalone Module	Low power, small size, and is actually available.
Power	IMREN batteries	Cheap, small, lightweight, durable, many options

6. Open Questions

The following are some open questions regarding the current design. These and other questions that arise will be investigated before committing to a low level design.

- Will the LiDAR work for object avoidance as anticipated?
- Will the Bluetooth beacons emit a strong enough signal for location triangulation?
- Will the batteries chosen be enough to adequately power the rover?
- What are some challenges associated with integrating the electronics into the body of the rover?
- How much protection do the PCB boards require from the stress of launch and landing?

7. Major Component Costs

The following table is a list of all parts we plan to order and the corresponding component and total cost. This tables does not include the cost of printing the board. Nor does it include the cost of the body of the rover.

Table 2. Cost of Major Electronic Parts

Part Description	Source/ Supplier	Part Number	Qty	Cost/piece	Total Cost
FGPMMOPA6H GPS Standalone Module	Adafruit	790	1	$29.950	$29.95
903 MHz SMA Connector Edge	Adafruit	1865	3	$2.500	$7.50
LIDAR-LITE V3	Digikey	1568-1437-ND	1	$150.000	$150.00
Multiplexor	Digikey	1727-2808-1-ND	3	$0.380	$1.14
GYROSCOPE/ACCELERO METER LSM9DS1	Digikey	497-14946-1-ND	3	$6.330	$18.99
IC REG LINEAR 5V 1A DPAK	Digikey	497-3455-1-ND	3	$0.720	$2.16
Micro USB connector	Digikey	609-4050-1-ND	3	$0.730	$2.19
600ohm/200mA ferrite bead size 0603	Digikey	732-1593-1-ND	3	$0.170	$0.51
Coin Cell Battery Holder	Digikey	952-1737-1-ND	9	$1.170	$10.53
Altimeter 1 MPL3115A2	Digikey	MPL3115A2-ND	3	$4.320	$12.96
680μF 10V Aluminum Electrolytic Capacitor	Digikey	PCE3781CT-ND	3	$0.750	$2.25

RN2903_LORA_MODULE	Digikey	RN2903A-I/RM098-ND	3	$13.440	$40.32
Bluetooth	DX	441852	6	$3.510	$21.06
PIC32 MX795	Microchip	PIC32MX795F512LT-80I/PT	3	$0.000	$0.00
PIC32 MX695	Microchip	PIC32MX695F512LT-80I/PT	3	$0.000	$0.00
				Total	$299.56

8. Conclusions

The specifications given by the Rocketry Club are broad enough that many different solutions exist to address the challenges. Our proposed methods for navigation and achieving the goal of unfolding solar panels five feet away from the rocket aim to be simple to implement and robust. The various subsystems will be rigorously tested to ensure functionality before integrating the electronics into the body of the rover. More testing will be required to ensure that the electronics interface with the body of the rover successfully. The last step is to integrate the rover body into the rocket payload and have a successful test launch.

9. References

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