Transnavigators

Voice Controlled Wheelchair

Fall Report

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Executive Summary

The Transnavigators' Voice Controlled Wheelchair is a multipurpose platform, which can turn nearly any existing chair into an autonomous voice controlled wheelchair. Users can attach their own wheelchair to the platform, which will enable their wheelchair to autonomously navigate itself throughout the room. The platform can fit any standard sized wheelchair and can navigate to specific points of interest with voice commands. A conceptual model is shown in Figure 1.

The wheelchair will assist users by bringing their wheelchair to them and optionally transporting them to known locations throughout the room. Unlike most motorized wheelchairs, which are commanded using a joystick, users can command this wheelchair naturally, using voice commands.

Figure 1. Full System with Wheelchair

Many technical issues arose from meeting design requirements while addressing design constraints. An example from the mechanical design was that the dimensions of the platform were one of the most nuanced aspects of the chassis design. The platform is designed with the following requirements in mind: the ability to hold a wheelchair, the ability to provide enough clearance for the light detection and ranging (LIDAR) sensor, and minimizing the distance from the ground for stability. The width of doors and slope of ADA accessible ramps also constrained the design. An example of an issue from the electrical design was providing enough power for each component. The motors require 24 V, but some of the sensors require 5 V and 3.3 V. In addition, each component has its own current demands.

A number of issues still exist. Currently, there is no way to attach the wheelchair to the platform. In addition, a ramp still needs to be designed to allow users to move off and on the platform. The gearing setup is not finalized. Since a prototype has not been built, many hidden challenges lie ahead. The control system has also not been implemented and the difficulty of this task is currently unknown.

Introduction

The Transnavigators' Voice Controlled Wheelchair will increase people's independence by autonomously navigating them to their destination using voice commands. It is a platform that users can attach to their existing wheelchair, allowing them to continue using their favorite chair while enjoying the benefits of an autonomous wheelchair. In situations where their wheelchair is far away, users can simply ask Alexa, and the chair will automatically navigate itself to their position. In addition, after they get onto their chair, the user can use directional and destination commands to navigate to a desired location. The voice controlled wheelchair has possible applications in a hospital setting where patients can ask Alexa for their wheelchair and the wheelchair will navigate itself to them automatically. The patient can then either take the wheelchair off the platform and propel themselves or continue using voice commands and have the wheelchair navigate for them.

Background

Right now, when someone needs a wheelchair, another person must bring them one. Typically, patients with disabilities either always have a wheelchair nearby or they have an in-home care nurse who can help them into their wheelchair. In a hospital or home setting, this means the patient needs to flag down a nurse and ask them to bring a wheelchair. This person may need a nurse for other reasons such as getting into the wheelchair, but some people are independent enough to move once a wheelchair is nearby.

Some progress has been made in the way of autonomous wheelchairs, which can navigate autonomously to patients. This progress is a consequence of the research and development of autonomous cars, which can be applied to wheelchairs. In 2009, MIT's Computer Science and Artificial Intelligence Laboratory created a voice-controlled autonomous wheelchair from an existing electric wheelchair.[1] In 2016, the Singapore-MIT Alliance for Research and Technology developed and tested an autonomous wheelchair in Singapore's Changi General Hospital.[2] The prototype was a modified electric wheelchair that uses a touch screen for navigation controls and maps a room using three LIDAR sensors. LIDAR is a surveying method that uses light to detect the distances to nearby objects, typically used for collision avoidance and navigation in autonomous cars.

Other autonomous wheelchairs are being tested. The WHILL NEXT is an autonomous wheelchair designed by Panasonic and WHILL Inc.[3] It is controlled via smartphone and uses image recognition to navigate and detect obstacles. It borrows its futuristic design from other WHILL wheelchairs and technology from HOSPI, an autonomous delivery robot at Changi General Hospital.[4] Its primary use is to provide a fleet of wheelchairs to travelers at an airport moving on a single path. The WHILL NEXT can also sync with nearby wheelchairs to form a column and return to its home base when done.

The idea of having an autonomous wheelchair is not new. A patent has been filed in 2002 for a computer-controlled power wheelchair navigation system.[5] With five years left on the patent, advancements in other fields are now making the idea practical to implement. Automobile manufacturers are developing autonomous cars, which require low cost LIDAR sensors. Several companies such as Velodyne and Quanergy are trying to drive down production costs of LIDAR sensors to meet the demands of automobile manufacturers and consumers. There have also been recent developments in indoor positioning systems (IPS). GPS is inaccurate indoors, so a different system must be used for positioning. Bluetooth Low Energy and Wi-Fi IPS have been adopted for indoor positioning, using cell phones for retail advertising and analysis. DecaWave developed a sensor with applications in IPS using ultra-wideband transceivers for tracking items or vehicles in industrial applications.[6] As the patent grows closer to expiration and LIDAR and other sensing technology improves with autonomous vehicle development, the market potential for autonomous wheelchairs will expand.

Analysis

Choosing System Solution

The platform design was chosen after considering several other solutions. One design was to adapt a folding wheelchair and attach motors to it and another was to create attachable motorization. In both designs, the sensors needed for navigation would also be attached to the

[1] Teller, Seth et al (2009).
[2] Teo, Pauline (2017).
[3] Panasonic Corporation (2017).
[4] Panasonic Corporation (2015).
[5] Fehr, L. (2002).
[6] DecaWave (2015).

wheelchair. The largest flaw with adapting a wheelchair was that the user would be restricted to using that specific wheelchair. A conceptual sketch of this idea is available in Appendix A-1. The largest flaw with the attachable motorization was the complexity of the design. One other concerning flaw with both designs was determining where to mount the LIDAR so that it could detect where obstacles were without being in the way of the user or being obstructed by the user. The platform does not have any of these flaws. The user can attach their existing wheelchair to the top, thus simplifying the design of the drivetrain and chassis. This also allows the LIDAR to be easily mounted to the bottom of the platform where the only obstructions will be the wheels. The following sections on Chassis Design and Drivetrain Design discuss the design process related to developing the platform.

Chassis Design

Design Considerations

There were several design considerations when designing the chassis. It needs to be wide, rigid, and strong enough to hold the wheelchair. The design must have the space to accommodate the electrical components and have enough bottom clearance for the LIDAR sensor while remaining as low as possible to the ground for the stability and comfort of the rider. In addition, it should be powerful enough to clear 5-degree inclines all while remaining reasonable to manufacture and not excessively heavy.

First Iteration

This design was intended to be made fully out of quarter inch aluminum, assumed directly driven wheels, and provided just enough clearance for the LIDAR. This lack of adequate tolerance was the main reason for moving onto a new iteration of the design. Other concerns were the two-inch castor wheels and the construction of the chassis. The castors may not be able to overcome small bumps or defects in flooring. The chassis construction was not clearly shown. This design is shown in Appendix A-2.

Second Iteration

This design was created to directly address the construction and clearance concerns. It utilized a wooden platform with aluminum square channels for structure and support. The driven wheel was changed to six inches in diameter and the castors to four inches in diameter. All wheels were mounted completely below the platform. This led to issues involving the height, stability, and comfort of the user. These concerns necessitated a new iteration. This design is shown in Appendix A-3.

Third Iteration

This design tried to find a middle ground between the first and second iteration. The structure of the chassis reflected that of the first iteration, but the size of the driven and castor wheels reflected those chosen in the second iteration. The driven wheel was six inches in diameter and the castor wheels were three inches in diameter. Slightly smaller castors were chosen because of the need to constrict the swivel space as much as possible to allow the supports surrounding the driven wheel to be as close to the wheels as possible. This design is shown in Appendix A-4.

Fourth Iteration

This was an alternative design that tried to even more drastically reduce the height of the top of the platform by sinking the surface that the wheelchair would be sitting on between the wheels. The ADA specified distance between the outside of the large wheels on an adult wheelchair is 26 inches. The minimum width of a door is 32 inches.[7] The swivel radius of the castors was just under 3 inches. Based on these measurements, it was determined that the tolerance for fitting this platform through a door was too tight and unfeasible. This design and dimension consideration is shown in Appendix A-5.

Fifth Iteration

This design returned to a model most like the third iteration except with considerations made for changes in the drive system and increased clearance through doorways. This design uses gears, which entails more difficult machining because placement of holes and creation of gears must be very precise. With the added gears, less space was available in the middle meaning that this design cannot allow a wheelchair to be rolled onto it. The width of the chassis was decreased by two inches to allow for more clearance through doorways because the wheelchair will no longer be rolled onto it. This design is shown in Appendix A-6.

Sixth Iteration

This design was created to address the needs of machining and creation. It utilizes 2x4 lumber and 1/2" and 1/8" plywood for structural materials. The drive train utilizes sprockets and chain. This was chosen as the power transmission system because it is easy to adjust and has high tolerances so precision when drilling holes for bearings and shafts is not required to be high. Since sprockets are being used, this also allowed for the slimming of the space needed for the drive elements, allowing enough space on top of the platform for the wheelchair to be rolled on. This design also began to analyze the space and placement of the motors and other electronic components other than the LIDAR as shown in Appendix A-7.

Drive System

The drive system chosen was a tank drive utilizing two independently driven wheels in the middle of each side of the platform with a 360-degree swiveling castor on each corner. This design was chosen over three other tank drive trains and one mecanum after evaluating each design using a weighted design matrix as shown in Table 1. The criteria each drive train was

[7] Department of Justice (2010).

scored on was its overall simplicity, stability, cost, maneuverability, ease of programming, and weight. A description of criteria can be seen below in Table 2.

Drive Train

Two AmpFlow E30-150 motors were chosen to drive the wheelchair. When calculating for a vehicle that will be operating at a constant speed, the most important aspect of the motor to consider was the necessary power required to move the wheels. The free body diagram shown in Figure 2 was used to calculate the amount of force needed to hold a constant speed on a slope within ADA specifications, 4.8° or 1:12.[8] For all calculations a weight of 300 pounds was used.

The force needed to overcome rolling resistance was calculated using the following equation:[9]

$$F_{roll} = \frac{fW}{R} \qquad (1)$$

where *f* is the coefficient of rolling friction, *W* is the weight on the wheel, and *R* is the radius of the wheel.

Due to the undeterminable location of the center of gravity, it was assumed that the back two sets of wheels took 40% of the weight each while the front two casters took the remaining 20% of the total load. The rolling frictions coefficients were conservatively assumed to be $8.52 * 10^{-3}m$ and $4.22 * 10^{-3}m$ for the solid tire drive wheel and standard front and back casters, respectively.[10] The total force needed to overcome rolling friction and the x-component of the weight was calculated to be 41.7 pounds. The force required to initiate motion is generally 2.5 times as large, ballooning the required force due to static friction to approximately 104 pounds.[11] To make sure slipping would not occur the maximum force due to static friction was also calculated and determined to be approximately 194 pounds, which exceeds the magnitude required.[12]

[8] Department of Justice (2010).
[9] Lippert, Dave et al (2012).
[10] Christophe Sauret et al. (2012).
[11] Lippert, Dave et al (2012).
[12] Hirai Ikuko and Gunji Toshihiro (2001).

Table 1. Drivetrain Design Matrix

Drivetrain Design	Simplicity (x5)	Stability (x5)	Cost (x4)	Maneuverability (x3)	Programming Ease (x3)	Weight (x2)	Total
Tank: Center drive wheel direct to motor- one on each side, 4 castors on corners	8	9	5	6	6	5	151
Tank: Four driven wheels, motor at center of each side, chain driven	7	7	5	6	5	5	133
Tank: 6 wheels, back four driven by chain, one motor on each side	7	9	4	6	5	5	139
Tank: Tank treads/tracks, two motors- one on each side	6	9	4	6	5	4	132
Mecanum: 4 mecanum wheels each driven independent of each other	5	7	3	9	4	5	121

Table 2. Description of drivetrain design matrix criteria

Criteria	1	5	10
Simplicity	Overly complicated and intricate mechanical design, requires special machining, programming is difficult	Neutral/Average	Most simple mechanical design and programming possible
Stability	Very wobbly and prone to tipping	Neutral/Average - 50% chance of stability issues (tipping, wobbling)	Extremely stable, no wobbling or tipping possible
Cost	Extremely expensive to manufacture, parts are expensive and numerous, far exceeds conceived budget	Neutral/Average - on conceived budget	Cheapest configuration wrt type and amount of materials and machining, much less than conceived budget
Maneuverability	Very clunky movement, large turning radius, difficult to move around obstacles	Neutral/Average	Extremely maneuverable, able to navigate tight turns or move in a variety of directions
Programming Ease	Difficult to program and control movement	Neutral/Average	Easy system to program and control
Weight	Weight to size/volume ratio is extremely high	Neutral/Average	Weight to size/volume ratio is extremely low

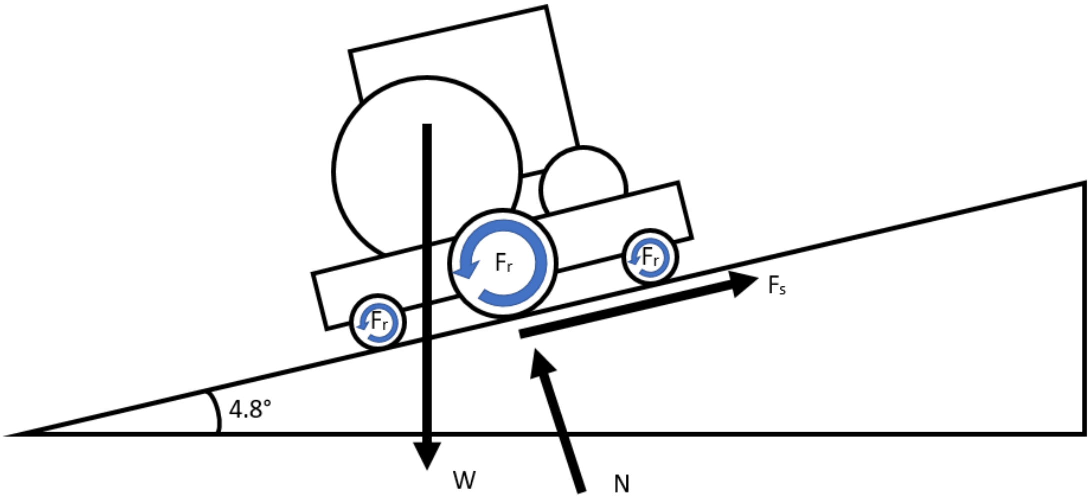

Figure 2. Free body diagram of a six-wheel drive system holding a wheelchair and an operator on the maximum slope ramp within ADA specifications. $W = Total\ Weight$ and is acting straight down at a location-assumed center of gravity, $N = Normal\ Force$, $F_s = Force\ due\ to\ Static\ Friction$ between the wheels and the assumed carpet floor, and $F_r = Force\ Needed\ to\ Overcome\ Rolling\ Resistance$.

To determine the power the motor would need to output, a desired speed of 4 mph was selected. This speed is around that of existing motorized wheelchairs and slightly faster than walking speed, making it an appropriate goal. It is also the upper speed limit of Class 2 motorized wheelchairs in the United Kingdom as stated by their Highway Code.[13]

Power was calculated using the following equation:

$$P = F_{static} * v \tag{2}$$

where F_{static} is the friction required to maintain a constant speed and v is the desired cruising velocity.

The power required to maintain a speed of 4 mph was calculated to be approximately 166 Watts. The AmpFlow E30-150 motors were selected because they have a peak efficiency at a power output slightly higher than what was calculated as shown in Figure 3. This buffer aims to serve as a factor of safety since conservative values were used in the calculations. Several things like the tires' moments of inertia and power loss from transitioning between gears were assumed to be negligible. The selected motor also has a peak power output of 725 Watts, which will be necessary for powering the startup of the vehicle.

The desired rpm of the drive wheel at a maximum speed of 4 mph was calculated using the following equation:

$$\omega = v/R \tag{3}$$

After conversions, the ideal angular velocity of the wheel was calculated to be approximately 224 rpm. The rpm of the motor when it outputs around 166 Watts is approximately 5,250 rpm as

[13] Department for Transport (2015).

shown in Figure 3. The required gear ratio to convert between the two can be calculated using the following equation:

$$Gear\ Ratio = \frac{\omega_{in}}{\omega_{out}} \tag{4}$$

An ideal gearing down ratio of approximately 23.4:1 was calculated, and therefore is what will be used to operate the vehicle at 4 mph. This gear ratio will be obtained by combining two approximately 4.8:1 gear ratios. All gears will likely be connected via chain to limit the need for extremely precise machining and placement of holes in the chassis.

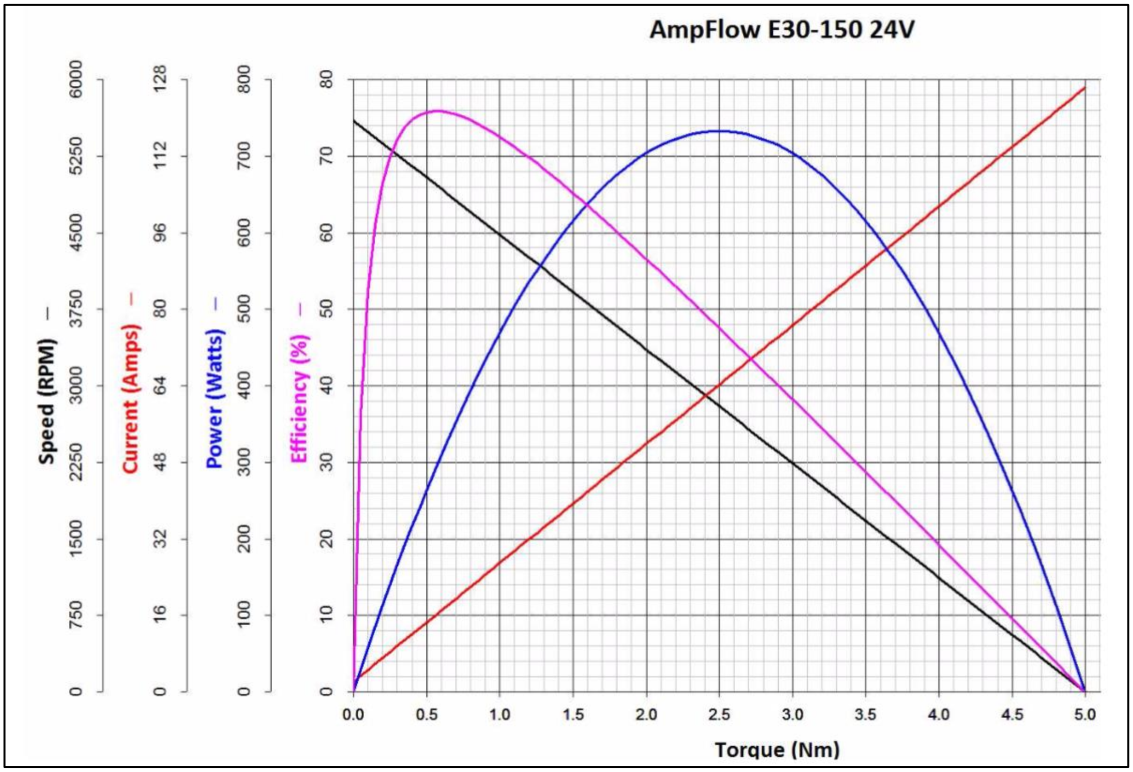

Figure 3. Motor performance graphs for AmpFlow E30-150 as displayed on their website.[14]

Power System

The wheelchair runs on a 24 V power system. Two 35 Ah 12 V Absorbed Glass Mat (AGM) batteries were purchased and connected in series to provide power for all the components on the chair. The current draw of the entire system was calculated to be about 44 A continuously and 264 A peak. These numbers are broken down in Table 3. For the wheelchair, the acceptable duration of drive time between charges was determined to be between 15 and 30 minutes, so 35 Ah batteries were fine for this purpose. A lead acid battery was chosen to power the wheelchair mainly because they are relatively inexpensive and can supply the large starting currents required

[14] AmpFlow (2012).

of the motors. The battery decision matrix is shown in Table 4 and the criteria is shown in Table 5. The specific type of lead acid battery chosen was an AGM battery. AGM batteries are a type of valve regulated battery (VRLA).[15] VRLA batteries do not need to be maintained like flooded batteries and can be positioned in any orientation without the danger of spilling. These are desirable features for the wheelchair because the orientation of the batteries and their maintenance do not to be worried about. In addition, these types of batteries are commonly used in motorized wheelchairs.

Table 3. Power requirements

Device	Voltage	Idle Current	Sys. Current	Peak Current	Recommend Current
Motor E30-150[16]	24V		17 A	127 A	
Motor E30-150	24V		17 A	127 A	
Raspberry Pi Model B	5 V	400 mA		1.2 A	2.5 A
Neato xv LIDAR Sensor	5 V	40 mA	135 mA		
Neato xv LIDAR Motor	3.3 V		60 mA		
Arduino Uno	9-24 V		500 mA	1A	
Rotary Motor Encoder (A6B2-CWZ3E-1024)	5-12V		100mA		
Rotary Motor Encoder (A6B2-CWZ3E-1024)	5-12V		100mA		
Localino Tag	5V		200 mA		

To step down the battery voltage to an acceptable level for the electronics, a Battery Eliminator Circuit (BEC) was purchased. Other alternatives considered included the LM2576 chip, a switching voltage regulator, and LM7805 chip, a linear voltage regulator. The LM2576, though efficient and cheap, could not be built on a breadboard and had to be soldered to a well-designed PCB according to several references.[17] The LM7805 chip though simple to incorporate into the system, was unable to supply the 2.5 A of current recommended for the Raspberry Pi.[18] The BEC purchased, Turnigy SBEC26, was advertised to provide a 5 V regulated output voltage for up to 5 A of current given an input voltage from 7 – 26 V.[19] After testing the chip, the maximum amount current that seemed to be safe was around 2.5 A. As a result, more BECs need to be purchased to power all the electronics. See Table 6 and Figure 4 for testing results.

A high-level diagram of the complete power system is shown in Figure 5. Notice that some of the microcontrollers are capable of powering other electronics and that different electronics need to be powered with 5 V and 3.3 V. For a detailed schematic, see Appendix B.

[15] Northern Arizona Wind & Sun (2014).
[16] AmpFlow (2012).
[17] Simkard (2011).
[18] Texas Instruments (2003).
[19] Vvbuy (2017).

Table 4. Battery Matrix

Battery Type[20]	Energy Density (x1)	Voltage Stability (x4)	Peak Current (x9)	Self-Discharge (x2)	Recharge Time (x1)	Cost (x8)	Reliability (x3)	Operating Temperature (x1)	Total
Nickel-Cadmium	5	8	9	7	8	8	7	6	231
Nickel Metal-Hydride	6	8	9	6	6	7	6	6	217
Lead Acid[21]	4	6	10	9	2	9	10	5	245
Lithium-Ion	9	5	6	8	6	5	4	8	165
Lithium-Ion Polymer	8	5	5	8	6	4	6	5	150

Table 5. Description of battery design matrix criteria

Criteria	1	5	10
Energy Density	Small amount of energy per kg/liter	Neutral/Average	Large amount of energy per kg/liter
Voltage Stability	Discharge affects voltage a lot	Neutral/Average	Holds a stable voltage while discharging
Peak Current	High ESR	Neutral/Average	Low ESR
Self-Discharge	Discharges quickly on the shelf	Neutral/Average	Holds its charge well on the shelf
Recharge Time	Charges very slowly	Neutral/Average	Charges Quickly
Cost	Expensive	Neutral/Average	Cheap
Reliability	Easily Damaged	Neutral/Average	Robust
Operating Temperature	Sensitive to fluctuations in Temperature	Neutral/Average	Insensitive to changes temperatures

[20] Chester, Simpson (2011).
[21] Northern Arizona Wind & Sun (2014).

Table 6. Turnigy SBEC26 Testing Results

Voltage (V)	Resistance (Ω)	Current(A)	Power (W)	Notes
5.12	O.C.	0	0	-
5.06	5.3	0.95	4.83	-
5	2.8	1.79	8.93	-
4.95	1.83	2.70	13.39	Plastic covering is sticky
4.45	1.42	3.13	13.95	Unstable (decreasing) voltage
3.71	1.12	3.31	12.29	Unstable (decreasing) voltage

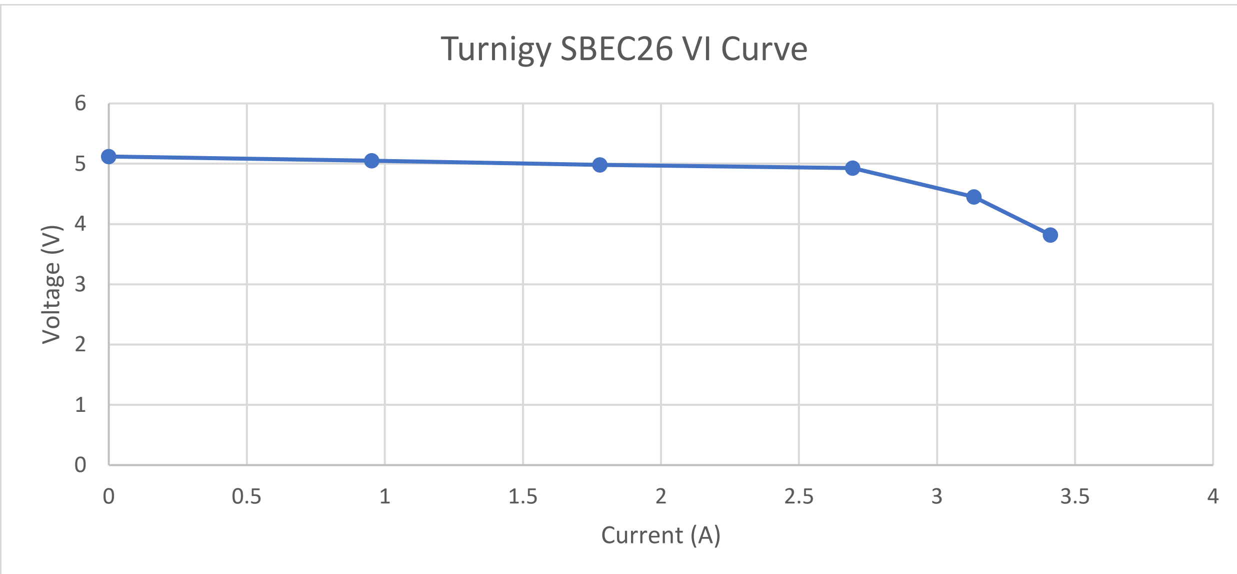

Figure 4. Turnigy SBEC26 Voltage vs Current Graph

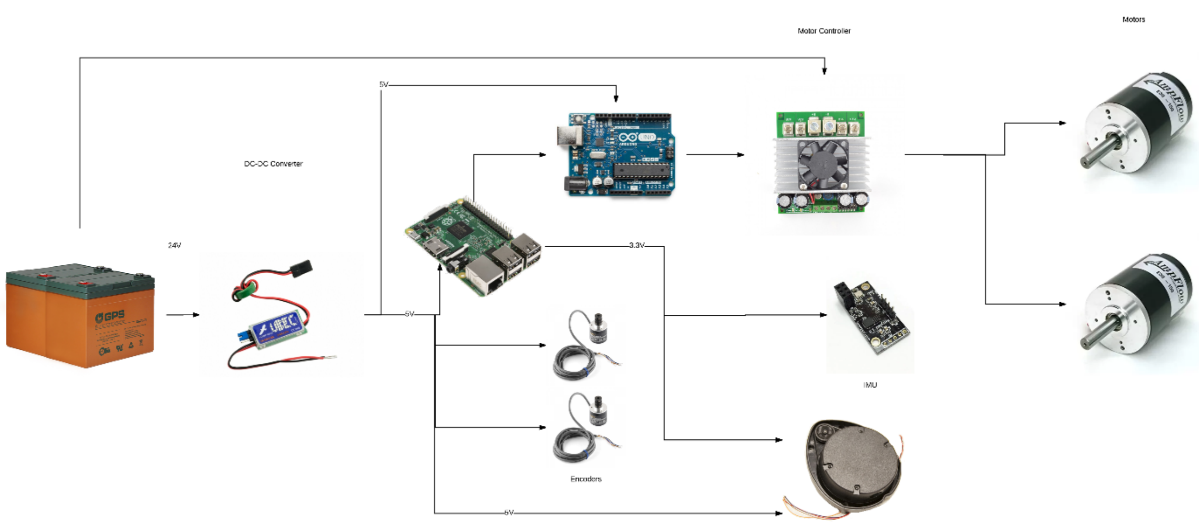

Figure 5. High level Power Diagram

Sensors

Positioning System

An accurate positioning system is necessary to give the wheelchair the capability of finding the user. A comparison of several positioning systems considered are shown in Table 7. The first type of positioning system investigated was the Global Positioning System (GPS). GPS normally is not very accurate, but enhancements exist that can give very precise positions, namely, Differential GPS (DGPS) and Real Time Kinematic (RTK). These technologies use special GPS receivers, which can correct errors in the satellite signal by using data received from reference stations with a known location. Preliminary research indicated that using any type of Global Positioning System (GPS) would not work for the wheelchair because GPS is not accurate indoors.[22] Signal attenuation and refraction through walls interfere with GPS calculations.

Next, Indoor Positioning Systems (IPS) were investigated. Several IPS services were available for free online including Wi-Fi based, beacon based, geomagnetic, and a combination of these. After testing the free services, none were found to be as accurate as they were advertised.

More research lead to the Decawave's DWM1000 chip, which is a chip designed specifically for positioning systems. Numerous online articles and videos demonstrated its accuracy. There are two companies actively developing positioning systems based on this chip. Since both companies' products are very expensive, the alternative of buying the DWM1000 chips and mounting them was considered. There is open source firmware and PCB Eagle schematics on GitHub, which are supposed to work with the chip.[23] Since the firmware on GitHub is not being actively maintained and can only support locating one object and building the board was too much of a technical risk, buying a system seemed like the best option. The system built by Localino was the cheapest, so this system was chosen.

Localization with the Localino system, requires a network of anchors and tags. Anchors are positioned in static, known positions around the room and tags are attached to the objects being tracked. For 2D positioning, three anchors are required. The supplied Localino firmware makes the anchors broadcast ranging data from the tags to the IP address 198.162.4.255. A network needs to be set up, which can accept and route these packets correctly. A server needs to read the packets, process the ranging data using software supplied by Localino, and transmit location data to the Raspberry Pi. An overview of the Localino system is shown in Figure 6.

[22] National Coordination Office for Space-Based Positioning, Navigation, and Timing (2017).
[23] Thotro (2017).

Table 7. Comparison of Location Technology

Technology	Name	Advertised Accuracy[24]	Pros	Cons	Cost	Testing Results	Notes
GPS	RTK	1cm	Accurate	Cost and indoor performance	$50ea[25]	N/A	GPS does not work indoors[26]
GPS	Differential GPS	10cm	Accurate	Cost and indoor performance	-	N/A	GPS does not work indoors
GPS	Phone GPS	5-8m	Cheap	Low precision	Free	N/A	GPS does not work indoors
Wifi	Find[27]	10ft	Free	Android required	Free	Unreliable	Inconsistent data
Bluetooth BLE	Bluetooth beacons	1.5m	Accurate	Not scalable	$2.60ea[28]	Unreliable	Inaccurate with sparse beacons
Geomagnetic	IndoorAtlas[29]	"High"	Free	Tedious mapping	Free	~10m	Inaccurate
Combination	Proximi[30]	1-2m	Accurate	Not scalable	Free	~8m	Inaccurate
LIDAR	LIDAR	3cm[31]	Cheap	Unreliable and complex	$119	N/A	Requires landmark system
Visual	Face recognition	~90%[32]	Cheap	Unreliable and complex	$48	N/A	Requires mounted camera
Sound	Sound localization	Unknown	Cheap	Unreliable and complex	-	N/A	Multipath interference
DWM1000	Pozyx[33]	10cm	Accurate	Expensive	599 €	N/A	Too expensive
DWM1000	Localino[34]	10cm	Accurate	Expensive	435 €	TBD	Selected this

[24] Koskiola, A. (2016).
[25] NavSpark (2017).
[26] National Coordination Office for Space-Based Positioning, Navigation, and Timing (2017).
[27] Find (2016).
[28] Shenzhen Eastwin Trading Ltd. (n.d).
[29] IndoorAtlas (2016).
[30] Proximi.io (2016).
[31] Konolige, Kurt et al (2008).
[32] Learned-Miller, Erik et al (2016).
[33] Poxyz (2016).
[34] Heuel & Loeher (2017).

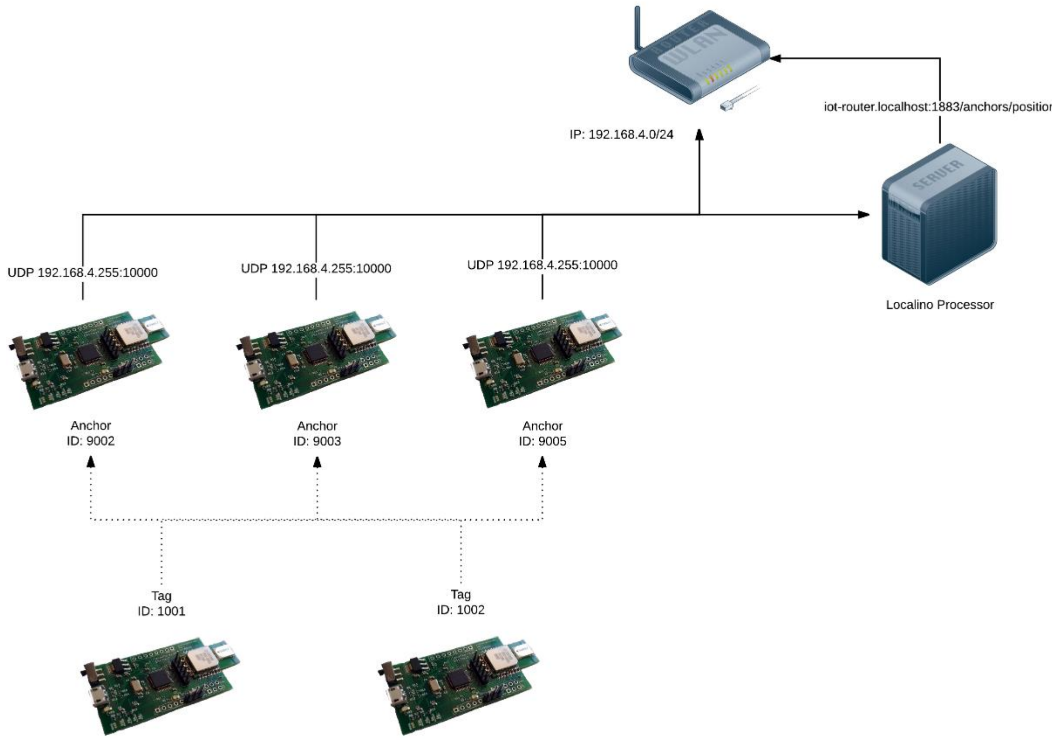

Figure 6. Localino System Diagram

Light Detection and Ranging (LIDAR)

LIDAR is a device used to detect obstacles around the wheelchair. The LIDAR sensor chosen, Neato XV11 LIDAR, uses a safe Class 1 laser to emit light pulses and an imager to detect when the light reflects back.[35] It can triangulate the distance to the nearest object tangent to the laser as shown in Figure 7 and collects a full 2D scan by rotating along its z-axis. This sensor will be used to detect obstacles in real-time to avoid collisions with people or objects. The Raspberry Pi will use the LIDAR's output to establish and update a map using a simultaneous localization and mapping (SLAM) algorithm.

[35] Neato (2013).

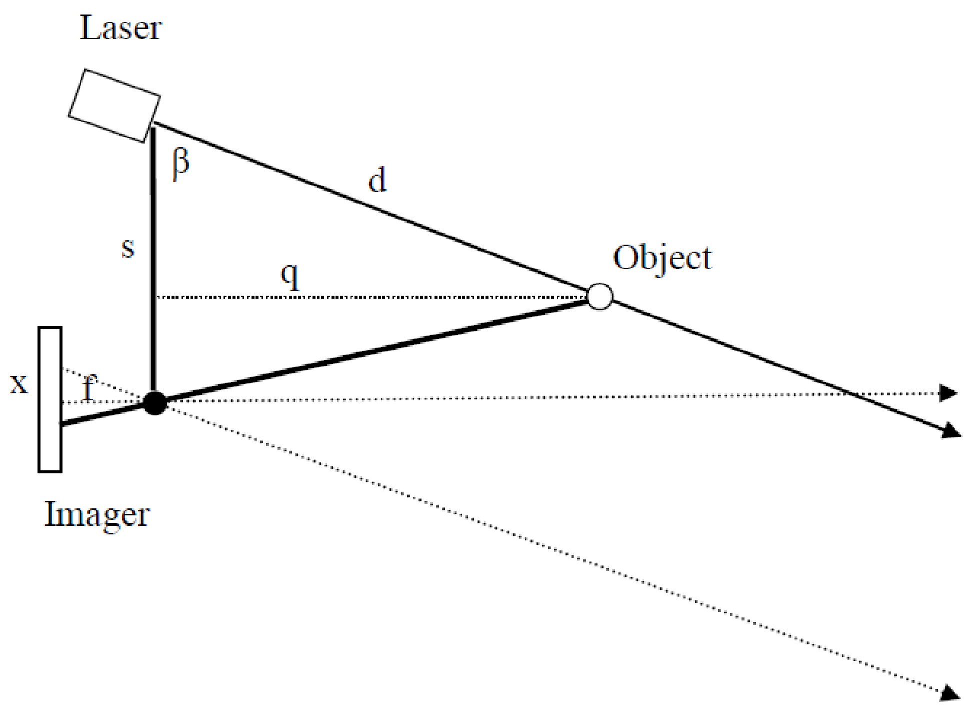

Figure 7. LIDAR triangulation diagram[36]

Encoder

An encoder is necessary to ensure that the motors are spinning at the correct rate. This sensor will be used primarily for determining the distance that the wheelchair travelled. When the user tells the wheelchair to turn a certain number of degrees or move forward a certain number of meters, the encoders will generate feedback to the microcontroller regarding how much the chair has actually moved so far. The encoder does this by generating a pulse every 0.35°.[37] The microcontroller will count these pulses and the time between them to determine position and velocity the chair. The encoder selected needs to have to have a resolution greater than the maximum speed of the motor. The encoder currently in consideration has a resolution of 6000 rpm, which is greater than the 5600 rpm of the motor at 24 V.

Inertial Measurement Unit (IMU)

The inertial measurement unit (IMU) is needed to establish the wheelchair's orientation and acceleration, independent of the wheels. An IMU consists of an accelerometer, gyroscope, and magnetometer.[38] The accelerometer will be used to detect when the tires no longer have traction, such as when the tires may slip on smooth surfaces. The magnetometer will be used as a compass to establish absolute bearings with the Localino.

[36] Konolige, Kurt et al (2008).
[37] Yumo (2015).
[38] Ozzmaker (2015).

Voice recognition

A voice recognition system is needed to receive voice commands from the user. Amazon Web Services (AWS) was chosen to provide voice recognition because it is free and widely used. Voice commands are recorded by Amazon's Echo Dot. Sound data is first sent from the Dot to Amazon Alexa, which process the speech into JSON, a data-interchange format.[39] This data is then routed through Amazon's serverless computing platform, AWS Lambda, and sent through Amazon's tool for the Internet of Things, AWS IoT, to a small computer where the speech data is used for controlling the wheelchair. A diagram of the data flow described is shown in Figure 8.

The voice interface currently consists of six main intents: LocateMe, MoveForward, MoveLeft, MoveRight, MoveTo, Stop. The LocateMe intent is a command where the wheelchair will find the user and navigate to them. The MoveForward intent moves the wheelchair forward a specified distance in meters but defaults to infinity if none is given. MoveLeft and MoveRight turns the chair in the respective direction a specified number of degrees and defaults to 45 if none is given. MoveTo navigates the wheelchair to a specified object or location in the room, and stop halts the wheelchair.

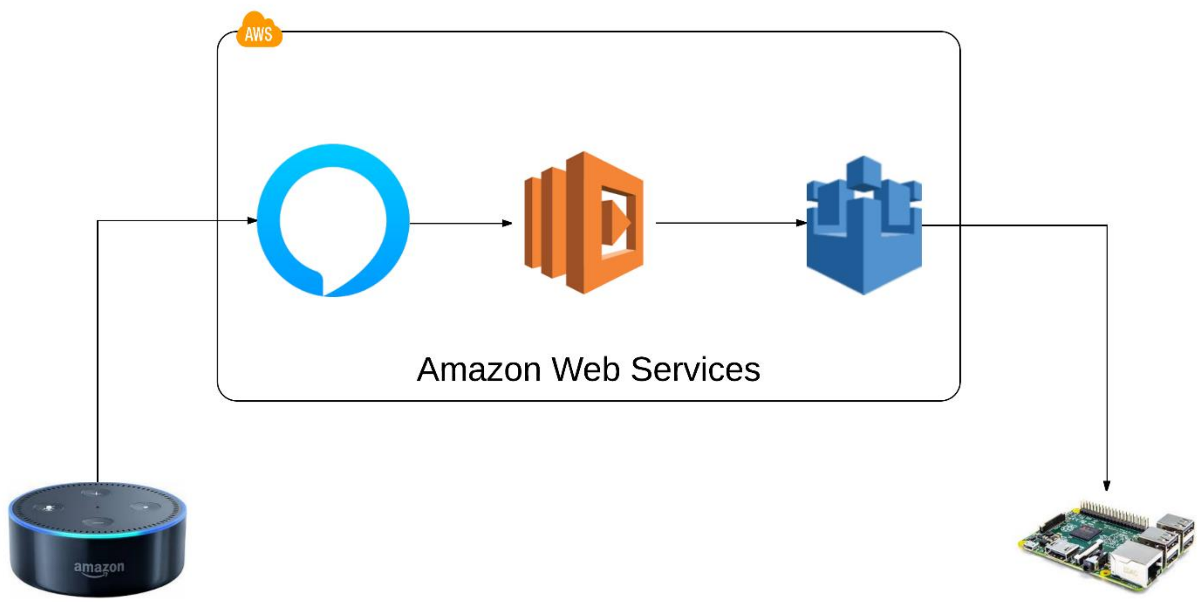

Figure 8. Voice Control System

Control System

The wheelchair is controlled using several programmable modules. All data flows that the system considers is shown in Figure 9. At the center of the system is a single board computer, the Raspberry Pi. It gathers data from the main sensors and gives high level output commands to

[39] McCauley, R. (2016).

a microcontroller, the Arduino, describing how the wheelchair should move. The Arduino itself is in a feedback loop with the motor controller and the encoders, and it sends speed commands for each motor to the motor controller. The motor controller was selected considering current and voltage requirements of the motor. It simplifies controlling motors using a microcontroller, permitting controls using standard protocols.

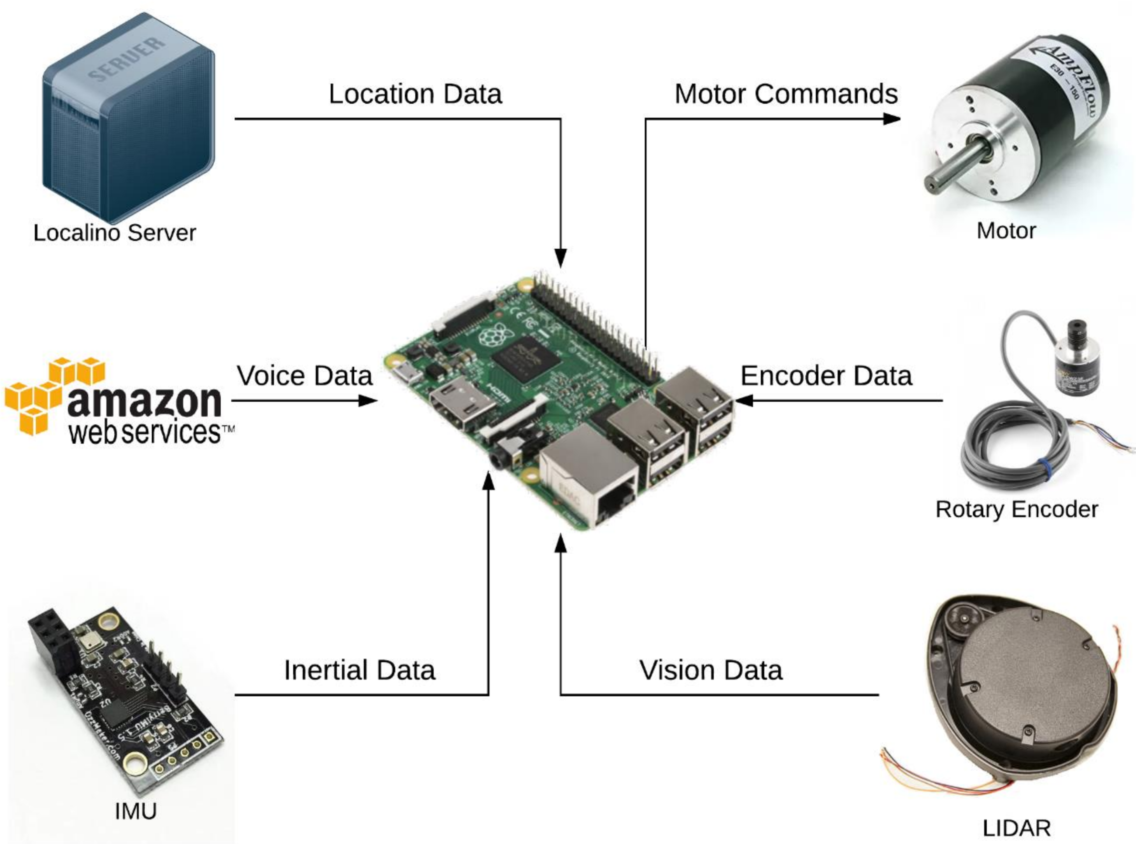

Figure 9. Data flows

Hardware Interfaces

The data flows shown above all communicate serially with the microcontrollers through different means. The IMU sensor interfaces using the I2C protocol.[40] More specifically, the magnetometer and accelerometer are assigned an address of 0x1E, the gyroscope an address of 0x6A, and the pressure sensor an address of 0x77. The LIDAR and motor controller interface using UART.[41] Location services and voice data is communicated using MQTT. The encoder sends Pulse Width Modulated (PWM) feedback based on the speed of the motors.[42]

[40] Ozzmaker (2015).
[41] Neato (2013).
[42] Yumo (2015).

Raspberry Pi

The Raspberry Pi is a small single-board computer often used for DIY projects. It has the processing power comparable with a laptop and can run Linux. The Pi will run on Robot Operating System (ROS), a popular framework for robotics projects. ROS will gather data from various sensors and services and send commands to the Arduino for controlling the motor. In ROS, each sensor corresponds to a ROS node. Message passing will be used to communicate between nodes, greatly simplifying inter-process communication. The Raspberry Pi will run ROS nodes to handle AWS commands and process Localino, IMU, and LIDAR data. The sensor data will be filtered using a Kalman filter, which will reduce noise from the IMU, LIDAR, and encoder to produce a single location estimate. During navigation, the LIDAR, IMU, and Localino data will be put into a mapping algorithm to update the Pi's environment map.

Arduino

The Arduino is a popular open source microcontroller. It will interface between the Raspberry Pi and the motor. After receiving a path from the Raspberry Pi, it handles moving along that path at the correct speed. The packet format for Raspberry Pi to Arduino communication can be seen in Tables 8, 9, and 10.

Table 8. The packet format for the move instruction.

Offsets	Octet	0								1							
Octet	Bit	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0	0	Address = 0xEE								Instruction = 0x2				Now			
2	16	Radius								Angle							

Table 9. The packet format for set max velocity and acceleration command.

Offsets	Octet	0								1							
Octet	Bit	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0	0	Address = 0xEE								Instruction = 0x1				Now			
2	16	Max Speed								Max Acceleration							
4	32	Max Centripetal Accel															

Table 10. The packet format for the stop and check battery command.

Offsets	Octet	0								1							
Octet	Bit	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0	0	Address								Instruction = 0x0 or 0x3				Now			

All instructions directed to the Arduino will be sent to address 0xEE. There are four instructions so far. There is a stop command (0), set max speed and acceleration (1), move (2), and check battery (3). The stop and check battery commands do not require any additional data fields. The stop command is used to stop the wheelchair in case of emergency. The two types of stops are a gradual stop or an immediate stop, depending on the now flag, which exists for all instructions. The gradual stop is intended for use when the wheelchair reaches its destination, and the immediate stop is for a dangerous situation where the wheelchair is about to crash. The check battery command is used to asynchronously report the remaining battery life for the wheelchair to the Raspberry Pi.

The move instruction moves the wheelchair per a simple turning model. The model used for turning is based on arcs of a circle. The wheelchair can move along any arc with a radius and an angle specified in the packet. It can even turn in place if the radius is set to zero.

The set max speed and acceleration command would be used less often than the other commands. It is used to specify the maximum permissible linear velocity, linear acceleration, and centripetal acceleration that the wheelchair can move at. The control interface to the Raspberry Pi is position control, which does not consider the speed or acceleration of the wheelchair. This limit is intended to allow the wheelchair to move at a maximum speed without harming the rider. The rider will be able to adjust this parameter, but only within safe ranges.

The Arduino will send feedback to the Raspberry Pi including the encoder and battery voltage data using the packet formats seen below in Tables 11 and 12. The Arduino will periodically send encoder data while running a movement to ensure that ROS has a correct current position for the wheelchair. The battery voltage data is less important and will be polled at a low rate such as 1Hz. There are many unused bits in the packet formats for Arduino and Raspberry Pi communication. These unused bits serve to align data to single octets, reducing the amount of bit shifting required for processing and increasing flexibility in adding new instructions.

Table 11. The packet format for encoder data

Offsets	Octet	0								1							
Octet	Bit	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0	0	Address								Data type = 0x00							
2	16	Left Wheel Velocity															
4	32	Right Wheel Velocity															
6	48	X Position															
8	64	Y Position															

Table 12. The packet format for battery voltage data

Offsets	Octet	0								1							
Octet	Bit	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0	0	Address								Data type = 0x01							
2	16	Voltage															

Motor Controller

In order to control the motor, a motor controller was purchased. The motor runs at 24 V and draws 17 A at peak efficiency. In addition, the motor can draw a peak current of 127 A. An alternative besides buying a motor controller was building an H-bridge using power transistors. Because designing and properly building the circuit up to specifications seemed too difficult, purchasing a motor controller seemed like the best option. Finding a reasonably priced motor controller, which could handle currents close the motor's 127 A peak current was difficult. The motor controller selected was the Sabertooth 2x60A regenerative motor driver.[43] This motor controller can power two brushed DC motors each with 60 A continuously. Although the motor controller can only handle up to 120 A peak, it was advertised to have overcurrent protection, so it should not burn out if more current is drawn.

Schedule

The original schedule planned for this project can be seen below in Table 13. An aggressive approach was desired for this project; A goal of prototyping by the end of the first semester to reserve the second for iterating and working out bugs. Unfortunately, the project is behind where it was intended, and a prototype has yet to begun being built. A couple of issues came up this semester that were unexpected. The project budget was approved later than accounted for in the timeline, which pushed everything that required hardware or materials back. Also, the designing duration of the project (the chassis, the communication system, the motors and batteries, etc.) was much more complex than anticipated and required more time than was allotted. All this being true, however, team members do intend to work on aspects between semesters and the project is still on track to finish in time for the Founder's Day presentations.

Table 13. Timeline of both semesters ending with Founder's Day presentations on April 4, 2018

Task Name	Duration	Start	Finish
CS: Define voice interface	3 days	Thu 9/14/17	Mon 9/18/17
CS: Testing software for IPS	17 days	Thu 9/14/17	Fri 10/6/17
ME: Brainstorm Wheelchair Designs	9 days	Thu 9/14/17	Tue 9/26/17
CS: Communication between AWS and Pi	5 days	Tue 9/19/17	Sun 9/24/17
EE: Research Controlling Motors	19 days	Thu 9/21/17	Tue 10/17/17
CS: Software system block diagram	15 days	Mon 9/25/17	Fri 10/13/17
ME: Initial Design	1 day	Wed 9/27/17	Wed 9/27/17
EE: Create Schematic of System	8 days	Thu 9/28/17	Mon 10/9/17
Finalize Budget	2 days	Thu 9/28/17	Fri 9/29/17
CS: Simulation: Render 2D shapes/points	7 days	Fri 9/29/17	Mon 10/9/17
CS: Finalize location tech	5 days	Mon 10/9/17	Fri 10/13/17
EE: Hardware system block diagram	22 days	Wed 10/18/17	Thu 11/16/17
Buy Everything	11 days	Mon 10/23/17	Mon 11/6/17
CS: Simulation: Make basic room using shapes	14 days	Tue 10/24/17	Fri 11/10/17
CS: Simulation: Make model for wheelchair & LIDAR	4 days	Tue 10/24/17	Fri 10/27/17
CS: Simulation: Wheelchair movement	7 days	Mon 10/30/17	Tue 11/7/17
CS: Simulation: Introduce Error	3 days	Mon 10/30/17	Wed 11/1/17

[43] Dimension Engineering (2011).

CS: Simulation: Self-calibration	7 days	Thu 11/2/17	Fri 11/10/17
EE: Test Hardware	7 days	Tue 11/7/17	Wed 11/15/17
ME: Obtain Motors and Wheelchair	1 day	Tue 11/7/17	Tue 11/7/17
CS: Simulation: Realistic physics	7 days	Wed 11/8/17	Thu 11/16/17
CS: Simulation: Pathfinding	21 days	Wed 11/8/17	Wed 12/6/17
ME: Build Motor Circuit	7 days	Wed 11/8/17	Thu 11/16/17
ME: Build Mount	7 days	Wed 11/8/17	Thu 11/16/17
Fall report	11 days	Fri 11/17/17	Fri 12/1/17
ME: First Prototype Built	16 days	Fri 11/17/17	Fri 12/8/17
CS: Test simulation many times	6 days	Thu 12/7/17	Thu 12/14/17
ME: Testing Movement	4 days	Mon 12/11/17	Thu 12/14/17
Integration	35 days	Mon 1/15/18	Fri 3/2/18
Testing	21 days	Mon 3/12/18	Mon 4/9/18

Budget

Table 14. Approved budget. Highlighted items have been purchased as of Nov. 26, 2017.

Project Materials/Supplies (Any single item under $500)			Quantity	Total
1.	Localino v2.0 Kit	$410.64	1	$410.64
2.	12 Volt/80 Amp Hour Battery	$158.49	2	$316.98
3.	NEATO LIDAR	$119.00	1	$119.00
4.	Localino v2.0 Tag	$102.66	1	$102.66
5.	DC Motor(24 V)	$94.36	2	$188.72
6.	PVC Spacer	$9.86	12	$118.32
7.	6 mm Rotary Encoder	$39.95	2	$79.90
8.	Sprockets	$10.00	8	$80.00
9.	Roller Chain	$5.14	10	$51.40
10.	Amazon Echo Dot	$49.99	1	$49.99
11.	DC-DC Converter (LM2576-3.3WU)	$2.60	1	$2.60
12.	DC-DC Converter(LM2576-5.0WU)	$2.27	3	$6.81
13.	Motor Controller (120 A peak)	$189.00	1	$189.00
14.	Arduino	$27.95	1	$27.95
15.	Raspberry Pi	$35.22	1	$35.22
16.	Casters	$10.01	4	$40.04
17.	High-Strength Rubber Wheels	$9.68	2	$19.36
18.	36" long, 1/2" diam. Metal Shaft	$28.01	1	$28.01
19.	36" x 36" x 1/2" Plywood Board	$5.00	1	$5.00
20.	2" x 4" x 36" Plank	$5.00	6	$30.00

21.	Fasteners	$30.00	1	$30.00
22.	Pool Noodles	$8.49	1	$8.49
23.	36" x 36" Aluminum Plate 1/2"	$30.08	1	$30.08
24.	36" Aluminum Square Tube 1" cross sectional diameter	$10.68	5	$53.40
		SUBTOTAL		$2,023.57
Miscellaneous			Quantity	Total
1.	Miscellaneous Electrical Engineering Materials	$30.00	1	$30.00
2.	General Components	$50.00	1	$50.00
3.	Shipping	$118.05	1	$118.05
			SUBTOTAL	$198.05
		TOTAL		**$2,221.62**

The budget and all current financial endeavors are currently proceeding smoothly. This budget request was initially planned around building a mostly wood prototype by the end of fall semester and then transitioning into a final product constructed mostly of aluminum for a higher strength to weight ratio. Changes being considered are purchasing more expensive casters that would have a spring to stabilize and smooth the ride; also purchasing a larger quantity of DC-DC converters as the current ones quickly overheat, lose function, and begin to melt with the passing of currents over 2.5 A. As of Nov. 26, 2017, $1,159.27 of the budget has been used to buy primarily hardware.

Pro Forma

Assuming the approved budget is what it costs to make every vehicle, subtracting the wood materials for the prototype, each platform would cost $2186.62 to produce. If one system is sold at $3000, which is reasonable as the average joystick-controlled motorized wheelchair goes for around $2000, the voice controlled wheelchair would have a margin of $813.38 per unit sold.[44] To keep this commercial enterprise projection/estimation simple, the customer base will be limited to only Providence Portland Medical Center. Providence currently has 493 licensed beds but only 50% will be assumed to be equipped with this device – 246 devices.[45] For labor, it is assumed that four skilled workers can assemble one unit in 2 hours - $40/hour.

Table 15. Projected Income Statement

Gross Revenue	$738,000.00
Cost of Goods Sold	$537,908.52
Cost of Labor	$39,360.00
Profit	**$150,731.48**

[44] 1800wheelchair.com (2017).
[45] Providence Health and Services (2017).

If this product were to go to market, it is hoped that it would be utilized by all hospitals, hospice care facilities, and nursing homes alike as it is extremely multi-purpose by design. The product can also be sold and used in a home, but the navigation accuracy and obstacle avoiding precision would need to be improved upon first most likely.

Conclusion

The Transnavigators' Voice Controlled Wheelchair, will give users the ability to control their wheelchair using voice commands. Since the wheelchair will fit nearly any type of existing wheelchair, users can continue to use whatever chair they have. The wheelchair is controlled naturally with voice rather than with a joystick, which characteristic of most motorized wheelchairs. Currently, the Transnavigators have done copious research in both the mechanical and electrical design. Most of the upcoming work that still needs to be done is in constructing the mechanical systems and creating the computerized control system.

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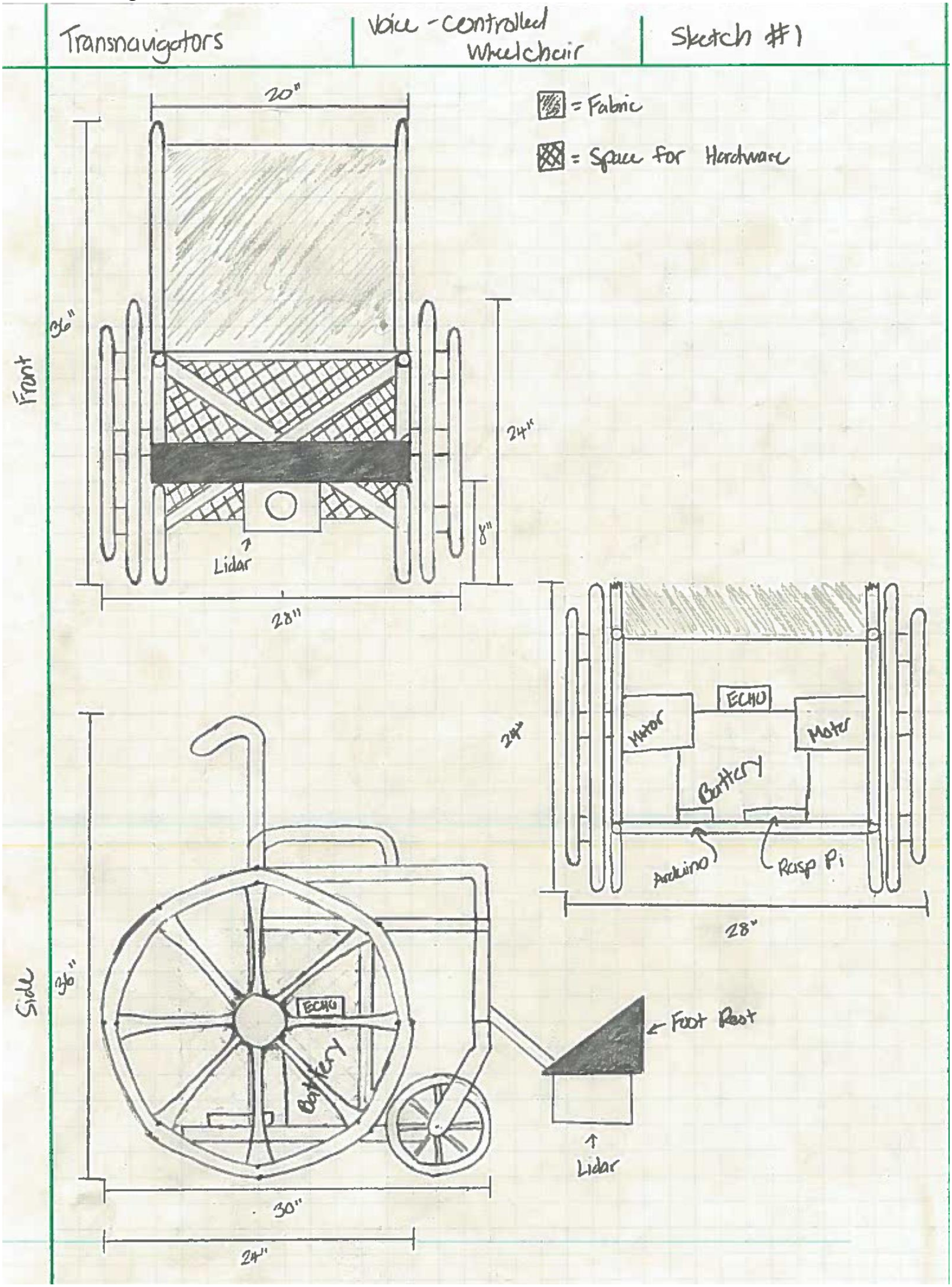
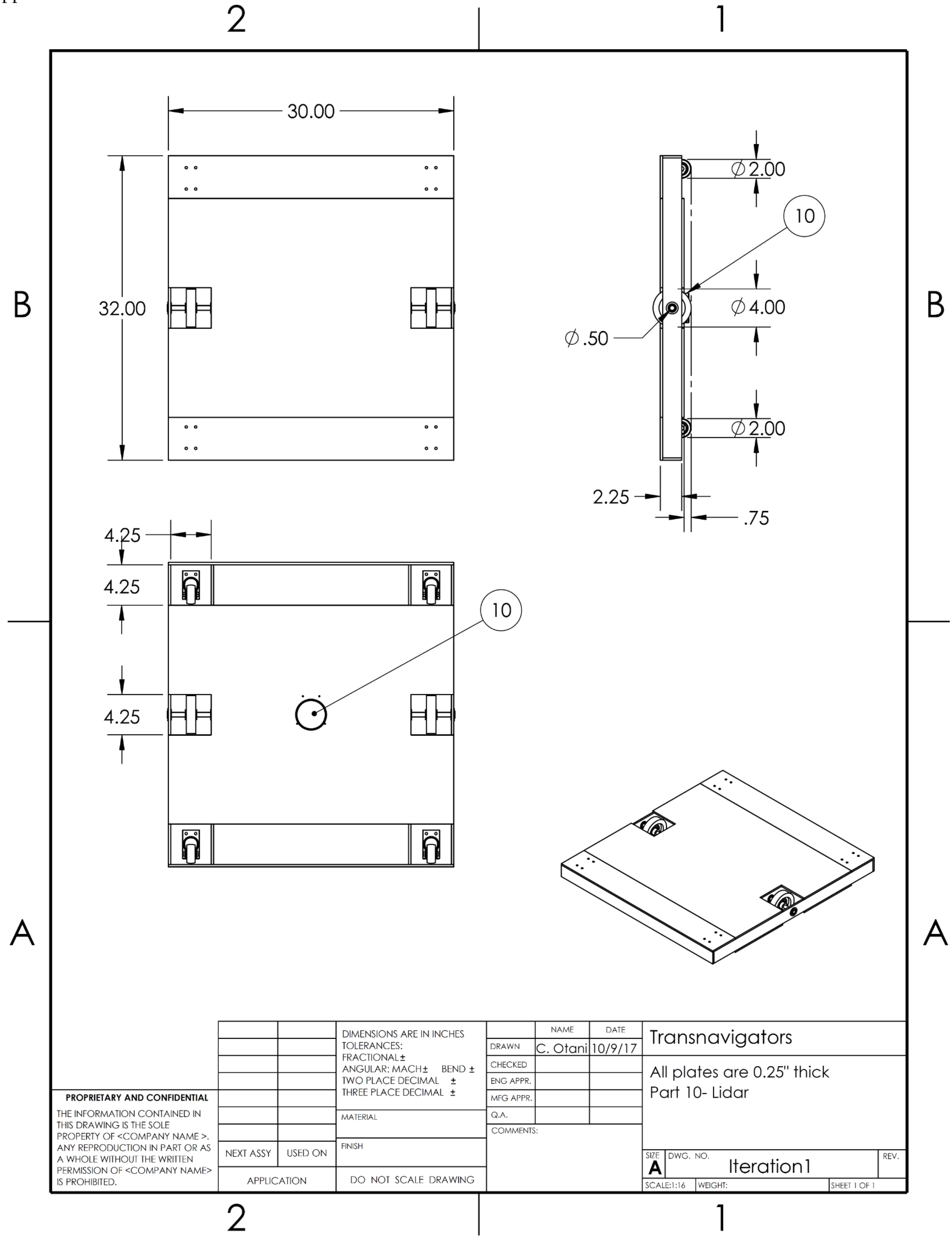
Appendices

Appendix A: Chassis Design

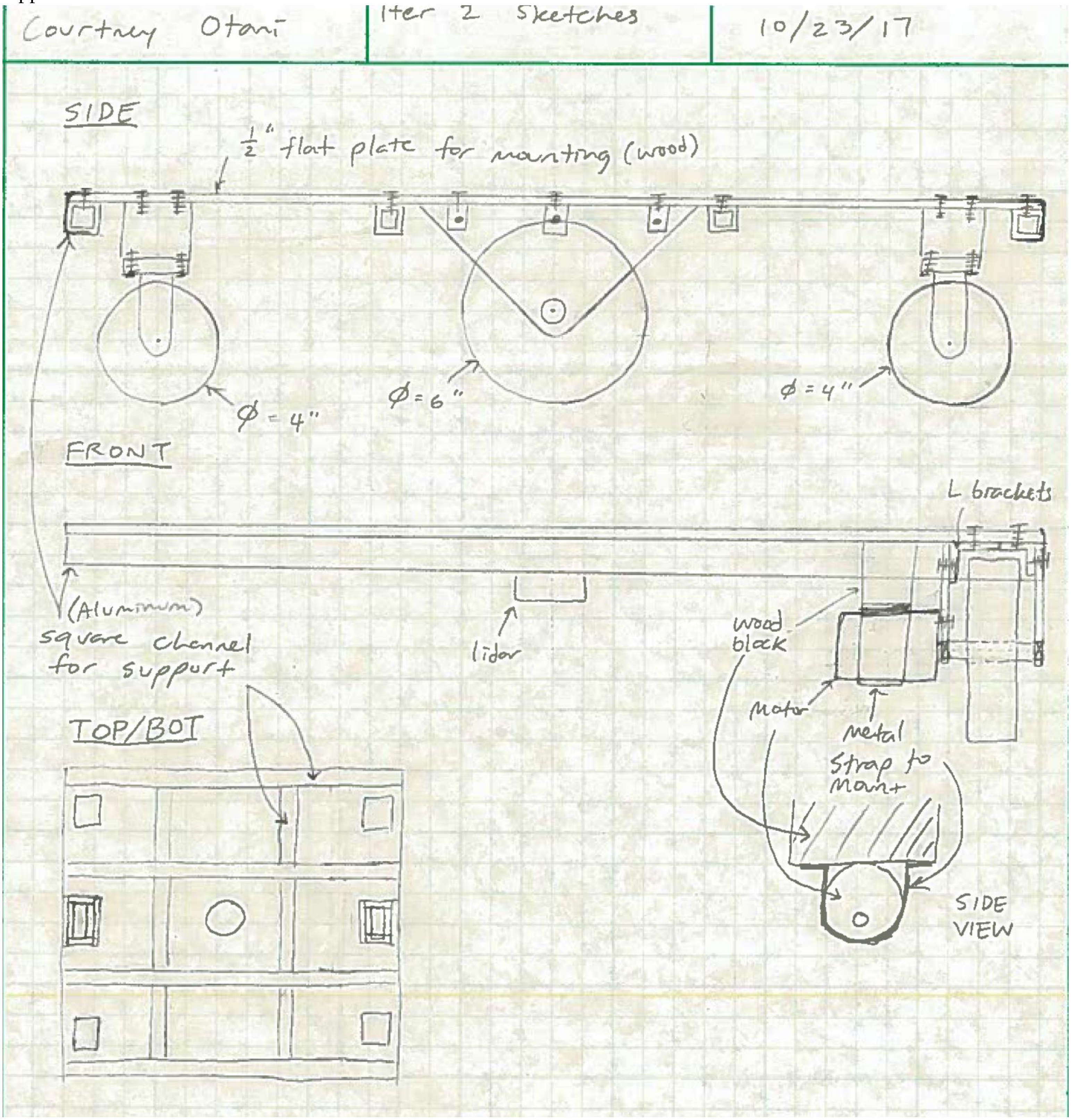
Appendix A-1: Original Idea



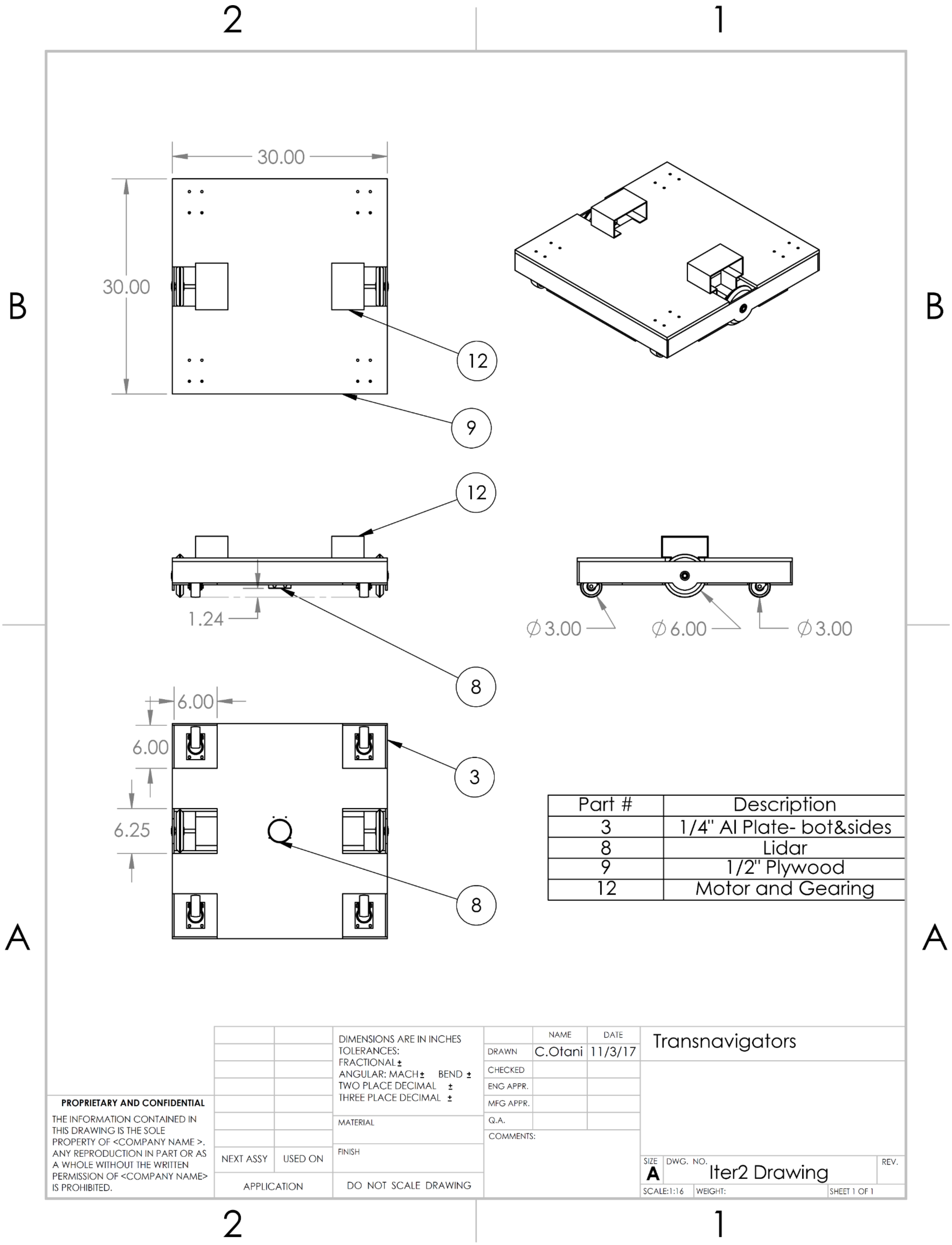
Appendix A-2: First Iteration



Appendix A-3: Second Iteration



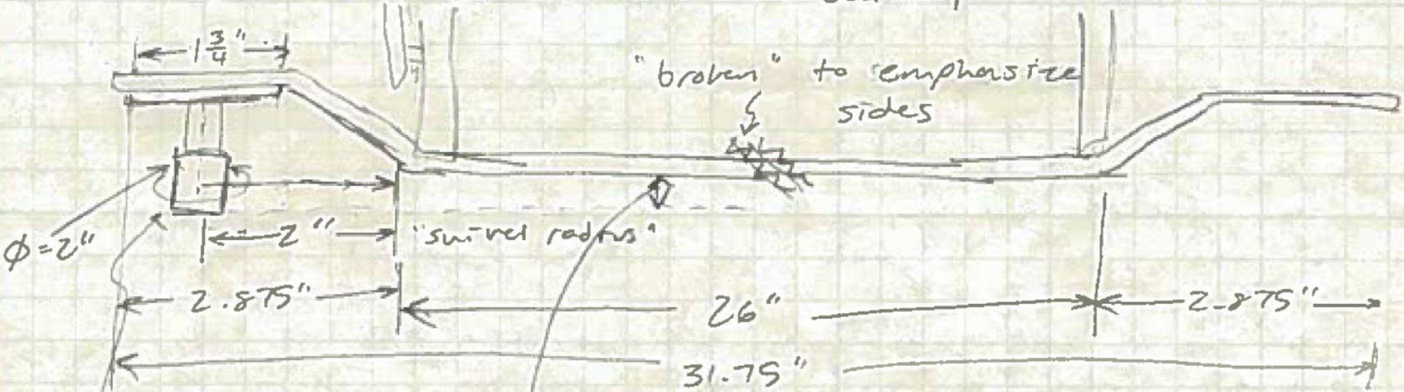
Appendix A-4: Third Iteration



Appendix A-5: Fourth Iteration

Courtney Otani	4th Iteration Design Chassis + Drive	11/6/17

Width of doors = 36", 32" ← measured dorm doors; main, bedrooms
width of wheelchair = 28" ← Medline Excel k1 Basic, measurement by Jarren
ADA standard = 26" think this includes wheel handles
outside wheel to outside wheel (the big wheels)
ADA standard is 32" minimum width for doorway



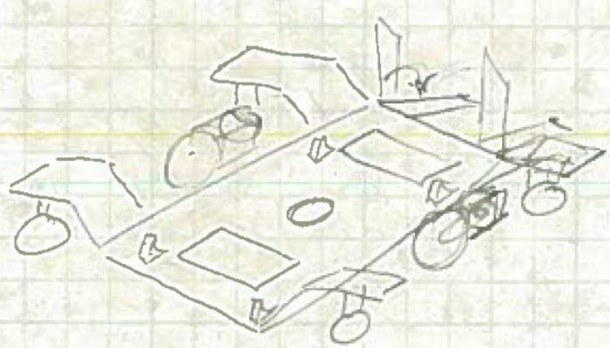
only left with $\frac{1}{4}$" tolerance

lowest profile swivel found

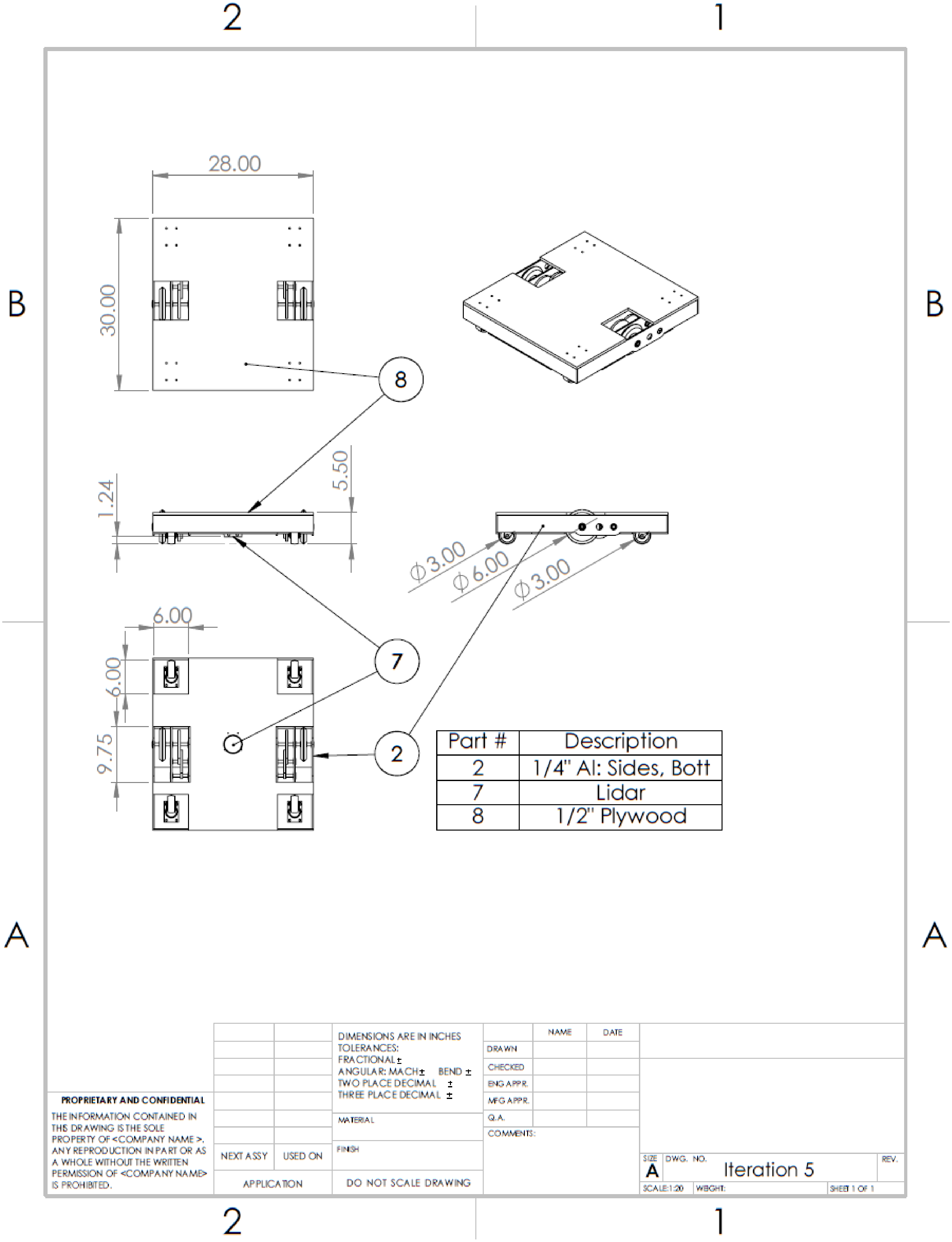
this clearance needs to be able to accomodate
- lidar ← must stay in scope
- going on ramps ← can go to this new design if get rid of this criteria

if saying this, need this dim/clearance to be about 2"

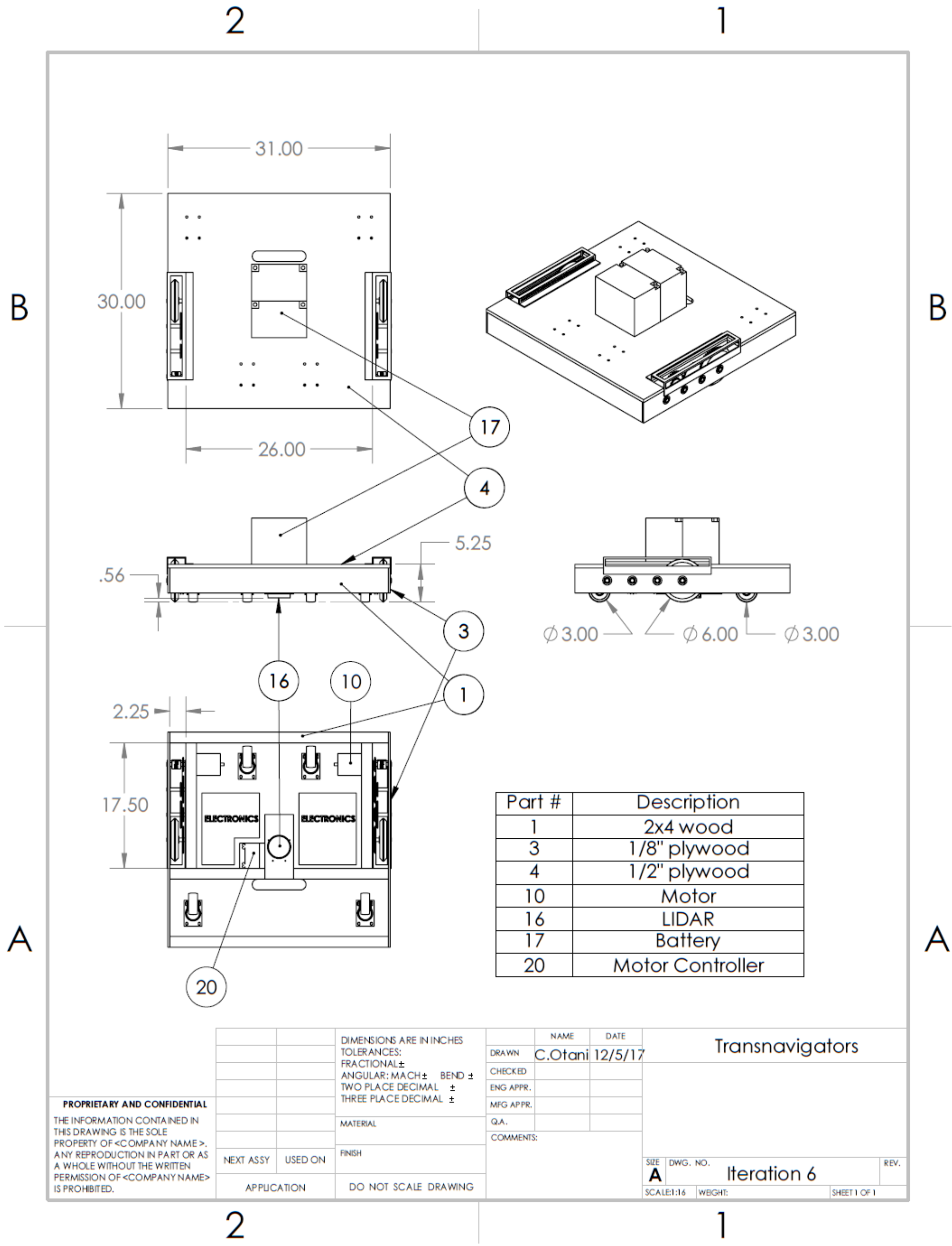
Extra Note on wheels:
Driven wheel width = 2"



Appendix A-6: Fifth Iteration



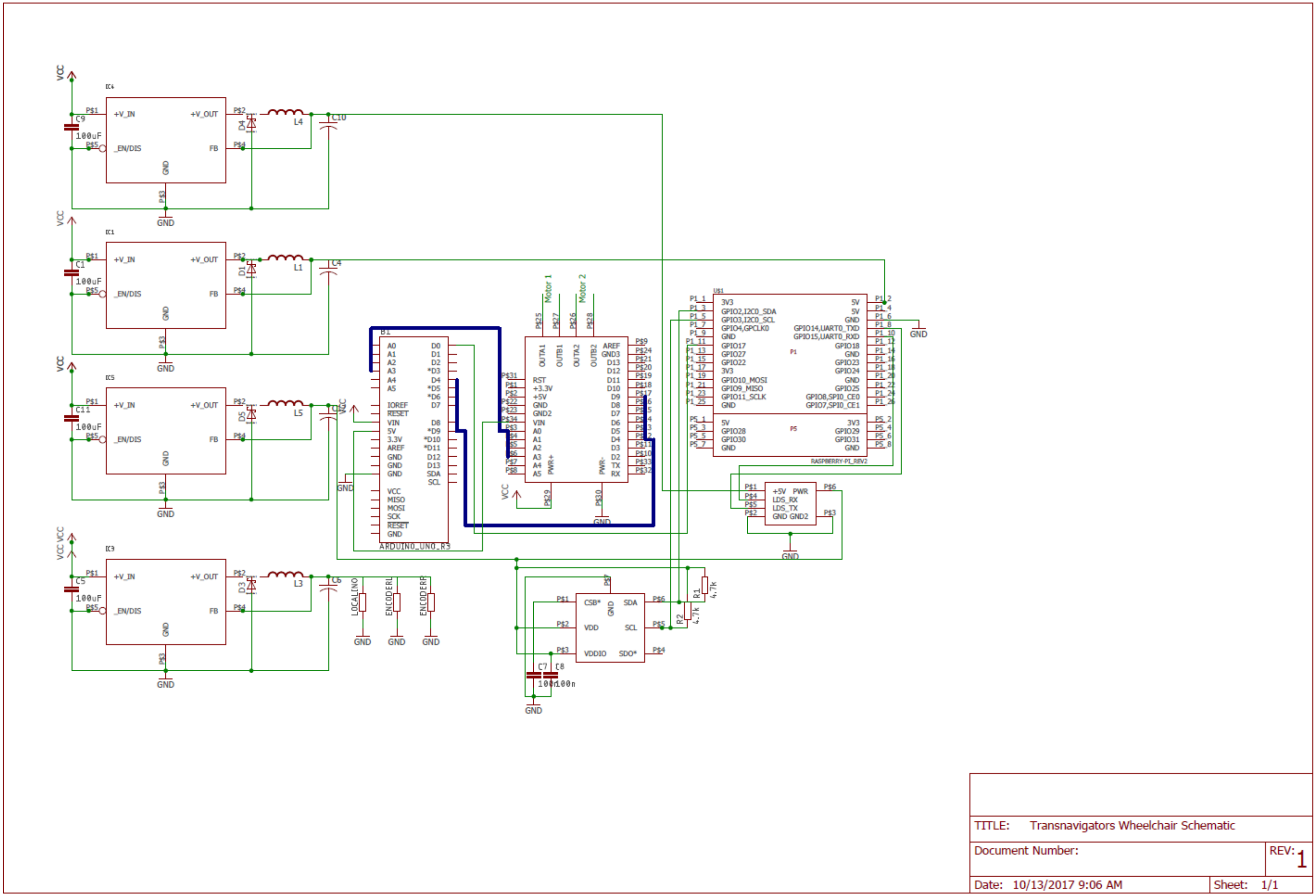
Appendix A-7: Iteration at the End of Fall Semester



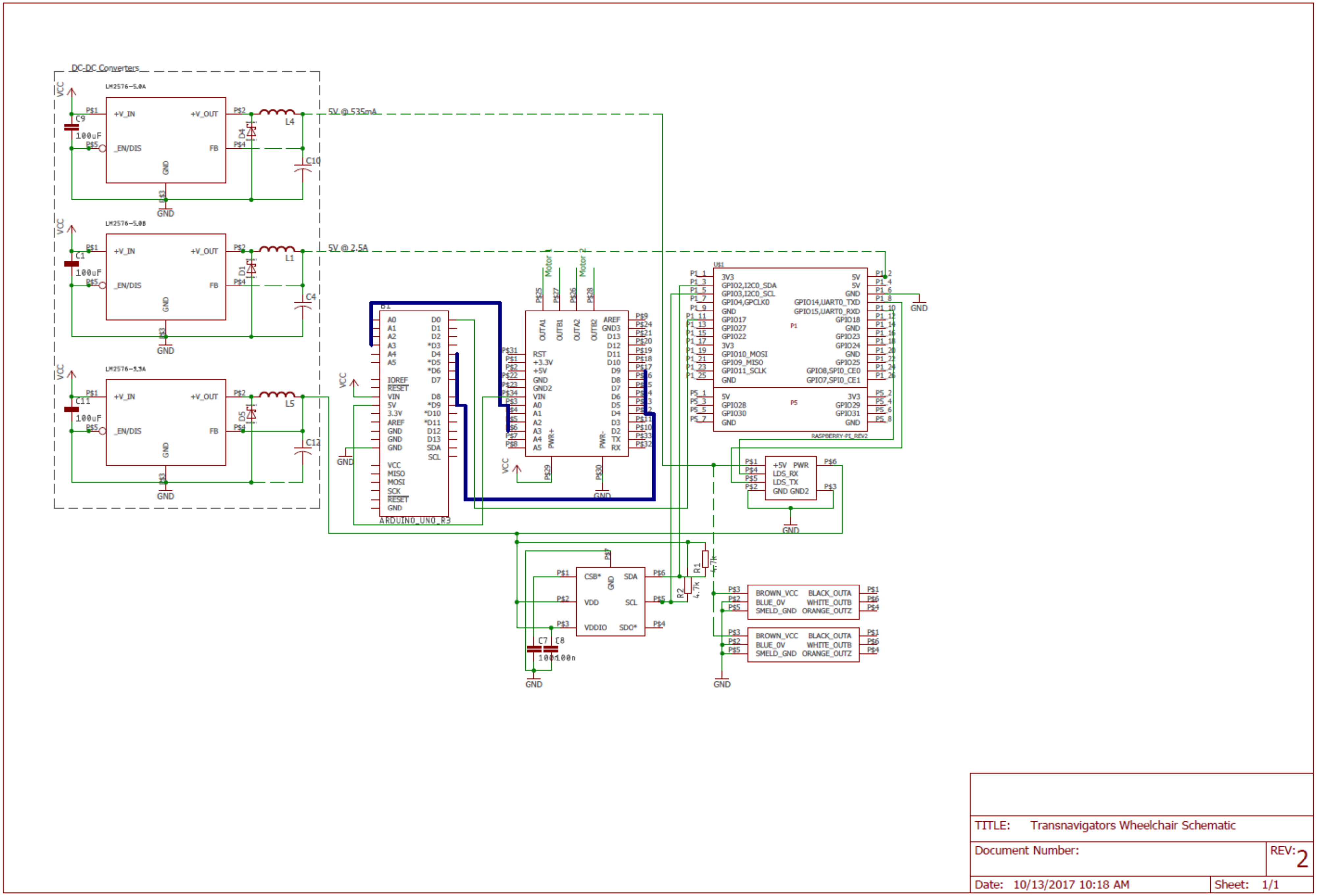
Part #	Description
1	2x4 wood
3	1/8" plywood
4	1/2" plywood
10	Motor
16	LIDAR
17	Battery
20	Motor Controller

Appendix B: Schematic

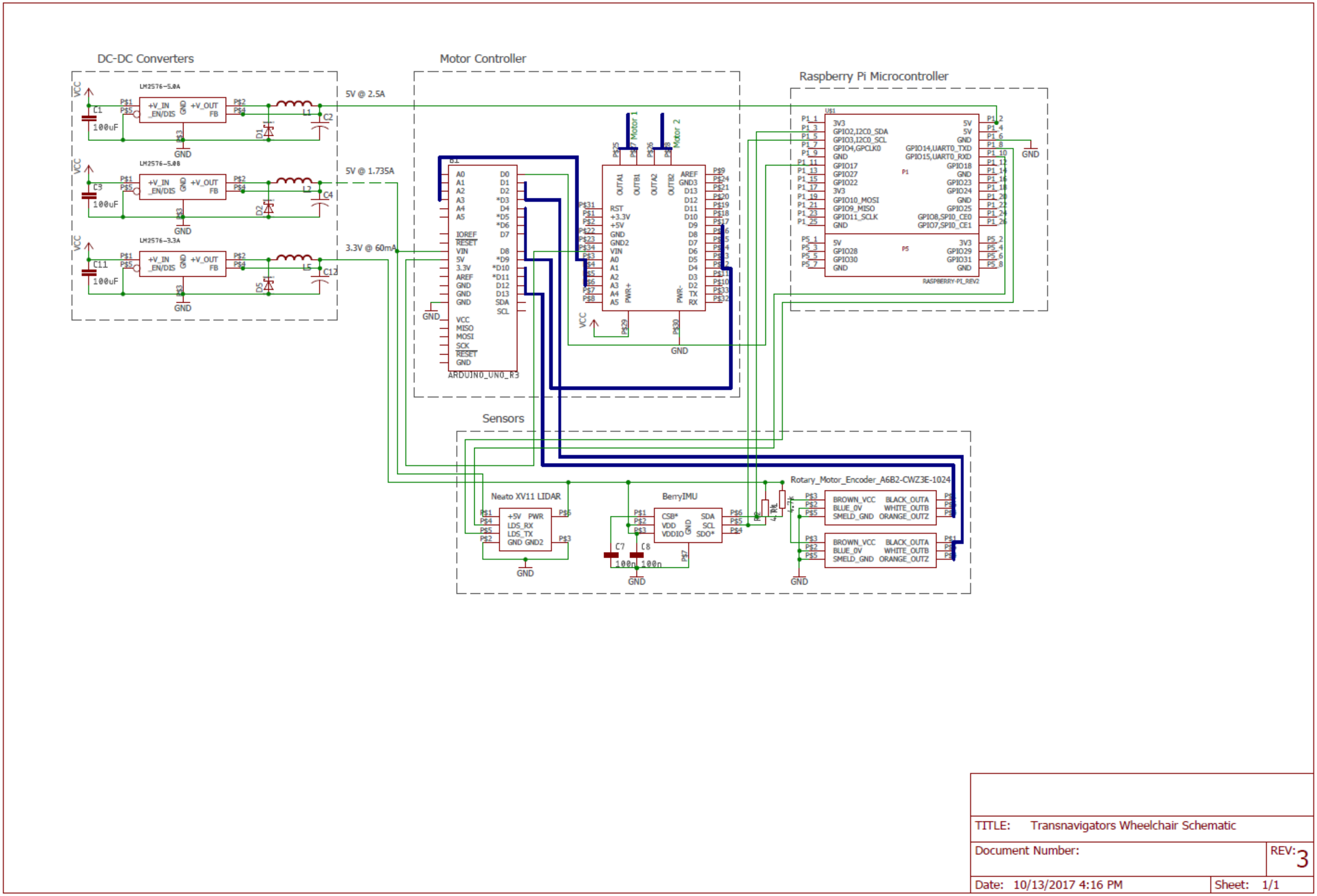
Appendix B-1: Schematic Revision 1



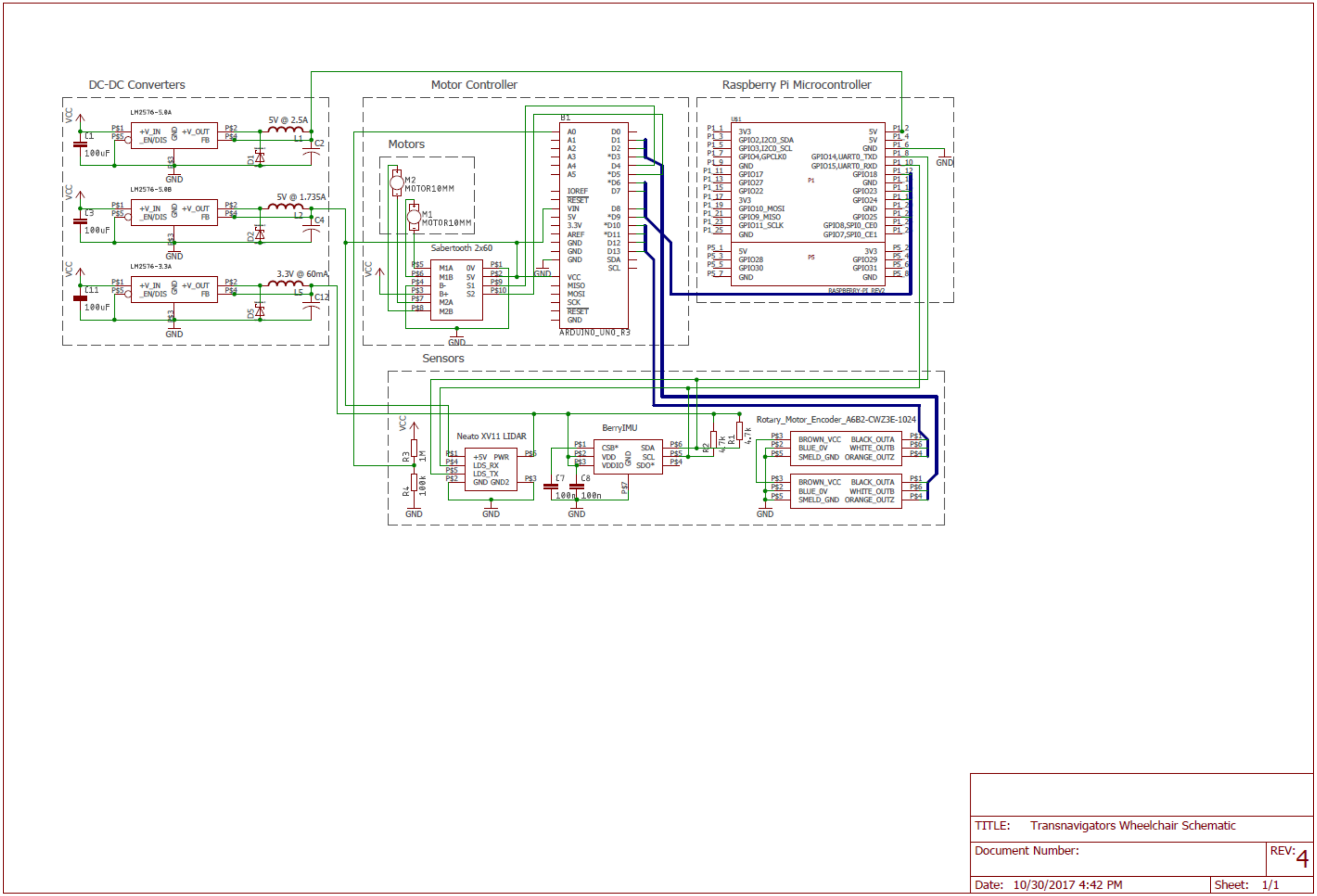
Appendix B-2: Schematic Revision 2



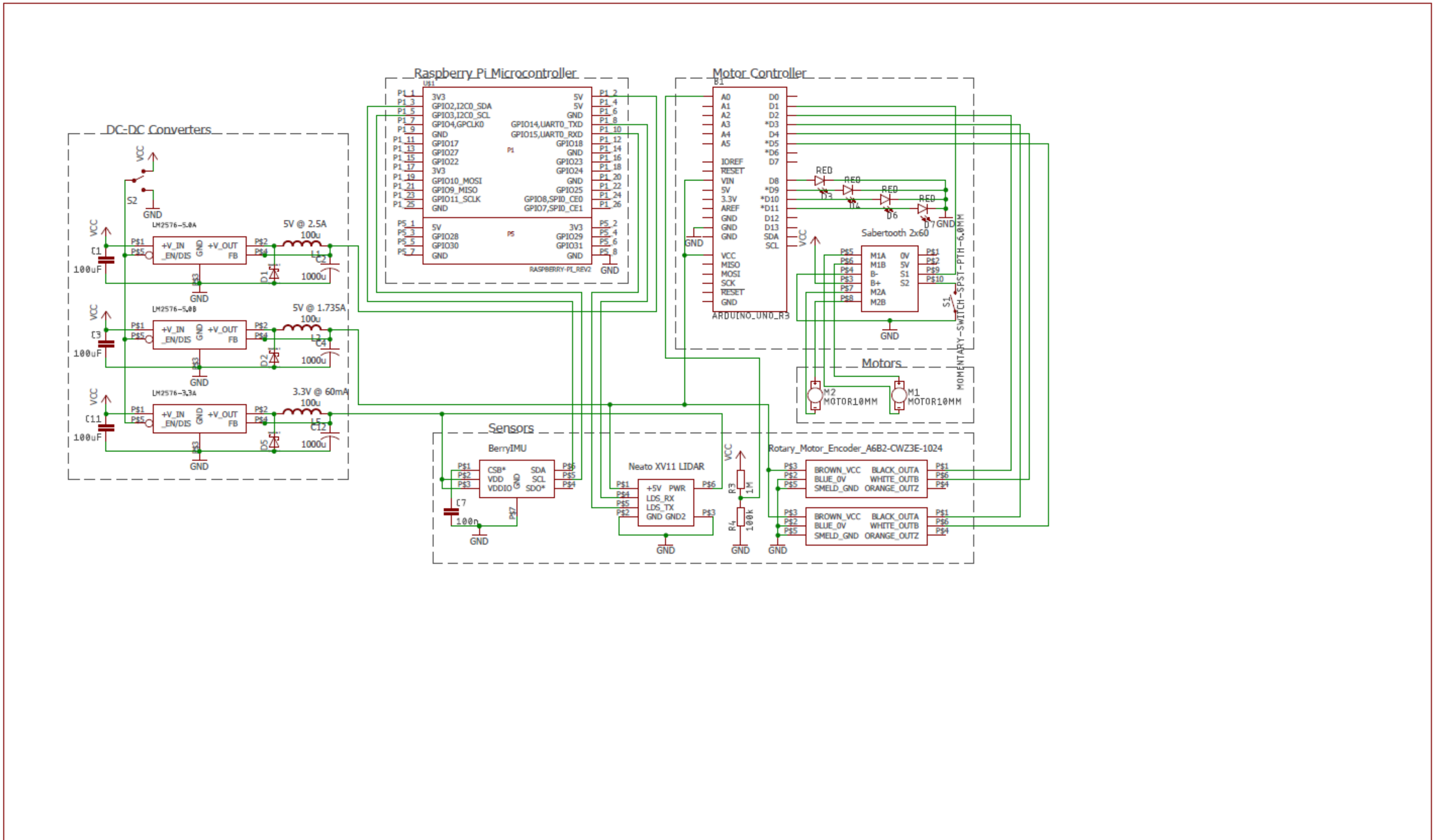
Appendix B-3: Schematic Revision 3



Appendix B-4: Schematic Revision 4



Appendix B-5: Schematic Revision 5



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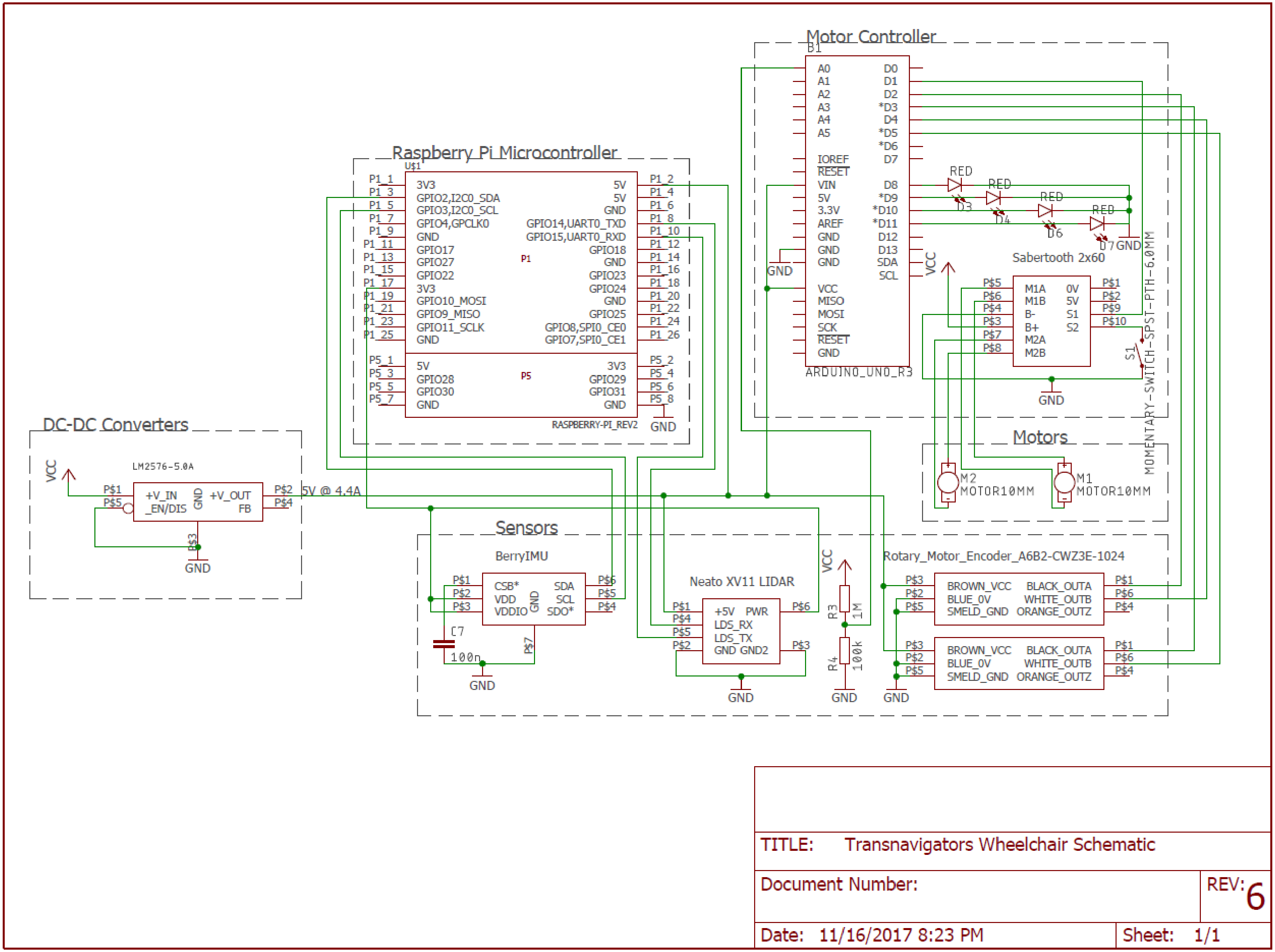
Appendix B-6: Schematic Revision 6



Appendix C: Weekly Reports

University of Portland

Weekly Report-Out

Name Matthew Yuen   Team Wheelchair Team

Today's Date: 09/08/2017

1 What commitments have you completed since our last check-in?
(let others know you've kept your commitments, declare work "done" so it can be accepted)

Customer	Commitment/Hours Expended
Wheelchair Team	Found an ME advisor and set up weekly meetings / 1 hour
Wheelchair Team	Installed Whatsapp for group communication / 0.5 hour
Wheelchair Team	Designated project roles / 0.5 hour
Wheelchair Team	Updated A3 to incorporate Levi / 2 hours
Wheelchair Team	Contacted possible industry advisor / 0.5 hour

2 What work will you complete this week (by our next session)?
(let others know what they can depend on)

Customer	Commitment/Hours Anticipated
Wheelchair Team	Update budget / 3 hours
Wheelchair Team	Research Location Technology / 4 hours
Wheelchair Team	Update A3 to reflect new CS/EE advisor & new requirements / 1 hour
Wheelchair Team	Apply for Dean's funding / 1 hour
Wheelchair Team	Find hardware components to be used for project / 3 hours
Wheelchair Team	Find a client / 2 hours

3 What constraints are keeping you from getting your work done?
(ask for help, declare a breakdown, raise concerns…)

Concern, breakdown, or help you need	Resolution (Action by When)	Who's Responsible?
Enough money for sensors/motors	Talk to Dr. Jones 9/13/17	Jarren
How feasible is finding the user?	Research/Choose solution 10/31/17	CS/EE

4 Overall, are you still on track to meet your commitments to the project?

Yes

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Appendix C-2: Week 2

University of Portland

Weekly Report-Out

Name COURTNEY OTANI Team TRANSNAVIGATORS Today's Date: 9/14/17

1 What commitments have you completed since our last check-in?
(let others know you've kept your commitments, declare work "done" so it can be accepted)

Customer	Commitment/Hours Expended
N/A	-INITIAL DESIGN CALCULATIONS / 1HR
↓	-CREATED/STARTED A SCHEDULE FOR MECHANICAL SIDE OF PROJECT / 1 HR
	-MET WITH INDUSTRY ADVISOR / 30 MIN
	-MET WITH BOTH FACULTY ADVISORS / 1 HR
NURSING DPT	-CONTACTED CLIENT (NURSING DEPT)
N/A	-CREATED/STARTED A SCHEDULE FOR CS/EE SIDE OF PROJECT
↓	-CREATED WEBSITE
	-RULED OUT GPS FOR INDOOR POSITIONING

2 What work will you complete this week (by our next session)?
(let others know what they can depend on)

Customer	Commitment/Hours Anticipated
N/A	-BEGIN RESEARCH W/ECHO DOT (CODING) / 4 HR
↓	-RESEARCH BEACON FOR INDOOR POSITIONING / 1 HR
	-WHEELCHAIR STORE / 1 HR
NURSING DPT	-FOLLOW UP W/NURSING DPT
N/A	-MEET W/BOTH FACULTY ADVISORS / 1HR
↓	-TALK TO LAB TECHNICIANS
	-RESEARCH OUTSIDE FUNDING / 2 HR

3 What constraints are keeping you from getting your work done?
(ask for help, declare a breakdown, raise concerns…)

Concern, breakdown, or help you need	Resolution (Action by When)	Who's Responsible?
LACK OF KNOWLEDGE	RESEARCH	
- INDOOR POSITIONING	for another	MATT, LEVI, ANTHONY
- MECHANICAL REQUIREMENTS	week or 2	COURTNEY & JARREN
	weeks	

4 Overall, are you still on track to meet your commitments to the project?

YES, IN PLANNING STAGE ON WAY TO CONCRETE 1ST ITERATION DESIGN

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University of Portland

Weekly Report-Out

Name Anthony Donaldson Team Transnavigators Today's Date: 9/22/17

1	What commitments have you completed since our last check-in? (let others know you've kept your commitments, declare work "done" so it can be accepted)	
	Customer	Commitment/Hours Expended
		Configured AWS interface to Pi / 8 hours
		Finalized Spring schedule / 1 hour
		Drew sketches of overall system design / 2 hours
		Measured wheelchair dimensions & specs / 30 mins
		Outlined budget / 4 hours
		Met with faculty advisors / 1 hour
		Attended safety training for lab access / 10 mins
		Researched motor controllers / 2 hours
		Updated A3 / 15 mins

2	What work will you complete this week (by our next session)? (let others know what they can depend on)	
	Customer	Commitment/Hours Anticipated
		Brainstorm mechanical designs / 6 hours
		Proof of concept for Proximi.io / 4 hours
		Update team member descriptions on the website / 1 hour
		Finalize budget / 6 hours

3	What constraints are keeping you from getting your work done? (ask for help, declare a breakdown, raise concerns…)		
	Concern, breakdown, or help you need	Resolution (Action by When)	Who's Responsible?
	Broaden design possibilities	Meeting with Symons on Tuesday (9/26)	Torren / Courtney
	P-card delivery date	Speak with Lisa Bassett	Levi

4	Overall, are you still on track to meet your commitments to the project?
	Yes, we are on track.

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Weekly Report-Out

Name: Levi Banks Team: Transnavigators

Today's Date: 9/29/17

1 What commitments have you completed since our last check-in?
(let others know you've kept your commitments, declare work "done" so it can be accepted)

Customer	Commitment/Hours Expended
	Completed budget / 4 hrs
	Brainstormed new design options / 6 hrs
	↳ chose one of these new designs to work with
	Updated sketch for our new idea / 2 hrs
	Met with faculty advisors / 1 hr
	Researched DWM1000 chips as cheaper alternatives / 2 hr
	Decided on alternative to proxim.io (DWM1000)
	Looked at PolySync for simulation (received license) / 0.5 hr

2 What work will you complete this week (by our next session)?
(let others know what they can depend on)

Customer	Commitment/Hours Anticipated
	Update team bios on website / 1 hr
	Work with simulation on 10/1 / 6 hrs
	~~Create~~ • Begin work on schematic of system / 6 hrs
	Begin CAD model of new design / 3 hrs
	Mechanical calculations / 1 hr

3 What constraints are keeping you from getting your work done?
(ask for help, declare a breakdown, raise concerns…)

Concern, breakdown, or help you need	Resolution (Action by When)	Who's Responsible?
Money (specifically lack thereof)	Turning in budget on 9/29	Galati
Lack of knowledge / experience	More research! (by next week)	Us!

4 Overall, are you still on track to meet your commitments to the project?

Yes, we are still on track.

University of Portland

Weekly Report-Out

Name: Jarren Takaki Team: Transnavigators Today's Date: 10/6/17

1 What commitments have you completed since our last check-in?
(let others know you've kept your commitments, declare work "done" so it can be accepted)

Customer	Commitment/Hours Expended
	Met with faculty advisors / 1hr
	Met with industry advisor / 0.5 hr
	Mechanical calculations / 1.5 hr
	Design matrix - Chassis / 5min
	Worked on simulation / 8hr
	Bios / 8 min

2 What work will you complete this week (by our next session)?
(let others know what they can depend on)

Customer	Commitment/Hours Anticipated
	Design Matrix - Battery / 2 hr
	Make Simulation Skeleton / 4hr
	Select a motor / 1.5hr
	Work on Bios / 0.5 hr
	Design Matrix - Motor / 1.5hr
	CAD (Iteration #1) / 5hr
	Schematic of Electrical Circuit / 5hr

3 What constraints are keeping you from getting your work done?
(ask for help, declare a breakdown, raise concerns...)

Concern, breakdown, or help you need	Resolution (Action by When)	Who's Responsible?
Lack of knowledge	Research (Always)	All
Unsure about budget	Wait till we hear back	Galati

4 Overall, are you still on track to meet your commitments to the project?

Of Course!

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Appendix C-6: Week 6

University of Portland

Weekly Report-Out

Name: Matthew Yuen Team: Transnavigators

Today's Date: 10/12/2017

1 What commitments have you completed since our last check-in?
(let others know you've kept your commitments, declare work "done" so it can be accepted)

Customer	Commitment/Hours Expended
Project	Met with faculty advisors / 1 hour
Project	Completed iteration 1 CAD design / 6 hours
Project	Completed iteration 1 circuit schematic / 6 hours
Project	Calculated power requirements and picked a motor / 4 hours
Project	Made a battery matrix + select a battery / 2 hours
Project	Updated bios on website / 30 minutes
Project	Updated A3 / 30 minutes
Project	Finished simulation skeleton / 3 hours

2 What work will you complete this week (by our next session)?
(let others know what they can depend on)

Customer	Commitment/Hours Anticipated
Project	* Finish calculating power requirements / Matthew 1 hour
Project	Iteration II of CAD design / Courtney 6 hours
Project	Iteration II of schematic / EEs 3 hours
Project	* Pick a motor controller & Encoder / EEs 3 hours
Project	* Pick a battery / MEs + EEs
Project	Simulation data: Lidar / Anthony 12 hours +
Project	Simulation data: Location, Bern, IMU, Encoder, Alexa / Levi 12 hours
Project	Thread the simulation, Wheelchair turning, Simulation stopping / Matthew 12 hours
Project	* Calculations for wheelchair / Jairen 6 hours

Priority for meeting with Jeffers on Tuesday after break

3 What constraints are keeping you from getting your work done?
(ask for help, declare a breakdown, raise concerns...)

Concern, breakdown, or help you need	Resolution (Action by When)	Who's Responsible?
Lack of knowledge	Research	All

4 Overall, are you still on track to meet your commitments to the project?

Yes

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University of Portland

Weekly Report-Out

Name COURTNEY OTANI Team TRANSNAVIGATORS Today's Date: 10/26/17

1 What commitments have you completed since our last check-in?
(let others know you've kept your commitments, declare work "done" so it can be accepted)

Customer	Commitment/Hours Expended
PROJECT	PICKED MOTOR CONTROLLER / 3HRS
↓	BATTERY SPECIFICATIONS DEFINED / 2 HRS
	THREADED SIMULATION / 1 HR
	COLLISION DETECTION, 1ST ITERATION / 1 HR
	PICKED ENCODER / 2 HR
	DRIVE + CHASSIS 2ND ITER. PAPER DRAWING / 2 HR
	WHEEL RESEARCH / 2HR

2 What work will you complete this week (by our next session)?
(let others know what they can depend on)

Customer	Commitment/Hours Anticipated
PROJECT	GENERATE RAMP + MOUNTING IDEAS/JARREN/2HR
↓	DRIVE + CHASSIS 3RD ITER. DESIGN/COURTNEY/3HR
	MOTOR CONTROLLER + ARDUINO INTERFACE/LEVI
	MATT, ANTHONY / 3 HR
	SIMULATION DATA: LIDAR / ANTHONY / 12 HR
	LOCATINO. BERRY, IMU, ENCODER, ALEXA / LEVI / 12 HR
	UML DIAGRAM FOR SIMULATION / MATT / 3 HR

3 What constraints are keeping you from getting your work done?
(ask for help, declare a breakdown, raise concerns...)

Concern, breakdown, or help you need	Resolution (Action by When)	Who's Responsible?
BUDGET UNKNOWN	ASK GALATI ON	MATT
DATE BUDGET RECIEVED	FRI 10/27/17	
IS UNKNOWN		

4 Overall, are you still on track to meet your commitments to the project?

YES, BUT STRUGGLING TO STAY ON TRACK.

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Appendix C-8: Week 8

University of Portland

Weekly Report-Out

Name Anthony Donaldson Team Transnavigators

Today's Date: 11/2/17

1	What commitments have you completed since our last check-in? (let others know you've kept your commitments, declare work "done" so it can be accepted)	
	Customer	Commitment/Hours Expended
	Project	Edited A3 / 30 mins
		Revised hardware interfaces in EE schematic / 5 hours
		Implemented Lidar in simulation / 3 hours
		Created UML diagram / 2 hours
		3rd iteration design CAD / 4 hours
		Battery research / 3 hours
		3rd iteration design sketches / 2 hours

2	What work will you complete this week (by our next session)? (let others know what they can depend on)	
	Customer	Commitment/Hours Anticipated
	Project	4th iteration CAD / 4 hours Courtney
		Ask for shop training and working space / 1 hour Jarren & Courtney
		Simulation data: Localino, BerryIMU, encoder, alexa / 12 hours Anthony & Matt
		Generate ramp & mounting ideas / 2 hours Jarren
		Research, design, and calculations for gear system / 2 hours Jarren
		EE Research / 3 hours Matt

3	What constraints are keeping you from getting your work done? (ask for help, declare a breakdown, raise concerns…)		
	Concern, breakdown, or help you need	Resolution (Action by When)	Who's Responsible?
	Budget approval	Next week	Lisa Bassett

4	Overall, are you still on track to meet your commitments to the project?
	No, we are not on track. We need to know if our budget was approved.

University of Portland

Weekly Report-Out

Name Jarren Takaki Team Trxnsvengators

Today's Date: 11/9/17

1 What commitments have you completed since our last check-in?
(let others know you've kept your commitments, declare work "done" so it can be accepted)

Customer	Commitment/Hours Expended
Project	Chassis Design Iteration #4 / 2.5
↓	DC-DC Converter Research / 2.0
	Worked on simulation / 1.0
	Motor - Gearmotor - Wheel Research / 1.5
	Purchasing / 0.5
	Meeting with faculty advisors / 1.5

2 What work will you complete this week (by our next session)?
(let others know what they can depend on)

Customer	Commitment/Hours Anticipated
Project	Purchasing / 0.5 - Jarren Takaki
↓	Gear Research / 1.5 - Jarren Takaki
	Chassis Design Iteration #5 / 3.0 - Courtney Otani
	Battery Research / 1.5 - Matt Yuen
	Talk to Allen / 0.5 - ME Members
	Test gezebo & ROS / 3.0 - Anthony

3 What constraints are keeping you from getting your work done?
(ask for help, declare a breakdown, raise concerns...)

Concern, breakdown, or help you need	Resolution (Action by When)	Who's Responsible?
Ramp for vehicle	Build Non-ADA Ramp	ME Members

4 Overall, are you still on track to meet your commitments to the project?

Slightly Behind

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University of Portland

Weekly Report-Out

Name_Matthew Yuen____ Team_Transnavigators______________ Today's Date:_11/16/2017__________

1	**What commitments have you completed since our last check-in?** *(let others know you've kept your commitments, declare work "done" so it can be accepted)*	
	Customer	Commitment/Hours Expended
	Project	CAD iteration 5 / 4 hours
	Project	Wheel research / 2 hours
	Project	ROS research / 6 hours
	Project	AGM Battery Batteries / 3 hours
	Project	DC/DC converter research / 2 hours
	Project	Bought hardware / 1 hours
	Project	Worked on Paper / 1 hour

2	**What work will you complete this week (by our next session)?** *(let others know what they can depend on)*	
	Customer	Commitment/Hours Anticipated
	Project	PosterPaper / 18 hours-All
	Project	CAD iteration 6 / 4 hours-Courtney
	Project	Testing the DC-DC Converter up to rating / 2 hours- EE
	Project	ROS Research / 10 hours-Anthony
	Project	Belt & Wheel Research / 3 hours-Jarren
	Project	Finalize Voice Interface / 2 hours-Matthew
	Project	Test LiDAR / 3 hours - EE
	Project	Localino Research / 2 hours-Matthew

3	**What constraints are keeping you from getting your work done?** *(ask for help, declare a breakdown, raise concerns…)*		
	Concern, breakdown, or help you need	Resolution (Action by When)	Who's Responsible?

4	**Overall, are you still on track to meet your commitments to the project?**
	We are still a week or two behind from getting the budget two weeks late

Appendix C-11: Week 11

University of Portland

Weekly Report-Out

Name_Courtney Otani　　Team_Transnavigators　　Today's Date:__11/30/2017

1	**What commitments have you completed since our last check-in?** *(let others know you've kept your commitments, declare work "done" so it can be accepted)*	
	Customer	Commitment/Hours Expended
	Project	Wrote the first draft of report/60hrs
	Project	Created first draft of poster/7hrs
	Project	Began work on Final CAD for Chassis/Full System/3hrs
	Project`	Begin testing localino/8hrs

2	**What work will you complete this week (by our next session)?** *(let others know what they can depend on)*	
	Customer	Commitment/Hours Anticipated
	Project	Finish Final CAD for full system/6hrs/Courtney
	Project	3D Print prototype/3hrs/Courtney
	Project	Revise/Edit draft report/2hrs/Jarren
	Project	Revise/Edit poster/2hrs/All
	Project	Purchase Encoders/2hrs/Matthew, Anthony, Jarren
	Project	CAD Localino anchor holder/2hrs/Matthew
	Project	Look for wheels to buy/3hrs/Jarren
	Project	Purchase wood for chassis/2hrs/Courtney and Jarren

3	**What constraints are keeping you from getting your work done?** *(ask for help, declare a breakdown, raise concerns…)*		
	Concern, breakdown, or help you need	Resolution (Action by When)	Who's Responsible?

4	**Overall, are you still on track to meet your commitments to the project?**
	Not with respect to our original time line but we are on track with respect to current expectations of when we expect
	things to be finished so we are prepared to hit the ground running next semester.

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University of Portland

Weekly Report-Out

Name: Anthony Donaldson Team: Transnavigators

Today's Date: 12/7/2017

1	**What commitments have you completed since our last check-in?** *(let others know you've kept your commitments, declare work "done" so it can be accepted)*	
	Customer	Commitment/Hours Expended
	Project	Edited paper and poster/30 hours
	Project	Bought encoder/1 hour
	Project	CAD development and render/10 hours
	Project	Motor, shaft, and wheel research/6 hours

2	**What work will you complete this week (by our next session)?** *(let others know what they can depend on)*	
	Customer	Commitment/Hours Anticipated
	Project	Decide gears vs sprockets/10 hours Jarren & Courtney
	Project	Finish design/30 hours Courtney & Jarren
	Project	Finish reading Robot Operating System book/50 hours Anthony & Matthew
	Project	Create updated 2nd semester timeline/4 hours All

3	**What constraints are keeping you from getting your work done?** *(ask for help, declare a breakdown, raise concerns…)*		
	Concern, breakdown, or help you need	Resolution (Action by When)	Who's Responsible?
	Gear vs Sprocket	Janurary 15th	Courtney and Jarren
	How to use Robot Operating System	January 15th	Anthony and Matthew

4	**Overall, are you still on track to meet your commitments to the project?**
	Yes

Appendix D: Resumes

Appendix D-1: Anthony Donaldson's Resume

16740 NE Glisan St
Portland, OR
971-401-6115
donaldsa18@up.edu

Anthony Donaldson

Objective Full-time position where I can apply and further develop my knowledge in Computer Science and Electrical Engineering.

LinkedIn - https://www.linkedin.com/in/anthony-donaldson-216704b2/

Team Projects

Android Chess - https://github.com/PawnStars/Pawn-Stars-Chess-Game

Team developed a networked Chess app with Stockfish Chess AI engine.

Gained experience pair programming and collaborating with to architect the app

Credo Reference Survey Data Website - https://github.com/DinocoCo/DinoGraph

Team developed a data visualization website using Google Charts, Node.js, and Heroku cloud services.

Learned website optimization

Practiced Agile software development methodology

Active Directory Account Lockout Inspector - https://github.com/donaldsa18/ADALI

Created a Java EE web application to query a domain controller, Cisco ISE server, and Oracle database for account information as a resource for the UP Help Desk

PIC Microcontroller Keypad and Audio Player - https://www.youtube.com/watch?v=KFzrQo8lHg4

Programmed a PIC microcontroller to play songs with a keypad and LCD using PIC Assembly

Learned how to debug microcontrollers and interface with

Skills

GitHub Repository - https://github.com/donaldsa18/

Programming languages

- Android, Assembly, C, C++,, Java, Javascript, Lisp, Python, MATLAB, SQL

Software

- Computer Science: Bootstrap, JUnit, Node.js, Heroku, MSSQL, MySQL
- Electrical Engineering: B^{2}Spice, Eagle, L-Edit, MPLAB, PSpice
- IDEs/Editors: Eclipse, Emacs, Netbeans, Notepad++, Visual Studio
- Adobe Creative Suite, Google Docs, LaTeX, Microsoft Office

Operating Systems

- Windows, Mac OS X, Linux (BSD, Debian, RHEL), Android

Soft skills

- Fast learner, collaborative, hardworking, innovative, self-motivated, organized, problem solver, team player

---

Education

University of Portland, Portland, OR — Expected May 2018

- B.S. Computer Science, Second Major in Electrical Engineering
- Member of the Tau Beta Pi Honor Society and Treasurer of the Association of Computing Machinery
- GPA: 3.90

Experience

Information Security Specialist, University of Portland — May 2017 – Present

- Implemented and managed a Splunk environment for machine data analytics

Computer Technician, University of Portland — May 2015 – May 2017

- Increased productivity by implementing SCCM and MDT to automate desktop imaging
- Created software packages for automated deployment with SCCM, Casper, and App-V
- Provided Tier 3 IT support by troubleshooting PC hardware and software

Computer Lab Aide, University of Portland — Sept 2014 – December 2015

- Provided desktop IT support

COURTNEY OTANI

5000 N. Willamette Blvd. Lund #214
Portland, Oregon 97203
(808) 206 -2937
otani18@up.edu

Mechanical engineering student excited to learn new skills and technical knowledge. Will demonstrate initiative, creative problem solving, conscientiousness, and interpersonal skills.

EDUCATION

UNIVERSITY OF PORTLAND: PORTLAND, OREGON — *Expected Graduation: May 2018*

- 4th Year Student, Senior credit standing — Current GPA: 3.805
- Major: Mechanical Engineering
- Minor: Entrepreneurship and Innovation Management

UNIVERSITY OF PORTLAND: SALZBURG, AUSTRIA — *Spring 2016 Engineers Program*

TECHNICAL SKILLS

Trained in:

- Software: CAD (Solidworks), MATLAB (basic knowledge)
- Tools: Basic power tools and hand tools: chop saw, drill press, hand drill, Laser cutter (Epilog Laser)

Some experience with:

- Software: Arduino Uno, Lab View, AutoCAD, FME, GeoMedia, Global Mapper
- Tools: CNC Milling Machine

RELATED EXPERIENCE

MAKAI OCEAN ENGINEERING: WAIMINALO, HAWAII

Internship — *May – August 2016 and 2017*

- Updated and expanded documentation for their submarine cable software training to a level where interested customers could follow the tutorial-style documentation as a self-taught course
- Performed SWAC (Sea Water Air Conditioning) modeling with AutoCAD drawings and company's software created using MATLAB to yield estimates for a client interested in installing a SWAC system
- Conducted extensive search of bathymetry data and electronic navigational charts for the development of
- a broader database to provide with the submarine cable software
- Assembled rigging for and performed tests on an integral component of a prototype

UNIVERSITY OF PORTLAND: PORTLAND, OREGON

President of Global Engineering Initiative Club — *Fall 2015 – Present*

- Advise structure of the club and its future endeavors such as involvement with Global Brigades
- Manage, motivate, and collaborate with other club leaders (ex. Vice President, Project Advisor, etc.)

'IOLANI SCHOOL: HONOLULU, HAWAII

Internship — *May – August 2015*

- Redesigned robotics spaces in Sullivan Center for Innovation and Leadership for better functionality and greater storage capacity for the engineering courses and two afterschool robotics programs
- Coordinated closely with Headmaster, faculty, and staff whose spaces I was redesigning
- Purchased, assembled, and installed furniture and equipment such as work benches and storage systems

Teacher's Aide for 4th Grade Robotics Class — *Summer 2013 and 2014*

- Designed and created robotics challenges for students to solve by creation of attachments and code
- Assembled student teams and answered students' questions in class for optimal student involvement

ACTIVITIES

- Corresponding Secretary of University of Portland Chapter of Tau Beta Pi Engineering Honor Society
- Research: Mathematical model of Oscillating Water Column Wave Energy Converters

Appendix D-3: Jarren Takaki's Resume

3480 Kupaa Drive Honolulu, HI 96816•(808)782-4101•takaki18@up.edu

Jarren Takaki

Education

University of Portland	B.S Mechanical Engineering	Estimated Grad: May 2018
Portland, OR	Double Major in Chemistry	Current GPA: 3.90

Related Experience

Organic Chemistry Workshop Leader — **8/16 - Current**
University of Portland – Portland, OR
- Leads a workshop to help students currently taking organic chemistry
- Communicates organic chemistry concepts in both a presentation and one on one manner
- Adapts and problem solves to resolve unforeseen issues in the workshop

Student Concessions Cashier & Runner — **8/15 - Current**
University of Portland – Portland, OR
- Works well and remains composed in hectic and crowded work spaces
- Deals with unsatisfied customers in a professional manner
- Efficiently works to ensure setup and clean up finish as quickly as possible

Summer Student Research Program — **6/17 to 8/17**
Hawai'i Pacific Health (HPH) – Honolulu, HI
- Retrospective chart review of the diagnosis and management of lung cancer treatment in Hawai'i
- Interacted with and received advice from a plethora of physicians and administration
- Shadowed several specialties including radiology, neurology, general surgery, and more
- Toured all the HPH facilities along with outside affiliated companies
- Gave a research presentation to 200+ people

Shadowed a Physician – Queen's Medical Hospital – Honolulu, HI — **12/16 to 1/17**
- Interacted with and learned how to communicate effectively with patients
- Observed how a physician deals with delivering bad news and consulting difficult patients
- Sat-in on numerous GI track procedures: Mostly Upper endoscopies, Colonoscopies, and ERCP

Engineering Internship – AECOM – Honolulu, HI — **5/15 - 8/15 & 5/16 - 8/16**
- Interned summer 2015 in the water department and summer 2016 in the wastewater department
- Shadowed engineers both in the office and out at the field
- Focused and remained productive for 40-hour work weeks

Engineering Student Advisory Council – President – Portland, OR — **8/16 - Current**
- Communicates between the students and dean of the engineering school to improve quality of life
- Leads meetings and maintains contact with the members

Engineering Group Project – University of Portland — **Spring '17**
Machine Design – Portland, OR
- Collaborated with peers to make a small LEGO agriculture vehicle that would transport a mass as quickly as possible while remaining within the set restrictions
- Maintained a schedule of deadlines before the final project presentation

Member of Tau Beta Pi – Oregon Gamma Chapter — **Fall '16 - Current**
- Engineering Honor Society

Eagle Scout / Senior Patrol Leader – Boy Scouts of America — **Summer '14**
- Organized a project to construct eight rolling whiteboards for Nu'uanu Elementary School
- Collaborated with professionals to develop a design and procedure

Matthew Yuen

yuenm18@up.edu
(808)-542-2492

5000 N Willamette Blvd
Tyson Hall Room #211C
Portland, OR 97203

Permanent Address:
1144 Kaluanui Road
Honolulu, HI 96825

EDUCATION

University of Portland, Portland, OR — Expected May 2018
Bachelor of Science, Computer Science, Minor in Mathematics — GPA: 3.90
Bachelor of Science, Electrical Engineering

- Dean's List
- Tau Beta Pi

EXPERIENCE

Student Web Developer, University of Portland, Portland, OR — Fall 2017

- Creating Liferay Portlets which will be used internally by the University
- Currently developing a portlet which will be used to sign-in students to the Academic Resource Center and improve the integrity of their data by reducing errors caused by manual data entry

Computer Science Fellow, University of Portland, Portland, OR — Fall 2017

- Mentoring sophomore level students in Intro to CS, Data Structures and OO Design
- Debugging code and explaining programming concepts to students

Grader/TA, University of Portland, Portland, OR — Fall 2017

- Grading homework and quizzes for Embedded System Design

Software Developer Intern, Pacific Disaster Center, Kihei, HI — Summer 2017

- Built a dashboard which monitors and locates failures in PDC's disaster monitoring platform
- Made system failure information readily accessible to both technical and non-technical people
- Presented the project and wrote an abstract as part of the Akamai Internship Program

Teaching Assistant, University of Portland, Portland, OR — Spring 2017

- Worked as a teaching assistant for the class, Engineering Computing with Applications
- Helped teach students basic programming concepts with MATLAB

Undergraduate Research, University of Portland, Portland, OR — Fall 2016 - Spring 2017

- Tested the susceptibility of different GFCI units to Electrical Fast Transients
- Presented a paper on the results at ISPCE 2017 and at an Oregon IEEE EMC society chapter meeting
- Showed that various GFCI perform differently in the presence of fast transients

TECHNICAL SKILLS

Programming Languages: Java, C, MATLAB, Python
Operating Systems: Windows, Mac OS, UNIX (Bash scripting)
Applications: Microsoft Office, Eclipse, Android Studio, Git, PSpice, B2Spice, MPLab

EXTRACURRICULAR ACTIVITIES

Member, Robotics Club — 2015 - 2017
Member, Global Engineering Initiative — 2016- 2017

- Built a water catchment system for the gardening club

Participant, AMC-ICPC Regional Programming Competition — 2016 - 2017
Volunteer, Stem Camp — 2016

- Helped children complete STEM related projects