**Robot Cognition Platform**

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# Executive Summary

The goal of the robot cognition design project is to create a platform that can incorporate sensors to allow for mapping of a surrounding area. The sensors to be integrated included a GPS (global positioning system), IMU (inertial measurement unit), LiDAR, and camera. The processor that was used was an NVIDIA Jetson Nano to format all the data into a single processing system. All the sensors and the processor were required to be integrated onto a physical platform weighing no more than five kilograms and operating between temperatures -10°C to 40°C. The platform now also provides five additional ports: 5VDC at 10A, 3.3VDC at 10A, and 12VDC at 5A. The finished product was expected to collect accurate geo-positioning, image, video, attitude, and gyroscope data.

In regard to the software integration, the software used for the LiDAR was ROS RViz 3D visualization software. For the camera, the default driver for Linux was used in addition to an inference that wrapped around TensorRT. Software was provided by Xsens to be downloaded in order to integrate the IMU. For the GPS, GPS-E and GPS-MON software was used.

# Introduction

The sponsor for the project was Professor William (Bill) Michael at the University of Colorado, Colorado Springs. Bill asked the team to create a platform that can use sensors like the LiDAR, IMU, GPS, and camera to be used for mapping out rooms and collecting data such as the GPS coordinates and attitude of a space. The end goal for this platform is to be mounted on a mobile robot.

# Problem Description:

## Customer Requirements

The sponsor for this project, Bill Michael, provided a list of requirements to be met to fulfill the expectations of this project. The platform must be powered by a battery that supplies between 18 and 48 volts. The platform must also weigh less than 5kg. The battery recommended by the sponsor is a lithium polymer battery that will fulfill that voltage requirement. The platform must include the following peripherals; global positioning system (GPS), inertial measurement unit (IMU), LiDAR, and a camera. These peripherals are going to be used to collect data in any environment. Along with the previous sensors the sponsor asked for three supplementary power ports. The first is 5 volts DC at 10 amps, second is 3.3 volts DC at 10 amps, the last is 12 volts DC at 5 amps. This platform must also generate point-cloud data from the LiDAR, spatial and image data from the camera and IMU, and location data from the GPS.

## Engineering Specifications

To ensure each of the project requirements are met, verifiable engineering parameters and accompanying target values are identified as follows. The sensor platform must have:

* four (4) ports for sensors
* two (2) ports to power additional equipment that use communication protocols I2C (Inter-Integrated Circuit) or SPI (Serial Peripheral Interface)
* one (1) port hold and power a processing system
* an inertial measurement unit (IMU) sensor to record gyro data
* a global positioning system (GPS) receiver to track location
* a light detection and ranging (LIDAR) sensor to generate point cloud data
* a camera sensor to generate at least HD (1280 x 720) resolution with at least 30 frames per second speed

# Conceptual Design:

## Platform Design

The design of the platform was determined by comparing the pros and cons of three separate designs, and the final design was a combination of the best parts of each design. The platform was designed in solid works and then built using carbon fiber plates and supports. The final model of the platform is shown in the figure below.

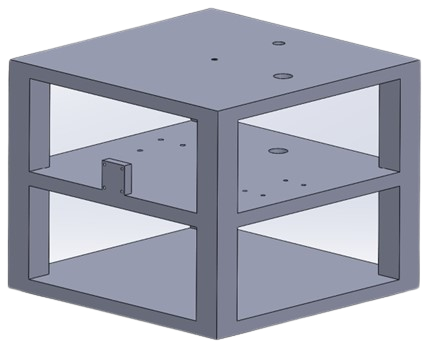


Figure 1 - Final SolidWorks model

The final platform will consist of three levels, the top level will be home to the LiDAR and the antenna for the GPS module. The second level is where the jetson nano, GPS module, IMU and the camera will be placed. The bottom level will house the battery, and all the PCB components.

# Finalized Design

## Sensors

The sensors for the platform will all be connected to the Jetson Nano which will handle the processing required for the platform. The sensors are connected to the nano in accordance with Table 1 below.

|  |  |  |  |
| --- | --- | --- | --- |
| **Point A​** | **Point B​** | **# of Connections​** | **Connector​** |
| Jetson Nano​ | LIDAR​ | 1​ | Ethernet​ |
| Jetson Nano​ | LEA-M8T (GPS)​ | 3​ | UART​ |
| Jetson Nano​ | Xsens MTI-10-2A8G4 (IMU)​ | 1​ | USB​ |
| Jetson Nano​ | e-CAM24\_CUNX​ (Camera)​ | 1​ | MIPI CSI-2​ |
| LEA-M8T​ | Antenna​ | 1​ | SMB to TNC Coax​ |
|  |  |  |  |

Table 1 – Sensor Connections

### IMU

The inertial measurement unit will be connected to the Jetson Nano via USB and powered by the Jetson Nano. The IMU will be placed on the middle level of the platform.

### LIDAR

The LiDAR will be connected to the Jetson Nano via ethernet and will be powered by one of the extra power connections that outputs 12 volts at 5 amps. The LiDAR will sit at the top of the platform to ensure that there is no obstruction to the 360-degree field of view.

### Camera

The camera was connected to the Jetson Nano via MIPI CSI-2. The camera was placed on the middle level of the platform and faced towards the front of the platform in order to get a view of what was in front.

### GPS

The GPS was connected to the Jetson Nano via UART (Universal Asynchronous Reciever-Transmitter). The GPS was placed on the side of the platform.

## Power Components

The power components for this project require high amperages to work as intended. The LiDAR requires 12V at 3A, The Nano requires 5V at 2A, and the extra ports require various high amperages of 3, 5, and 10A. The GPS and IMU are powered from the Jetson Nano and their power requirement is included in that amount. To meet these requirements with a 16V-36V LiPo battery source, DC/DC converters are used to convert the power to each of the sensors and ports. These DC/DC converters also require additional external components to meet Class B requirements for EN55032​ emissions guidelines to be used in residential areas. The Circuit Schematic for this power design can be seen in Figure 2 below. Additional information on the external components used can be found in the appendix.

Diagram, schematic

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Figure 2 – Circuit Design for Platform Power

The DC/DC converters used in this design are as follows:

* CP40\_1233036 - provides 12V at 3A
* CP40\_1790018 – provides 3V at 5A
* CP40\_1180018 – provides 5V at 8A
* RSDW60G-12 – provides 12V at 5A
* PQQE50-0240550D – Provides 5V at 10A

The external components need to be placed on PCBs designed to account for the large amperages used by the system. In the scope of this project, the PCBs are designed to meet the standard of the OSH Park PCB manufacturer in Oregon. A 3d rendering of the PCB design can be seen in the figure below.

Diagram

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Figure 3 – PCB 3d Rendering

The Connections for the platform are summarized in the Table below. Table 2 summarizes how the power connections are implemented to provide power to the individual components. Most of the connections are soldered wire with a few being wire pin terminals.

|  |  |  |  |
| --- | --- | --- | --- |
| **Point A​** | **Point B​** | **# of Connection​** | **Connector​** |
| Battery​ | Wire A (6 AWG)​ | 2​ | EC5​ |
| Wire A​ | CP40B Externals​ | 6​ | Soldered 14 AWG Wire​ |
| Wire A​ | PQAE50 Externals​ | 2​ | Soldered 14 AWG Wire​ |
| Wire A​ | RSDW60G Externals​ | 2​ | Soldered 14 AWG Wire​ |
| CP40B Externals​ | CP40B DC/DC​ | 6​ | Wire Pin Terminal​ |
| PQAE50 Externals​ | PQAE50 DC/DC​ | 4​ | Wire Pin Terminal​ |
| RSDW60G Externals​ | RSDW60G DC/DC​ | 4​ | Wire Pin Terminal​ |
| CP40B DC/DC (5V)​ | Jetson Nano​ | 2​ | Wire Pin Terminal​ |
| CP40B DC/DC (12V)​ | LIDAR​ | 2​ | Soldered 14 AWG Wire ​ |
| CP40B DC/DC (3.3V)​ | Port A​ | 2​ | Female to Male Pin Connector​ |
| PQAE50 DC/DC (5V)​ | Port B​ | 2​ | Female to Male Pin Connector​ |
| RSDW60G DC/DC (12V)​ | Port C​ | 2​ | Female to Male Pin Connector​ |

Table 2 – Platform Power Connections

## Platform

The finalized platform has been changed from being 3D printed to being comprised of multiple carbon fiber pieces. The levels of the platform are now 300 by 300 mm thin sheets of carbon fiber. The supporting legs are carbon fiber and will be held together with screws. The completed platform with all the sensors attached is depicted below.

A picture containing indoor

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Figure 4 - Finalized Platform

# Testing and Analysis

## IMU

Communication between the IMU and Jetson Nano was never fully established. The Jetson Nano could recognize the IMU but could not get data from it. If communication is established in future work, the IMU needs to have its functionality tested. These functionality tests would include: rotational, velocity, acceleration, and altitude measurement tests. These tests would need to be conducted in a variety of environments to make sure the IMU is giving accurate data.

## LiDAR

In this project the LiDAR being used was faulty and could not be tested on the platform or on another computer. When attempting to test we used ROS RVIZ on the jetson nano as well as using the manufacturer’s software velo-view on windows, both with the same result. The LiDAR would be detected by the host computer but would not output any form of data to either program.

## Camera

The tests for the camera were the simplest. The camera was verified to turn on and be powered through the CCSI-MIPI-2 connection to the Jetson Nano. The camera was then verified to produce imagery that could be seen by users in the Jetson Nano GUI. The imagery could be successfully used to detect images using TensorRT. This performance showcased that the camera was working satisfactorily for robot cognition purposes.

## GPS

The GPS was successfully connected to the Jetson Nano and communication was established using UART. The camera showed connection to the antenna via the SMB to TNC coax cable. Accurate time information was received from the GPS, but accurate positional data was not. The platform was never tested outside so the GPS was not given enough time to synchronize with the positional system satellites. Future testing outside is required.

## Power

The power systems for the platform were tested independently. The PCB and DC/DC converter combinations were each tested to make sure they delivered appropriate voltages when supplied by 16-36V by a bench power supply. All three completed PCBS worked efficiently in these tests. The systems still need to be tested at higher amperage to make sure the systems can handle those. Additionally, an end-to-end power test with a LiPo battery is required to ensure the system works all together.

# Final Design Package

## Sensors

All sensors were connected to the Jetson Nano efficiently in the final design. Currently, the GPS and Camera are the main working sensors. The LiDAR and IMU are connected, but do not currently work. The LiDAR is believed to be faulty and needs to be replaced, but the same connections can be used for the replaced model. The IMU is either faulty or there is just a software problem preventing its full integration. The IMU can be replaced with an available OEM version using UART connections on the Jetson Nano, or more work can be explored on the software side of the problem.

## Software

The LiDAR will be using Robot Operating System (ROS) to control the unit. The 3D visualization software being used for this project will be ROS RViz. This software can output the point cloud live or it can be used to save the raw data to be used later. When using a non-ARM processor, the program Velo-View can be used in place of ROS and RViz.

## Power

The PCBs and power connections for the Jetson Nano, LiDAR, and the 3.3V extra port were all finalized in the final design. Three PCBs were completed and can be seen in the Figure below.

A picture containing electronics

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Figure 5 – Finalized PCB Integration

The PCBS are supplied power through an EC5 male connector in parallel to each of the components. The Jetson Nano is powered from the PCB connected to the appropriate DC/DC converter which is then attached through two female pins onto the GPIO of the Jetson Nano. The LiDAR has powered through wires soldered from the 12V and 3A DC/DC converter. The extra port is open ended at this point. There are extra wires at the bottom of the platform capable of supplying power at 3.3V and 5A to any future external tool or sensor.

# Conclusion

Overall, this platform provides a solid prototype version of the product. The implementation ideas and design are all solid and can be used to build a more put together product I the future. The current design would be complete with a working IMU and LiDAR once the final testing is completed. The wire management needs work, but all the connections work as is even if it is not the prettiest. The making of this platform offered a great multi-discipline learning experience and is a good starting point for doing many robot cognitive tasks.

# Project Planning and Project Management

The planning for this project was broken down by the main components that needed to be put together. There was the integration of the individual sensors, the building of the physical platform, and the design of the power systems. Those tasks were further broken down and a gantt chart was made for the schedule of the project. Individual team members were then assigned the tasks in a manageable fashion. For example, each team member was assigned an individual sensor to integration into the Jetson Nano.

# Sponsor Interactions

The team regularly interacted with the sponsor of this project, Bill Michael. The team met with the sponsor in person at least once a week in person and various other times using email and Microsoft teams. Interactions were positive and productive.

# Team Interactions

The team interacted on a regular basis. Regular meetings were held multiple times a week, during class time and outside of class. Meetings were held on Microsoft teams and in person. The team used Discord as a regular group chat to notify the team of any changes in the project and schedule new meetings as needed. Many parts of the project were worked on together such as soldering the PCB boards, helping each other with the individual sensors, and putting the physical platform together. The team interactions were mostly positive with minor conflicts within the team resolved with the help of faculty.

# Appendix

Diagram

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CP40\_1233036 External Components to provide 12V at 3A

Diagram

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CP40\_1790018 External Components to provide 3.3V at 5A

Diagram, schematic

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CP40\_1180018 External Components to provide 5V at 8A

Diagram

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RSDW60G-12 External Components to provide 12V at 5A

Diagram

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PQQE50-0240550D External Components to provide 5V at 10A