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Rocket Car Write Up

Intro

Throughout the entire design and build process, we encountered many obstacles and setbacks before ultimately creating a cart we believed to be suitable for competition. In total, we had three concrete design plans (two of which were illegal or insufficient) and many more rough sketches of possible designs. Due to the resources at hand (*ahem* Nathan's 3D printer at home) and laser printer at school, we decided to build the car almost entirely of parts we designed ourselves. Not only have we built a car that uses rocket propulsion to move forward at least three meters (this task seemed difficult at first), we have also devised a manner to manipulate the distance according to the random distance during the testing. We hope our hard work pays off on the day of competition with successful launches.

Rocket Car Design Process:

Car Design #1

Our first idea was to use the gravitational force of falling marbles to rotate the rear axle. Our design had a hopper of marbles suspended on a rod of 2020 Aluminum extrusion. We chose to use this type of support structure because of its ease of attaching parts in any direction and height onto it. The marbles would then fall down a tube into a wheel that only took 1 marble at a time to space out the marbles lower down, as we planned on using time as a manner to manipulate the distance travelled. The marble would then fall out of the spacer and down a tube where it would hit a cross and cause it to rotate. The cross would be connected to the rear axle using long supports and would cause the axle to rotate simultaneously with the cross after the collision with the falling marble. After almost building all of it in Fusion 360, we found out the idea was illegal and went on to Car Design #2.

Our first idea was illegal because the marbles directly rotated the cars axle. This was illegal because the propellant needed a create thrust that would cause the car to move, not directly move it.

Step To Get To Car Design #1:

- Sketches on paper
- Visualization and construction of a mental 3D model
    - Playing around with different parts
    - Trying new ideas
    - Problem solving
- Once mental images and ideas were brought onto paper, we began 3D modeling on the computer.

- We started with base of the car, working on the larger components before moving onto the smaller ones

- Once most of the car was designed, we started printing prototypes of parts to test possible flaws and fine tune designs. This is where we could fix and solve any major issues before printing a large scale model.

To build the first car, we decided to use Fusion over tinkercad mainly because of its abundance of useful features. Plus, it offered a new challenge. At the start we didn't know Fusion, so we had to watch videos and learn as we went along. Learning how to use Fusion made the first car very labour-intensive to design, but it paid off in the long run. Once we had the base and most of the car designed in Fusion, we laser cut the base plate out of cardboard as a prototype for testing to ensure everything fit. Even though our idea had to be scrapped because it was illegal, we acquired a stronger understanding of Fusion and an idea of how to build the base of the car and the wheels, the mounts and the axles (the only parts of the design that weren’t illegal).

Car Design #2

After reviewing the requirements and regulations once more (and meeting with the head judge), we finally understood how our car must be propelled forward. The specific requirements of rocket propulsion made designing our next model much more difficult. After a few whiteboard brainstorming sessions, we created our next design, which was legal, but also a failure. We planned to keep with the design of having a hopper on top of 2020 Aluminum Extrusion, but this time we would have many more marbles. The car would move by having all the marbles run down a slanted pipe and exit at the rear of the car. The action of the marble rolling down the slanted pipe would cause movement of the entire car. We also figured that the base should be smaller because this idea would likely generate less thrust, so the overall car mass needed to be considerably lighter. After designing the entire car again and laser cutting the new smaller base from plywood, we discovered that this idea would not provide sufficient thrust, thus leading to our second idea also getting scrapped.

Steps To Get To Car Design #2

- Started with brainstorming rough sketches on whiteboards

- We looked at all the different ways we could have the marbles eject form the car and how tall parts needed to be to generate sufficient acceleration and thrust

- After having a general sketch, we started designing the car on the computer

- we visually constructed a full scale 3D model and played around will all the components until we were satisfied with how it looked and then went to work in Fusion

- We built the base first so that Joyce could laser cut it

- The idea for the wheels and axle design (discussed in further detail in Design #3) was similar to Design #1, so that part was relatively easy to recreate.
- At this point because of the countless hours we spent learning Fusion for the first design, this design process took less time and the design quality was greater.
- Some of the wheels and axle components were printed at this point which turned out to be decent, and thus were used in our next design. Besides those parts, no components of design #2 went past a 3D model before this idea was scrapped.

Car Design #3 (the final design). The slingshot car.

After having fully designed and scrapped two ideas, we had a pretty good idea of what worked in the designs and what did not. We finally created a manner to propel the car in a legal manner, with the option to adjust elements of the car for the random aspect of the distance. Our design was essentially a slingshot. We used stored potential energy in the form of elastic potential energy in the slingshot to convert the energy into kinetic energy to eject a mass off the back of the car. By ejecting the mass, we create momentum (momentum is mass multiplied by velocity). The car's motion forward can be explained using Newton's third law of motion as for every action, there is an equal and opposite reaction. The slingshot bracket that is being launched forward against the mass pushes against the mass with a force. The mass then pushes in return against the slingshot bracket with the same force. It is this force that causes the car to launch in the opposite direction of the ejected mass. We can change the amount of elastic potential energy and kinetic energy by increasing the tension in the rubber bands. A rubber band with a higher spring constant is able to produce a greater force against the mass, and cause more propulsion.

The way our slingshot propulsion system works is by a very similar design to a crossbow. There is a central gear crank that allows us to adjust the tension of the cord to vary the distance. On this gear, there is a locking mechanism that holds in it in place once the tension has been set. This locking mechanism allows for tension to be stored in the string. At the back, there is a slot where the mass to be ejected is placed. Going across the track is a beam that the tension cord is connected to. On both sides of the mass track there are guide rails for the beam to follow, and a "home" position where it gets locked into when it is ready to fire and is under tension. When the beam is released from its locked position, the elastic tension ejects the mass and propels the cart forward simultaneously. The trigger mechanism for the car works by pressing up on the beam in its "home" position form beneath, which in turn releases it and sets it free. The cord we used in the gear crank mechanism is only capable of obtaining enough tension to reach accurate distances up to 1.5 m, so any distances above that point require the use of two rubber bands in hand with the cord. The rubber bands give us the power we need to reach 3m and the cord still allows for adjustability from 1.5 – 3m.

We decided to repurpose the base from Car Design #2. This made designing the car considerably more difficult because of the design restrictions we had now created. When designing the car base in design #2, we cut out rectangles wherever we could to eliminate as much mass as possible. Now that our propulsion system has changed from dropping marbles, to a slingshot design, it was hard to design everything to fit and function on the pre-designed base. It was our goal to try and drill as few holes as we could. Essentially, repurposing an older design is not always the smartest idea.

The wheels on the car are 3D printed out of flexible filament to give the tires more grip. The tires attached to the axle through bearings help reduce the friction in the axle. Because the axle is a wooden rod and the diameter of the bearings couldn't be adjusted to fit the rod, bearing to axle adaptors had to be designed for everything to work.

Step To Get To Car Design #3

- After many ideas being tossed around, we settled on a slingshot powered car.
- Like the previous two designs, as soon as we had some ideas, we sketched and visualized components in our minds and on whiteboards.
- Moving into Fusion, we already had a head start on this design because we decided to use the older base and wheel system from design #2.
- The first parts we built were the gear crank and the mass slot. These are the two biggest components in the design and it is easier to build the smaller components around them.
- After the big components were complete, we started printing and prototyping them and completing the car design with all the small parts, such as cord guides and the trigger mechanism.
- As parts were printed, we assembled the car and everything came together exactly as planned. All the parts were accurate to ±0.03mm (the tolerance of our 3D printer).
- From here we began testing
- Initially we planned to shoot a big marble as the ejection mass, but quickly realized that it was way too light. We switched to a 550 g mass constructed of a 1/2 and 3/8 inch solid steel bar cut into lengths that fit in our mass slot.
- This mass was enough to get the necessary momentum to reach 3m.

Adjustments after initial testing

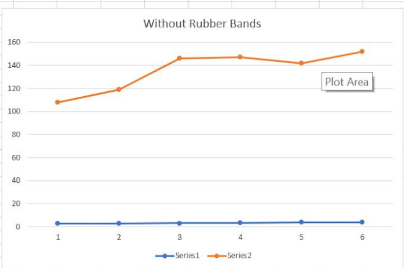
- A new piece supporting the crank that stops the gear containing the cord had to be printed because the original broke under stress.
- A longer trigger arm was designed to increase consistency of launches. Often times, the person launching the car (Hamilton, our appointed launcher in-chief) would hit the car with their finger when triggering the launch. By extending the trigger, it reduced the chances of the car body being hit.

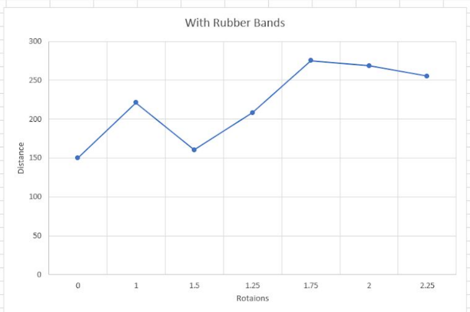
Testing

- We spent the next few days testing our design to collect data to help with the uncertainty of the distance on test day.
- We can adjust the tension in the slingshot by the number of rotations we twist on the gear that contains the cord.
- We tried different number of rotations and recorded the distance travelled.
- Depending on what part of the floor we tested, the car travelled different distances due to the friction of the floor.
- Throughout testing, we discovered an alarming trend of inconsistency regarding the distance travelled and the increase of tension. Often times, the same amount of tension would vary in distances up to 1m.

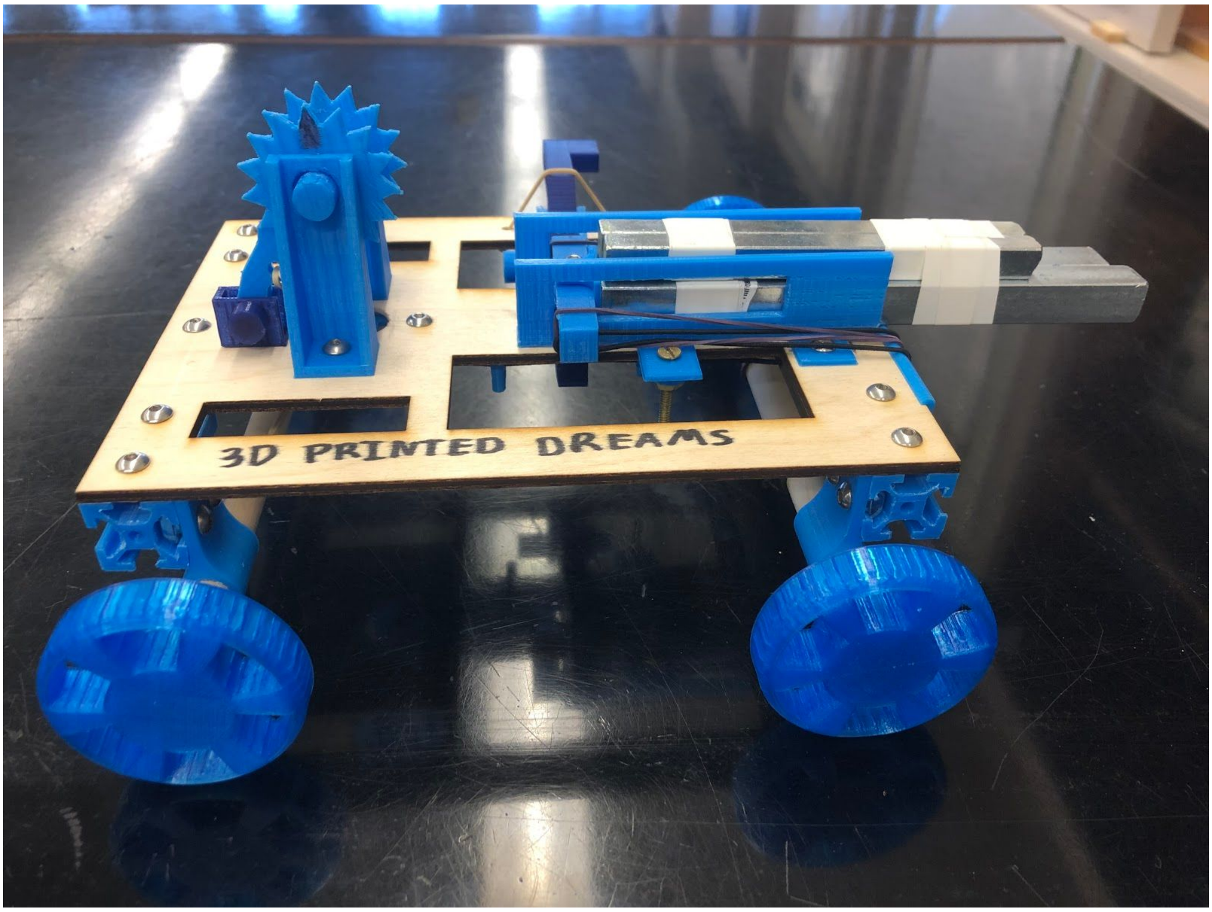
Data From Testing

E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
		No rubber bands		Rotations	Distance (cm)									
				2.5	108									
				2.75	119					Locker # Start	672			
				3	146									
				3.5	147									
				3.75	142									
				4	152									
				4.5	166									
				5	226	236								
	Inconsistent range		max	5.75	184									
			with rubbrer bands									Average Distance		
				0	150							150		
				1	176	250	250	209				221.25		
				1.5	3	222	226	190				160.25		
				1.25	143	212	256	222				208.25		
				1.75	280	266	281	273				275		
				2	257	273	284	250	277	271		268.667		
				2.25	267	228	271					255.333		





Our built car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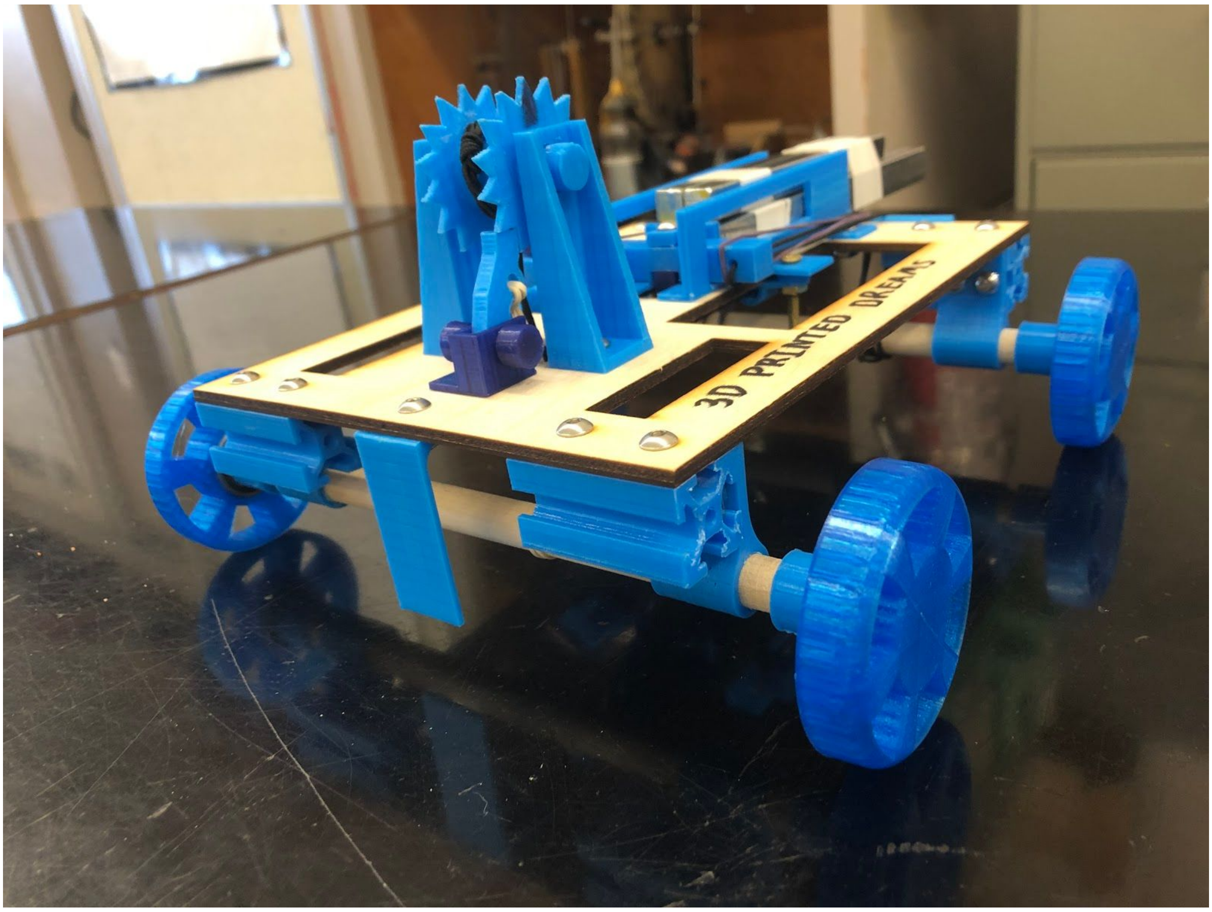
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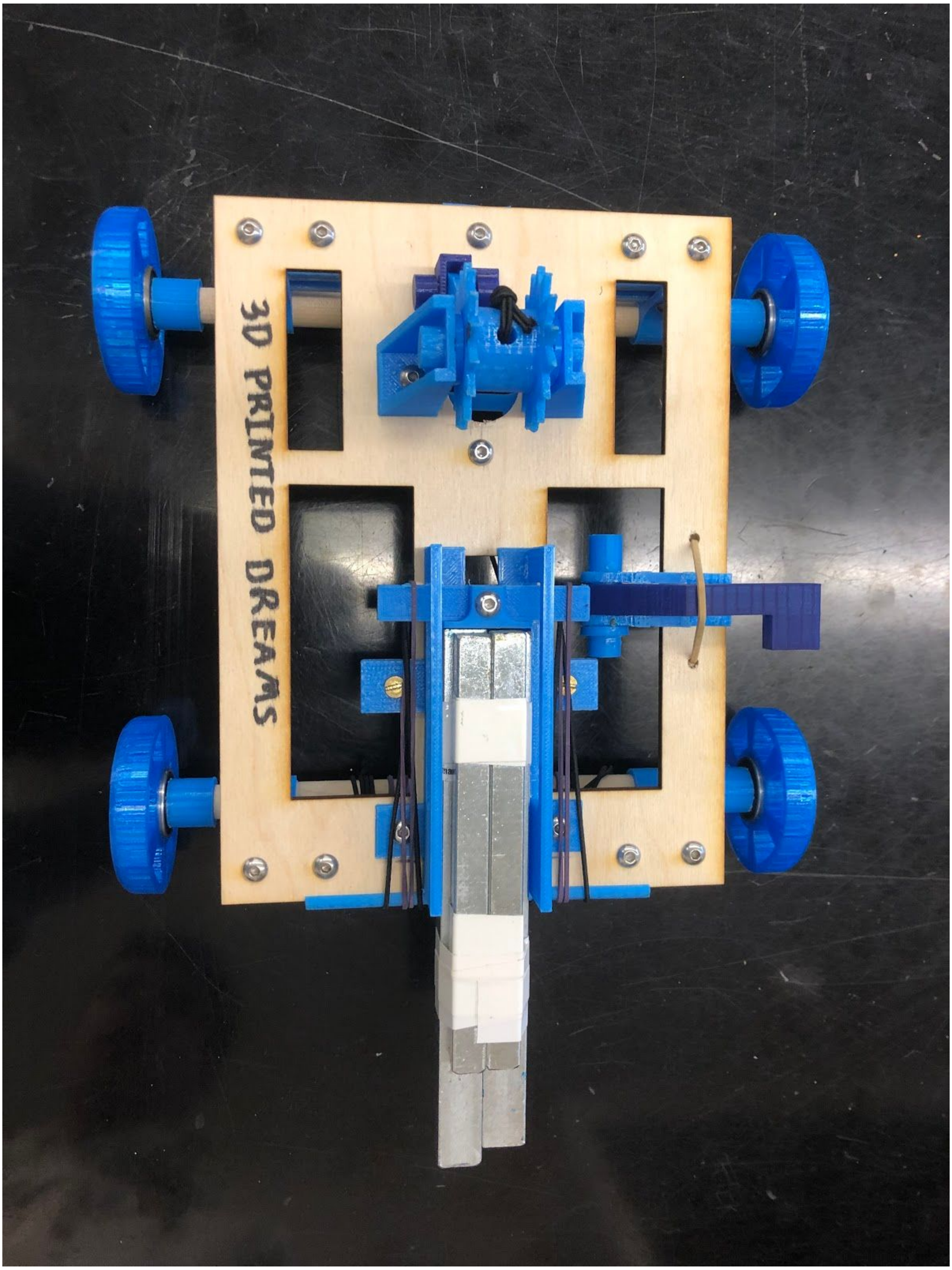
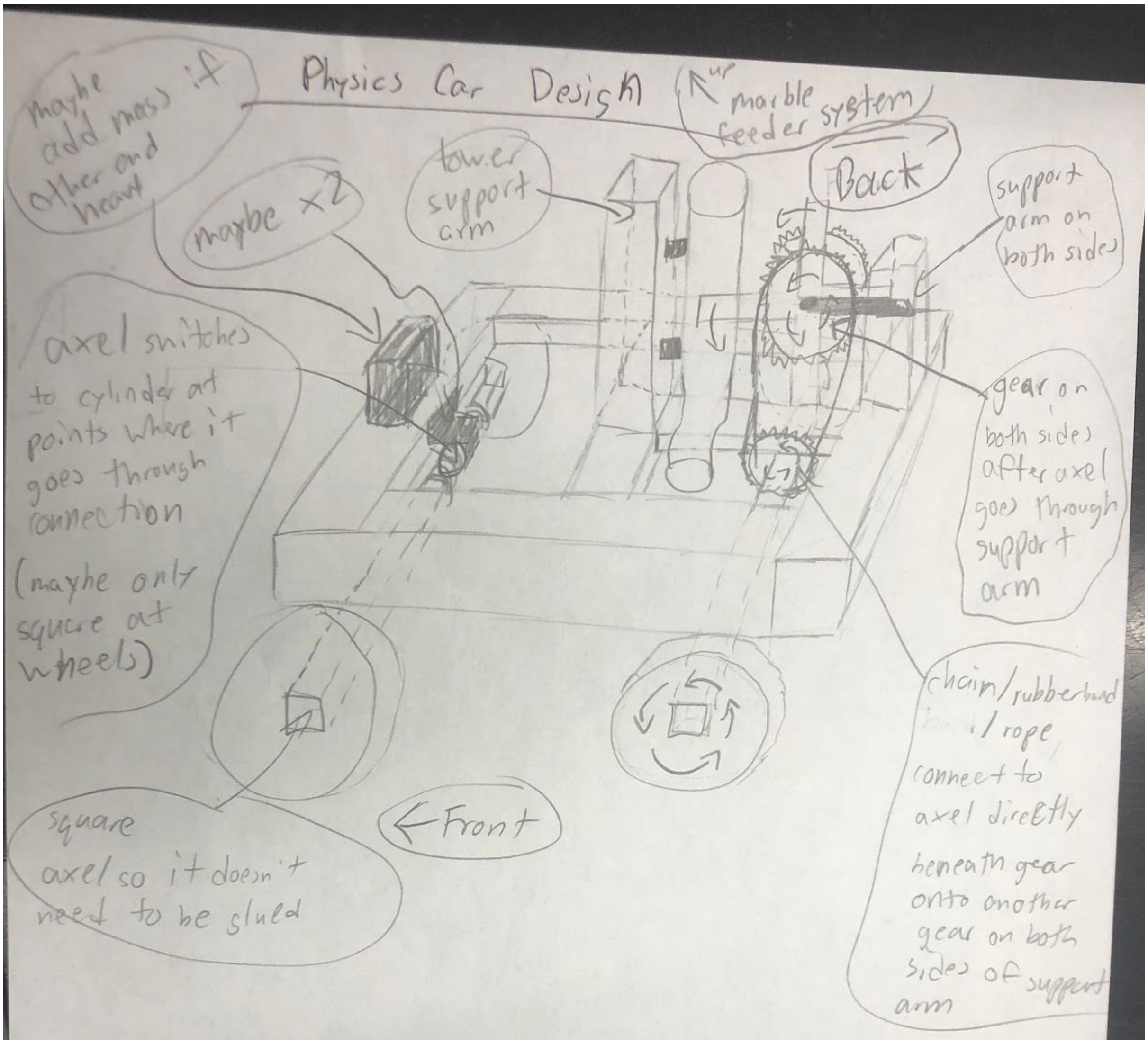


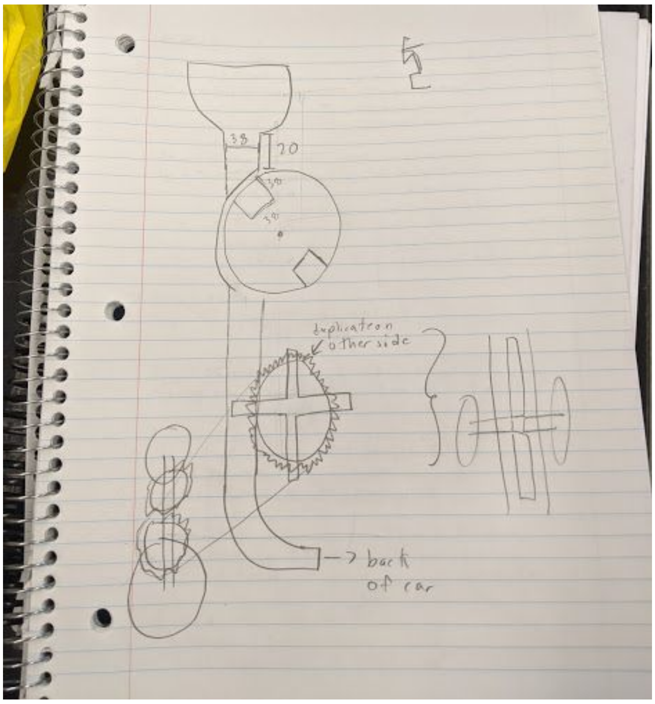
Performance

Our performance today was dismal; it didn't go as planned. Our goal was 1.80m: our first launch was 2.20m, so we decided to go for a second launch. Unfortunately, our second launch only went 0.59m. For next time during the competition , instead of taking off the rubber bands, we would use the rubber bands but release all of the tension in the string. Design-wise, we should have put lubricant or grease onto the bearings of the wheel to make it spin better. For the part where we hook the string on, we should've made the edges round instead of 90 degrees, because the tension of the string was caught onto the sharp corner, and that affected the adjustments of the crank.

Images

Car design #1

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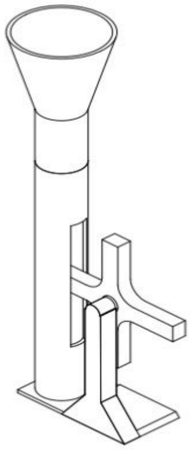

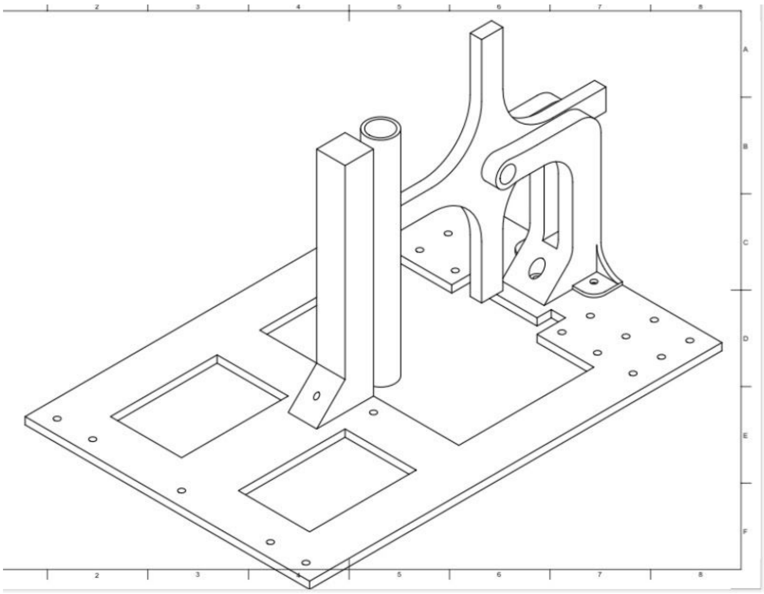

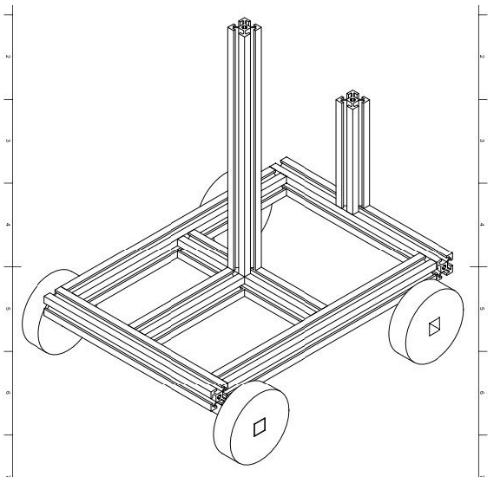

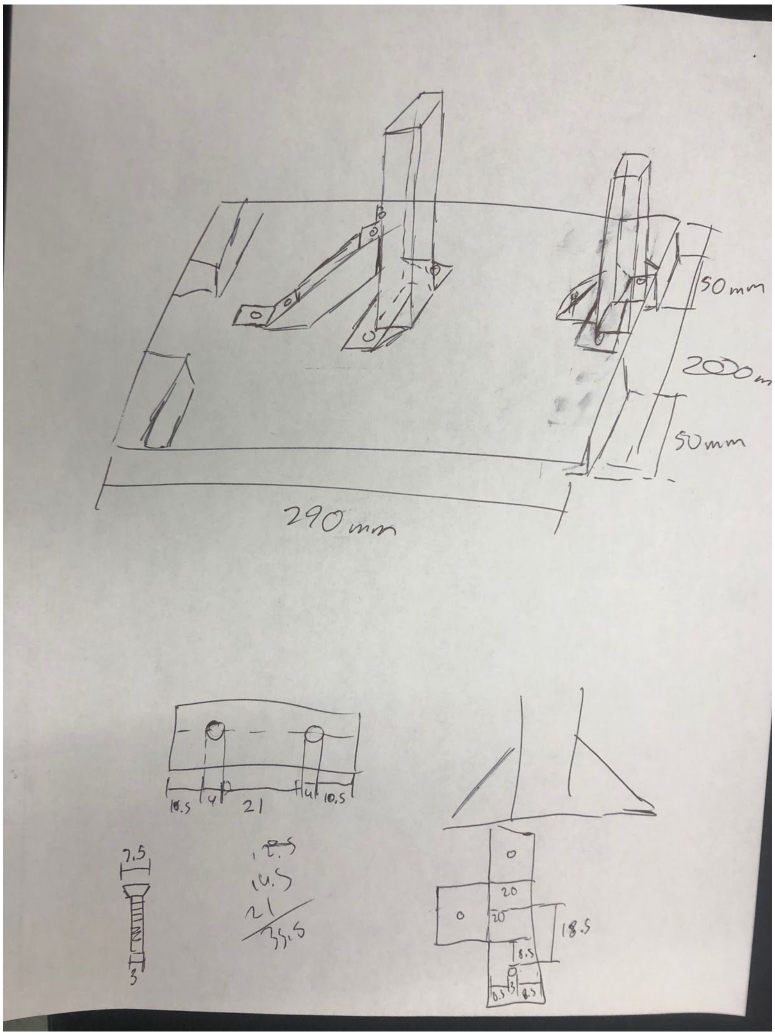

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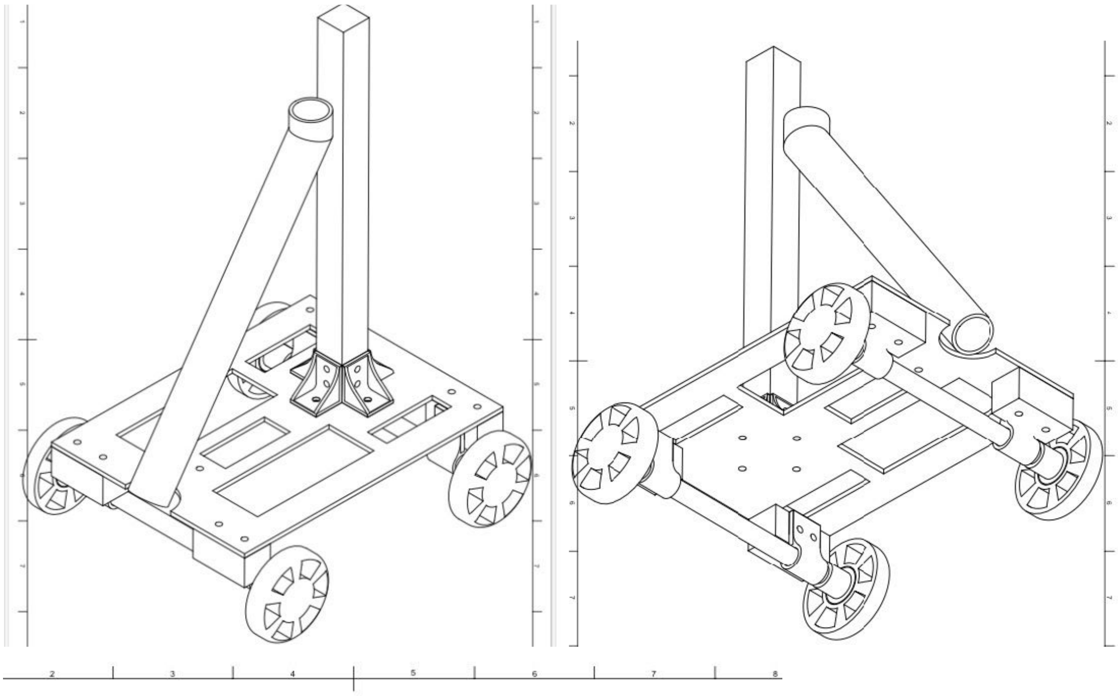
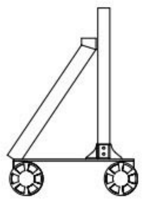
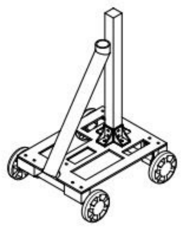
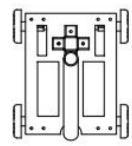
Car Design #2

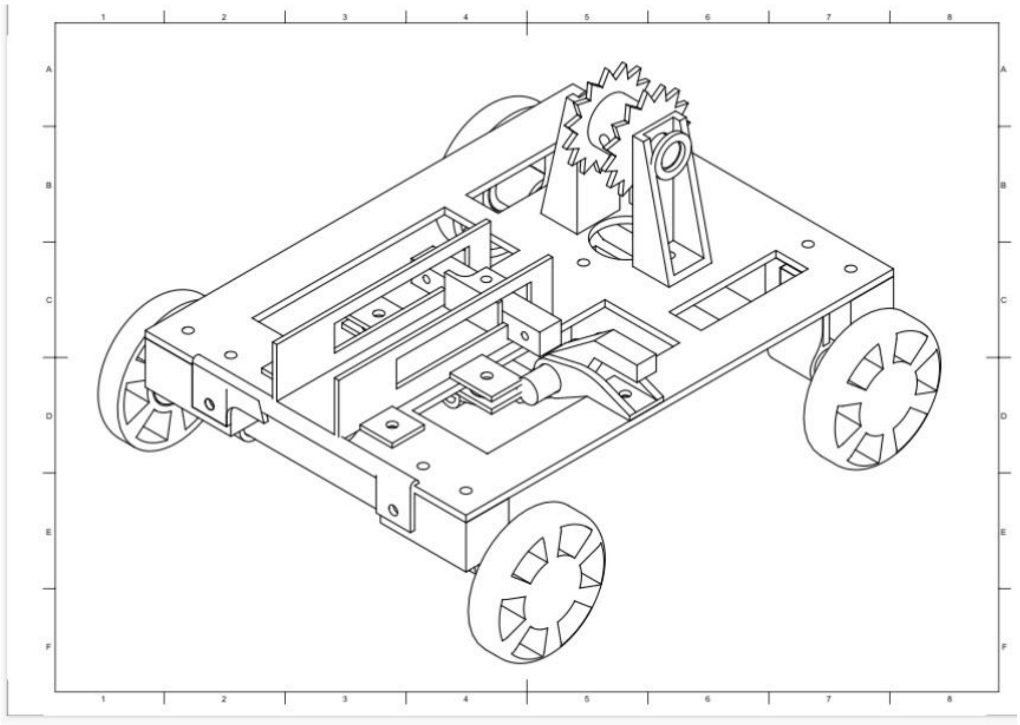




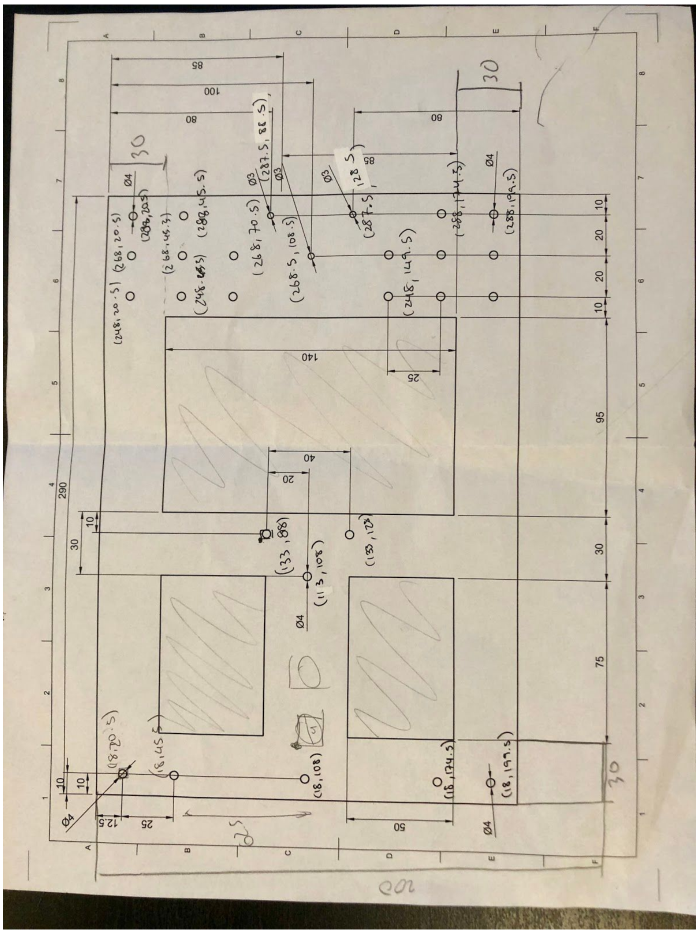


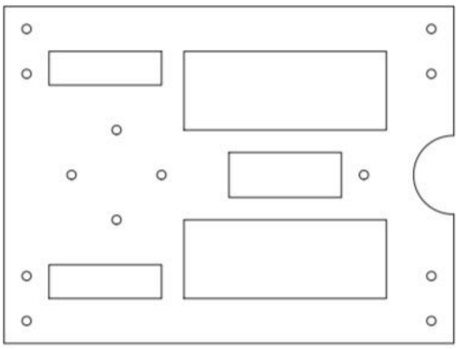


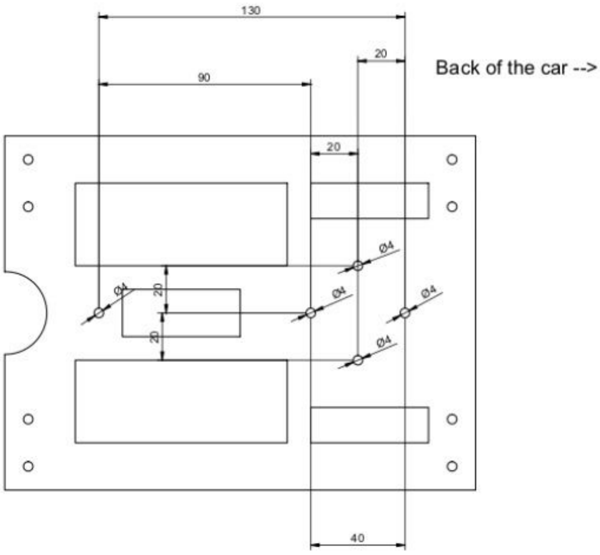
Car Design #3

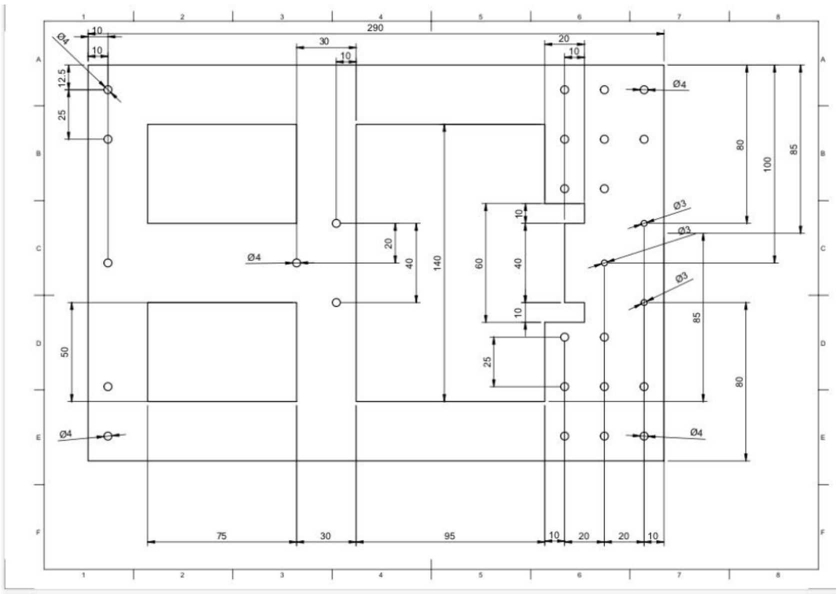


Base plate designs and measurements









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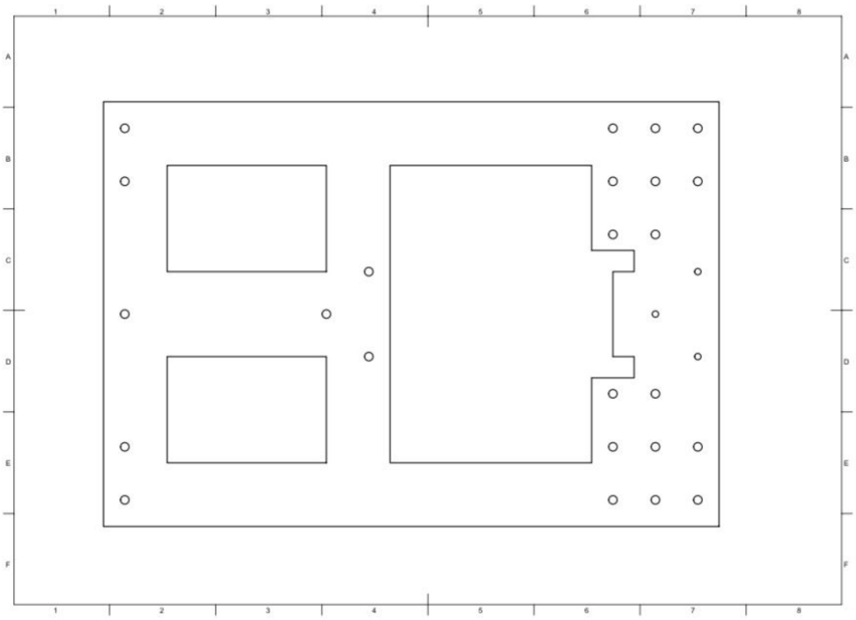

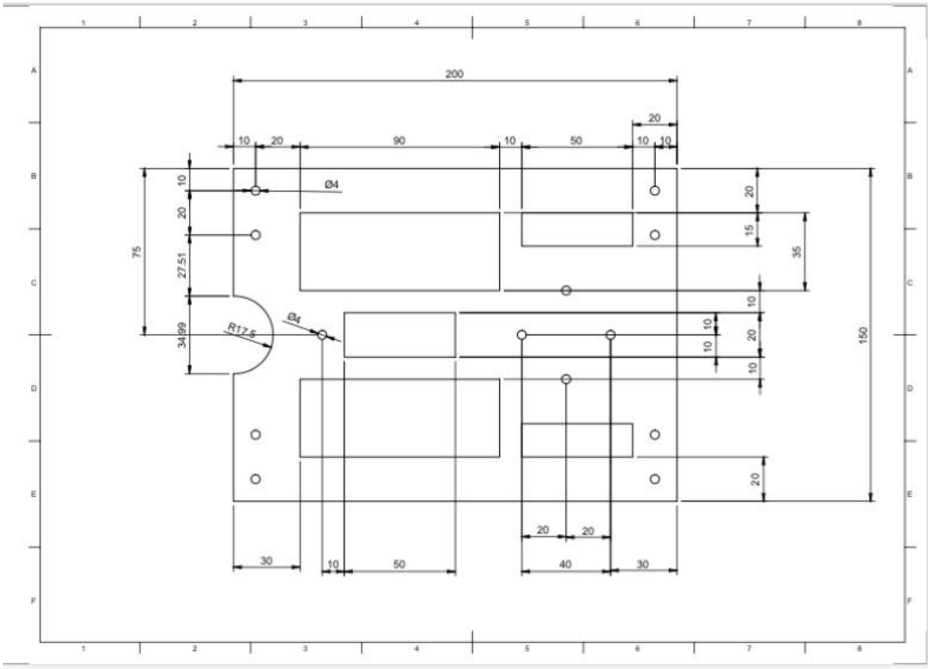
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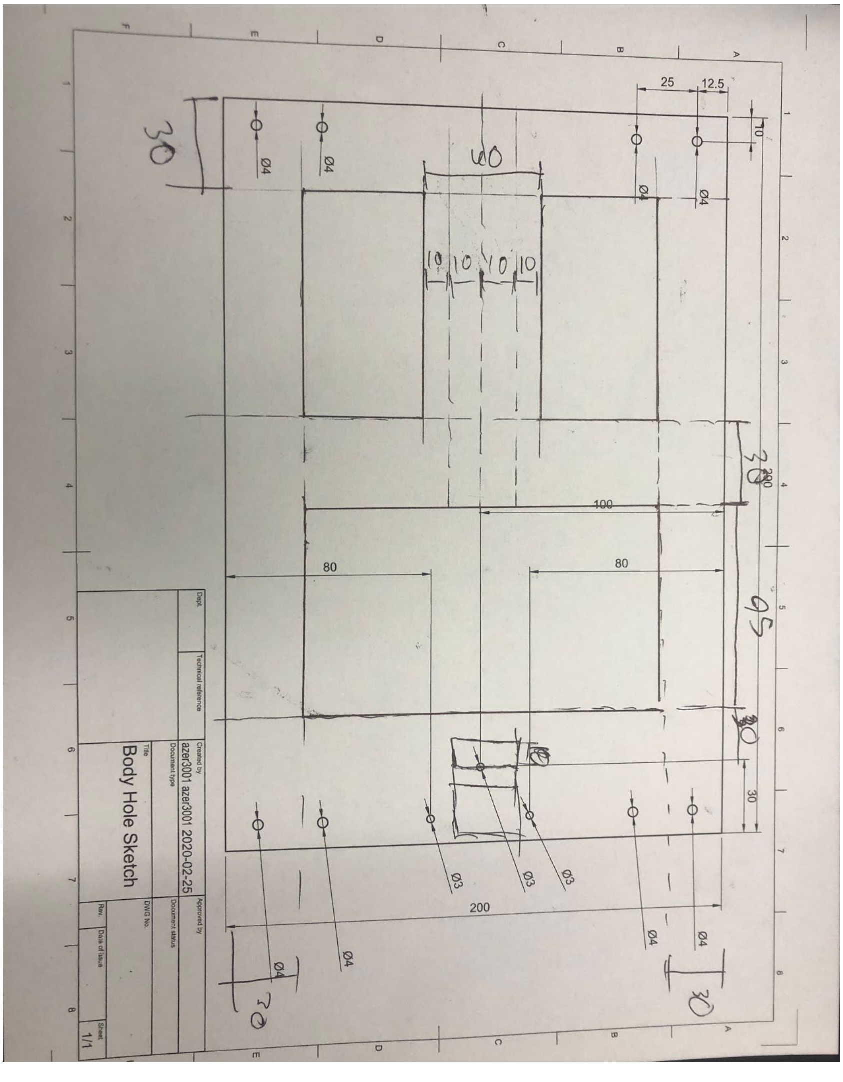
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Approved by
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2020-02-25
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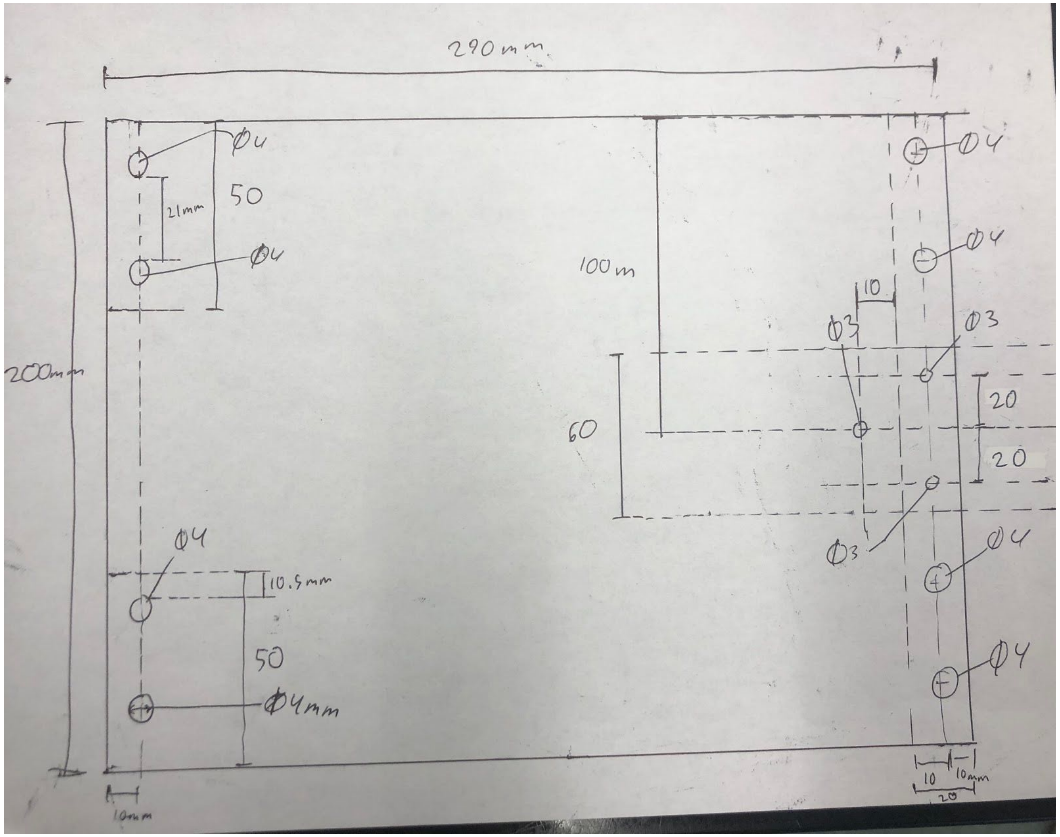
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Random/other illegal ideas