Cover page:

OTV Project (ENES 100, Section 0201)

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Date: March 10, 2024

<u>Contributions</u>

Jack Gordon: Full System CAD, Mission Design Brief, Chassis Design Brief, Propulsion Design Brief, Bill of Materials, Engineering Drawings, Motor Selection

Miranda Wang: Circuit Design, Control Flow Algorithm Diagramming, Mission Design Brief, Teamwork

Mabel Heine: Chassis Design Brief, Center of Mass Calculations, Torque Calculations, Wheel Selection

Naina Ray: Battery Calculations, GitHub Formation, Control Flow, Teamwork

Haarith Jayakumar: Electronics Design Brief, Circuit Design, Battery Calculations, Control Flow

Vonn Sayasa: Chassis Design Brief, Motor Calculations, Motor Selection, Torque Calculations

Travis Filbert: Propulsion Design Brief, Torque Calculations, Motor Selection, Wheel Selection, Finance and Mass Estimates

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Section A: Chassis Design Brief

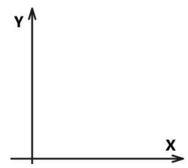
When deciding characteristics for the chassis design, the material, the shape, and the size were the main things that were taken into consideration. The chassis had to be large enough in order to fit all of the electronic and mechanical components while simultaneously being able to support the weight of everything. It also needed to be able to integrate well with the mission mechanism, which was the OTVs way of completing the mission. Finally, the chassis had to be small enough in order to effectively maneuver the arena and avoid obstacles.

With all of these considerations in mind, it was decided that the chassis would be made out of a thin layer of wood, and the shape would be an indented rectangle. The dimensions of the rectangle are 150 mm wide by 350 mm long, while the indent, which is located at the front end of the chassis, is 110 mm wide at its most narrow part by 140 mm long. The indented part is shaped similarly to a trapezoid, and the mouth of the indent is wider than the other end.

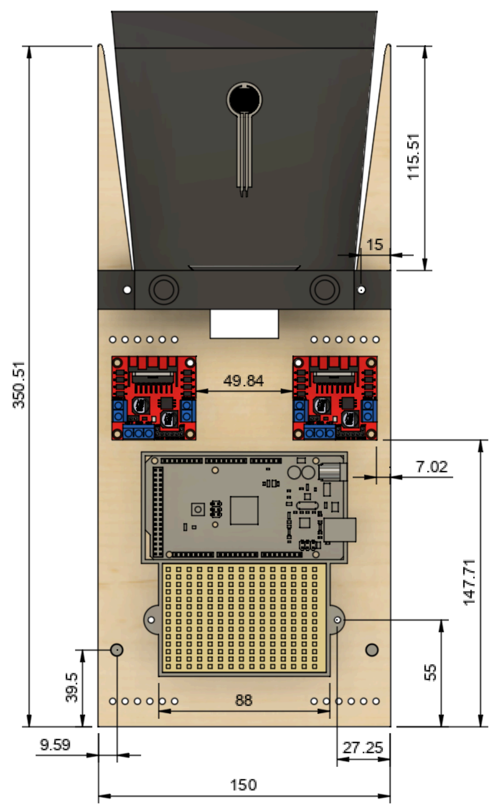
The indented section is designed to interface well with the mission mechanism, which is a forklift. The indent allows the forklift to be inside of the chassis, which will help keep the center of gravity closer to the middle of the chassis. The trapezoidal indent will allow some margin of error when aligning the OTV with the block, as the block will be guided to the center with the slanted sides. The material of the chassis will be wood, as it was determined that wood was sturdy enough to support the weight of everything without being relatively lightweight itself. The chassis will be laser cut with predetermined hole distances and sizes on the face of the chassis, and nuts and bolts will be used to secure the components.

The body of the OTV will also have a lid structure on top of the chassis. This was added so that the OTV would be able to fit all necessary components. On top of the lid there is a place for the battery and the aruco marker. The lid has a wall on the backside of the OTV to provide an area to mount the ultrasonic sensor on the back that will be used for navigation after the mission goal is complete. There are 2 holes on the backend of the lid and chassis where 2 M6 x 60 mm bolts and 6 nuts will be used to hold up the lid; 1 bolt and 3 nuts for each hole. In the front the lid will rest on the forklift. The lid will be made out of acrylic because it is lightweight and stable and have laser cute holes.

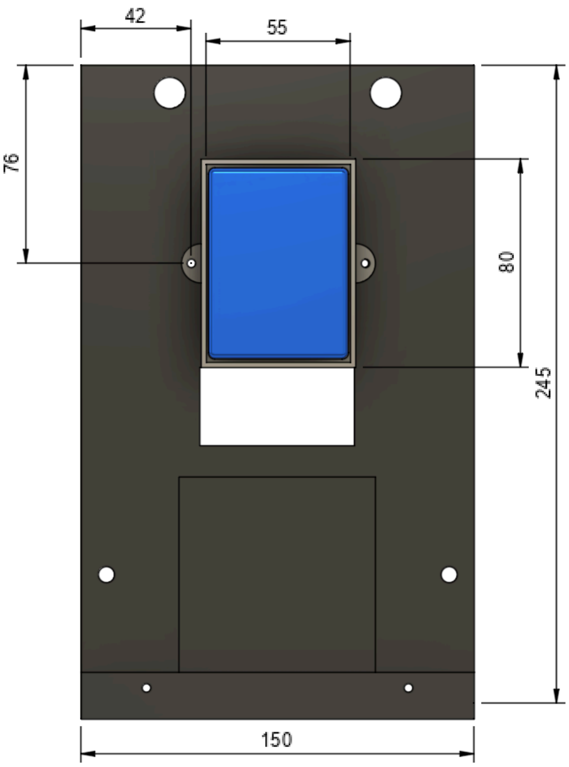
If the origin is the top left corner of the OTV and aligned with the bottom of the wheels, the center of mass is about +60 mm (z), -196.14 mm (y), and +75 mm (x). The x coordinate lies along the middle line of the OTV; this section is symmetrical. The y coordinate lies slightly more towards the back as the overall dimension is about 380 mm including the forklift.



Coordinate Axes for C.O.M (z is pointing out of the screen)



Chassis bottom layer dimensioned view



Chassis top layer dimensioned view

Section B: Propulsion Design Brief

As a team, the first consideration we made was the wheels. In order to best complete the mission, we chose to use mecanum wheels which would allow the OTV to move laterally. This makes it easier for the OTV to align itself with the block. The wheels and strafing will also come into play later on when it is time to navigate to the exfil point. Using its wheels, the OTV will be able to correctly orient itself along the arena wall, navigate through the narrow spaces and away from obstacles, and finally move under the limbo. As an added plus, the code to drive the mecanum is actually easier to create than regular wheels. Note: the wheels in the full system cad are stand in wheels and are accurate in dimensions but not looks.

While determining the best propulsion system to complete the mission, several points such as maneuverability, compatibility, stall torque, torque at max efficiency, and max efficient speed were taken into account. For starters, the motors selected for the propulsion system would need to have enough torque to start moving from rest, as well as have enough torque to skid steer and strafe using the mecanum wheels. Aside from the motors, the wheels would have to have the capability to move the OTV in a way that it can easily maneuver the arena to complete the mission and return to the extraction point safely. Lastly, height is an issue as the OTV can not be too tall or else it would not be able to pass under the limbo.

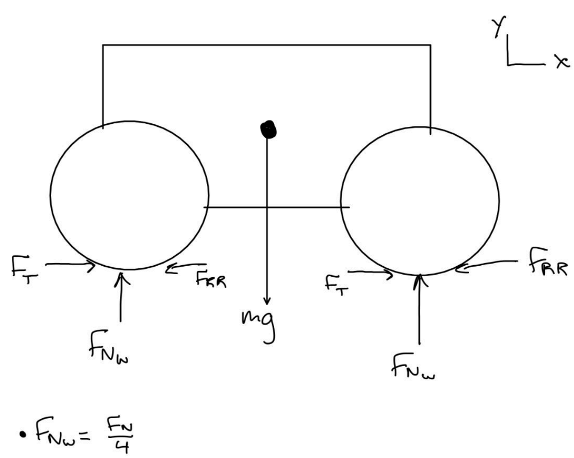
Factoring in all these different constraints, it was deduced that mecanum wheels with an 80mm diameter, 37 mm width, and a 6mm coupling would be best for our OTV. In terms of motors, pololu metal gear motors were chosen. For the assembly, the motors are going to be mounted directly under the chassis using motor mounts, and the motors are to be directly coupled with the wheels. Doing this eliminates the need for a traditional drivetrain.

Motor Mounts

While two motors would suffice in providing enough power for our OTV, due to our implementation of a mecanum wheel subsystem the propulsion system is required to not only be capable of providing power to 4 wheels, but also must have the ability to provide enough torque for certain tasks such as skid steering and lateral strafing. The latter of which requires 4 motor driven wheels so that it can turn every wheel in different directions from the others. This is what gives the wheels the ability to strafe. When calculating required torque that the motors the motors would need to be able to output, rolling resistance and static friction constants of 0.02 and 0.9 were used respectively. These constants are indicative of rubber on asphalt, and it was determined that using these in the torque calculations would result in more than enough torque to be able to traverse the arena floor. Below are the calculations used in order to determine our motor:

Variables for Motor Calculations

- Radius of Wheel (r) = 0.04m
- Max Ball Weight (b_{max})= .295 kg
- Gravity (g) = 9.81
- Rolling Resistance Coefficient = 0.02
- Static Friction Constant = 0.9
- Weight of Vehicle (w) = 1.617483 kg



OTV Free-Body Diagram

Equilibrium Equations

- $\Sigma F_x = 4F_T - 4F_{RR} = 0$
    - $F_{RR} = (\frac{1}{4})(r)(g)(w+b_{max})(0.02) = 0.0037523$ N-m (per wheel)
    - $F_T = F_{RR}$

- $\Sigma F_y = F_N - mg = 0$
    - $F_N = 9.81*(1.62+0.295) = 18.79\ N$
    - $F_{Nw} = F_N / 4 = 4.7\ N$ *(per wheel)*

Torque Required for Straight Driving (Constant Velocity)

- 0.0037523 N-m

Torque Required to Start Moving

- $(\frac{1}{4})(r)(g)(w+b_{max})(0.9) = 0.1688531$ N-m

Ideal RPM (target velocity is 10 cm/s)

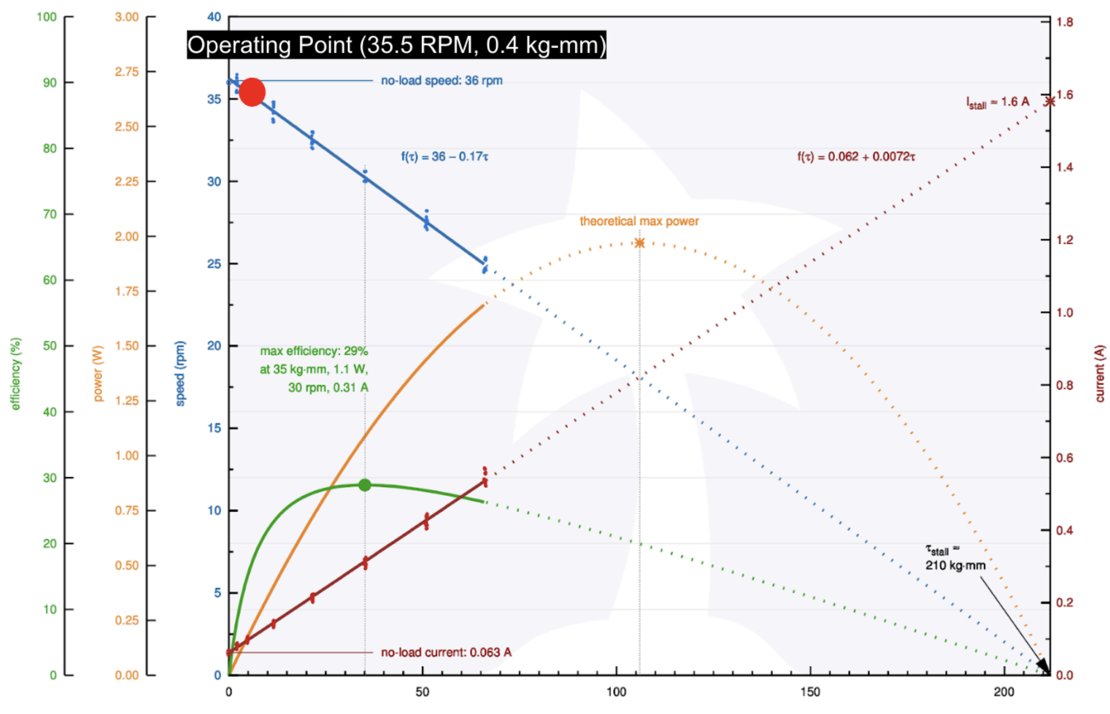
- (10 cm/s) / 4 cm = 2.5 rad/s = 23.9 RPM

With these calculations in mind, we decided to purchase a motor from pololu. Below are the for said motor specs:

Motor Specs

- 36 RPM no load performance
- 0.063 amps no load current
- 210 kg-mm stall torque
- 1.6 amps stall current
- 12 volt
- 20 mm diameter x 47.7 mm long
- 47 grams

Motor Characteristic Graph from [Pololu]



The motors that we selected have more than enough torque to move our OTV, which is beneficial because strafing is much more demanding than moving forward. This motor also operates relatively close to our target velocity, so our OTV will not be moving too fast. Also, because we are operating close to the low end of its torque, the power draw is minor, so it will not be too taxing on the battery. It will operate at around 35.5 RPM & 0.4 kg-mm, and will have a power draw of around 0.08 amps. Converting 35.5 RPM to linear velocity considering 80 mm wheel diameter gives us around 15 cm/s, which is slightly fast but still in our desired range.

Section C: Mission Design Brief

For the Material Identification mission, the OTV must be able to 1) fully get the target block off the ground, 2) identify the material as either foam or plastic, and 3) determine if it is of light, medium, or heavy weight.

To accomplish this task, we implemented a forklift design with a load sensor and two ultrasonic sensors.

1. Lifting the block off the ground

The forklift at the front of our OTV will be joined to the chassis using vertical rods. The top part of the forklift T has holes that go entirely through and the chassis will have complementary horizontal bars that have holes cut out as well. The T of the forklift will rest on the horizontal bars and vertical rods will be used to join the two together. The vertical rods will also prevent rotation of the forklift. We opted for cutting out a trapezoidal shape from our chassis to give the OTV greater room for error when approaching the block to scoop it up. If the forklift was perfectly square and the block wasn't perfectly centered when the OTV drove into the wall, the block wouldn't be able to slide onto the forklift - it would just get jammed between the side of the OTV body and the wall. With a trapezoidal shape, the OTV doesn't need to be perfectly aligned because the guide rails in place would help funnel the block to the center.

The two sensors that will be integrated into the forklift are an ultrasonic sensor and a load sensor. The ultrasonic sensor has a sensing range of 2-400 cm, with a resolution of 1 cm and a power requirement of 5V. The load sensor has a sensing range of 0-25 lb, with an accuracy of +/- 3%, and a maximum current capacity of 2.5 mAh. The specific power needs of the two sensors were accounted for in our circuitry design. The ultrasonic sensor will sit on a 3D printed mount on the vertical face of the forklift and the load sensor will rest on the horizontal face of the forklift, which will be 3D printed to achieve maximum precision.

2. Identifying the material

The ultrasonic sensor on the forklift will serve the dual purpose of both navigating for the initial half of our mission and identifying the material. Ultrasonic sensors work by sending out sound waves and detecting the time it takes for them to return from bouncing off of the object. This allows it to detect obstacles in its path which will assist in navigation. However, these distance readings also differ depending on material. Hard materials like plastic act as a normal surface, as the sound waves will perfectly bounce off of them and return an accurate distance for the ultrasonic sensor to read. However, soft and lighter materials like foam distorts these sound waves and gives an inaccurate distance reading. This was tested in the lab, and the results demonstrated that the ultrasonic sensor was a viable way of determining the material.

3. Determining the weight

The load sensor is a force sensitive resistor that changes its resistivity depending on the amount of pressure that is applied to the surface of the sensor. The changes in resistivity can be translated into force readings, which will allow us to determine the weight of the block and report whether or not it was light, medium, or of heavy weight depending on the range of values the reported value falls within.

Combining the forklift design, load sensor, ultrasonic sensor, and Mecanum wheels, the OTV will be able to execute the mission specific tasks.

The distance from the starting site to the mission should be around 0.9-1 m. Therefore, the block will be resting about 0.9-1 m away. As this distance exceeds the accurate sensing range of the ultrasonic sensor, the OTV will be instructed to drive 70 cm towards the mission site so that the block can be brought within sensing distance. The mission site also has horizontally constrained coordinates, meaning that we can instruct the OTV to strafe from side to side within this limited coordinate range to attempt to detect the block. This will allow the ultrasonic sensor to collect distance readings, which can be used to determine when the block enters its field of vision (FOV).

When the block enters the ultrasonic sensor's FOV, one of two things can happen. In the case of the plastic block, sound waves are perfectly reflected, so we expect an accurate reading on the distance, therefore, we would expect a distance reading of about 30-40 cm. In the case of the foam block, sound waves are greatly distorted, leading to greatly inaccurate distance readings.

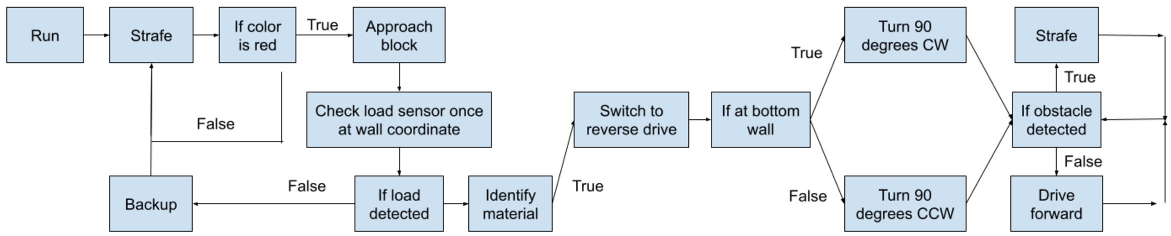
During testing in lab, a block positioned about 10 cm away was read to be 1000 cm (10 m) away, which completely exceeds the dimensions of the arena. In this case, we would expect that upon the block's entrance to the sensor's FOV, we would get similarly large numbers. Thus, the ultrasonic sensor can simultaneously detect the presence of the block and determine the material of the block.

Upon determination that the block is lined up in front of the OTV, the OTV will drive the block against the wall using the forklift. The load sensor can be checked to determine if any change in resistivity has occurred, which would indicate that the block has been successfully loaded onto the forklift. If the OTV was unsuccessful in loading the block, then the OTV will back up and attempt to realign itself with the block before driving forward again.

Once the block has been successfully loaded onto the OTV, its weight will be able to be read. At this point, all 3 mission specific objectives will have been accomplished. The rest of the mission would be to navigate through the obstacles to the goal zone. As the ultrasonic sensor placed on the forklift would be blocked by the ball, further navigation would become inhibited, so we decided to add a second ultrasonic sensor to the back of the vehicle. Because our OTV is a four wheel drive, the OTV would be able to drive in reverse and navigate based on the ultrasonic sensor placed on the back of the vehicle.

As the OTV will be against the wall at this point, its location could either be the very top wall or the very bottom wall. These locations can be verified or checked using the coordinates and location provided by the Aruco marker. If the OTV is at the bottom wall, it will rotate 90 degrees clockwise and if it's the top wall, it will rotate the opposite direction so that the back-end with the ultrasonic sensor is now positioned towards the obstacle course. Because our OTV is 23 cm wide, it should be able to fit through the 25 cm wide gaps in the obstacle course, allowing our OTV to completely bypass the obstacles in the center of the arena. In addition, our OTV has a height of 14 cm which allows our OTV to clear the limbo. In the case that the OTV encounters the rumble strip, the OTV will be able to strafe over to the limbo and enter the goal zone.

Below is a diagram of the control flow algorithm that our OTV will utilize to navigate from start to finish.



Section D: Electronics Design Brief

The main requirement regarding powering and controlling the OTV was making sure that the battery will run for an hour at least. In terms of challenges with powering and controlling the OTV, based on our calculations, we may not be able to have the OTV running for long enough if it comes out to be the worst case; however, this is unlikely. Below are some of the details for our selected battery:

Battery Specs:

- Voltage: 12 V
- Capacity: 2000 mAh
- Max discharge rate: (1C/ 1344.5mA) = 0.74 hr = 44.4 minutes

Run-time Calculations (time to power OTV before recharging):

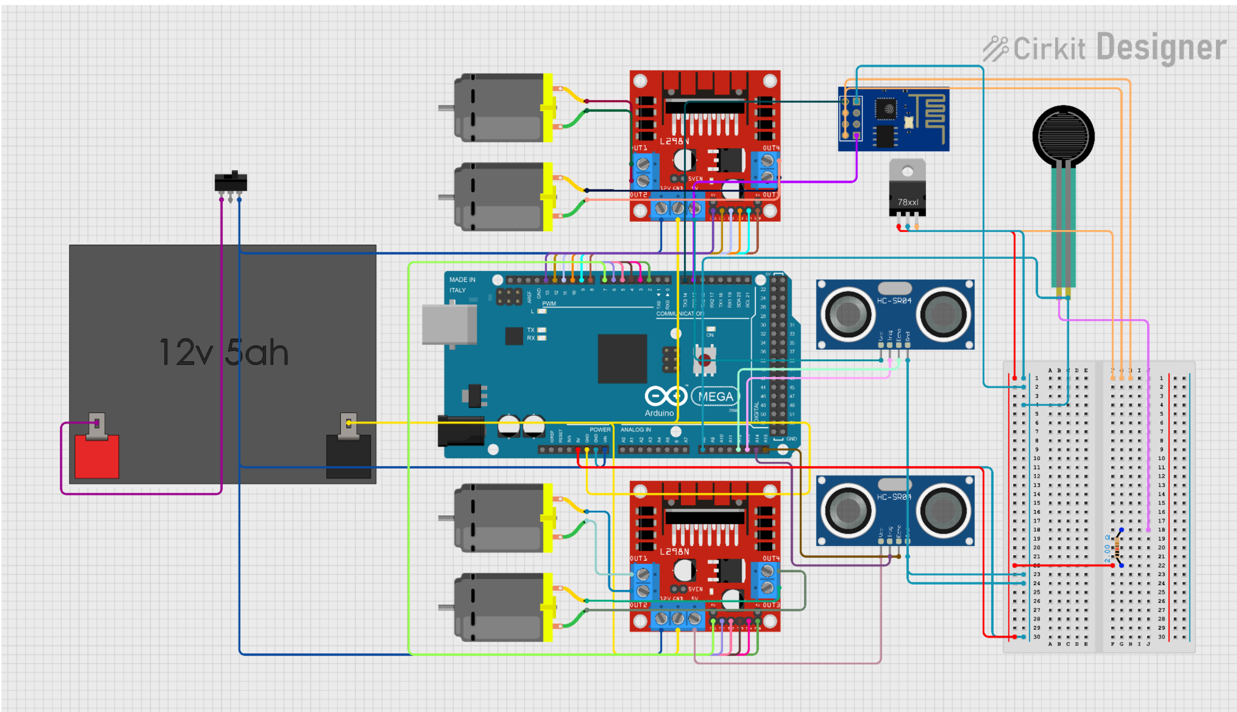
- Runtime worst case
  - 2000 mAh/ 6504.6 mA = 0.307 hours = 18.45 minutes
- Runtime best case
  - 2000 mAh/ 1344.5mA = 1.487 hours = 89.25

Total Current Draw (considering all electronics):

- Total current drawn using stall torque
  - (1600mA)4 + 2(36 mA) + 2(15 mA) + 2.5 mA = 6504.6 mA
- Total current drawn using max efficiency
  - (310mA)4 + 2(36 mA) + 2(15 mA) + 2.5 mA = 1344.5 mA

Our battery will be connected to a kill switch that connects in parallel to our motor controllers using one wire that splits into 3 separate connectors, one of which will power the arduino. The battery also connects to a ground pin slot on the arduino. Our 2 motor controllers will be connected to our 4 motors with 2 motors per controller that each have power in and ground pins. The controllers will take up 6 digital pin slots in our arduino mega. The 2 ultrasonic sensors will be connected to the motor controllers that have 5v outputs to power them, as well as having 2 analog connections to our arduino, the ground pin on the ultrasonic sensors are connected to the breadboard that is connected to the ground pin on the arduino. The wifi card originally was wired to a voltage converter but since it has a 5v converter provided to us it will now be connected to the breadboard that takes power from the 5v on our arduino. Finally the load sensor will get power from the 5v on the breadboard with a 2Ω resistor that will convert the current to 2.5 mA, which is the maximum current that the load sensor can take.

Circuit Diagram



Arduino Pin Assignment Chart

Pin #	**Wire**	**Pin #**	**Wire**	**Pin #**	**Wire**	**Pin #**	**Wire**
VIN	Wired from battery	5	IN 2 controller 1	11	IN 2 controller 2	A15	TRIG US 2
GND	Wire to breadboard	6	IN 1 controller 1	12	IN 1 controller 2	TX3	TXD wifi chip
GND	Wire to	7	ENA	A8	Wire to force	RX3	RXD wifi

	battery		controller 1		resistor		chip
2	ENB to controller 1	8	ENB controller 2	A12	ECHO US 1	5V	Breadboard
3	IN 4 controller 1	9	IN 4 controller 2	A13	TRIG US 1		
4	IN 3 controller 1	10	IN 3 controller 2	A14	ECHO US 2		

Section E: Teamwork

Our team's design was largely based on our common interest to meet the project requirements given all the restrictions. We were also influenced by what was reasonable given our materials. Our team draws on individual strengths by distributing work based on past experience and what perhaps a team member would be interested in learning more about and applying to the OTV. For example, Vonn Sayasa contributed heavily to our robot's motor selection and calculations by pulling on his mechanical engineering background. Jack Gordon utilized his CAD skills to generate 3D models of our intended robot design. Haarith Jayakumar and Naina Ray pulled on their coding backgrounds to lay out a working control flow algorithm. Miranda Wang helped design the circuit using her past circuitry and electronics class from high school. Travis Filbert assisted in designing the forklift by providing his experience and knowledge of how forklifts work in his job. Mabel Heine helped design the chassis and determined fastening methods drawing on her past building experience.

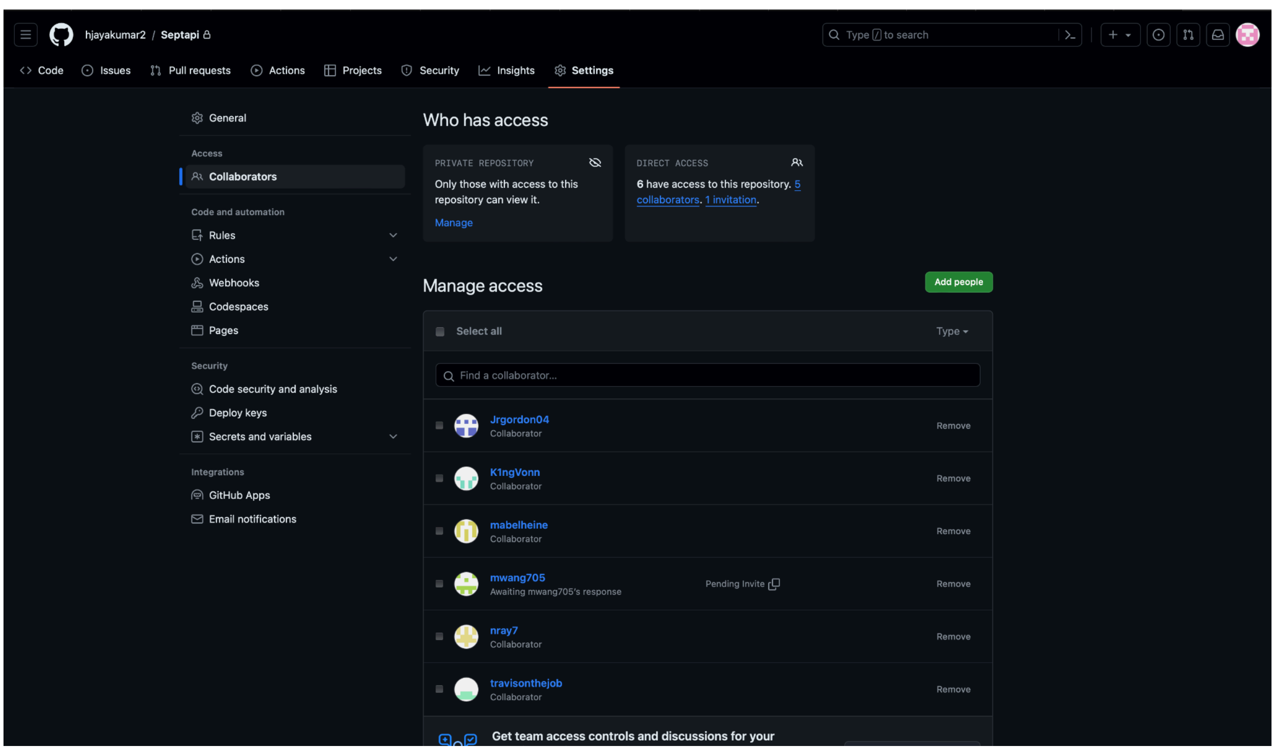
The team is advancing individual growth by allowing team members to work independently on different parts of the OTV. We also made sure that people that wanted to learn about subsystems they lacked experience in could be partnered with a more experienced member to accelerate their learning and make sure everyone had an opportunity to both contribute their expertise and learn something new. Our team especially excels in learning from setbacks. Using the feedback provided from both Professor Cumings, our TA, and the other students in our class, we made many modifications to our design for MS2. From improving our project management plans to providing more specific details regarding the motor and battery, we were able to not only develop a more fleshed out design, we were also able to improve the functionality of our OTV.

Some areas our team could grow would be in communication and productive discourse. Since our schedules are so different sometimes it is difficult to arrange meeting times that work for everyone and when we do meet, getting enough done. If we could develop a schedule that is more accommodating for each individual person, every person would have a more equal opportunity to contribute to the project. Some strategies the group will use to make our sessions more productive and communicate better include letting group members know about schedule changes and what needs to be done in advance, as well providing a more structured breakdown of necessary tasks to complete.

Team Resources:

Assignment	Completion	Start Date	Meeting Dates	Due Date
Team Project Plan	done	2/6	2/6	2/8
MS1: Initial Design	done	2/13	2/13, 2/15, 2/18, 2/20	2/22
MS2: Design Review	done	2/22	2/29, 3/2, 3/3, 3/5	3/7
MS3: Design Blueprint	in progress	2/22	3/1, 3/2, 3/3, 3/5, 3/7	3/8
MS4: Fabrication Start		3/8		3/12
MS5: Systems		3/12		4/4
MS6: Systems Integration		4/4		4/18
MS7: Final Performance		4/18		5/7
MS8: Final Design Presen		5/7		5/13
MS9: Final Design Brief		5/7		5/13

Google Spreadsheet with notes (on second page of sheets doc), meeting times, and progress



Team GitHub for sharing code

Section F: Testing Plans

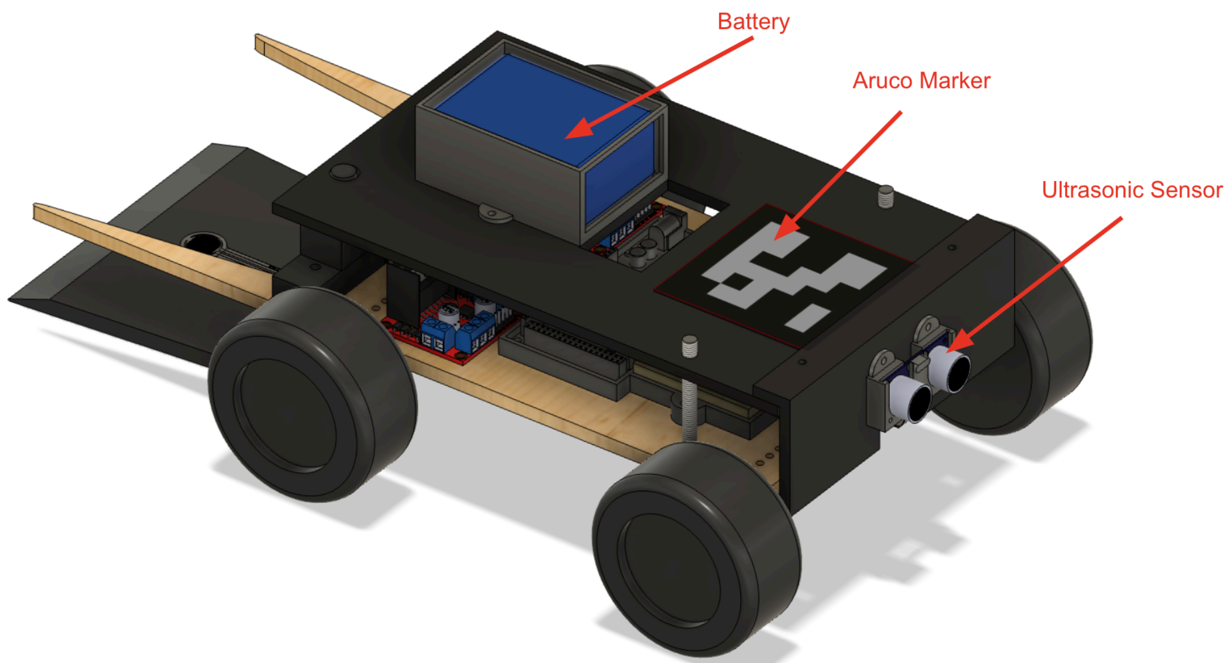
The OTV must be able to use the forklift to get the block off the ground, use the load sensor to accurately classify the weight of the block, and the front ultrasonic sensor must be able to correctly classify the block's material to complete the mission objective. The OTV must also be able to navigate around the obstacles in the course and under the limbo in order to reach the goal zone in order to be successful.

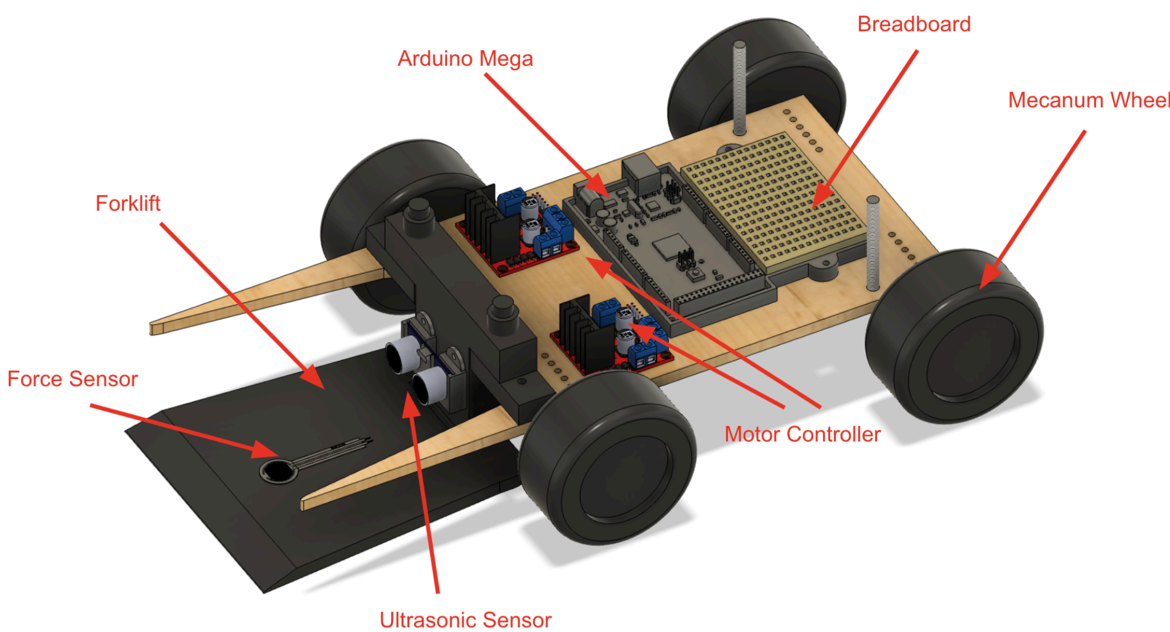
For the prerequisite test we want to test all of the mission mechanisms and if they are able to perform the mission as expected. The ultrasonic sensor has already been tested for material identification. It was found that the ultrasonic sensor when reading the plastic block gave accurate distances around 9 cm, but when reading the foam block at a similar distance the reading was over 1,000 cm. Therefore, we can use this discrepancy in order to determine the material. The 3-D printed forklift has also already been printed and tested, and it is able to pick up the block with help from the wall.

Testing will still need to be done for the accuracy of the load sensor to weigh the block. This testing will be successful if the load sensor is able to detect all three weight categories with distinct values. In order to test this, we will put different block weights on the sensor and record its output. If the output range is wide enough to determine the weight, then this will be a successful way of determining weight; otherwise, we will need to reconsider our mechanism for this. Testing will also be done with the ultrasonic sensor and our navigation algorithm. We will test this by simulating the mission and seeing if our OTV can successfully navigate the course. For this to pass, the OTV would need to navigate from the mission site to the goal zone with no assistance and would fail if it is unable to do so.

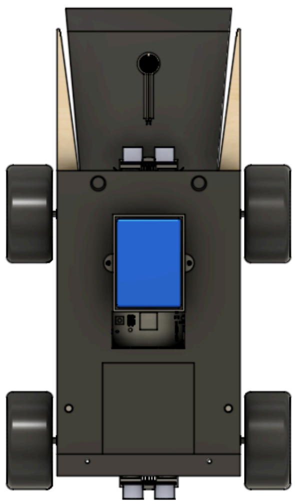
In order to evaluate these tests, our group plans to analyze the results of each test and collectively decide if our current method is either accurate or needs improvement. If it is deemed accurate, we will move on to the next set of tests; otherwise, we will do secondary testing on the mechanism and if necessary, redesign it.

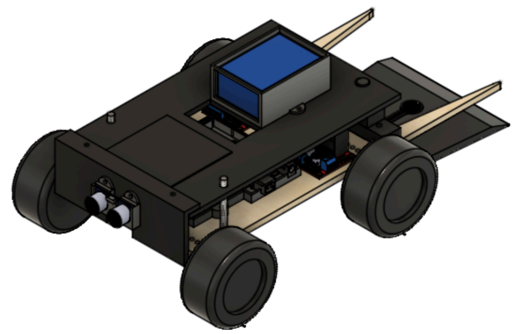
Section G: Compiled Set of Engineering Drawings

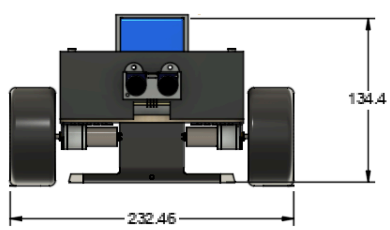




**Motor and motor mounts are attached & mounted under chassis*



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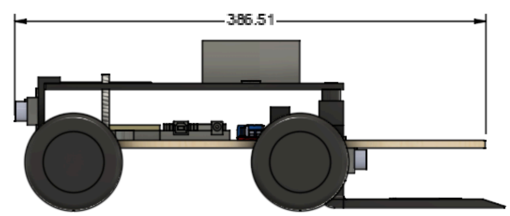
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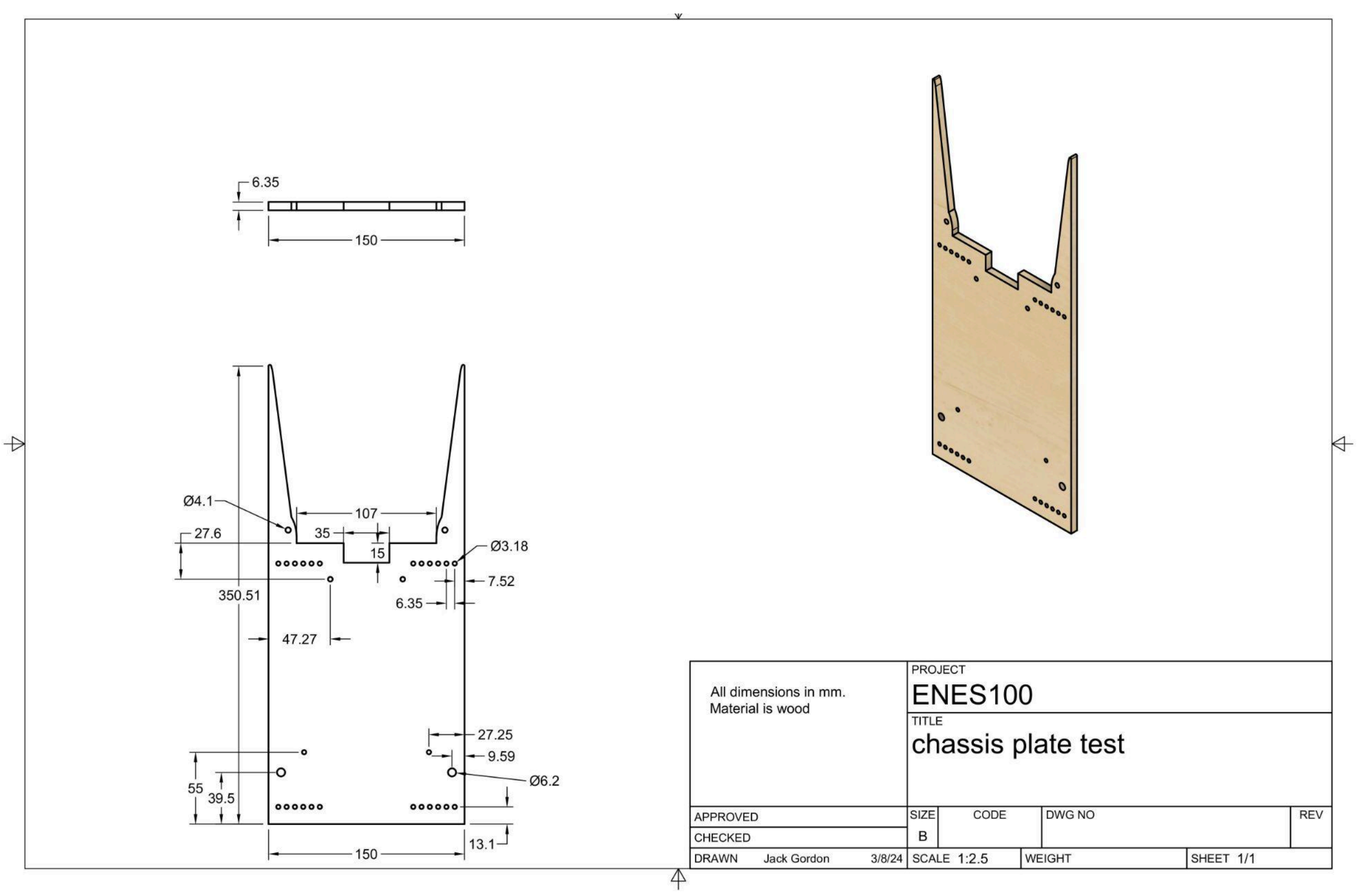
6.35
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Ø4.1
27.6
107
35
15
Ø3.18
7.52
6.35
350.51
47.27
27.25
9.59
Ø6.2
55
39.5
150
13.1
All dimensions in mm.
Material is wood
PROJECT
ENES100
TITLE
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APPROVED
CHECKED
DRAWN Jack Gordon 3/8/24
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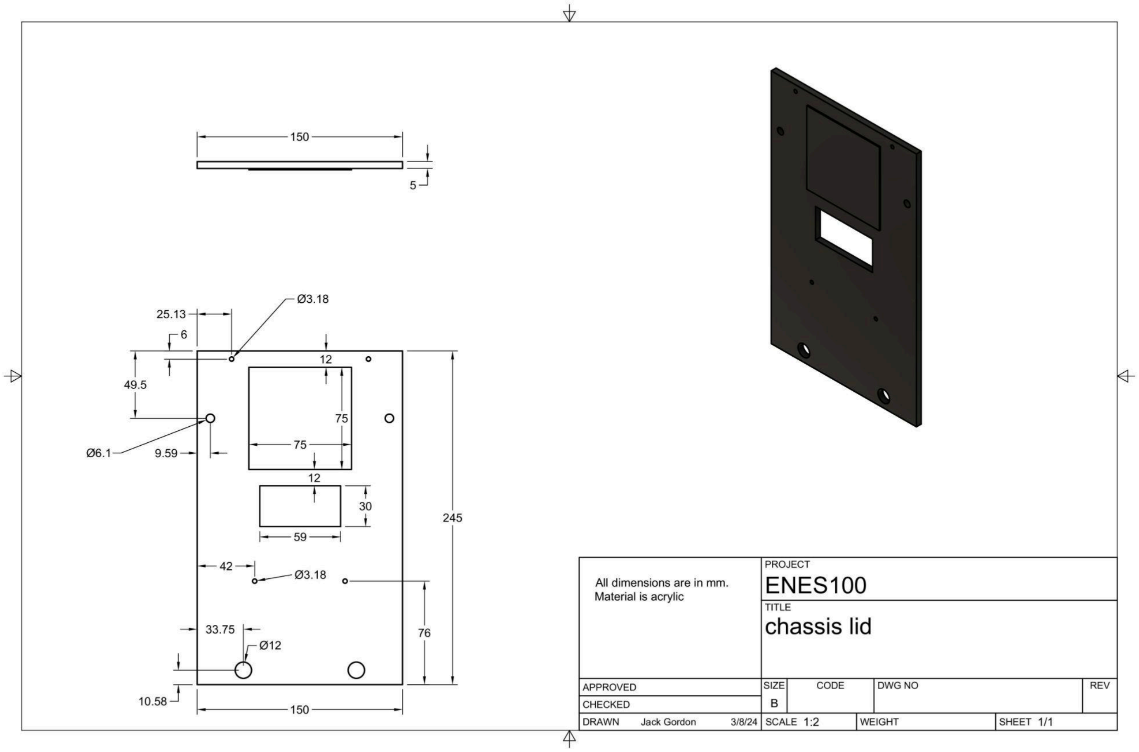
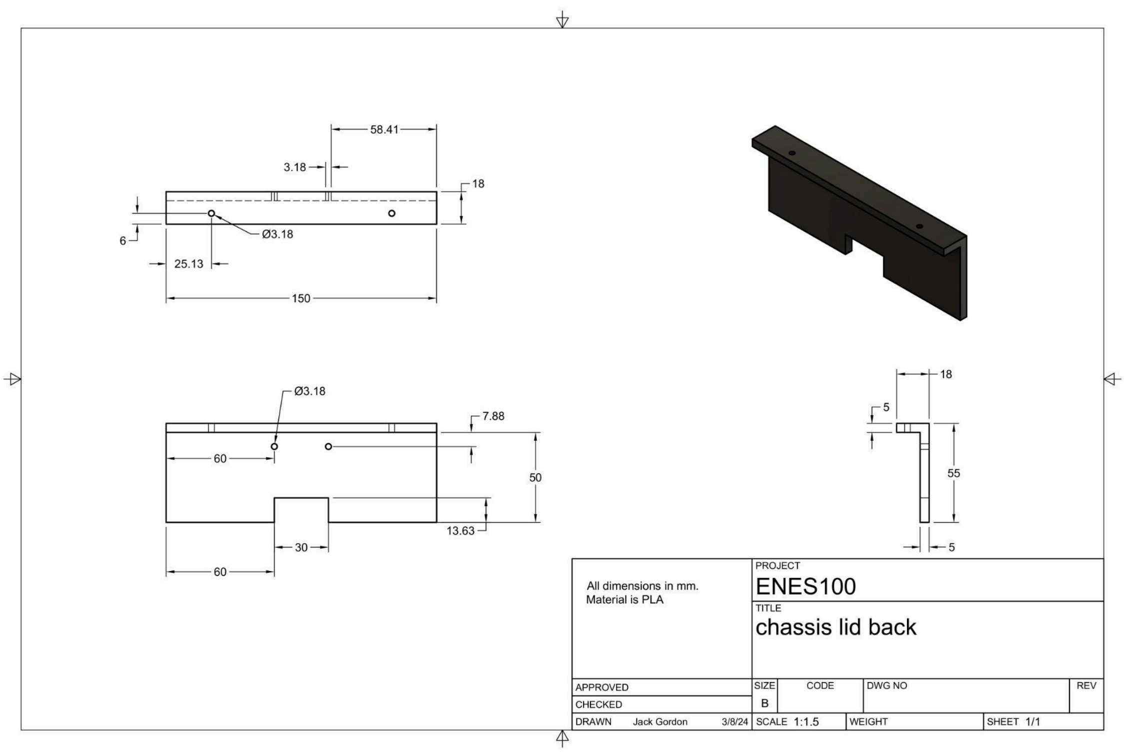
WEIGHT
SHEET 1/1


150
5
25.13
Ø3.18
6
12
49.5
75
Ø6.1
9.59
75
12
30
245
59
42
Ø3.18
33.75
Ø12
76
10.58
150
All dimensions are in mm.
Material is acrylic
PROJECT
ENES100
TITLE
chassis lid
APPROVED
CHECKED
DRAWN Jack Gordon 3/8/24
SIZE B
CODE
DWG NO
REV
SCALE 1:2
WEIGHT
SHEET 1/1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18
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Ø3.18
25.13
150
Ø3.18
7.88
60
50
13.63
30
60
18
5
55
5
All dimensions in mm.
Material is PLA
PROJECT
ENES100
TITLE
chassis lid back
APPROVED
CHECKED
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REV
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WEIGHT
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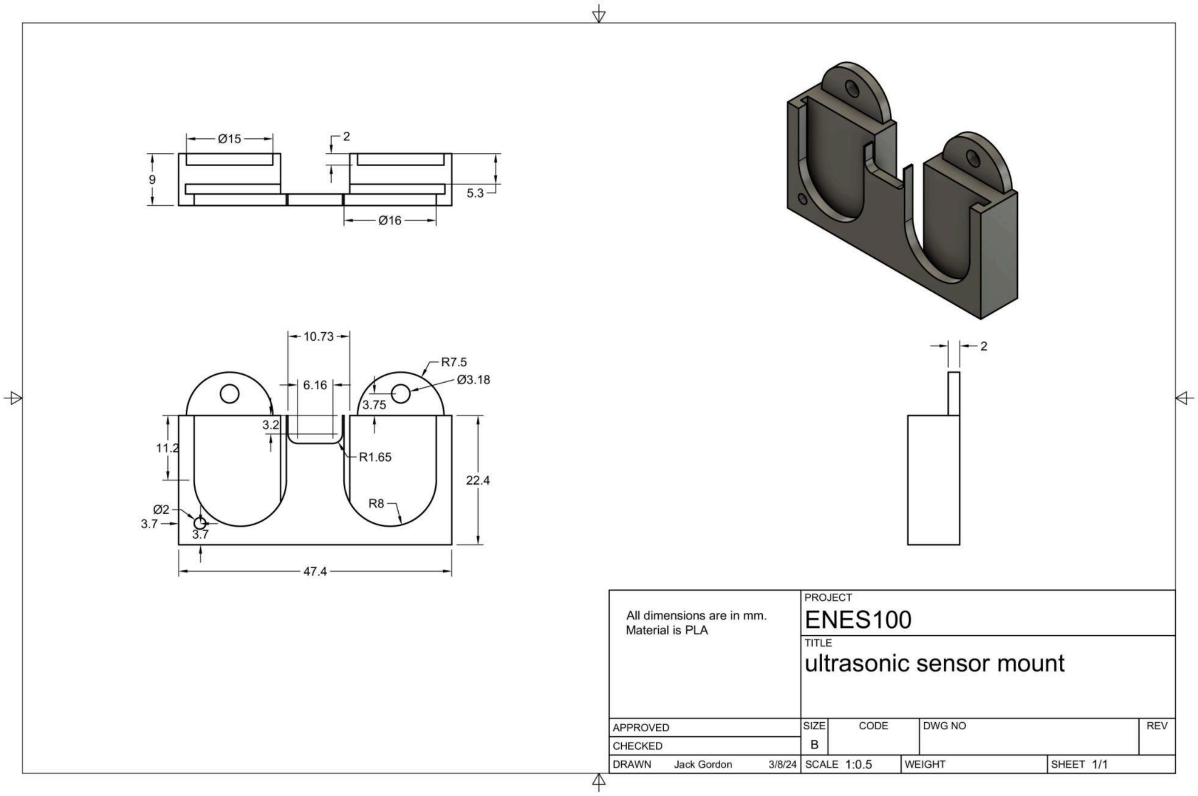
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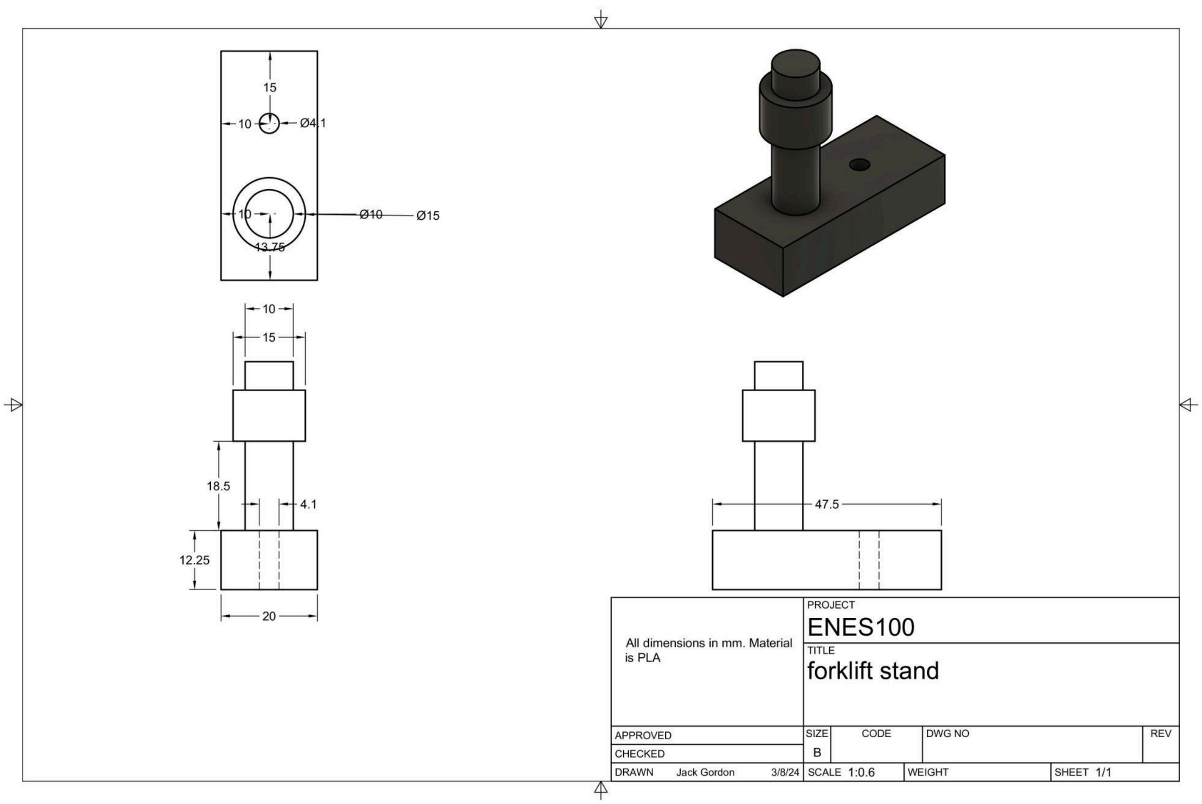
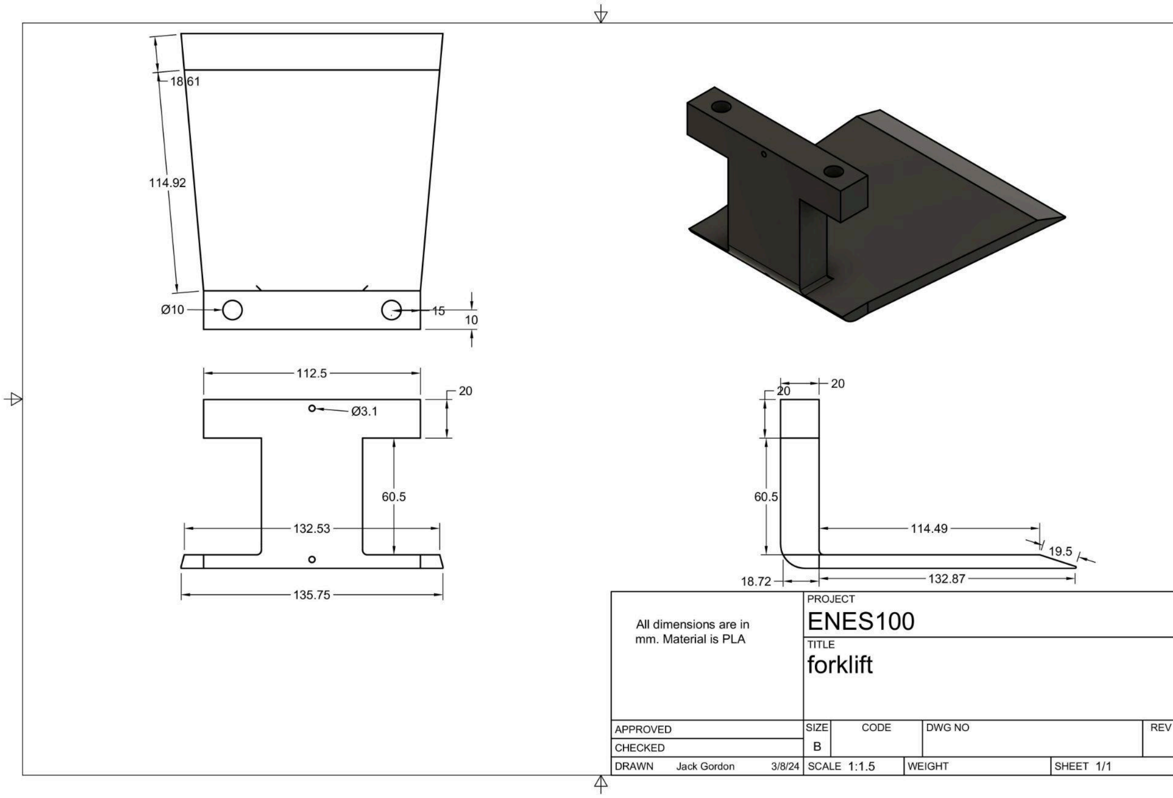
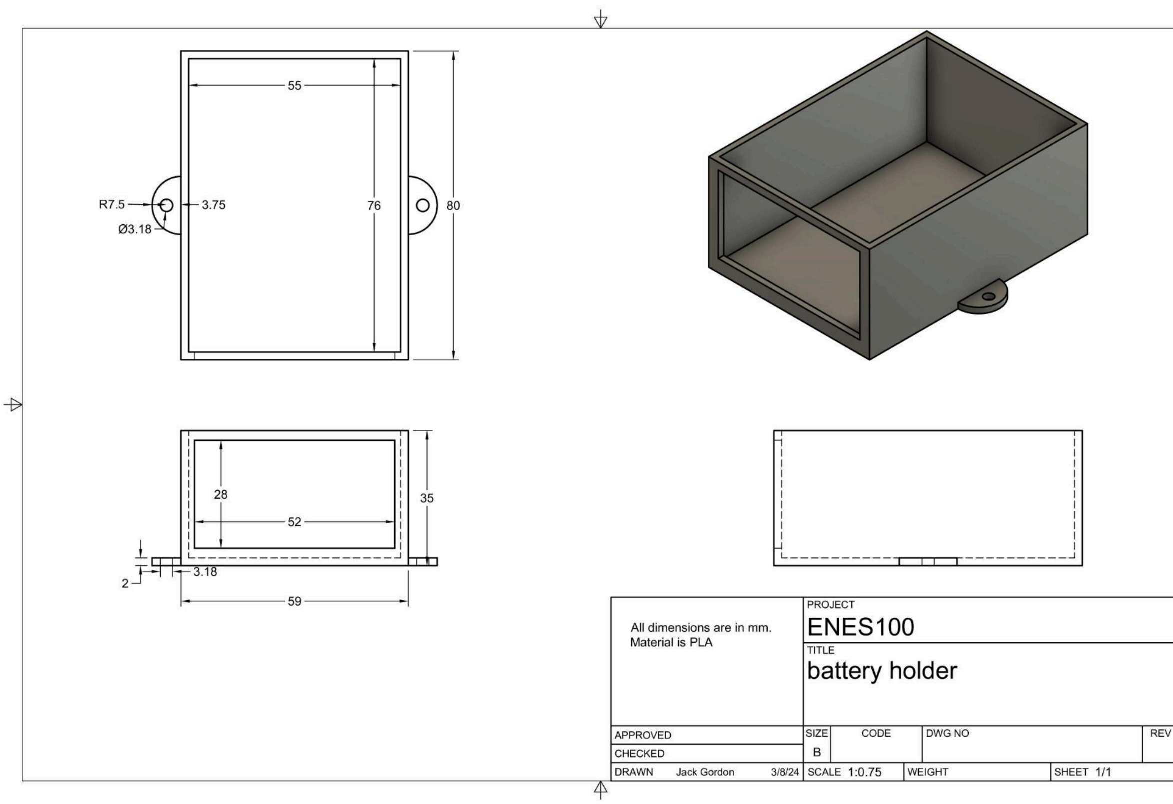
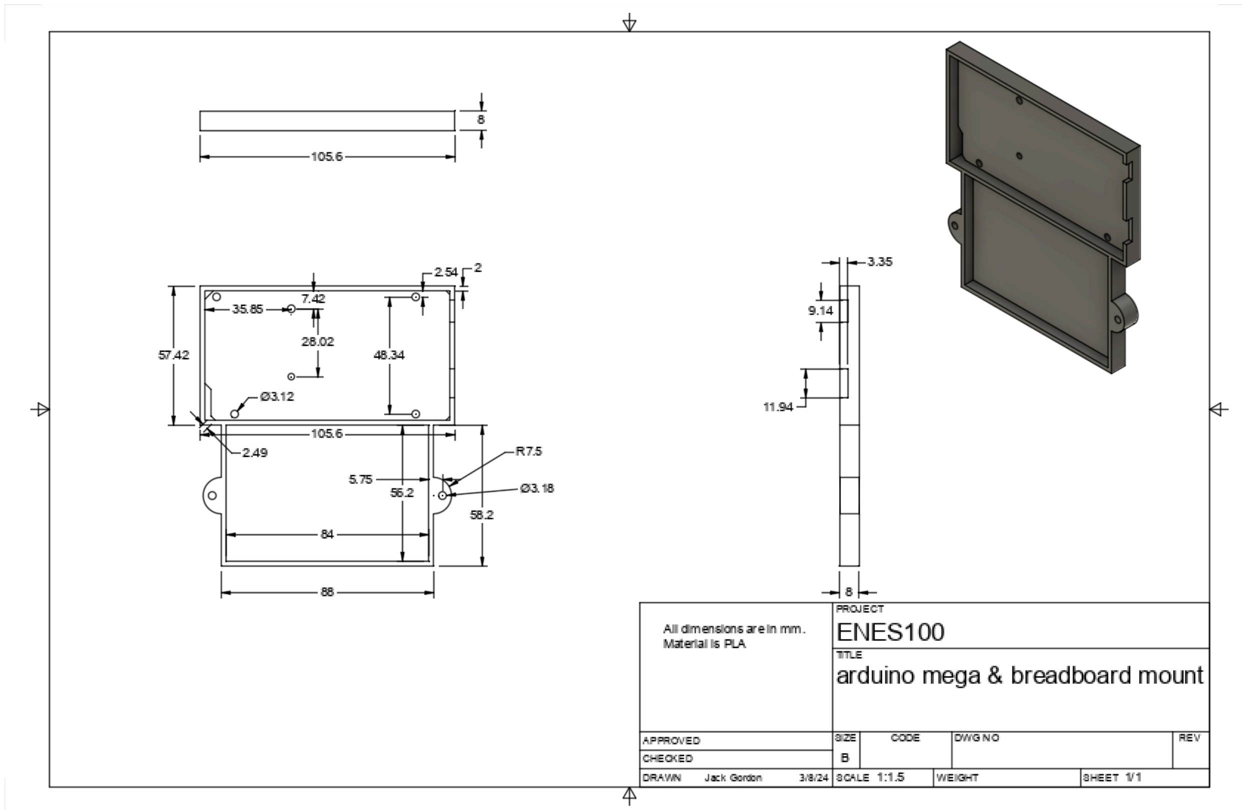
5.3
Ø16
10.73
6.16
R7.5
Ø3.18
3.75
3.2
11.2
R1.65
22.4
R8
Ø2
3.7
3.7
47.4
2
All dimensions are in mm.
Material is PLA
PROJECT
ENES100
TITLE
ultrasonic sensor mount
APPROVED
CHECKED
DRAWN Jack Gordon 3/8/24
SIZE B
CODE
DWG NO
REV
SCALE 1:0.5
WEIGHT
SHEET 1/1


15
10
Ø4.1
10
Ø10
Ø15
13.75
10
15
18.5
4.1
12.25
20
47.5
All dimensions in mm. Material is PLA
PROJECT
ENES100
TITLE
forklift stand
APPROVED
CHECKED
DRAWN Jack Gordon 3/8/24
SIZE B
CODE
DWG NO
REV
SCALE 1:0.6
WEIGHT
SHEET 1/1


18.61
114.92
Ø10
15
10
112.5
20
Ø3.1
60.5
132.53
135.75
20
20
60.5
114.49
19.5
18.72
132.87
All dimensions are in mm. Material is PLA
PROJECT
ENES100
TITLE
forklift
APPROVED
CHECKED
DRAWN Jack Gordon 3/8/24
SIZE B
CODE
DWG NO
REV
SCALE 1:1.5
WEIGHT
SHEET 1/1


55
R7.5
3.75
Ø3.18
76
80
28
52
35
2
3.18
59
All dimensions are in mm. Material is PLA
PROJECT
ENES100
TITLE
battery holder
APPROVED
CHECKED
DRAWN Jack Gordon 3/8/24
SIZE B
CODE
DWG NO
REV
SCALE 1:0.75
WEIGHT
SHEET 1/1

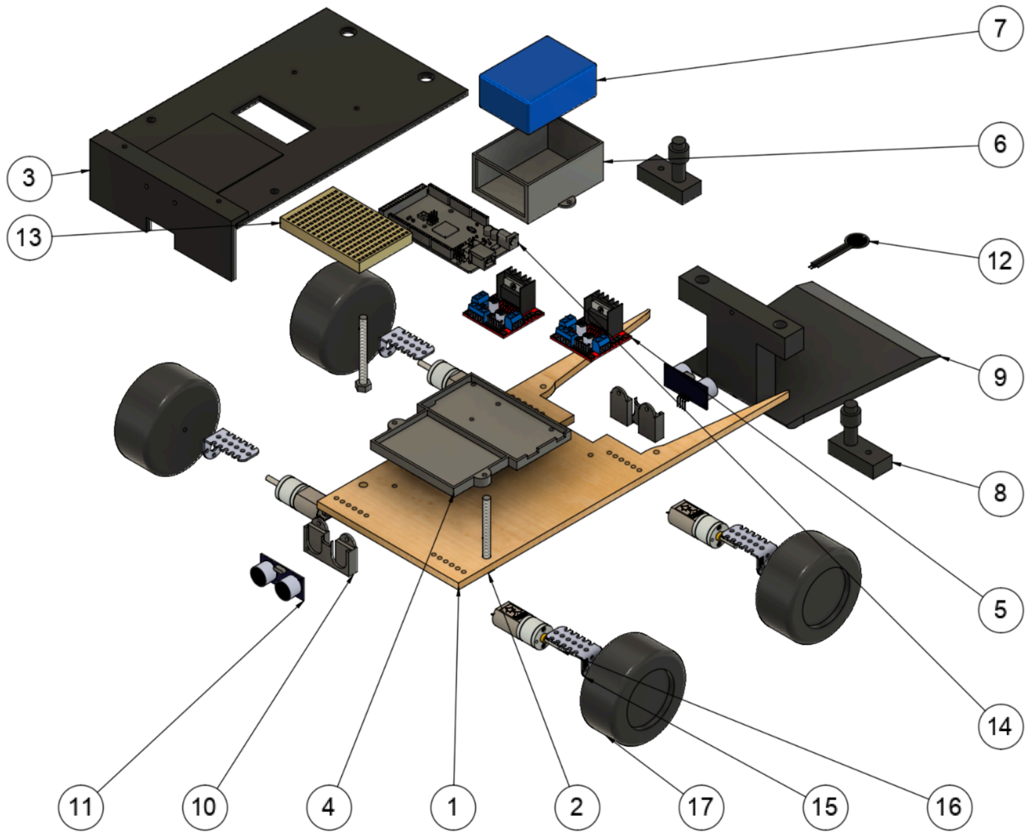

8
105.6
3.35
2.54
2
7.42
35.85
9.14
28.02
57.42
48.34
Ø3.12
11.94
105.6
2.49
R7.5
5.75
56.2
Ø3.18
58.2
84
88
8
All dimensions are in mm.
Material is PLA
PROJECT
ENES100
TITLE
arduino mega & breadboard mount
APPROVED
CHECKED
DRAWN Jack Gordon 3/8/24
SIZE B
CODE
DWG NO
REV
SCALE 1:1.5
WEIGHT
SHEET 1/1

Section H: Bill of Materials

The total cost of all components is $312, while the weight comes out to be 1.62 kilograms.

ITEM	QTY	PART NUMBER	MATERIAL	VENDOR
17	4	STAND IN WHEEL	Plastic	Amazon
16	4	MOTOR	Metal	Pololu
15	4	MOTOR BRAKCET	Metal	Pololu
14	1	ARDUINOMEGA_STEP_AP203	Metal	Amazon
13	1	CUSTOM BREADBOARD	Plastic	
12	1	STRAIN GAUGE-1	Metal	Digikey
11	2	HC-SR04--3DMODEL-STEP-1	Metal	Adafruit
10	2	ULTRASONIC SENSOR MOUNT	Plastic	
9	1	FORKLIFT	Plastic	
8	2	FORKLIFT STAND	Plastic	
7	1	STAND IN BATTERY	Metal	Amazon
6	1	BATTERY HOLDER	Plastic	
5	2	L298N DRIVER DC MOTOR, STEPPER MOTOR	Metal	Amazon
4	1	ARDUINO MEGA & BREADBOARD MOUNT	Plastic	
3	1	CHASSIS LID	Acrylic	
2	2	CHASSIS UPPER LEVEL SUPPORT	Metal	
1	1	CHASSIS PLATE TEST	Birch Plywood	

PARTS LIST



item	#	cost	total cost	source	weight	in kg	total wt (kg)
wheels (1 set)	1	39.99	39.99	Amazon	480g	0.48	0.48
motors	4	28.95	115.8	pololu	47 g	0.047	0.188
load sensor	1	26.3	26.3	digikey	2.2 g	0.0022	0.0022
ultrasonic sensor	2	3.95	7.9	adafruit	6 g	0.006	0.012
battery (w/ tamiya connector)	1	21.99	21.99	amazon	255 g	0.255	0.255
tamiya connectors	1	3.49	3.49	amazon	0.48 oz	0.007	0.007
killswitch	1	1.25	1.25	pololu	info not provided		
motor mounts	4	7.95	31.8	pololu	3.7 g	0.0037	0.0148
Body	1	3	3	umd	150g	0.15	0.15
motor controllers (4 pack)	1	11.49	11.49	arduino	5.1oz	0.14458	0.144583
arduino mega	1	48.9	48.9	umd	36 g	0.036	0.036
other: components that won't be bought							
jumper wires	tbd	n/a	n/a	umd	info not provided		
wifi chip	1	n/a	n/a	umd	info not provided		
breadboard	1	n/a	n/a	umd	1.34 oz	0.038	0.038
bolts and nuts	tbd	n/a	n/a	umd			0.0668
Forklift	1	n/a	n/a	umd	75g	0.075	0.075
Aruco Stand	1	n/a	n/a	umd	148.81	0.1481	0.1481
Ball (Max Weight Assumed)	1	n/a	n/a	umd	295g	0.295	0.295
			311.91				1.617483