Department of Computer Science & Engineering
The University of Texas at Arlington

Architectural Design Specification
CSE 4317: Senior Design II
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Positioning Partners
Positron

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Revision History

Revision	Date	Author(s)	Description
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1 Introduction

Positioning Partners is creating an autonomous rover that is capable of completing some simple tasks. One of these tasks would include spraying dots or lines of paint on the ground in a grid. The second task would include driving a stick of rebar into the ground at any of the marked locations. The rover would be able to maneuver autonomously to GPS coordinates, or a person could manually pilot the rover using a remote control allowing for more freedom in driving the rover. This would allow the rover to paint the dots and lines on the ground, and also allow it to drive rebar into the ground at any specified locations. Whilst driving, the rover would be able to scan its environment and surroundings using a lidar scanner and camera that is attached to it, allowing for safer traversals from point to point.

2 System Overview

To improve the deign and allow the team to easily modify parts of the design without the need to redesign other non dependent modules. This approach to design also improves the ability of team members to work on separate modules and make improvements to packages/layers without having to include others and contain bugs and crashes to the layer that contains it and those that directly depend on the data it provides. Some of these layers will be software based and others will be hardware as well as most will have a portion of them that is both software and hardware. A Graphical representation of these layers has been provided with a in depth explanation of its responsibilities, dependencies, and capabilities.

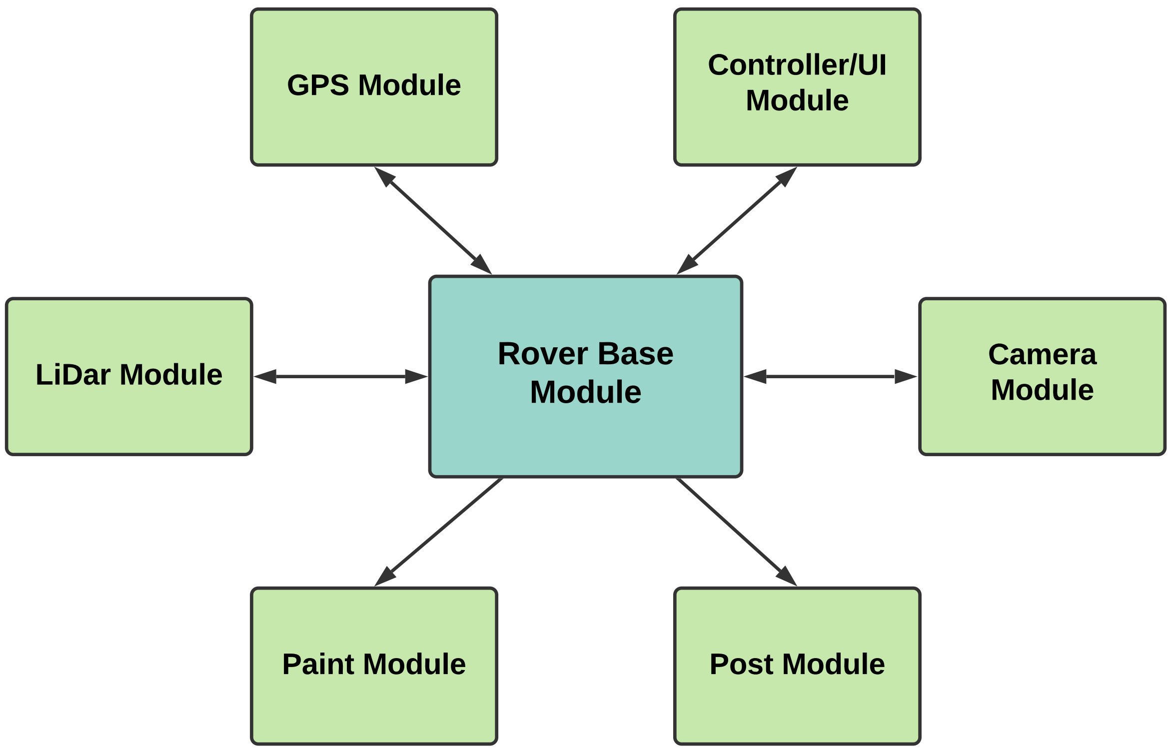

Figure 1: Architectural Layer Diagram for the Positron Rover

2.1 Rover Base A

The Rover Base is the center of the rover where all other modules connect and is the most critical. This layer is responsible for the power management of the rover supplying the power distribution to different components and interfacing the other components to the Raspberry Pi that acts as the brain of the rover. This layer is also the drive train of the rover allowing the device to move. This includes the mechanical hardware of the base of the rover and the motor controllers for the two primary drive motors.

2.2 Controller B

The Controller is used as the primary user interface of the rover and allows the pilot to control the rover both manually and autonomously where the user would program in jobs for the rover to complete and monitor the rover. This layer will be wirelessly connected to the Rover Base through a LoRa connection allowing for low latency and long range. The Controller will comprise of a display as well as analog joystick and digital switches and buttons to allow the user to quickly change preferences and control the rover.

2.3 Camera C

The Camera is responsible for providing the pilot with a FPV image of what the rover currently sees to the rover can be far from the pilot and still allow the user to see what the river does. The camera is also able to create a 3D map of the rovers surroundings so that we can integrate collision avoidance.

2.4 Paint D

The Paint module is responsible for dispensing paint onto the ground to mark key locations with lines and or dots. This is done with a servo that presses the button on a surveying spay paint can. This module can be removed from the rover as it is modular and is not critical to the robots function.

2.5 Post E

The post module is responsible for holding a rebar bar at a specified point so that the pilot or assistant can drive the rebar into the ground using a hammer drill with a special attachment on it. This module is passive in nature and does not require any electrical or software support as it is entirely mechanical in nature.

2.6 Lidar F

The Lidar module, like the Camera is used to provide the driver with a real time map of the surroundings of the rover. This module is only comprised of a Lidar scanner that will be focused on the rear and sides of the rover leaving the camera to focus on the front of the rover. The Lidar module is also used to provide the rover with feedback and allow it to autonomously provide collision avoidance.

2.7 GPS/IMU G

The GPS/IMU module is responsible for providing the rover with real time location, speed, acceleration, and orientation data with the integrated GNSS receiver, accelerometer, and magnetometer. This module will be used to the user can plan jobs for the rover to automatically navigate to specified locations and perform tasks.

3 Subsystem Definitions & Data Flow

The data system overview gave a brief introduction to the different layers that make up the system of the rover. Below, in Figure 2, it is shown how every layer communicate with each other and with any subsystem defined inside. The main layer, which is the brain of the rover is the Rover Base which communicates and interact with all the other 5 layers of the robot.

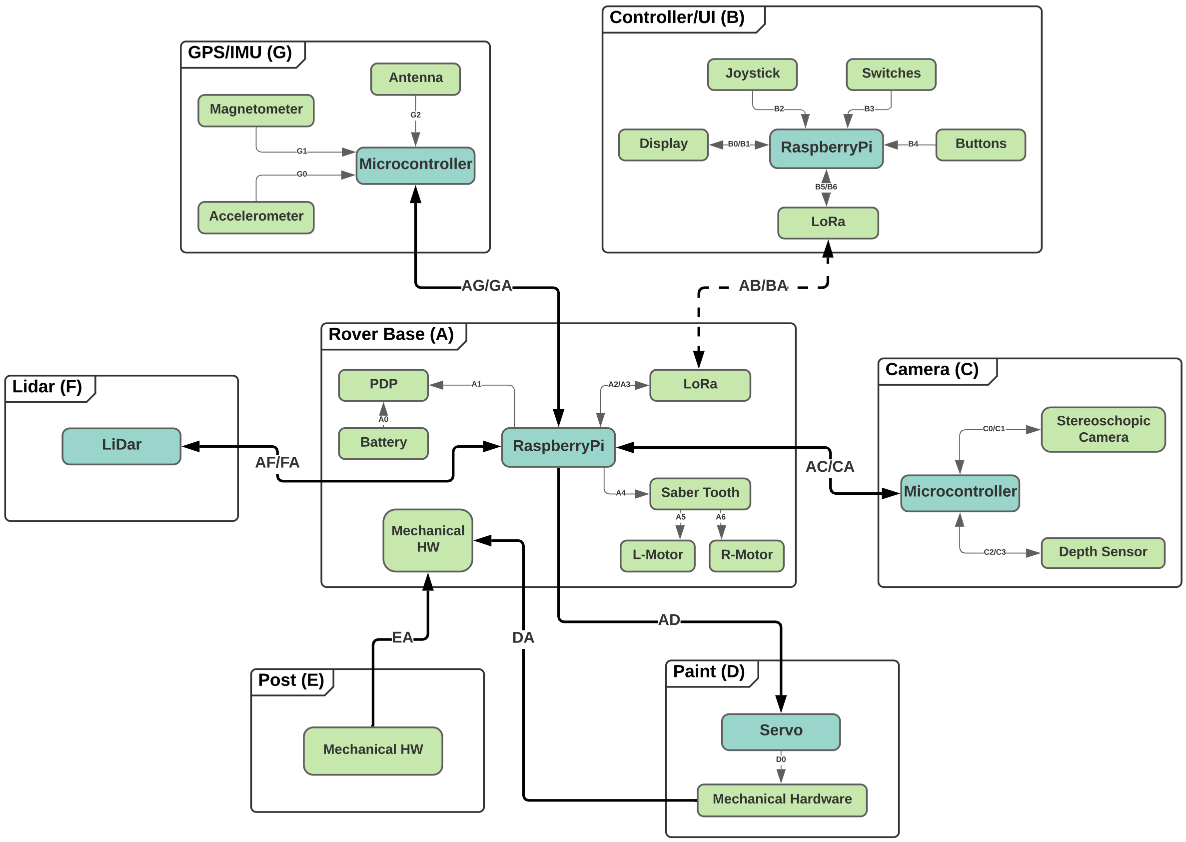

Figure 2: Positron Data Flow Diagram

4 Rover Base Subsystems

The Rover Base is the central point of communication for all components and houses the primary computer that is responsible for all decisions that the rover makes. This is done with the use of a Raspberry Pi and then the device interfaces will all sensors, inputs, and control outputs to perform the desired tasks.

4.1 Raspberry Pi

The Raspberry Pi is responsible for communicating will all peripherals and making the final decisions for the movement of the rover. This unit communicates with the other components with USB, Ethernet, SPI, I2C, and PWM.

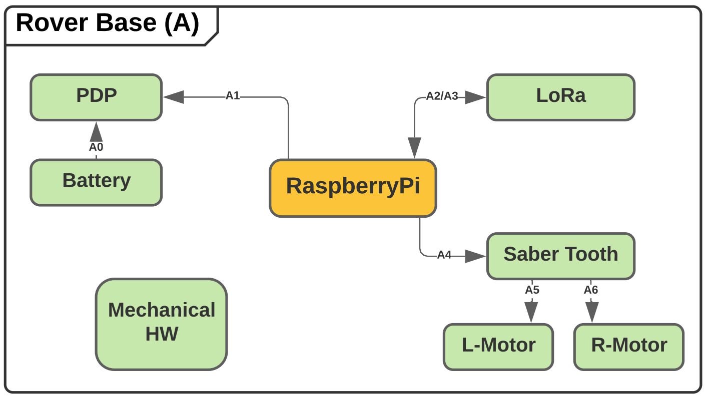

Figure 3: RaspberryPi Subsystem

4.1.1 Assumptions

The Raspberry Pi is able to perform fast enough for the needed tasks, particularly with any AI if used. The Raspberry Pi will have enough interfaces to not need any explanation devices.

4.1.2 Responsibilities

The Raspberry Pi is responsible for controlling the motors as well as all collision avoidance systems and software are run on the Raspberry Pi. This system is the 'brain' of the rover and will be the controller for all peripherals and modular components.

4.1.3 Subsystem Interfaces

The Raspberry Pi connects to many external interfaces through UART, I2C, Ethernet, USB, and PWM. Listed are all connections from the point of view of the Raspberry Pi.

Table 2: Subsystem interfaces

ID	Description	Inputs	Outputs
A1	DC 5v connection from PDP to Raspberry Pi to supply Power	DC +5V	N/A
A2	SPI Interface between RPi and LoRa module	SDA INT	SCK SDA CS
A4	PWM Interface between RPi and Saber Tooth	N/A	Digital
AC	USB Interface between RPi and Camera	Data+ Data-	Data+ Data-
AD	PWM Interface between RPi and Paint Servo	N/A	Digital
AF	Ethernet Interface between RPi and Lidar	RX+ RX-	TX+ TX-
AG	UART Interface between RPi and GPS/IMU	RX	TX

4.2 LoRa

The LoRa module in the Robot Base acts as the Transmitter/Receiver for the Controller to be able to communicate with the rover. This module is capable of fast long range communication with the Controller

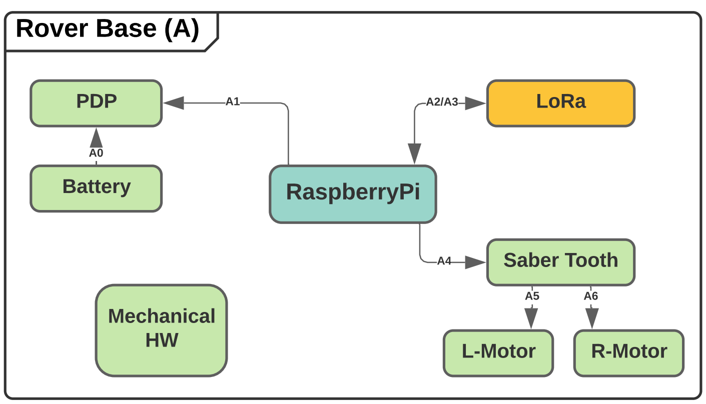

Figure 4: LoRa Subsystem

4.2.1 Assumptions

The LoRa module will have long enough range to be used out of site or within a 2km range
The LoRa module will have the necessary throughput to communicate with the Controller effectively.
The Latency of the LoRa module will be low enough for use with manual piloting.

4.2.2 Responsibilities

The LoRa module is responsible for sending all telemetry data to the controller as well as receiving all controls and commands that the controller send for the rover to complete.

4.2.3 Subsystem Interfaces

The LoRa module communicates to the Raspberry Pi via a UART connection.

Table 3: Subsystem interfaces

ID	Description	Inputs	Outputs
A3	UART Interface between LoRa and RPi	RX	TX
AB	Wireless communication between LoRa modules	LoRa	LoRa

4.3 Saber Tooth

The Saber Tooth module serves and the motor controller for the drive motors on the rover. These server as the primary means of movement for the rover and run on a DC 24V input.

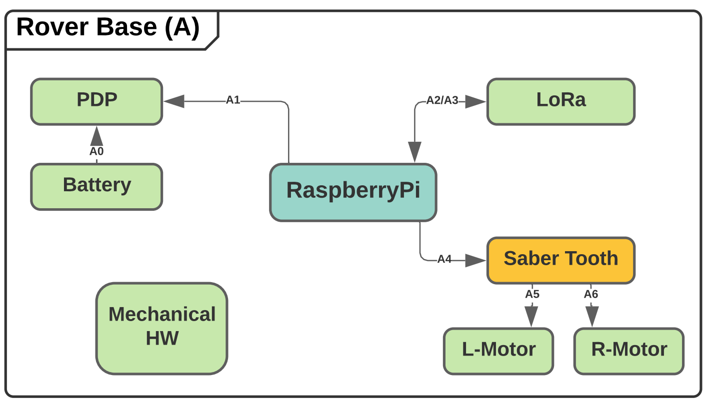

Figure 5: Saber Tooth Subsystem

4.3.1 Assumptions

The Saber Tooth will be able to interface as needed with the Raspberry Pi.
The Saber Tooth will be able to power the motors at their full speed and be accurate enough with power levels.

4.3.2 Responsibilities

The Saber Tooth is responsible for converting the PWM signal generated from the Raspberry Pi and turning it into a DC output for the motors to use.

4.3.3 Subsystem Interfaces

The Saber Tooth communicates with two PWM signals for the two motors that are controlled.

Table 4: Subsystem interfaces

ID	Description	Inputs	Outputs
A4	PWM Interface between RPi and Saber Tooth	PWM0 PWM1	N/A

4.4 L-Motor

The Left motor is to drive the left wheel of the rover in the forward and reverse direction at the speed desired.

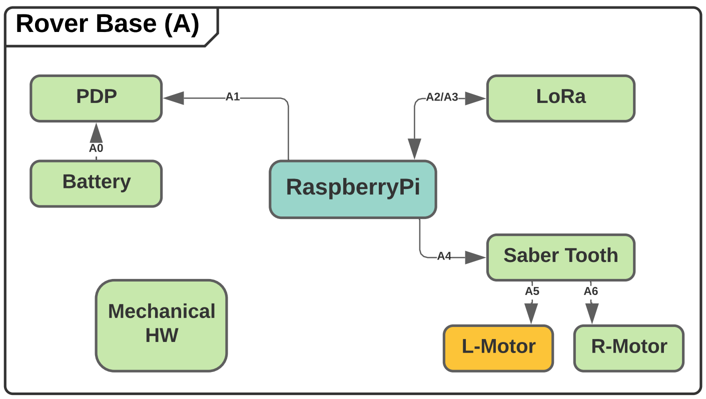

Figure 6: L-Motor Subsystem

4.4.1 Assumptions

Provide enough toque for the rover to overcome inertia and other forces.

4.4.2 Responsibilities

The Left Motor is responsible for driving the the rover and controlling its speed on the left side.

4.4.3 Subsystem Interfaces

The Left Motor communicates and gets its speed from the Saber Tooth in the form of a DC Voltage.

Table 5: Subsystem interfaces

ID	Description	Inputs	Outputs
A5	DC Interface between Saber Tooth and Left Motor	DC	N/A

4.5 R-Motor

The Right motor is to drive the right wheel of the rover in the forward and reverse direction at the speed desired.

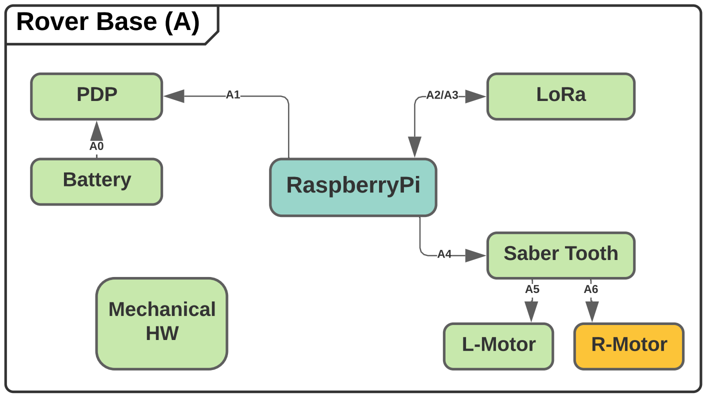

Figure 7: R-Motor Subsystem

4.5.1 Assumptions

Provide enough toque for the rover to overcome inertia and other forces.

4.5.2 Responsibilities

The Right Motor is responsible for driving the the rover and controlling its speed on the right side.

4.5.3 Subsystem Interfaces

The Right Motor communicates and gets its speed from the Saber Tooth in the form of a DC Voltage.

Table 6: Subsystem interfaces

ID	Description	Inputs	Outputs
A5	DC Interface between Saber Tooth and Right Motor	DC	N/A

4.6 Mechanical Hardware

The Mechanical Hardware represents the physical rover base drive train and all mechanical parts such as the wheels and electronics panel.

4.6.1 Assumptions

Provide the needed strength for the rover to drive outdoors.

4.6.2 Responsibilities

The Mechanical Hardware is responsible for connecting all of the mechanical parts to the rover base.

4.6.3 Subsystem Interfaces

The Mechanical Hardware interfaces with the Paint and Post modules as these are modular and have mechanical parts.

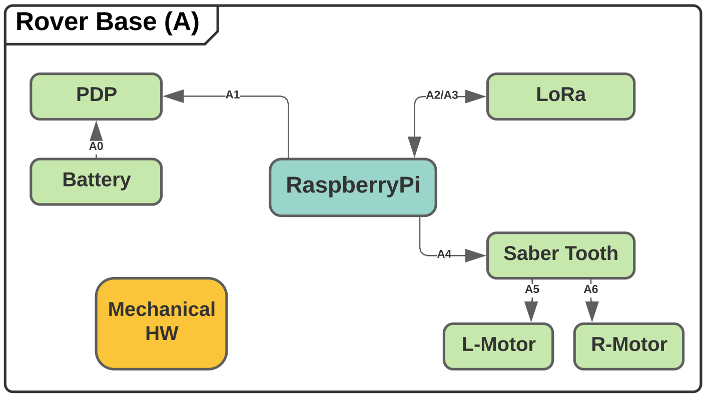

Figure 8: Mechanical Hardware Subsystem

Table 7: Subsystem interfaces

ID	Description	Inputs	Outputs
DA	Mechanical Linkage between Rover Base and Paint	N/A	N/A
EA	Mechanical Linkage between Rover Base and Post	N/A	N/A

4.7 Battery

The Battery is used to provide power to all components and is comprised of two 12V batteries that are wired in series to provide 24V to the rover. The Batteries are able to be recharged and this module includes the connection to the charger that allows this to be done externally.

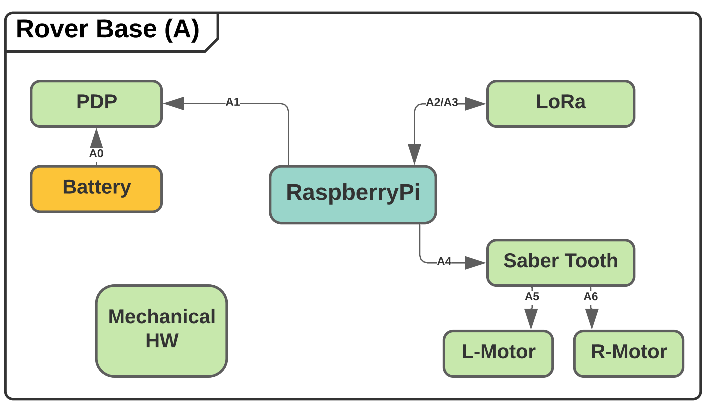

Figure 9: Battery Subsystem

4.7.1 Assumptions

Provides sufficient time for the rover to operate without an input source of power.
The Batteries are able to be recharges quickly.
The Batteries last a long time and can be easily replaced when needed.

4.7.2 Responsibilities

The Battery is responsible for supplying power to all parts of the rover and this is done with a 24V output that can be stepped down as needed for other modules.

4.7.3 Subsystem Interfaces

The Battery outputs its power to the PDP Power Distribution Panel as a 24V DC Signal.

Table 8: Subsystem interfaces

ID	Description	Inputs	Outputs
A0	DC Interface between Battery and PDP	N/A	DC 24V

4.8 PDP

The Power Distribution Panel (PDP) can convert power from the batteries 24V to other voltage levels used by the rover like 12V and 5V. These different voltage levels can then be distributed to parts of the rover through multiple connections for each voltage level with fused connection to protect modules from one another.

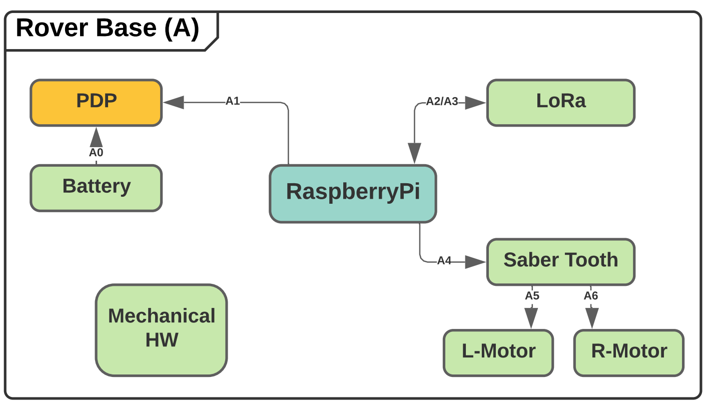

Figure 10: PDP Subsystem

4.8.1 Assumptions

The PDP is able to supply stable power at 24V, 12V, and 5V with safe connections to protect other devices.

4.8.2 Responsibilities

The PDP is responsible for connecting all parts of the rover for power and providing it to each component at the needed level.

4.8.3 Subsystem Interfaces

The PDP connects to many modules and provides a DC voltage for them.

Table 9: Subsystem interfaces

ID	Description	Inputs	Outputs
A1	DC Interface between PDP and RPi	N/A	DC 5V

5 Controller Subsystems

This subsystem consists of raspberry pi, joystick, display, LoRa, buttons and switches which is responsible for creating user interface.

5.1 Display

This module is responsible for both receiving text input as well as displaying UI information to the user.

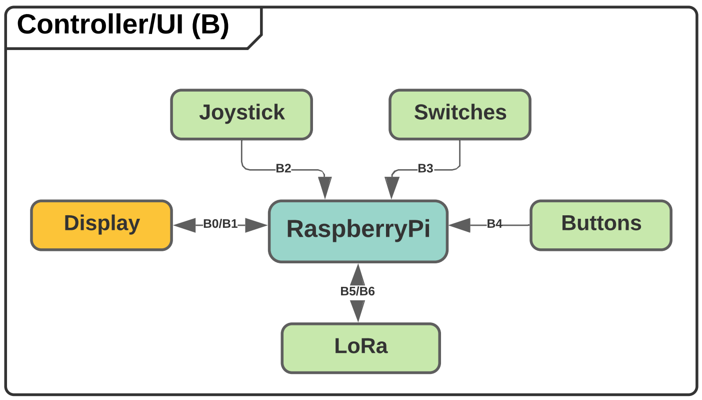

Figure 11: Display Subsystem

5.1.1 Assumptions

It will be able to display UI information on 800*480 resolution touchscreen.

5.1.2 Responsibilities

It is responsible for displaying all the graphical user interfaces to the user as well as accepting input for touchscreen usage and controlling other subsystem.

5.1.3 Subsystem Interfaces

Each of the inputs and outputs for the subsystem are defined here.

Table 10: Subsystem interfaces

ID	Description	Inputs	Outputs
B0	Connecting the display to raspberry pi	DSI	DSI
B1	Connecting the raspberry pi to display	DSI	DSI

5.2 Joystick

The joystick connects the rover in order to control the movement. It allows the users to interact with the GUI. Its main purpose is to guide the rover to the desired location.

5.2.1 Assumptions

User will be able to control the rover position, acceleration, direction, and speed.

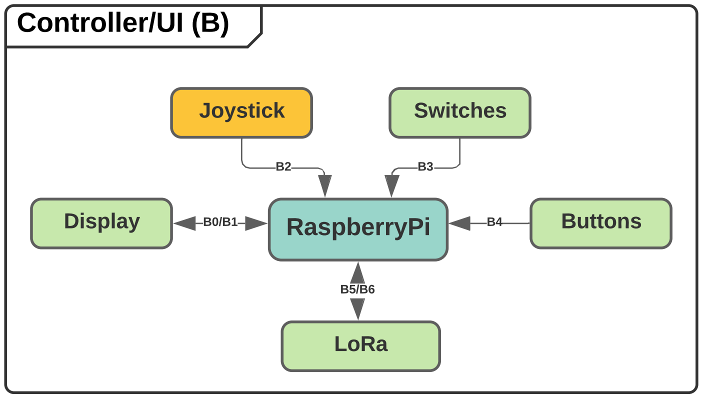

Figure 12: Joystick Subsystem

5.2.2 Responsibilities

The joystick is responsible for controlling the rover movement using the Mission Planner

5.2.3 Subsystem Interfaces

Table 11: Subsystem interfaces

ID	Description	Inputs	Outputs
B2	2X analog signals between joystick and raspberry pi	Analog	Analog

5.3 Switches

Switches helps to ensure the power is supplied to the rover's components.

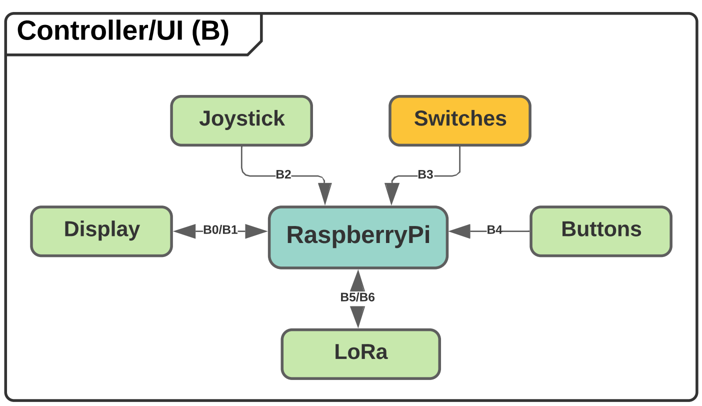

Figure 13: Switches Subsystem

5.3.1 Assumptions

Once the switch is turned on, it will supply power to the raspberry pi.

5.3.2 Responsibilities

The switch is responsible to manually turning on and off the power to the raspberry pi.

5.3.3 Subsystem Interfaces

Each of the inputs and outputs for the subsystem are defined here.

Table 12: Subsystem interfaces

ID	Description	Inputs	Outputs
B3	Connecting switch to raspberry pi	Digital	N/A

5.4 Buttons

It is a super small subsystem for the physical push buttons on the controller. It uses GPIO pins to connect all the inputs.

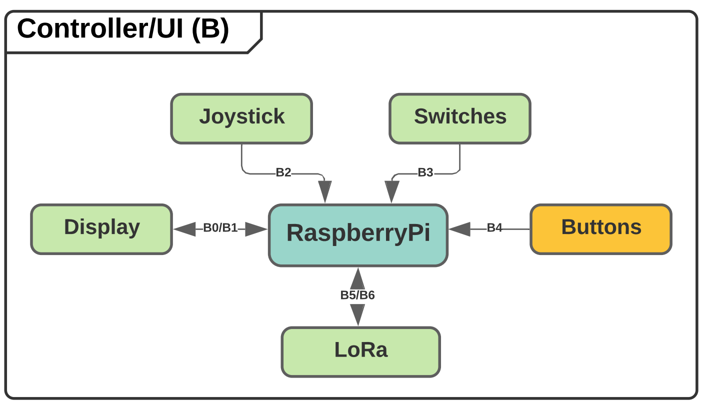

Figure 14: Buttons Subsystem

5.4.1 Assumptions

Electrical current flows through the button through input pin and raspberry pi detect the input pin.

5.4.2 Responsibilities

It is responsible for controlling GPIO interface on the raspberry pi.

5.4.3 Subsystem Interfaces

Table 13: Subsystem interfaces

ID	Description	Inputs	Outputs
B4	Digital signal connecting the push buttons to raspberry pi	N/A	Digital

5.5 Raspberry pi

This raspberry pi connects the whole user interface like joystick, switches, buttons, and display. In other words, it is the CPU of whole user interfaces. This raspberry pi receives the input from the user interface devices and sent to the rover base through LoRa.

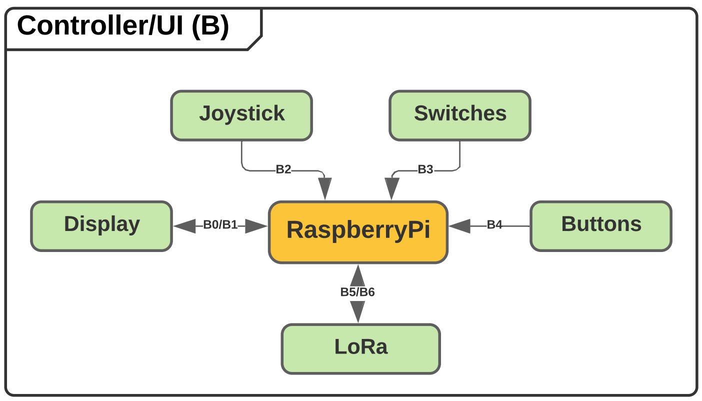

Figure 15: RaspberryPi Subsystem

5.5.1 Assumptions

The raspberry pi has enough ports to connect to user interfaces devices.

5.5.2 Responsibilities

This raspberry pi is responsible to control and regulate all the user interface devices.

5.5.3 Subsystem Interfaces

Each of the inputs and outputs for the subsystem are defined here.

Table 14: Subsystem interfaces

ID	Description	Inputs	Outputs
B5	Interface connecting raspberry pi to LoRa	UART	UART
B1	Interface connecting raspberry pi to display	DSI	DSI

5.6 LoRa

Communication is created between the controller and rover base through LoRa radio. This LoRa will communicate with another LoRa connected to rover base to pass and receive the data and instructions between the two raspberry pi.

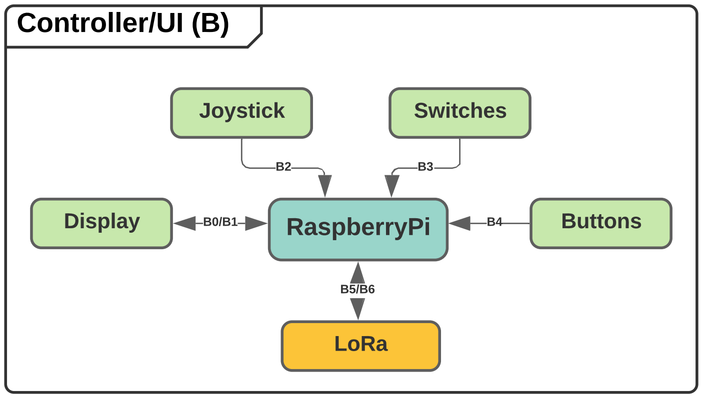

Figure 16: LoRa Subsystem

5.6.1 Assumptions

The LoRa radios are of the same frequency.

5.6.2 Responsibilities

This LoRa is responsible to pass any user interface to the main rover base and receive information from the rover station back to the controller.

5.6.3 Subsystem Interfaces

Each of the inputs and outputs for the subsystem are defined here.

Table 15: Subsystem interfaces

ID	Description	Inputs	Outputs
B6	Connecting LoRa to raspberry pi	UART	UART

6 Camera Subsystems

The camera layer would work with the lidar layer to be able to give the rover view of its surroundings. The camera would be giving the rover the back side view of the rover, and wherever else the lidar's view cannot see. This module is referenced in the figure as layer C.

6.1 Stereoscopic Camera

The stereoscopic camera will be able to capture the 3d surroundings of the rover.

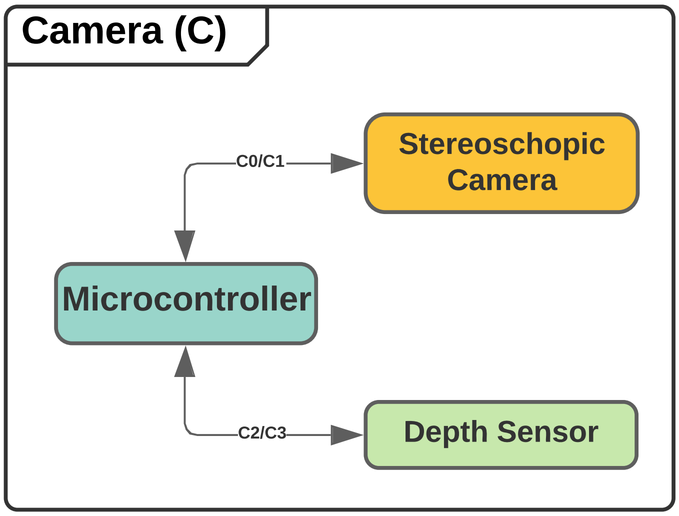

Figure 17: Stereoscopic Camera Subsystem

6.1.1 Assumptions

The accuracy of the camera would be able to provide a good picture at a good framerate.

6.1.2 Responsibilities

The camera is responsible for finding the back surroundings of the rover, or to where the lidar is unable to see.

6.1.3 Subsystem Interfaces

Table 16: Subsystem interfaces

ID	Description	Inputs	Outputs
C0	Connecting the stereoscopic camera to the micro-controller.	Data+ Data-	Data+ Data-

6.2 Depth Sensor

The depth sensor will be able measure the distance between the camera position and any objects that would be around the rover.

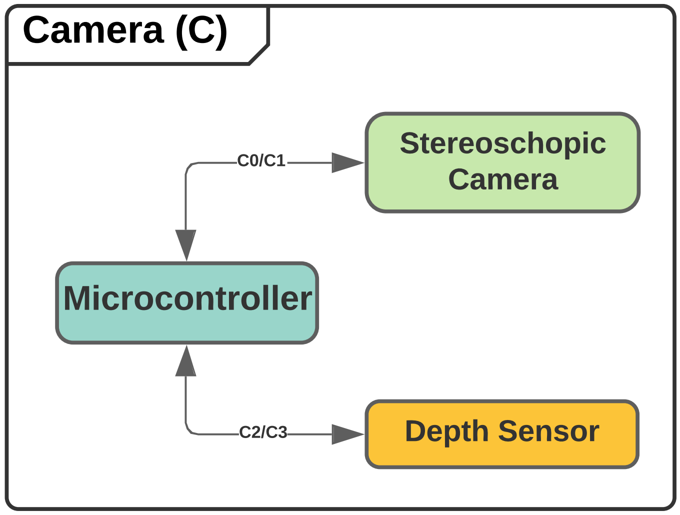

Figure 18: Depth Sensor Subsystem

6.2.1 Assumptions

The depth sensor will give an accurate reading of the distances around the rover. The latency between each reading will be fast enough to use accurately.

6.2.2 Responsibilities

The depth sensor is responsible for making the rover alert to how close it is to anything it could hit.

6.2.3 Subsystem Interfaces

Table 17: Subsystem interfaces

ID	Description	Inputs	Outputs
C1	Connecting the depth sensor to the micro-controller.	SDA SCL	SDA SCL

6.3 Micro-controller

The micro-controller is a small computer on the chip set in the inner workings of the camera. The micro-controller receives data from the other subsystems and will pass it on to the other systems.

6.3.1 Assumptions

The micro-controller will receive all the information from the other systems fast and efficiently.

6.3.2 Responsibilities

The micro-controller is responsible for any incoming or outgoing data that it might receive. It will take the image from the camera, along with the measurements from the depth sensor and send the information to the raspberry pi.

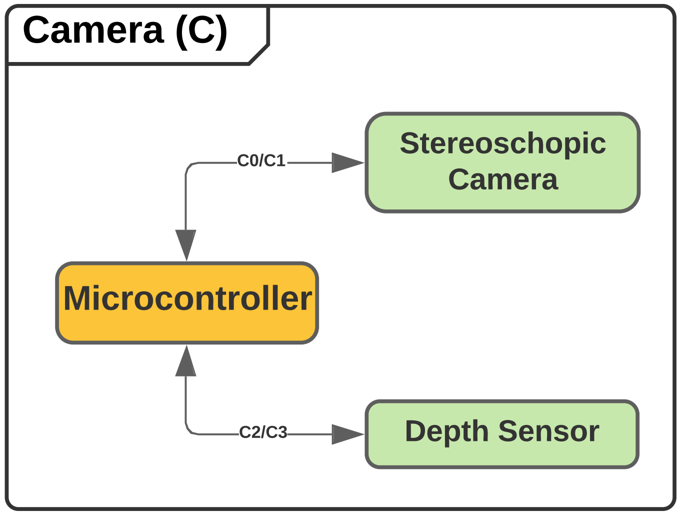

Figure 19: Micro-controller Subsystem

6.3.3 Subsystem Interfaces

Table 18: Subsystem interfaces

ID	Description	Inputs	Outputs
C0	Connecting the stereoscopic camera to the micro-controller.	Data+ Data-	Data+ Data-
C1	Connecting the depth sensor to the micro-controller.	SDA SCL	SDA SCL
AC	Connecting the camera to the raspberry pi.	Data+ Data-	Data+ Data-

7 Paint Subsystems

The Paint module communicates with the main Rover Base module through both its subsystems. This module is responsible to mark the ground with paint when a signal is sent from the main system to the servo which controls the mechanical part of this module.

7.1 Servo

This subsystem is the servo motor which controls the mechanical hardware part of the robot designated to use spray paint to mark specific points on the ground. The servo is controlled by the Raspberry Pi in the Rover base module through a PWM communication.

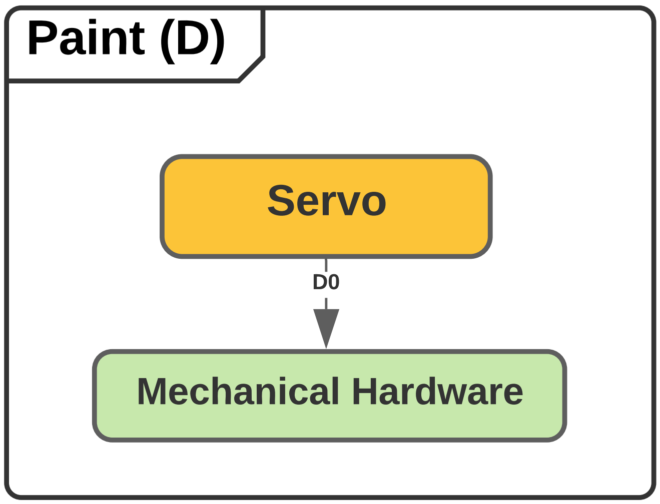

Figure 20: Servo Subsystem

7.1.1 Assumptions

The servo motor has enough torque to press the spray paint can button.

7.1.2 Responsibilities

The responsibility of this module is to execute the commands sent from the main system.

7.1.3 Subsystem Interfaces

Table 19: Servo Subsystem interfaces

ID	Description	Inputs	Outputs
AD	PWM - from Rover Base module to Servo	Digital	N/A
D0	Mechanical linkage between servo and paint can	N/A	mechanical

7.2 Mechanical Hardware

This subsystem contains the mechanical hardware needed to press the nozzle of a spray paint can. The nozzle will be pressed by the servo motor in the servo subsystem through a mechanical linkage.

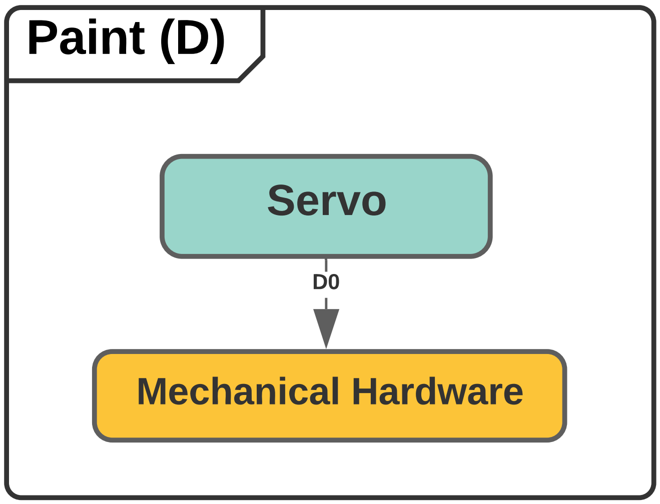

Figure 21: Mechanical Hardware Subsystem

7.2.1 Assumptions

The spray can nozzle is easy to be pressed and the spray can is easily replaceable.

7.2.2 Responsibilities

The responsibility of this module is to hold and press the nozzle of a spray can when the servo motor is activated by a command from the main system of the rover.

7.2.3 Subsystem Interfaces

Table 20: Subsystem interfaces

ID	Description	Inputs	Outputs
D0	Mechanical linkage between the servo and the paint can	Mechanical	N/A
DA	Mechanical linkage between the paint can and the mechanical base of the rover	N/A	Mechanical

8 Post Subsystems

The Post module purpose is to assist the manual placement of a metal rod (post) to the ground on the marked location by the Paint module. Thus, the only subsystem present in the module it is the mechanical hardware which is served for this purpose.

8.1 Mechanical Hardware

This subsystem is the only one present in the post module as it has the mechanical components needed to aid the manual placement of a post into the ground. This module is connected to the main Rover base through a mechanical linkage.

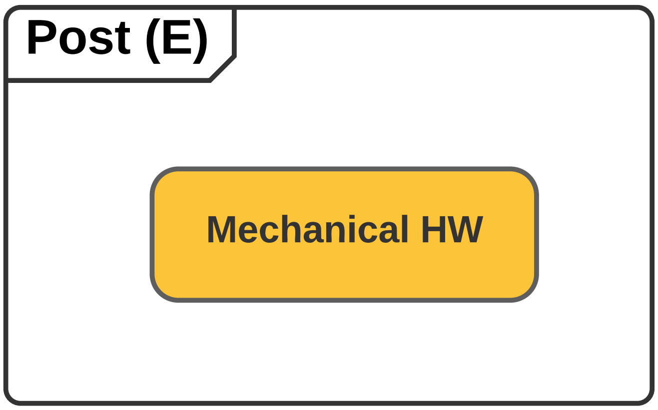

Figure 22: Mechanical Hardware Subsystem

8.1.1 Assumptions

This subsystem is assumed to be able to hold a metal rod and released when driven away.

8.1.2 Responsibilities

The mechanical parts will hold the metal rod when manually placed through a hammer drill to the ground.

8.1.3 Subsystem Interfaces

Table 21: Subsystem interfaces

ID	Description	Inputs	Outputs
#EA	Mechanical linkage between the post module and the mechanical base of the rover	N/A	Mechanical

9 Lidar Subsystems

The lidar layer will be used to provide the rover with a scanning function that will be able to sense the environment behind it. The lidar module will communicate with the rover base through the raspberry pi. This module is referenced in the figure as layer F.

9.1 Lidar

This instrument will allow for environmental scans around behind the rover.

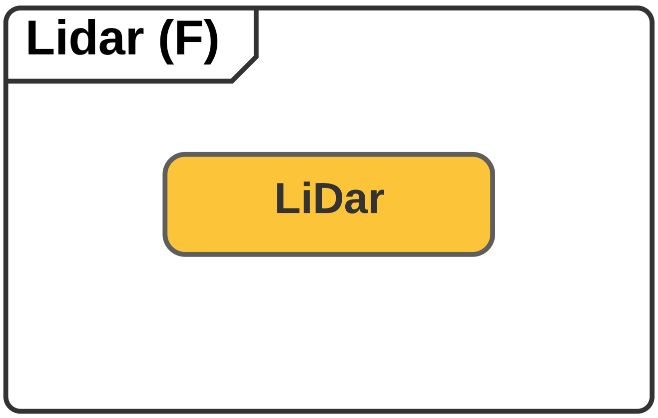

Figure 23: Lidar Subsystem

9.1.1 Assumptions

The first assumption would be that the drivers provided work properly. The lidar is able to produce an accurate reading of its surroundings at a fast pace.

9.1.2 Responsibilities

The responsibility of the lidar layer is to provide the rover with the back sensors to see what is behind it at all times.

9.1.3 Subsystem Interfaces

Table 22: Subsystem interfaces

ID	Description	Inputs	Outputs
FA	Connection between Pi and Lidar through ethernet	RX+ RX-	TX+ TX-

10 GPS Subsystems

The GPS/IMU layer will consist of four critical subsystems the accelerometer, antenna, magnetometer, and microcontroller. Our GPS module with RTK allows the Positron Rover to achieve centimeter location accuracy. The GPS module will communicate with the Raspberry Pi controller on our rover platform using I2C interface.

10.1 Accelerometer

An instrument that measures proper acceleration and uses an I2C interface for communicating with the embedded microcontroller.

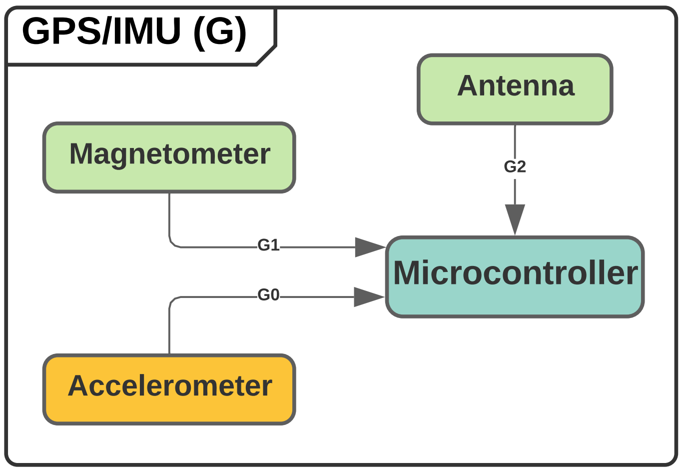

Figure 24: Accelerometer Subsystem

10.1.1 Assumptions

The team assumes the accelerometer will properly communicate with the embedded microcontroller with minimal integration using I2C.

10.1.2 Responsibilities

Responsible for measuring acceleration forces. Such forces may be static, like the continuous force of gravity or, as is the case with many mobile devices, dynamic to sense movement or vibrations.

10.1.3 Subsystem Interfaces

Table 23: Subsystem interfaces

ID	Description	Inputs	Outputs
G0	I2C Interface between accelerometer and embedded microcontroller	SCK SDA	SCK SDA

10.2 Antenna

The primary function of the antenna is to receive signals from GPS satellites in space. The antenna will relay GNSS positioning data to the embedded microcontroller.

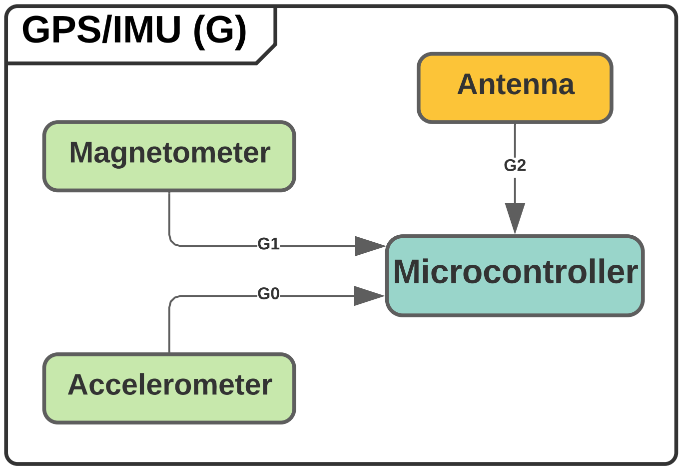

Figure 25: Antenna Subsystem

10.2.1 Assumptions

The team assumes the antenna will properly communicate with the embedded microcontroller with minimal integration using GNSS positioning data.

10.2.2 Responsibilities

The antenna acts as a transducer as it converts one form of energy into a different form. As at the transmitting end, an electrical signal is transformed into a radio wave and receiving end changes radio waves back to electrical form.

10.2.3 Subsystem Interfaces

Table 24: Subsystem interfaces

ID	Description	Inputs	Outputs
G2	Raw GNSS data from space to embedded microcontroller	N/A	GNSS

10.3 Magnetometer

An instrument that measures the direction, strength, or relative change of a magnetic field at a particular location. The magnetometer will relay magnetic field data to the microcontroller using an analog signal.

10.3.1 Assumptions

The team assumes the magnetometer will properly communicate with the embedded microcontroller with minimal integration using an analog signal.

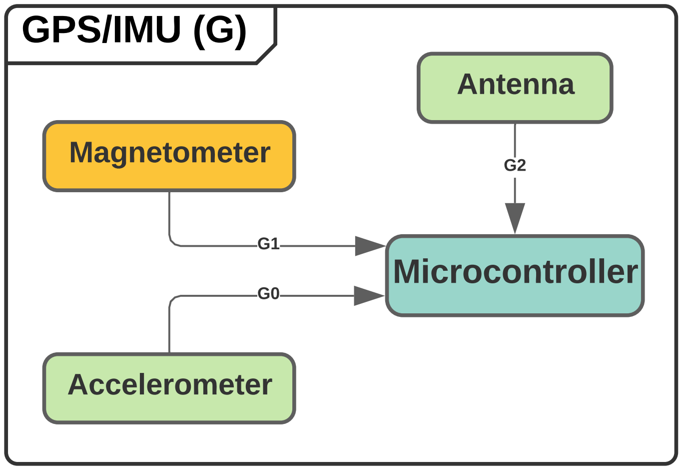

Figure 26: Magnetometer Subsystem

10.3.2 Responsibilities

The magnetometer is responsible for measuring the strength and sometimes the direction of magnetic fields, including those on or near the Earth and in space.

10.3.3 Subsystem Interfaces

Table 25: Subsystem interfaces

ID	Description	Inputs	Outputs
G1	Analog signal for current magnetic heading to embedded microcontroller	N/A	Analog

10.4 Microcontroller

The microcontroller is a small computer on a integrated circuit chip. The microcontroller contains one or more CPUs along with memory and programmable input/output peripherals. The microcontroller will receive data from the accelerometer, antenna, and magnetometer.

10.4.1 Assumptions

The team assumes the microcontroller will properly communicate with the accelerometer, antenna, and magnetometer with minimal integration.

10.4.2 Responsibilities

The microcontroller calculates the rover position by reading the signals that are transmitted by the satellites. Each satellite transmits a continuous signal which contains the time the signal was sent. The microcontroller measures the distance to each satellite based on the arrival time of each signal. This information is used to calculate the position of the rover. The received raw data is converted by the microcontroller for the user as LATITUDE, LONGITUDE, ALTITUDE, SPEED and TIME.

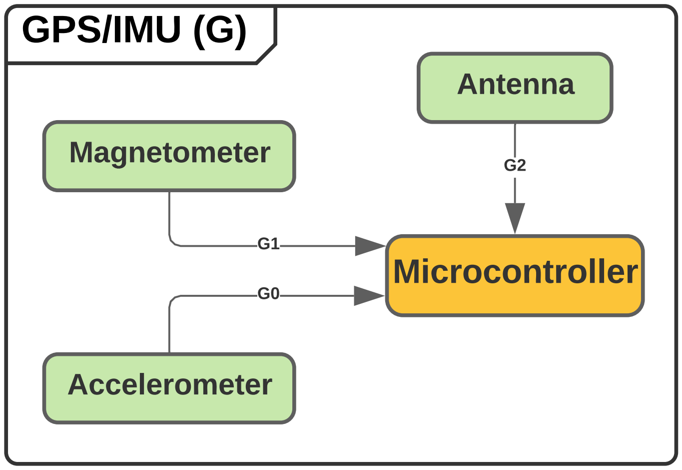

Figure 27: Micro-controller Subsystem

10.4.3 Subsystem Interfaces

Table 26: Subsystem interfaces

ID	Description	Inputs	Outputs
G0	I2C Interface between accelerometer and embedded microcontroller	SCK SDA	SCK SDA
G1	Analog signal for current magnetic heading to embedded microcontroller	Analog	N/A
G2	Raw GNSS data from space to embedded microcontroller	GNSS	N/A

References