OneWheel Redesign

Senior Design Proposal submitted to the
Department of Mechanical and Materials Engineering
College of Engineering and Applied Science
University of Cincinnati

in partial fulfillment of the
requirements for the degree of

Bachelor of Science

in Mechanical Engineering Technology

by

Alex Poole, Spencer Gregory, and Quoran Knights

May 2022

Thesis Advisor:

Christopher Calhoun, PhD

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

This project was the brian child of two skateboarding enthusiasts who have always been interested in the idea of the OneWheel. We have ridden every type of wheeled device since we were young and loved the idea of a self balancing skateboard. Also, we are getting older and admittingly lazier, so a battery powered device intrigued us even more. After some research into the subject, and hearing the opinions of friends, we realized there were some design aspects of the OneWheel that everyone was vocal about and we thought we could tackle it ourselves. We started by researching the construction of the device and brainstorming how we could improve upon the community's request while still keeping the integrity of the original design. We designed the product to be easily worked on and safe for the rider as well. We modeled the entire design using two main parts as the structural backbone, and did the necessary analysis to figure out the required materials. We ordered stock materials and manufactured them to our liking, and 3D printed the more complex parts that weren't necessary to the structural integrity. We designed and manufactured every aspect of the product from the bottom up including the batteries themselves, excluding the motor and speed controller because those are out of our wheelhouse. We started manufacturing all our parts in preparation for the motor’s delayed delivery, which unfortunately came in undersized causing major rework models, requiring all previously made parts to be redone. Even with the unforeseen circumstances we were able to create a final product that was up to the standards of the original OneWheel while improving on the safety, ease of use, and customizability of the device.

PROBLEM DEFINITION AND RESEARCH

PROBLEM STATEMENT

The biggest product on the market for electric self-balancing skateboards, the Onewheel, fails to address the entry-level demographic and multiple safety factors. Poor communication with the rider and a lack of accessibility can create an environment that people who are unfamiliar with riding similar devices are afraid of.

RESEARCH

BACKGROUND AND SCOPE OF THE PROBLEM

Skateboarding dates to the 1950's when surfers in California and Hawaii turned to another thrill-seeking adventure when the waves were not ideal. By attaching wheels to small surfboards, they were able to capture a similar feeling by being "asphalt surfers" (1). This idea started out rough, and only captured the attention of surfers at the time. Today, skateboarding is more popular than ever with its recent debut at the 2020 Summer Olympics in Tokyo being one of the biggest highlights for the sport. The global market for skateboards was $1.9 billion in 2018, with teenagers taking up 44.1% of the market demographic and kids only slightly less, it is expected to reach a value of $2.38 billion by 2020 [market research]. Expanding the market demographic to adults would allow for a significant growth in the market.

This is where electric powered boards come into play. They allow users who previously did not ride boards because of the physical aspect a chance to try them out. Electric powered longboards were the first to pop up on the scene, and thanks to the bigger wheels on them they brought an easy riding experience where all you need to do is control speed on a remote and lean left and right to turn. They are extremely easy to stay stable on since it sits on four wheels whose spin is always controlled. Unfortunately, this heavy controlling of the board limits the rider's capability to feel the surfing aspect that skating came from. To get that smooth feeling back, people looked to self-balancing electric boards. They ride on one wheel in the middle and balance the rider as they use it. This design allows for an extremely unique experience that had yet to be captured by previous boards.

Because of the innate design that these self-balancing boards have, it can look and feel very overwhelming to people who are poor at balancing or have not had previous experience in board riding sports. The single wheel design creates an awkward mount and dismount feeling that can be frightening for new people, since mounting the board usually leads to newer individuals accelerating without meaning to, creating a panic. The act of moving on the board is also very foreign since the self-balancing boards are not mainstream. People getting overwhelmed is the root for these safety issues because inexperienced users are being thrown onto a board with near no help on how to ride it. It is like when people get overwhelmed when learning to drive, they will press on the brakes and instead hit the gas, causing panic to take over, resulting in them press down harder on the gas, thinking the car was doing something wrong. Eliminating this human error of getting stressed out will allow the demographic to expand to those who are discouraged by their inability to balance, lack of experience, or fear of getting hurt and give them the opportunity to partake in this glorious feeling of street surfing.

Also, these boards are susceptible to nose diving which is where the front of the board will go straight downwards and stop self-balancing. This is extremely dangerous, as the board could nosedive at any speed, sending the user flying forward off the board. It is one of the biggest reasons people fall and has even resulted in multiple deaths and serious injuries (2). There are multiple reasons for why this happens; too steep of a decline, riding too fast, applying too much downward force on the nose, or riding on too low of battery. We plan to adapt different ways in alerting the user of possible hazardous situations to prevent falls from happening as frequently and look to teach the user how to prevent being in that situation all together before riding the board.

CURRENT STATE OF THE ART

In this current day in age the use of electrical transport of all measures is exploding us into the future desire of less emissions caused by travel. The main mode of electric travel stretches from trains to cars to even more common electric scooters or skateboards. We divided this project into 3 parts: the structural, electrical, and the programming layout with each one being intricate to work together as a unit. For our design, we will be focusing on the most efficient structural design that will fit our desired outcome in improving the product to user communication for safety improvement. The type we will focus on are different style electrical unicycles (EUC), who only have one wheel in the middle but still run off battery power. In this category, (3)there are 2 major structural designs leading the mark and they are the unicycle design where the rider faces forward while straddling the wheel or the design that resembles an electric skateboard with one wheel placed in the middle.

King Song 16X

In the unicycle design the current state of the art Product is the King Song 16X, as shown below, that can get 65 miles on a full charge, 31 mph and has a 2200W motor (4). Structurally it has a common look with a lightweight but durable frame surrounding the single tire with two pedals on either side to place your feet. A more in-depth specifications look, this unicycle sits at 52 lbs., which may seem like a heavy item but when you think at it holding up to 330 pounds in body weight as well as lightweight handle to help carry the of the board. To travel on multiple different terrains, it sports an extra-wide 16x3 inch wheel that also pushes you to physically adjust to the wheel wanting to stay vertical. On either side there are foldable petals with comfortable but effective grips for foot placement. Some other extra features it has that draws customers' eyes are built in speakers/subwoofers to connect to your phone music and LED lights for moving in lowly lit area.

An electric unicycle (EUC) is like the Onewheel, the difference being the direction you ride it. These are ridden like a unicycle, going forwards and backwards from your chest and back respectively. What they do to maximize safety is utilizing a self-balancing device, and then instead of push back, most EUCs are equipped with audio capability that produces a high-pitched beeping sound to alert the rider of a dangerous situation. While this is on the right track, I do not believe that should be the only factor of safety installed.

Figure 1: King Song 16X Side View

OneWheel Plus XR

With the other design the current leading product is the OneWheel Plus XR, topping out at 19 mph and a range 18 miles on a full charge (5). Unlike the unicycle it has a wider base on the pedals to place your feet however you feel comfortable. The wider 11.5 by 6.5 in wheel is held in place by the frame attached to the rim with a thin (optional) cover, allowing the wheel to truly spin in between your feet but making it easier to traverse rockier terrain. Even with the size of the wheel it all together weighs 27 lbs. with a handgrip to attempt to carry as comfortably as possible. The built-in lights help light the path whether you are moving forward or reversing and an app for your phone is raved to have some useful, plus user-friendly features.

Onewheel's main safety feature is called pushback, which is where the nose of the board will push back into the user, alerting them to shift their weight backwards to slow down. When the board thinks it is in a dangerous situation and it may have to give out to protect the motor, it'll initiate pushback. While this is their main combatant towards dangerous situations, it is severely flawed.

Going uphill makes it extremely difficult to notice any pushback since riders are already leaning into it, so if you are straining the motor on too steep of an incline the board can suddenly give out with no previous warning. Also, pushback is easily ignored since the user is accustomed to the self-balancing feeling and may not think that the force from pushback is any different than the one they feel from normally riding. This could result in them pushing down even harder on the nose to counteract the push back force, which is easy to do. These two reasons make pushback very inefficient at communicating with the rider.

Other than this feature, the product offers no help to riders learning how to use it. Although it does come with a manual and has an app to adjust some settings, their manual still requires you to have someone there when first learning how to ride it. Even after you are balancing on the board, getting comfortable with turning and speeding up or slowing down is a whole other beast that this board fails to tackle.

Figure 2: OneWheel Plus XR Side View

The OneWheel XR+ uses a 750W Hypercore hub motor. A 63V 324Wh NMC battery powers both and allows the vehicle to reach a speed of 19mph with 12-18 miles of range depending on riding style.

Fangs

Fangs are a third-party product that aims to help users with the nose-diving issue mentioned previously. It is a single snap on attachment that goes under the nose of the board. They work by, "reducing friction of the nose bumper on the ground, allowing you to jump off or regain control instead of coming to a dead stop" (5). They reduce friction by attaching wheels under the nose of the board.

This solution plays perfect into my area of safety as it works great in the sense that it helps protect the rider when a nosedive happens, but it does nothing to teach people how to react to a nosedive or offer any way to alert the user better. The design solely helps you deal with a problem and doesn't aim to eradicate it.

The singular wheel skateboard is a relatively new mode of transportation which means the design has plenty of room for improvement. It uses batteries to power both a hub motor that fits inside the wheel and a Vedder Electronic Speed Controller (VESC) with an Internal Measurement Unit (IMU). The IMU contains both an accelerometer and a gyroscope which communicates with a speed controller to help self-balance the board for the rider. The original OneWheel was released in 2015, but the current top-of-the-line OneWheel XR+ came to market in 2018 and has been their top performer since. I was unable to find any specific motor specs for their 750W Hypercore motor, but it allows the OneWheel to reach a top speed around 19mph (3). The MAG Wheel is one of their top competitors and for good reason, with a lower price point and a motor with double the power(1500W) that can push the board to its top speed of 22mph (4).

The VESC used is an open-source speed controller that can reverse current flow and take advantage of regenerative braking. These usually communicate with a remote, but the IMU replaces that and uses orientation and acceleration values to balance and accelerate. The newer versions include upgrades like better performance and high current capabilities (5)

There are two battery types typically used in an electric vehicle and both have advantages in certain situations. Lithium phosphate (LiPo4), used in the MAG Wheel, is the most common and is used in most applications because it operates more efficiently in warmer climates, has a longer life span and is more suited to handle over charging/discharging. NMC, used in the OneWheel, is also a lithium-based battery, but uses Nickel Manganese Cobalt Oxide as the Cathode. This type of battery is very enticing because its energy density is slightly more than twice that of Lithium Phosphate but does come with downsides that are hard to avoid. The LiPo4 battery will retain around 80% of its total energy capacity after 2500 cycles but the NMC battery will reach that after only 1000 cycles. More importantly the NMC powder is extremely hazardous and can be flammable when exposed to water (6). The single wheeled boards also have light/audio indicators to communicate with the rider as well as a power switch and battery percentage display.

Figure 3: MAG Wheel Skateboard

The MAG Wheel max is a powerful 1500W single-wheeled electric vehicle that uses a VESC similar to the OneWheels. It's powered by a 60V, 420Wh LiPo4 battery and reaches 22mph with 17 miles of range.

END-USER

The main end-user for this device would be anyone who rides it no matter the rider's skill level. Whether it be from purchasing it themselves or riding someone else's, anyone who steps onto this device is looking to enjoy the thrill of it. Being able to actually ride the electric skateboard is up to the rider's current ability, so those who are less experienced will only utilize a fraction of the device's potential. Making up for this experience deficit will allow all users to ride this device to its fullest potential. Another goal is also adding the safety features while making it more affordable to the common user, at the moment similar designs are being sold for over $1000. The price alone tends to deter off users so in changing this it can also be more marketable to first-time users.

CONCLUSIONS AND SUMMARY OF RESEARCH

The current technology that the Onewheel utilizes is insufficient in teaching people how to ride, and their only safety warning is something that goes easily ignored. Although pushback does work sometimes, and audible beeping is very helpful, combining these or adding multiple factors of safety would prevent many injuries. Another thing that we should consider adding on to our product would be some other form of haptic feedback like vibration. Creating multiple alert systems would result in a higher chance of the user noticing.

The fangs do their job perfectly and are nearly flawless in their design, yet they do not fix the problem of helping new people learn to ride. Adapting the fangs design into an attachment that is meant to teach people how to ride it instead would be a good place to start. Pair that with a program that can be set on the Onewheel that is specifically for teaching people how to ride it would open this experience to many more people. Lastly, adding some type of LED screen to better communicate with the rider would be a nice quality of life change.

The current designs that provide users comfort while riding tend to do well in their respective areas. I think it would be smart of us to consider adapting some of their foundational structure designs then tweaking so we can make it our own and more suited for the plans of fixing the safety issues in pushback. Between the two designs I mentioned, the team's ideas are leaning towards the one-wheeled skateboard style to give us more creativity in the frame as well as balance the needed attachments. Some thoughts and experiments we can look for are a possibly a lighter weight material to reduce the overall product weight but not diminishing the products desired performance or quality.

The lack of a competitive market meant it was difficult to gather information on the specifications of the products designs, but it does give us the opportunity to improve upon certain areas. Speed is dangerous so our group wants to input riding styles that could be optimized for learning, battery usage or speed. We also want to implement a more effective communication system that will have an easier time notifying a distracted rider. Structurally we want to experiment with new designs that break the current market mold in order to increase usability and investigate out of the box wheel variations to make the vehicle more efficient or increase off road capabilities.

QUALITY FUNCTION DEPLOYMENT

SURVEY SAMPLE

This survey will gauge the importance of different features to customers to increase the desirability of the product. The product is a rechargeable, electric one-wheeled skateboard for recreational and travel purposes.

Have you ever ridden a Onewheel (seen here) or other self-balancing skateboards (excluding hoverboards)?

Please circle the appropriate response.

Yes No

If you were to invest in a self-balancing skateboard, how important would each of the following features be?

Please circle the appropriate response. 1 = Low importance 5 = High importance

Initial Cost	1	2	3	4	5	N/A
Ease of Use	1	2	3	4	5	N/A
Safety	1	2	3	4	5	N/A
Aesthetic	1	2	3	4	5	N/A
Battery Life	1	2	3	4	5	N/A
Audio Capability	1	2	3	4	5	N/A
LED Info Screen	1	2	3	4	5	N/A
App Capabilities	1	2	3	4	5	N/A

Are there any other features you would like to see implemented?

What price range would be most reasonable?

☐ $200-$499

☐ $500-$749

☐ $750-$1000

☐ $1000+

How experienced are you with riding similar products that are NOT electric (skateboard, surfboard, snowboard etc.)?

☐ Very experienced, comfortable at most speeds

☐ Experienced, comfortable riding casually

☐ Slightly experienced, only rode a couple times

☐ Unexperienced, only ever stood on a board

☐ Never rode similar products

If you have ridden a Onewheel or self-balancing skateboard, how well did it address each of the following features?

Please circle the appropriate response. 1 = Low importance 5 = High importance

Initial Cost	1	2	3	4	5	N/A
Ease of Use	1	2	3	4	5	N/A
Safety	1	2	3	4	5	N/A
Aesthetic	1	2	3	4	5	N/A
Battery Life	1	2	3	4	5	N/A
Audio Capability	1	2	3	4	5	N/A
LED Info Screen	1	2	3	4	5	N/A
App Capabilities	1	2	3	4	5	N/A

For those who have not ridden a Onewheel, if you were to ride a Onewheel today, how comfortable would you feel in your ability to ride it alone?

	1	**2**	**3**	**4**	**5**	
Very Uncomfortable	☐	☐	☐	☐	☐	Very Comfortable

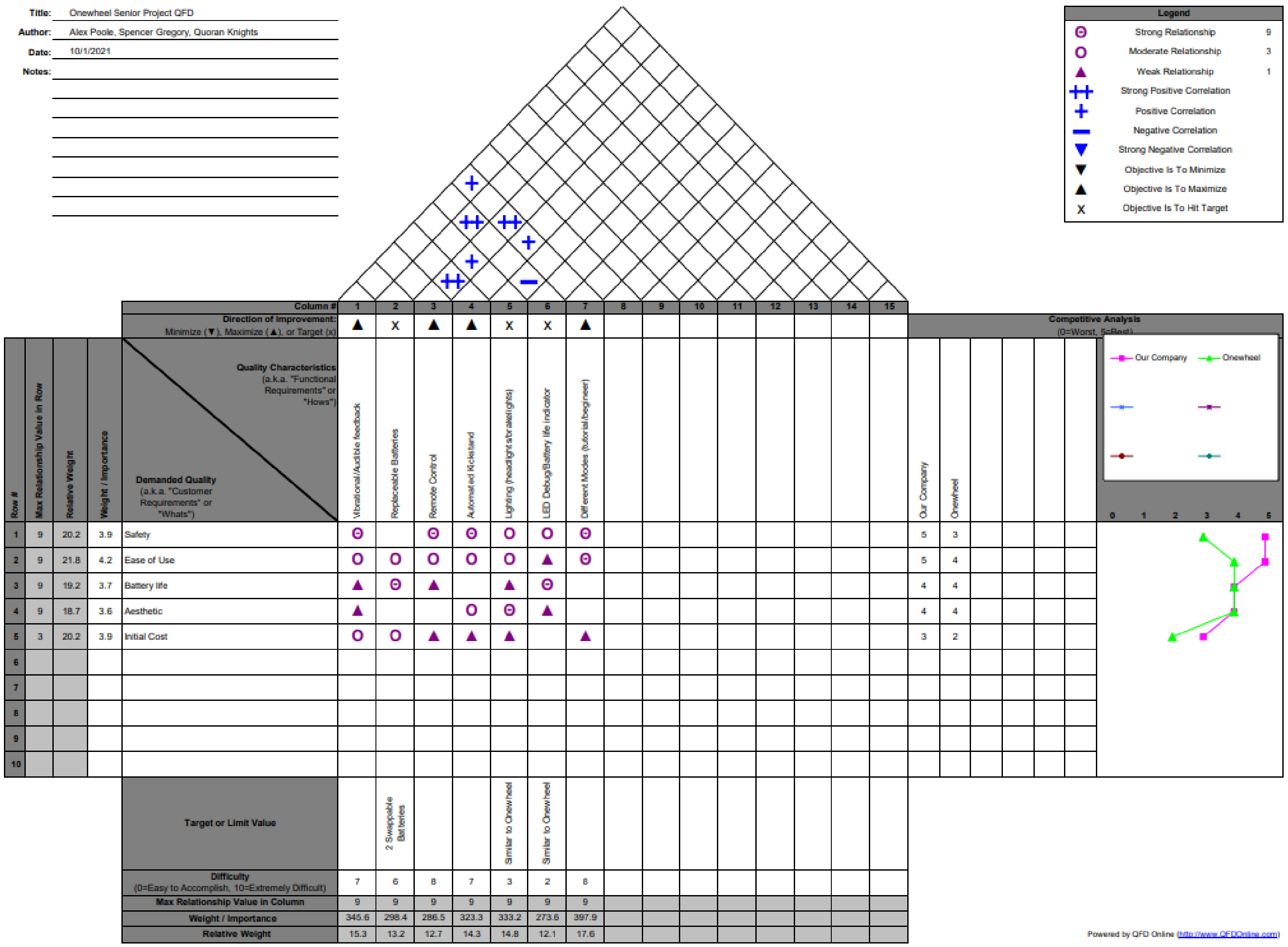
CUSTOMER FEATURES

Safety
Ease of Use
Battery Life
Aesthetic
Initial Cost

ENGINEERING CHARACTERISTICS

Vibrational/Audible Feedback
Remote Control
Automated Kickstand
Lighting (headlights/brake lights)
LED Debug/Battery Life Indicator
Different Modes (tutorial/beginner)

HOUSE OF QUALITY



Title: Onewheel Senior Project QFD
Author: Alex Poole, Spencer Gregory, Quoran Knights
Date: 10/1/2021
Notes:

Legend		
Θ	Strong Relationship	9
O	Moderate Relationship	3
▲	Weak Relationship	1
++	Strong Positive Correlation	
+	Positive Correlation	
−	Negative Correlation	
▼	Strong Negative Correlation	
▼	Objective Is To Minimize	
▲	Objective Is To Maximize	
x	Objective Is To Hit Target	

Row #	Max Relationship Value in Row	Relative Weight	Weight / Importance	Demanded Quality (a.k.a. "Customer Requirements" or "Whats") / Quality Characteristics (a.k.a. "Functional Requirements" or "Hows")	Vibrational/Audible feedback	Replaceable Batteries	Remote Control	Automated Kickstand	Lighting (headlights/brakelights)	LED Debug/Battery life indicator	Different Modes (tutorial/beginner)	Our Company	Onewheel
				Column #	1	2	3	4	5	6	7		
				Direction of Improvement: Minimize (▼), Maximize (▲), or Target (x)	▲	x	▲	▲	x	x	▲		
1	9	20.2	3.9	Safety	Θ		Θ	Θ	O	O	Θ	5	3
2	9	21.8	4.2	Ease of Use	O	O	O	O	O	▲	Θ	5	4
3	9	19.2	3.7	Battery life	▲	Θ	▲		▲	Θ		4	4
4	9	18.7	3.6	Aesthetic	▲			O	Θ	▲		4	4
5	3	20.2	3.9	Initial Cost	O	O	▲	▲	▲		▲	3	2
6													
7													
8													
9													
10													
				Target or Limit Value		2 Swappable Batteries			Similar to Onewheel	Similar to Onewheel			
				Difficulty (0=Easy to Accomplish, 10=Extremely Difficult)	7	6	8	7	3	2	8		
				Max Relationship Value in Column	9	9	9	9	9	9	9		
				Weight / Importance	345.6	298.4	286.5	323.3	333.2	273.6	397.9		
				Relative Weight	15.3	13.2	12.7	14.3	14.8	12.1	17.6		

Competitive Analysis (0=Worst, 5=Best)

Powered by QFD Online (http://www.QFDOnline.com)

Figure 4: House of Quality

PRODUCT OBJECTIVES

Different Modes (tutorial/beginner) – 17.6

Creating different modes gives new riders the opportunity to learn at their pace. Walking the rider through each step of riding the board will build muscle memory and allow them to safely try out the device with restrictions based on the mode being used.

Vibrational/Audio Feedback – 15.3

To make communication with the rider more efficient, a loud audio noise will be added to alert the rider of certain situations. Also, vibrational feedback will be placed to further improve the communication in case the rider can't hear the audio queue.

Lighting (headlights/brake lights) – 14.8

Adding lighting is essential in keeping people safe, making themselves easily visible to cars and other people, while also providing the rider with light to see their path ahead.

Automated Kickstand – 14.3

The kickstand will allow riders to easily step on and off the device without any wobbling.

Replaceable Batteries – 13.2

The rider will be able to swap out the battery on the go, creating longer sessions.

LED Debug/Battery Life Indicator – 12.1

Easily reading the battery life or the problem on the product allows the rider to better understand what the product is requiring of them to do.

Remote Control – 12.7

Controlling the different modes, kickstand, and possible other features from a remote helps create a safe environment. Instead of having to reach down and open the kickstand while riding, they can simply press a button. This is also better than using an app since the rider could possibly drop and break their phone, while the remote will be significantly more durable.

DESIGN

DESIGN ALTERNATIVES AND SELECTION

Concept 1

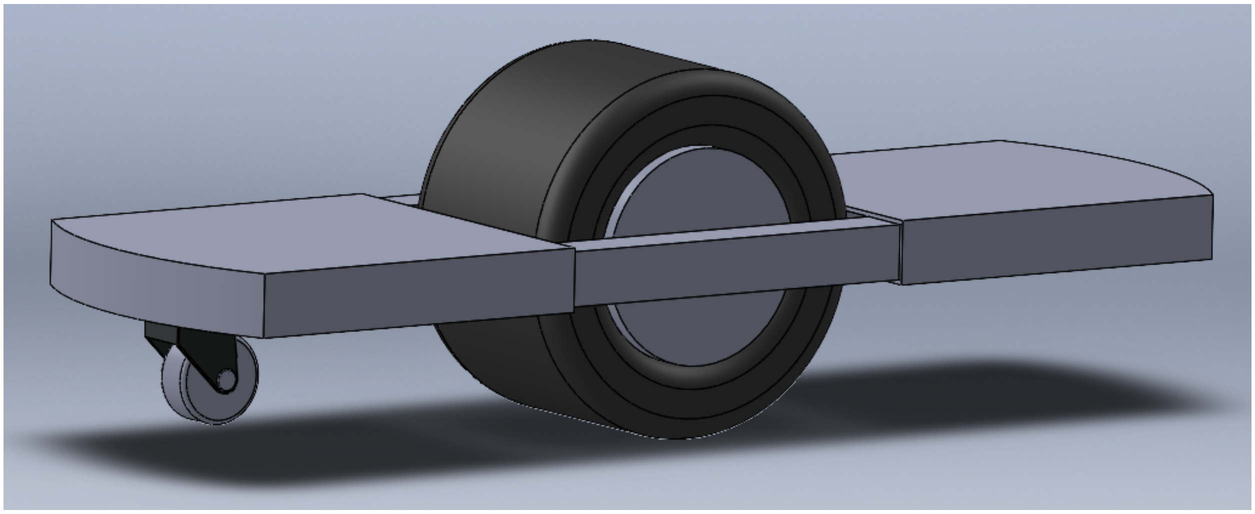


Figure 5: Caster Wheel Concept

This concept utilizes a caster under the nose of the board, one similar to those used on office chairs for hardwood floors. The caster's purpose is to act as a training wheel, restricting the angle of the nose of the board. This restriction will prevent newer users from being scared of leaning too far forwards and accelerating heavily. It will work hand in hand with our tutorial program that is installed on the board and will guide the user through the steps of accelerating and braking. If the caster were to make contact with the ground, the rider would simply continue riding forwards at an easy, consistent speed, allowing them to readjust their positioning without worry

Also, there is no need for another one on the tail end of the board, as any downward motion the nose has will only result in breaking. If one of these casters were installed under the tail of the board, it wouldn't allow for any breaking. This design is simple and will be an attachment to the board, allowing for its removal once the rider is comfortable without it.

Concept 2

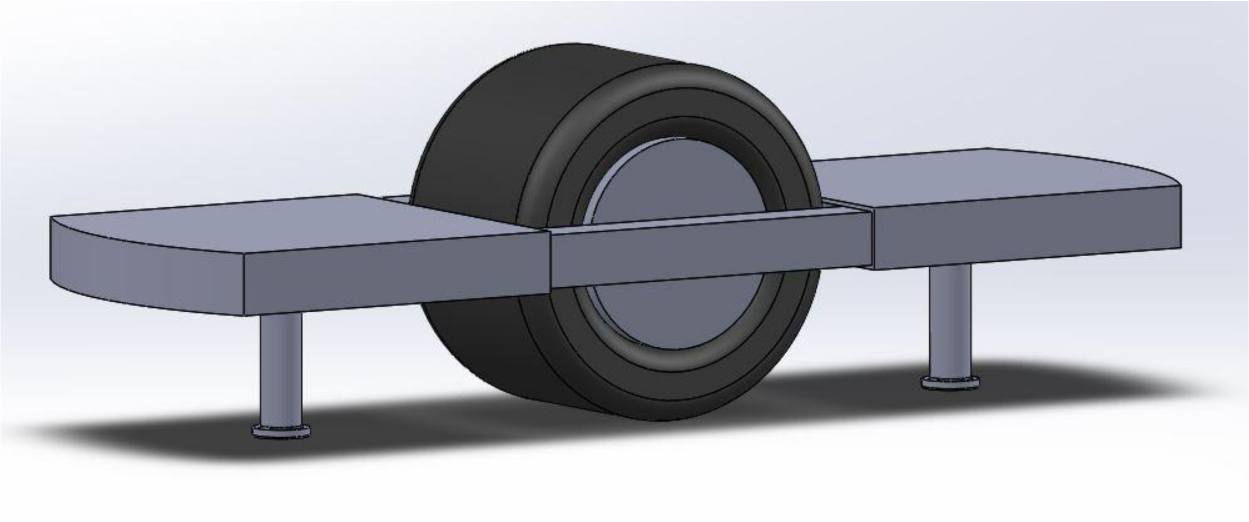


Figure 6: Pneumatic kickstand concept

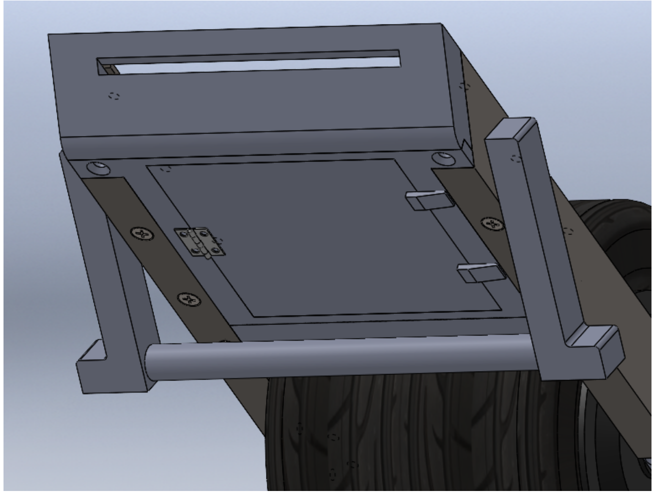


Figure 7: Step motor kickstand concept

This concept utilizes two retractable pegs on either side of the wheel to serve as a kickstand. The purpose of the kickstand is to help newer users balance and get used to the feel of the board. Connected to the remote, they will extend or retract at the press of the button. While retracted you wouldn't even notice unless color-wise the customer wanted them a different color. The placement while extended allows the wheel to still lightly touch the ground without rocking. It also retracts at a slow speed to give the rider time to not fall with less support.

This concept will structurally be a challenge to build in because of how it will need to retract into the board, but programming wise it will tie right into the rest of the functions. Material wise it is not adding much cost because it can be made from the same material as the frame.

Concept 3a

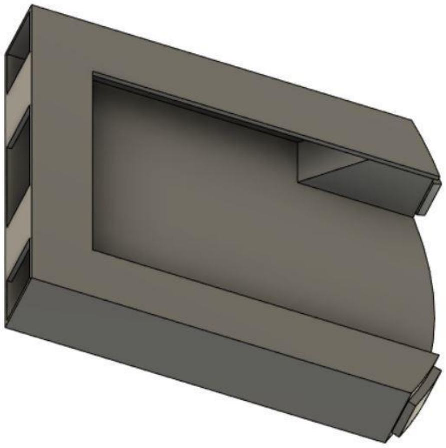


Figure 8: Battery slide concept

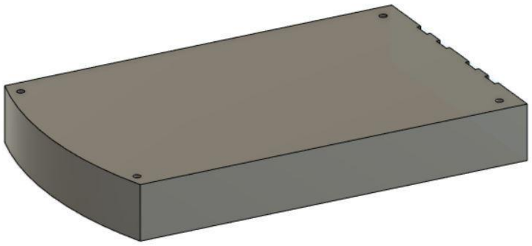


Figure 9: Battery case concept

This concept utilizes two slides on the nose of the board that hold a removable battery pack in place. We could improve the batteries efficiency or size so we decided to design a pack that can be stored in a backpack and easily exchanged without tools. We can use a wireless connection to keep it clean and safe. We can use plastic to construct the case so manufacturing and design should be relatively easy and affordable.

It might be a challenge to get slides that are robust enough to hold in the case but I'm sure we could upgrade to higher quality clips. It should be easy to manufacture with a large enough 3d printer and will allow us to increase the overall range by carrying a backpack with you.

Concept 3b

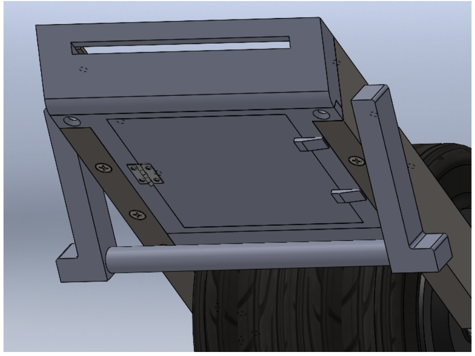


Figure 10: Trapdoor concept

This concept involves cutting a square hole in the bottom of the rear panel and using hinges and latches to create a trapdoor design. We would use a hinge on one side and spring latches on the other to make sure that the compartment stays shut while riding through rougher terrain. We would like to keep the entire bottom as a clean sheet of metal but removing the interior square might prove to be a challenge from a manufacturing aspect but a thick square of 3D printed material would do the same thing and allow us to account for any uneven edges.

This design is simpler and more effective at retaining valuable compartment space needed to build the largest battery possible. It would also keep the nose of the board in a stationary position which would make the wiring less complex if we have time to put headlights and brakelights on our product.

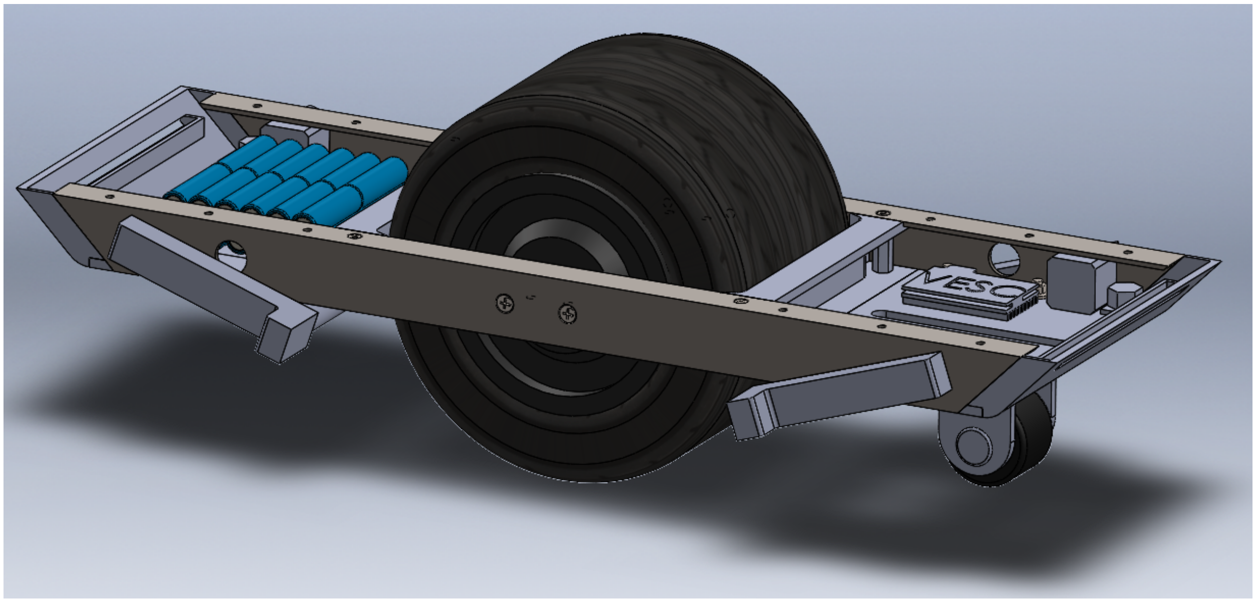


Figure 11: **Final Design Idea**

ENGINEERING CALCULATIONS

~Constants~Compartment size~

Compartment size = 6.5” wide x 6” long x 2” tall

Individual battery = .7” diameter x 2.55” length

Trapdoor width and length = 5.5” x 5.5”

~If arranged as shown in the image above~

$Width \ = \ 6.5"/2.55" \ = \ 2.54 \ = 2\,batteries$

$Height \ = \ 2"\,/\,.7" \ = 2.85 \ = 2\,batteries$

$Length \ = \ 6"\,/\,.7" \ = \ 8.57" \ = \ 8.57 \ = 8\,batteries$

Based on these calculations we could get 32 batteries into this compartment but since the trap door is smaller than the compartment itself we had to cut the length of our battery, but if we slide it in at an angle we could fit a little more than the trapdoor allowed.

$Length\ =\ 5.5"/.7"\ =\ 7.82\ =\ 7\ batteries$

We could have theoretically made a 14s2p (14 series, 2 parallel) battery but that would give us a maximum voltage of 58.8 which is dangerously close the the maximum rating of the VESC (60V) so we decided to keep it 13s2p which is why the battery is slightly lopsided

~Calculating Torque, Power draw and Amp draw~
13s2p
$13\ batteries\ (series)\ *\ 4.2\,V\ =\ 54.6\,Volts\ (V)$
$2\ batteries\ (parallel)\ *\ 3.5\,ah\ =\ 7\ Amp\ Hours\ (Ah)$

~From motors website~
Power out = 800W
Radius = .1252m (4 in)
Top speed = 35 km/h (9.71 m/s) (22mph)
Efficiency (at 800W) = 75%

$\omega\ =\ v/r\ =\ (9.71\,m/s)\,/(.1252\,m)\ =\ 77.556\,rad/s$
$Torque\ =\ Pout\ /\ \omega\ =\ 800W\ /\ 77.556\,rad/s\ =\ 10.32\,Nm$
$Pin\ =\ Pout/Efficiency\ =\ 800W\ /\ .75\ =\ 1067\,W$
$Amp\ draw\ =\ Pin/Voltage\ =\ 1067\,W/\,56.4\,V\ =\ 19.8\,A$

~Calculating Range~
$Watt\ hours\ (Wh)\ =\ V\ *\ Ah\ =\ 56.4\ V\ *\ 7\,Ah\ =\ 392\,Wh$
~Average of 20Wh/mi on flat paved road~
$Range\ (miles)\ =\ Wh\ /\ ratio\ =\ 392\,Wh\ /\ (20\,Wh/mi)\ =\ 19.6\,mi$

MANUFACTURING DRAWINGS

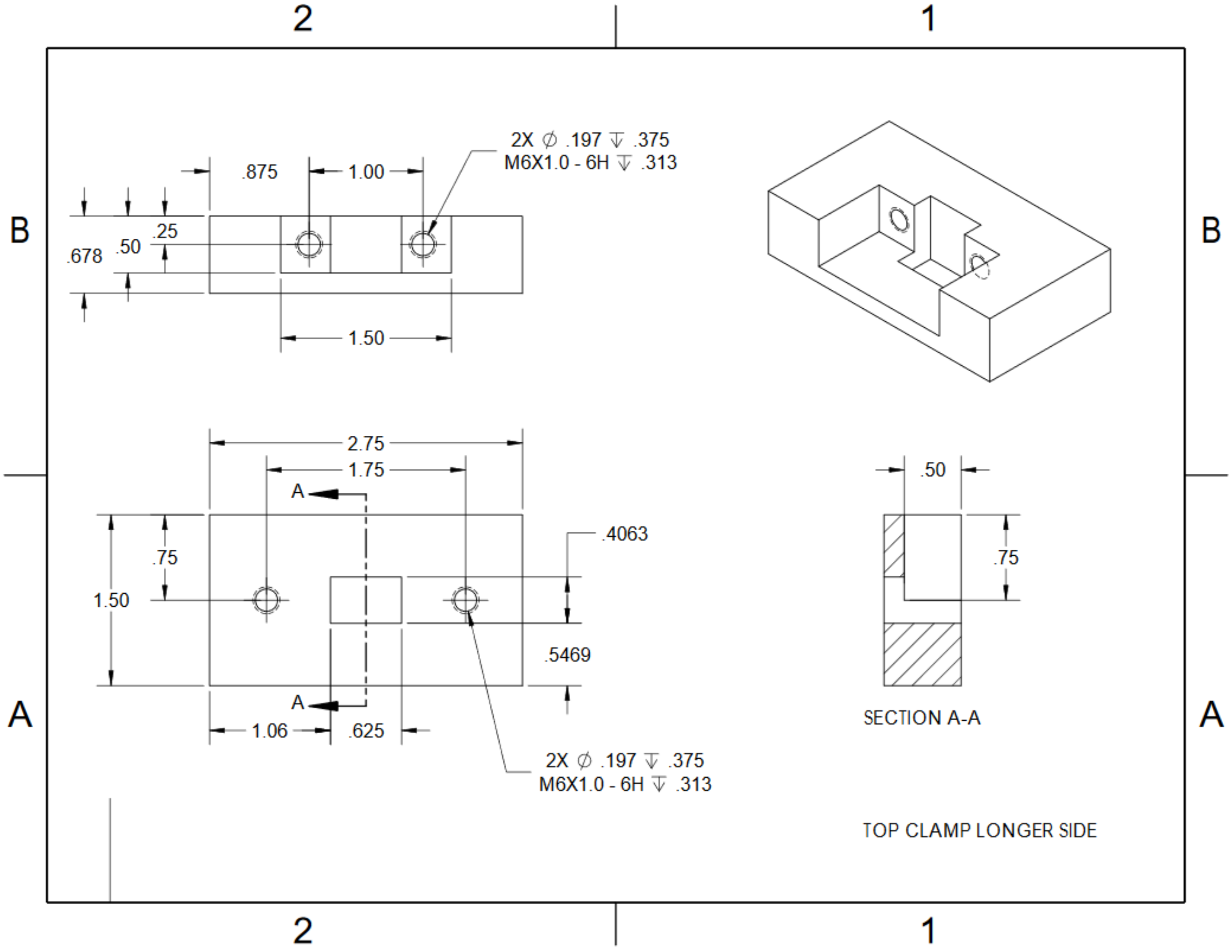


Figure 12: Top clamp for longer axle side

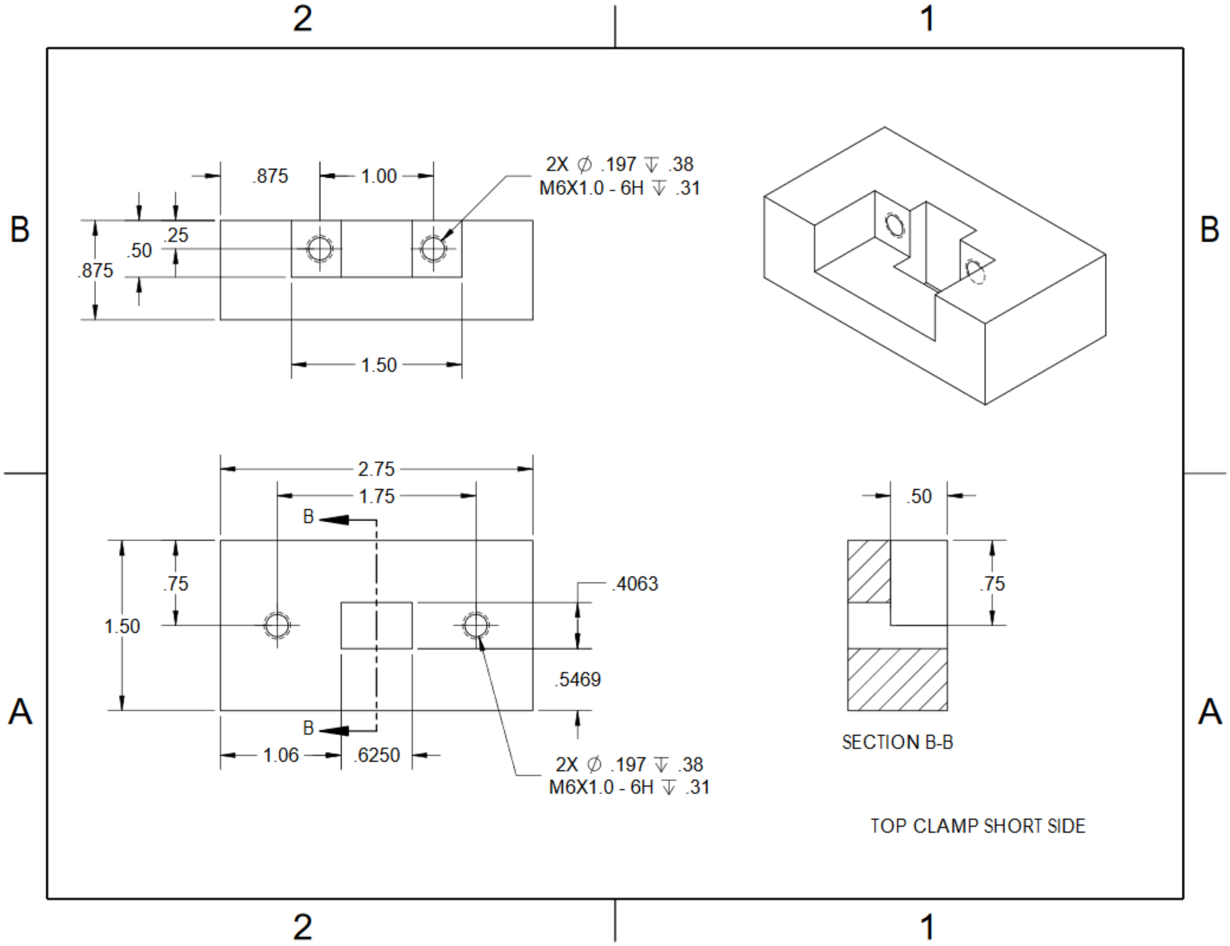


Figure 13: Top clamp for shorter axle side

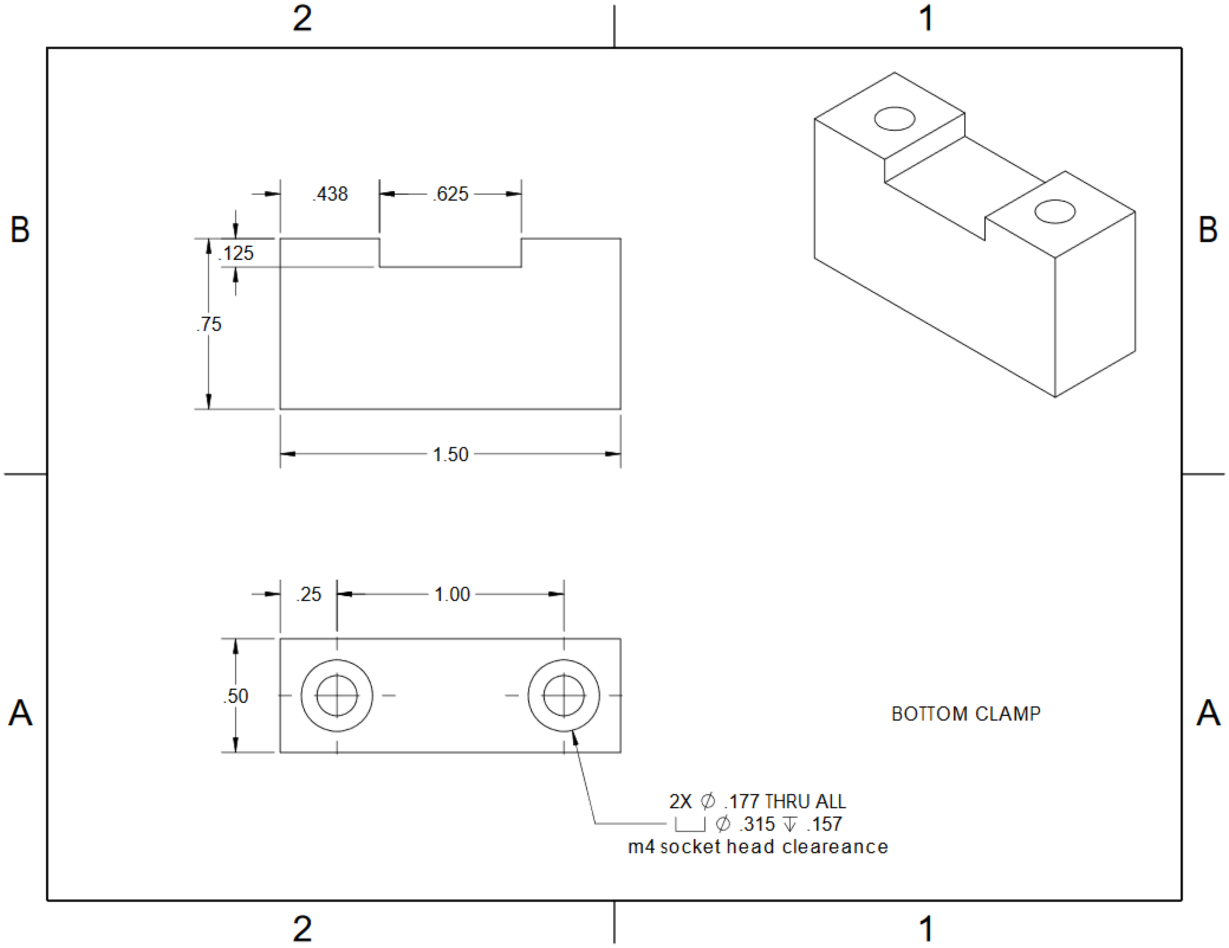


Figure 14: Bottom clamp for both axles

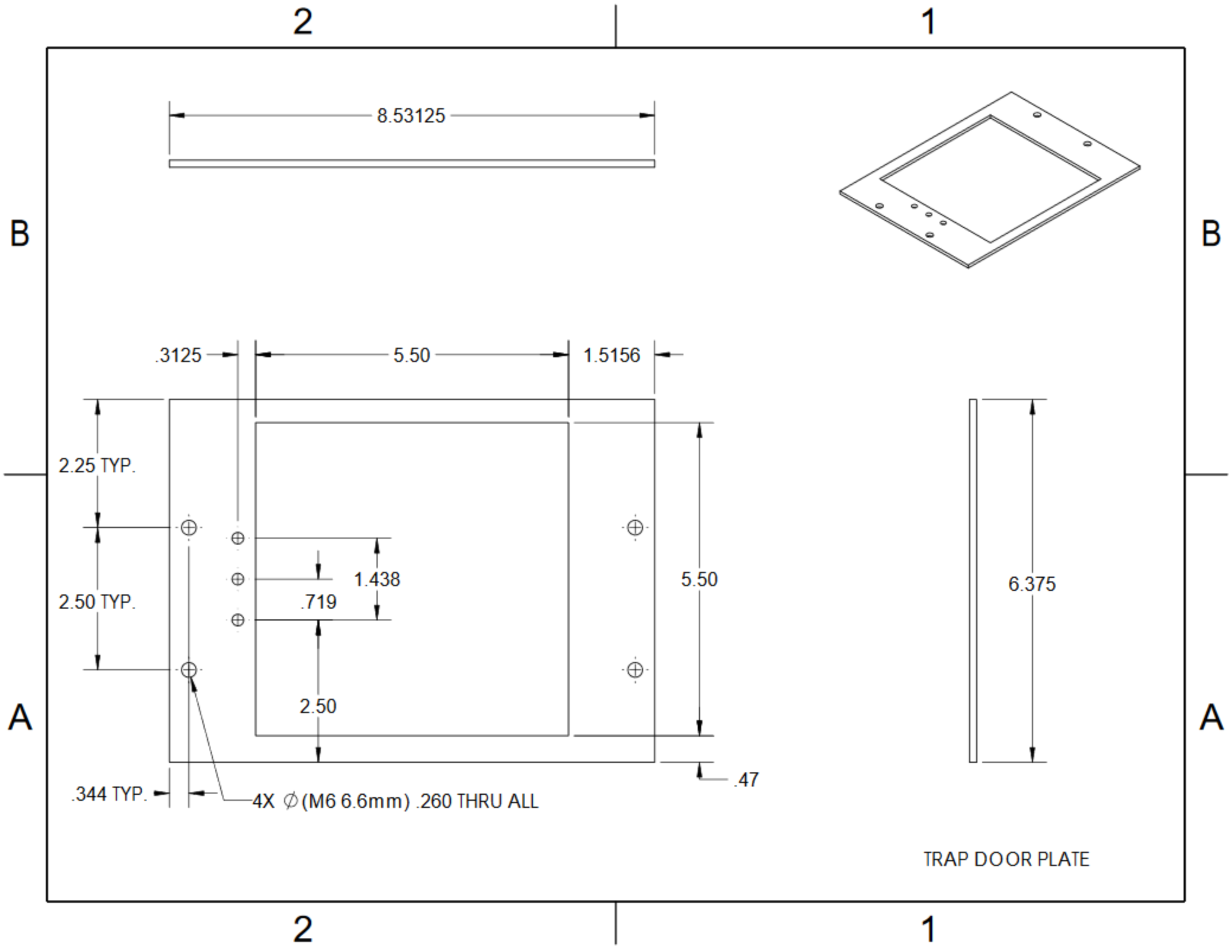


Figure 15: Trap door panel

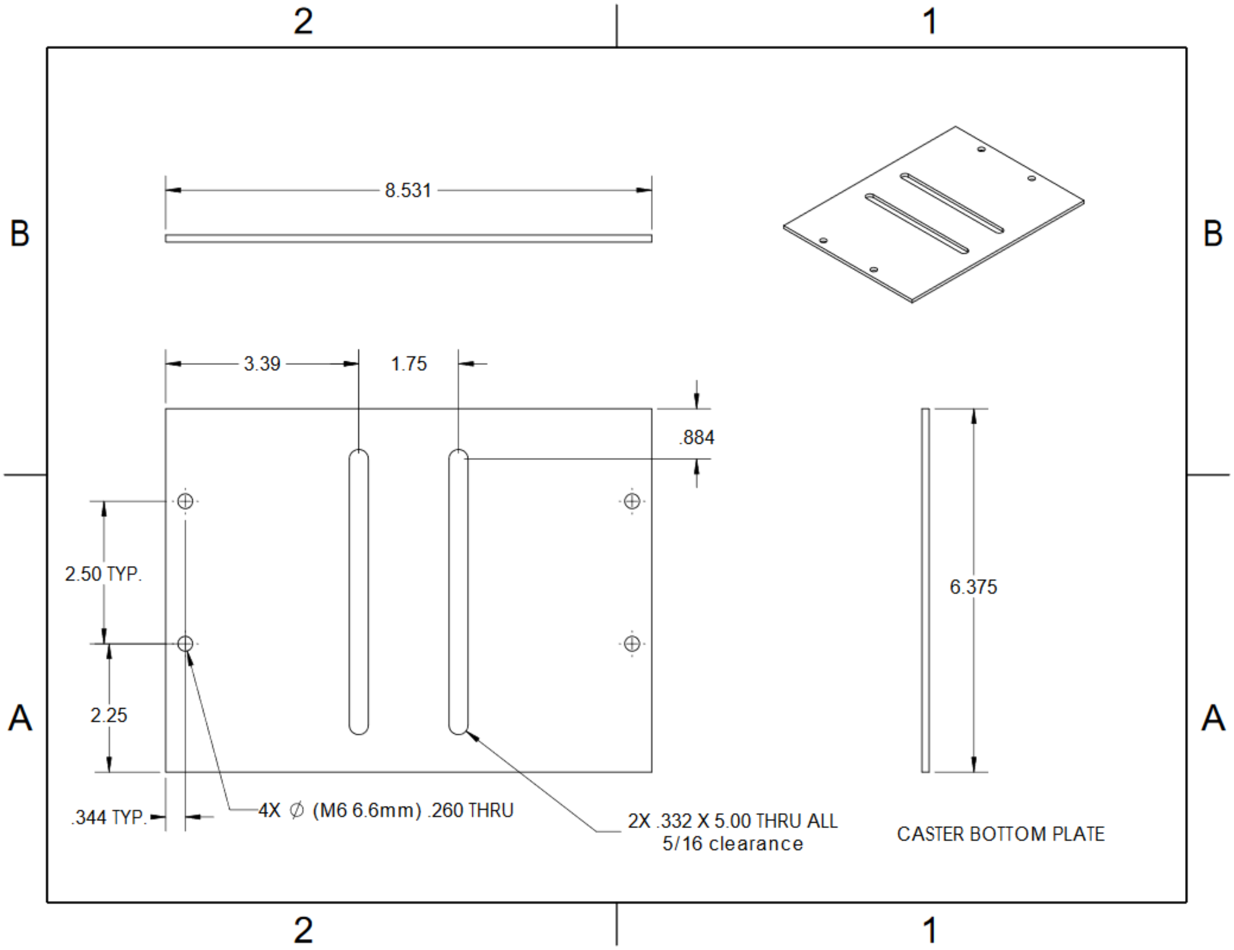


Figure 16: Caster wheel panel

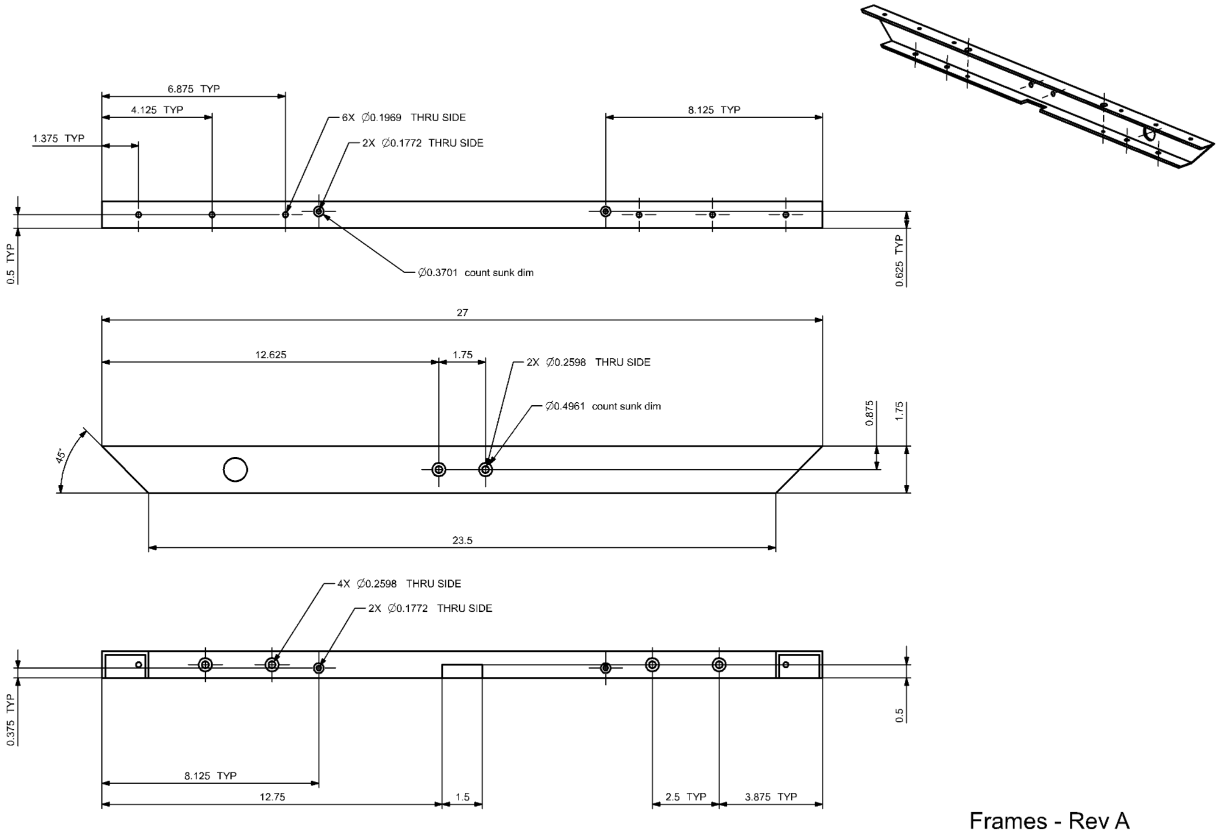
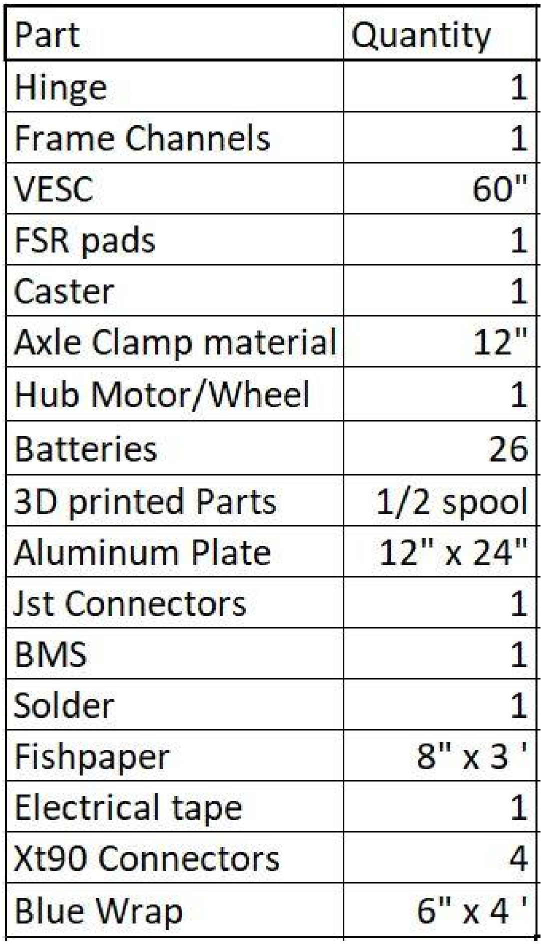


Figure 17: U Channel frames

BILL OF MATERIAL



Part	Quantity
Hinge	1
Frame Channels	1
VESC	60"
FSR pads	1
Caster	1
Axle Clamp material	12"
Hub Motor/Wheel	1
Batteries	26
3D printed Parts	1/2 spool
Aluminum Plate	12" x 24"
Jst Connectors	1
BMS	1
Solder	1
Fishpaper	8" x 3 '
Electrical tape	1
Xt90 Connectors	4
Blue Wrap	6" x 4 '

Table 1: Bill of Materials

BUILD AND TEST

DISCUSSION OF MANUFACTURING PROCESSES UTILIZED

Our Hub motor and VESC were ordered through third party websites.

The side frame pieces were aluminum U-bars whose sizes were picked based off of FEAs in SolidWorks, to ensure a safe riding experience. We used a bandsaw to rough cut the chamfers and belt grinder to finish them off, while all the holes were cut using a drill press.

The slotted bottom panel was cut to size using the programmable bandsaw, while the slots and holes were cut with the ProtoTRAK Mill at VPC. The trap-door panel also used the mill for the mounting holes and the square hole was made by drilling large holes and using a hacksaw to cut the rough shape and finished using different hand files.

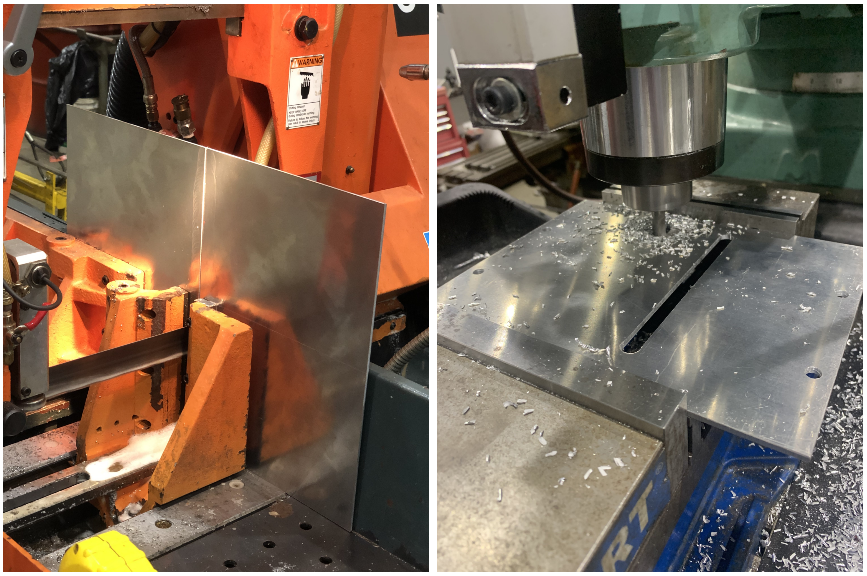


Figure 18: Panels cut with programmable bandsaw and ProtoTRAK Mill

The motor clamps utilized the same mill as the panels. This was extremely helpful as there were two sets of parts, with each set having two identical pieces. This mill allowed us to get a tolerance of +- .005. This tight tolerance allowed us to center our hub motor extremely well.

All 3D printed parts were modeled using SolidWorks and printed with the Ender 3 Pro using a PLA filament. The spacers and the trap door were printed with through holes and counter sinks for the bolts. The nose guards and wheel guards were designed with spaces to add heated inserts to allow for strong connections to the frame, and an easy assembly process.

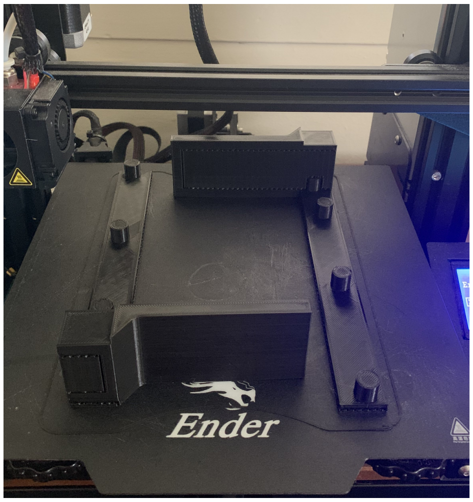


Figure 19: **3D Printed spacers with extrusions for heated inserts**

The footpads were originally going to be 3D printed, but after testing that design it showed immediate flaws that we forgot to account for. We had to split up a footpad into four different parts due to the constraints of the 3D printer's bed size, which created an unstable part. There was an intense amount of flexing being seen. The design and drawings were kept the same, but we changed the material that we used to wood. This created a significantly more stable foot pad, and had no flexing.

On the footpad were force-sensitive resistors that were wired to the VESC to relay information that would let the controller know when the rider is fully on the board. This prevented any ghosting, which is when the board would move on its own which is extremely dangerous. Two of these sensors were used which made mounting and dismounting significantly easier as the board will be able to realize when the heel or balls of your feet are leaving the footpad, indicating that the rider is trying to step off. The layer of plastic on top protects them from the griptape.

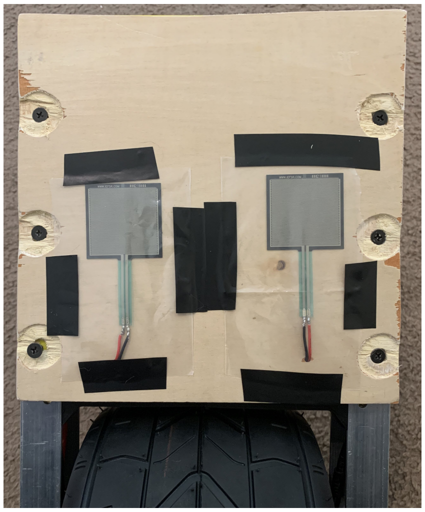


Figure 20: **Wooden footpads with force-sensitive resistors**

The battery compartment was padded with a combination of bubble wrap and hot glue to prevent contact between the battery and any sharp edges on either the panels or bolts. This was necessary due to the nature of riding a OneWheel causing turbulence and potentially moving the batter around. The VESC was secured by using standoffs that were attached to the slotted panel. These standoffs prevented any contact between the VESC and the bolts used on the caster wheel.

For the construction of the battery, the max amperage value found during the calculations was extremely important. If the motor can draw 19.8 amps at time it is important to have batteries that will allow us to do this. Since we have a two parallel structure we only needed a battery that can deliver 10A continuously, but we chose to go with a 20A battery simply because it was the cheaper option. We also needed the 19.8A value because when constructing the battery you spot weld nickel strips between the cells to carry the current, and the 0.1 mm nickel strips we purchased can only carry 5 amps each. Because of this, we made sure to connect each series connection with four strips. We only put one in parallel because the BMS is rated for 30 amps to charge the battery which is split amongst the 13 series cells. This is well below the 5 amp rating of the nickel strip.

Each set of 2 parallel batteries was connected and then the exterior and positive ends were covered with fish paper to prevent short circuiting. It was then hot glued in an alternating fashion, so that positive lead into negative, and then we spot welded all parallel tabs along the negative ends. We then went back and spot welded the four strips between each set of two cells. The battery had two different layers, one 7s2p and one 6s2p, so multiple layers of fish paper and insulation were required between them before connecting them in series to create the final 13s2p pack. The Battery management system (BMS) was fastened to the top, the lead wires were soldered into the parallel tabs while the larger positive and negative wires were soldered between the battery pack and BMS. The entire pack was wrapped in electrical resistant tape and the blue shrink wrap which was sealed with a heat gun.

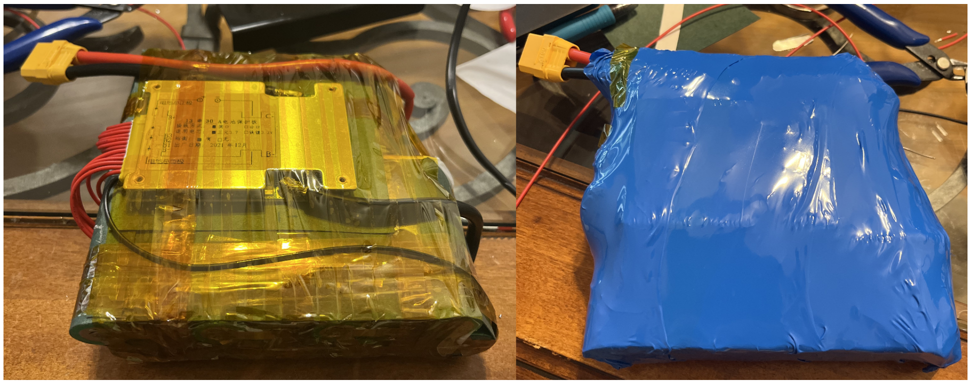


Figure 21: Battery pack before and after shrink wrapping

TEST PROCEDURE AND CRITERIA

Due the setbacks that arised from receiving the hub motor late and undersized, we weren't able to test the actual speed or range, but we were able to test the structural integrity of the device, trap door battery competent, and caster wheel. The structural integrity aimed to provide a riding experience that felt safe, with no bending in the frame or panels. This was tested by having each of us ride the device, and see how it felt. There is not an exact science to comfort, as each rider will prefer different things, but overall safety is usually agreed upon by all riders. The trap door is meant to be easy to use, and swap out batteries on the go, while the caster wheel wanted to create a safer environment for the rider. This was tested by restricting the max acceleration and also how much it helped you feel more confident in your ability to ride the board without worrying for your safety.

We would have liked to do more testing with the battery and speed capabilities, but due to the time restrictions mentioned before we were not able to do so. Testing the range attainable would have been done by riding on a fully charged battery and measuring the time, distance, terrain, and final charge of the battery after the session with riders of different weights. This would have given us a more accurate range for how far our device was able to ride. Top speed would have been tested on flat, smooth asphalt with multiple riders of different weights. Each rider would accelerate until the pushback safety feature initiated, indicating the max power attainable by our battery and motor was near its limit. The speeds attained would be averaged out to get our max speed (each rider would be in full protective gear to prevent any injuries during this test).

TEST RESULTS AND FINDINGS

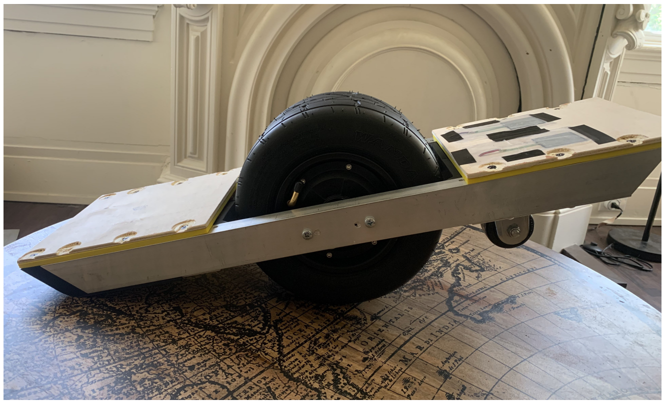
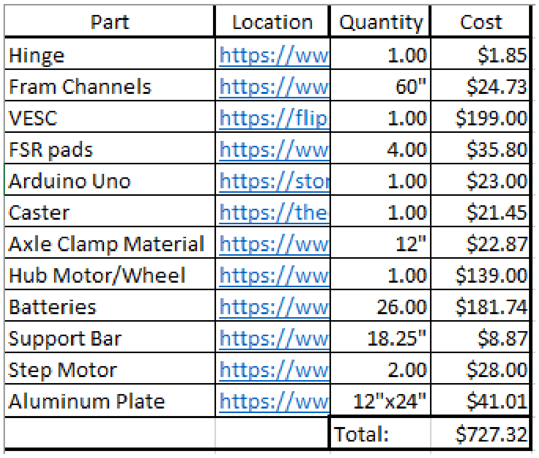


Figure 22: Final Product

The structural design of our final product proved capable for each rider. There was no flexing seen on the frame and the caster wheel panel. Our final design provided an extremely comfortable and safe experience. While the trap door was easy to use, it was slightly undersized because we did not account for the extra dimensions from the insulation, fishpaper, and BMS that went into the construction of the battery. Lastly, the caster wheel fulfilled its purpose in preventing riders from becoming uncomfortable and losing their balance, while also restricting the max acceleration attainable.

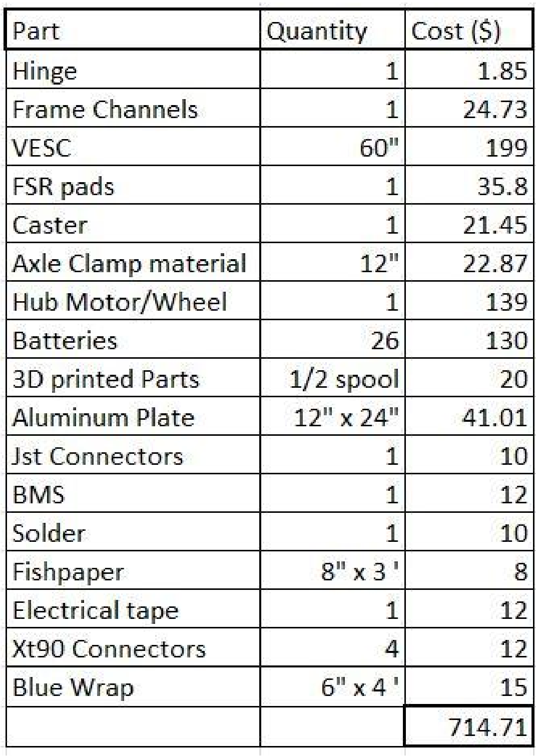
PROJECT MANAGEMENT

BUDGET, PROPOSED/ACTUAL



Part	Location	Quantity	Cost
Hinge	https://ww	1.00	$1.85
Fram Channels	https://ww	60"	$24.73
VESC	https://flip	1.00	$199.00
FSR pads	https://ww	4.00	$35.80
Arduino Uno	https://stor	1.00	$23.00
Caster	https://the	1.00	$21.45
Axle Clamp Material	https://ww	12"	$22.87
Hub Motor/Wheel	https://ww	1.00	$139.00
Batteries	https://ww	26.00	$181.74
Support Bar	https://ww	18.25"	$8.87
Step Motor	https://ww	2.00	$28.00
Aluminum Plate	https://ww	12"x24"	$41.01
		Total:	$727.32

<u>Table 2</u>: Proposed Budget



Part	Quantity	Cost ($)
Hinge	1	1.85
Frame Channels	1	24.73
VESC	60"	199
FSR pads	1	35.8
Caster	1	21.45
Axle Clamp material	12"	22.87
Hub Motor/Wheel	1	139
Batteries	26	130
3D printed Parts	1/2 spool	20
Aluminum Plate	12" x 24"	41.01
Jst Connectors	1	10
BMS	1	12
Solder	1	10
Fishpaper	8" x 3 '	8
Electrical tape	1	12
Xt90 Connectors	4	12
Blue Wrap	6" x 4 '	15
		714.71

<u>Table 3</u>: Actual Budget

SCHEDULE, PROPOSED/ACTUAL

Dates	Milestone
December 15th	Order all necessary parts
January 12th	Models for 3D printed parts completed
January 19th	Print parts
February 1st	Preliminary coding for electrical parts completed
February 14th	Board fully assembled
March-April	Testing and modifications until Tech Expo

Table 4: Proposed Schedule

Dates	Milestone
December 15th	Order all necessary parts
January 10th	Raw aluminum parts delivered
January 24th	Begin manufacturing of the parts (construct and 3D print)
February 25th	Batteries arrive, charging and construction begins
March 28th	Hub motor arrives, begin to put together board
April 12th	OneWheel assembled
April 20th	Begin Re-construction after identifying weak points of the board
April 26th	Final product put together and assembled

Table 5: Actual Schedule

SUSTAINABILITY AND MATERIAL USAGE

The structurally important parts of this design were manufactured with aluminum for longevity and strength. Conducting FEAs in SolidWorks proved that the parts were able to withstand forces up to a factor of safety that would effectively protect the rider from all forces seen during riding in all types of terrain, and significantly then some. Multiple pieces were 3D printed with PLA filament because the manufacturing complexity was high and these parts offered no structural benefit. The original footpads were one of these 3D printed parts, but proved not durable enough to stand on so we instead went with wooden footpads. They offered more strength, and didn't flex which helped make a safer environment for riders. They also would not have any interference with the force-sensitive resistors used.

CONCLUSIONS

Due to the numerous shipping setbacks we encountered throughout this project, we were not able to implement all the safety features we initially planned for, but we did address the major issues surrounding the OneWheel. We learned alot about the manufacturing process, including designing a product that can be easily manufactured, assembled, and disassembled while still being adaptable for future changes. With this in mind, we were able to remodel our parts with ease and manufacture them swiftly when our hub motor came in undersized.

During our research and time at the tech expo we discovered that the ability to easily alter the OneWheel was a common request from the community and that our design allows the user to do just that. It was extremely rewarding to see avid OneWheel users say how they wish our design ideas were implemented by the company Future Motion. The caster wheel was a good training tool for someone who is learning, allowing for a safer and easier riding experience, preventing the nosedive issue that is common with new users Designing the battery gave us a greater understanding of the electrical system behind the products, and its replaceability solved one of the largest problems coming from the original OneWheel where tampering with the battery at all would cause it to malfunction and and void the warranty. The force-sensitive resistors we attached to the footpads solved the ghosting issue faced by many OneWheel riders, and created an easier mounting and dismounting experience. We were able to increase our mastery over the design and manufacturing process as well as an added bonus of a better understanding of the electronics behind these electric powered transportation devices. Considering our setbacks and limited time, we are extremely proud of the final product we have created and are excited to show it off to the many OneWheel riders out there.

WORKS CITED

1. **SkateDeluxe.** History of Skateboarding. *SkateDeluxe.* [Online] [Cited: September 14, 2021.] https://www.skatedeluxe.com/blog/en/wiki/skateboarding/history-of-skateboarding/.

2. **Heckaman PLLC, Bailey Cowan.** Onewheel Nosedive Caused Long Island Man's Death, New Suit Alleges. *AP News.* [Online] July 17, 2021. [Cited: September 16, 2021.] https://apnews.com/press-release/pr-newswire/business-health-b908e4a5ca916b6441aaa59c7713270b.

3. **Chang, Jimmy.** Onewheel Versus Electric Unicycle (EUC): Which Should I Get? *Oneradwheel.* [Online] 11 20, 2019. [Cited: September 20, 2021.] https://oneradwheel.com/onewheel-versus-electric-unicycle-euc-which-should-i-get/.

4. **Strobel, Paul.** King Song 16X Electric Unicycle Review. *ERIDEHERO.* [Online] June 5, 2020. [Cited: September 20, 2021.] https://eridehero.com/review/king-song-16x-electric-unicycle/.

5. **Misselwitz, Mike.** Is Onewheel+ XR the Future of Personal Transportation? *GearJunkie.* [Online] November 13, 2018. [Cited: September 20, 2021.] https://gearjunkie.com/technology/onewheel-plus-xr-review.