# Development of an Autonomous Ground Vehicle

## Operation Manual

Team 22

April 1, 2016

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## Acknowledgements

As a team, we would like to thank our advisors, Dr. Nikhil Gupta and Dr. Matthew Jensen, for the time and effort they put forth towards bettering our project. Without them, our research and development would be aimless.

We would like to thank the Florida Space Grant Consortium along with Dr. Chiang Shih for funding and organizing our project. Dr. Shih organized a dual university collaboration between the FAMU/FSU College of Engineering and the Florida Institute of Technology which provides us with a valuable work experience.

## Introduction

The autonomous ground vehicle (AGV) will operate by itself once turned on. A differential drive system will able the AGV to change directions. This system allows for pinpoint maneuvering as it can swivel around a fixed point to turn. Obstacle detection is done using image processing. Once a predetermined image is seen, the processors can evaluate what direction the AGV should go to avoid a collision. As a precautionary measure, a LIDAR system will be used as a back up to the image processing unit. Path following is also done by image processing. If the side of the AGV gets too close to the lane boundary, then the processors will turn the AGV towards the correct path. Emergency stops are also implemented on the AGV. There is a mechanical stop attached the back of the vehicle as well as a wireless push button held by the judges. A more detailed analysis of these components, as well as any steps needed to fix common problems, is described throughout this report.

## Functional Analysis/Functional Diagram

The course created for the robot to navigate depends mainly on two concepts: the concept of depth and color sensing, and the concept of object recognition. Sensors have advanced to the point where it is now economical to do the first concept with a sensor alone. The sensor chosen, a ZED 2k Stereo Camera from STEREO Labs, offers both color and depth sensing in amazing definition. ZED offers depth and color sensing officially up to 15m in any lighting and precipitation conditions. ZED builds a 3D point cloud of the area with color and depth identified. Using a PCL, a software library for transforming 3D point clouds, that information can be turned into a 2D map from which obstacles may be identified. That information is then saved into a growing database of information on obstacles present in the course and used by the algorithm to identify the best path through the course. The data is retrieved using C++ and CUDA libraries stored on the NVIDIA Jetson board.

The actual representation of data is kept as minimal as possible. The robot only knows three kinds of data: obstacles, GPS waypoints, and flags. A line is an obstacle, a fence is an obstacle, a barrel is an obstacle; this determination means that the robot needs to know nothing other than the locations of obstacles and waypoints. Every time the robot takes a snapshot of its surroundings, it catalogues the obstacles and then places them in its current existing map. The robot starts with paths to all of its destinations marked out, as paths become infeasible (an obstacle is added to its known map) the robot deletes and modifies paths. Once an updated map is reached, the robot then adjusts to calculate the known path to its next destination.

With the path known the robot then plots a course to that point in real time and navigates to that point. The data is passed through ROS, an open source operating system for robots through a serial port on the NVIDIA Jetson and to two Pololu Motor Controller which handles one motor each. A case diagram is shown in Figure 1.

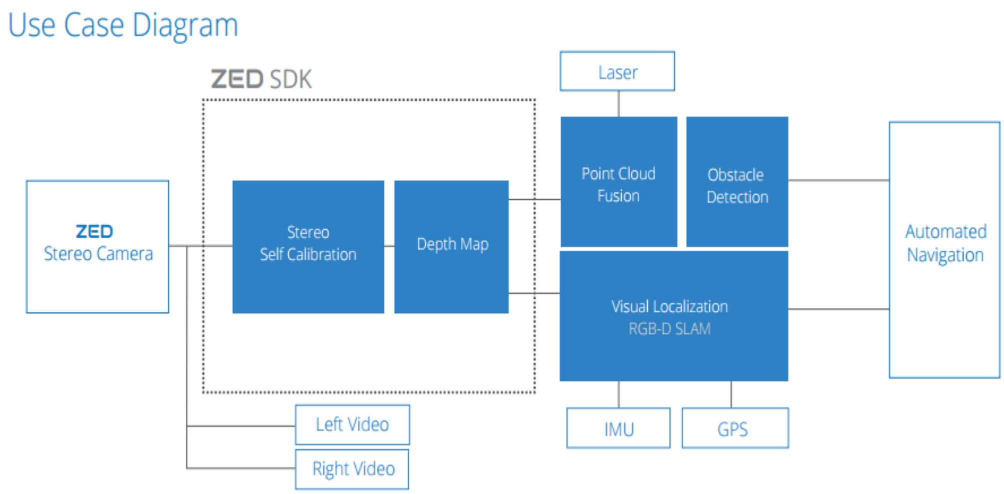


*Figure 12: Case diagram of the ZED 2k Stereo Camera*

## Project Specifications

NVidia Jetson TXI

*Figure 13: NVIDIA Jetson Tx1*

*Table 5: NVIDIA Jetson Specifications*

| General | Technical Specifications |
|---|---|
| **Power** | Micro USB socket 5V, 2A |
| **CPU** | 1.73 GHz ARM® Cortex® -A57 MP Core (Quad-Core) Processor with NEON Technology |
| **Memory** | 4 GB RAM |
| **Size** | 50 mm x 6.25mm x 87 mm |
| **Weight** | 75g |
| **Operating Voltage Range** | 5.5~19.6V |

Raspberry Pi B+


*Figure 14: Raspberry Pi B+*

*Table 6 - Raspberry PI 2 Model B+ Specification*

| General | Technical Specifications |
|---|---|
| **Power** | Micro USB socket 5V, 2A |
| **Size** | 85 x 56 x 17mm |
| **Current Consumption** | 700 – 1000 mA |
| **Chip** | Broadcom BCM2835 SoC |
| **CPU** | 900MHz quad-core ARM Cortex-A7 |
| **Memory** | 1 GB RAM |

*Table 7- Raspberry PI 2 Model B+ Connectors*

| General | Connectors |
|---|---|
| **GPIO Connectors** | 40 GPIO pins (+3.3V, +5V and GND) |
| **USB** | 4 USB 2.0 |
| **Video Output** | HDMI |
| **Ethernet** | 10/100 BaseT Ethernet socket |
| **Memory Card Slot** | SDIO |

## ZED 2K Stereo Camera


*Figure 15: ZED 2K Stereo Camera*

*Table 8 - ZED 2K Stereo Camera Specifications*

| General | Technical Specifications |
|---|---|
| **Size** | 33 x 30 x 175 mm |
| **Weight** | 159g |
| **Operating Voltage** | 5.5V |
| **Power** | 380 mA |
| **Field of View** | 110° |
| **Depth Range** | 15m |

## Pololu High-Power Motor Controller

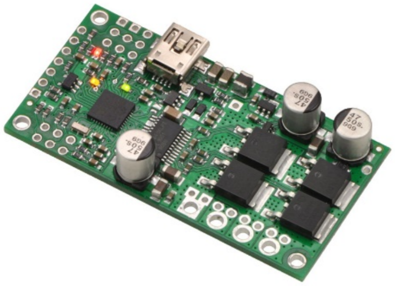

*Figure 16: Pololu High-Power Motor Controller*

*Table 5 - Pololu High-Power Motor Controller Specifications*

| General | Technical Specifications |
| --- | --- |
| **Size** | 2.3 x 1.2 x 0.4 in |
| **Weight** | 12g |
| **Maximum Operating Voltage** | 30V |
| **Minimum Operating Voltage** | 5.5V |
| **Continuous output current per channel** | 25A |
| **Maximum PWM frequency** | 21.77 kHz |
| **Motor Channels** | 1 |
| **Control Interface** | USB; non-inverted TTL serial; RC servo pulses; analog voltage |

PG27 Planetary Gearbox with RS775 Motor and Encoder

*Figure 17: PG27 Planetary Gearbox w/ RS775 Motor and Encoder*

*Table 6 – PG27 Planetary Gearbox w/ RS775 Motor and Encoder Specifications*

| General | Technical Specifications |
|---|---|
| **Weight** | 1.6 lbs. |
| **Size** | 6.125 in |
| **Gearbox Reduction** | 26.9:1 |
| **Voltage** | 12 V DC |
| **No Load Current** | 0.6 A |
| **Stall Torque** | 6.3 ft-lbf |
| **Stall Current** | 22 A |

*Table 7 – Encoder Specifications*

| General | Technical Specifications |
|---|---|
| **Pulses per revolution** | 7 |
| **Operating voltage** | 5 V |

<u>Xbee 802.15.4 Module</u>

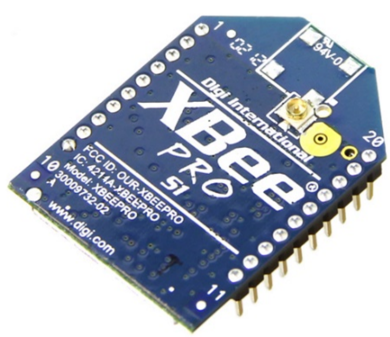


*Figure 18: Xbee 802.15.4 Module*

*Table 8 – Xbee 802.15.4 Module Specifications*

| General | Technical Specifications |
|---|---|
| **Operating Frequency** | 2.4 GHz |
| **Range** | 300 ft. |
| **Transmit Current** | 45mA |
| **Receive Current** | 50mA |
| **Operating Voltage** | 3.3V |
| **Data Rate** | 250 kbps |
| **Receiver Sensitivity** | -92 dBm |

## Product Assembly

### Frame


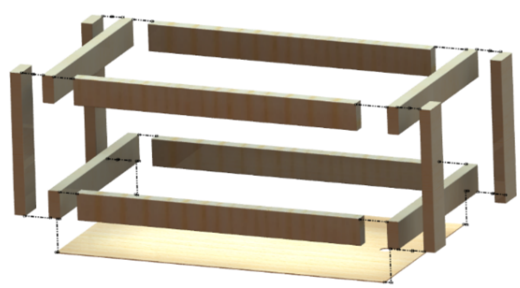

*Figure 19: Prototype frame (left) and exploded view (right)*

### Motor Mounts

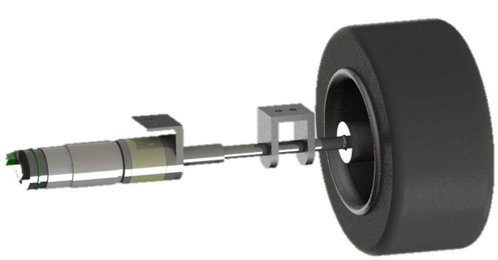
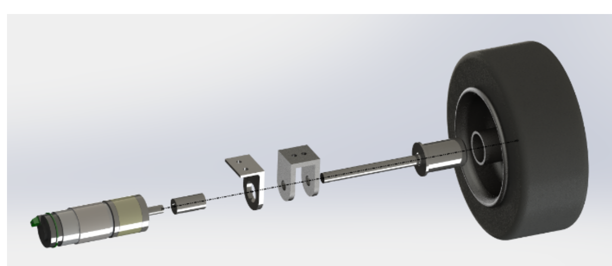

*Figure 20: Motor mount assembly (left) and exploded view (right)*

Electronic Housing Compartment

*Figure 21: Electronic housing compartment (left) and exploded view (right)*

Complete Prototype Assembly

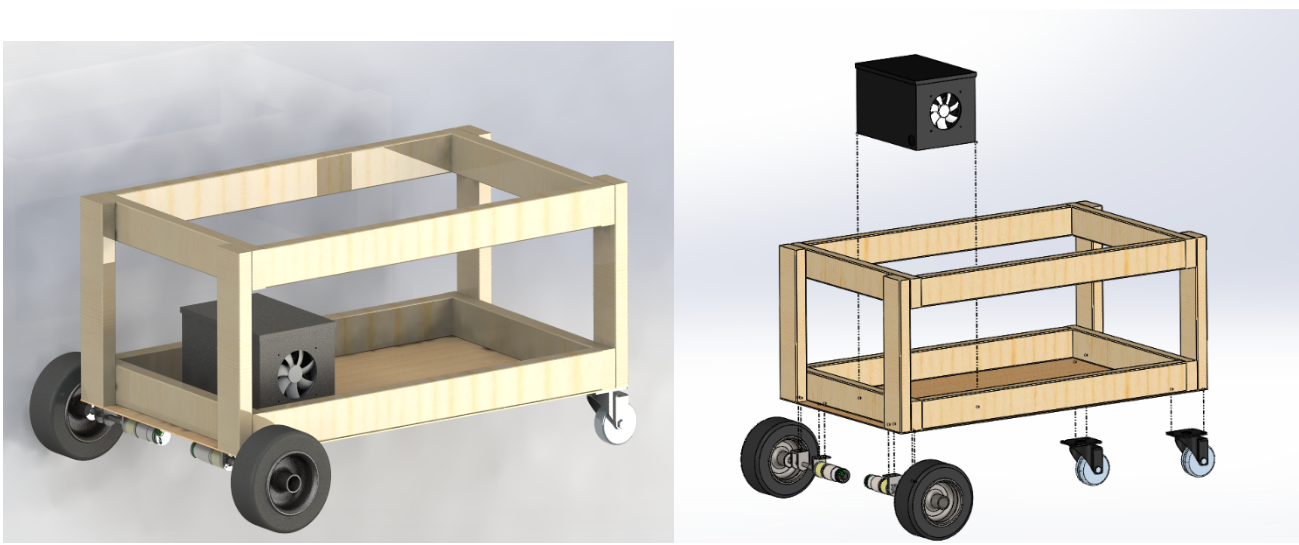

*Figure 22: Completed Prototype Frame (left) and exploded view (right)*

## Operation Instructions

*Start – Up Instructions*

In preparing for driving, some preliminary checks must be done to ensure the vehicle can move in a safe fashion. These checks involve doing a visual and manual inspection of all components. The frame must be free of defects such as holes, cracks, and erosion of materials that could limit the functionality of the vehicle. The two front tires must be spun by hand to ensure full free rotational status of the motors. Wiring from the motors and encoders must be traced to their initial point to confirm all connections are properly made and that there are not faulty wires that will short circuit or cause any damage to other components. If any of these occur, wires must be properly disconnected and replace prior to operation. All battery sources must be inspected to ensure they not only contain a full charge; but they also do not have any corrosion due to excess discharge. The safety light must be tested to certify full functionality as well. Following the above procedure, a battery source must be connected to the motor controllers to supply power to the motors, microprocessors and the cooling fan within the electronic box. At this point, all necessary components will have been assembled. After assembly, the vehicle is now ready to be turned on. A solid indicator light will used to verify the vehicle is on. All systems within the vehicle must now be booted and tested to verify that each sensor is receiving power from their respective microprocessor and receiving and transmitted accurate data. Once all systems have checked out, it is now time to operate the vehicle.

*Autonomous Mode Instructions*

The vehicle will remain stationary until the autonomous mode is triggered via push button. Only then will the light go from solid to flashing. While in this mode the vehicle will be moving hands free; the sensors will help to maneuver the vehicle around objects and detect lane patterns.

*Shutdown Instructions*

The vehicle can be taken out of autonomous mode two ways: mechanical emergency stop or wireless emergency stop. As soon as the vehicle comes out of autonomous mode the light will go back to solid. The mechanical emergency stop is a red push button located on the vehicle that will bring the vehicle to a quick and complete stop. On the other hand the wireless emergency stop, which will be held by the judges, once activated will send a signal to motor controller that will completely stop the vehicle as well. After the vehicle is stopped, all batteries must be disconnected and stored in the temperature regulated area for immediate charging. This is detrimental for the lithium ion polymer to prolong the usage of these batteries. Any systems changes must be made after disconnection of batteries to avoid short-circuiting components.

## Troubleshooting

A number of problems can be encountered while operating this vehicle, which include but are not limited to:

**Sensors not receiving data**

1. Check connections to microprocessors
    a. Unplug and re-plug wires to microprocessors
        i. Re-ground all wires
        ii. Plug wires into different input and output ports
    b. If the sensor is plugged into a USB hub, unplug the hub and then plug it in again.
        i. Connect the sensor to another port on the microprocessor

ii. Plug the hub into a different USB port on the same computer.
iii. Make sure that you are using a powered hub that is appropriate for the device.

2. Check the power
    a. Make sure the correct amount of power is supplied to the device. For information about proper power supply, see the documentation that was included with the device.
3. Reset the power to the device
    a. If your device has a power switch, turn the device off.
    b. If your device has removable batteries, remove the batteries and reinstall them. Make sure that they are positioned correctly.
    c. If your device has a power switch, turn the device on.

**Vehicle not turning on**

1. Check that the batteries are fully charged
    a. Make sure the battery has a charge that will power the vehicle. See specifications for components to ensure correct voltage and current outputs

**Caution: Do not over charge the battery**

2. Check battery connections
    a. Check to be sure the battery connector is plugged tightly into the motor drivers. Replace wiring connections if necessary.
3. Check electrical system
    a. Exposure to water, moisture, and dirt can damage or corrode the vehicles electrical system.
4. Replace battery
    a. If battery is old and will not accept full charge.

**Vehicle not moving**

1. Check front motors
    a. The vehicle is equipped with two front motors, make sure each motor is properly connected to their respective motor driver.
2. Check for overloading
    a. Do not exceed the necessary weight limit for the vehicle to strain motors.

**Wireless signal lost for the emergency stop**

1. Check the connection between receiver and transmitter
    a. Make sure that is no interference between the access points.
    b. Clear any object from the path of the transmitter.
2. Check to see that all local and remote setting are enabled

    a. Make sure all remote and local settings are established.
3. Check to see if the network is in the proper range.
    a. Make sure both modules are within the properly detection range of no greater than 90m indoor/outdoor.
4. Check to ensure all data packets from were successfully delivered.
    a. Make sure API operation mode is enabled to ensure packets are sent as a whole from one module to the other.
    b. Each packet provides destination information, network diagnoses and a frame id for monitoring.
5. Refresh the wireless connections
    a. Re-establish a wireless link between modules either manually or automatically
    b. Reset to default values.

**Vehicle behaving erratically**

1. Immediately stop the vehicle
2. Check all electrical system components
3. Re-calibrate PID control values

**Image Processing**

1. If the simulation runs but collects incorrect data, then the algorithm in the simulation needs to be adjusted
2. If the data collected is accurate, and there is still an issue
    a. ZED is unresponsive, needs to be replaced
    b. ZED is responsive, then the data cannot be visualized
        i. Use PCL library to construct a map step by step to spot anomalies

**Other difficulties**

For all other problems, please refer to the product guides and specifications or any other help guides. The internet provides a plethora of forums that will allow for easy troubleshooting of devices.

## Regular Maintenance

The design of the autonomous ground vehicle incorporates both motion components as well as electrical components. As outlined in the operation section, start-up and shutdown instructions should be followed both pre and post operation of the vehicle to avoid damage or injury. The motors and battery are vital pieces to the successful operation of the vehicle and should be regularly checked. As long as maintenance is done efficiently and properly, the lifespan of the direct current motors will be favorable. It is recommended wipe off dust, dirt and oils monthly and avoid wet conditions that could cause them to rust. A noise and vibration inspection should be conducted monthly to ensure no electrical or mechanical imbalances exist. The lithium ion polymer batteries selected have considerably low discharge, which increases the shelf life or idle time of them. The batteries require delicate care to guarantee the maximum usage before replacement. Overcharging, misuse, and bad storage can cause the lifespan to decrease in the batteries and reduced capacity. It is recommended to keep them clean and dry, out of contact with random metal objects and at a safe, non-extreme temperature. If replacement is necessary, it is recommended to cycle the new batteries a few times to help recover any lost capacity while in storage.

## Spare Parts

Safely operating the vehicle is essential to minimizing the need for spare parts, however batteries recommended to have as a spare part because there is higher risks of these being damaged and having a need for replacement. Spare wiring cables are also recommended to avoid connection lost and short-circuiting.

## Appendix A

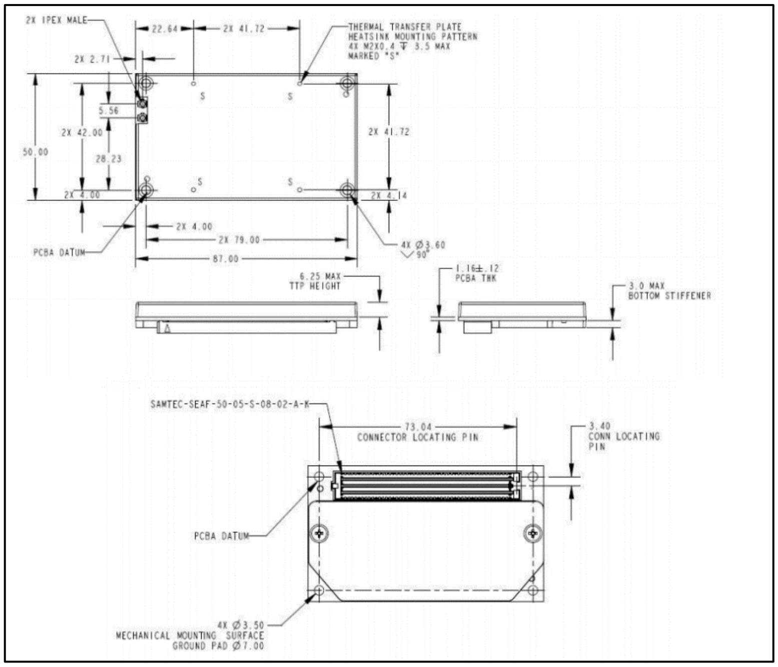


*Figure A-1: NVIDIA Jetson CAD*

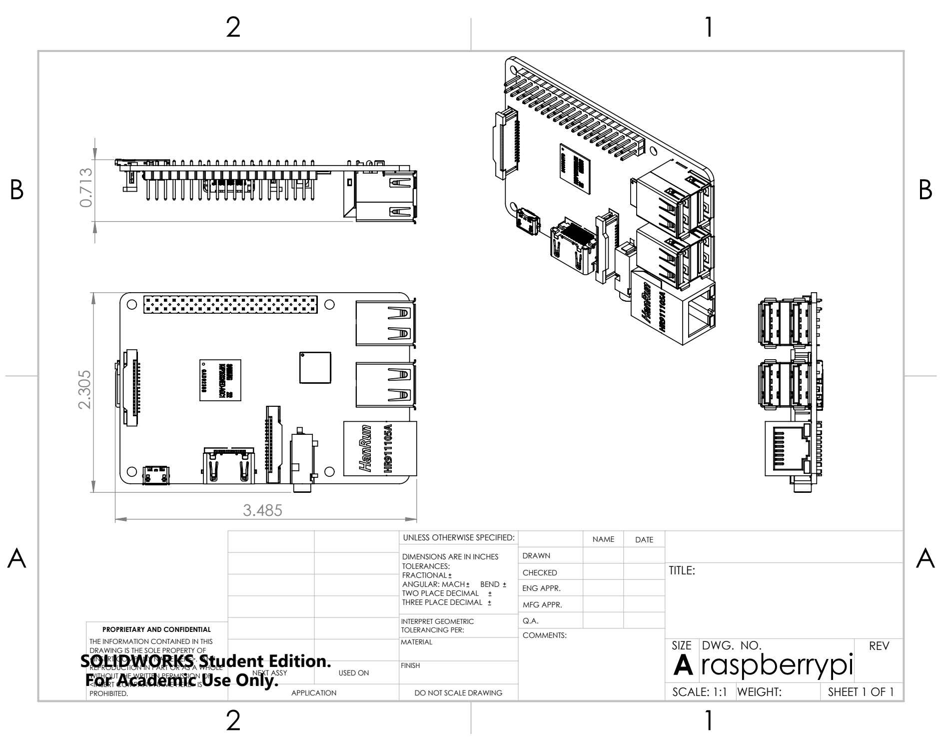


*Figure A-2: Raspberry Pi B+ CAD*

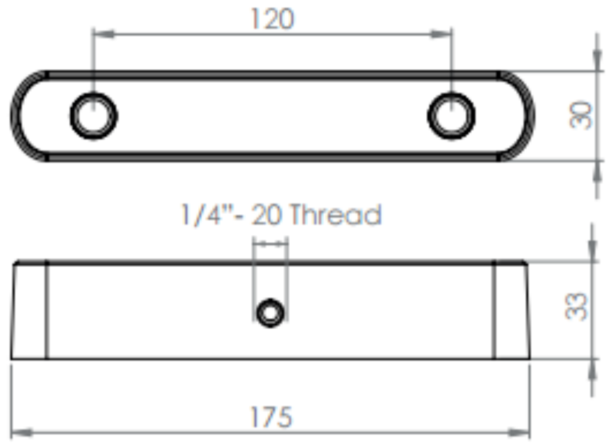


*Figure A-3: ZED 2K Stereo Camera CAD*

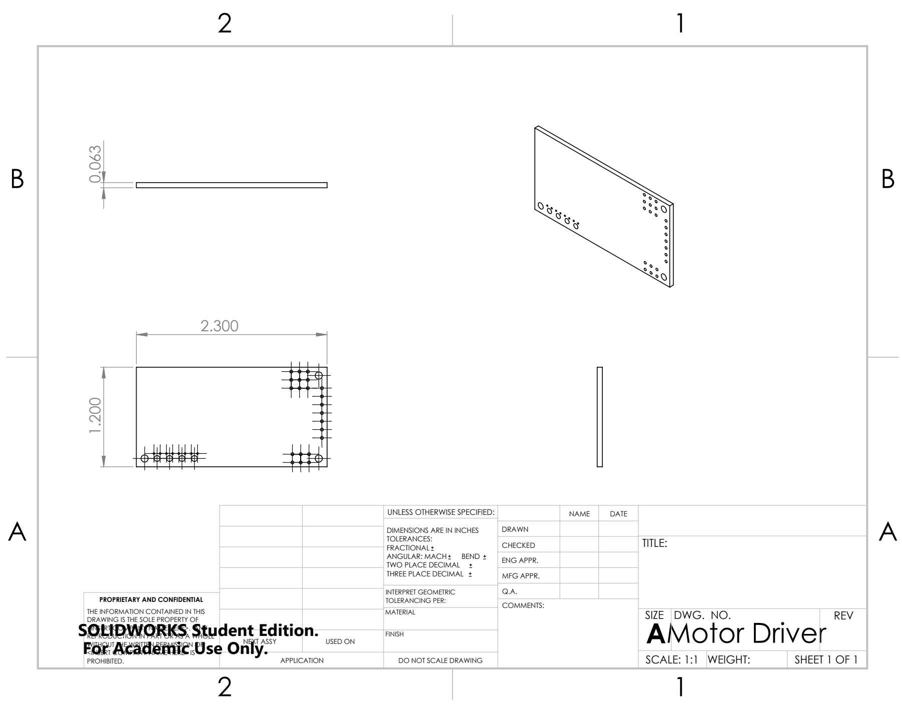


*Figure A-4: Pololu High Powered Motor Controller CAD*

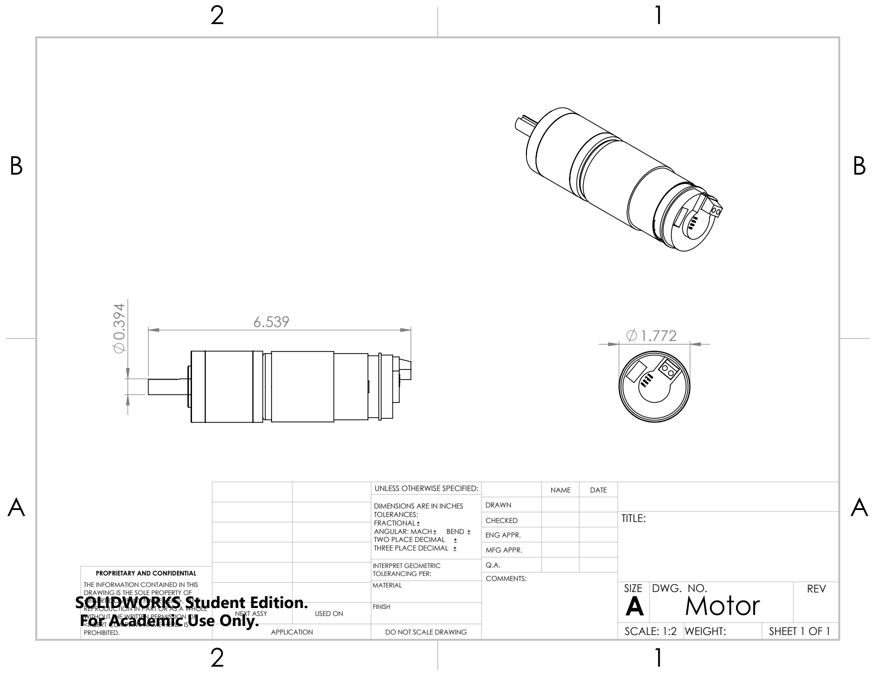


*Figure A-5: Planetary Gearbox w/ RS775 motor and encoder CAD*

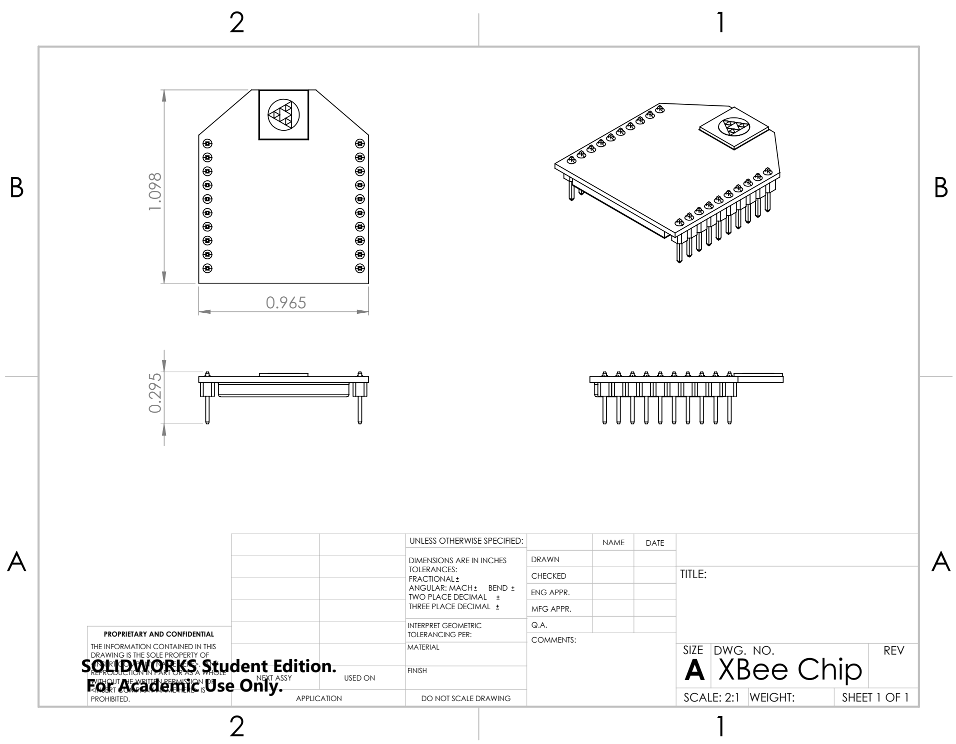


*Figure A-6: Xbee 802.15.4 Module CAD*