ROBOT DESIGN

ABOUT

We have been able to accomplish all of the robot goals we set, and more, declaring our game strategy, clear goals, and following our design philosophy and design process, while utilizing CAD and incorporating important math and science concepts.

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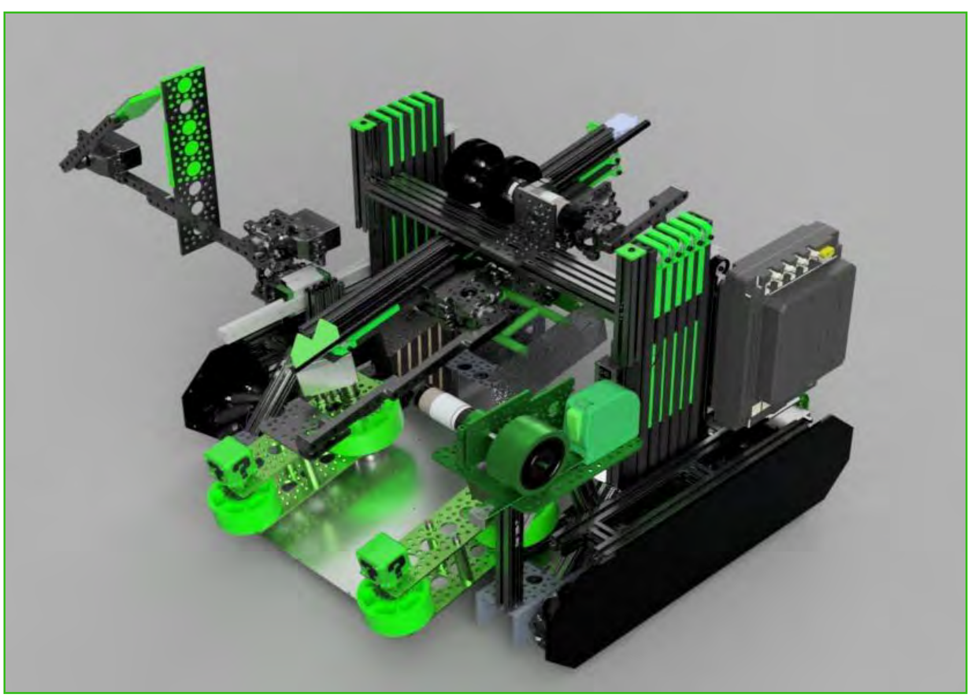
ROBOT SUMMARY

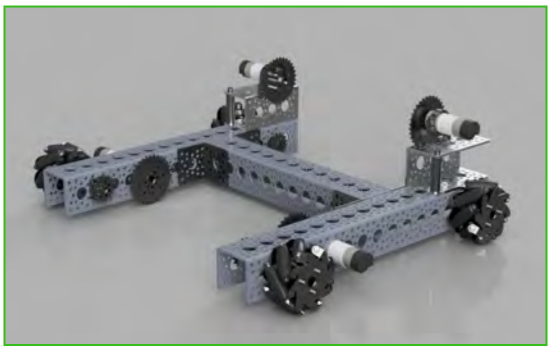
Robotiana, our robot, is designed for speed and precision. We judged that the Skystone challenge of this season is all about speed and precision in collecting and stacking stones, and in completing the autonomous and end-game portions of play. To ensure Robotiana's speed and precision, we designed her with a philosophy of simple and linear motion. We used geared motors to increase her speed, and we eliminated sources of friction that slowed the motion of the blocks through the robot. Robotiana carries our capstone to save time in end-game. And we gave her a tape measure to help with the parking elements of the game. We also worked, over the season, to make the stone intake robustly pick up stones from any orientation.

The base of our robot is our chassis. We have four, ball bearing, nexus, mecanum wheels that are run by 40:1 motors, geared 2:1, which makes them very fast and efficient. The chassis itself is made out of the Servocity ball bearing building system; the intake ramp is attached to the chassis to the top of the channels and front brace. Our intake is a key part of our game plan and enables many of the things that our robot does. We use green compliance wheels on our intake. Two wheels on each side are run by fast, vex motors. Our wheels are at the same angle as our ramp to make picking up stones faster. We use physics to prove this on page H-148. Our vertical lifts use Long robotics, ball bearing slides, and with six slides on each side and a cross bar that attaches the horizontal slides to the vertical slide. Both lifts use green, 3D-printed parts and are run by 20:1 motors, as well. Our capstone and its deploying system are in the middle of our robot and sit near the end of the intake ramp. The capstone deploys on a servo with a pin and drops on the stone. Our foundation movers are located on the back of our robot and swerve down and clamp onto the foundation to move it. Lastly, our autonomous claw is on a linear rail which makes it able to be used for either alliance. We have three servos that make the claw able to swing forward and side to side so we can pick up a stone and not hit the skybridge. This also allows for more options in future autonomous.

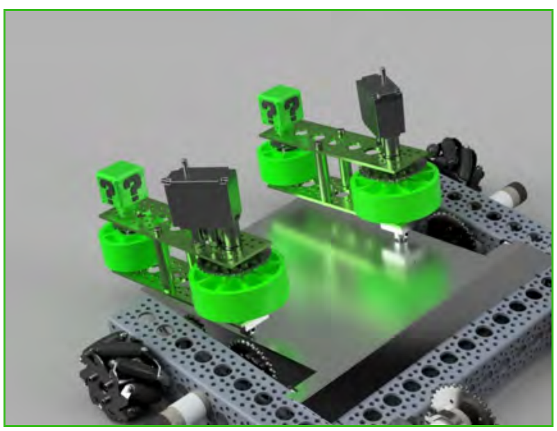


ROBOTIANA’S PROFILE

OVERALL
This is our robot, Robotiana! Throughout the robot, we use a combination of servocity, gobilda, andymark, and rev building systems, along with many other parts.

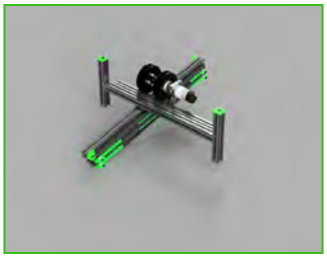


CHASSIS
The chassis uses the servocity ball bearing system with nexus mecanum wheels for maneuverability and 40:1 motors, which are geared up 1:2 for increased speed.



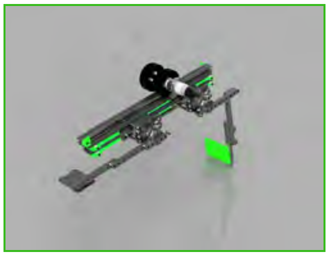
INTAKE
The intake is run by two vex motors and geared up 1:2.6. It has four andymark compliance wheels, and is mainly made of the servo city ball bearing building system.

VERTICAL LIFTS
The two vertical lifts are the Long Robotics ball bearing linear slides with bright green 3D printed parts. They are strung cascading and driven by two 20:1 neverest motors.



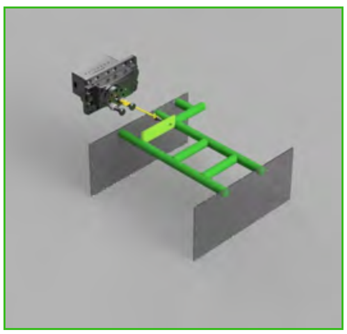
HORIZONTAL SLIDES

The horizontal slides are the Long Robotics ball bearing linear slides with bright green 3D printed parts for the horizontal slides. They are strung continuously, double spooled, and driven by a 20:1 neverest motor.



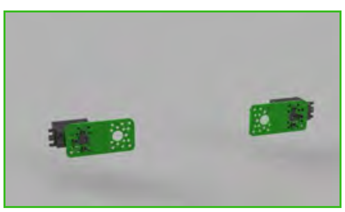
DRIVER CONTROLLED CLAW

The driver controlled claw is mounted to the bottom stage of the horizontal slides and uses 2 rev smart robot servo arms, which clamp onto stones.



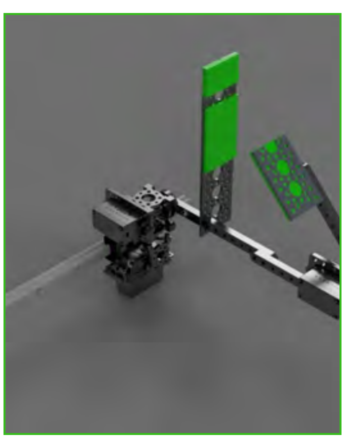
CAPSTONE MECHANISM

The capstone mechanism sits in between the driver controlled claw on the bottom horizontal slide, and holds our capstone with a key that fits into the rev extrusion and a pin. The pin inserts into the capstone key and the key in the extrusion keeps the capstone from swinging around; when we are ready to place our capstone, the pin is pulled by a servo and drops onto the stone within our robot



FOUNDATION MOVERS

The foundation movers rotate down and clamp onto the foundation using two green plates that are attached to two gobuilda dual-mode servos with steel gear trains.

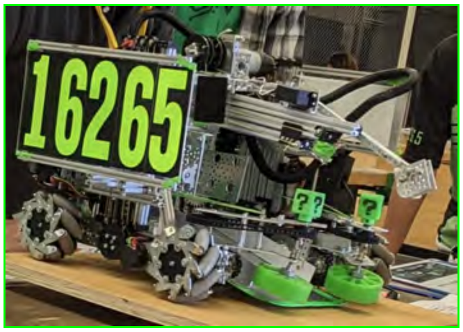


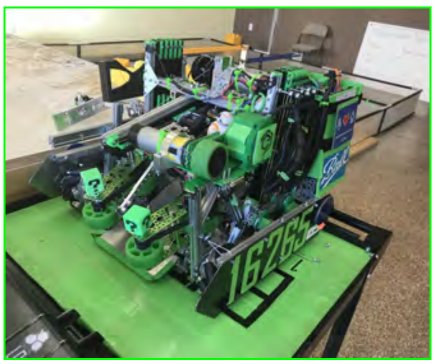
AUTONOMOUS CLAW

The autonomous claw is used in autonomous in order to more precisely and quickly grab the stones. It utilizes three servos, one to spin the claw on the z axis, one to rotate down on the y axis, and one to clamp the stone. The claw itself is on a locking slide on the side of our robot so we can change where the claw mounts on the robot depending on what side of the field we get.

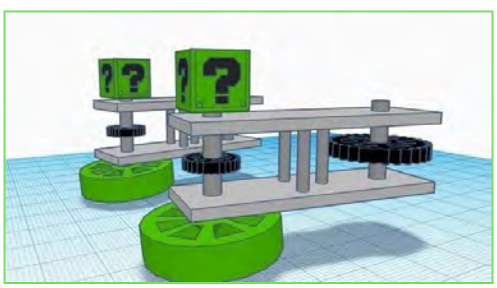
ROBOT ITERATIONS VISUAL

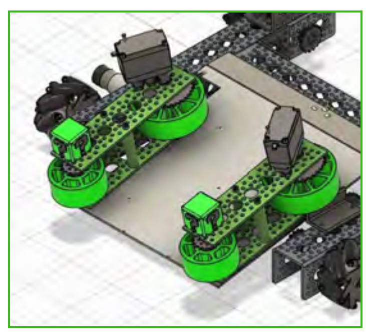
OVERALL



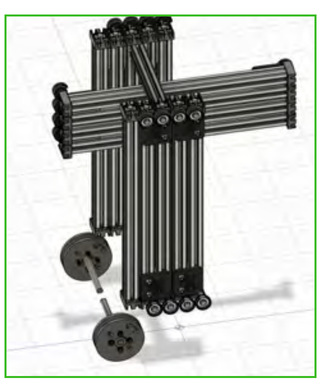


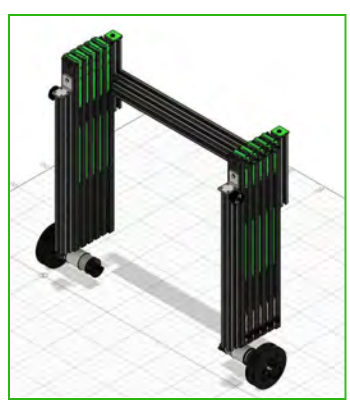
INTAKE



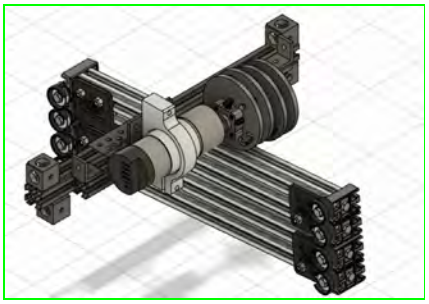


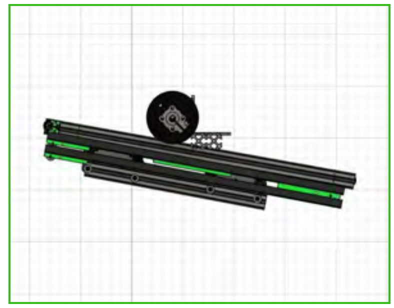
VERTICAL LIFTS



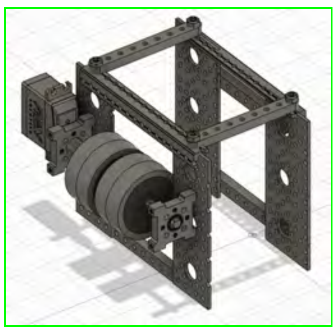


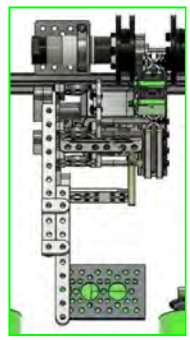
HORIZONTAL SLIDES



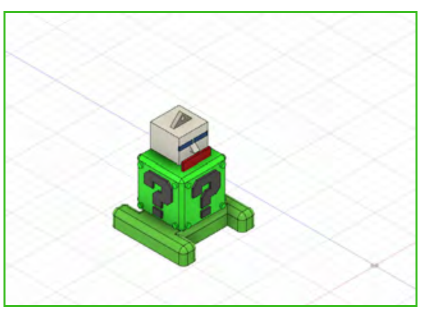


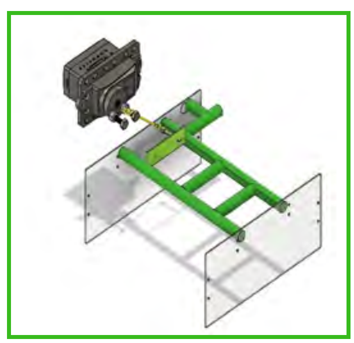
DRIVER CONTROLLED CLAW



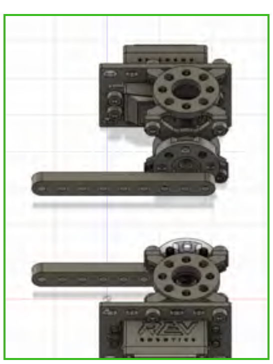


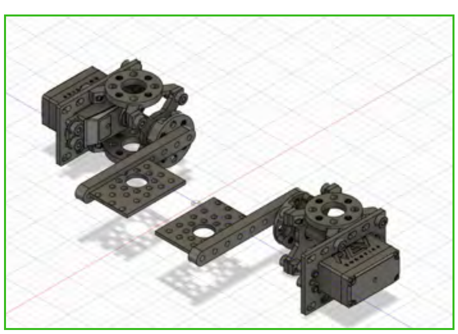
CAPSTONE MECHANISM

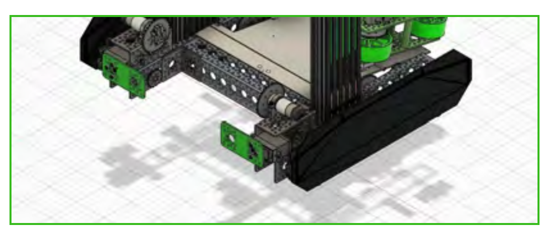




FOUNDATION MOVERS



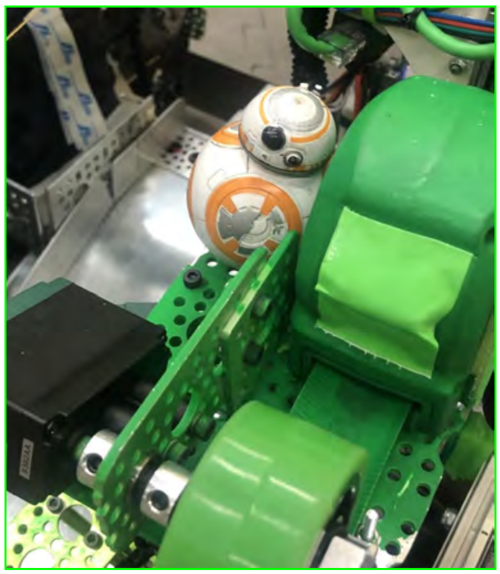




ROBOT AESTHETIC

One of the things that is very important to our team is making our robot look slick, interesting, and fun! We realize that the more we do this, the more it appeals to the public; it is also very fun to decorate the robot and quite satisfying to work hard on making something appear slick and intentional! The first few examples are **Star Wars** themed!

BB8

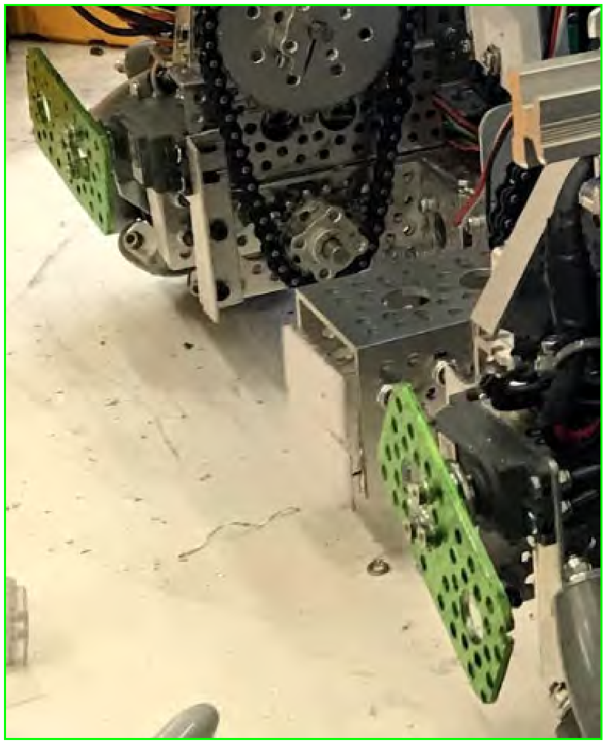


R2-D2

BLACK VERTICAL LIFTS & GREEN ATTACHMENTS

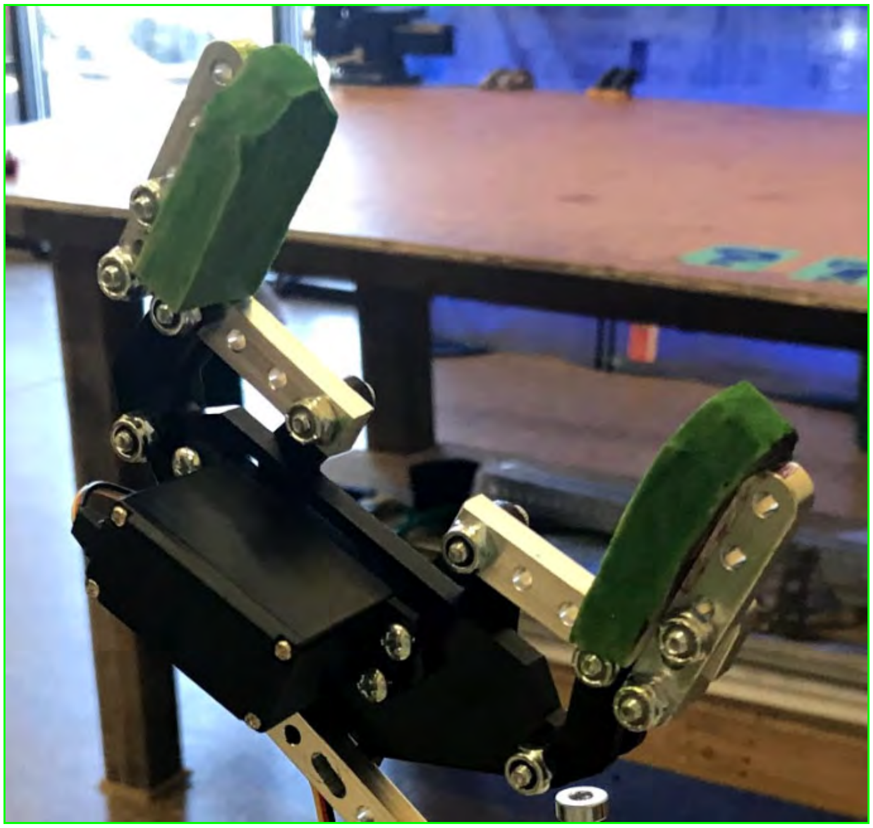
GREEN EXTRUSION INSERTS

GREEN SHARPIED FOUNDATION MOVERS



INTAKE: GREEN COMPLIANT WHEELS, GREEN SHARPIE, GREEN QUESTION CUBES

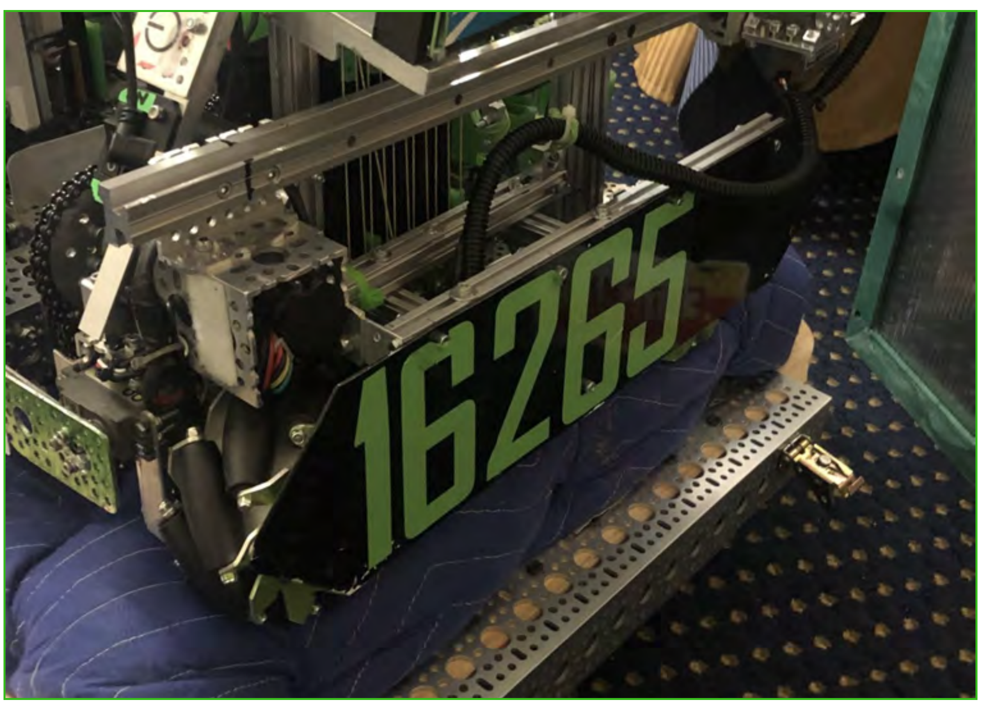
CLAW: GREEN WEATHER STRIPPING



NEW MEXICO LICENSE PLATE

GREEN WHEEL RIMS

BLACK & GREEN SIDE SHIELDS



GREEN TAPE MEASURE (PARKING)

GREEN ODOMETRY PODS

CURRENT CAPABILITIES

AUTONOMOUS	DRIVER CONTROLLED	END GAME	TOTAL
Max Solo Points: **43**	Max Solo Points: **44**	Max Solo Points: **36**	**122**
Average Solo Points: **43**	Average Solo Points: **28-36**	Average Solo Points: **32-34**	**103-113**
Program One • Deliver and place **2 skystones** • Move foundation • Park Program Two • Move foundation • Park Program Three • Park	• Deliver stones under the 14” skybridge • Stack up to **11** stones high (highly depends on robot traffic)	• Place capstone • Move foundation • Park in building site	

GAME STRATEGY & GOALS

This challenge seems to be less of a strategy game, and more of a speed game, especially because almost most scoring opportunities are related to manipulating the stones. Thus, our strategy is to be able to do everything, and to be able to do it with speed and consistency. This season, even though we are a rookie team, we wanted to set high goals for ourselves and see how far we could go! As you can see by comparing the chart above with that below, we have exceeded the goals we set for ourselves at the beginning of the season.

POINTS GOALS SET AT THE START OF THE SEASON

AUTONOMOUS	DRIVER CONTROLLED	END GAME	TOTAL
Max Solo Points: **29**	Max Solo Points: **32+**	Max Solo Points: **33**	**94**
Program One • Deliver and place **1 skystone** • Move foundation • Park Program Two • Deliver **2 skystones** • Park Program Three • Reposition foundation • Park	• Deliver stones under the 14” skybridge • Stack **8+** stones high	• Place capstone • Move foundation • Park in building site	

We also set competition specific goals, in order to set a pace for reaching our overarching end goals.

WHITE MOUNTAIN GOALS

AUTONOMOUS	TELE OP	END GAME
• Reposition foundation • Park under skybridge	• Deliver & stack 3-5 stones	• Place capstone • Move foundation • Park in building site

ALAMOGORDO GOALS | **UNEXPECTED, JUST ONE WEEK AFTER WHITE MOUNTAIN**

AUTONOMOUS	TELE OP	END GAME
• Reposition foundation • Park under skybridge	• Deliver & stack 3-5 stones	• Place capstone • Move foundation • Park in building site

SOCORRO GOALS

AUTONOMOUS	TELE OP	END GAME
• Sense and deliver 2 skystones	• Deliver & stack 6-7 stones	• Place capstone • Move foundation • Park in building site

SANDIA PARK GOALS

AUTONOMOUS	TELE OP	END GAME
• Sense, deliver, and place 1-2 skystone(s) • Reposition Foundation	• Deliver & stack 6-7 stones	• Place capstone • Move foundation • Park in building site

ARIZONA STATE GOALS

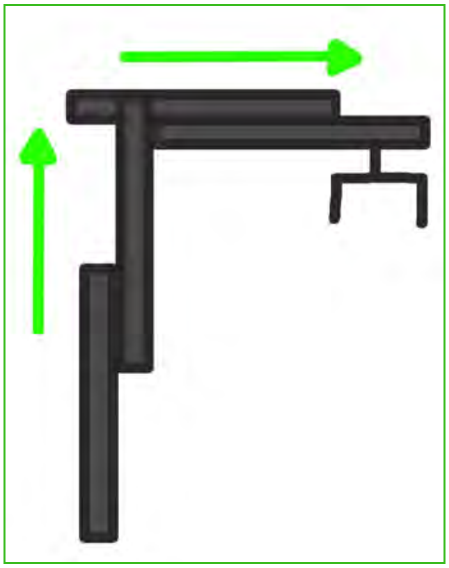
AUTONOMOUS	TELE OP	END GAME
• Sense, deliver, and place 4 stones • Reposition Foundation	• Deliver & stack 8-10+ stones	• Place capstone • Move foundation • Park in building site

NEW MEXICO STATE GOALS

AUTONOMOUS	TELE OP	END GAME
• Sense, deliver, and place 4 skystones • Reposition Foundation	• Deliver & stack 10+ stones	• Place capstone • Move foundation • Park in building site

DESIGN PHILOSOPHY

With some of our members' past experience with FTC and FRC, we noticed that **simple, rigid, linear** systems seem to work much better than complicated multipurpose systems. With that in mind, our goal is always for almost everything on our robot to be **linear** and **serve just one purpose**.



When designing, we are always thinking about the fastest possible way to get the game piece (or whatever else) from where it is to where it needs to be. This season, the stone follows a very simple series of straight lines from the floor to the foundation/skyscraper within our robot, so it is very fast and effective: the stone is autocorrected and comes in through the intake, the claw then quickly clamps the stone, and the stone goes up and out. There is **no unnecessary motion,** and the mechanisms that complete each task are **fine tuned**, **simple**, **rigid**, and **linear** (for the most part).

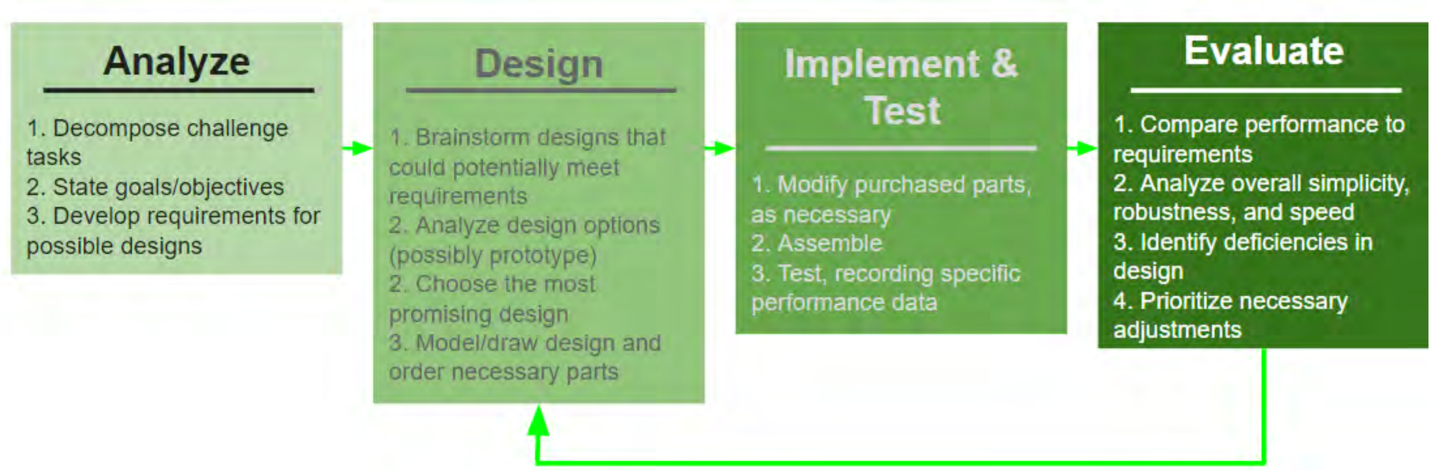
From a competition standpoint, we are only competing against ourselves and the clock. In each round, we have 2 minutes and 30 seconds to complete the greatest quantity of tasks possible. It is always our goal that our robot completes all autonomous tasks, and, in tele-op, do each task as efficiently as possible (**everything measured in seconds**); if a task requires a chain of mechanisms, each mechanism is measured by the time it takes to complete that part of the task. Each mechanism, whether isolated or parts of a whole, should be linear and quick (similar to **Occam's Razor**). Each mechanism bearing weight should be **rigid** (no flopping around when fully extended). At competitions, it is also our goal to learn as individuals and as a team and to be helpful to FIRST and other teams.

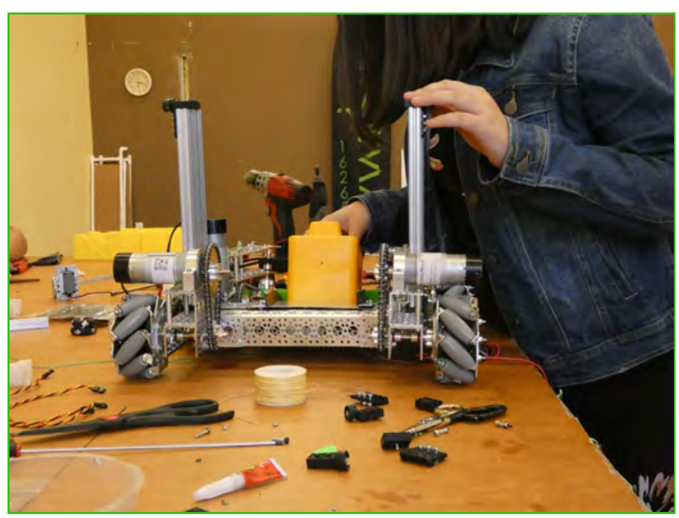
HOW WE USE OUR DESIGN PHILOSOPHY

The purpose of our design philosophy is to guide our design in a direction that is backed up by simple logic in order to produce the best possible results. We do not use this to limit our design ideas or discussions, but to remind us of very simple facts that have been observed in science, math, and by our own team in watching successful systems on the most efficient robots. Using this design philosophy, we are enabled to brainstorm effective ways to complete each task.

DESIGN PROCESS

Our design process is a huge part of our team and robot development. One thing to note about our design process is that we do not do extensive prototyping of multiple designs, as many other teams do. Instead, we do a very deep analysis of potential designs, take a vote, and pick one to give all of our attention and dedication to. We then break the design up into its sub-systems and give them to sub-build teams; **however, that chosen design is treated as a prototype throughout the whole season, evolving, improving, and perfecting it as we go, in order to reach the best possible performance.** Because of this strategy, we have a large amount of time to spend on that one design. We have found this strategy to work very well for our team.





1: OVERALL ROBOT

1.1: ANALYZE | DECOMPOSE CHALLENGE

After the challenge was released, we all started analyzing the game, strategies, and each task's point value. We predicted there would be **a lot of traffic on the field because of the opposite depos**, and maybe some defensive movements by other teams. We also thought many teams would form alliances where one robot brings stones to a robot that stacks. We knew we wanted to be a stacking robot, and explored how stacking robots may also stack in a pattern that would make their skyscraper more structurally sound. We experimented with stacking methods, by hand, and determined that overlapping blocks at 90-degree angles produced a very stable skyscraper. We predicted that scores would average in the 50s and a very high score would be in the early 100's.

STRATEGY ONE: Robots try to stack two separate skyscrapers on their alliance foundation.

STRATEGY TWO: Robots try to both stack/add to the same skyscraper, switching off.

STRATEGY THREE: One robot stacks and the other delivers stones.

AUTONOMOUS

SCORING ACHIEVEMENT	DIFFICULTY	AUTONOMOUS POINTS
Skystone deliveries	HARD	10
Stone deliveries	NORMAL	2
Stone placings	HARD	4
Reposition	NORMAL	10
Park	EASY	5

DRIVER CONTROLLED

SCORING ACHIEVEMENT	DIFFICULTY	AUTONOMOUS POINTS
Stone deliveries	EASY	1
Stone placed on foundation	NORMAL	1
Stone stacking	HARD	2 per skyscraper level

ENDGAME

SCORING ACHIEVEMENT	DIFFICULTY	AUTONOMOUS POINTS
Reposition	NORMAL	15
Cap skyscraper	HARD	5 plus 1 per skyscraper level
Park	EASY	5

PREDICTED SCORES

HIGH SCORE	AVERAGE SCORES
100s	50s

1.2: ANALYZE | STATE GOALS/OBJECTIVES

We then listed our goals, which were to be able to go under the 14” skybridge, move the foundation, stack 8+ stones, and place our capstone. In autonomous we wanted to have 3 programs. One that delivers both skystones, and parks under the skybridge, a second program that moves the foundation and parks under the skybridge, and a third program that delivers 1 skystone, moves the foundation, and parks under the skybridge.

GOALS

AUTONOMOUS	DRIVER CONTROLLED	END GAME
Program One • Deliver and place **1 skystone** • Move foundation • Park Program Two • Deliver **2 skystones** • Park Program Three • Reposition foundation • Park	• Deliver stones under the 14” skybridge • Stack **8+** stones high	• Place capstone • Move foundation • Park in building site

1.3: ANALYZE | DEVELOP REQUIREMENTS

After analyzing the game and stating our goals/objectives, we thought of requirements for designs that might complete those objectives. We made four lists under systems we knew would be a part of our design based off of our goals, as well as a general requirements list.

NOTE: when brainstorming ideas to meet requirements, we use them as loose guidelines; requirements (not relating the rules in the game manual) can be changed if necessary.

SUB-SYSTEM REQUIREMENTS

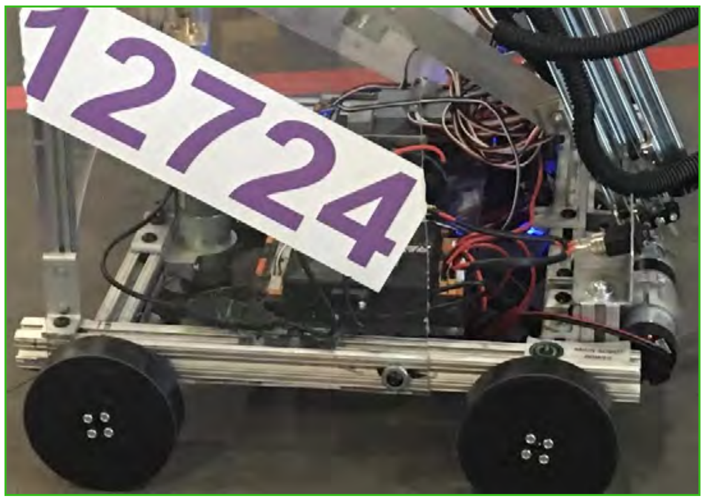
GENERAL	CHASSIS/DRIVETRAIN	STONE MANIPULATOR
• Speed • Simplicity • Stability • Stone move through the robot	• Can't exceed 18" x 18" • Speed (6ft/sec) • Forward, strafe, and rotating motion • Accommodate side shields: ~12" x 15" • Accommodate dead wheels for odometry	• Securely holds stone • Securely holds capstone • Obtains stone within 3 seconds • Interface with vertical extension • Weigh less than five pounds

VERTICAL EXTENSION	FOUNDATION MOVER
• Under 14" when collapsed • 34" or more when extended • Interface/manipulate with stone • Collapse to extend in under 2 seconds • Stable/rigid	• Contact foundation in more than one place • Cannot slip • Stored within the robot at the start of the match

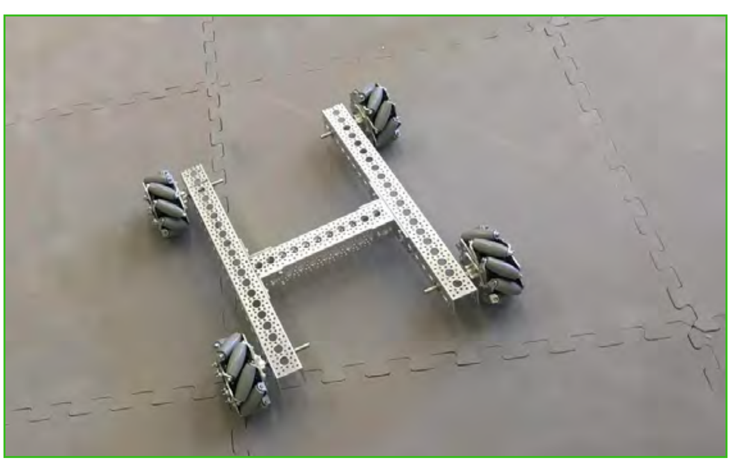
1.4: DESIGN | BRAINSTORM IDEAS THAT MIGHT MEET REQUIREMENTS

CHASSIS/DRIVETRAIN

1. We talked about using 80/20 extrusion and stealth wheels because two of our members had a lot of past experience with this system. Similar to this, the chassis from Biohazard Robotics Detail -Madelene and Isabel's old team.

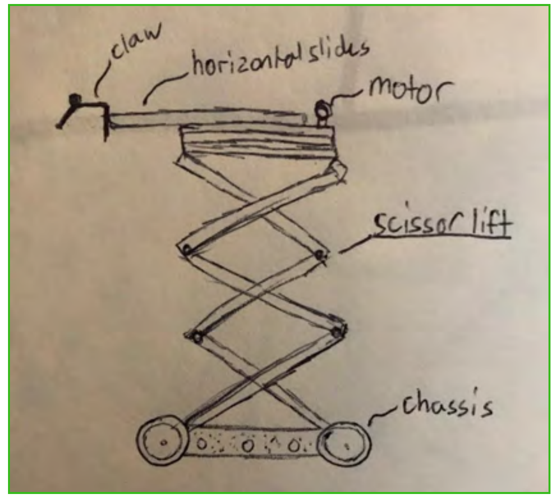


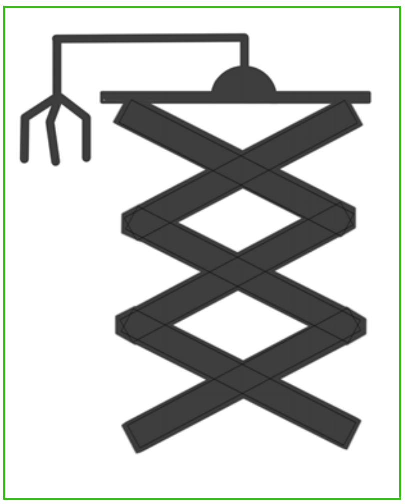
2. We also talked about using the servo city channel, with mecanum wheels geared up 1:2. We had watched a youtube video of a team who had this set up for their chassis, and we liked the look, structure, and convenience of pre-drilled holes in the channel.

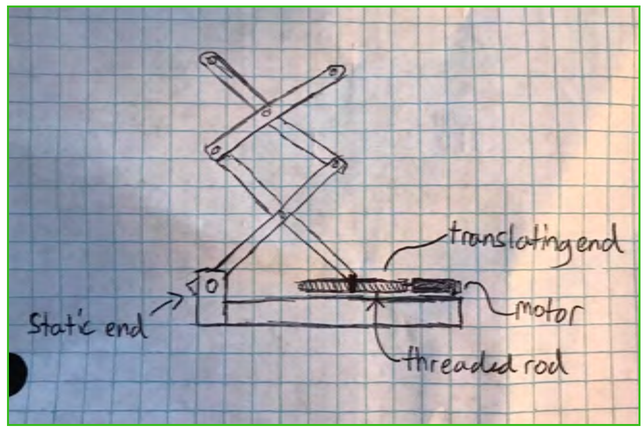


OBTAINING AND PLACING STONES

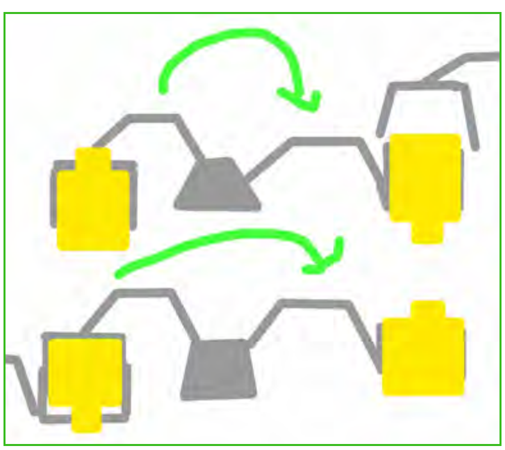
1. We talked about using a scissor lift with horizontal slides mounted on top of it with a claw on the end of the horizontal slides.

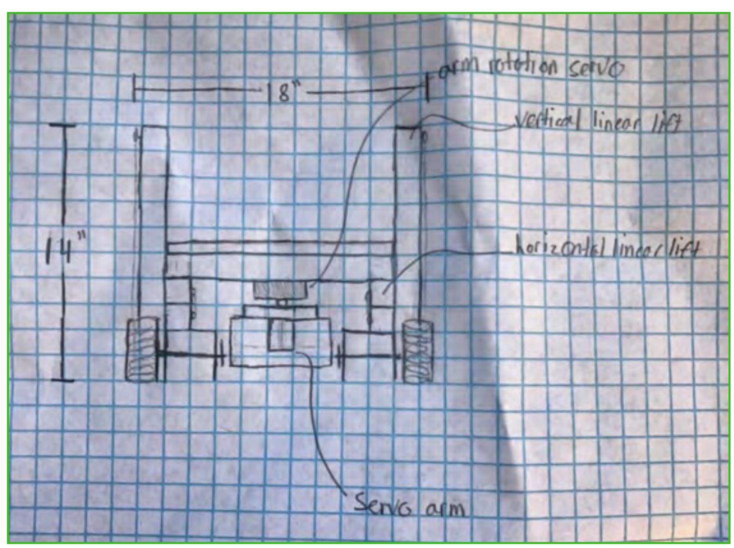






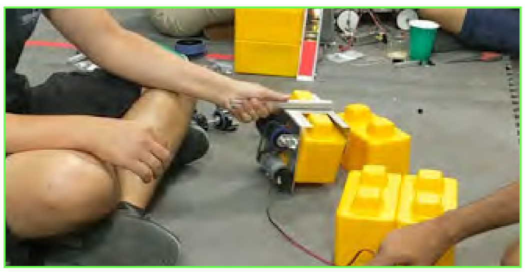
2. We also talked about mounting a claw that flipped in and out of the robot, which would transfer to another claw within the robot with a similar design, so the stone would go through the robot utilizing two claws.





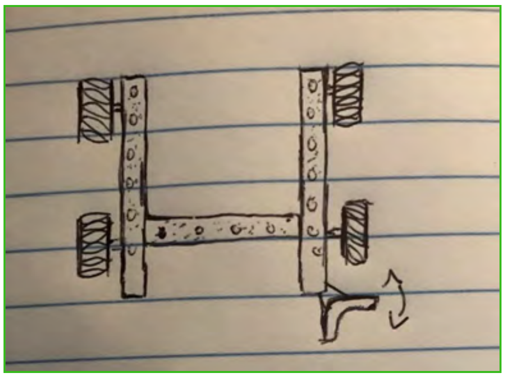
We then discussed the possibility of using an intake.

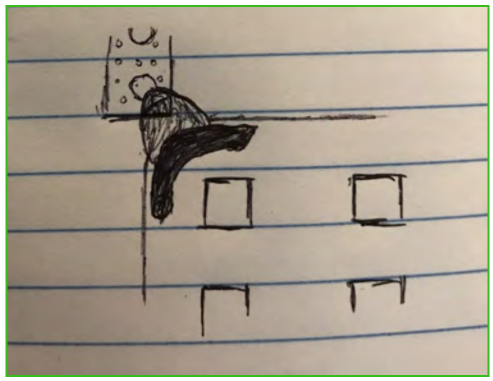
a. With that in mind we needed to think of a way to get the stone onto the foundation. We saw a design for a “roller claw” from another team sharing their ideas on youtube, and noticed that it might work well for our design since it would pick up the block from within the robot.
b. Lastly we discussed the use of a set of vertical and horizontal slides in order to move and place the stone on the foundation.

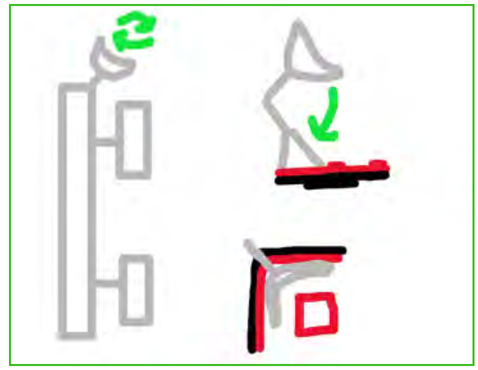


MOVING THE FOUNDATION

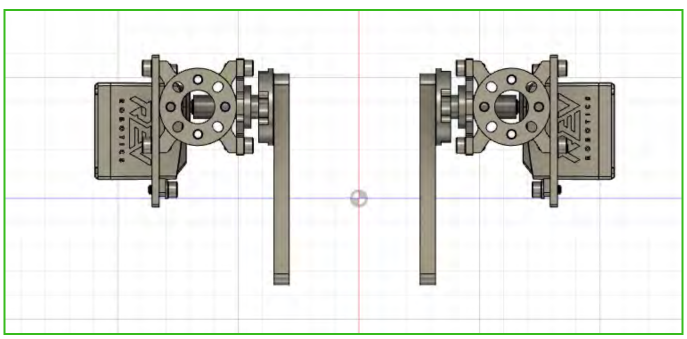
1. We talked about building a mechanism that mounted on the corner of our robot and swiveled, rotating the foundation by its corner, which may be a more sturdy way to move the foundation. The material used would have to be grippy, and well into the corner of the foundation. We also talked about the possibility of having two of them on each corner of the robot for convenience.

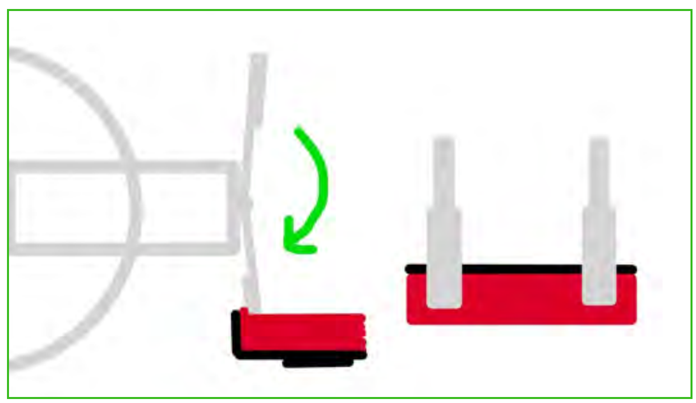






2. We then talked about two plates that clamped onto any side of the foundation using two servos and servo blocks. This would allow us to move the foundation from all four sides, and would also be quite simple to build.





PLACING THE CAPSTONE AND PARKING IN BUILDING SITE

Our original plan was to obtain our capstone through the depot, and to park in the building site by driving into it. After difficulty completing these tasks at our first two qualifiers, we decided to build the capstone and dowel mechanism. Documentation on those can be found on page 44.

1.5: DESIGN | CHOOSE THE MOST PROMISING DESIGN

CHASSIS/DRIVETRAIN

✗ **not chosen:** We did not go with the 80/20 and stealth wheel idea because, although this system is rigid, it can be hard to modify and very limiting. It also did not meet the requirement of strafing motion.

✓ **chosen:** We chose the servo city building system and mecanum wheels because, after some research, we found that the servocity axles, bearings, shaft spacers, and collars, form a very effective and rigid wheel mounting system. We also chose this design because it allowed us to gear up our drive.

OBTAINING AND PLACING STONES

✗ **not chosen:** We did not go with the scissor lift idea because we were concerned about the speed and stability of the scissor lift. We also believed that any loosening of the joints in the scissor lift would make the robot wobbly and inaccurate with stone placement. We were also concerned that using a claw may slow us down due to difficult lining up with the stone.

✗ **not chosen:** We did not go with the claw flipping idea because it seemed overly complicated and had a higher chance of breaking. We were also concerned about the use of a claw to obtain a stone, for the same reason in the first idea -difficulty lining up.

✓ **chosen:** We chose the intake and linear slides idea. We liked the intake idea because intakes are fast and can autocorrect the stone's orientation through the use of the compliant wheels. We also liked the vertical and horizontal slides because they are fast, modifiable, and rigid. In addition, limiting movement to orthogonal directions, limits block positioning error and required driver skill. The intake and slide conform to our **design philosophy of simple, rigid, and linear design**.

MOVING THE FOUNDATION

✗ **not chosen:** We did not go with the corner swivel mechanism because we thought it was overly complicated, and we did not like the idea of only being able to move the foundation from its corner. It also did not meet the requirement of contacting the foundation in more than one place.

✓ **chosen:** We chose the two clamping plates because it was simple and we could move the foundation from any side.

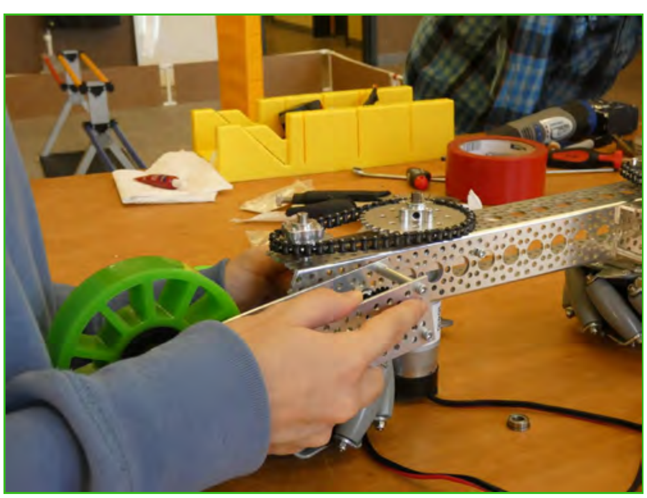
1.6: DESIGN | MODEL FINAL DESIGN AND ORDER PARTS

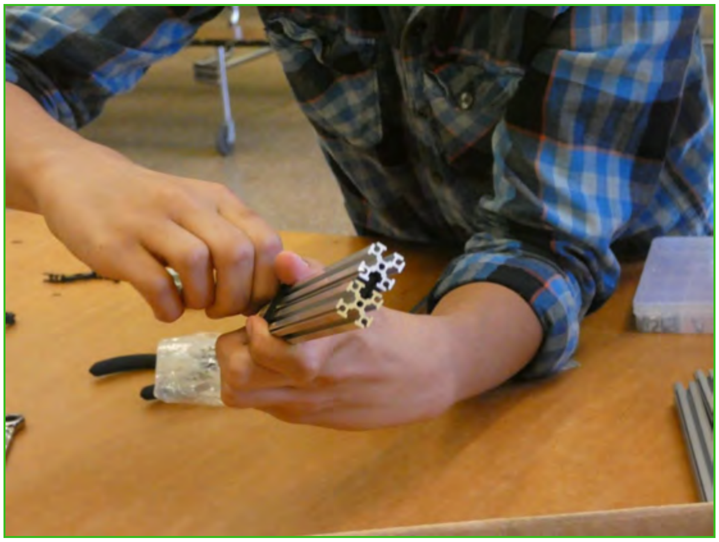
CAD and sketches are very helpful in the process of ordering parts and assembling.

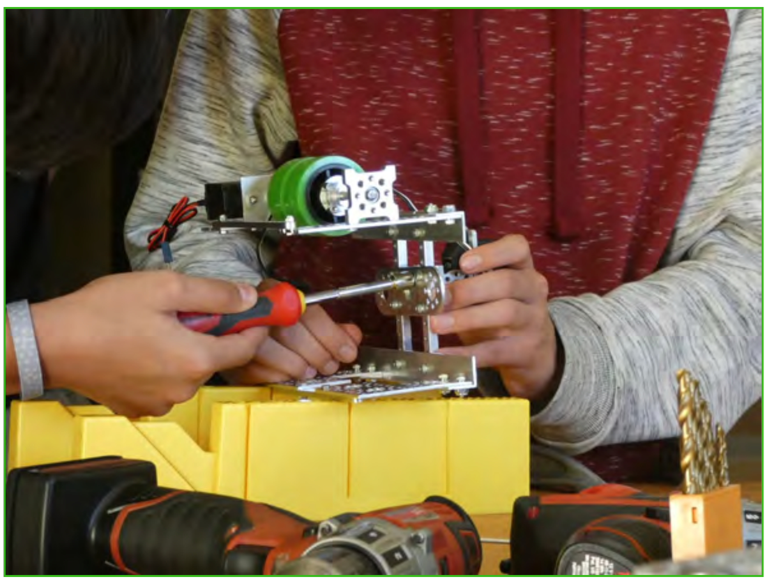
Our CAD can be found on pages 102 - 153

1.7: IMPLEMENT AND TEST | MODIFY PURCHASED PARTS | ASSEMBLE

DOCUMENTATION OF THE BUILDING OF EACH MECHANISM/SUB-SYSTEM CAN BE FOUND ON PAGES 61 - 101





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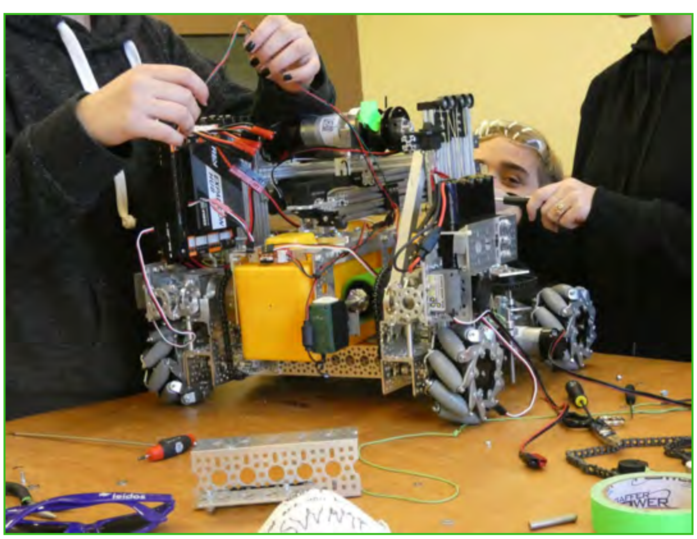
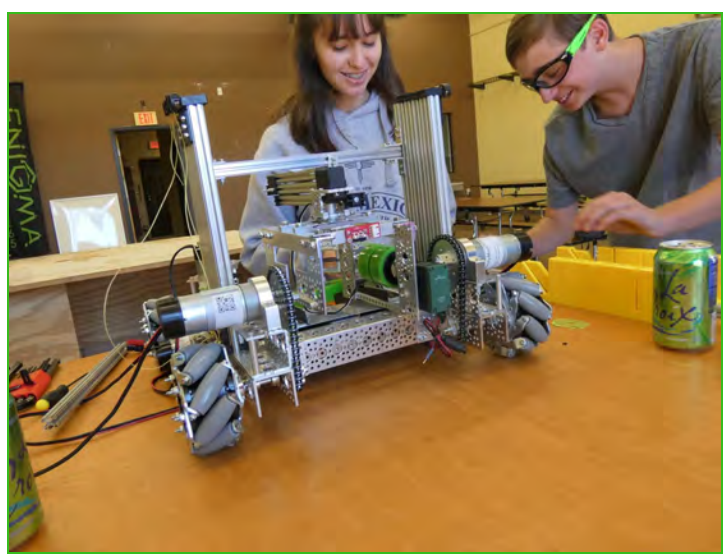
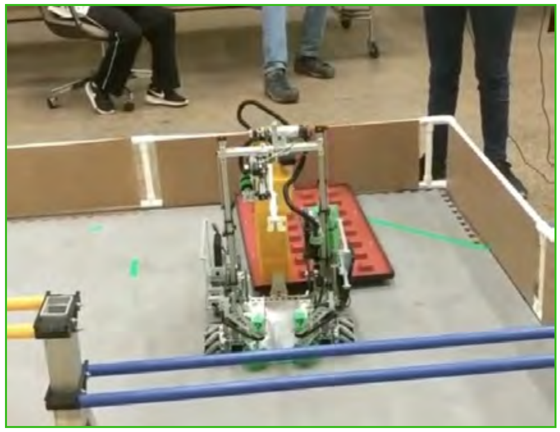
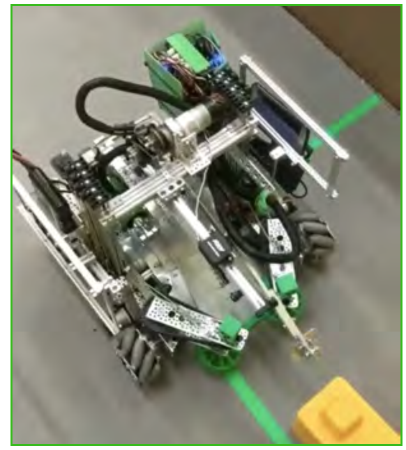




1.8: IMPLEMENT AND TEST | TEST, RECORDING PERFORMANCE DATA

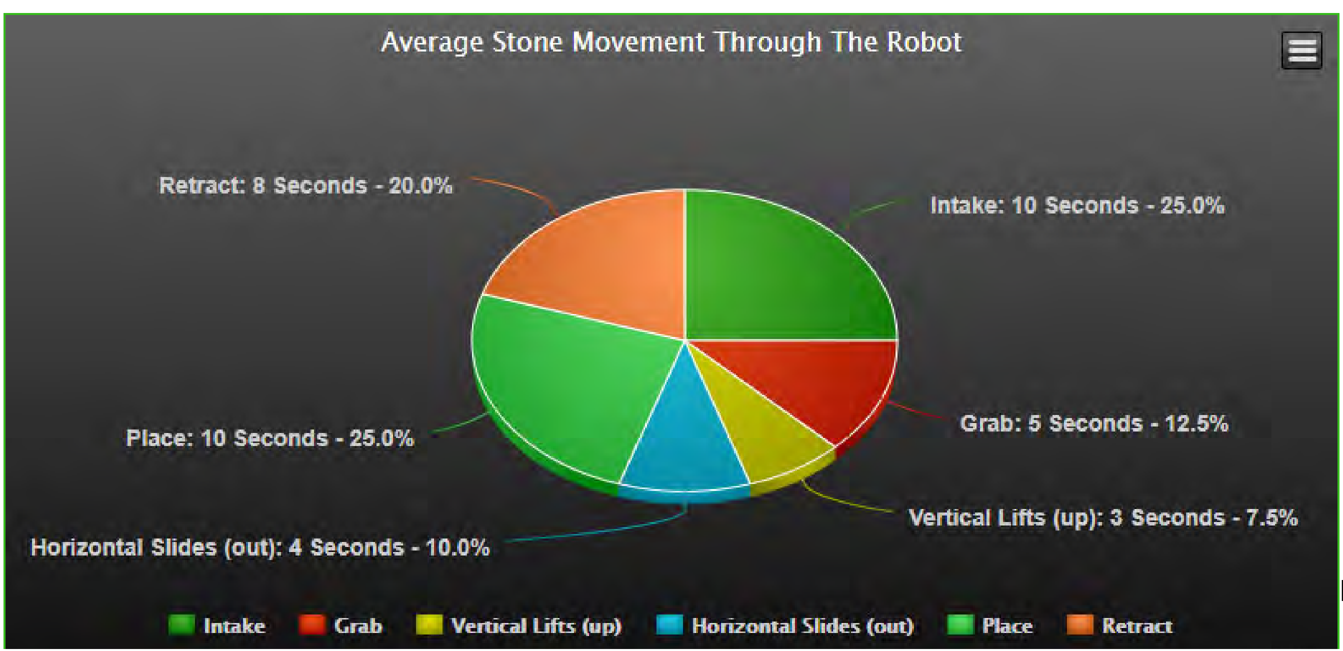
With our first design, we averaged **2-3** stones per match, averaging **40 seconds per stone**. We broke down each mechanism and on average, how long each mechanism was taking to do its part.





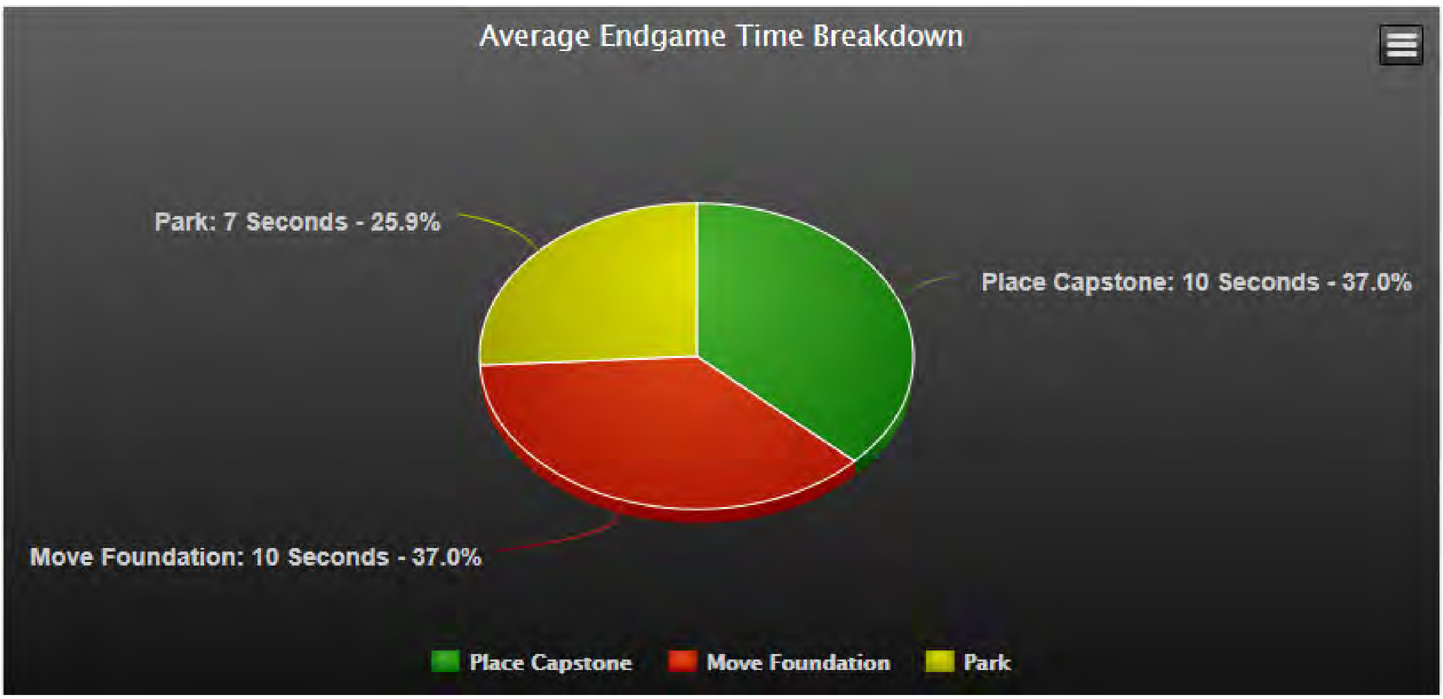
AVERAGE STONE MOVEMENT TIME BREAKDOWN -ROBOT V1

TASK	TIME (S)	PERCENT OF TOTAL	NOTES
Intake	10	25%	
Grab	5	12.5%	Includes stone mover servo and roller claw
Vertical Lift (up)	3	7.5%	
Horizontal Slide (out)	4	10%	
Place	10	25%	Difficulty lining up
Retract	8	20%	Includes both vertical and horizontal slides



AVERAGE ENDGAME TIME BREAKDOWN -ROBOT V1

TASK	TIME (S)	PERCENT OF AVAILABLE	NOTES
Place Capstone	10	37%	We had to go to depot to get capstone
Move Foundation	10	37%	
Park	7	25.9%	We moved the foundation from opposite side of building site, so it was far away



1.9: EVALUATE | COMPARE PERFORMANCE TO REQUIREMENTS

AVERAGE STONE MOVEMENT TIME COMPARISON -ROBOT V1

TASK	TIME (S)	REQUIRED/WANTED TIME (S)
Intake	10	1 - 2
Grab	5	1
Vertical Lift (up)	3	2
Horizontal Slide (out)	4	1
Place	10	1
Retract	8	2

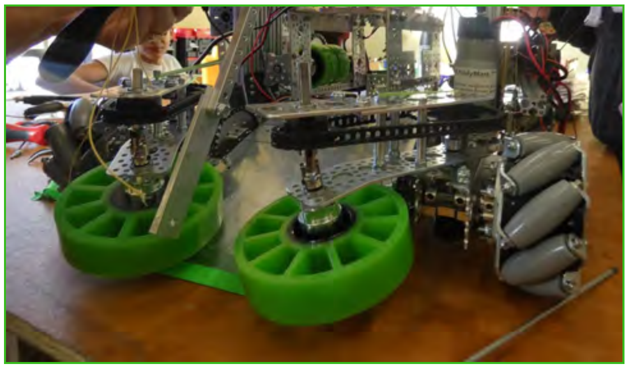
AVERAGE ENDGAME TIME COMPARISON -ROBOT V1

TASK	TIME (S)	REQUIRED/WANTED TIME (S)
Place Capstone	10	4
Move Foundation	10	4
Park	7	2

1.10: EVALUATE | ANALYZE OVERALL SIMPLICITY, ROBUSTNESS, AND SPEED

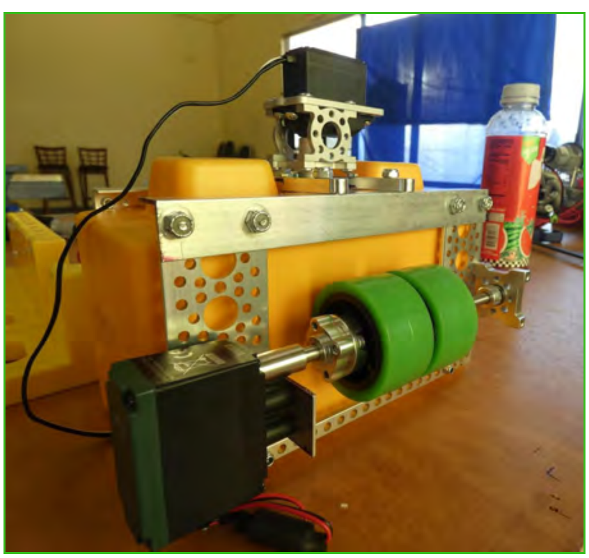
INTAKE ANALYSIS

SIMPLICITY | ✗	ROBUSTNESS | ✓	SPEED | ✗
Contains an unnecessarily complex system of gears, chains, and sprockets	It hardly ever breaks	It can take up to 10 seconds to intake a stone, and it often only intakes when the stones is perfectly lined up



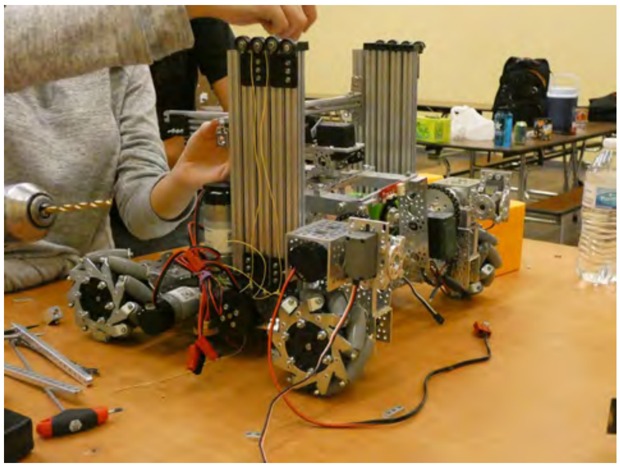
ROLLER CLAW ANALYSIS

SIMPLICITY | ✗	ROBUSTNESS | ✗	SPEED | ✗
Contains an unnecessary set of rollers. We also have to use the “stone move servo” to get it all the way in	The servo with the plate that clamps onto the stone has moved multiple times	It can take up to 5 seconds to get the stone within the roller claw, especially because we have to use the “stone move servo”



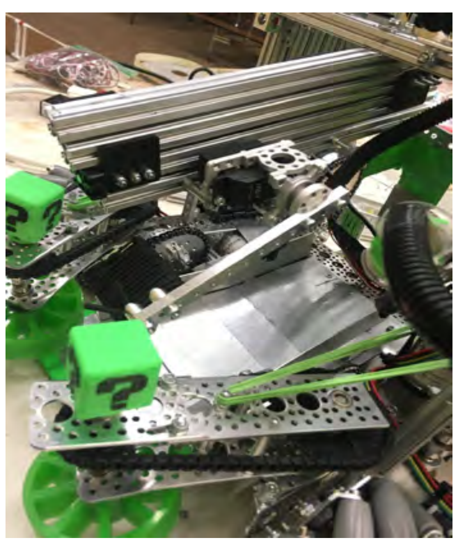
VERTICAL LIFT ANALYSIS

SIMPLICITY | ✓	ROBUSTNESS | ✓	SPEED | ✗
The vertical lifts are quite simple, especially because we use the rev linear slide kit and decided to string it continuous instead of cascading	The vertical lifts never break	It can take up to 3 seconds to extend a short distance



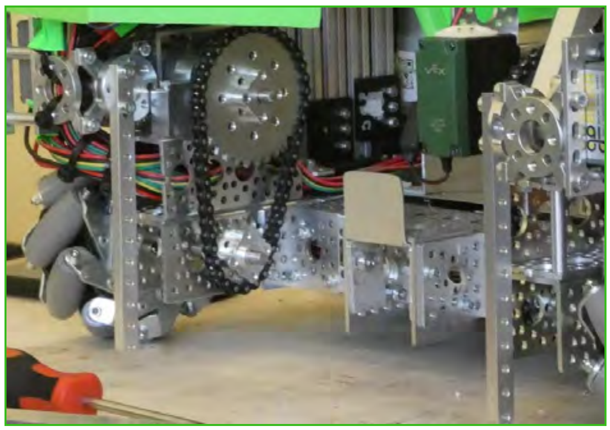
HORIZONTAL SLIDES ANALYSIS

SIMPLICITY | ✓	ROBUSTNESS | ✗	SPEED | ✗
The horizontal slides are quite simple, especially because we use the rev linear slide kit and decided to string it continuous instead of cascading	The pulley caps break quite often	It can take up to 4 seconds to extend a short distance



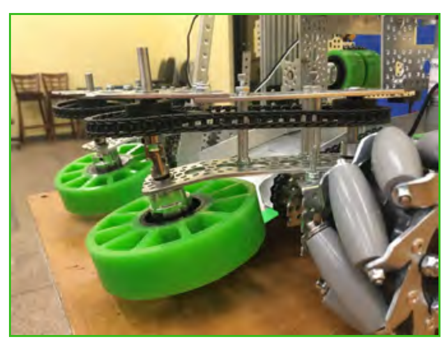
FOUNDATION MOVERS ANALYSIS

SIMPLICITY | ✓	ROBUSTNESS | ✗	SPEED | ✓
The foundation movers are quite simple: two servos, two servo blocks, and two plates	They slip a lot. We are unsure if it is the servo or the plates slipping on the foundation's surface	They are very quick and efficient, time-wise

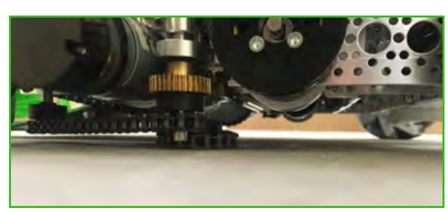


1.11: EVALUATE | IDENTIFY DEFICIENCIES IN DESIGN

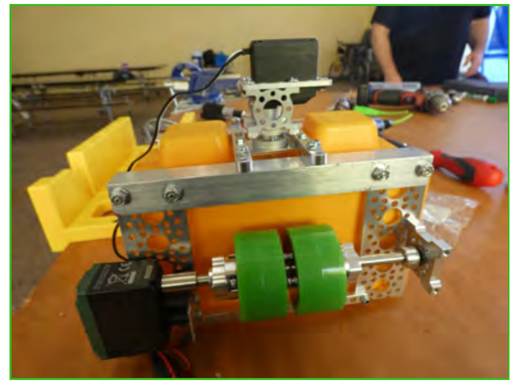
INTAKE:



1. Contains an unnecessarily complex system of gears, chains, and sprockets.
2. The intake is also weakly sprung, so it has a hard time clamping onto the stone.
3. The mechanical stops keep moving, causing the intake to open up too wide.
4. The intake does not take the stone all the way into the robot



ROLLER CLAW:



1. The stone hits the top of the roller claw, due to the steep angle of the ramp.
2. The Roller claw is also too complex and subject to error. It does not need to have rollers on it; it also does not need to have the ability to rotate.

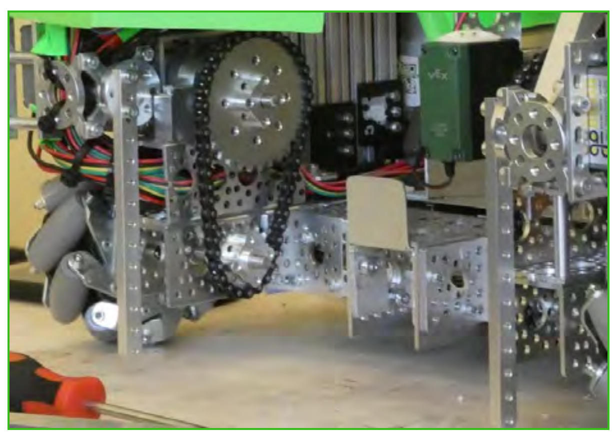
VERTICAL LIFT:

1. It is ran off of a slow 40:1 motor
2. Strung continuously instead of the much faster cascading
3. The driver breaks the lifts by moving too far in one direction.

HORIZONTAL SLIDE:

1. Horizontal and vertical lift movement takes too long and sometimes
2. the driver breaks the slides by moving too far in one direction.
3. The horizontal slide is also not mounted very well and was able to move in matches.

MOVING FOUNDATION:



1. The foundation movers have such a small surface that makes contact with the foundation, so they tend to slip.

NOTE: Although this was more of a strategy deficiency, during this time, we identified the need for a **capstone mechanism** that held our capstone on the robot because it took too long to go to the depot to get it. Sometimes other teams could block us from even picking up our capstone. We also identified the need for an **extension mechanism** that could park in the building zone from farther away because sometimes it was very difficult to get both robots to park.

1.12: EVALUATE | PRIORITIZE NECESSARY ADJUSTMENTS

Because we decided to fill in for Alamogordo, and it was only a week after our first qualifier, we did not make any robot changes, so these are the prioritized design deficiencies we decided to focus on for our third qualifier, Socorro.

1. **HORIZONTAL SLIDE: DEFICIENCY 2, 3**
1. **ROLLER CLAW: DEFICIENCY 1, 2**
2. **MOVING FOUNDATION: DEFICIENCY 1**
3. **CAPSTONE/DOWEL MECHANISM**
4. **INTAKE: DEFICIENCY 2,3**
5. **VERTICAL LIFT: DEFICIENCY 3**

We then go back to the design phase of our design process in order to begin the process of making needed changes/improvements to our mechanisms.

1.13: DESIGN | BRAINSTORM DESIGNS, ANALYZE, AND CHOOSE

HORIZONTAL SLIDE

DEFICIENCY 2: The driver breaks the slides by moving too far in one direction

✓ **chosen:** Add magnetic limit switches so the lift cannot over extend
WHY: We went with this idea because we felt it may be more reliable and precise than a lever switch that has a mechanical component, and we also wanted to learn more about magnetic limit switches and how they work.

The magnetic limit switch is an omnipolar momentary switch; A omnipolar momentary is a switch that will trigger when there is a certain amount of magnetic energy on either pole detected. The way we integrate the Magnetic Limit Switch on our robot is by putting them on are lifts. We have one switch on our vertical lift and one on our horizontal lift. We place magnets on our lifts, and when they are fully extended the switches sense them and stop the motor, so the lifts won't break.

✗ **not chosen:** Add lever switch to act as a limit switch
WHY: The decision came down to the touch sensor and the magnetic limit switch; we decided not to use the touch sensor because we wanted to learn more about magnetic limit switches

✗ **not chosen:** Program stops in the program based on encoder counts
WHY: We decided using a magnet or touch sensor would be more accurate and effective than programming stops based off of encoder counts

✗ **not chosen:** Strengthen the parts that are breaking when overextending
WHY: Although it would be good to strengthen parts that are weak, we do not want to rely on strong parts when a mechanism is being over extended, so we decided a stop using some sort of sensor would be much better practise

DEFICIENCY 3: The horizontal slide is also not mounted very well and was able to move in matches.

✓ **chosen:** Hard mount the lift by drilling straight through the top extrusion and extrusion between the vertical slides
WHY: We decided this was the best option because hard mounting meant drilling straight into the extrusion in two places, which definitely would not allow it to move

✗ **not chosen:** Add more brackets to attachment point
WHY: This was a good option but we felt that there was still a chance of movement and loosening even if we added a couple more brackets

✗ **not chosen**: Use lock-tight on the screws that are loosening
WHY: We felt this was good practise, but not the best and most robust solution

ROLLER CLAW

DEFICIENCY 2: The stone hits the top of the roller claw, due to the steep angle of the ramp.

✓ **chosen:** Angle the horizontal slides to the same angle as the ramp
WHY: We decided this was the best option because it gave us the advantage of not having to lift up when retracting the horizontal slide after placing a stone2

✗ not chosen: Make the angle of the ramp shallower
WHY: We did not go with this idea because changing the angle of the ramp would lift the edge too high off of the ground

✗ not chosen: Mount the roller claw a little higher
WHY: Mounting the roller claw higher meant mounting the whole horizontal lift higher, which would translate into the robot being over 14”, so we did not go with this idea

DEFICIENCY 3: Too complex and subject to error; it does not need to have rollers on it; it also does not need to have the ability to rotate.

✓ chosen: Remove the rollers and the servo that rotates it and make the claw grab from the front and back instead of the side
WHY: This idea eliminates the extra arm needed to push the stone the rest of the way into the robot. We decided to go with this idea because we were very confident it would fix the deficiency and was the only solution we could think of

FOUNDATION MOVERS

DEFICIENCY 1: Small and slippery surface that makes contact with the foundation, so they slip

✓ chosen: Add a plate to the end of the beams and add rubber bands
WHY: We went with this idea because the added plate at the end of the beam would add more surface area that contacted the stone and the rubber band would make it more grippy, lessening the chance of the foundation movers slipping

We proved our second foundation movers are better than our first foundation movers by using phsyics and friction. The force between the movers and the foundation is Coulomb friction which is given by this equation:Loading...The equation means friction equals coefficient of friction times normal force. So in order to use this equation we added rubber bands to the clamps on the servos which increases the coefficient of friction. Another option we had was to add more powerful servos. Stronger servos would increase normal force but to add rubber bands was simpler.

✗ not chosen: Replace the thin beams that currently grab the foundation with a wider plate
WHY: We did not go with this idea because we did think it was necessary to replace the whole beam

CAPSTONE/DOWEL MECHANISM | (COMPLETELY NEW MECHANISM)

BRAINSTORMED IDEA: Make the capstone with a hole for a pin to go through. Connect a pin with a string to a servo. Load the capstone in a “box” with a slot cut out for the part of the capstone with the whole to come through, then stick the pin through the capstone, and when the servo pulls the pin, the capstone will fall out. On the same box that holds the servo/capstone, attach another servo with a wooden dowel for more extension in endgame.

INTAKE

DEFICIENCY 2: Weekly sprung, so it has a hard time clamping onto the stone.

✓ **chosen:** Add more rubber bands for greater tension
WHY: We chose this solution because adding more rubber bands would increase the tension, therefore forcing the intake in and clamping onto the stone better

DEFICIENCY 3: The mechanical stops keep moving, causing the intake to open up too wide.

✓ **chosen:** Redo the stops and mount them with more than one mounting hole
WHY: We chose this solution because adding more than one mounting place would no longer allow the stops to move

VERTICAL LIFT

DEFICIENCY 3: The driver breaks the lifts by moving too far in one direction

✓ **chosen:** Add magnetic limit switches so the lift cannot over extend
WHY: We went with this idea because we felt it may be more reliable and precise than a lever switch that has a mechanical component, and we also wanted to learn more about magnetic limit switches and how they work

✗ **not chosen:** Add touch sensors to act as limit switches
WHY: The decision came down to the touch sensor and the magnetic limit switch; we decided not to use the touch sensor because we wanted to learn more about magnetic limit switches

✗ **not chosen:** Program stops in the program based on encoder counts

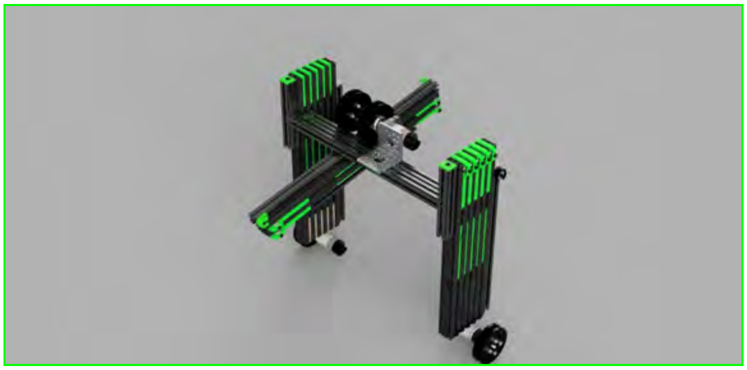
WHY: We decided using a magnet or touch sensor would be more accurate and effective than programming stops based off of encoder counts

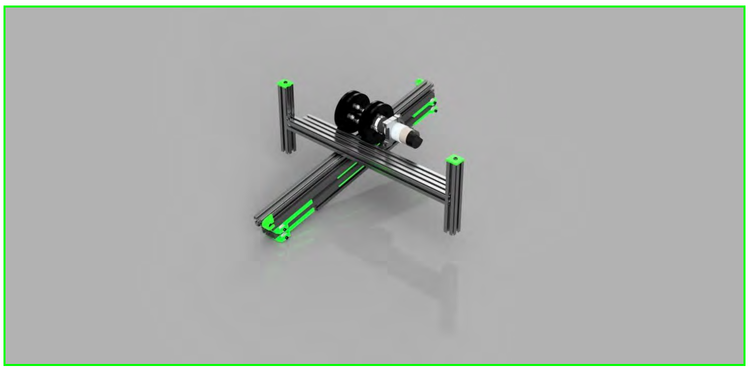
✗ not chosen: Strengthen the parts that are breaking when overextending

WHY: Although it would be good to strengthen parts that are weak, we do not want to rely on strong parts when a mechanism is being over extended, so we decided a stop using some sort of sensor would be much better practise

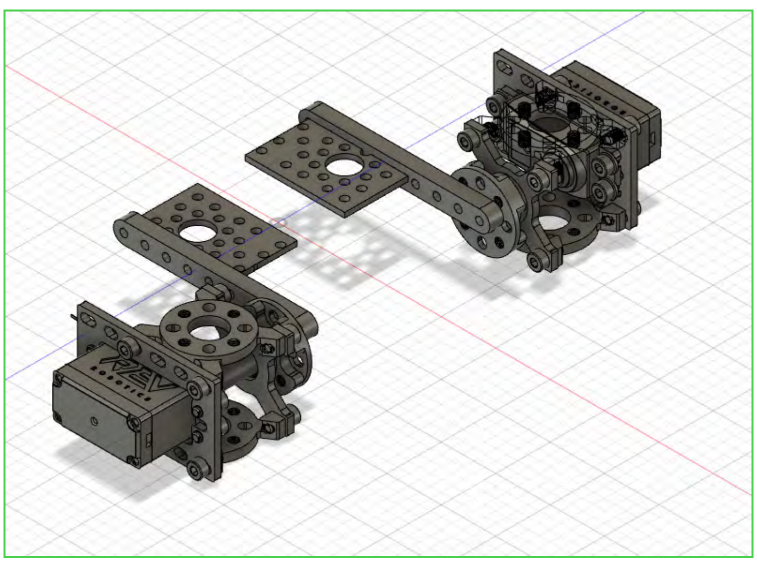
1.14: DESIGN | FINAL MODEL OF DESIGN(S) & ORDER PARTS

Horizontal Slide Mounted at an Angle

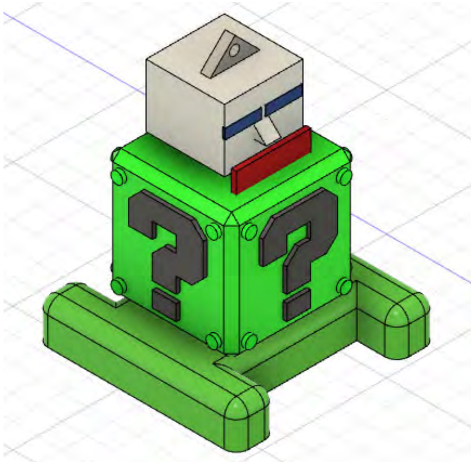




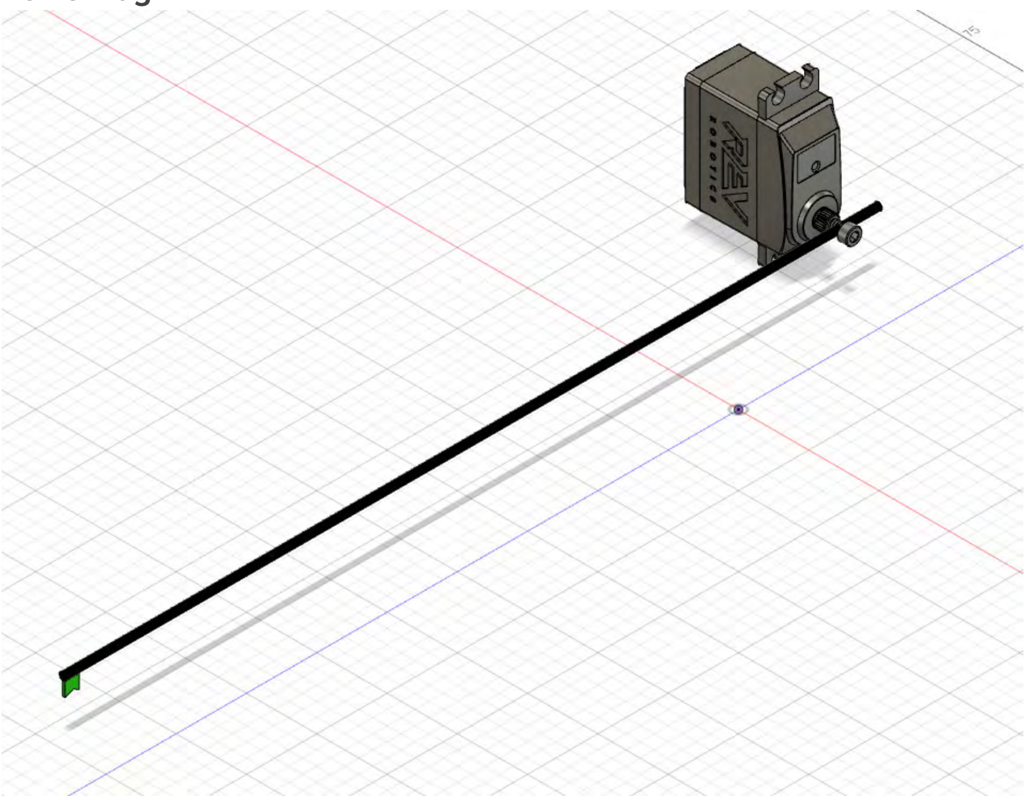
Plates added to the foundation movers



Capstone mechanism



Dowel flag

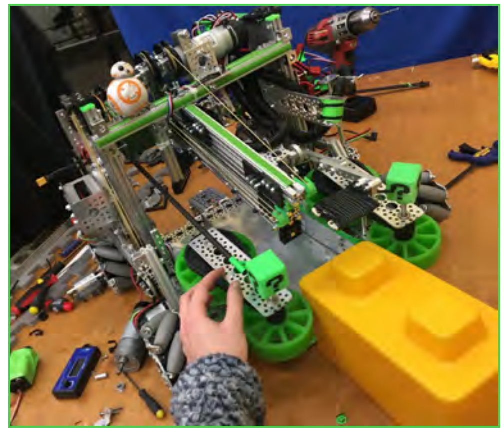


1.15: IMPLEMENT AND TEST | MODIFY PURCHASED PARTS | ASSEMBLE

DOCUMENTATION OF THE BUILDING OF EACH MECHANISM/SUB-SYSTEM CAN BE FOUND ON PAGES 61 - 101

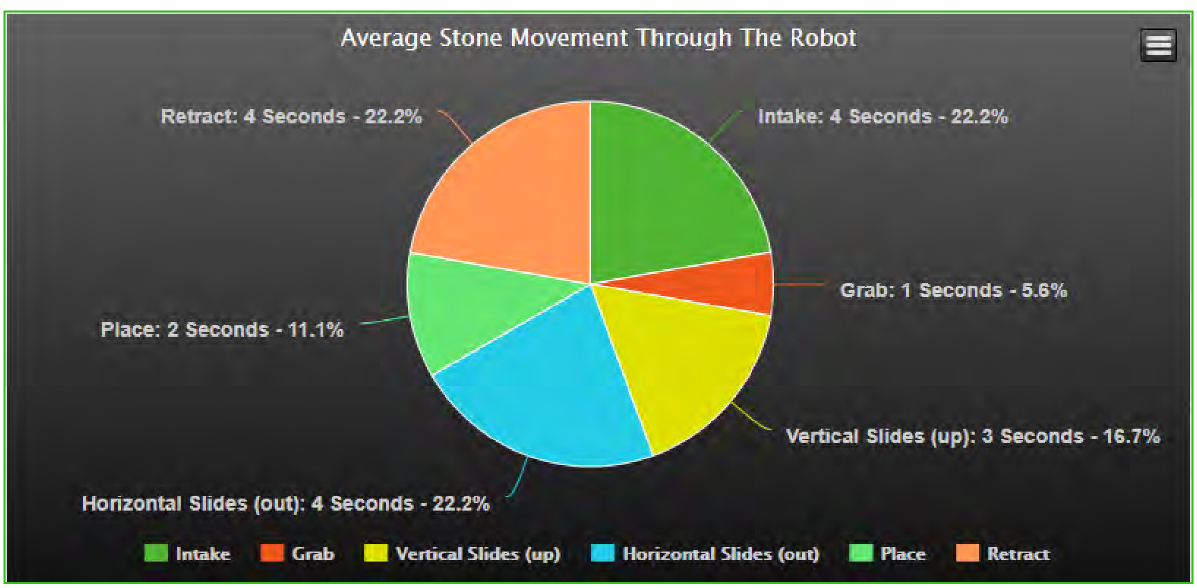
1.16: IMPLEMENT AND TEST | TEST, RECORDING PERFORMANCE DATA

We averaged 5-6 stones per match, averaging 17 seconds per stone. We broke down each mechanism and on average, how long each mechanism was taking to do its part.



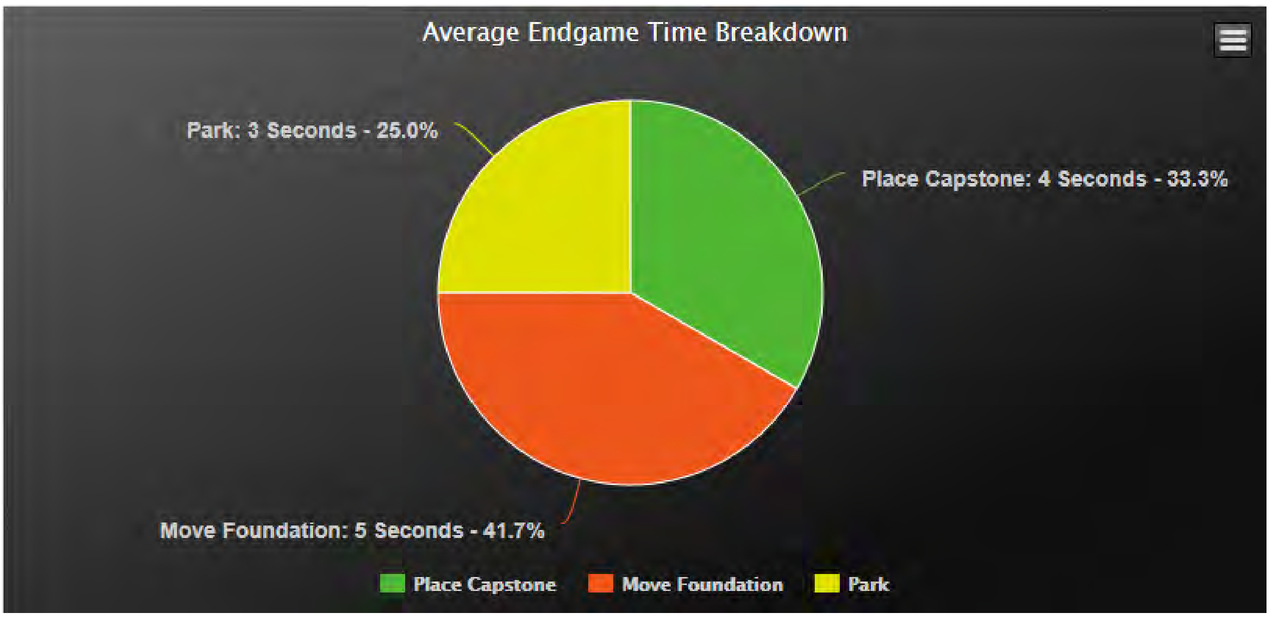
AVERAGE STONE MOVEMENT TIME BREAKDOWN -ROBOT V2

TASK	NEW TIME (S)	OLD TIME (S)	NEW PERCENT OF TOTAL	NOTES
Intake	4	10	22%	
Grab	1	5	33%	
Vertical Lift (up)	3	3	16%	
Horizontal Slide (out)	4	4	22%	
Place	2	10	11%	Difficulty lining up
Retract	4	8	22%	Includes both vertical and horizontal slides



AVERAGE ENDGAME TIME BREAKDOWN -ROBOT V2

TASK	NEW TIME (S)	OLD TIME (S)	NEW PERCENT OF AVAILABLE	OLD PERCENT OF AVAILABLE
Place Capstone	4	10	33%	33%
Move Foundation	5	10	41%	33%
Park	3	7	25%	23%



1.17: EVALUATE | COMPARE PERFORMANCE TO REQUIREMENTS

AVERAGE STONE MOVEMENT TIME COMPARISON -ROBOT V2

TASK	TIME (S)	REQUIRED/WANTED TIME (S)
Intake	4	1-2
Grab	1	1
Vertical Lift (up)	3	2
Horizontal Slide (out)	4	1
Place	2	1
Retract	4	2

AVERAGE ENDGAME TIME COMPARISON -ROBOT V2

TASK	TIME (S)	REQUIRED/WANTED TIME (S)
Place Capstone	4	4
Move Foundation	5	4
Park	3	2

INTAKE

SIMPLICITY | ✗	ROBUSTNESS | ✓	SPEED | ✗
Contains an unnecessarily complex system of gears, chains, and sprockets	It hardly ever breaks	It can take up to 4 seconds to intake a stone, and it often only intakes when the stones is perfectly lined up

ROLLER CLAW ANALYSIS

SIMPLICITY | ✓	ROBUSTNESS | ✓	SPEED | ✓
Only contains two servos with beams and plates attached to them	It has never breaks because it is very simple and utilizes servo blocks	It clamps onto the stone and lets go with the simple push of a button

VERTICAL LIFT ANALYSIS

SIMPLICITY | ✓	ROBUSTNESS | ✓	SPEED | ✗
The vertical lifts are quite simple, especially because we use the rev linear slide kit and decided to string it continuously instead of cascading.	The vertical lifts never break	It can take up to 3 seconds to extend a short distance, however retracting was improved because of the limit switch -the drivers could retract it at full speed

HORIZONTAL SLIDES ANALYSIS

SIMPLICITY | ✓	ROBUSTNESS | ✓	SPEED | ✗
The horizontal slides are quite simple, especially because we use the rev linear slide kit and decided to string it continuous instead of cascading	The limit switch does no longer allow it to overextend, which is what was breaking pulley cpas	It can take up to 4 seconds to extend a short distance, however retracting was improved because of the limit switch -the drivers could retract it at full speed

FOUNDATION MOVERS ANALYSIS

SIMPLICITY | ✓	ROBUSTNESS | ✗	SPEED | ✗
The foundation movers are quite simple: two servos, two servo blocks, and two plates	Despite the fact that we added plates with rubber bands for more surface area and grip, they still slip	Now that we started stacking taller, we had to worry about knocking our stack over, and because they foundation movers rotate up, there was always a chance of them hitting our stack, so we had to drive slower and careful

CAPSTONE MECHANISM ANALYSIS

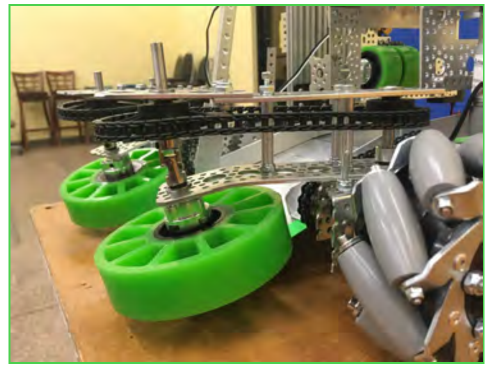
SIMPLICITY | ✓	ROBUSTNESS | ✓	SPEED | ✗
This mechanism is quite simple as it is just a servo with a pin that pulls out and drops the capstone	It hardly ever breaks	Although it is faster than getting the capstone from the depot, we believe we can make it even faster

PARKING MECHANISM ANALYSIS

SIMPLICITY | ✓	ROBUSTNESS | ✓	SPEED | ✓
This mechanism is quite simple as it is just a servo with wooden dowel which rotates out when we are ready to park	It never breaks	This mechanism is quite fast, as it rotates out to park with the push of a button

1.18: EVALUATE | IDENTIFY DEFICIENCIES IN DESIGN

INTAKE:



1. Contains an unnecessarily complex system of gears, chains, and sprockets
2. The intake does not take the stone all the way into the robot

VERTICAL LIFT:

1. It is run off of a slow 40:1 motor
2. Strung continuously instead of the much faster cascading

MOVING FOUNDATION:

1. The foundation movers slip because all of the stress is on the servo gears because of the orientation of the servos

HORIZONTAL SLIDE:

1. Horizontal slides are ran off of very slow 40:1 motors

CAPSTONE MECHANISM

1. Instead of placing the capstone on the last stone within the robot, the robot has to strafe over and place it on top of the skyscraper after we have placed our last stone.

1.19: EVALUATE | PRIORITIZE NECESSARY ADJUSTMENTS

These are the design deficiencies we decided to focus on for our last qualifier, Sandia Park, in order.

1. **INTAKE** | **DEFICIENCY 1,2**
2. **MOVING FOUNDATION** | **DEFICIENCY 1**
3. **HORIZONTAL SLIDE** | **DEFICIENCY 1**
4. **VERTICAL LIFT** | **DEFICIENCY 1**

We then go back to the design phase of our design process in order to begin the process of making needed changes/improvements to our mechanisms.

1.20: DESIGN | BRAINSTORM IDEAS & CHOOSE

INTAKE

DEFICIENCY 1: Contains an unnecessarily complex system of gears, chains, and sprockets

✓ **chosen:** Instead of running the intake off of one motor, run it off of two vex motors, which count as servos in FTC and gear them up

WHY: We went with this idea because it seemed to be the best, and only option as we were at our motor limit, and it would successfully remove the complicated chain and sprocket system that ran under the robot

DEFICIENCY 2: The intake does not take the stone all the way into the robot

✓ **chosen:** Add two more wheels further inside of the robot in order to bring the stone all the way into the claw

WHY: We went with this improvement because it would eliminate the use of the claw when bringing stones all the way into the robot. Two sets of wheels are simpler than wheels and a claw, following our design philosophy.

FOUNDATION MOVERS

DEFICIENCY 2: The foundation movers slip because all of the stress is on the servo gears because of the orientation of the servos

✓ **chosen:** Change the orientation of the servos so the stress is on the servo blocks and not the actual servos

WHY: We went with this idea because it would take the stress off of the servo's gears and would also solve the problem of sometimes knocking our skyscraper due to the foundation movers rotating up into the skyscraper

HORIZONTAL SLIDE

DEFICIENCY 1: Horizontal slides are ran off of very slow 40:1 motors

✓ **chosen:** Replace the 40:1 motors with 20:1 motors

WHY: We went with this idea because it seemed simple and would definitely make the slides much faster

✗ **not chosen:** String the slides cascading

WHY: We did not go with this idea because we had tried stringing the horizontal slides cascading before and we could not figure out how to prevent the string from getting tangled and keeping tension on it

VERTICAL LIFTS

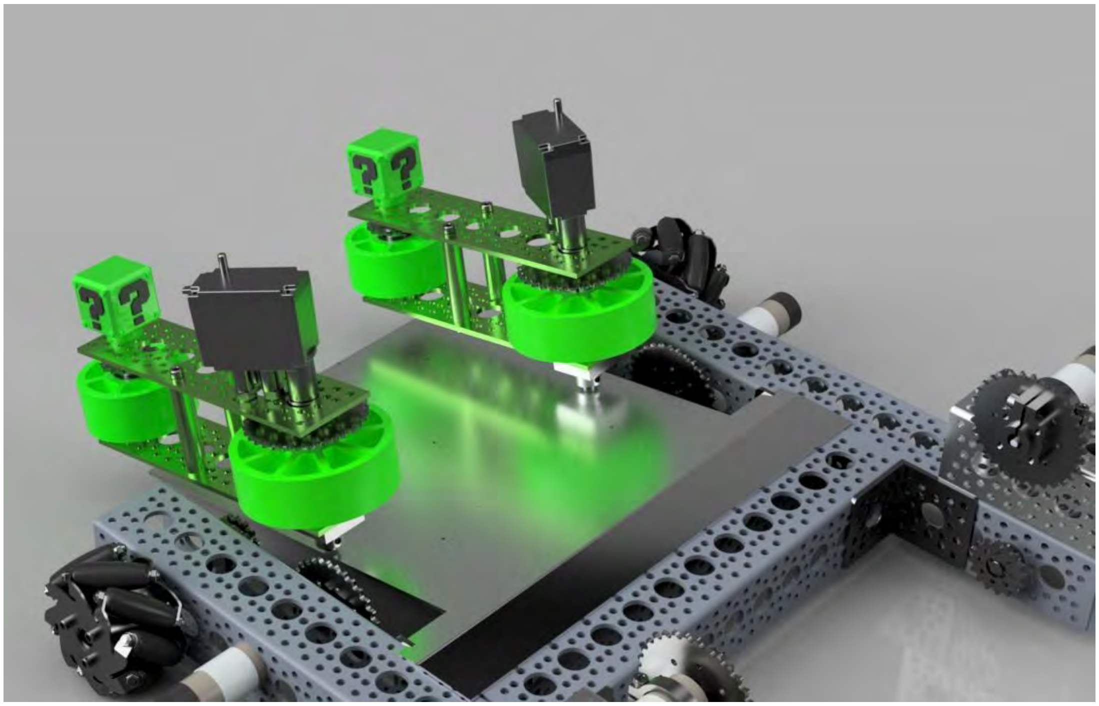
DEFICIENCY 1: Vertical lifts are ran off of very slow 40:1 motors

✓ **chosen:** Replace the 40:1 motors with 20:1 motors

WHY: We went with this idea because it seemed simple and would definitely make both lifts much faster

1.21: DESIGN | FINAL MODEL OF DESIGN(S) & ORDER PARTS

New intake with four wheels and two vex motors

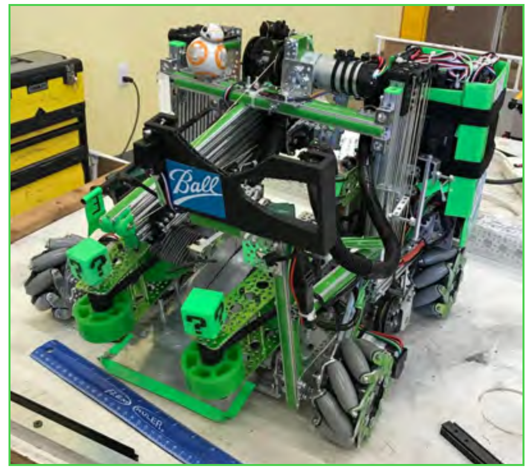


1.22: IMPLEMENT AND TEST | MODIFY PURCHASED PARTS | ASSEMBLE

DOCUMENTATION OF THE BUILDING OF EACH MECHANISM/SUB-SYSTEM CAN BE FOUND ON PAGES 61 - 101

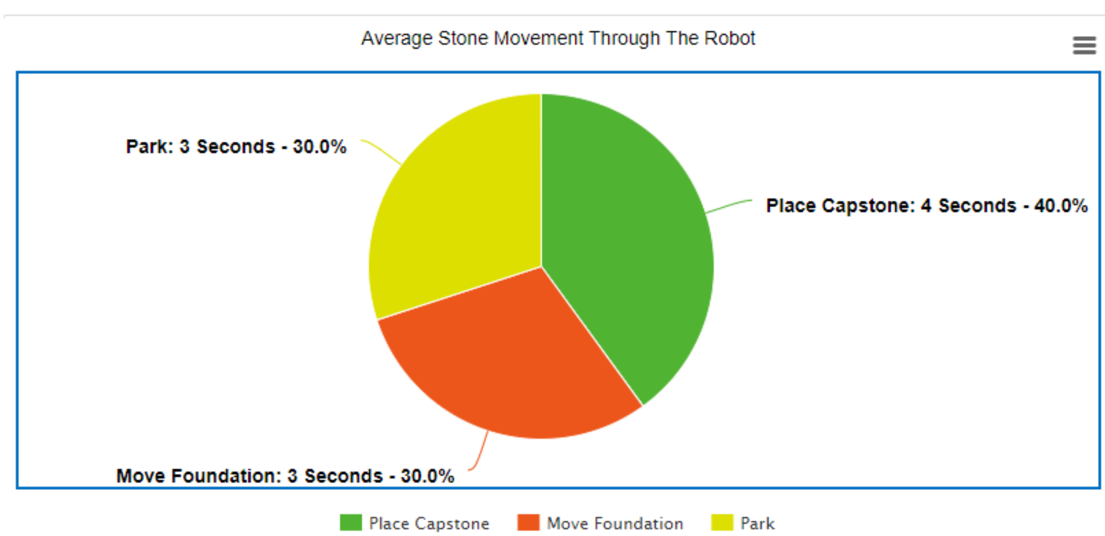
1.23: IMPLEMENT AND TEST | TEST, RECORDING PERFORMANCE DATA

We averaged 6-7 stones per match, averaging 12 seconds per stone. We broke down each mechanism and on average, how long each mechanism was taking to do its part.



AVERAGE STONE MOVEMENT TIME BREAKDOWN -ROBOT V3

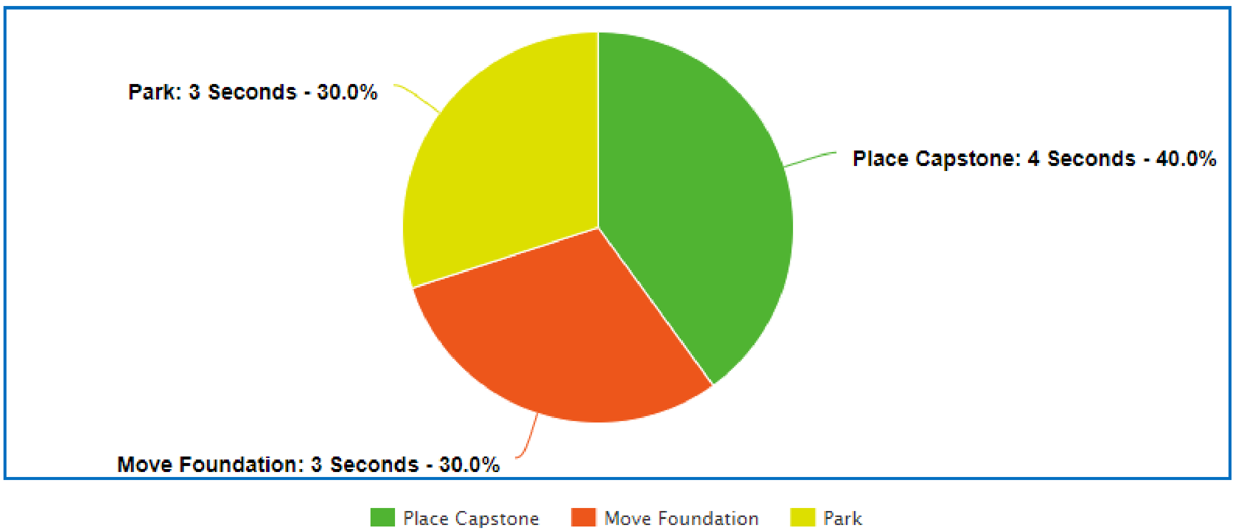
TASK	NEW TIME (S)	OLD TIME (S)	NEW PERCENT OF TOTAL	NOTES
Intake	2	4	16%	
Grab	1	1	8%	
Vertical Lift (up)	2	3	16%	
Horizontal Slide (out)	2	4	16%	
Place	2	2	16%	Difficulty lining up
Retract	3	4	25%	Includes both vertical and horizontal slides



AVERAGE ENDGAME TIME BREAKDOWN -ROBOT V3

TASK	NEW TIME (S)	OLD TIME (S)	NEW PERCENT OF AVAILABLE	OLD PERCENT OF AVAILABLE
Place Capstone	4	4	33%	33%
Move Foundation	3	5	41%	33%
Park	3	3	25%	23%

Average Stone Movement Through The Robot



1.24: EVALUATE | COMPARE PERFORMANCE TO REQUIREMENTS

AVERAGE STONE MOVEMENT TIME COMPARISON -ROBOT V3

TASK	TIME (S)	REQUIRED/WANTED TIME (S)
Intake	2	1-2
Grab	1	1
Vertical Lift (up)	2	2
Horizontal Slide (out)	2	1
Place	2	1
Retract	3	2

AVERAGE ENDGAME TIME COMPARISON -ROBOT V3

TASK	TIME (S)	REQUIRED/WANTED TIME (S)
Place Capstone	4	4
Move Foundation	3	4
Park	3	2

INTAKE

SIMPLICITY | ✓	ROBUSTNESS | ✓	SPEED | ✓
Directly driven on each side by a vex motor; only contains one system of chains and sprockets on each side	It hardly ever breaks	The intake can correct stones from any angle

ROLLER CLAW (NOW JUST CLAW) ANALYSIS

SIMPLICITY | ✓	ROBUSTNESS | ✓	SPEED | ✓
Only contains two servos with beams and plates attached to them	It has never breaks because it is very simple and utilizes servo blocks	It clamps onto the stone and lets go with the simple push of a button

VERTICAL LIFT ANALYSIS

SIMPLICITY | ✓	ROBUSTNESS | ✗	SPEED | ✗
The vertical lifts are quite simple, especially because we use the rev linear slide kit and decided to string it continuously instead of cascading.	Now that we are focusing on stacking 7+ stones, the rigidity of the lifts have become more important, and the rev slides are allowing a lot of play causing the lifts to be unstable	Although we sped the lifts up with the new motors, we still believe we can get them even faster

HORIZONTAL SLIDES ANALYSIS

SIMPLICITY | ✓	ROBUSTNESS | ✗	SPEED | ✗
The horizontal slides are quite simple, especially because we use the rev linear slide kit and decided to string it continuous instead of cascading	Now that we are focusing on stacking 7+ stones, the rigidity of the lifts have become more important, and the rev slides are allowing a lot of play causing the slides to be unstable	Although we sped the slides up with the new motor, we still believe we can get them even faster

FOUNDATION MOVERS ANALYSIS

SIMPLICITY | ✓	ROBUSTNESS | ✓	SPEED | ✓
The foundation movers are quite simple: two servos, two servo blocks, and two plates	The new orientation of the foundation mover servo does not allow the foundation or the plates to slip	The new orientation of the servos allows the driver to clamp on and let go of the foundation fast because we do not have to worry about them rotating up and knocking over the skyscraper

CAPSTONE MECHANISM

SIMPLICITY | ✓	ROBUSTNESS | ✓	SPEED | ✗
This mechanism is quite simple as it is just a servo with a pin that pulls out and drops the capstone	It hardly ever breaks	Although it is faster than getting the capstone from the depot, we believe we can make it even faster

PARKING MECHANISM

SIMPLICITY | ✓	ROBUSTNESS | ✓	SPEED | ✓
This mechanism is quite simple as it is just a servo with wooden dowel which rotates out when we are ready to park	It never breaks	This mechanism is quite fast, as it rotates out to park with the push of a button

1.25: EVALUATE | IDENTIFY DEFICIENCIES IN DESIGN

VERTICAL LIFT:

1. The rev linear slides are not rigid and not very smooth
2. Strung continuously instead of the much faster cascading

HORIZONTAL SLIDE:

1. The rev linear slides are not rigid and not very smooth

CAPSTONE MECHANISM

1. Instead of placing the capstone on the last stone within the robot, the robot has to strafe over and place it on top of the skyscraper after we have placed our last stone

NOTE: During this time, we also identified the need for an autonomous claw, because although the intake performed well in driver controlled, it was not the best thing to use to obtain the stones in autonomous, so we decided to build an "**autonomous claw**"

1.26: EVALUATE | PRIORITIZE NECESSARY ADJUSTMENTS

These are the design deficiencies we decided to focus on for Arizona State, in order.

1. **VERTICAL LIFTS | DEFICIENCY 1,2**
2. **HORIZONTAL SLIDE | DEFICIENCY 1**
3. **AUTONOMOUS CLAW**
4. **CAPSTONE MECHANISM | DEFICIENCY 1**

We then go back to the design phase of our design process in order to begin the process of making needed changes/improvements to our mechanisms.

1.27: DESIGN | BRAINSTORM IDEAS

VERTICAL LIFTS

DEFICIENCY 1: The rev linear slides are not rigid and not very smooth

✓ chosen: Switch to rigid ball bearing slides

WHY: We went with this idea because ball bearings are automatically more rigid and smooth than the rev sliding kit, which utilizes 15mm extrusion and plastic sliding pieces, there were also no other obvious solutions as the quality of slides just depends on the company. **Rigid** slides fulfill part of our **design philosophy**.

DEFICIENCY 2: Strung continuously instead of the much faster cascading

✓ chosen: String the lifts cascading

WHY: We went with this idea because stringing cascading as opposed to continuous is much, is very fast.

HORIZONTAL SLIDE

DEFICIENCY 1: The rev linear slides are not rigid and not very smooth

✓ chosen: Switch to rigid ball bearing slides

WHY: We went with this idea because ball bearings are automatically more rigid and smooth than the rev sliding kit, which utilizes 15mm extrusion and plastic sliding pieces, there were also no other obvious solutions as the quality of slides just depends on the company. **Rigid** slides fulfill part of our **design philosophy**.

CAPSTONE MECHANISM

DEFICIENCY 1: The capstone is preloaded on the side of our horizontal slides, which means the driver has to place the capstone on top of the last stone on the skyscraper as a whole separate movement

✓ chosen: Load the capstone in between the two sides of the claw where the stone sits within the robot, so it can just be dropped on the last stone within the robot

WHY: We went with this idea because it would substantially decrease the time it takes to place the capstone and would be more consistent since it relies less on the drivers

AUTONOMOUS CLAW

NOTE: This does not have a deficiency because it is a completely new mechanism added as a result of the poor performance of the intake in autonomous**. We had to think of a way to be able to pick up the stone near the wall from the red or blue alliance, which meant we had to have a claw that could mount on both sides of the right side of the robot**

✓ chosen: Build a claw that mounts on a locking slide on the right side of the robot (looking from the intake as the front)

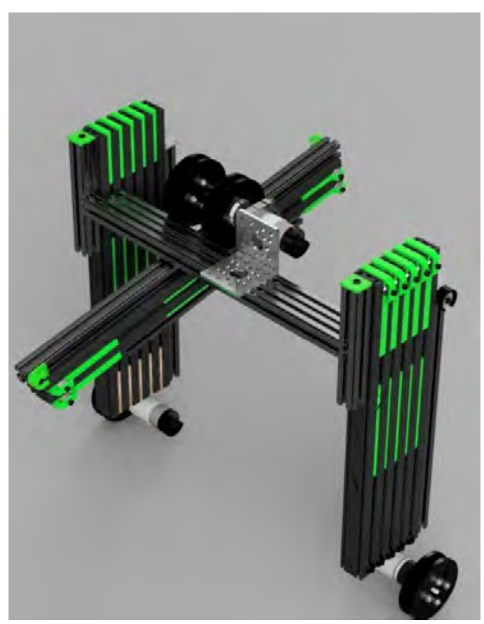
WHY: We went with this idea because it would be much simpler and take up less space and use less parts than having two claws. This **simple** design follows our **design philosophy.**

✗ not chosen: Build two claws, one on each side of the right side of the robot

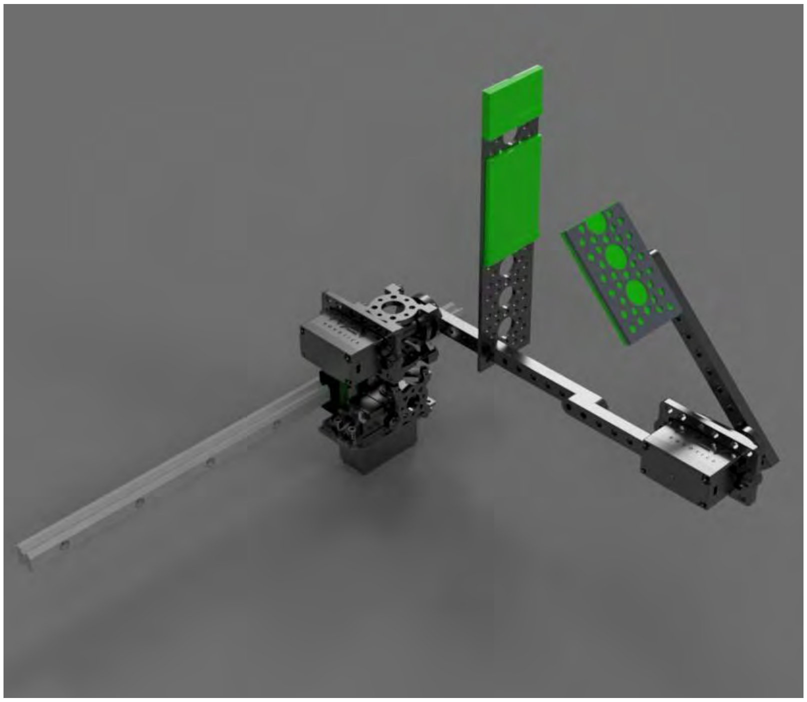
WHY: We did not go with this idea because would take up too much space

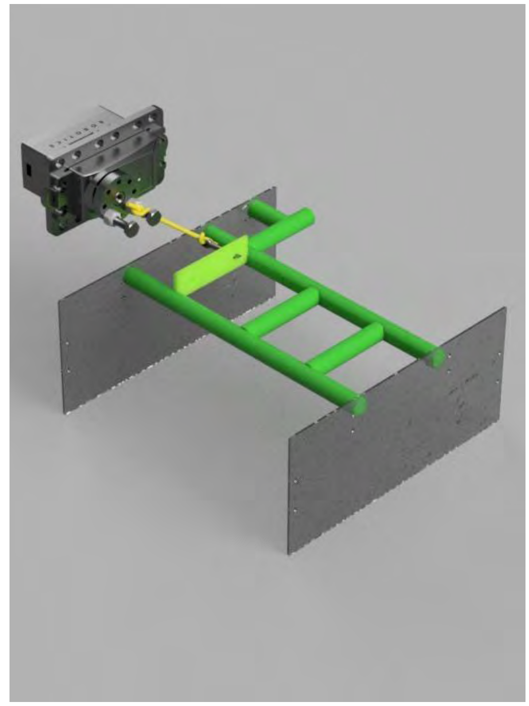
1.28: DESIGN | FINAL MODEL OF DESIGN(S) & ORDER PARTS

New Slides for Vertical and Horizontal Lifts



New Autonomous Claw and Capstone Mechanism

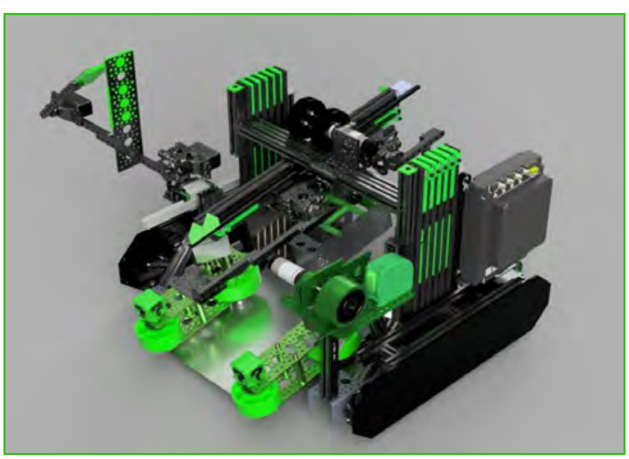


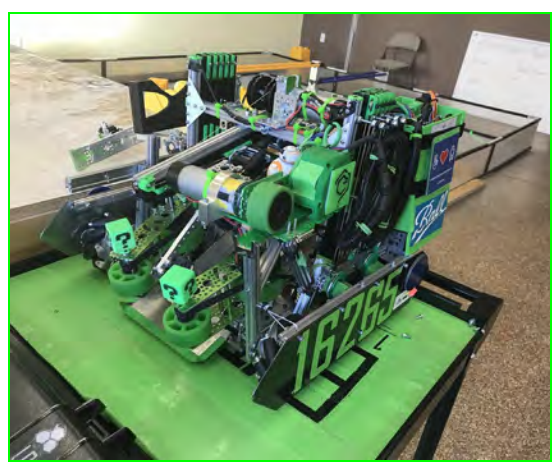


1.29: IMPLEMENT AND TEST | <u>MODIFY PURCHASED PARTS | ASSEMBLE</u>

<u>DOCUMENTATION OF THE BUILDING OF EACH MECHANISM/SUB-SYSTEM CAN BE FOUND ON PAGES 61 - 101.</u>

ROBOT V4 is our current iteration, which we are still in the process of testing.

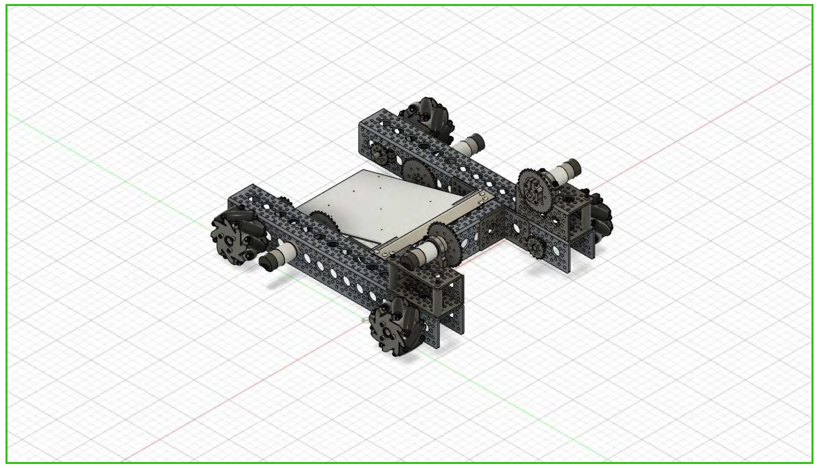




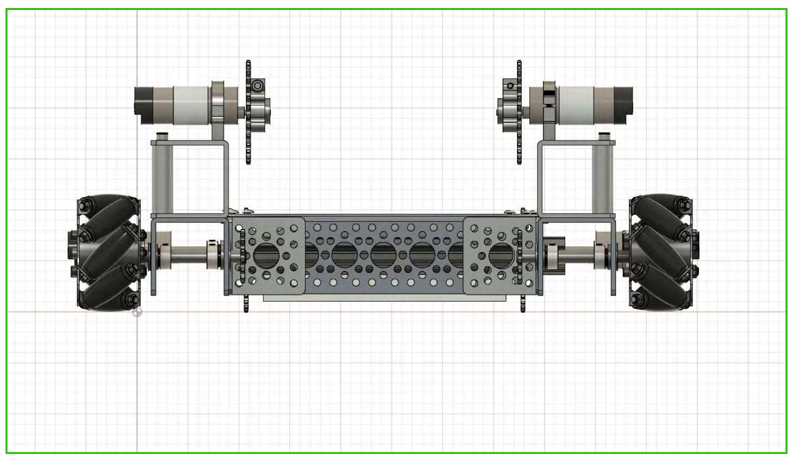
SUB SYSTEM BUILD DOCUMENTATION

CHASSIS | 1 DESIGN ITERATION

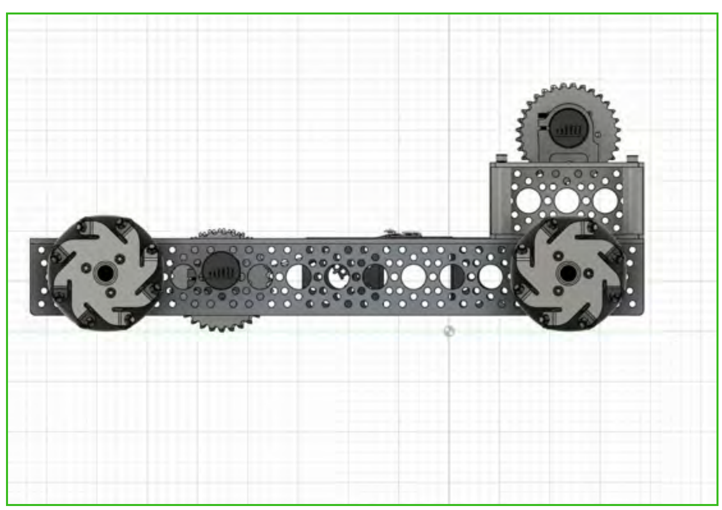
CHASSIS DESIGN



In designing the chassis, there were many things we had to take into consideration, such as leaving room for side shields, chassis shape, mounting motors, leaving mounting space for mechanisms, odometry, etc. We decided to go with servocity's ball bearing building system, as their channel has a lot pre pre-drilled holes for mounting various things as well as for press fit ball bearings. We also liked the idea of using bearings, axles, spacers, and collars for mounting wheels as opposed to directly to the motor. If the wheels are mounted directly to the motor, the motor shaft is receiving a lot of the stress, and we wanted to avoid this. Using the ball bearing system also allowed us to gear up the drivetrain.



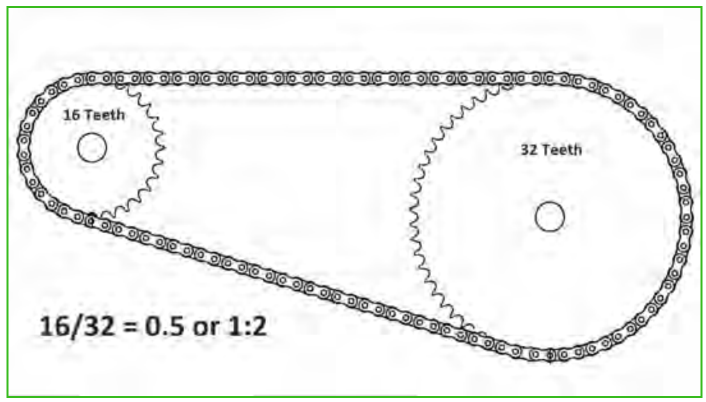
We also took into consideration where motors would mount and how much room they would leave to mount other mechanisms. In order to leave the maximum amount of room on the top of the chassis, we decided to mount the back motors directly above the back wheels, and the front motors inside of the channel parallel to the front wheels. We also decided to leave room for side shields, and we had to leave room for the wide mecanum wheels, so we left about 3 inches on each side, and about 4 inches in the front for the intake to stick out.



DRIVETRAIN SPROCKETS

We decided very early that we wanted to gear up all of our drive motors, thus we all learned how to calculate gear ratios.

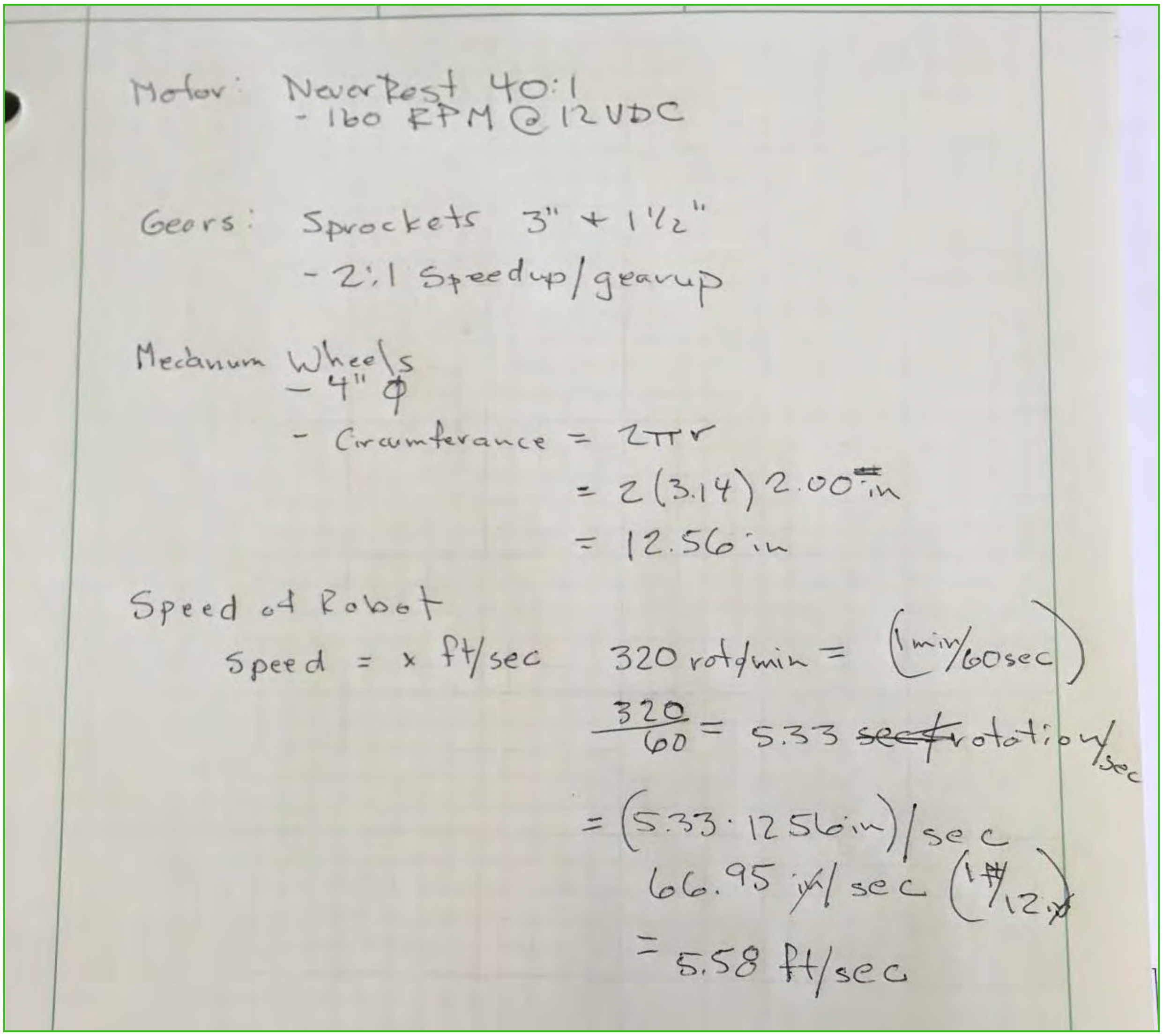
1. Counted the number of teeth on the drive sprocket and the driven sprocket: **in our case, the drive had 32 teeth, and the driven had 16 teeth**
2. Divided the number of teeth on the driven sprocket by the number of teeth on the drive sprocket: **16/32** = **0.5 which can also be expressed as 1:2**
3. **Thus the driven sprocket (16 teeth) rotates twice for every one turn of the driver (32 teeth); because the 32 tooth sprocket is on the motor and the 16 tooth sprocket is on the axle with the wheel attached to it, our wheels spin twice as fast.**



ROBOT SPEED IN FT/SEC

Soon after we calculated our drivetrain sprocket ratios, we decided it would be useful to know how fast our robot is. We calculated the robot's speed in ft/sec.

1. Found the rpm (rotations per minute) of the neverest 40:1 drivetrain motors: **the rmp was 160**
2. Multiplied the motor's rpm by 2 to account for our gear up: **the driven sprocket (16 teeth) rotates twice for every one turn of the driver (32 teeth), thus 2x160** = **320rpm**
3. Converted rotations per minute to preferred unit, rotations per second: **320 rotations/60 seconds** = **5.33rps**
4. Calculated the circumference of our wheels using the formula circumference = 2Loading...r: **the wheel's diameter is 4in, thus its radius is 2in, when plugged into the formula, the wheels circumference** = **2(3.14)2in** = **12.56in**
5. Converted inches into feet: **12.56in / 1ft or 12in** = **~ 1.04ft**
6. Calculated the speed of the robot in feet per second: **5.33 rotations x 1.05ft** = **~ 5.58ft/sec**



Motor: NeverRest 40:1
- 160 RPM @ 12VDC

Gears: Sprockets 3" + 1½"
- 2:1 Speedup/gearup

Mecanum Wheels
- 4" ϕ
- Circumferance = $2\pi r$

$= 2(3.14)2.00$ in

$= 12.56$ in

Speed of Robot

Speed = x ft/sec   320 rot/min = (1 min/60 sec)

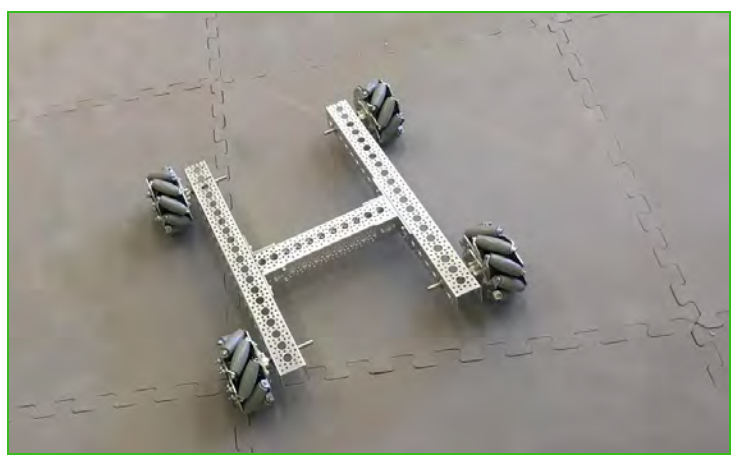
$\frac{320}{60} = 5.33$ ~~sec~~ rotation/sec

$= (5.33 \cdot 12.56\text{ in})/\text{sec}$

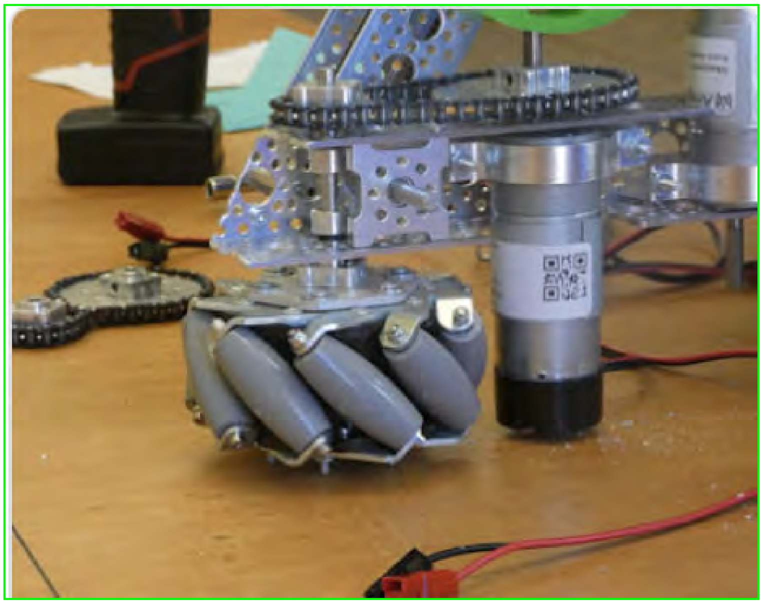
66.95 $\cancel{\text{in}}$/sec (1 ft/12 $\cancel{\text{in}}$)

$= 5.58$ ft/sec

CHASSIS ASSEMBLY



We started by cutting the servocity channel to specified lengths in order to leave room for the wide mecanum wheels and potential side shields. We decided to start out with an H shape chassis, so we cut two sides and one middle piece. We then attached the three pieces with 90 degree angle brackets. After we had the three channels connected, we attached the wheels using two ball bearings, two shaft spacers, and two shaft spacers. Since we were using the andymark mecanum wheels and servocity axles and hubs, we had to use a hole plate converter. So, we attached the converter plate to the wheels and then the wheels to the hubs, the hubs to axles, and the axles to ball bearings and collars.



After the channels and wheels were all attached, we started attaching the motors. As was stated in the design portion, we decided to attach the motors out of the way. So, we dremeled out a space on both sides of the channel on both sides of the channel for the front motors to fit into. We then attached and tetrix motor mount to the inside of the chassis and slid the motor in. After the motors were attached, we slid the chains and sprockets onto the motor shafts and wheel axles.

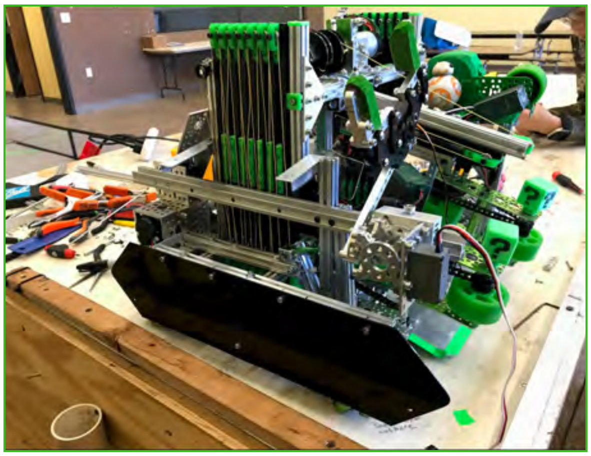
We then had to attach the back motors. Again, in order to save space, we decided to mount the motos above the the wheel axles using more servo city channel and spacers. Then, on top of the channel, we mounted the tetrix motor mounts and slid the motors in, as well as the chains and sprockets.

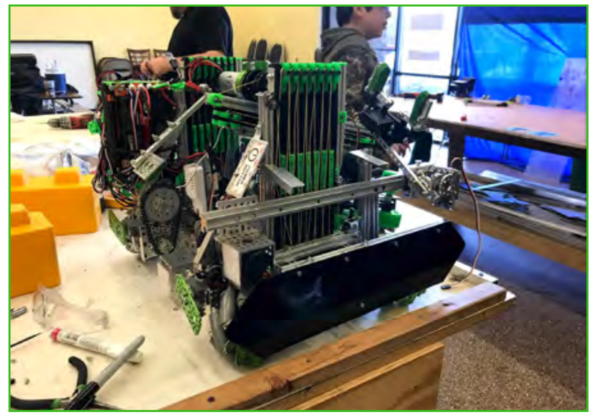
Later in the season, when attaching the intake, we decided to cut 4" inches off of the front and take off both inside corners of the two sides of the chassis in order to fit the intake.

We also decided to add additional bracing to the chassis so that the middle channel was not the only thing holding the two sides of our chassis together. We added two 15mm extrusion pieces to the inside of the chassis to ensure there was no flexing of the two channels that make up the side of our chassis.

Later in the season, we also decided to switch out our andymark mecanum wheels to nexus mecanum wheels. Nexus mecanum wheels use ball bearings for each roller instead of bushings, which are what andymark mecanum wheels use. These wheels are much smoother and durable.

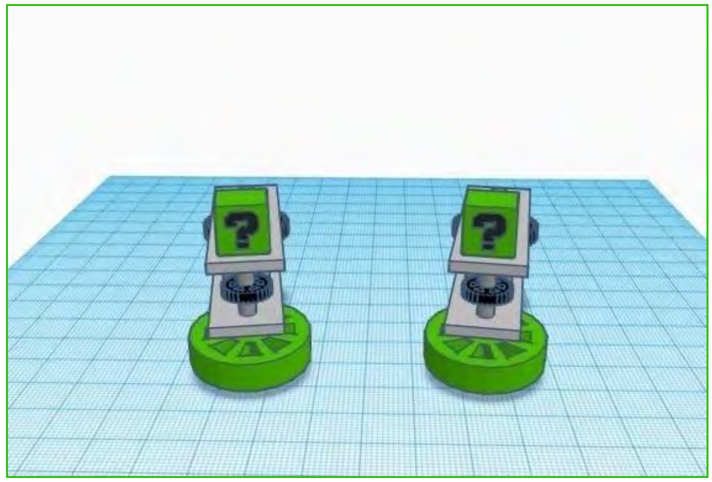
Lastly, later in the season we decided to add side shields to our chassis. So, we cut some sheets of metal and spray painted them black and attached them to the rev extrusion used for our handles. We also added a spacer to the bottom in order to mount it at the top and the bottom.





INTAKE | 2 DESIGN ITERATIONS

INTAKE V1 DESIGN



Our main goals for our design was to be able to pick up the stones fast and deliver them with ease. We realized that an intake may be able to pick up the stone faster than something like a claw, because you do not have to line up extremely precisely in order to pick it up; if built correctly, an intake would be able to **correct the orientation of the stone** and be able to pick it up from multiple angles.

When initially designing the robot, we knew we wanted to have two vertical lifts, a horizontal lift, a mecanum drive, and an intake, which all require motors. Since two motors for the intake, along with 4 motors for the drive base, 2 for the vertical slides, and 1 for the horizontal slides would be 9 motors, **we decided to figure out a way to run the intake off of one motor.**

So, we started designing our intake system. We decided to use **green compliant wheels** because they are grippy and give way to rigid objects. Next, we decided to use **chain and sprockets** to transfer power from the motor to the intake, since they do not slip as much as belts; our next decision was to use **two gears to reverse the direction** of one of the sides of the intake, because the compliant wheels have to rotate in opposite directions in order to intake. We also decided to use the **ball bearing servocity system** in order to build most of our intake because servocity had worked well for the chassis so far! We also decided to use the holes on the chassis in order to attach our intake; the goal was for both sides of the intake to be able to **pivot** out a little bit to give even more "way" for the stone coming in, but to have tension on them to keep them in.

INTAKE V1 ASSEMBLY

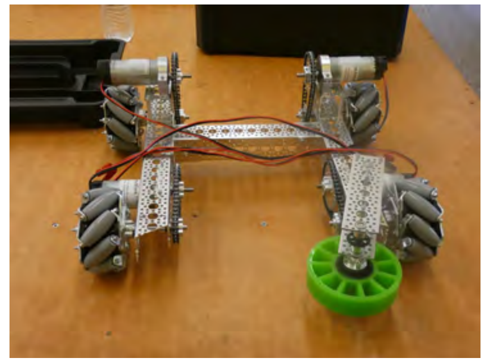
Once we had our general outline, we ordered all of our parts and started building. The initial assembly went quite well, and we soon had them both assembled and attached to the robot.

CHALLENGE 1

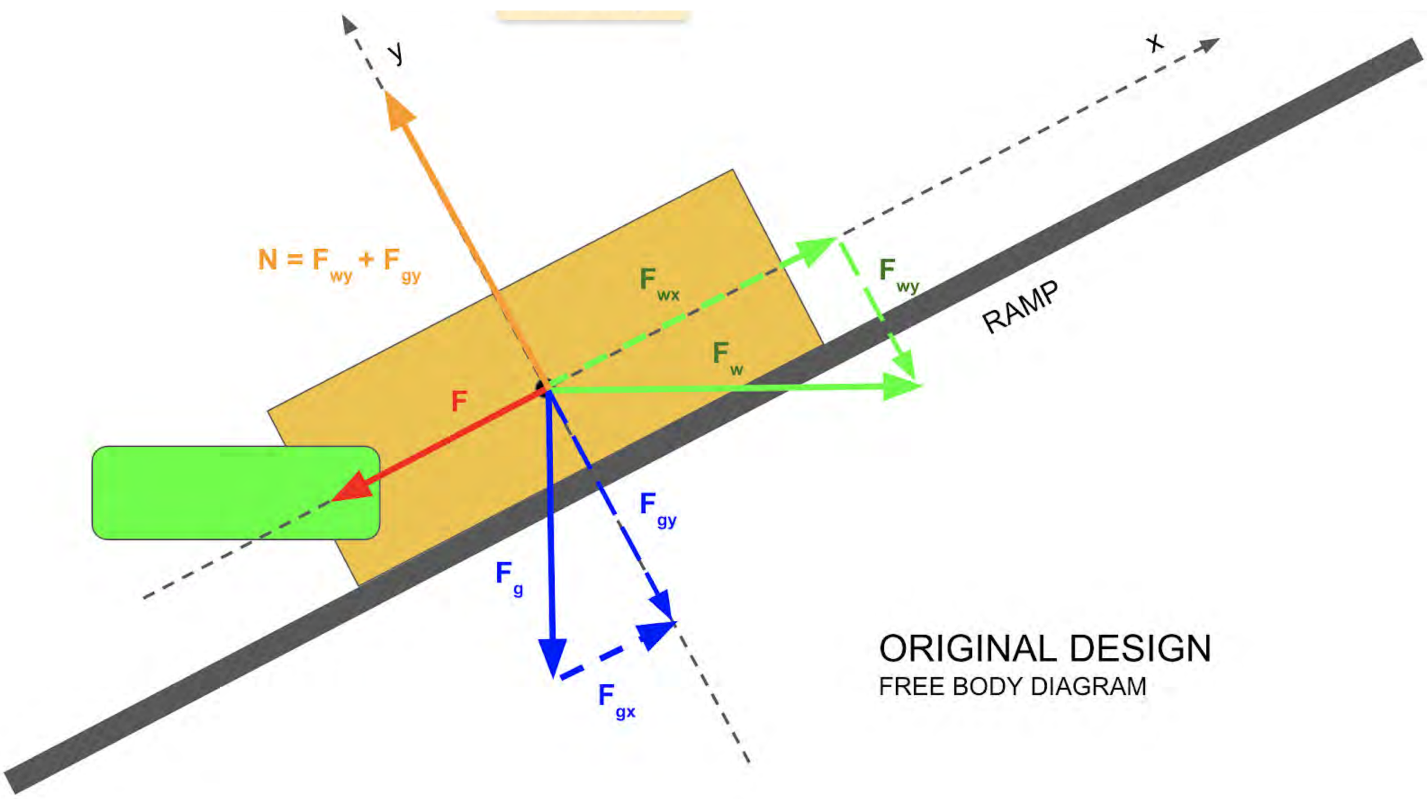
However, our first problem arose when we mounted our ramp that the stone sits on when inside the robot. **The incline of the ramp was too steep, and the intake wheels were too grippy and also mounted level, so there was way too much friction when intaking the stone**.

SOLUTION

In order to fix this, our mentor Renzo, suggested that we angle the wheels of the intake so that it matches up with the angle of the ramp. The free body diagrams below illustrate why this is a better solution.



When the wheels are not aligned with the ramp, force from the



wheels is applied in the ramp direction, but also in the direction orthogonal to the ramp. This orthogonal force is wasted. But worse than that, this orthogonal force increases the frictional force on the block. Frictional force is proportional to normal force:

Loading...

Since there is no acceleration orthogonal to the ramp, the sum of the forces orthogonal to the ramp must also be zero:

Loading...

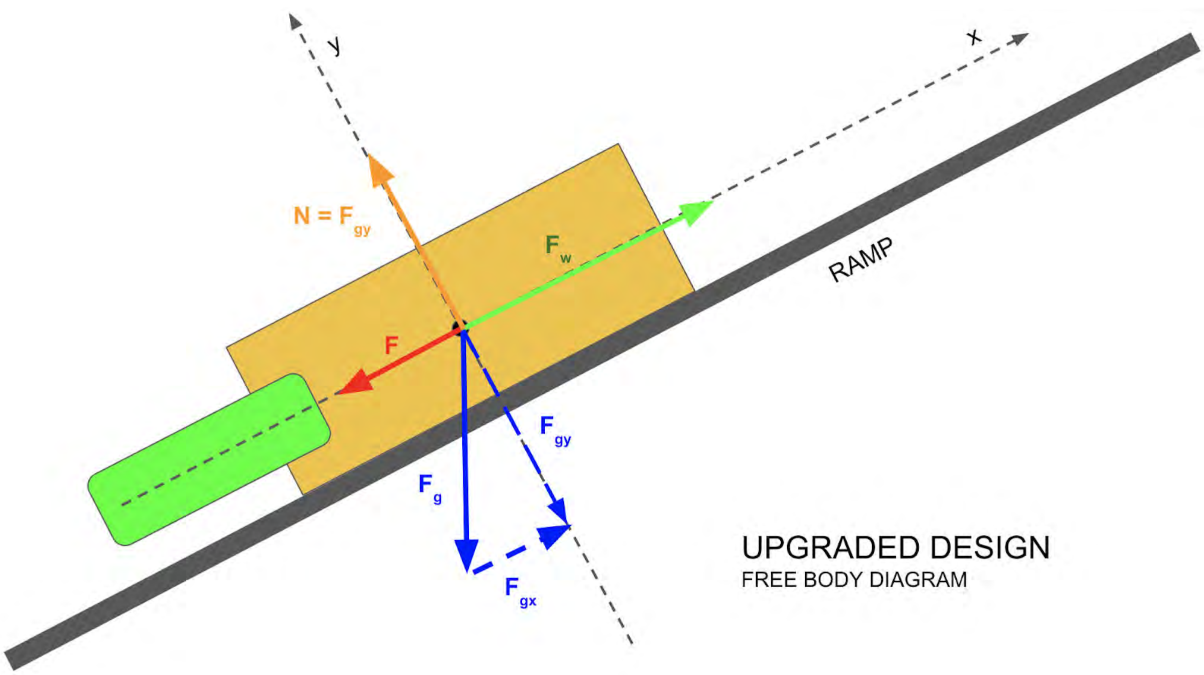
The force orthogonal to the ramp is equal to the sum of the force of gravity orthogonal to the ramp, the normal force, and the portion of the wheel force orthogonal to the ramp. Solving this equation equal to zero shows that the normal force, and thus the friction, is increased when some of the wheel force is directed orthogonal to the ramp.

Loading...

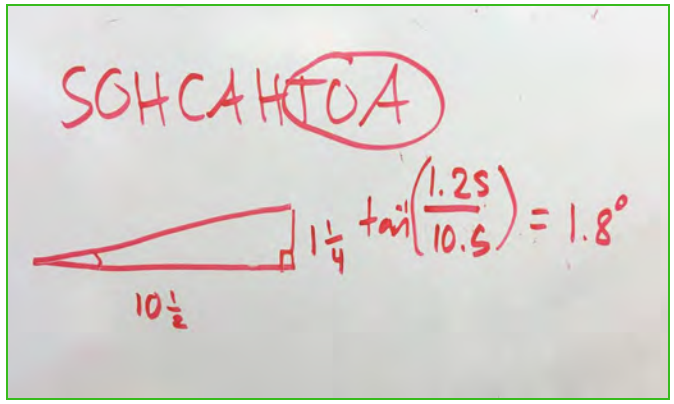
Loading...

Loading...

Therefore, the situation where the intake wheels are used most efficiently, and the frictional force on the block is the lowest, is when the wheels are aligned with the ramp.



We used trigonometry to calculate the angle of the ramp, so we could then angle the wheels to that same angle. We decided to do this by bending the bottom plate of the intake, and then cutting the top plate of the intake, and slotting a bracket that we could use to adjust the angle. We did this in just one meeting, and after testing once more, it seemed to work well!



CHALLENGE 2

However, a second problem soon arose. When hooking the intake up to a motor and intaking a stone, our press fit sprockets from servo city would spin without spinning the axle when under too much stress, and the very small plastic chain would also pop off when under too much stress

SOLUTION

We quickly ordered larger and stronger chain and sprockets with set screws. We also decided to order two larger sprockets to speed up the intake.

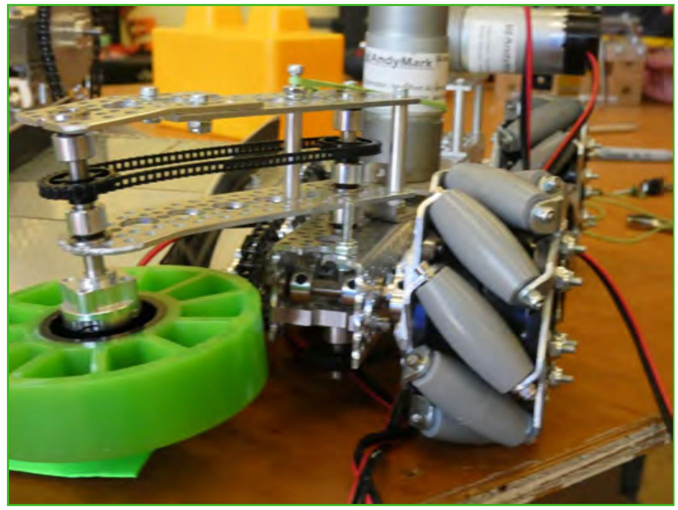
INTAKE SPROCKETS

We calculated how much faster these new sprockets would make the intake:

1. Counted the number of teeth on the sprockets: **we calculated the drive sprocket has 32 teeth and the driven sprocket has 9**
2. Divided the number of teeth on the driven sprocket by the number of teeth on the drive sprocket: **9/32** = **0.28**
3. **Thus the driven sprocket (9 teeth) rotates 2.6 times for every turn of the drive sprocket (32 teeth); because the 32 tooth sprocket is on the motor and the 9 tooth sprocket is on the axle with the 2 inch compliance wheel attached to it, because of this, the front compliance wheels spin 2.6 times as fast.**

CHALLENGE 3

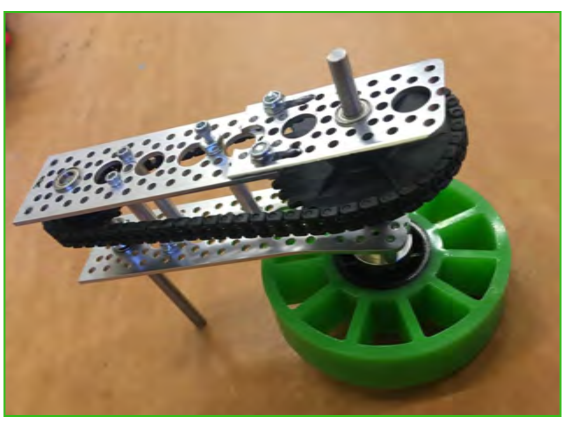
After we reassembled the intake with the new chain and sprockets, we noticed a new problem which we suspected might come up. The stronger and larger chain would not accommodate the angle of the axle, and would bind up when spun. C

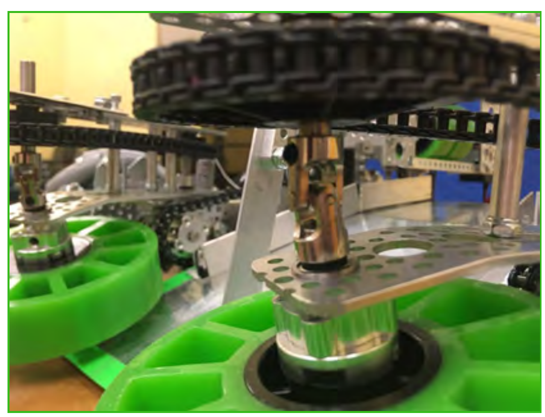


SOLUTION

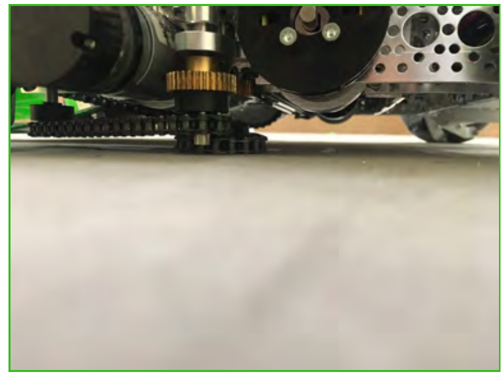
coach Russ suggested using a **universal joint which separates the axle into two sections. One section is straight and is where the sprocket would attach and the other section is at an angle, which is where the compliant wheel attaches.** We decided that would be a good solution to try, and so we ordered them and reassembled the intake once more!

After installing the universal joint and attaching everything to the robot, we tested it, and it worked quite well, however we noticed that we put the large sprocket and small sprocket in the wrong places, so it was actually slowing the intake down instead of speeding it up, so we took it apart and switched them around.





CHALLENGE 4

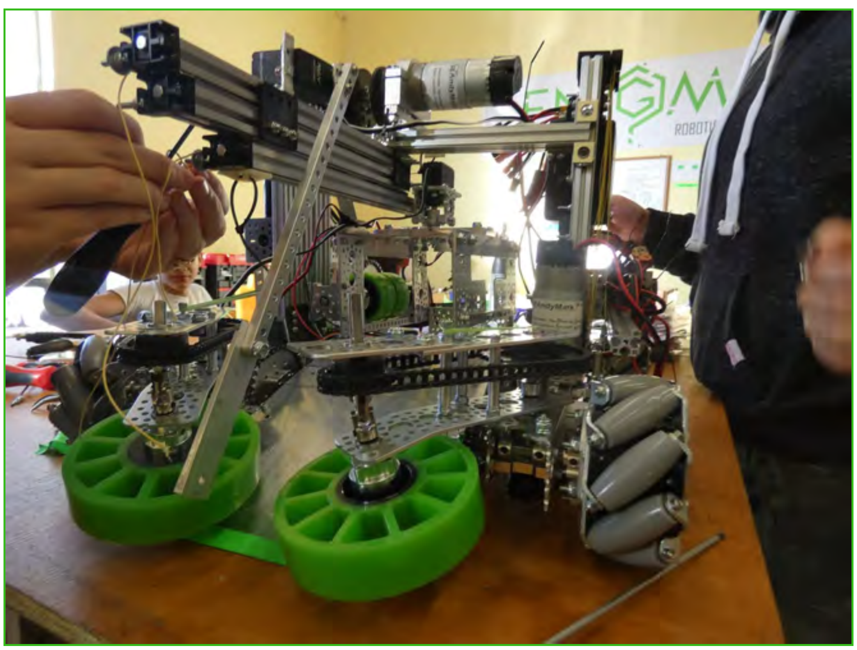


We thought we were done with the intake until we put the robot on the field and noticed that the chain and sprocket system under the robot that transferred power to both sides of the intake was **too low, and touching the field tiles**.

SOLUTION

So we eliminated one of the unnecessary connections of the chain and sprockets which raised the whole system, clearing the tiles by about ⅛ of an inch. The last change we made to the intake was changing out the compliant wheels. **The 4” compliant wheels were too big and hard to maneuver with, so we changed them to 3” compliant wheels**. We also redid one of the intake stops, making the stop studier, and putting it inside of the intake instead of at the back.

FINAL VERSION 2!

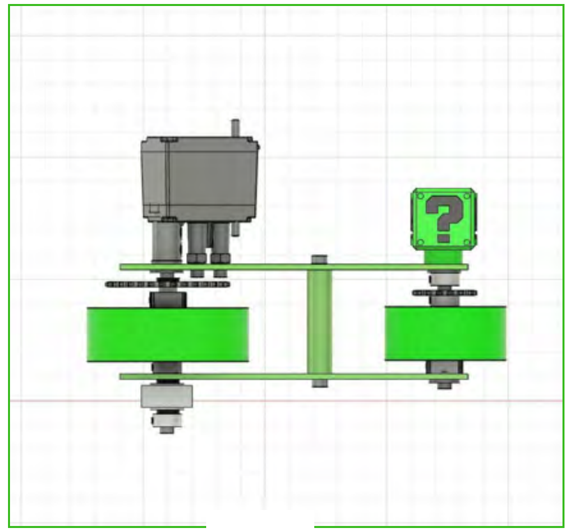


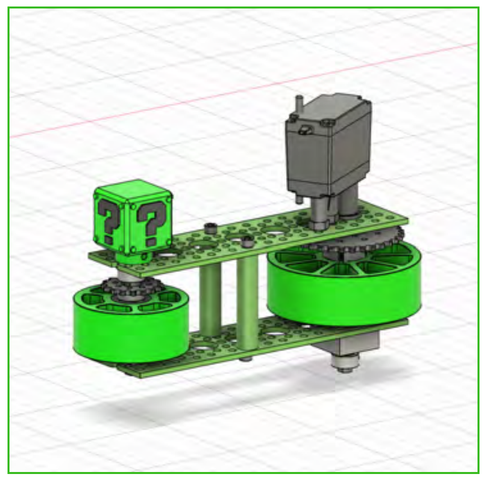
INTAKE V3 DESIGN (CURRENT)

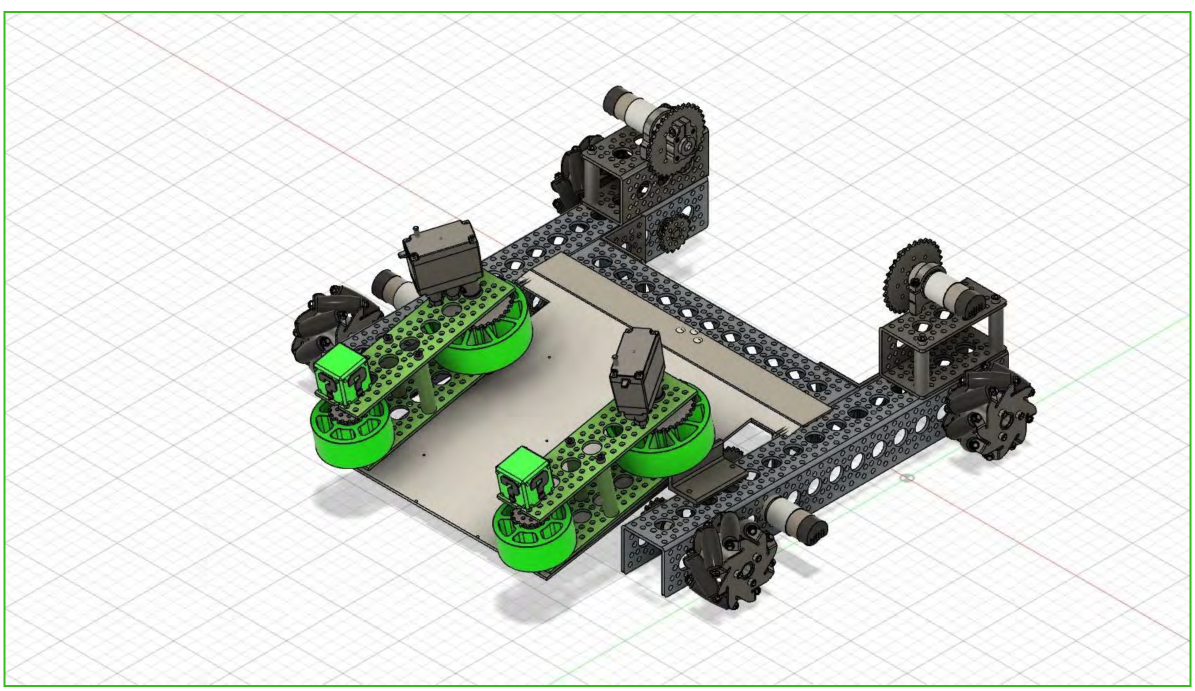
Our Intake is run off of 2 Vex EDR 393 motors mounted directly on top of the intake but conveniently these are counted as servos in FIRST. We have also geared up the front set of compliance wheels which is discussed on page 47.

The Intake itself is mounted off of 2 custom made pillow blocks with bearings in the middle for each side. The left side of the intake's pillow block is mounted on a brace that is mounted onto the chassis. The right side of the intake's pillow block is braced onto the ramp but is also braced onto the chassis. Because it is mounted on the ramp, our intake is at the same angle as the ramp. It is also sprung with 10 rubber bands on each side. This allows our intake to stay tensioned in a specified position as well as flex out in order to intake the stone from any orientation.

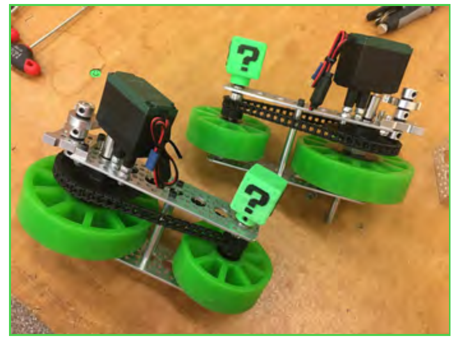
The actual intake consists of two servocity plates with pre-drilled holes for their press fit ball bearings. We are also using 2 inch AndyMark compliance wheels in the front, and 3 inch compliance wheels in the back attached to 0.25" axles.





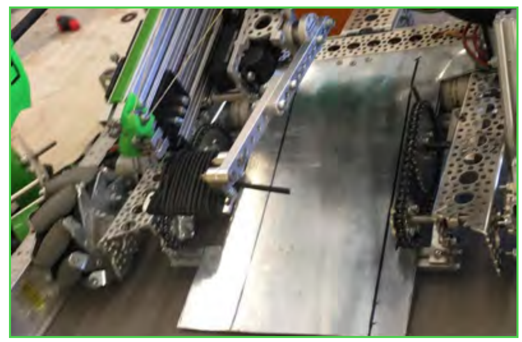


INTAKE V2 ASSEMBLY



We started by taking apart the old intake and sorting out the parts. After taking some measurements, we realized we could reuse a lot of the parts from the old intake for the new intake. We then assembled the right and left side using the same servo city plates, bearings, and axles as well as the same chain and sprockets -all we had to do was add the two 3” compliant wheels to the back.

The next task was mounting the vex motors to both sides of the intake in order to drive it. We found that two holes on the servocity plates already lined up, so we attached the vex motor to those holes and used a .125” tp .25” coupler to attach the vex shaft to the servocity shaft.



After both sides were assembled and colored green with green sharpie of course, we had to mount them. This part took a while because, as depicted in the picture to the right, we had very little room to mount them, besides on the top of the chassis channel, which we could not do because of the precise spacing we needed between the two back wheels for the stone to fit in between them.

We started with the right side. We found that we had room in between the chain and sprockets for the drive train to attach a custom pillow block. We decided to make the custom pillow block out of scrap aluminum that we had, so we cut it, drilled holes for press fit bearings on the top and bottom, and attached it directly to the side of the chassis behind the chain and sprockets.

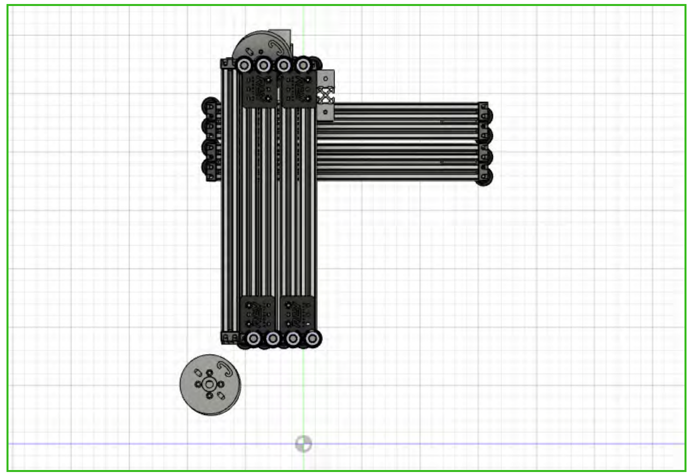
This design worked quite well, so we moved on the left side. This side was a little bit different because the pillow block had to mount a little farther into the robot, which meant we could not mount it directly to the side of the chassis. We decided to instead mount the pillow block to the braces of our chassis and ramp, which meant the pillow block would be angled the same as the ramp, which was our goal in the first place, so we cut two servocity spacers to different lengths in order to preserve the needed angle and attached the pillow block to those!

After some initial testing, we noticed that the force of the stone coming in pushed the left pillow block out, so in order to add some additional rigidity, we added some spacers to attach the pillow block to the side of the chassis. This eliminated side to side movement.

FINAL PRODUCT!

VERTICAL LIFTS | 2 ITERATIONS

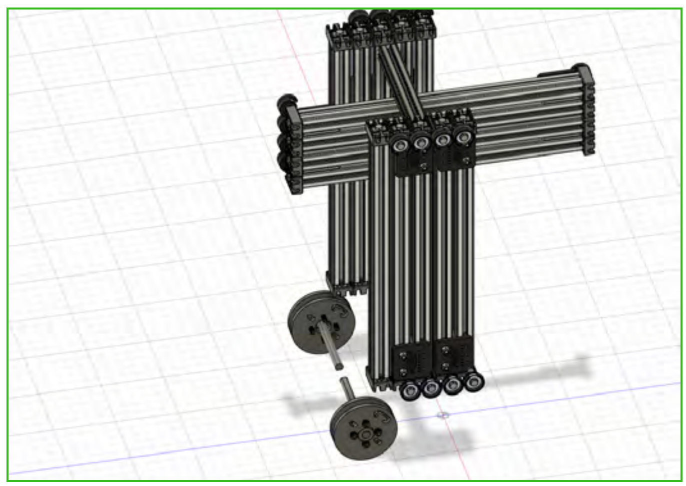
VERTICAL LIFTS V1 DESIGN



In order to stack the stones to make a skyscraper, we needed vertical motion, preferably fast, tall, and rigid.

We considered using a scissor lift because it can compact better than other systems, and this was an important aspect to consider since it had to compact to under 14”.

However, scissor lifts can be extremely slow and unstable, so we went with linear slides driven by a pulley system, because they are fast and can be rigid when built right; we could also modify the lengths of each stage and the number of stages so that we could fit under the skybridge.



We decided to use the rev linear slide system because we had observed other teams’ success with them, and because they are easily modifiable. We also decided to use two linear slides instead of one for a more rigid system.

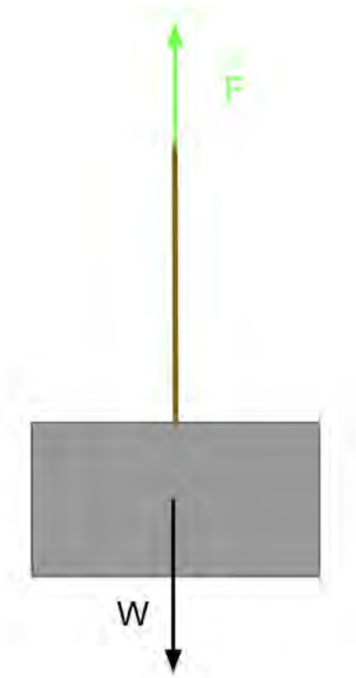
WHY PULLEYS

We use pulleys on our vertical and horizontal lifts. Pulleys are one of the three types of simple machines:

1. Pulleys
2. Ramps (see Intake above)
3. Lever

Simple machines use mechanical advantage to multiply force. The free body diagrams below show how pulleys multiply force.

In order to lift a weight, Loading..., one has to exert a force of at least Loading...:

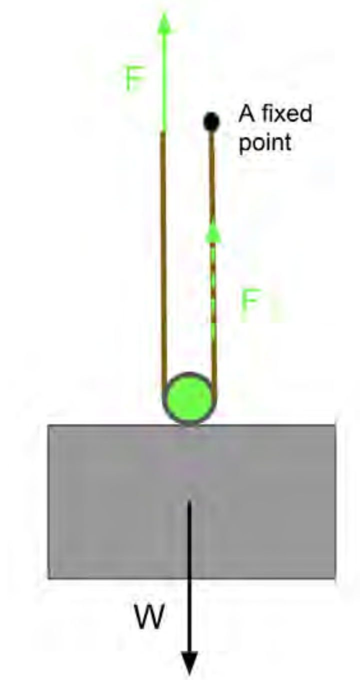


A pulley is a wheel with a rope around it. The basic rule of pulleys is that the tension, or pulling force, on the rope going into the pulley is the same as the tension on the rope coming out of the pulley. If we attach a pulley to the weight we want to lift, we can lift it with half the force, because that force is multiplied by each rope of the pulley. So, with a pulley, to lift the block the forces will be, as follows:

Loading...

Loading...

Using pulleys helps our motors lift the vertical lifts with less force, making them faster and more reliable.



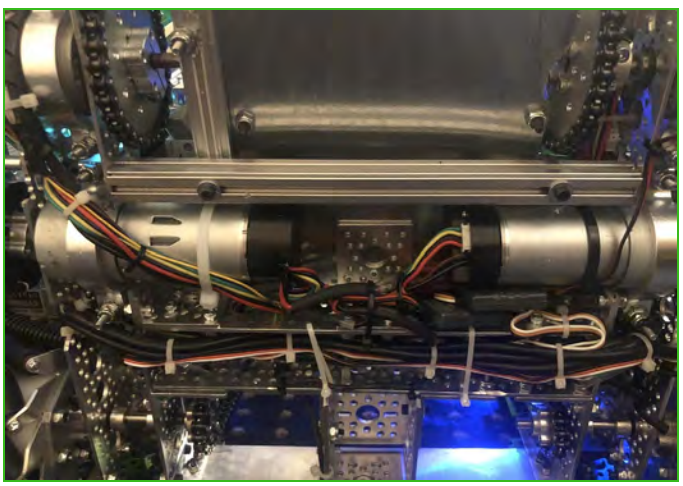
Since we used the rev linear slides, most of the building was just assembling the kit. Even though we thought this would be a relatively easy task, we ran into some problems.

CHALLENGE 1

The **plastic slides** that go in between each stage **kept getting stuck and binding up** the whole system. They are supposed to be tightened to one stage and then loosely slide on the other. We took them apart and put them back together multiple times, but the problem persisted.

SOLUTION

After doing some research, we realized other teams were having the same problem; one team suggested removing **the screws in those troublesome slides** and just let them slide freely on both sides of the extrusions. After we tried removing the screws, it finally slid smoothly.



While the vertical lifts were getting assembled, some of us worked on mounting the two motors that would drive the lifts. We cut two large holes in the chassis channel so that the motor would sit within the channel; the shaft then stuck out of the outside of the chassis with enough room to mount a winch.

Once we got them to slide properly, we mounted them to the robot.

CHALLENGE 2

However we noticed that we did not cut each stage enough, and we were touching the skybridge.

SOLUTION

We took the slides off, cut each stage, and remounted them.

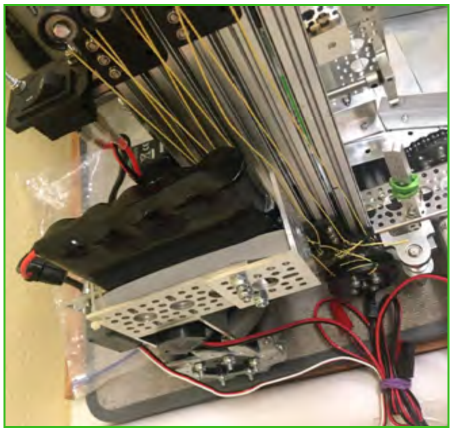
Once the lifts were mounted, we started stringing them. We decided to string them as a cascading lift so that they would lift a little bit faster.

CHALLENGE 3

After stringing the lifts and testing them, our string snapped.

SOLUTION

We ordered stronger string, tied better non-slip knots, and tried again.



CHALLENGE 4

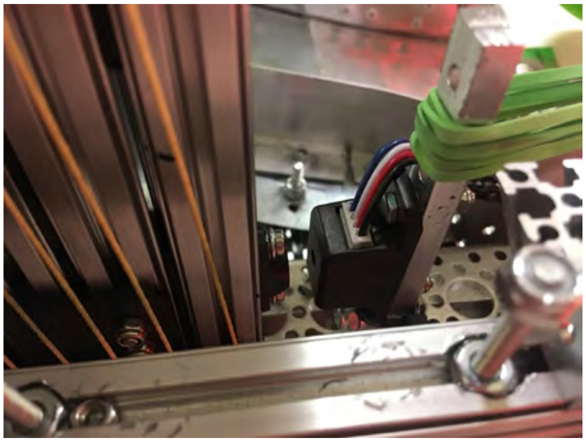
When testing for a second time, we noticed that the string was getting extremely tangled each time the lifts went back down.

SOLUTION

After we had strung the horizontal lift as a continuous lift and noticed that the string does not get as tangled, we decided to string the vertical lifts as continuous as well. After we re-strung them as continuous, the tangling problem was eliminated.

One last thing we did to the vertical slides was reinforce them by adding a support/brace, which attaches to the top of the stationary stage of the vertical slides and runs down to the rear left motor mount.

After Socorro, we decided it was necessary to add limit switches in order to prevent the spool from unwinding when coming back down.

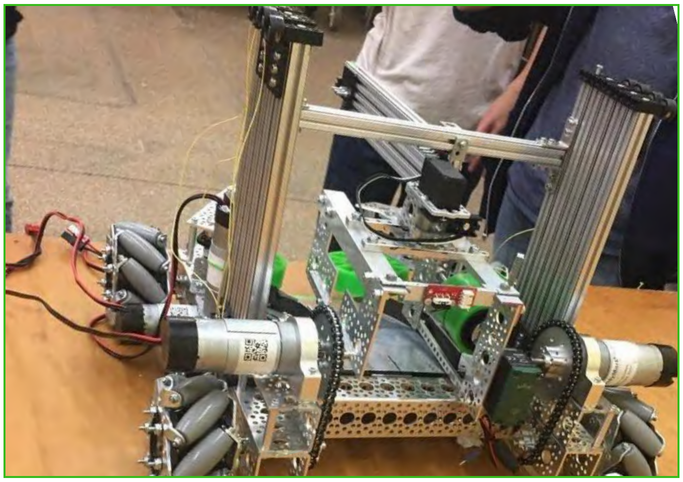


MAGNETIC LIMIT SWITCHES

The **magnetic limit** switch is an **omnipolar momentary switch**; A omnipolar momentary is a switch that will trigger when there is a certain amount of magnetic energy on either pole detected. The way we integrate the Magnetic Limit Switch on our robot is by putting them on are lifts. We have one switch on our vertical lift and one on our horizontal lift. We place magnets on our lifts, and when they are fully extended the switches sense them and stop the motor, so the lifts won't break.

We decided to go with a rev magnetic limit switch. The installation was quite simple, but we had some trouble programming it. We figured that the code would look something like: if magnet is sensed, then do not keep unwinding, but it turns out it was the other way around. Once we figured this out, they worked great!

FINAL VERSION 1!



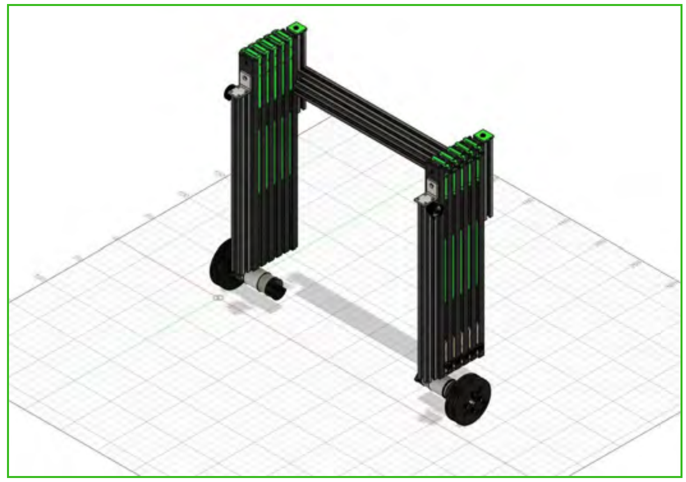
VERTICAL LIFTS V2 DESIGN (current)

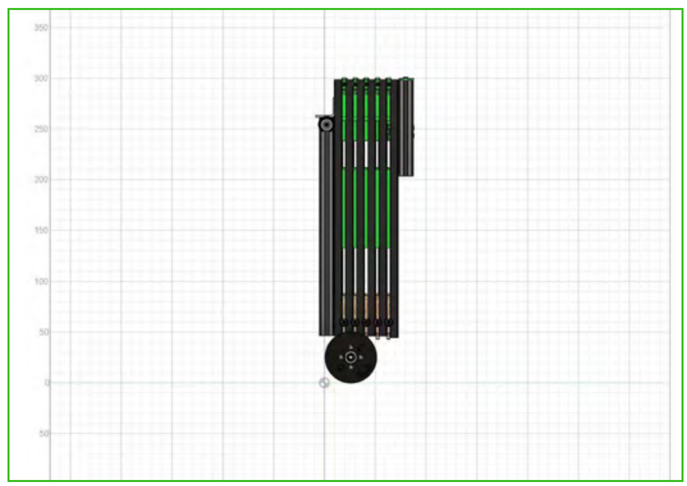
We noticed that the rev linear slides were not very smooth nor sturdy, so we decided we wanted to try ball bearing slides.

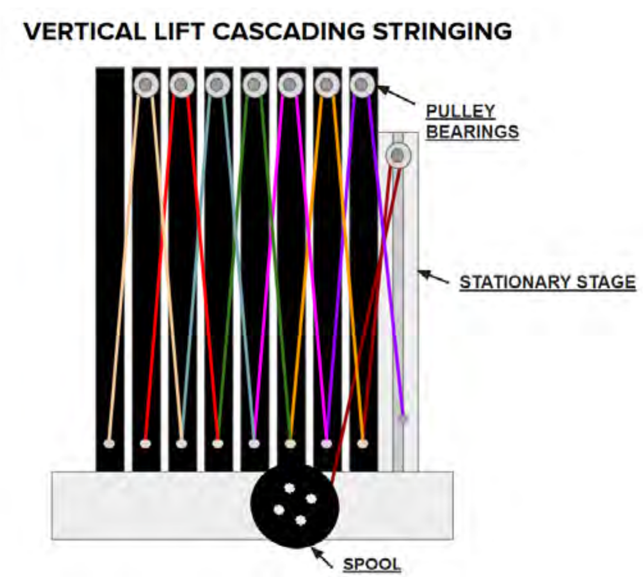
We did some research and narrowed it down to Long Robotics slides, Misumi slides, and Sugatsune slides. We chose to use the Long Robotics slides because they were a little bit cheaper and black, which fit our team color! Long robotics also offered the files for the 3D printed parts in order to attach stages, which Misumi and Sugatsune did not.

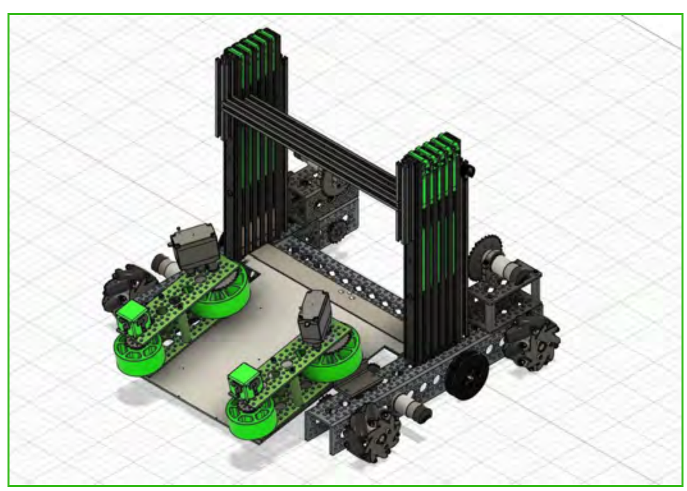
We decided to add 3 stages, making 8 stages on each side and mount them to the stationary extrusion of the rev slides in the same orientation the rev ones were mounted.

We also decided we wanted to try to string cascading instead of continuous for more speed. In order to make sure we knew what we were doing before stringing it, we made a stringing diagram. We posted a video of our lifts and instagram and and **10 teams asked to see our diagram. We were happy to help!**









VERTICAL LIFTS V2 ASSEMBLY

After 50 hours spent printing all of the 3D printed parts we needed in order to attach each stage to one another, we were ready to start mounting. We soon ran into multiple issues:

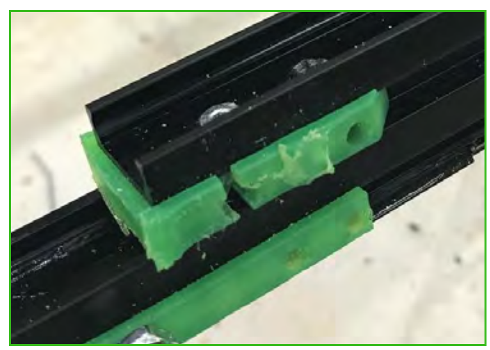
CHALLENGE 1

The shortest size long robotics had were 300mm tall, which happened to be about 1” too tall for our robot in order to fit under the 14” skybridge. At first, this was a very concerning issue because cutting ball bearing slides is much harder than cutting something like rev extrusion because of the ball bearings.

SOLUTION

In order to keep the ball bearings in, we figured that we had to cut the slide and then dimple it at the end so the ball bearings could not fall out. We tried this and it worked quite well, so we proceeded to cut all 16 slides!

CHALLENGE 2



After we mounted and strung all of the slides cascading, we tested them with our old 20:1 motors. We ran into two issues: the 20:1 motors did nor have enough torque, and the 3D printed parts snapped when lifting.

SOLUTION

In order to fix this, we remade all of the bottom 3D printed pieces out of oak because oak is very strong and was easy to cut and drill. After all 16 pieces were cut and drilled, we attached them. We also changed out the 20:1 motors with 40:1s to increase the torque.

CHALLENGE 3

After the new oak pieces and new 40:1 motors were installed, we tested again. Unfortunately, the 40:1s sunk very badly when lifting the slides.

SOLUTION

In order to fix this, we needed to try out a motor with more torque or try going back to continuous stringing. We decided to try using motors with more torque first, so we ordered gobilda 26.9:1s, with 530 oz-in of torque, compared to the 40:1s 350 oz-in of torque. The 26.9:1 also had an rpm of 223, opposed to the 160 rpm of the 40:1s, so they were faster.

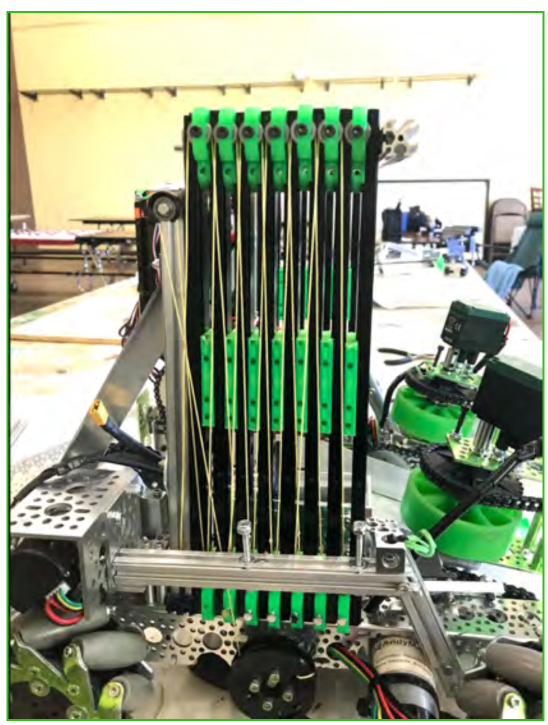
CHALLENGE 4

After the new motors came in, we installed them and tested the lifts. They still sunk!

SOLUTION

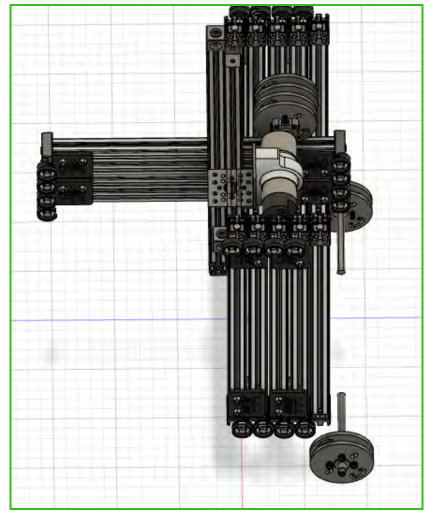
We did some research on the effect of cascading stringing on torque, and found that with the amount of stages we had on our lifts, it was vastly increasing the required torque needed to lift it and the tension on the string. With this information, we learned the importance of researching before making big design changes. We decided to go back to continuous stringing and try the 20:1 motors we had. After adding the required pulleys for continuous at the bottom of each stage, and replacing the goBilda 26.9:1s with the old 20:1s, we tested it, and it worked! No sinking and no broken 3D printed parts!

FINAL PRODUCT!

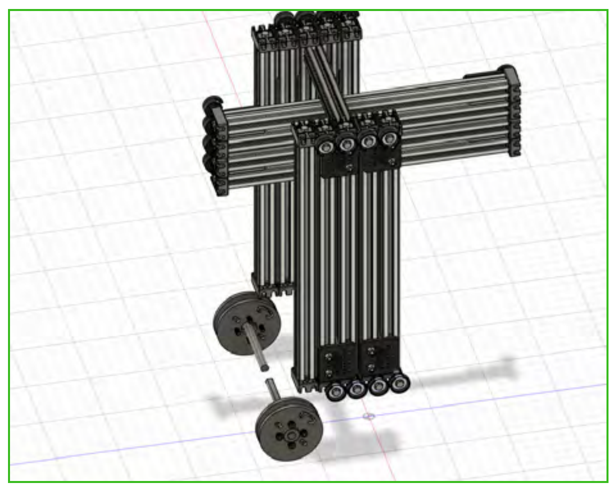


HORIZONTAL SLIDE | 3 ITERATIONS

HORIZONTAL SLIDE V1 DESIGN



In order to reach the foundation and place the stone, we needed to be able to extend outside of the robot by about 1'. When first designing, we thought about rotating in and out instead of linearly extending out. However, in order to rotate in and out, the roller-claw would have to stay straight, while everything around it was rotating; we found that this may be too complicated, and we liked the idea of keeping things linear, so we went with a horizontal slide, identical to the vertical slides, using the rev kit. One drawback to using horizontal slides powered by a pulley system was that it can be hard to bring the stages back without the help of gravity. We considered using surgical tubing, but were afraid that it may strain the slides when going out, and may not be consistent enough. After looking at what some other teams had done to retract horizontal slides, we found one team that had two spools: one that extended the lift, and one that retracted it.



HORIZONTAL SLIDES V1 ASSEMBLY

We learned our lesson with the vertical slides, so we were able to assemble the horizontal slides without much trouble. At first, we only had two stages, one of them is stationary, but found that we needed a little more extension, so we added a third stage. In order to attach the horizontal lift, we attached 15mm extrusion in between the vertical slides, and mounted the horizontal slides to that with a plate and one mounting cube.

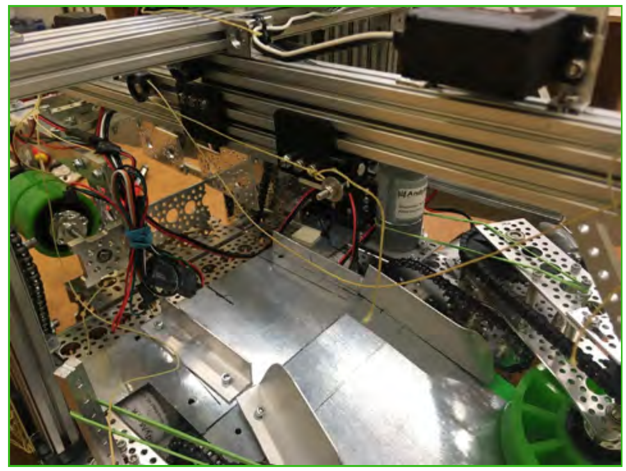
This way of mounting it was okay, but we knew we could do better and make it a little more sturdy (the extrusion was bending slightly on the y axis) so we added a second 15mm extrusion right behind the first one, and mounted that with 4 mounting cubes. We also added plates to the top of the two extrusions to hold them together and reduce any bending.

Lastly, the horizontal lift tended to rotate on the x axis, so we added 1 cube on each side of the 1 cube already there, so that it could no longer rotate.

We decided to string the horizontal slides as a cascading, just like the vertical slides originally were. That took a whole meeting because we found it difficult to tie the special knots. After we finished stringing it, and the other spool that would be retracting, we tested it.

CHALLENGE 1

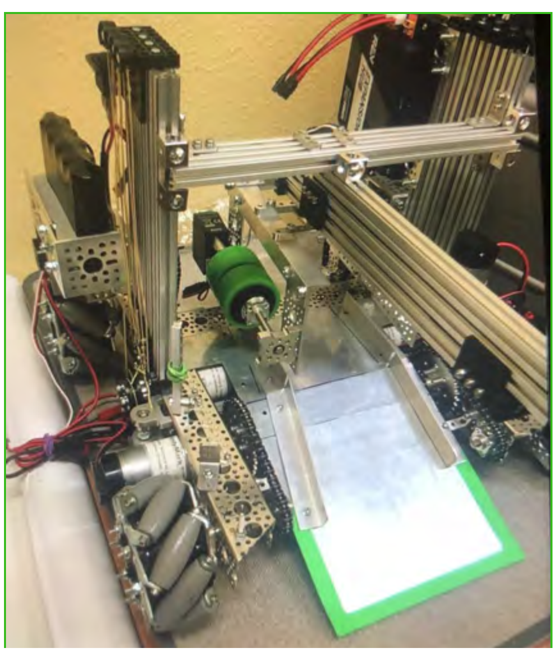
We ran into three problems: the string kept getting tangled, there was a lot of friction when extending, and the string was rubbing up against the extrusion between the vertical lifts, causing the string to tear. The whole thing looked like a mess and did not work very well.



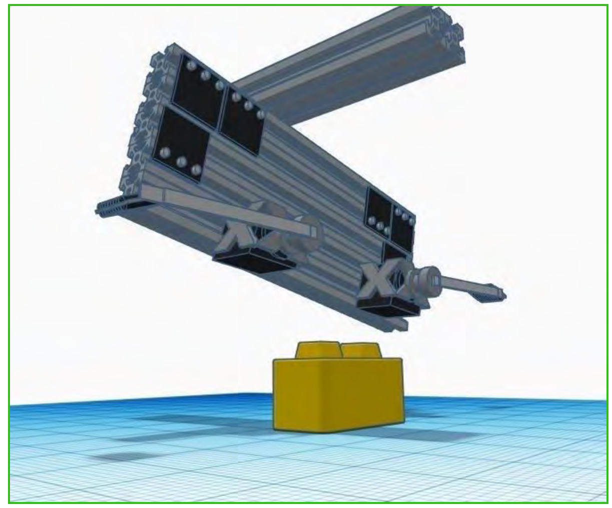
SOLUTION

So the next meeting, we decided to try stringing it as a continuous lift; we also remounted the motor so that the string would not rub up against the extrusion and so that one of the spools could be on the other side of the lift; this allowed the string that extended to be on one side, and the string that retracted to be on the other side, which really cleaned it all up. Everything worked very well after those few changes!

FINAL VERSION 1!



HORIZONTAL SLIDES V2 DESIGN



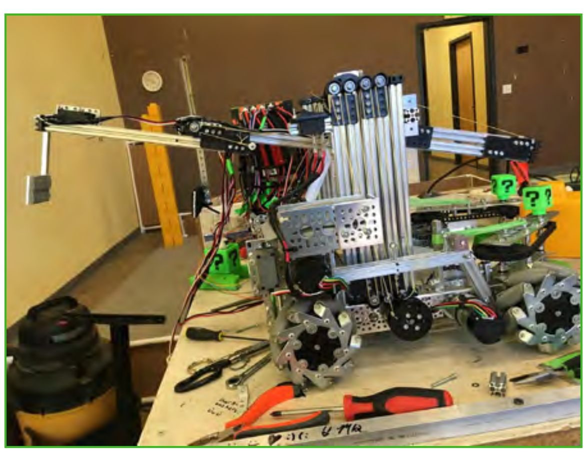
At the Alamogordo qualifier, the mounting of the horizontal lift failed and the horizontal lift moved out of alignment, which resulted in an inability to place stones. This was a large contribution to our loss in the finals. The first change we made once we got back was to hard mount and slant the lift upwards to the angle of the ramp.

After this change, along with some other changes we made, we attended a local scrimmage to help with some software issues. At the scrimmage, we broke multiple of the horizontal slide's end caps that come with the rev linear slide v2 kit. This had been a problem all season, but this time we decided to come up with a solution to fix it. Coach Russ suggested that we make our own end-caps out of metal, which would be much sturdier than plastic. He came up with a design and made a couple to show us. They worked very well! They attach to the extrusion in three places, and have a brace inside to make sure they don't bend. They also use stainless steel screws.

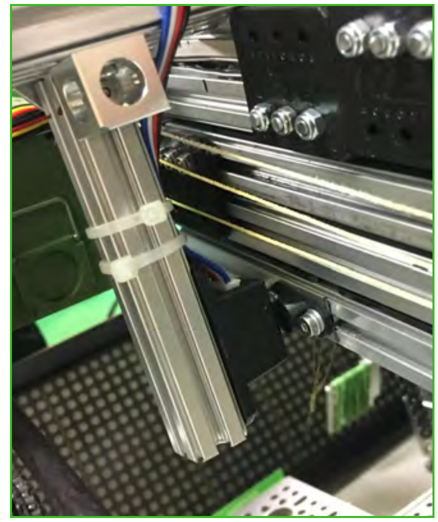
One last problem we noticed was, when in use, sometimes the driver could not see the hard stop, and would overrun the motor, snapping the string and bending the parts of the slide. We decided to add a magnetic limit switch in addition to the hardstop.

HORIZONTAL SLIDES V2 ASSEMBLY

In order to hard mount the horizontal slides, we decided to drill straight through the extrusion mounted between the vertical lifts and the top extrusion of the horizontal slides at two points and put two screws through them. We also cut an angle in the top extrusion in order to angle the horizontal slides.

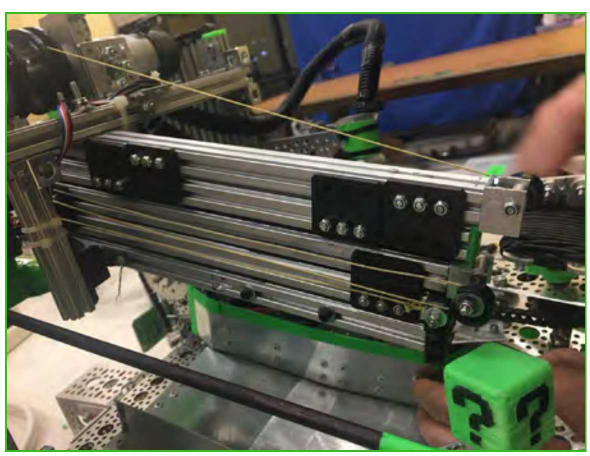


No one on the team had ever worked with limit switches, but we soon figured it out, and had it mounted and programmed. In order to mount it we used the rev extrusion and the extrusion corner cubes. This addition was extremely helpful to the drive team.

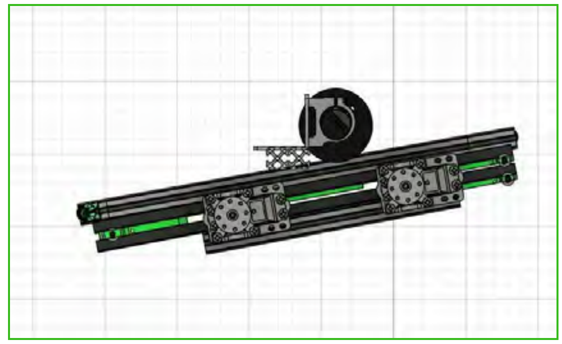


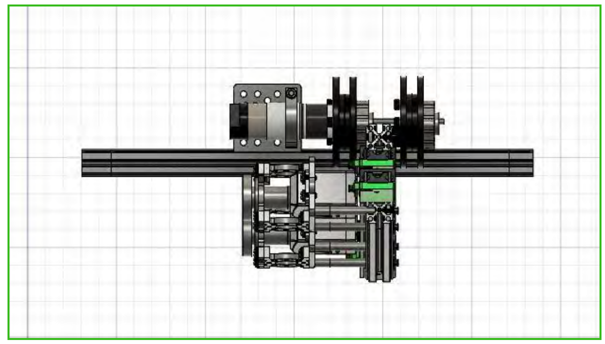
The new end caps were made using aluminum channel. We drilled four holes: two for attaching to the end of the extrusion, and two for a screw to go through both sides of the channel to a pulley and pulley cap. We also added a spacer in between the two sides of the channel to prevent them from caving in. These were much stronger than the rev plastic ones.

FINAL VERSION 2!



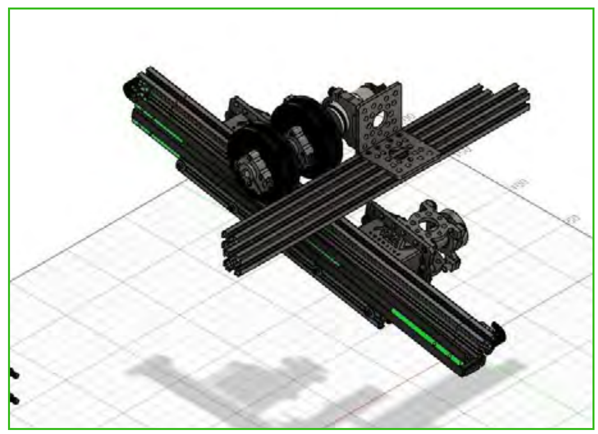
HORIZONTAL SLIDES V3 <u>DESIGN</u>





Because we decided to change the vertical slides to Long Robotics ball bearing slides, we decided to do the same to the horizontal slides for the same advantages: less friction, they're lightweight, and they're black!

In order to remove weight from the whole horizontal slide assembly, we decided to take out the extra top and bottom extrusions that were there for mounting purposes, and just use the top extrusion in order to mount the Long Robotics slides to because the top extrusion had the angled cut in it, which angled our whole horizontal slides.



We also decided to remove the capstone mechanism from the side of the horizontal slides and move it to the center in between the two claws.

In summary, the new design was quite simple, just leaving the top and bottom extrusions and mounting the new slides in between!

HORIZONTAL SLIDES V3 <u>ASSEMBLY</u>

We started by taking apart the old slides and setting the top and bottom rev extrusions aside. We then assembled the Long Robotics slides, attaching two of them together with the 3D printed parts! We then attached the two Long robotics slides to the original top and bottom extrusions. This process was very simple and took no time at all.

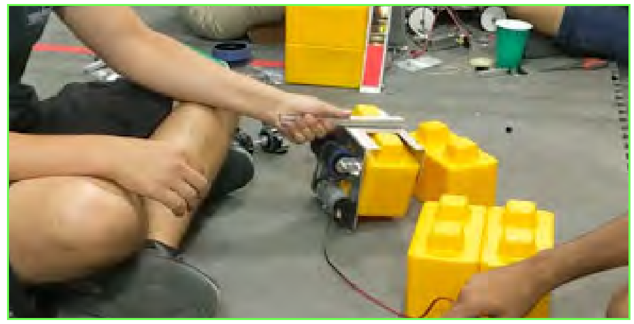
The next step was to mount them to the vertical lifts. We decided to use rev extrusion again because the slides are easy to mount to rev extrusion. We simply attached two pieces of extrusion on both ends of the horizontal extrusion that was left over from the original slides with custom plates, then mounted the two pieces of vertical extrusion to the two last stages of the vertical slides. This process was also very straightforward and took no time at all!

The last step was to string and test!

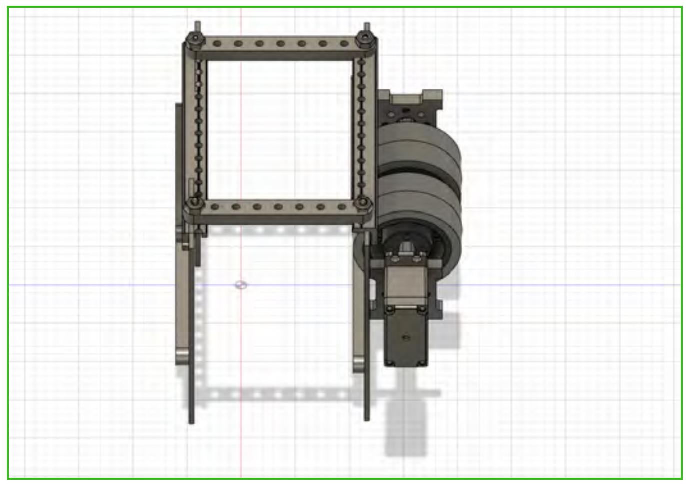
FINAL PRODUCT!

DRIVER CONTROLLED CLAW | 2 ITERATIONS

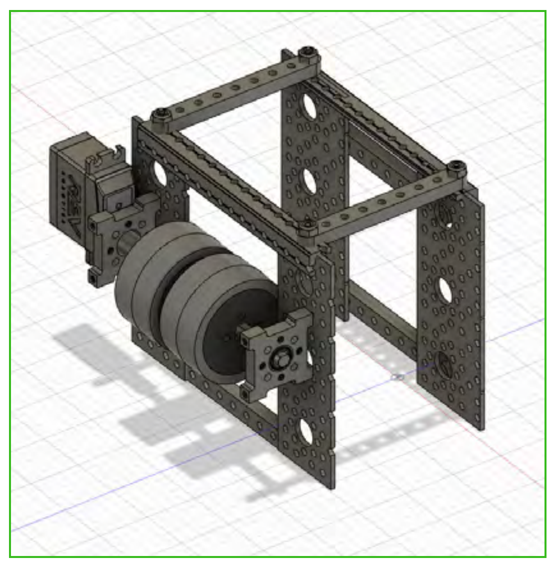
DRIVER CONTROLLED CLAW V1 DESIGN



Once we knew that we wanted to build an intake, we then had to design something that could pick the stone up from within the robot, hold it, and drop it onto the foundation. We saw an early design on youtube of a team with a mechanism that fit onto the block and had two wheels that rolled the stone or sucked the stone in and spit it out. We liked this design because we could mount it to the horizontal slides and suck the block in from within the robot and then spit it out onto the foundation once the vertical and horizontal slides were extended.



We decided to go with this design and call it the “roller claw.” We had to think about what we would use to power the wheels. We were out of motors, so we did some research on “fast servos” and found that vex motors are counted as servos in FTC, and are actually quite fast. Additionally, we thought that it would be convenient if the roller claw could rotate so that we could put the stone on the foundation in both orientations. So we decided to attach the roller claw to servo with a servo block, which would then attach to the last stage on the horizontal slide.



DRIVER CONTROLLED CLAW V1 ASSEMBLY

We were able to build the roller claw in one meeting because most of the parts were ordered from servocity and needed **almost no modification**. We also assembled the servoblock very quickly, and the roller claw was mounted in no time.

CHALLENGE 1

After running the intake with the roller claw mounted, the stone was not going straight into the roller claw on its own.

SOLUTION

We decided to add guides, and a stop at the end of the robot (so that the stone could not fly out of the back).

CHALLENGE 2

When testing the intake, we also realized that the compliance wheels were not spinning fast enough to get the stone all the way into the robot under the roller claw.

SOLUTION

We decided to add an “arm” to push the stone the rest of the way in the robot. We also added the arm to keep the stone in place when driving around until the roller claw sucked it in. We decided that a simple design for the arm would be to mount a servo to the stationary stage on the horizontal lift and add a bar to it with a plate on the end that would push the stone the rest of the way within the robot.

CHALLENGE 3

The original idea was for the intake to bring the stone into the robot, and then to have the the roller claw come down on it and suck it in, which required the vertical lifts to be extended a little bit when intaking. We began to realize that this might slow us down.

SOLUTION

We took off the plate across from the roller claw wheels and attached it to a servo, so that when the stone comes in, the plate will be out and it can slide into the claw, instead coming down on the stone and sucking it in. This eliminated the need to have the vertical lifts up when intaking a stone.

CHALLENGE 4

However, after making the previous change and testing it, we realized that the stone was following the angle of the ramp and hitting the top of the roller claw instead of coming in flat.

SOLUTION

To fix this, we mounted the 15mm extrusion between the vertical lifts a little bit higher, which raised the roller claw. We also modified the roller claw by using thinner metal at the top of it and riveting in place of large screw heads. Lastly we changed the angle of our ramp by flattening it out a little bit. All of these small changes worked quite well!

CHALLENGE 5

A few days later, we switched the wheels on the intake to 3” compliant wheels instead of 4”. This affected the length of our ramp, because when we switched to smaller wheels, the ramp hit the block before the wheels did.

SOLUTION

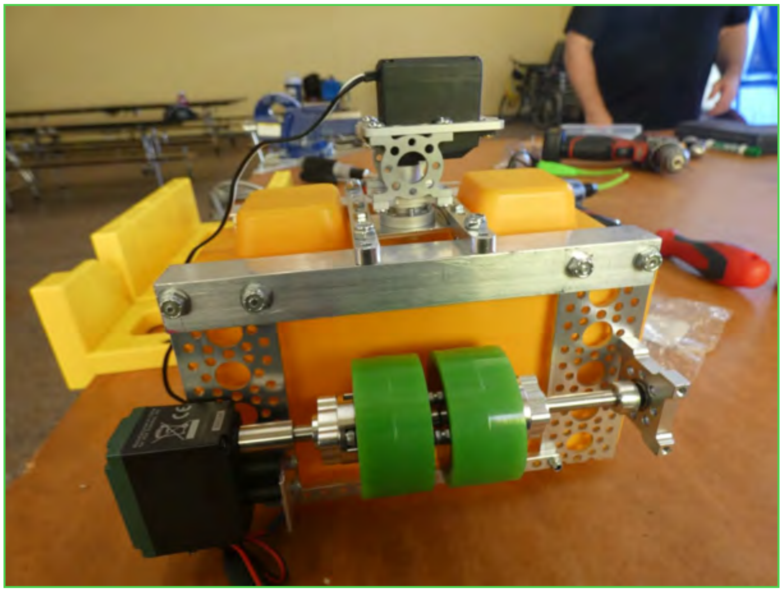
We then had to shorten the ramp and bend it down again, which increased our angle.

CHALLENGE 6

This caused the same problem that we had just fixed: the stone was following the angle of the ramp and hitting the top of the roller claw instead of coming in flat. We knew what we could not do anything more to the ramp, or to the roller claw in order to fix it, so we thought about how we could move or change the mounting of the horizontal slide.

SOLUTION

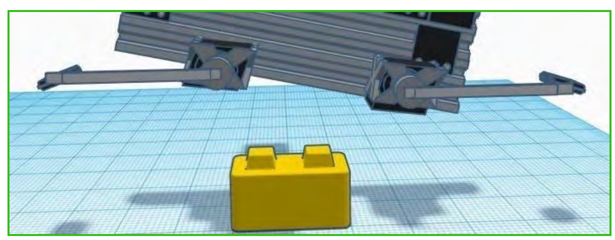
It turned out to be a very simple fix: we put a spacer under the mounting block that mounted the horizontal slide to the 15mm extrusion between the vertical lifts. This tilted the back of the horizontal slides down and the front of the slides (the side with the roller claw on it) up. With this change the block no longer hit the roller claw!



FINAL VERSION 1!

DRIVER CONTROLLED CLAW V2 DESIGN

After our qualifier in Alamogordo, we realized that our roller claw was unnecessarily complicated, having compliant wheel rollers on it, and being able to rotate. We decided to instead, replace it with a claw that grips from the front and back of the long side of the stone.

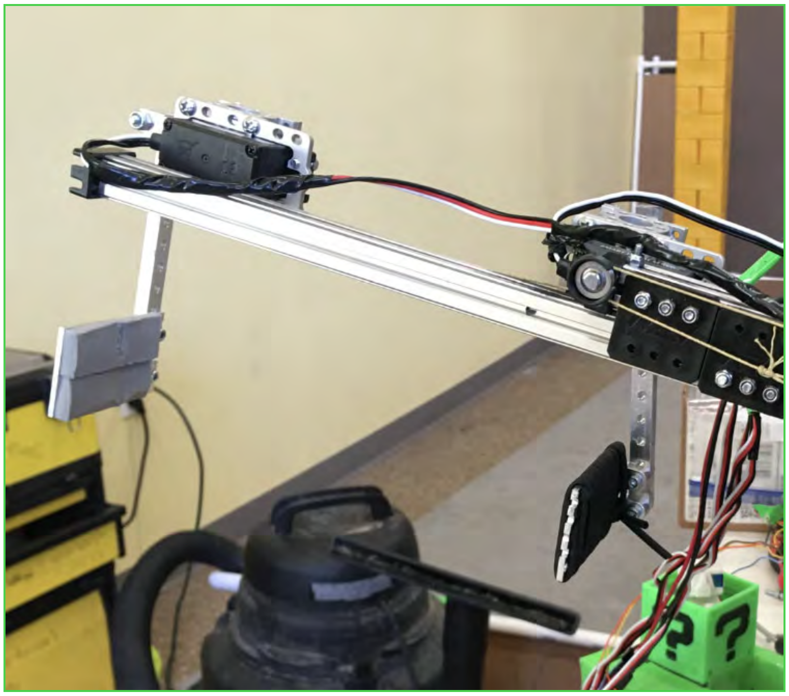


We decided to use two rev smart robot servos and servo blocks, and attach them to the bottom stage of the horizontal slides with servo city spacers. Then attach beams with plates at the end to the head of the servo blocks. We also decided it would be a good idea to add some sort of grippy surface to the plates that would be clamping onto the stones.

DRIVER CONTROLLED CLAW V2 ASSEMBLY

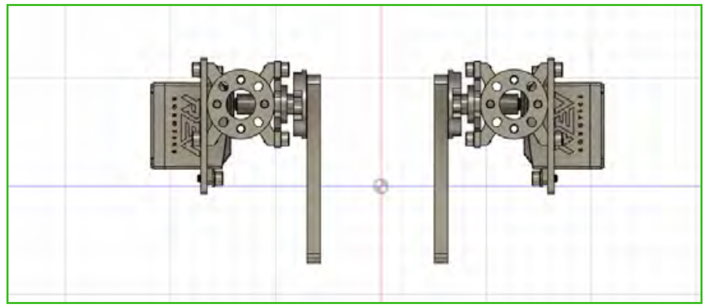
We attached two rev servos to the last stage of the horizontal slide using servo blocks and servcity spacers. We then mounted a long beam and an angled plate to the front servo and wrapped it with surgical tubing. This surgical tubing is both compliant, which helps when gripping the block, and slippery, which helps when pushing it to the other rear claw. We then mounted two beams perpendicular to each other to the other servo in the back. At the end of the beam, we attached a plate with weather stripping on it, for both compliance and a grippy surface.

FINISHED VERSION 2!

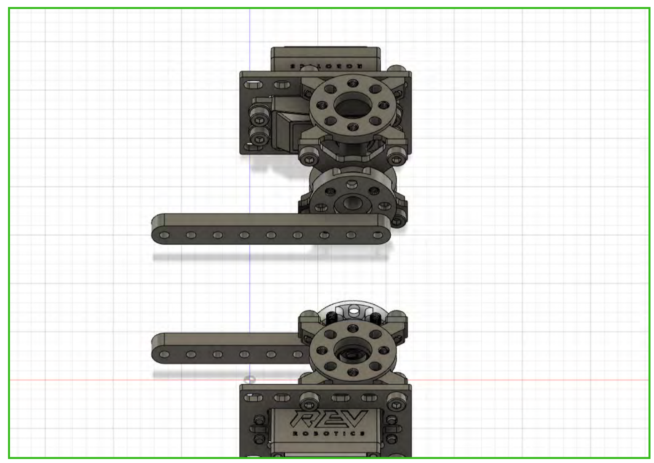


FOUNDATION MOVERS | THREE ITERATIONS

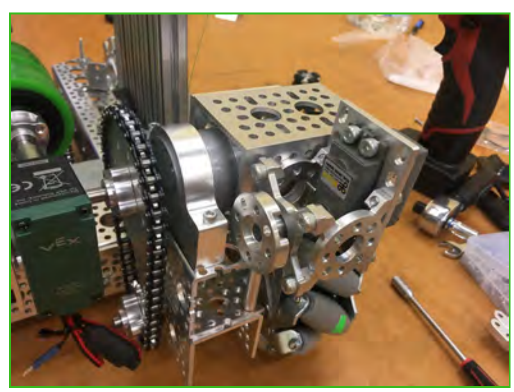
FOUNDATION MOVERS V1 DESIGN



In order to move the foundation, we went with simplicity and decided to use two servos on each side of the back of the robot with long beams attached to them, which clamp onto the foundation and move it when the robot is driven. We also decided to use servo blocks to strengthen the mounting and make sure all of the force wasn't on the head of the servo. This design was quite simple and easy to build. The only slight challenge was figuring out how and where to mount the servo blocks. These two servos were the last components of the robot that we mounted, so we did not have much space to mount them. We decided to mount them above the back motors because that seemed to be the only space on the robot that we could make work. We realized we could use some large gobuilda channel that fit over the back wheel motors and attached our servo blocks to that.

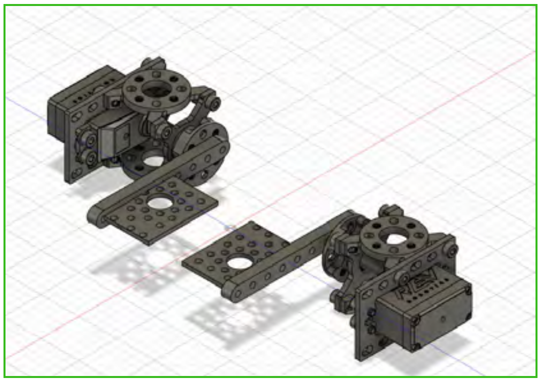


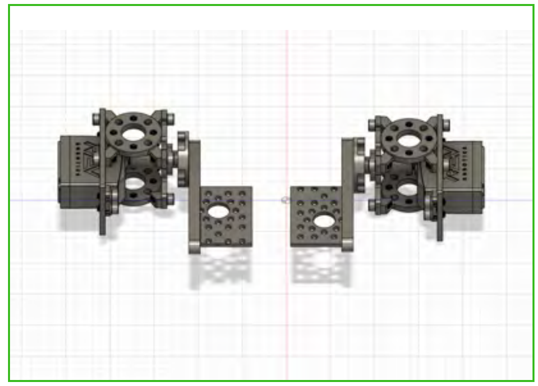
FOUNDATION MOVERS V1 ASSEMBLY



The assembly of the foundation movers was very straight forward and took less than one meeting. All we had to do was assemble the gobilda servo blocks and mount the channel above the drive motors. We then mounted the sero blocks to the channel and attached the servocity beam to the servo block! The only challenge was getting nuts on the bolts that were between the motor and gobilda channel.

FOUNDATION MOVERS V2 DESIGN





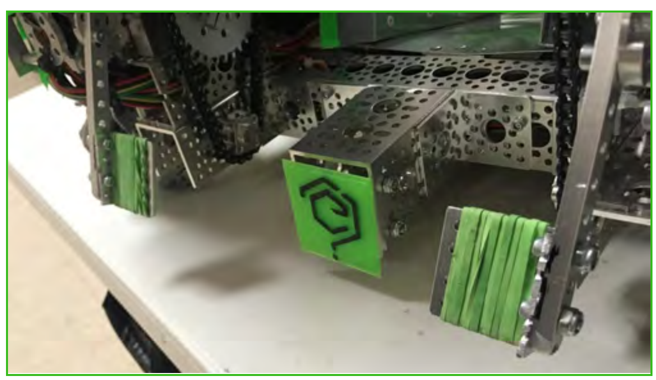
We had many issues with the foundation mover's beams slipping when pulling the foundation. We figured this was because the beam was contacting the foundation on a rounded edge with the rounded end of the beam with no grippy surface on it. We decided to fix this by adding two plates to the ends of the beams in order to increase the surface area contacting the foundation. We also decided to add rubber bands for a more grippy surface!

STATIC FRICTION

We proved our second foundation movers are better than our first foundation movers by using physics and friction. The force between the movers and the foundation is Coulomb friction which is given by this equation:Loading...The equation means friction equals coefficient of friction times normal force. So in order to use this equation we added rubber bands to the clamps on the servos which increases the coefficient of friction. Another option we had was to add more powerful servos. Stronger servos would increase normal force but to add rubber bands was simpler.

FOUNDATION MOVERS V2 ASSEMBLY

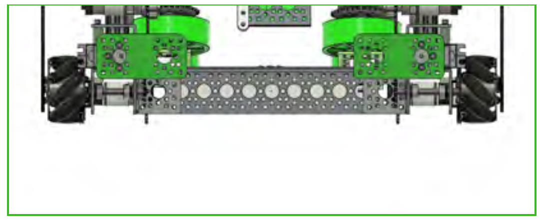
The assembly was very straightforward, as well we did was add two plates and rubber bands!



FINAL VERSION 2!

FOUNDATION MOVERS V3 DESIGN (current)

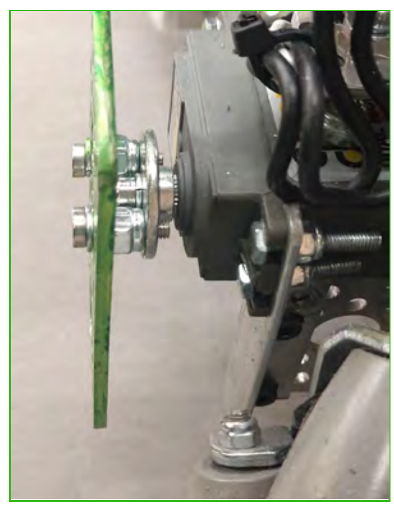
At Socorro, we still were having issues with the foundation movers slipping. In brainstorming what the issue could be, we realized that the foundation was pulling on the actual gears of the servo when pulling it. In order to fix this, we decided to rotate the servos so that they rotated sideways and the pull was on the servo head and not the gears of the servo. Unfortunately, in order to do this, we had to eliminate the servo blocks because they were too bulky for the servo to be in that orientation.



Also, instead of adding the beams with plates and rubber bands back on, we decided to make two completely new plates without rubber bands. We did not feel rubber bands were necessary because the new orientation was no longer relying on them to grip the foundation.

FOUNDATION MOVERS V3 ASSEMBLY

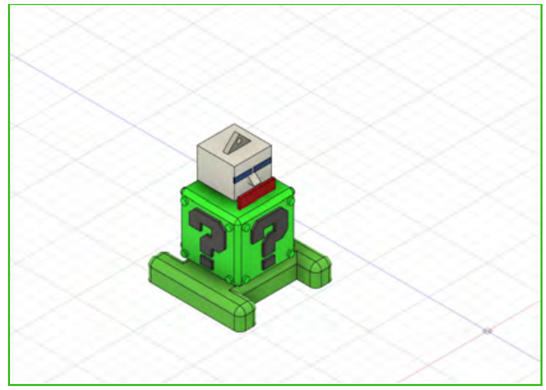
The assembly of the new foundation movers went very well. Since we could no longer use the bulky servo blocks, we made mounting plates out of Home Depot angle aluminum and made the new clamping plates out of servocity plates (we also colored it green of course).



FINAL PRODUCT!

CAPSTONE MECHANISM | 2 ITERATIONS

CAPSTONE MECHANISM V1 DESIGN



After the Alamogordo qualifier, we decided that it would be best to design and build an “endgame mechanism,” because picking up the capstone from the depot takes too much time.

Coach Russ suggested the design of having a box that we preload the capstone into, with a hole at the top that a pin with string can attach to. The string would be tied to a servo, and when the servo moved to a different position, it would pull the string and release the capstone.

CAPSTONE MECHANISM V1 ASSEMBLY

The first thing we did was make our new capstone. This capstone would have to have a portion of it that fit in our box, and that also fit a pin through it. We cut up some foam, and glued a 3D printed question cube to it, and then taped the whole thing. We also added a little robot that a team gave us at a competition inside of the box. Lastly, we glued a “key” to the head of the little robot. This key is a small plate that fits through the top of the box that held the capstone in and prevented it from swinging around.

The next step was to figure out the box that would hold the capstone. We looked around the shop and decided to try to make it out of servo city 90 degree brackets and aluminum sheets.

CHALLENGE 1

However, after we finished, we realized it was too big and much too heavy.

SOLUTION

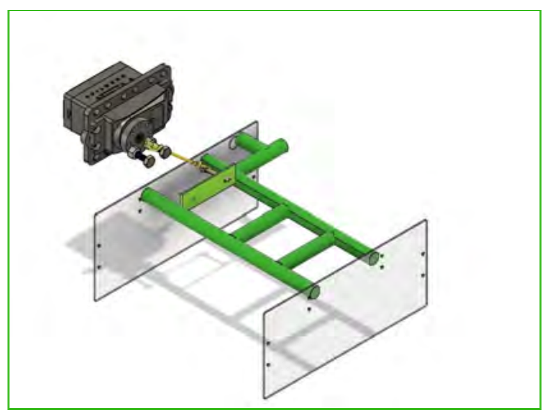
As there is an Albertsons right next to our shop, we decided to take a trip there and see if they had any sort of lightweight small box that would work. After looking around for sometime, we found a toy fortnite crate that was perfect! So, we bought the toy, brought it to the shop, cut a hole in the top for the key to be stuck through, and it worked!

Next we had to figure out how to mount the servo that would pull the pin. We decided to mount it directly to the box with zip ties, which was quite simple. We then attached the servo head with string and a pin attached. Lastly, we mounted it to the side of the last stage of the horizontal slide with a servocity beam.

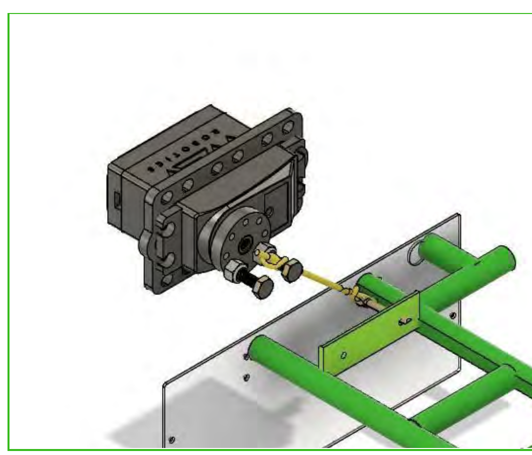
The final step was to test it: it worked! The capstone could now be pre-loaded in our robot, and dropped onto our last stack by pulling the pin with the servo!

FINAL VERSION 1!

CAPSTONE MECHANISM V2 DESIGN



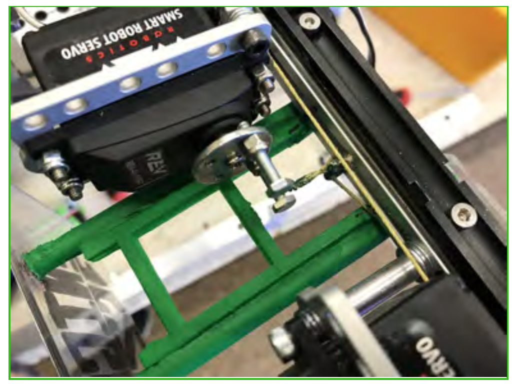
After Sandia Park, we decided to change our capstone mechanism to drop the capstone directly onto the last stone within our robot, instead of having to strafe over and place the capstone separately onto the skyscraper -this wasted time.



In order to accomplish this, we needed to design a very low profile capstone that could fit in between the both sides of the claw. We started off by thinking about how we would deploy the capstone. Since our original pull pin design was unique and quite effective, we decided to do the same thing for the new capstone mechanism. With this in mind, we needed to design our capstone with some sort of key like the last one. Since we did not have room for a huge box in between the claw, we decided to use the rev extrusion as a fitting for the key, which meant we had to design the new capstone with a key that fit in the rev extrusion.

We 3D modeled the key with some extra mounting surface and printed it, and decided to work off of that in order to assemble our new capstone. The rest was just transferring the servo with the pull pin to the extrusion between both sides of the claw!

CAPSTONE MECHANISM V2 ASSEMBLY



The assembly of the new capstone took a whole meeting, but we were super happy with the product! We started out with the 3D printed key, and glued small pieces of wooden dowel to form a frame. We then attached some plexi glass to wrap around the stone. Lastly, we spray painted the frame and Jenna colored on some ENIGMA art work and our number!
After the capstone was done, we started attaching the servo that would pull the pin in between the both sides of the claw on the horizontal slide. We used half of a servo block to attach the servo to the rev extrusion. We then drilled a hole in the extrusion for the pin to go through, and we were done!

PARKING MECHANISM

PARKING MECHANISM V1 DESIGN

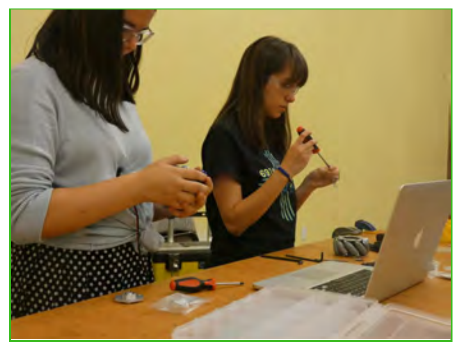
After Alamogordo, we identified the need for some sort of parking mechanism as we were having a lot of trouble fitting both us and our alliance partner in the building site.

We thought of the simplest way to implement a parking mechanism, and came up with a dowel rod that flips out on the end of the horizontal slide.

The benefit to having the parking mechanism on the horizontal slide was so it could reach over other robots, in case we needed to park “above them”.

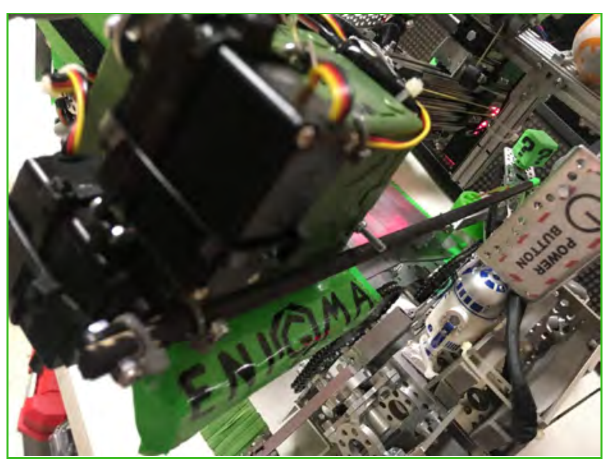
Our design was very simple: a servo on the end of the horizontal slide with a wooden dowel attached to the servo head.

PARKING MECHANISM V1 ASSEMBLY

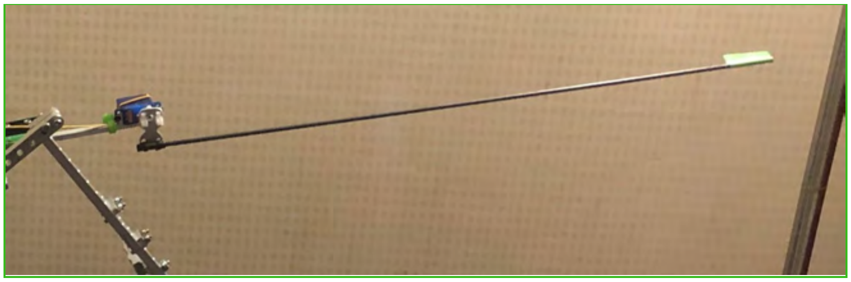


The assembly of the new parking mechanism was relatively simple. We just zip tied the servo onto the box that held our capstone, attached an aluminum servo head, and attached the wooden dowel. We also added a little flag to the end of the dowel for aesthetic!

FINAL VERSION 1!

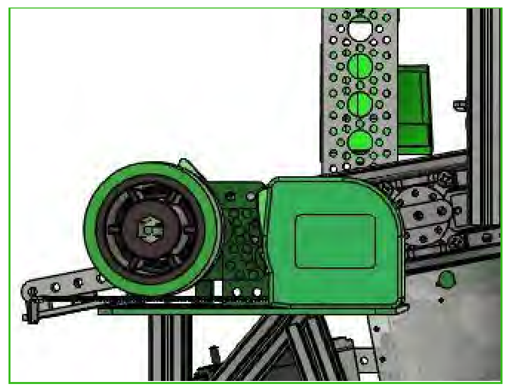


After we took off the old capstone mechanism and moved it to the middle of the horizontal slide, we had to re mount the servo and dowel. We decided to use a super small servo to remove weight and replace the wooden dowel with **a small carbon fiber rod.** This made the whole mechanism much lower profile and lightweight!



ADDITIONAL PARKING MECHANISM DESIGN

After Sandia Park, we decided we wanted to add a parking mechanism that could park from father away and from lower to the ground, especially because we wanted to be able to park under the bridge in autonomous without the robot having to drive under. We had seen a lot of teams add a tape measure driven by a small compliant wheel to their robot in order to park. We liked the simplicity and effectiveness of this, so we decided to implement it into our own robot!



ADDITIONAL PARKING MECHANISM V2 ASSEMBLY

We went to Home depot and bought a tape measure that would stay up without breaking for 16ft! We then attached that to a servocity plate and attached a vex motor to a compliance wheel and jammed a part of the tape measure under the compliance wheel. We also build a structure out of rev extrusion to hold the whole mechanism.

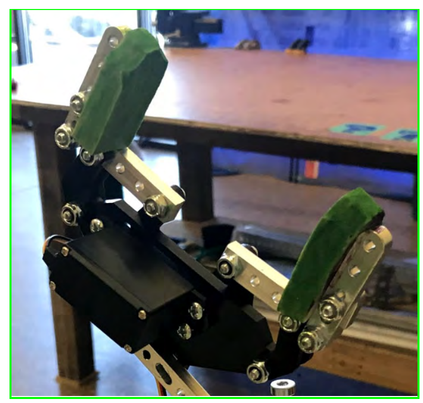
FINAL PRODUCT!

AUTONOMOUS CLAW

AUTO CLAW V1 DESIGN

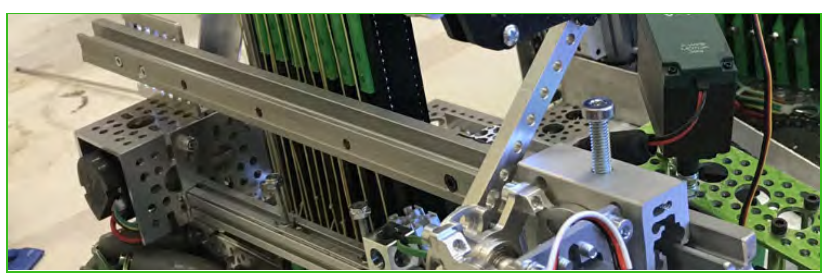
After Sandia Park, we decided we wanted to add a claw for autonomous that would obtain the stones instead of the intake, which was taking too long to get the stones. Our initial thought was to use a servo to rotate the claw down onto the stone, and another servo to clamp the two sides of the claw. We found a claw kit on servo city and decided to try that. Another thing we needed to think about was being on different sides of the field. If we mounted the claw far to one side of the robot for red alliance, the claw would not be able to get the stone to the wall on the blue alliance because the robot would be flipped. With that in mind, we decided to buy a rail with a sliding platform that we could mount the claw on. Then, in between matches, we would simply slide the claw to the either the left or right side of the side of the robot depending on which alliance we got.

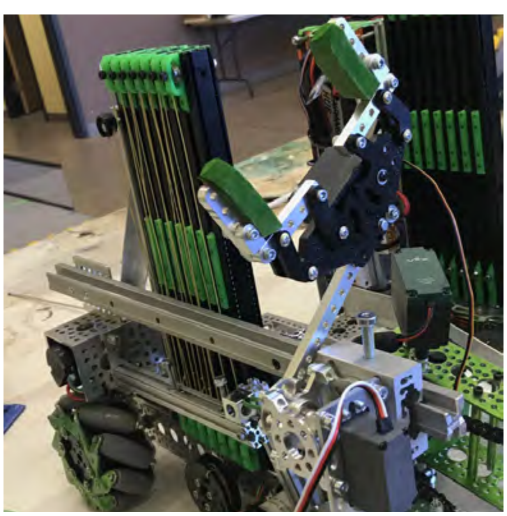
AUTO CLAW V1 ASSEMBLY



We started by mounting the rail that we bought from McMaster, which is the claw would slide on. On the left side, we mounted the rail to the go bilda channel that covered our rear left motor, and the other side we mounted it to some...

After the rail was mounted, we mounted a go bilda servo with a servo block to the sliding platform. We then assembled the servo city claw kit and attached that to a beam which was attached to the head of the servo.

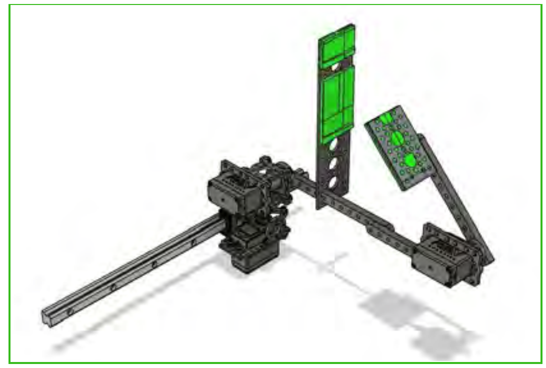


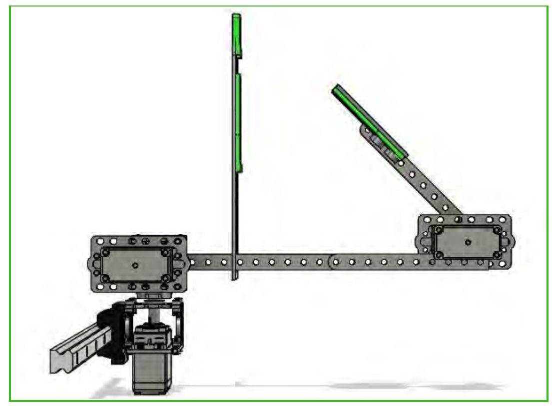


FINAL VERSION 1

AUTO CLAW V2 DESIGN

After some initial testing, we realized that the claw had very little margin for error because both sides of the claw moved in linearly, so the robot would have to perfectly align with the stone in order to pick it up in autonomous. We decided to redo the claw, so that one side opened up and rotated down onto the stone instead of linearly sliding in like the servo city claw kit; then the other side would stay static.

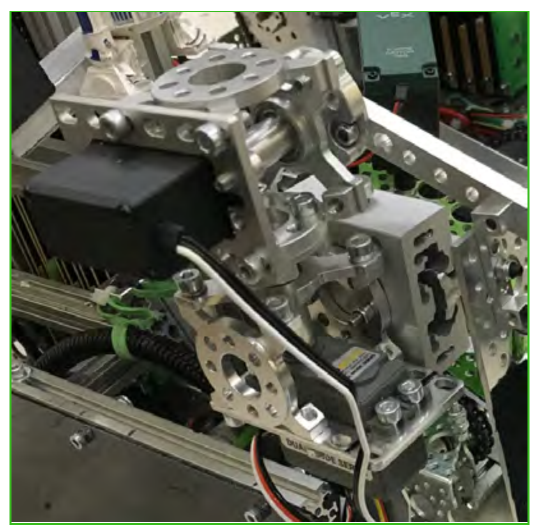




We also started thinking about the robots movement in autonomous. If we could somehow have the claw swing the stone out of the way of the skybridge, the robot could drive back and forth between the stones and foundation without having strafe over in order to avoid hitting the skybridge with the stone. In order to accomplish this, we knew we had to add a servo.

We decided to flip the original go bilda servo so that it spun the claw on the z axis, and add a rev servo with a servo block to that servo head. The rev servo would rotate the claw up and down on the y axis as the go bilda servo originally did. Then attach the actual clamping claw to the rev servo.

AUTO CLAW V2 ASSEMBLY



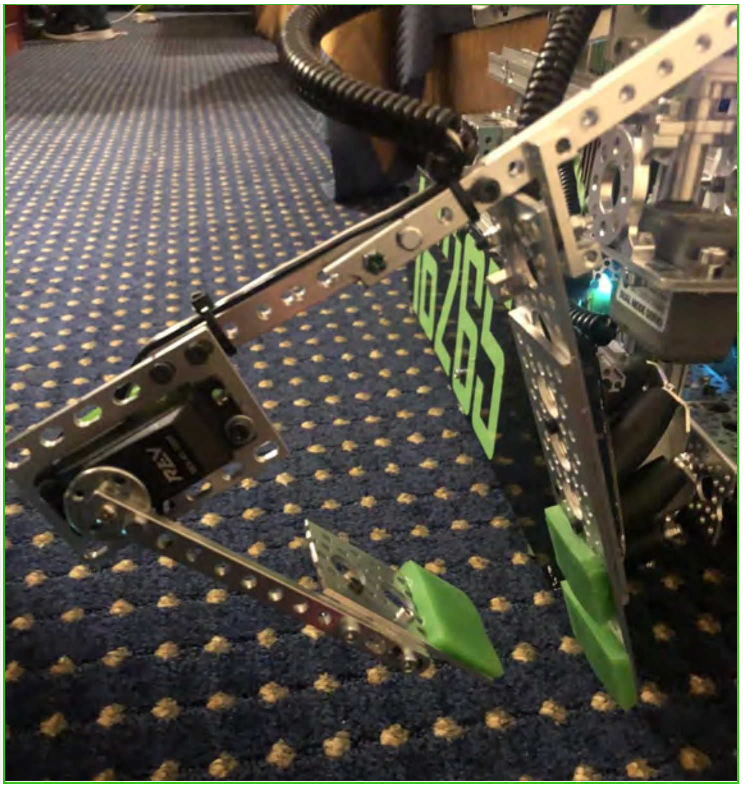
We first took apart the servo city claw kit, and flipped the go bilda servo so that it would rotate on the z axis.

We then assembled another servo block and attached the rev servo to the head of the go bilda servo for rotation on the y axis.

After the first two servos were mounted, we attached a beam to the y axis servo and mounted a long static plate that the claw would clamp against. A little farther down the beam, we mounted another rev servo with part of a servo block, and attached another beam to the head of that servo with a small plate, which would rotate down and clamp onto the stone.

Lastly, added hockey tape to the static plate and cut some rubber off of a compliance wheel and attached that to both the long static plate and small clamping plate.

FINAL PRODUCT!



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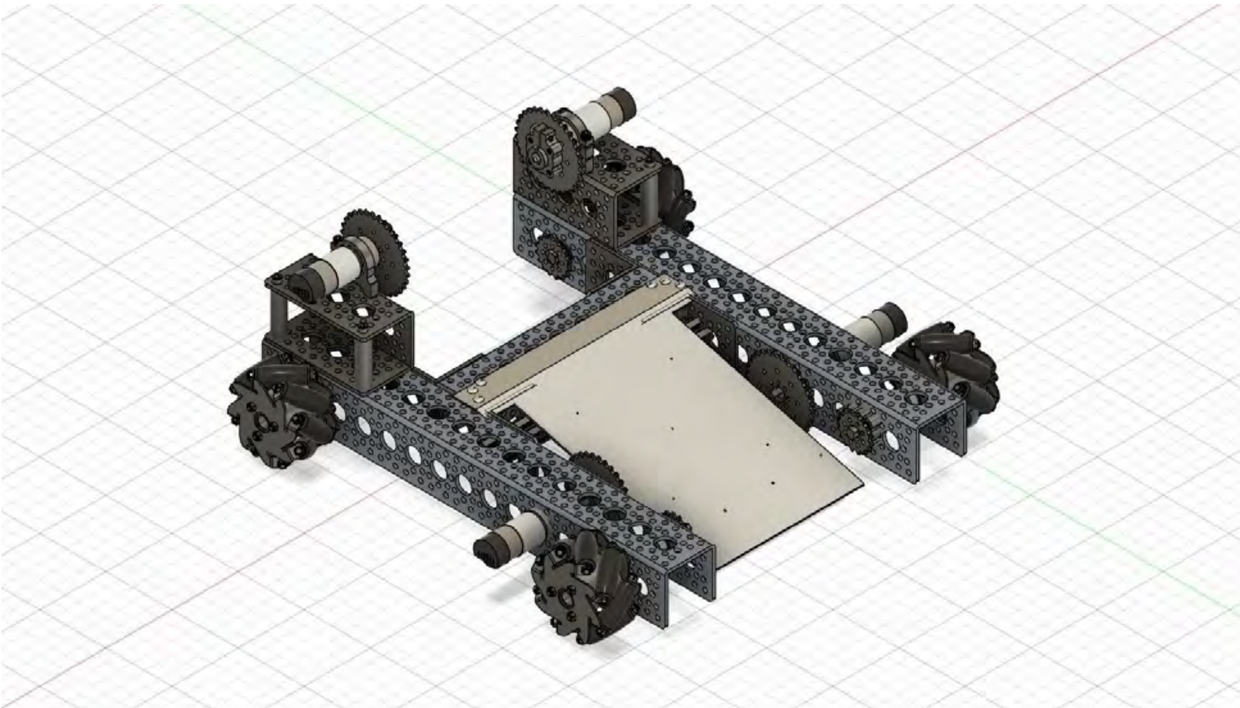

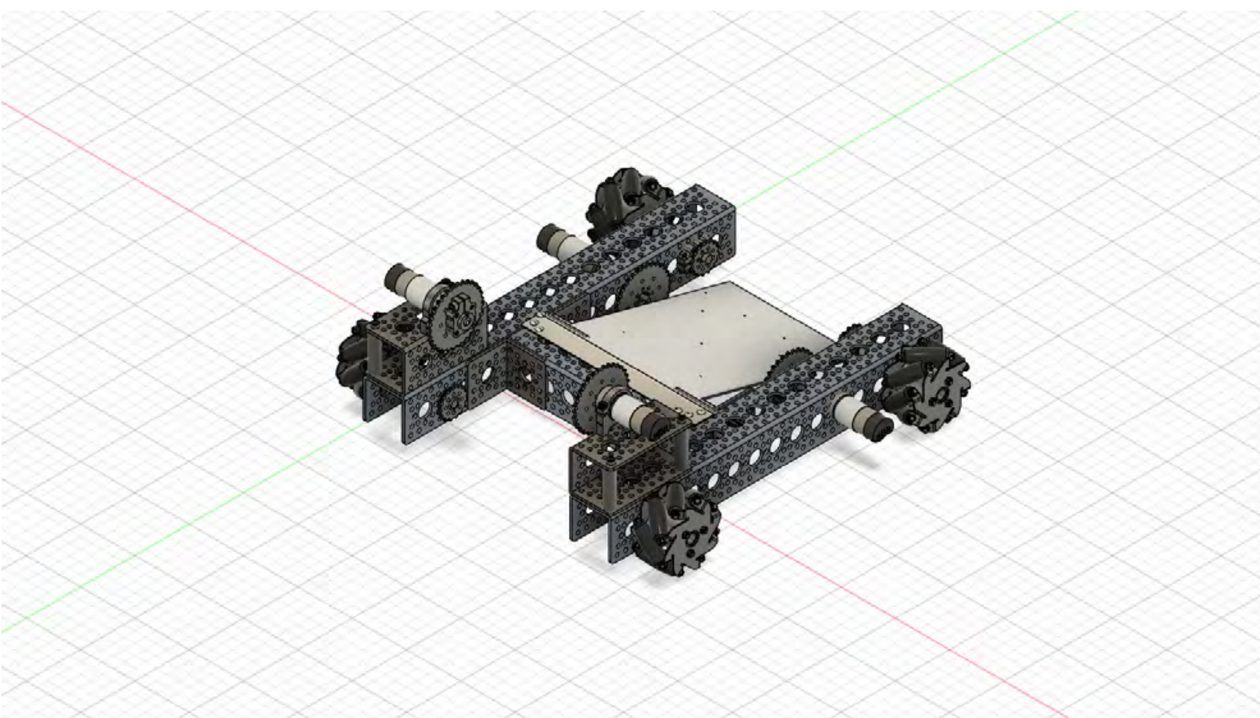

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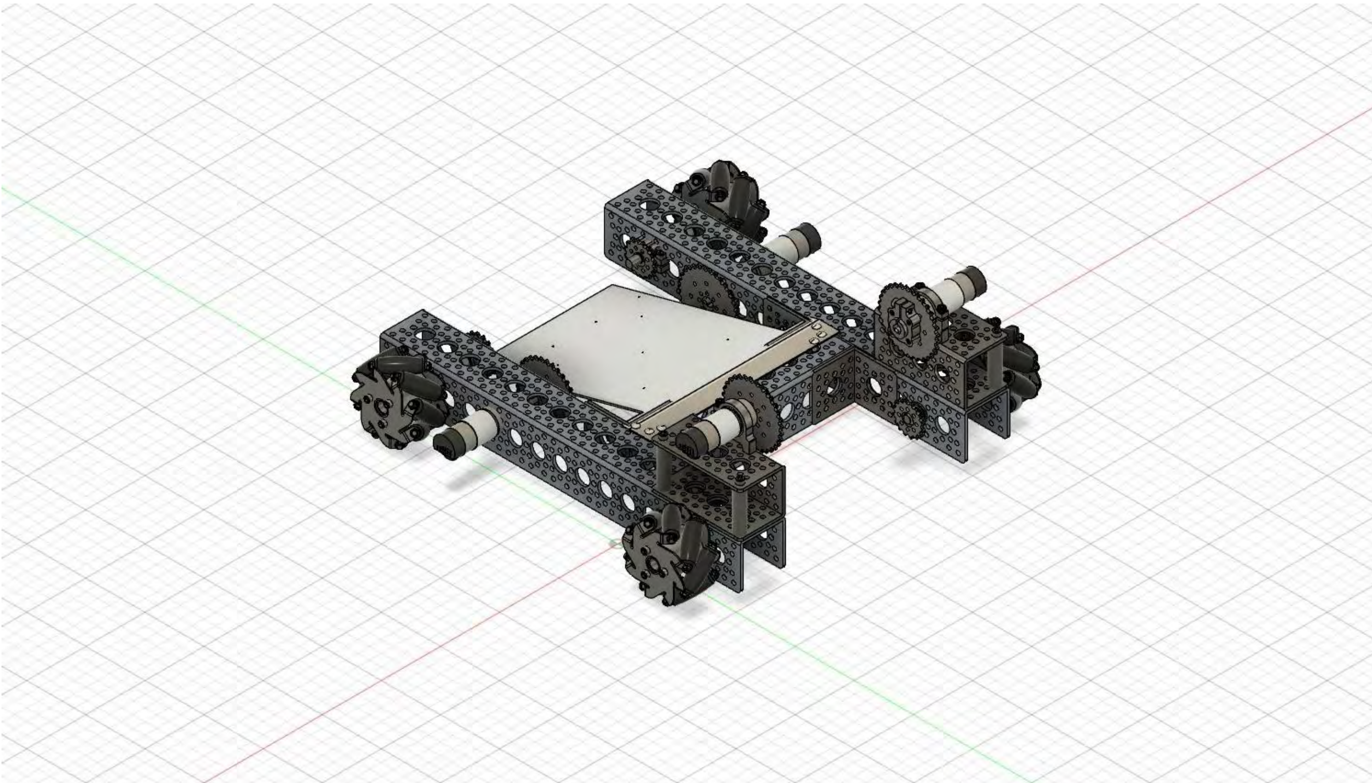

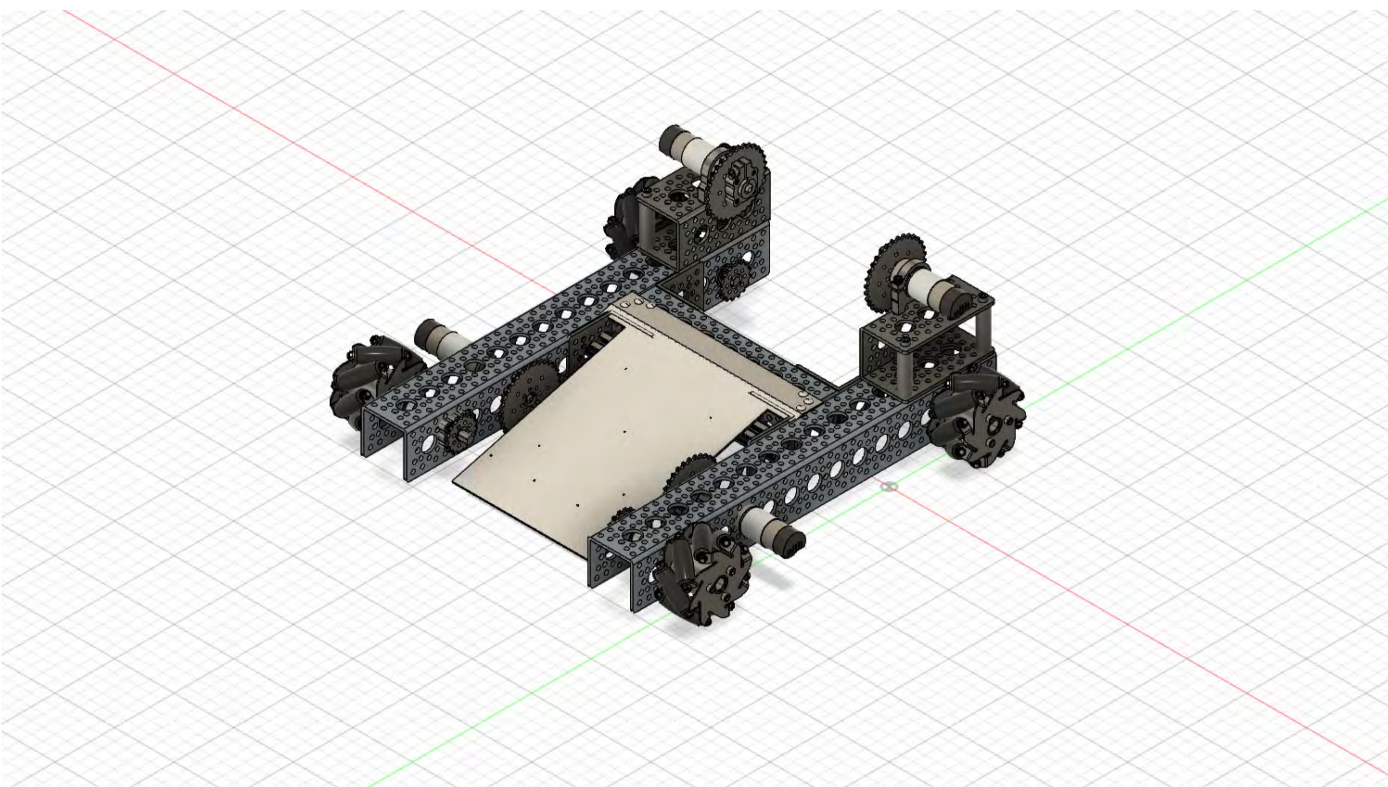

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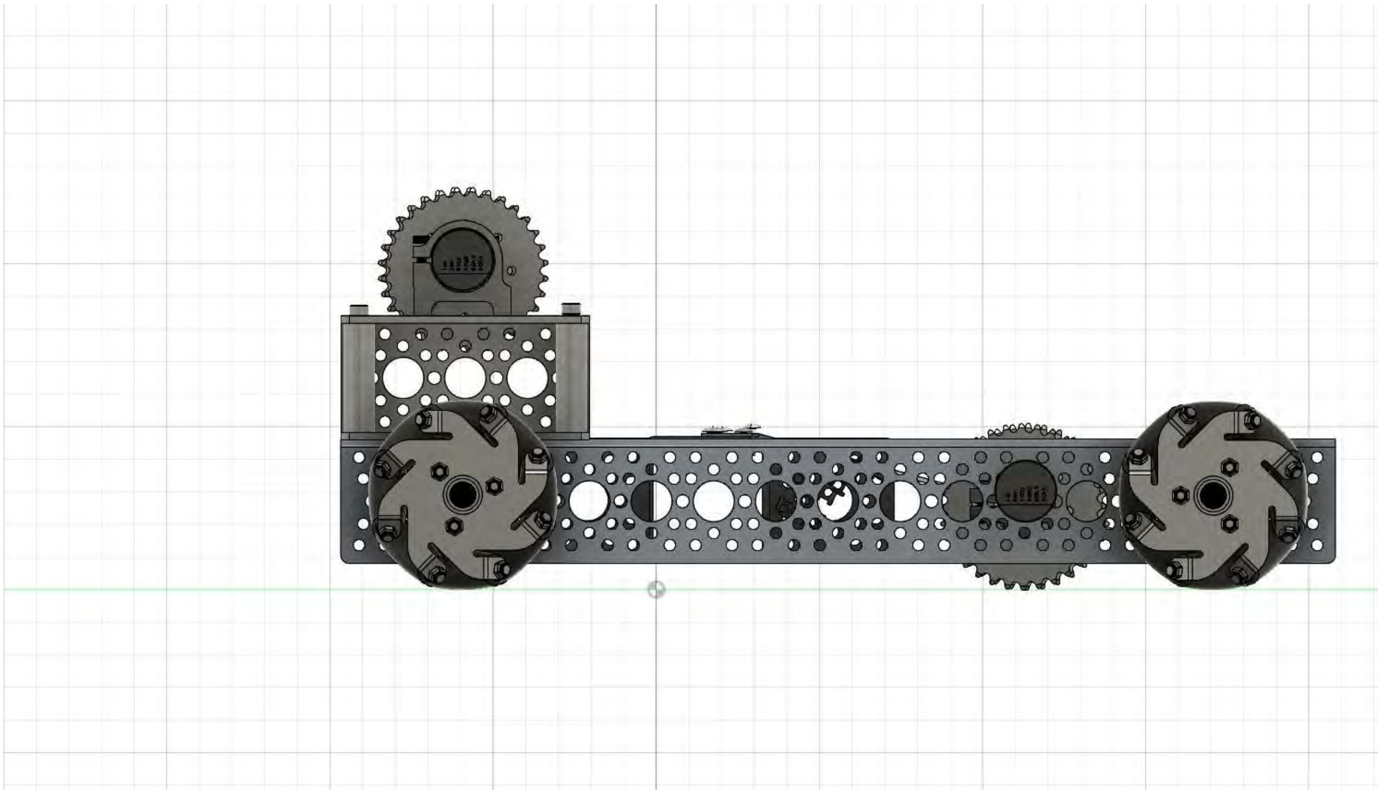

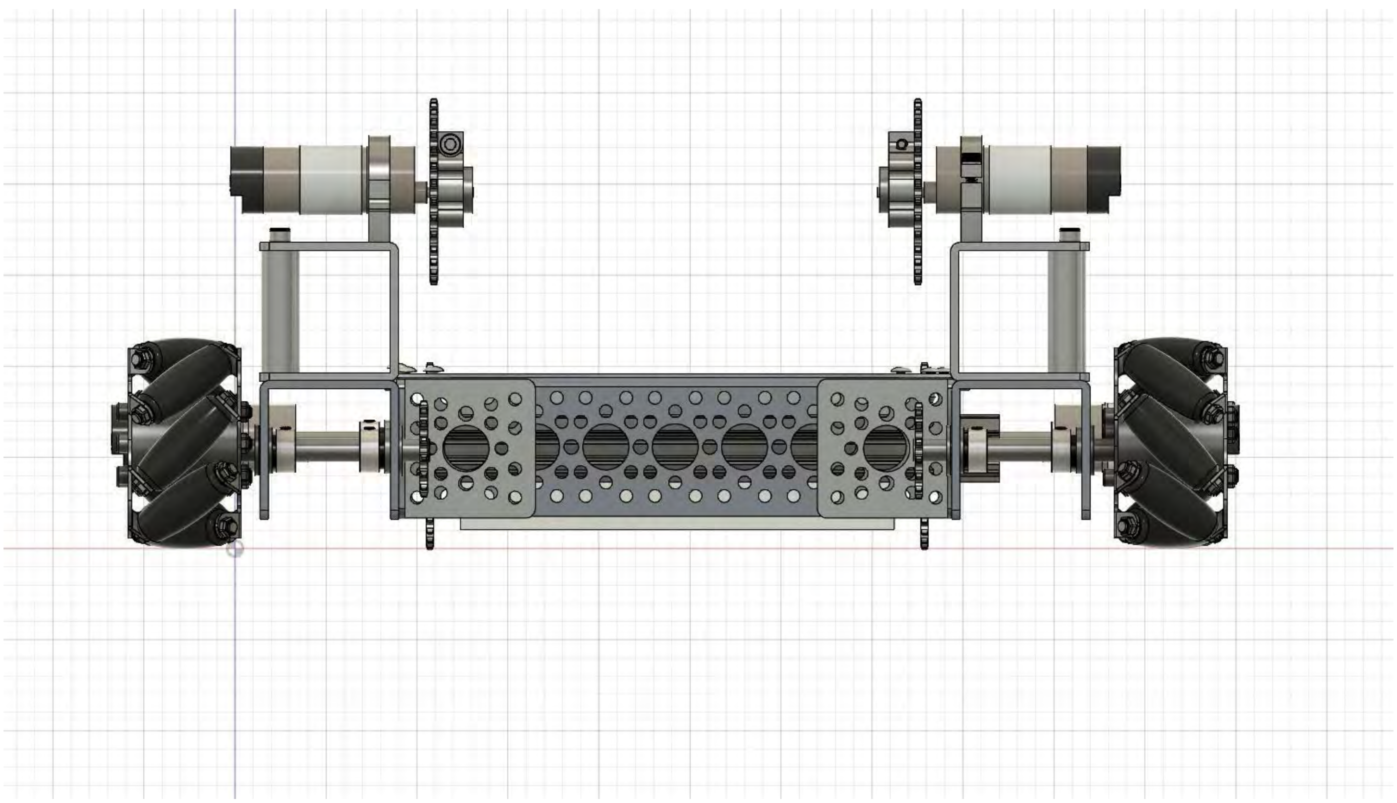

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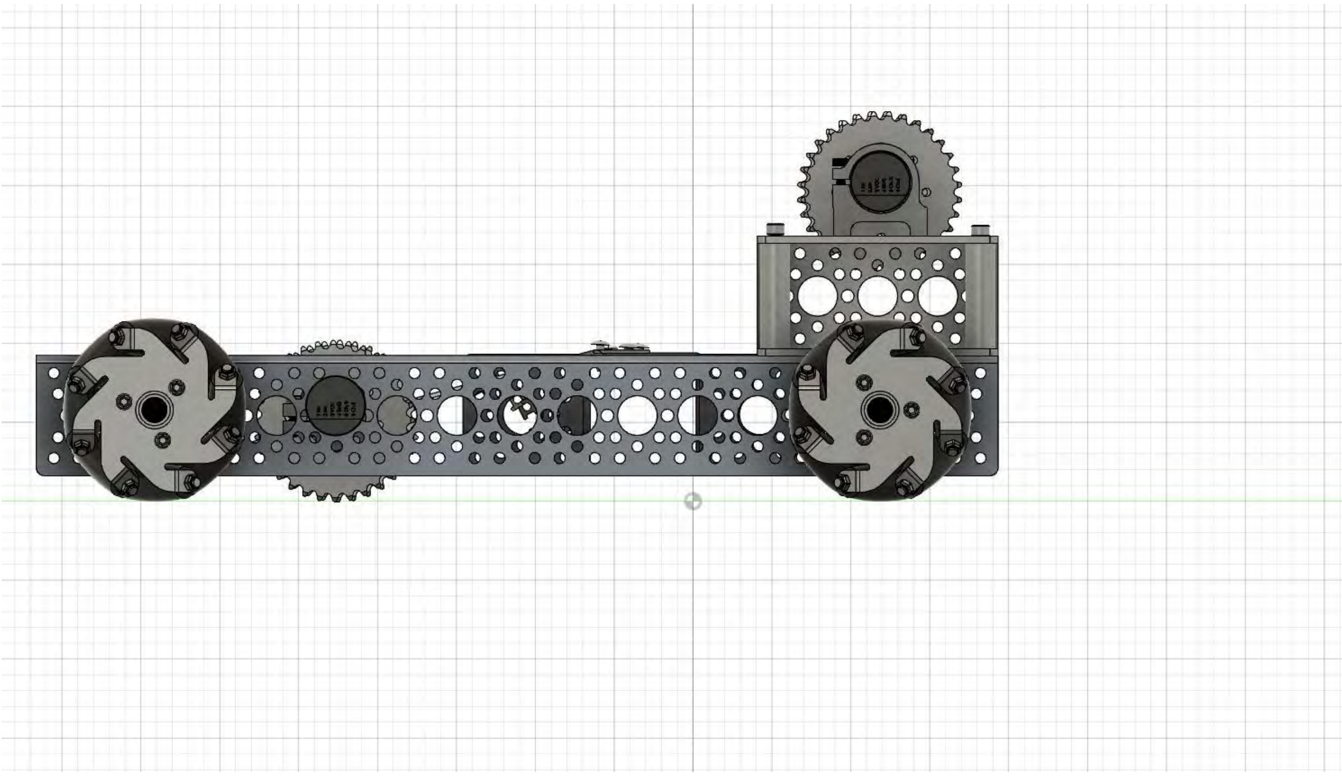
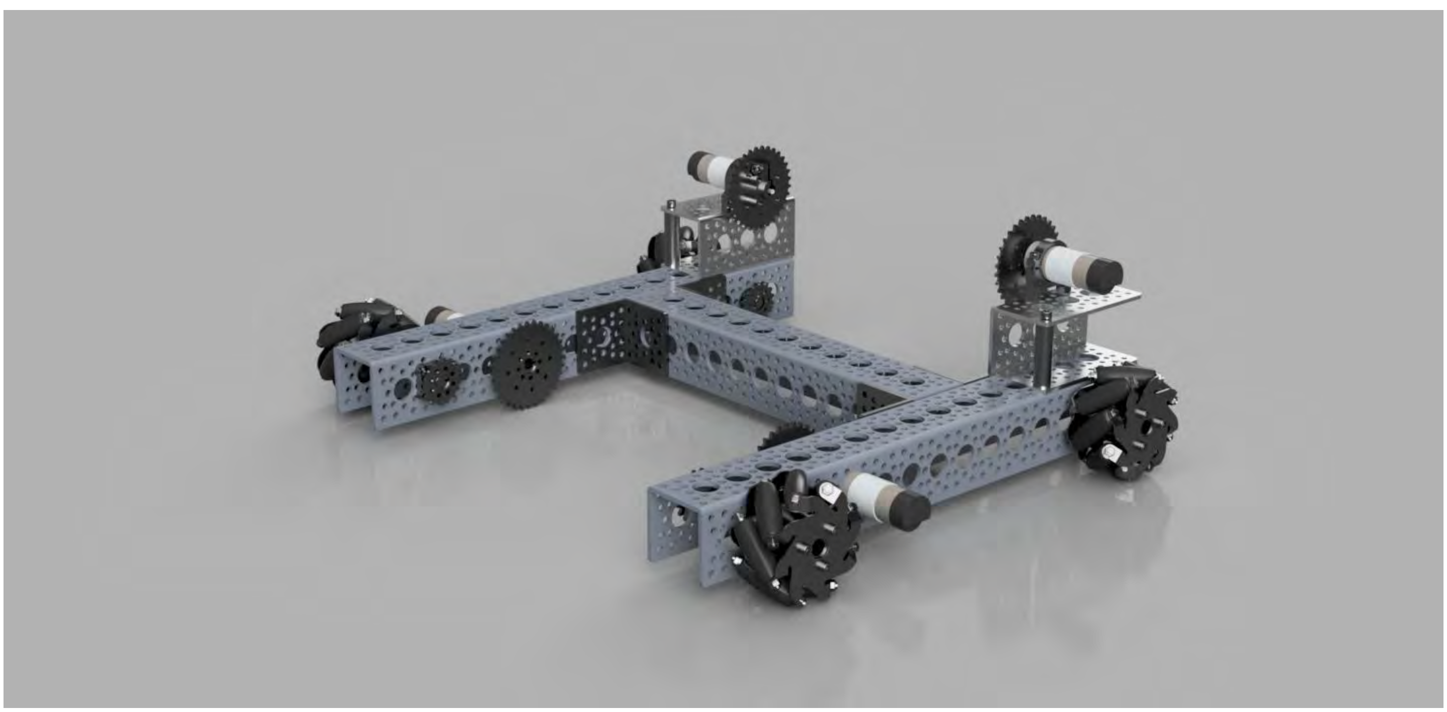
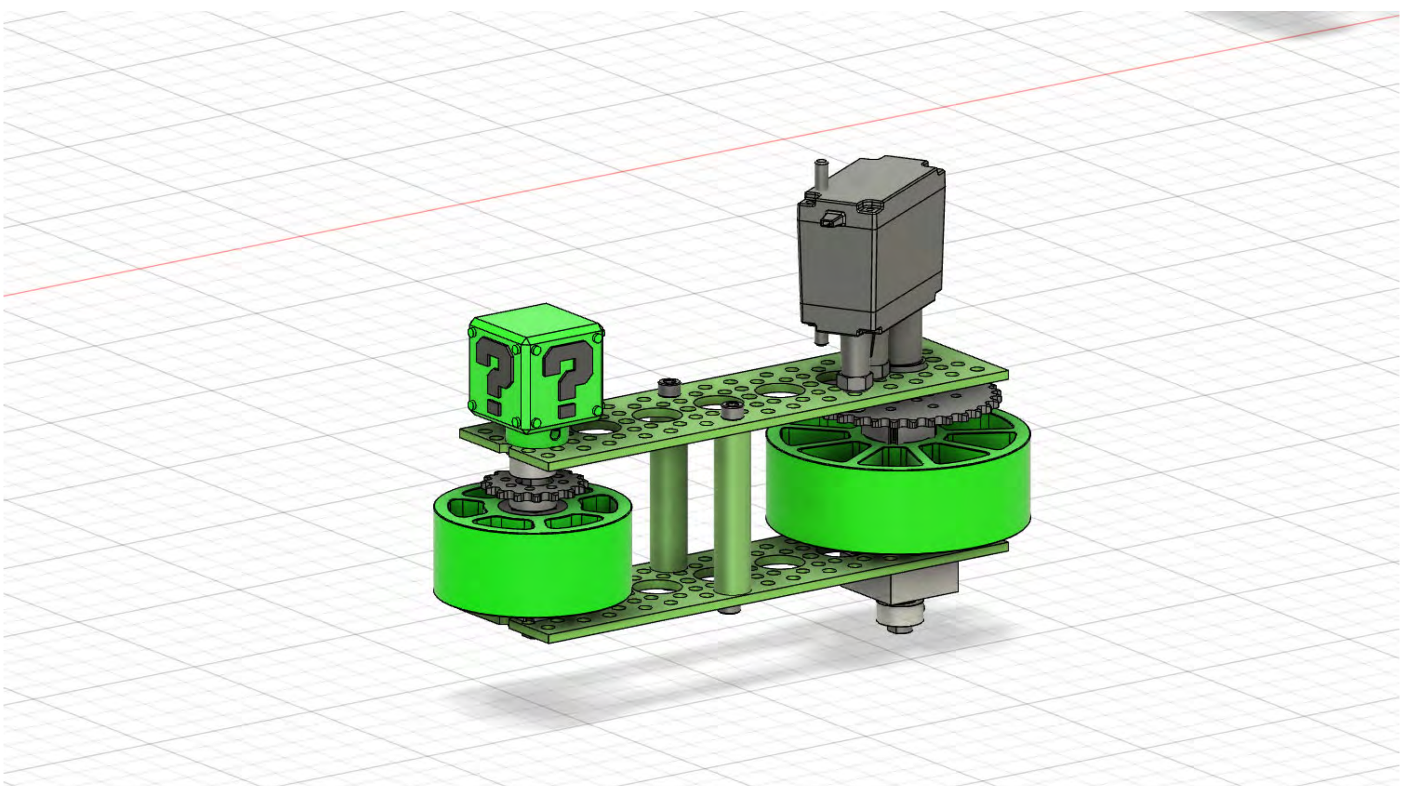




CURRENT CHASSIS

CURRENT INTAKE



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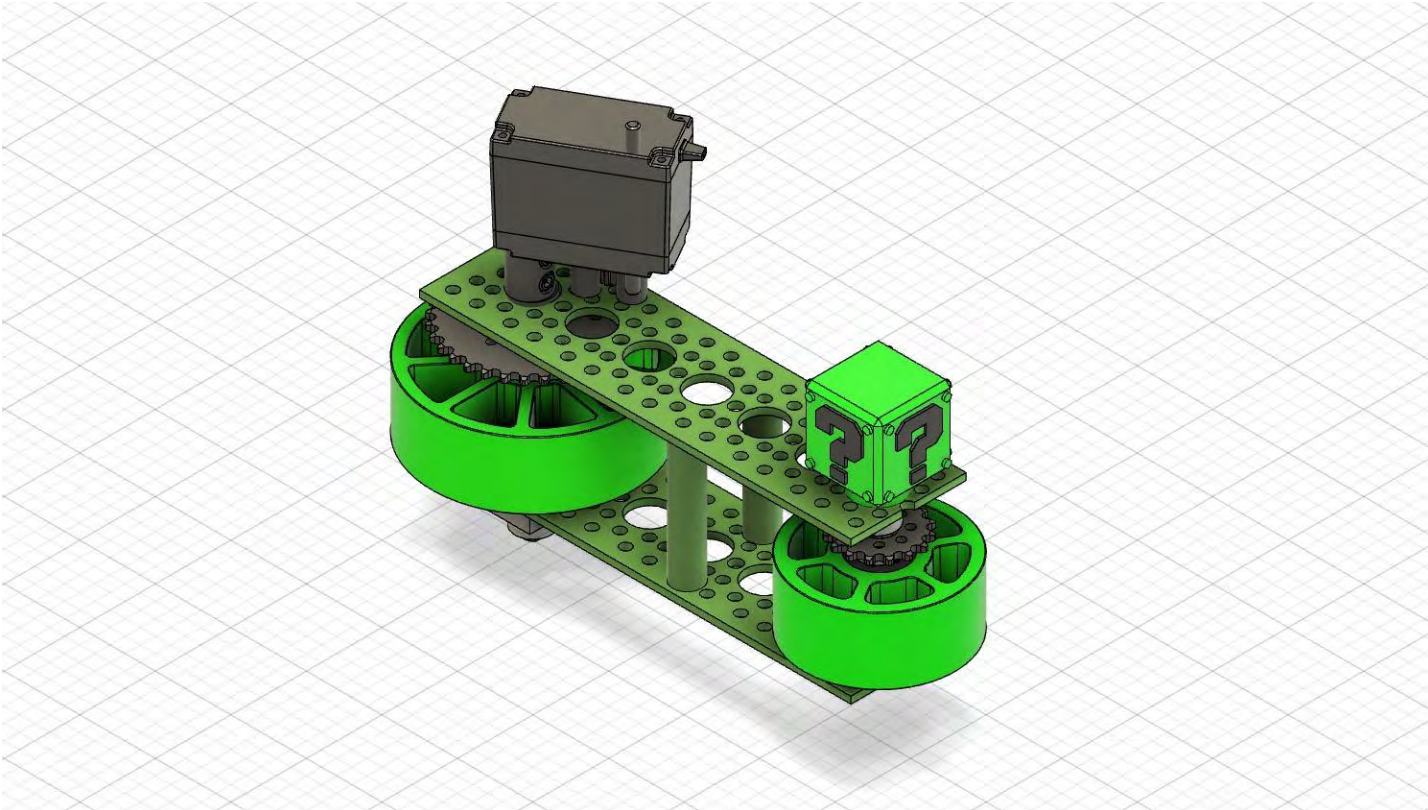

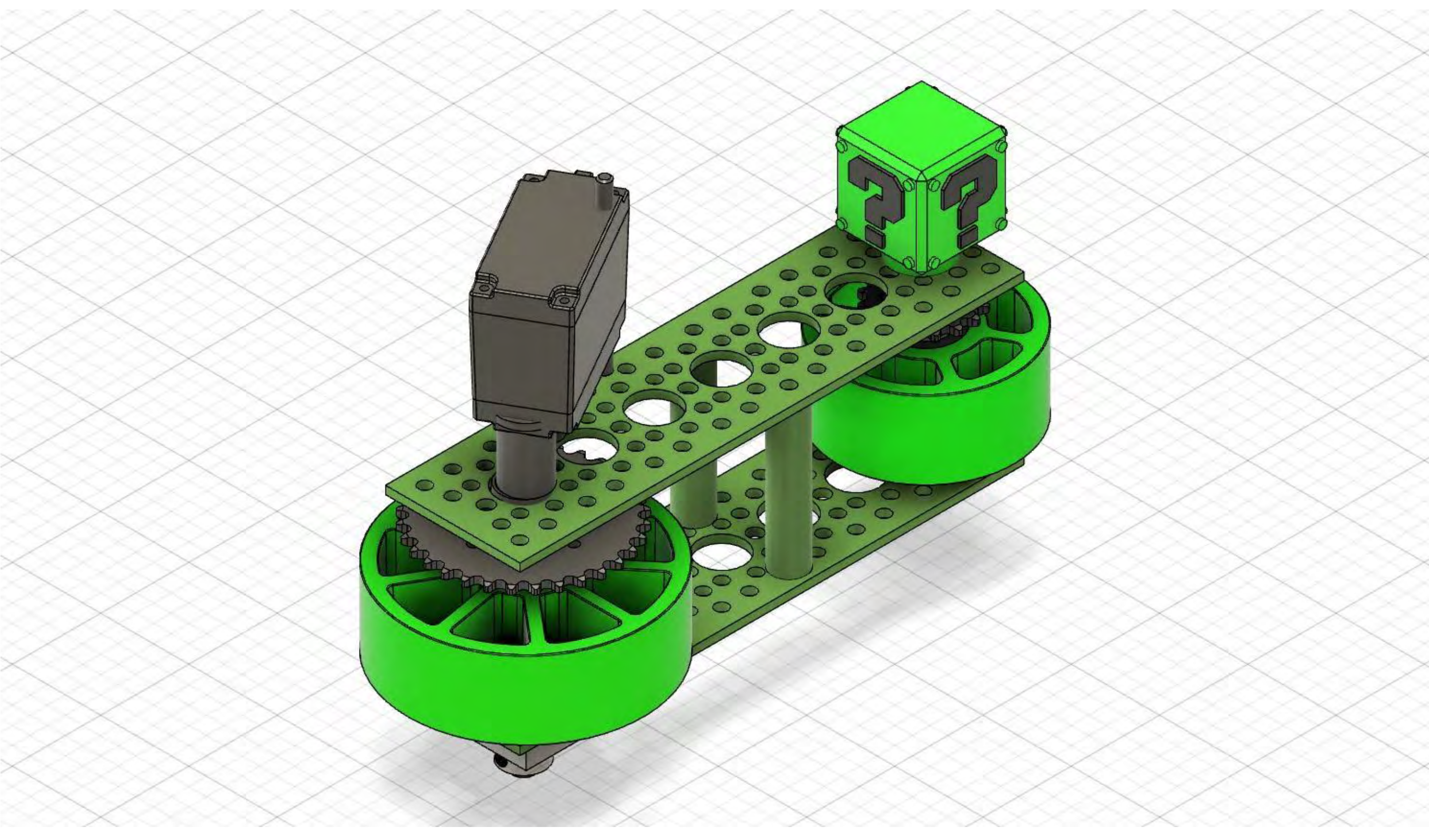

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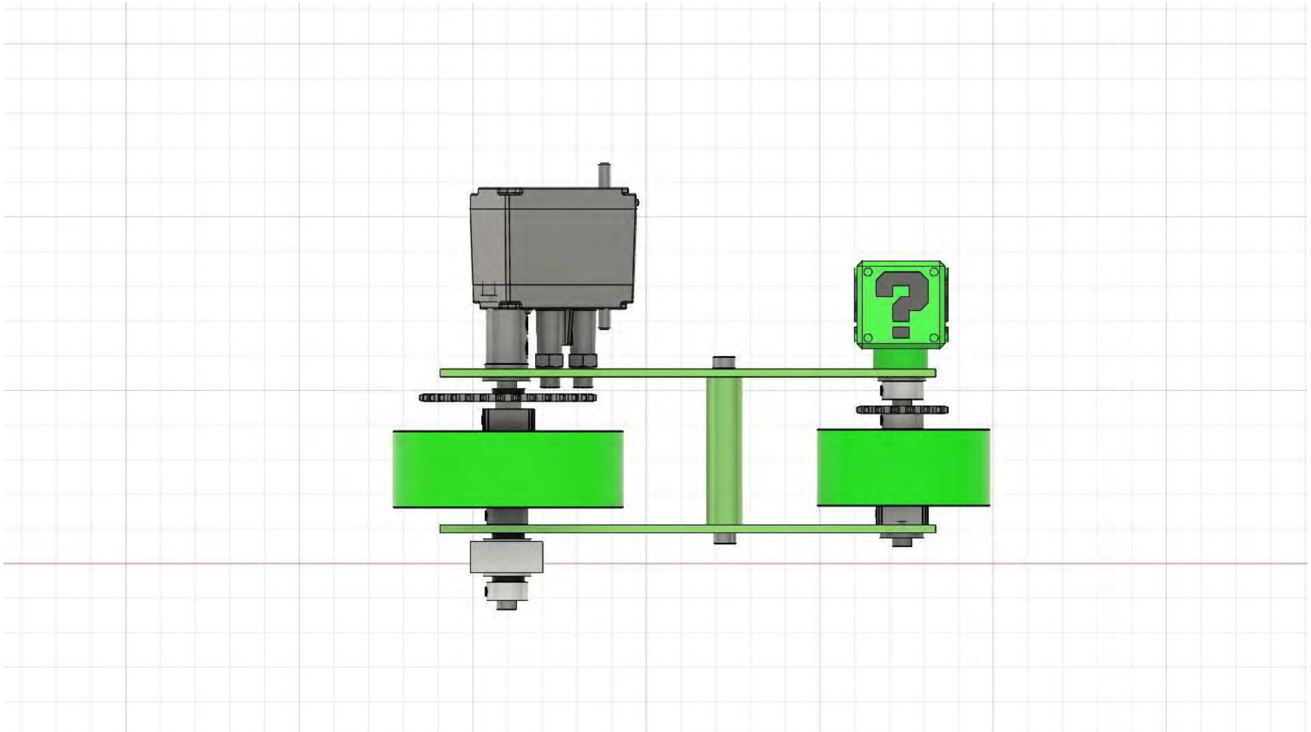

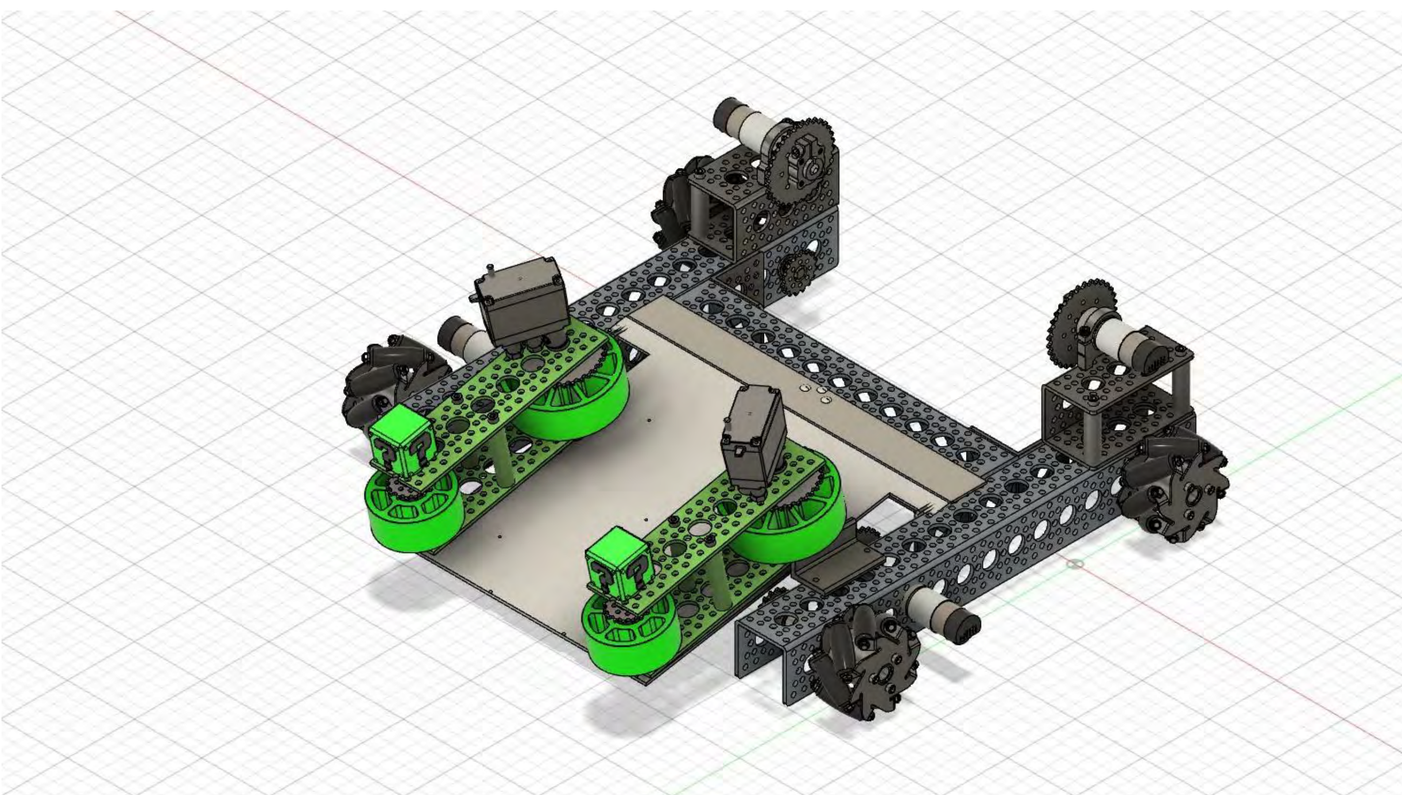

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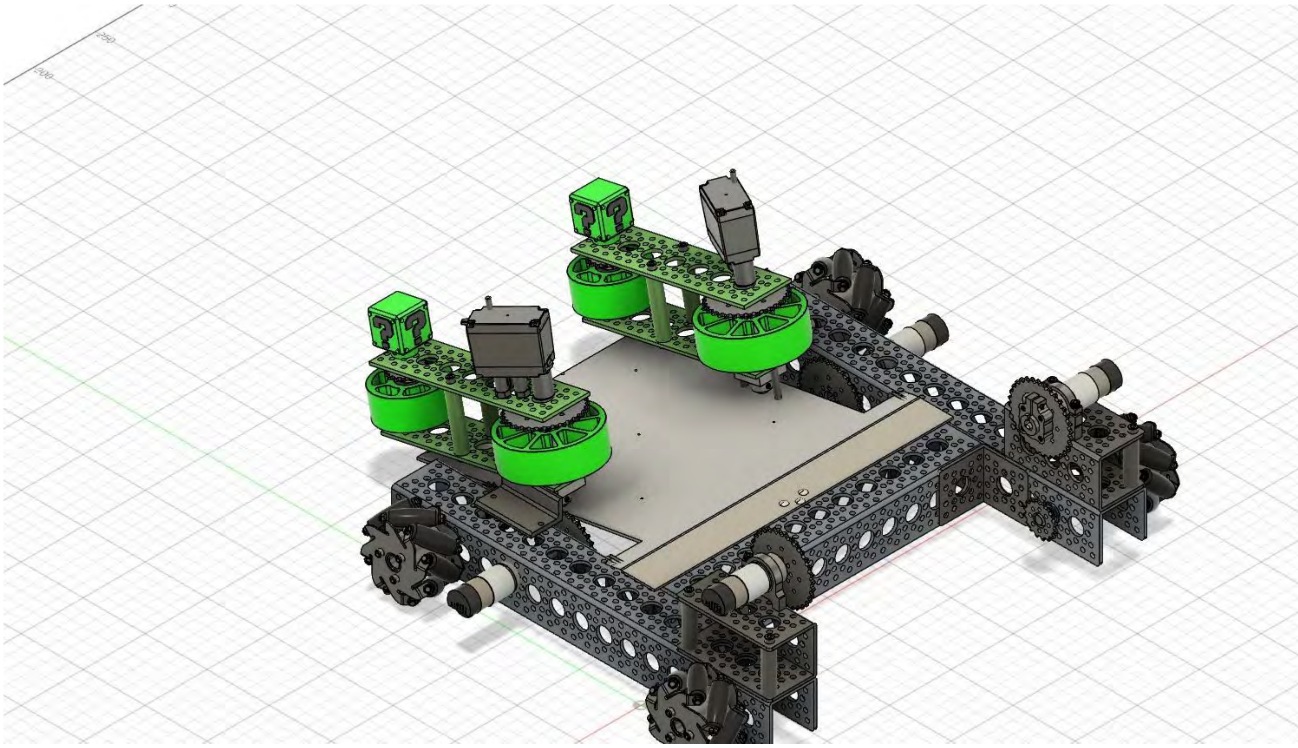

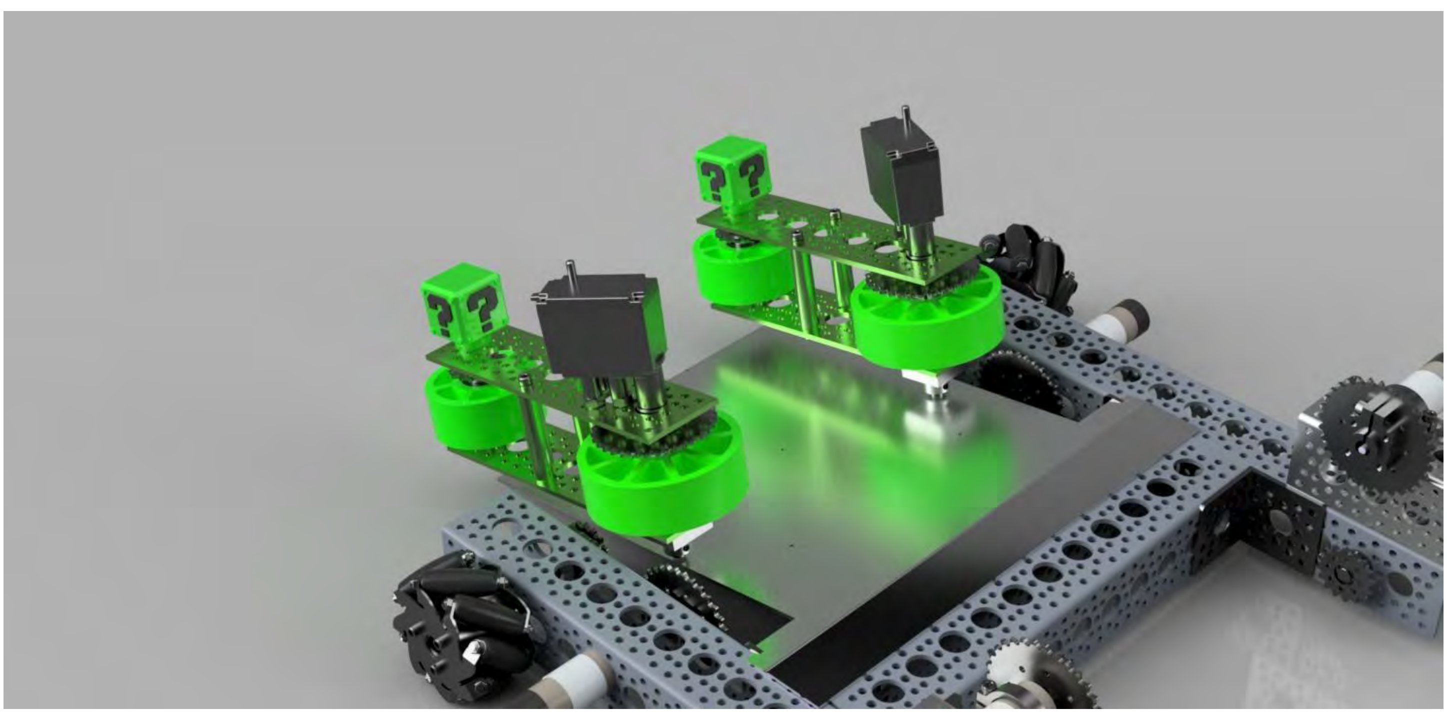

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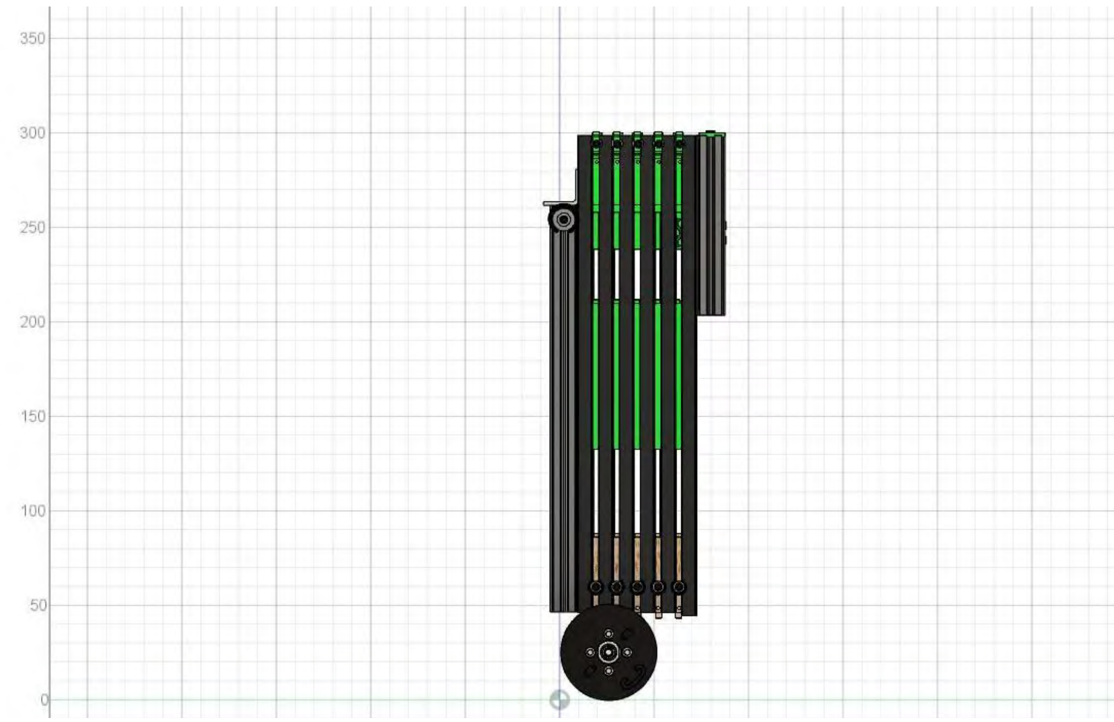

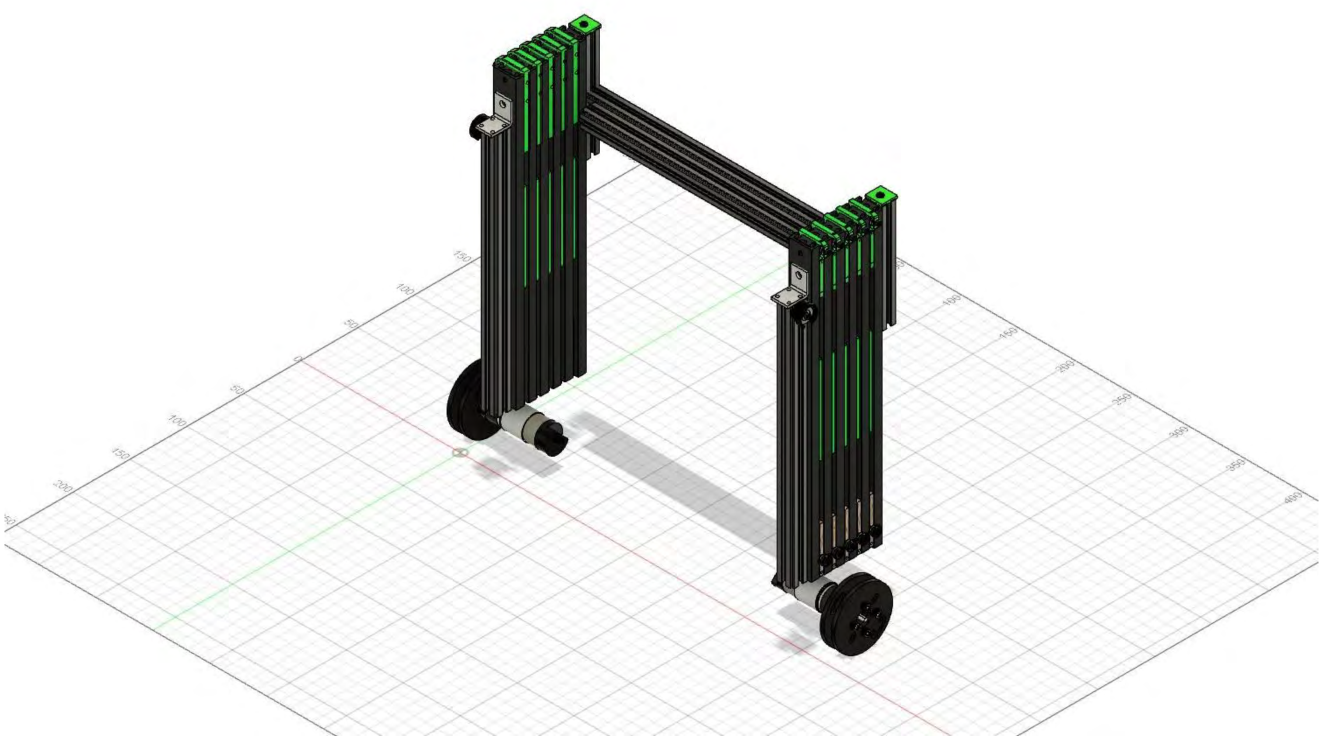

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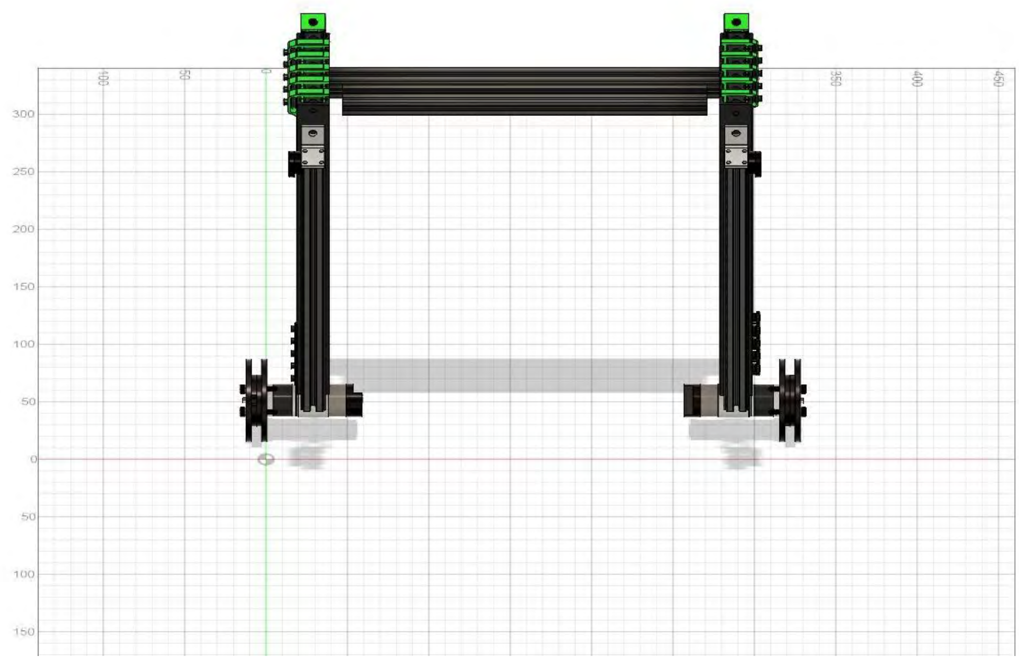

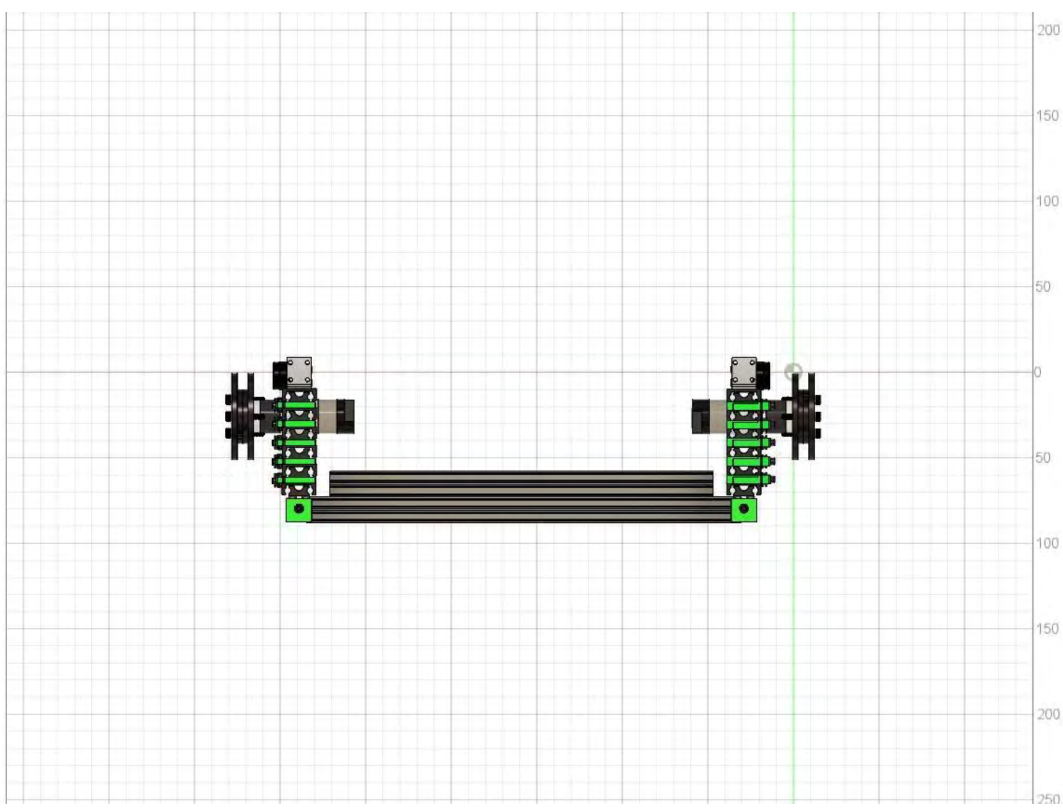

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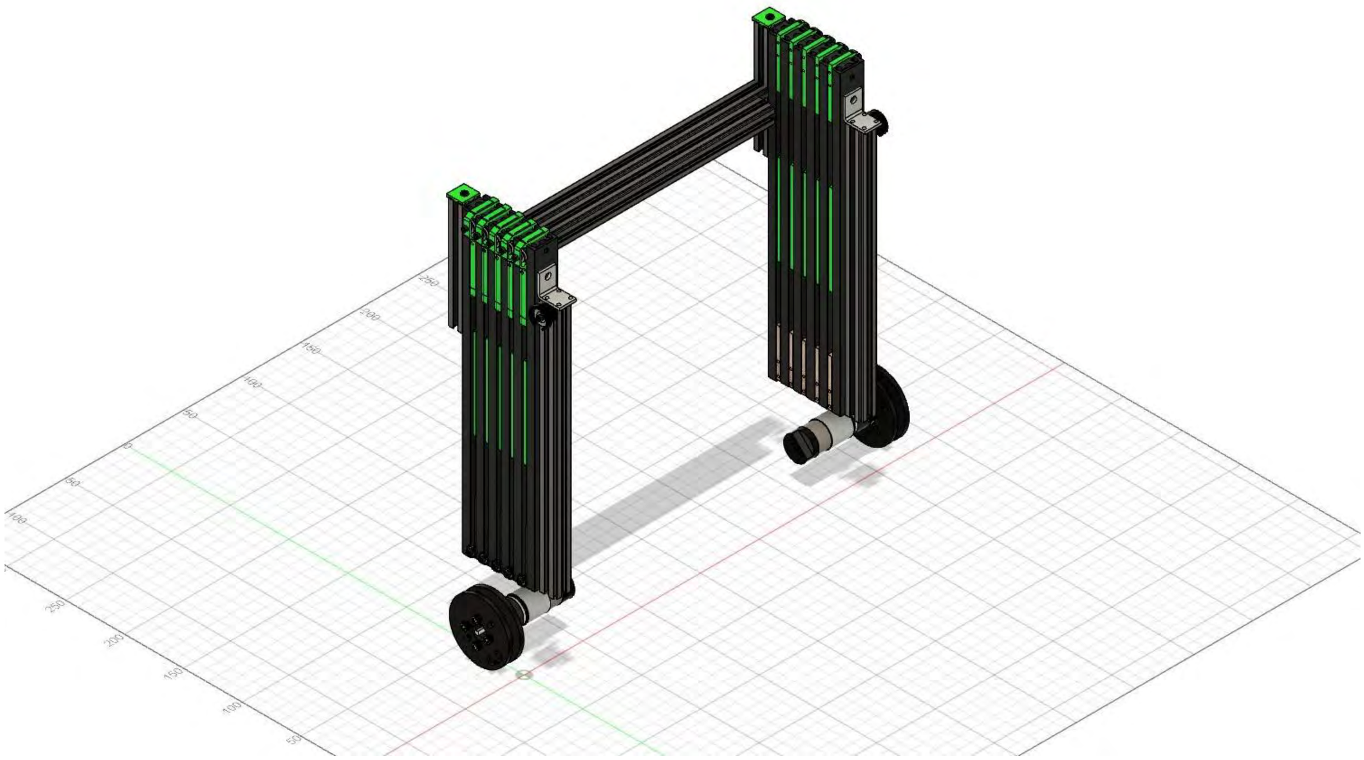

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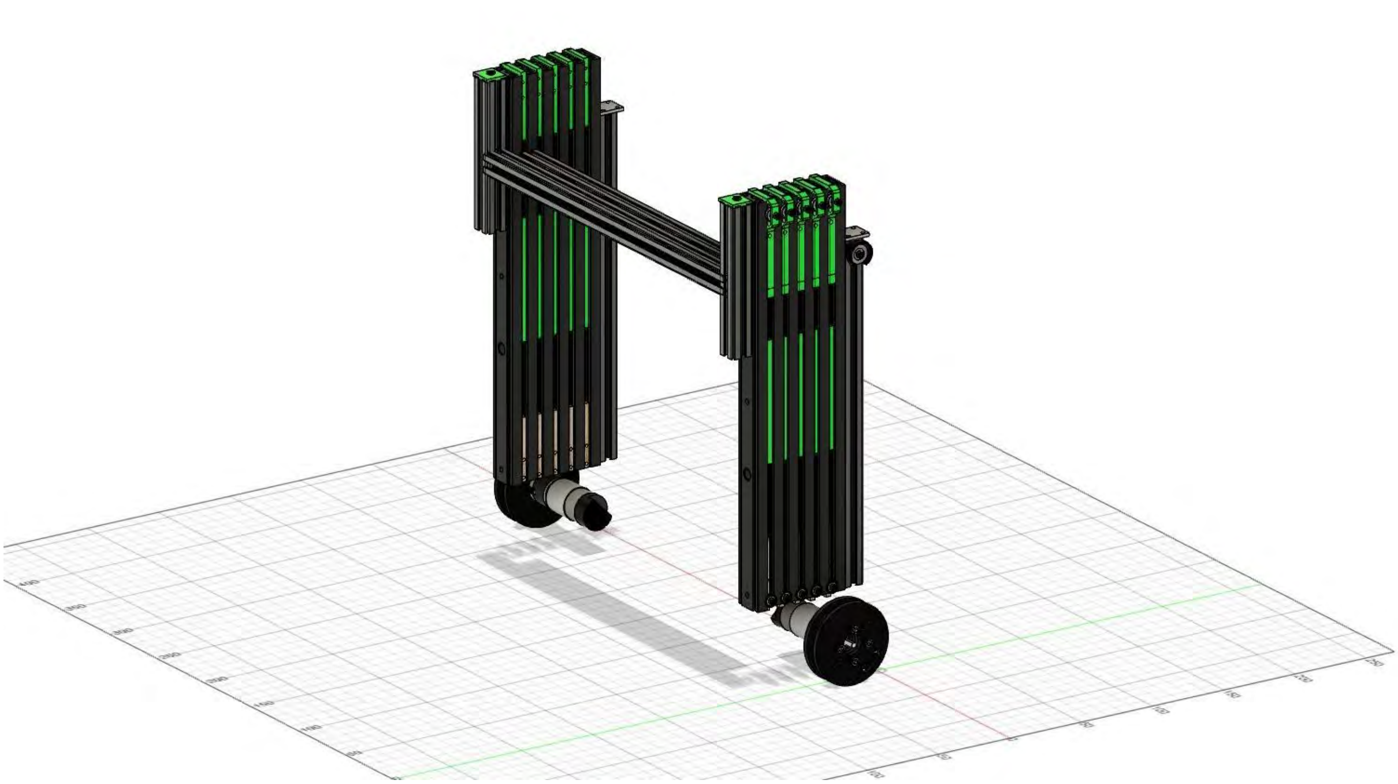

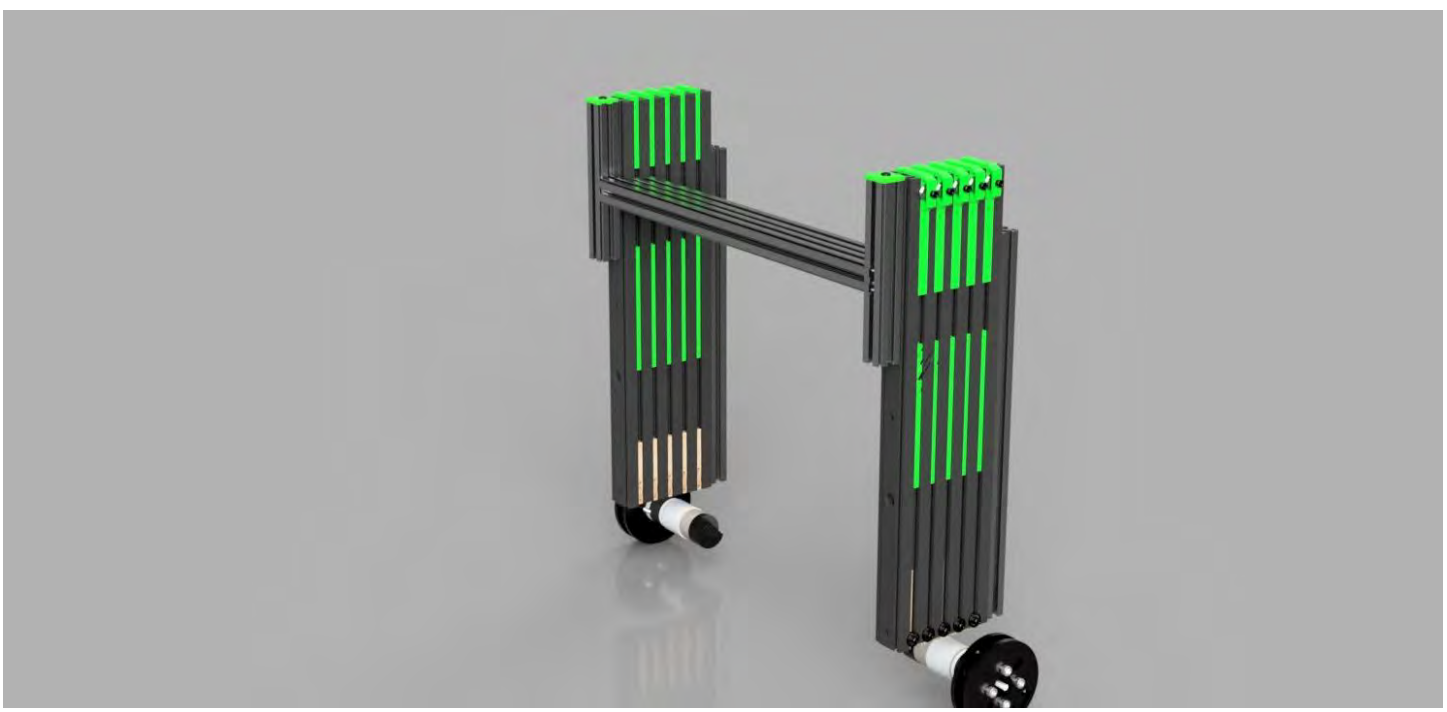

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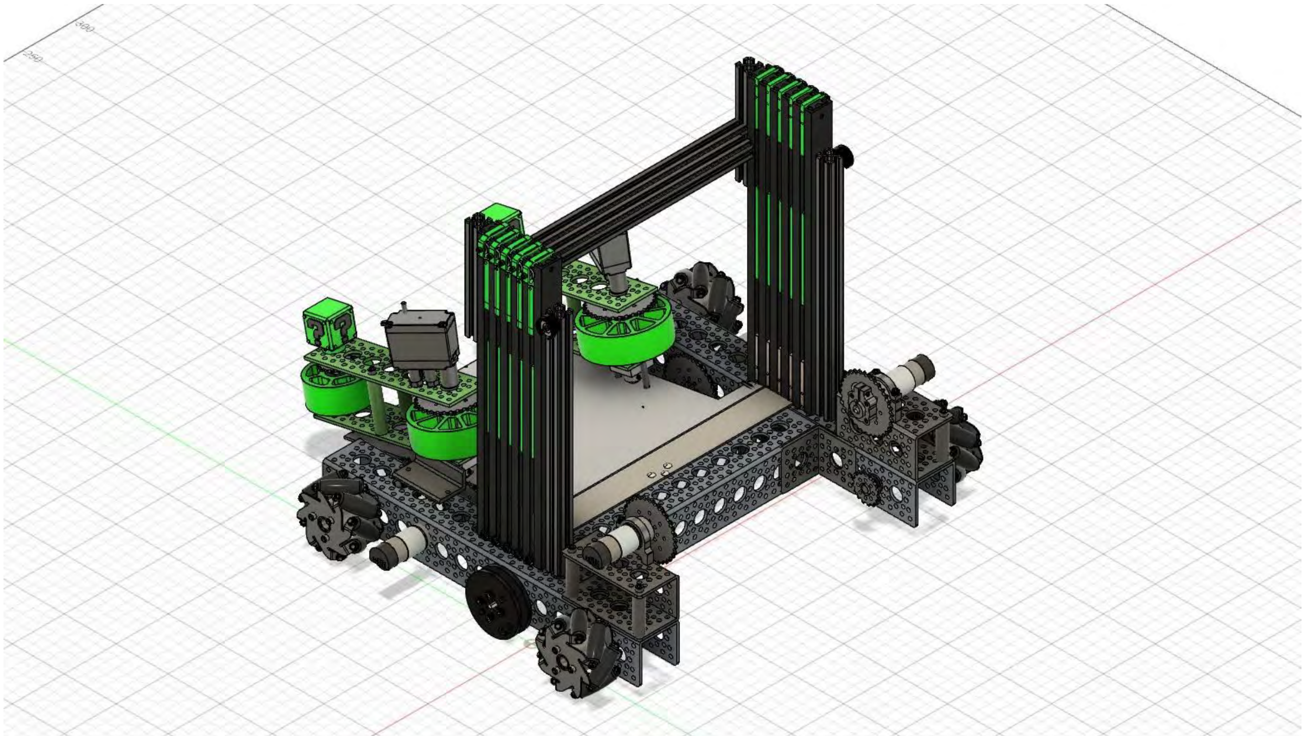

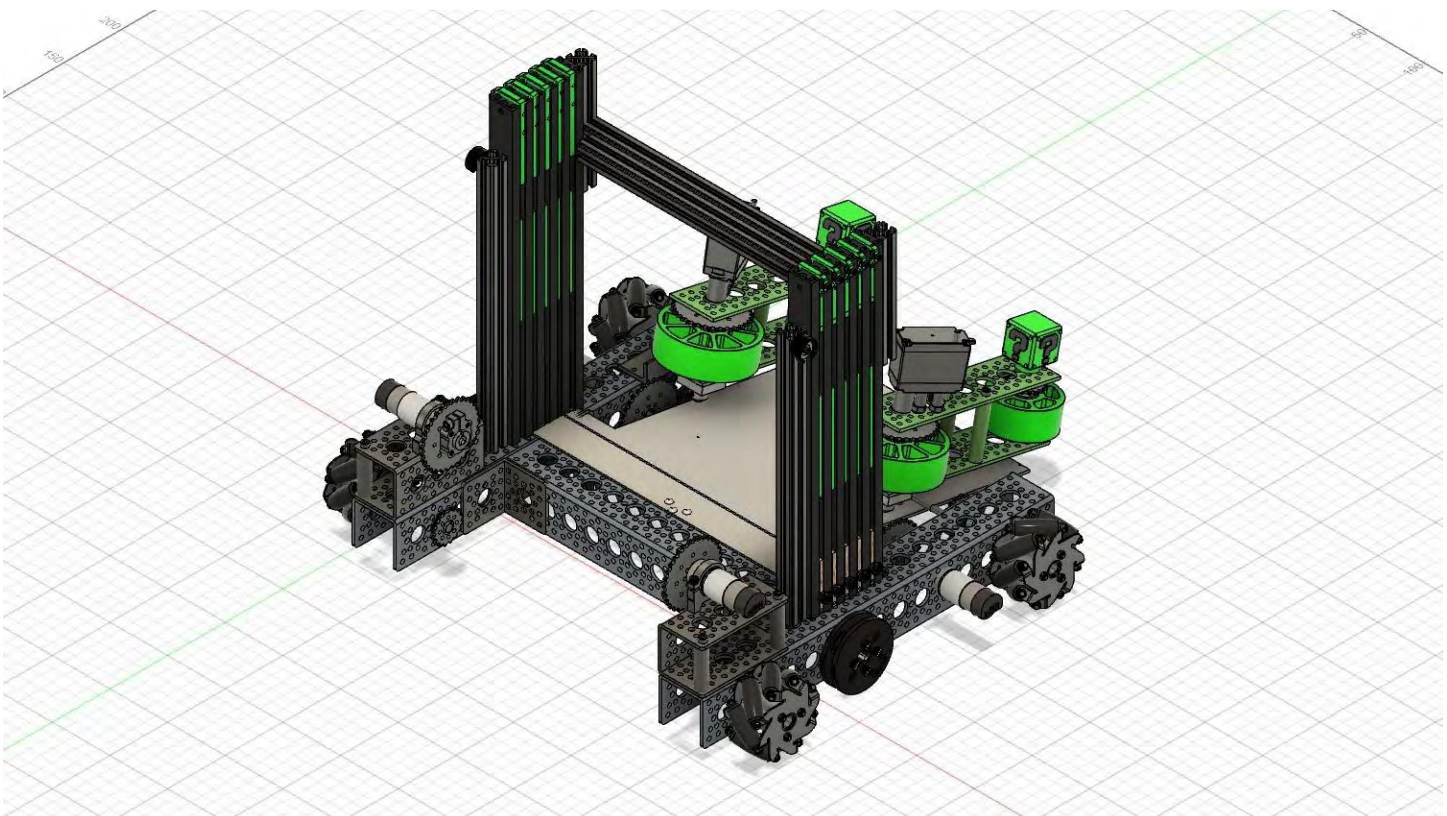

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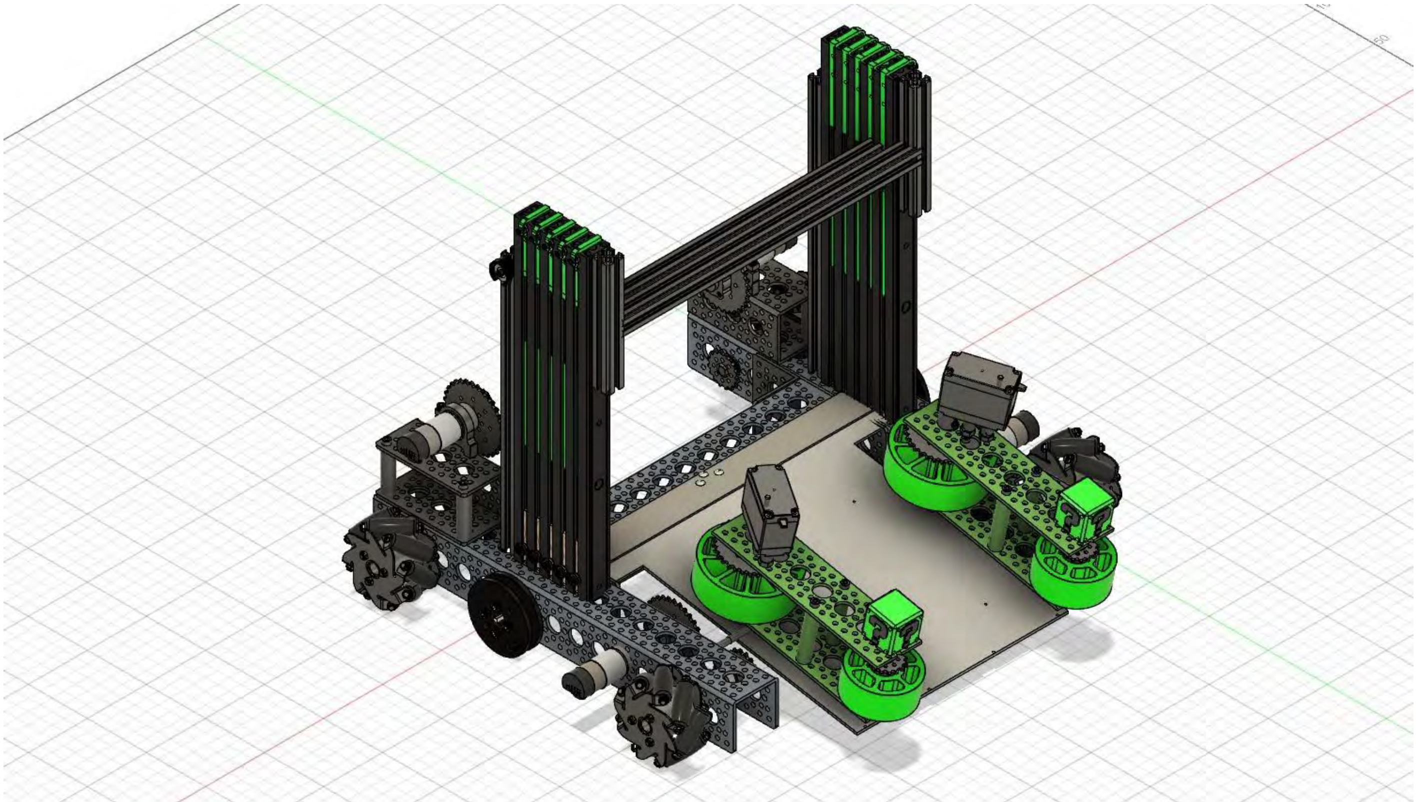

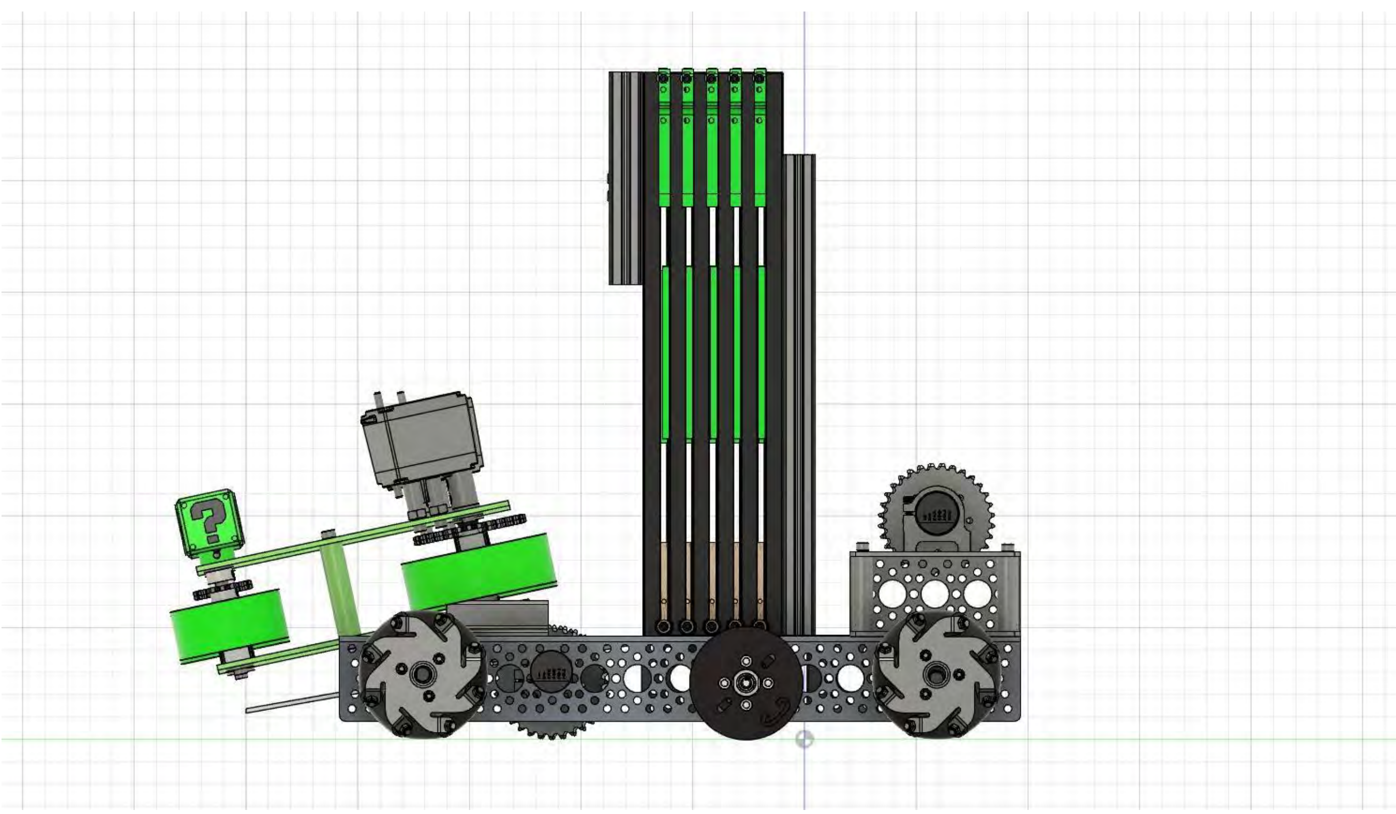

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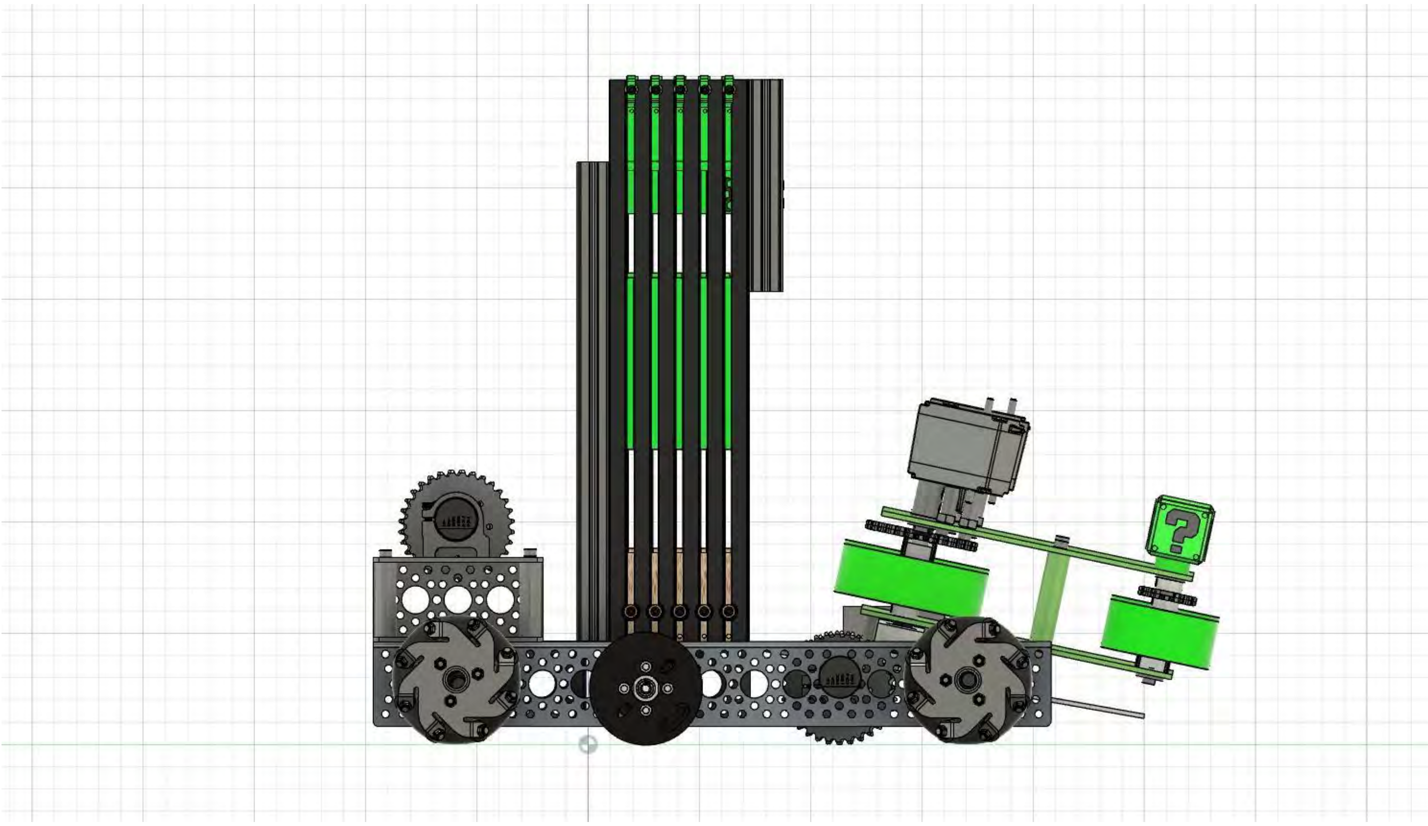

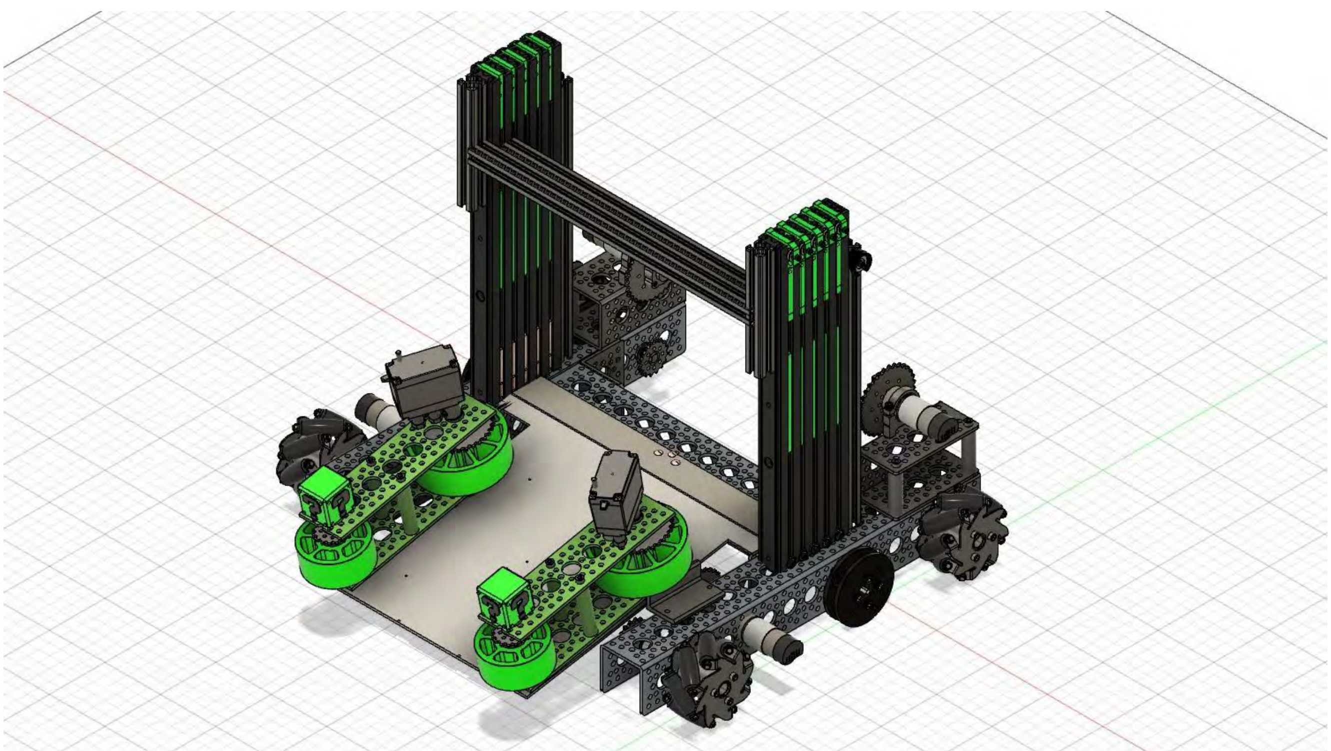

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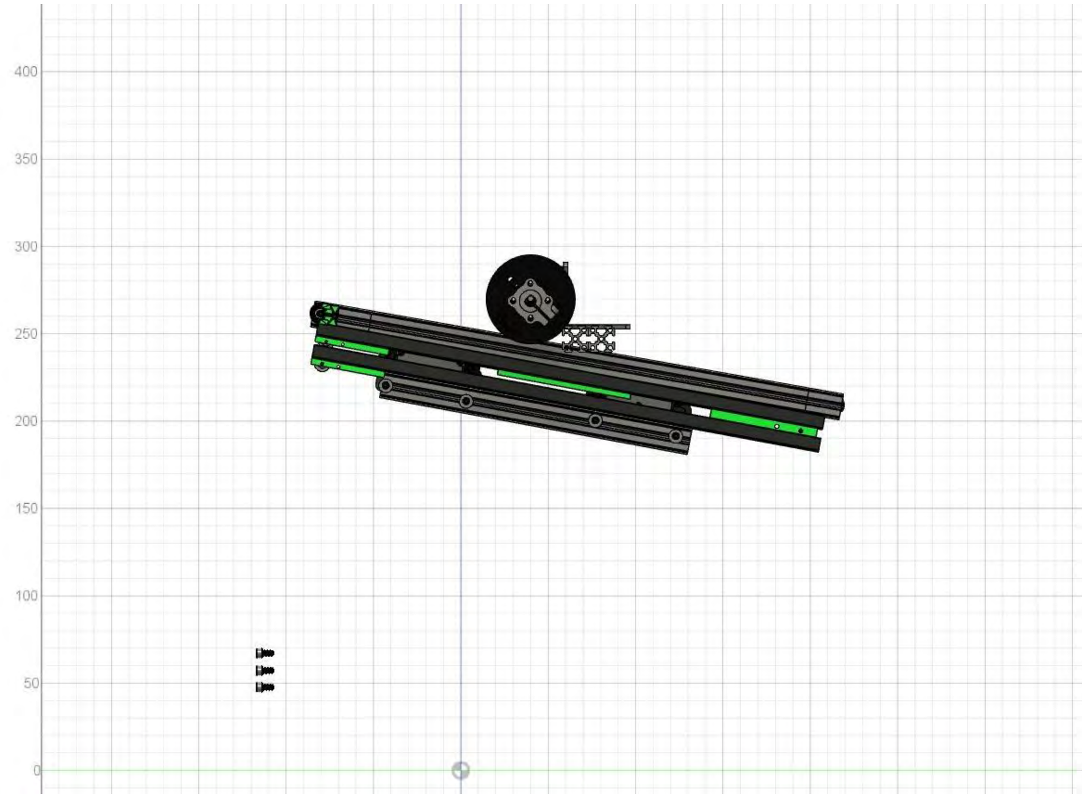

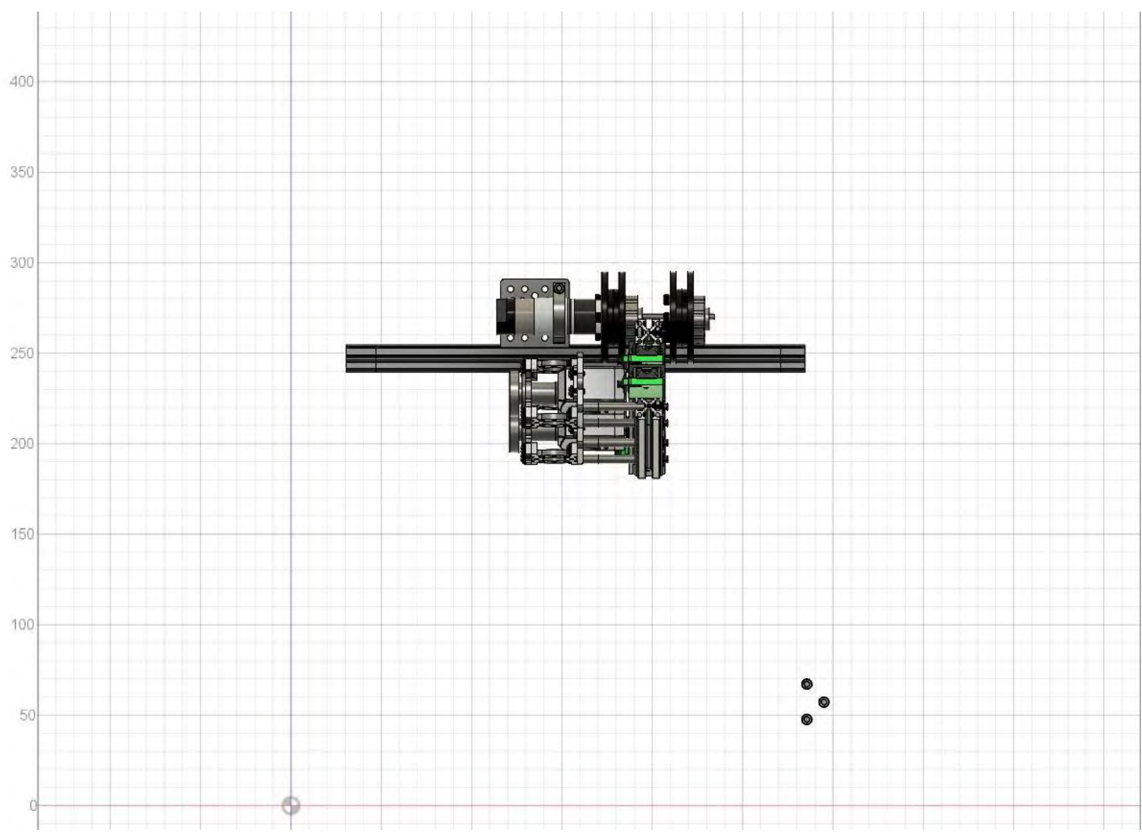

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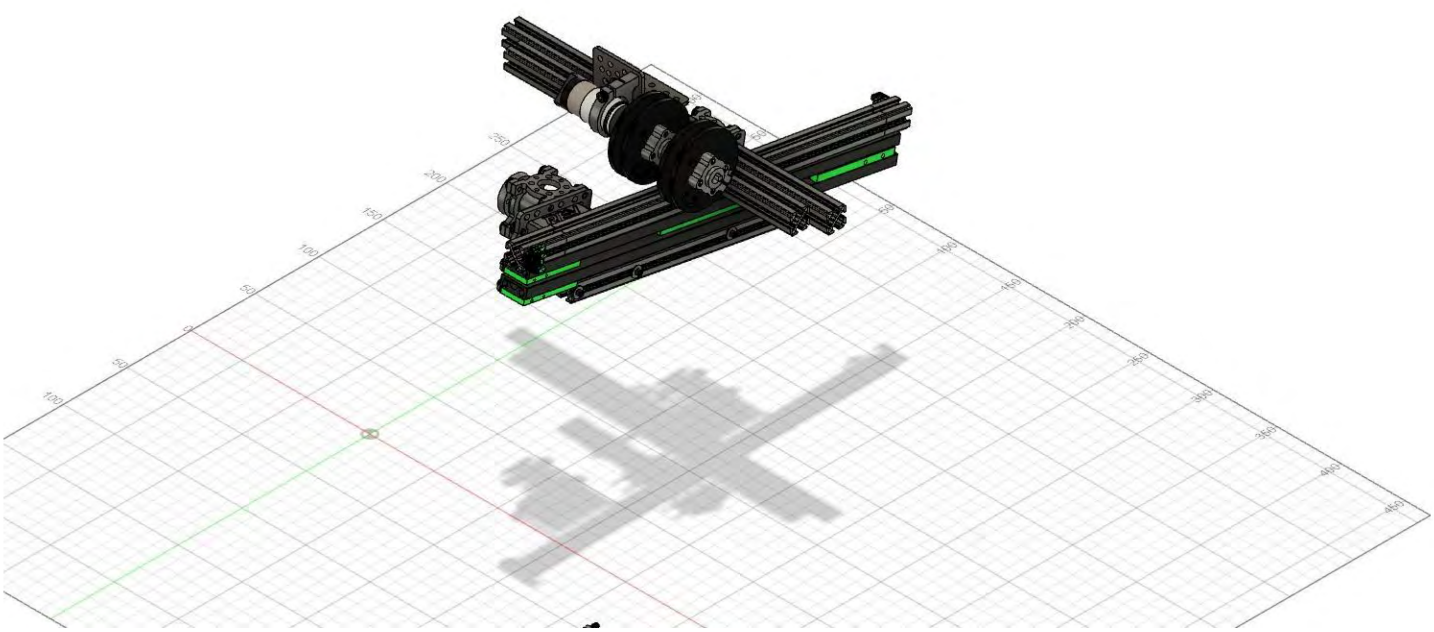

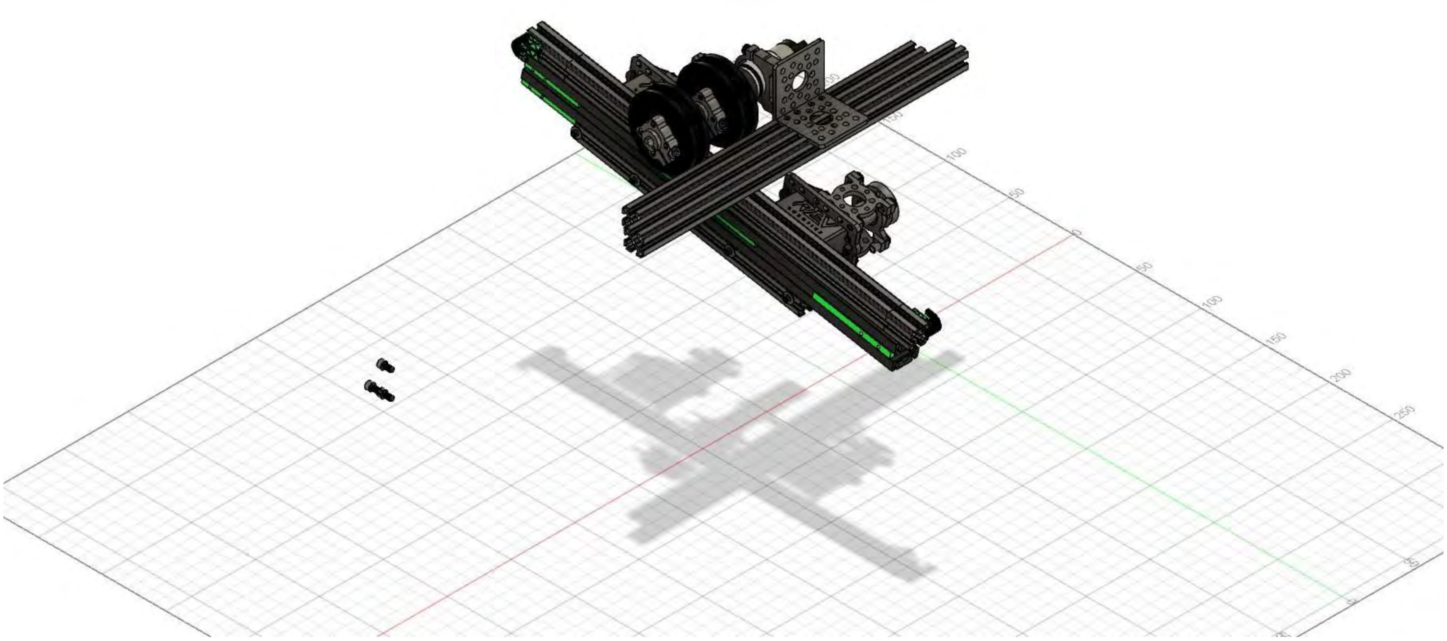

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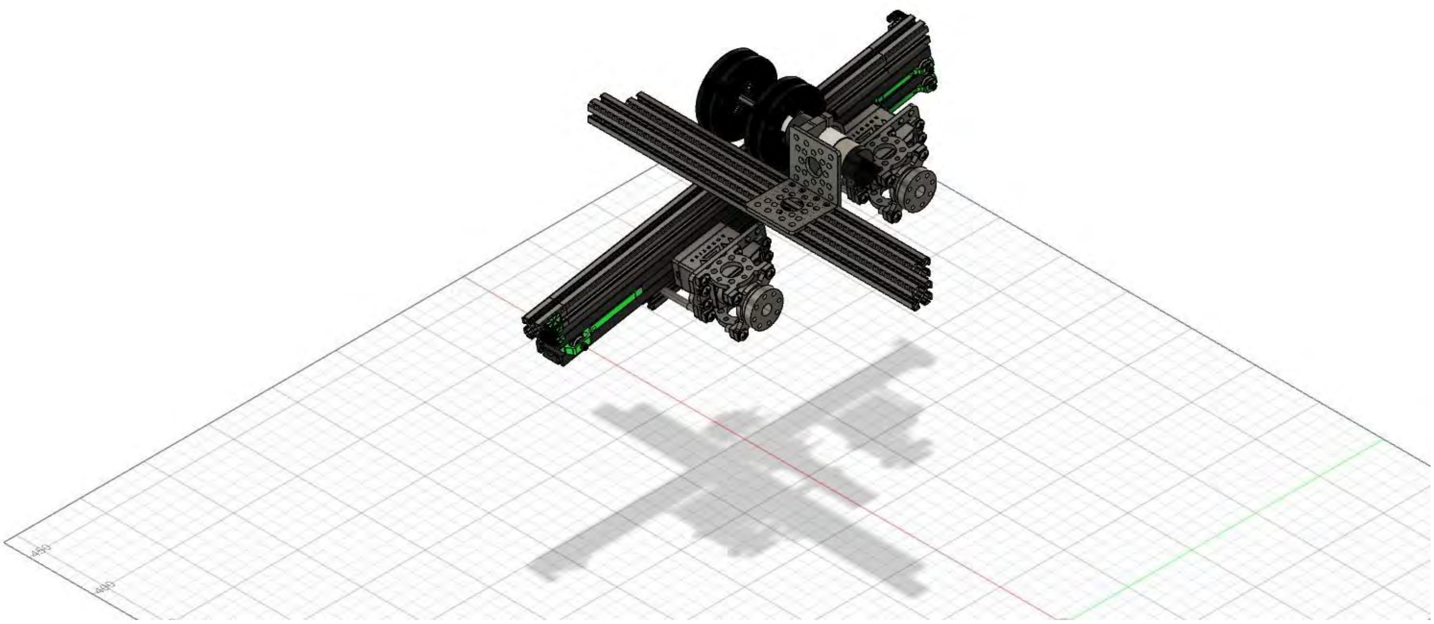

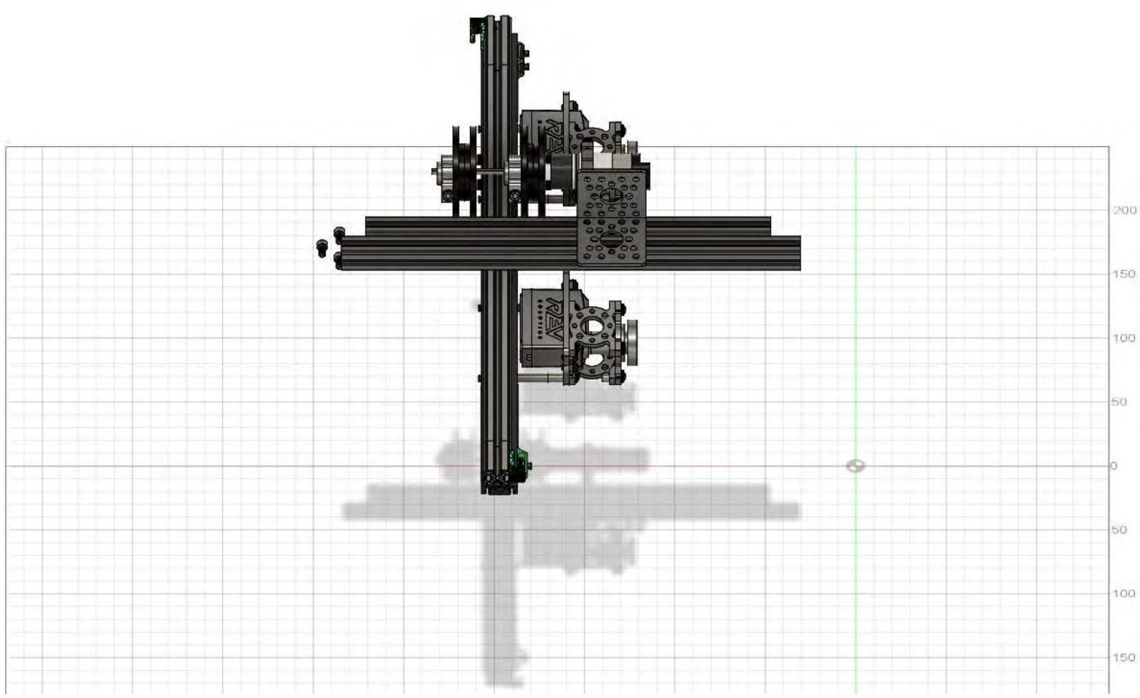

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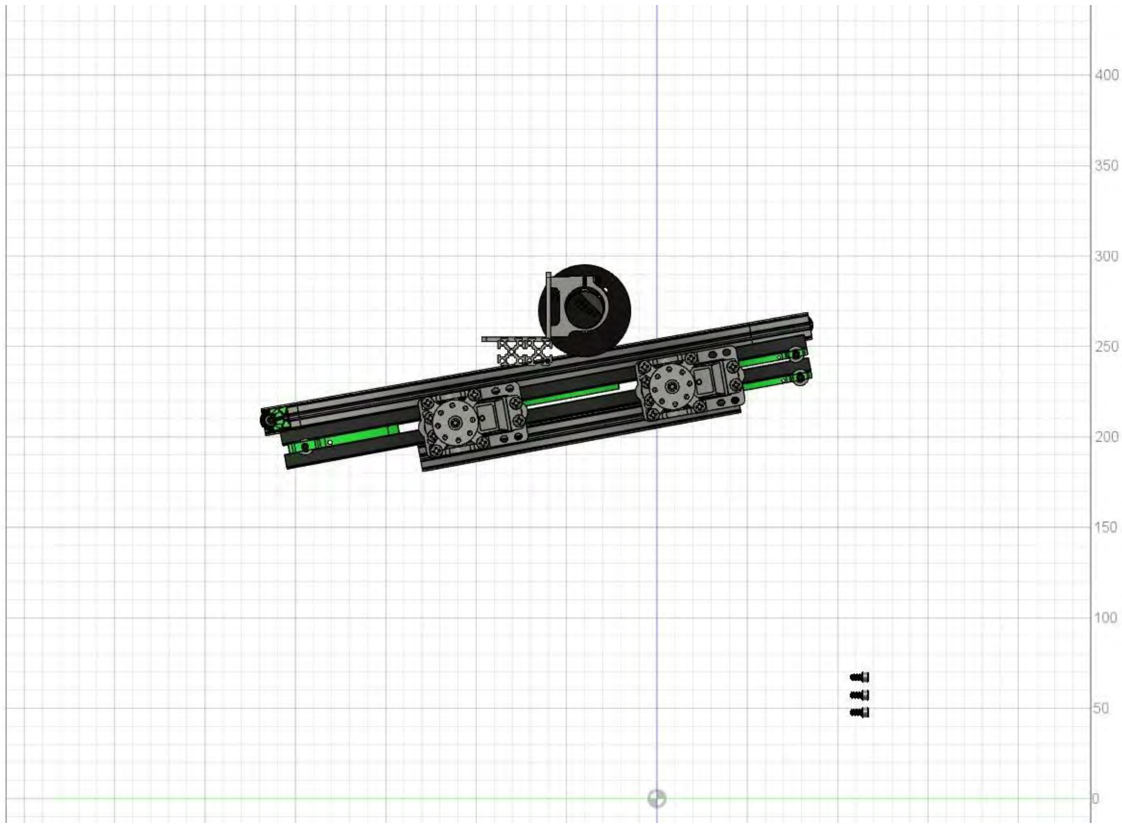

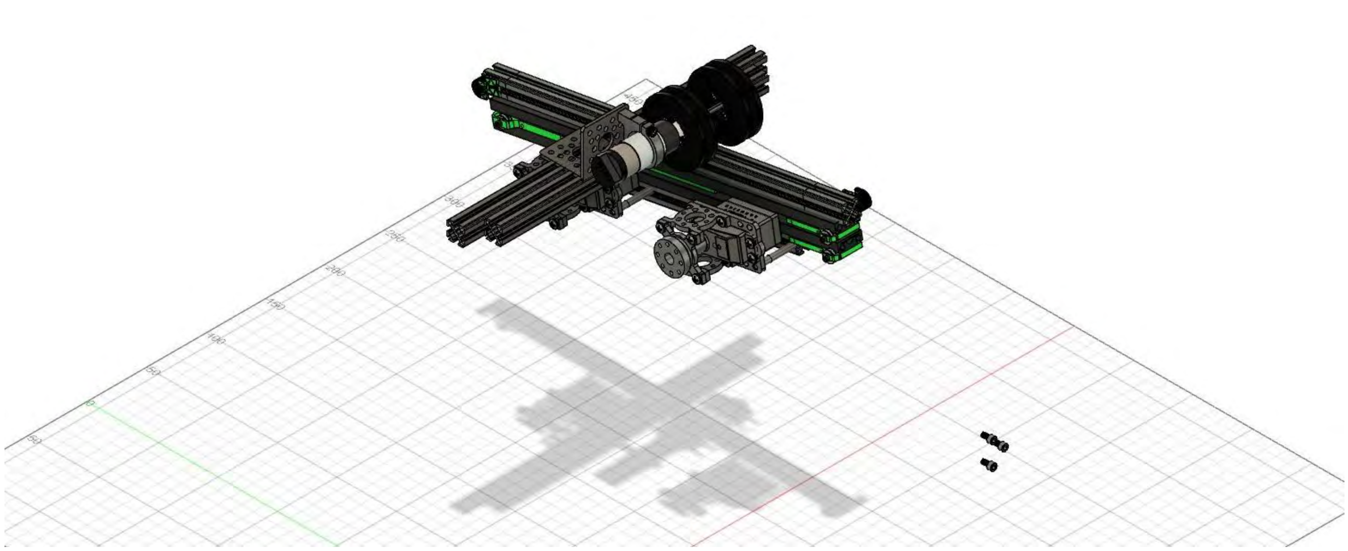

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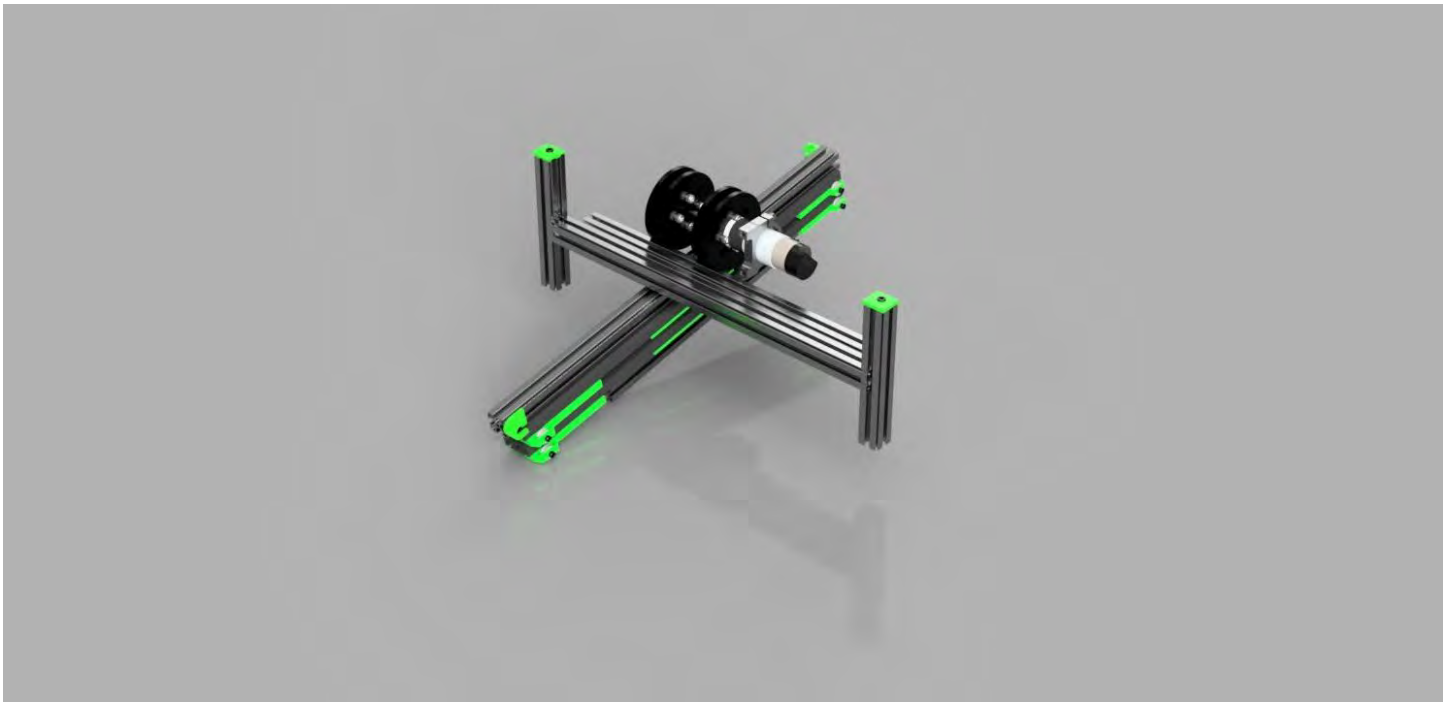

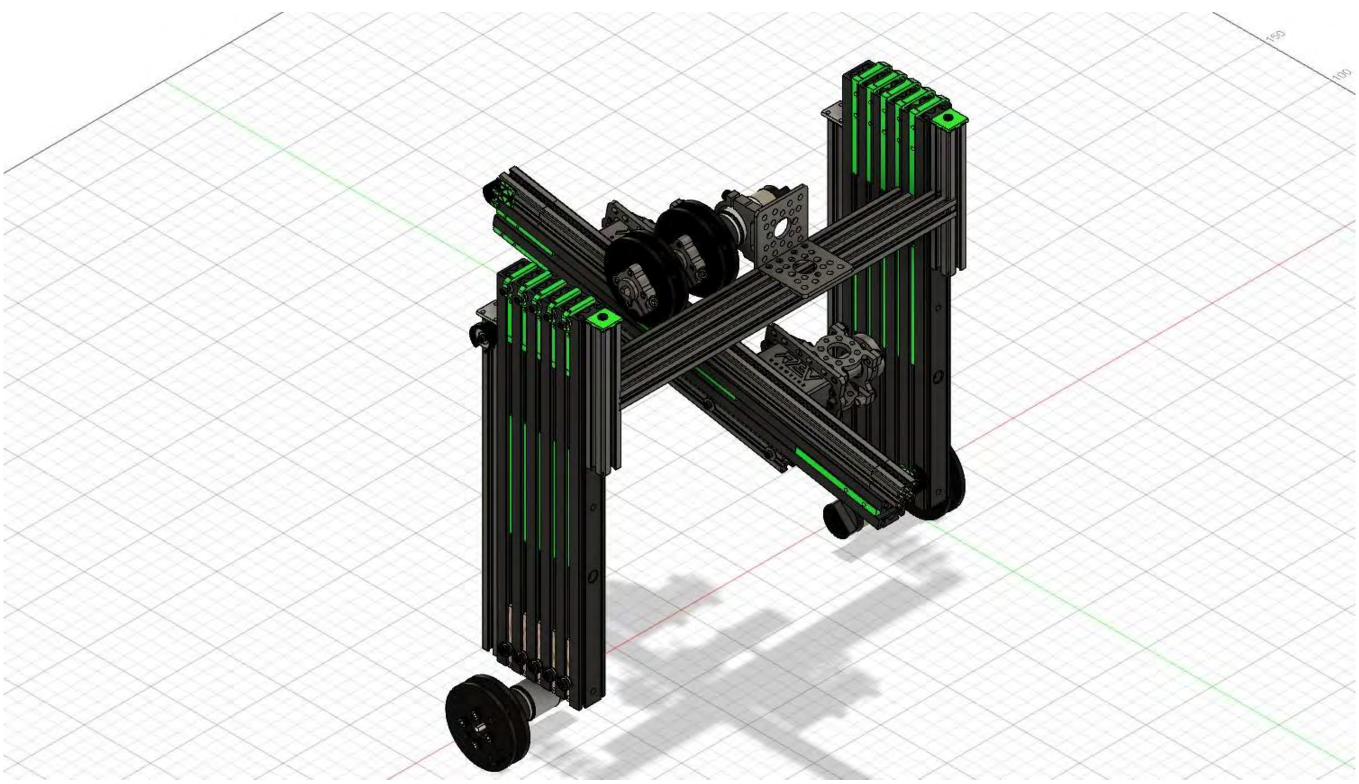

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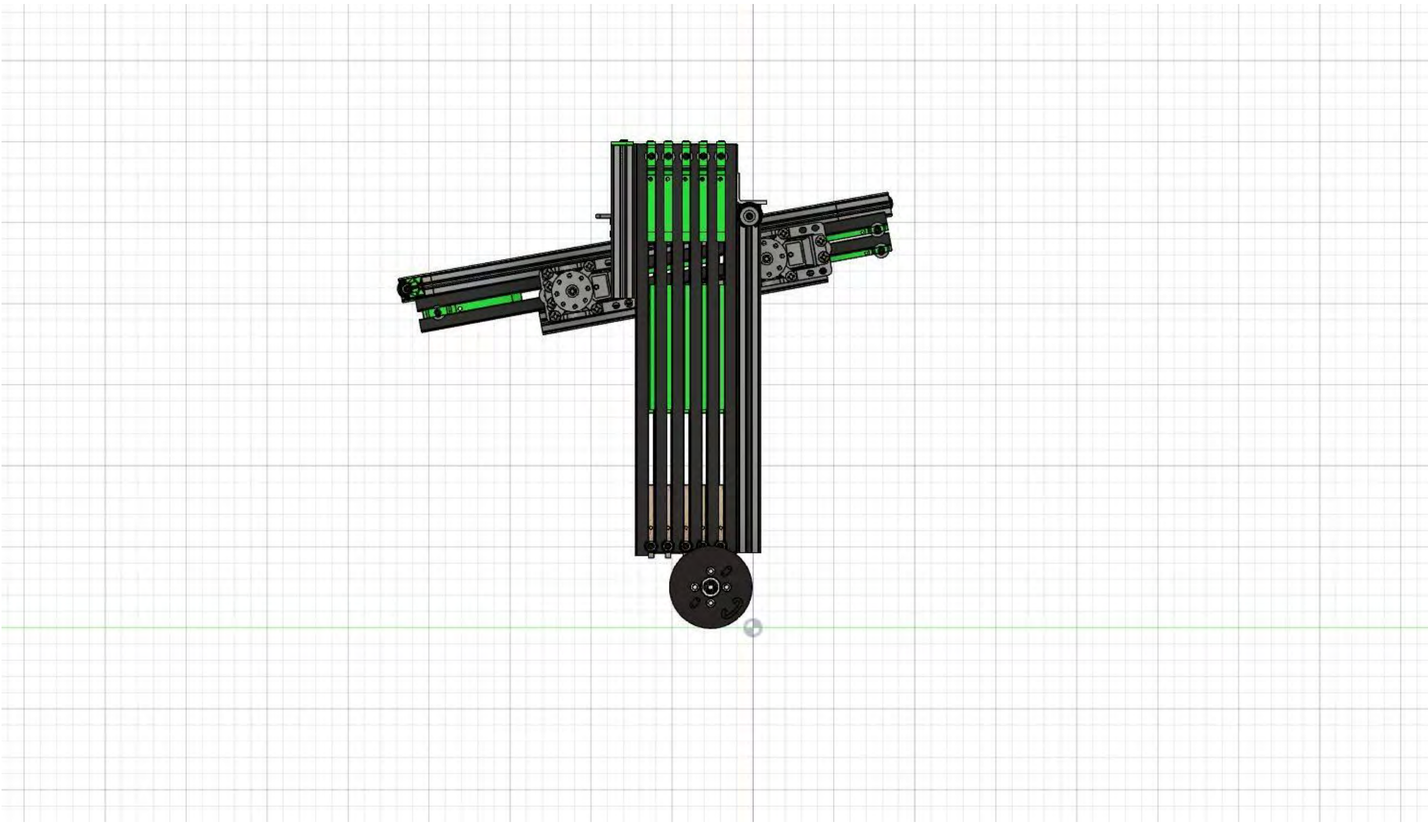

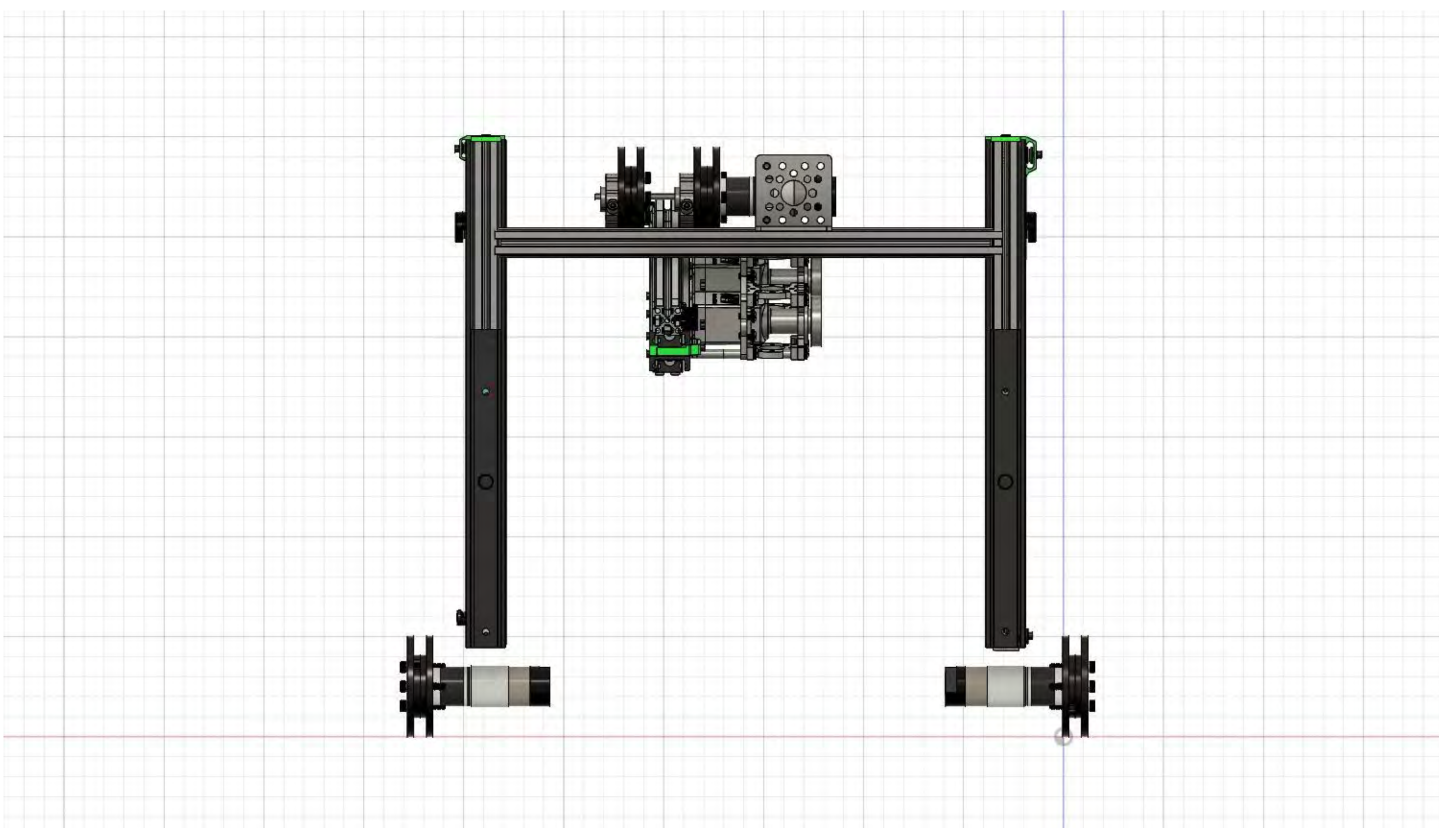

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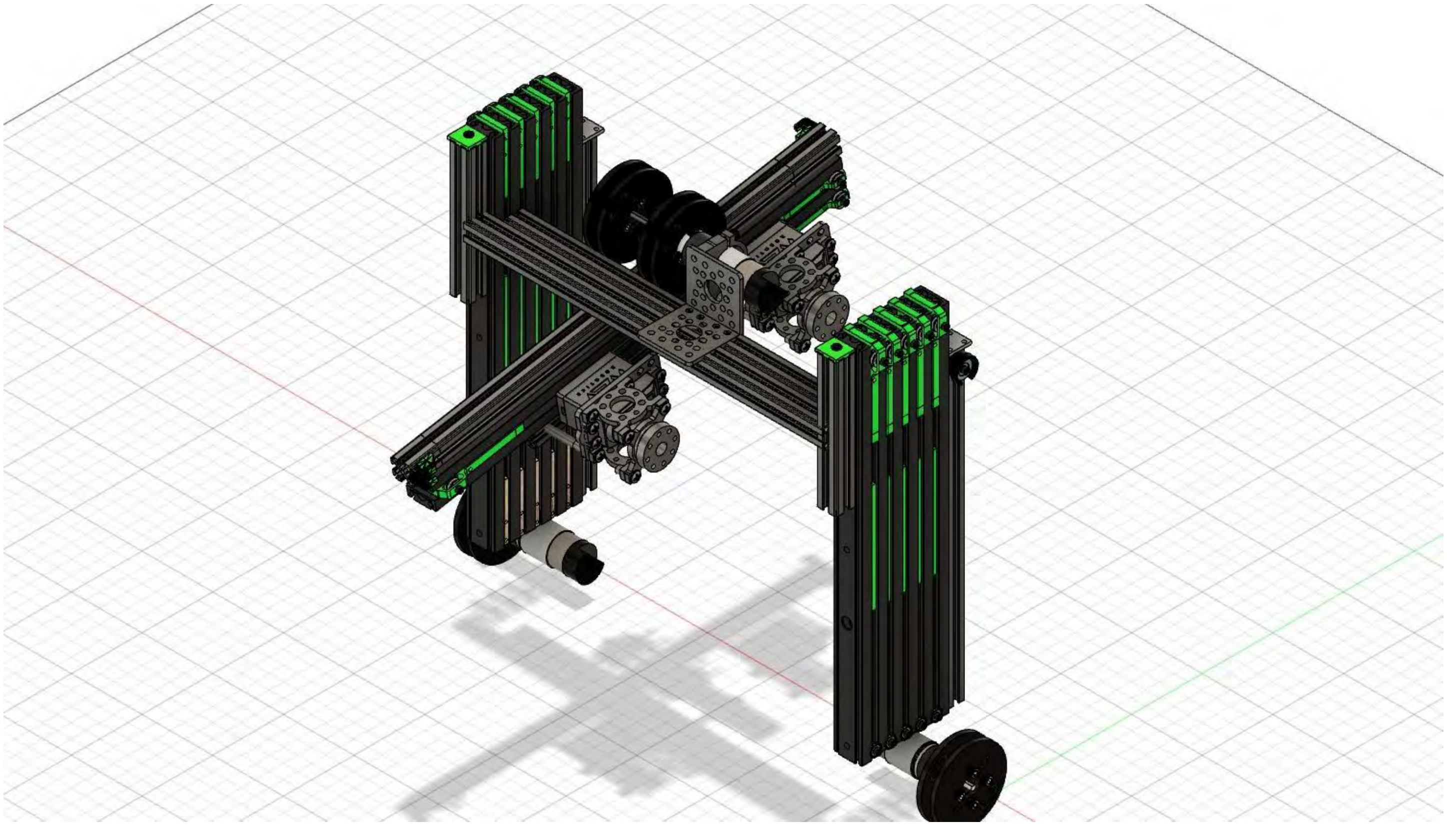

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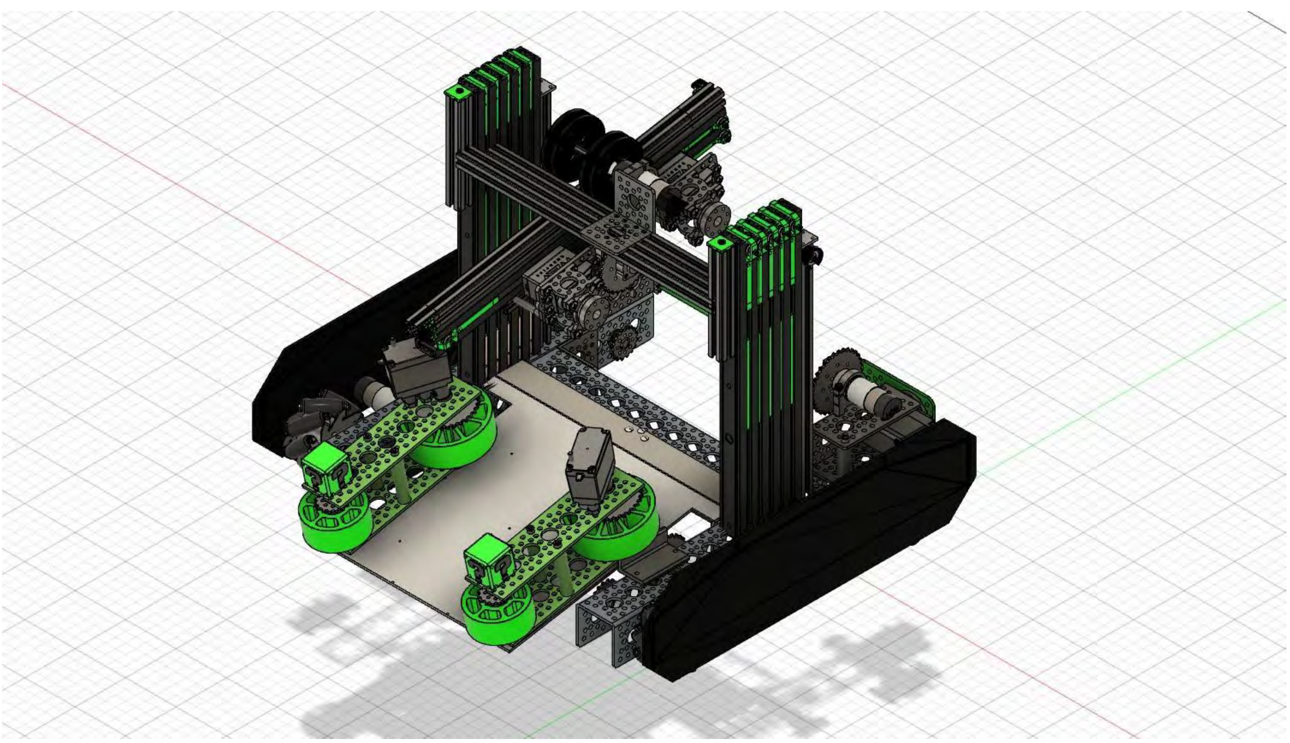

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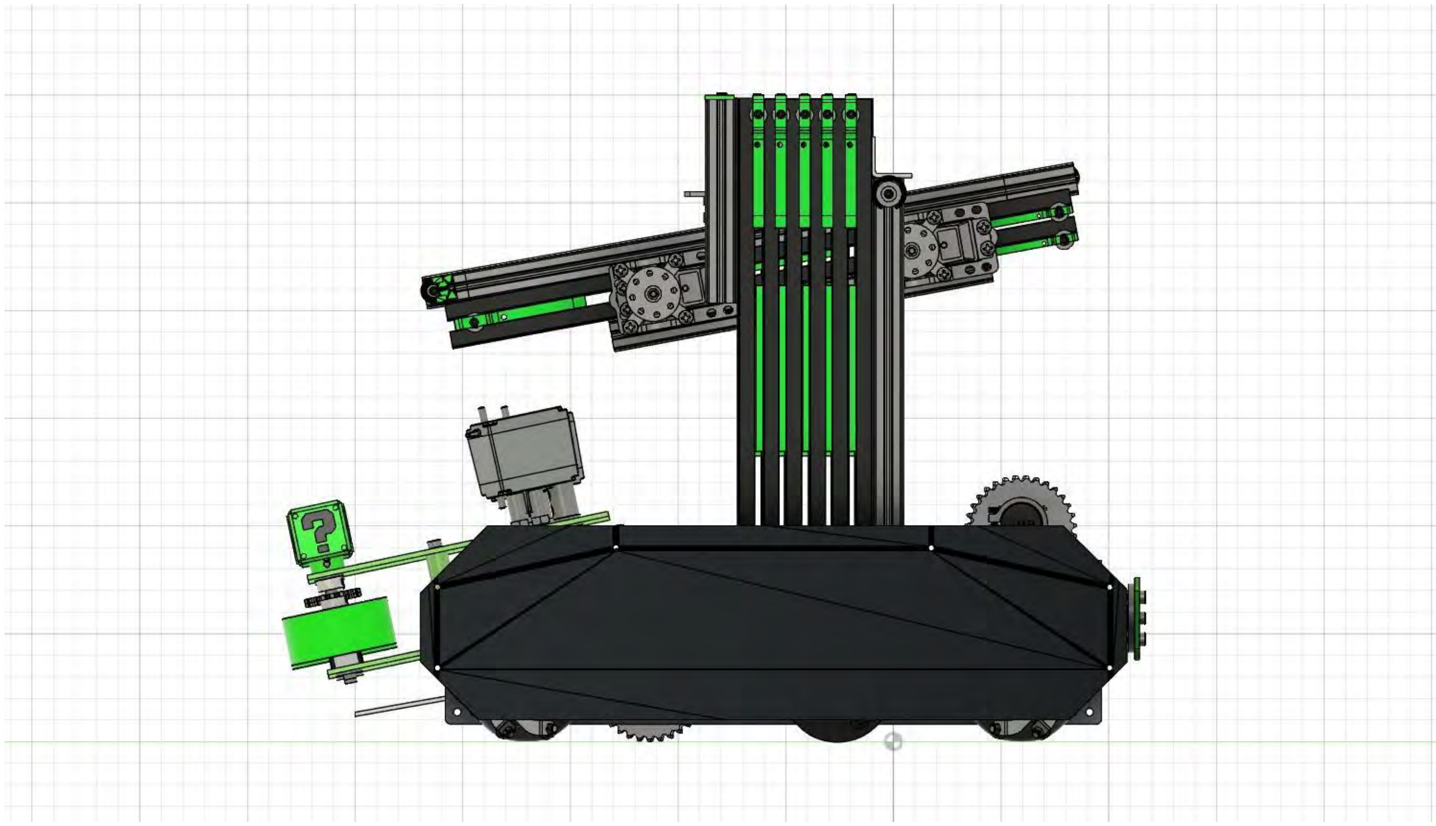

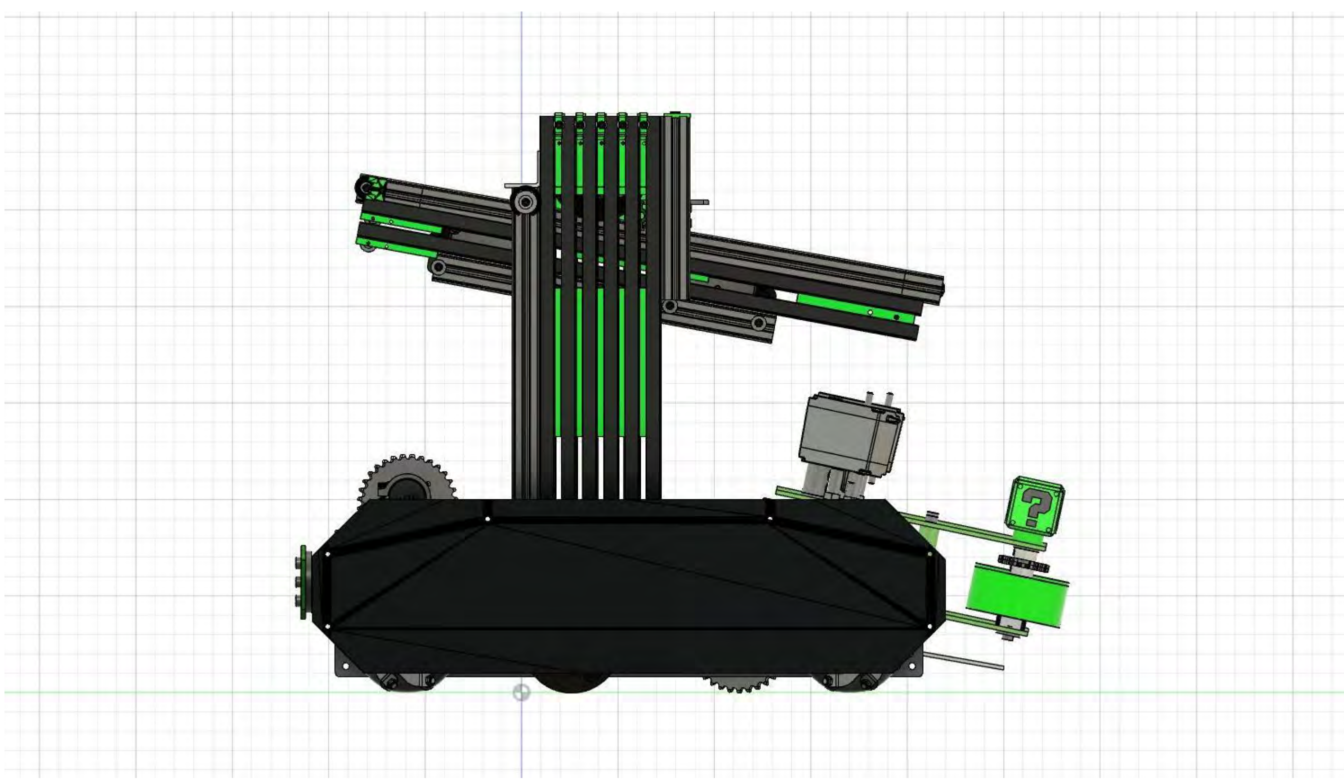

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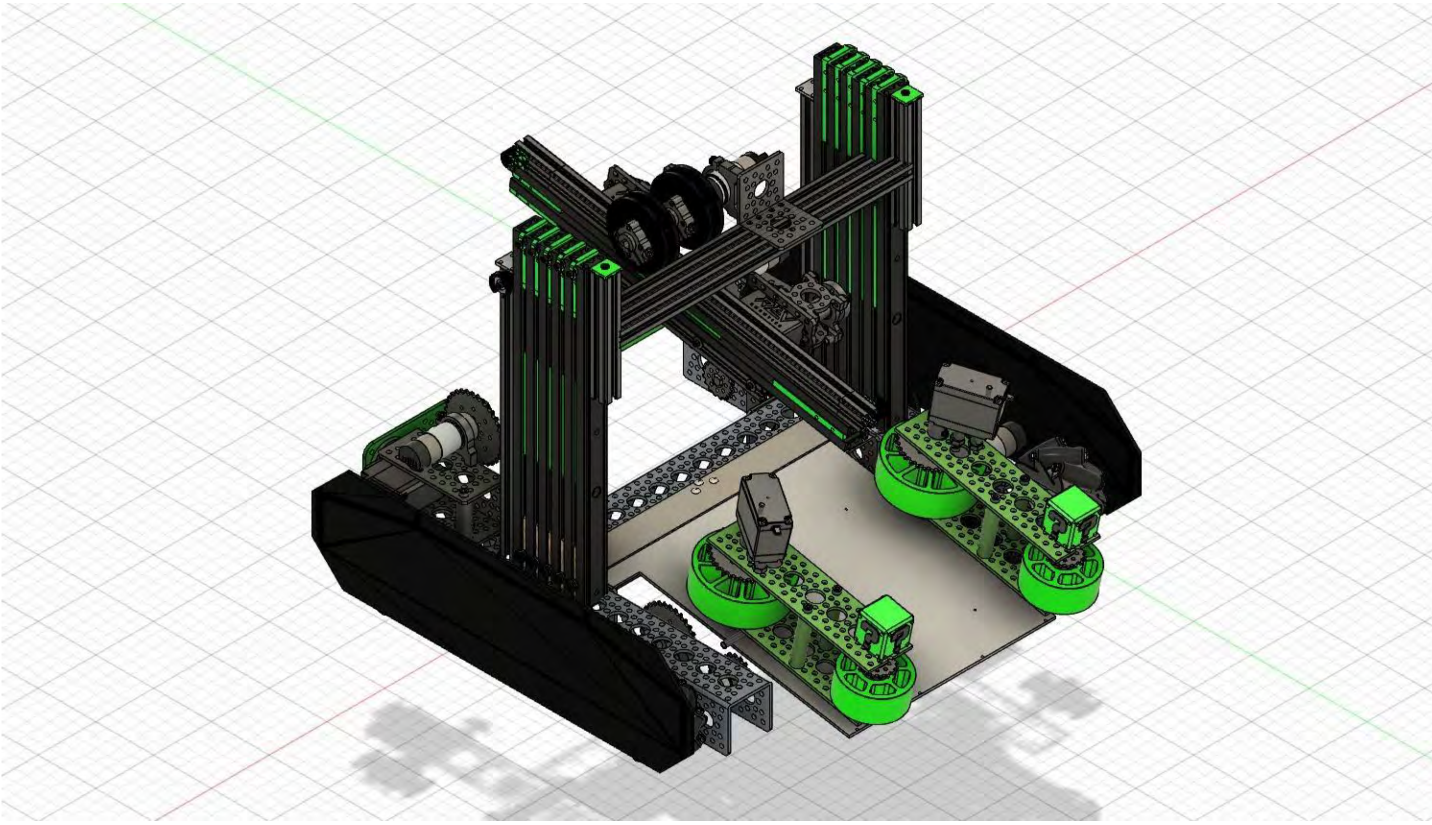

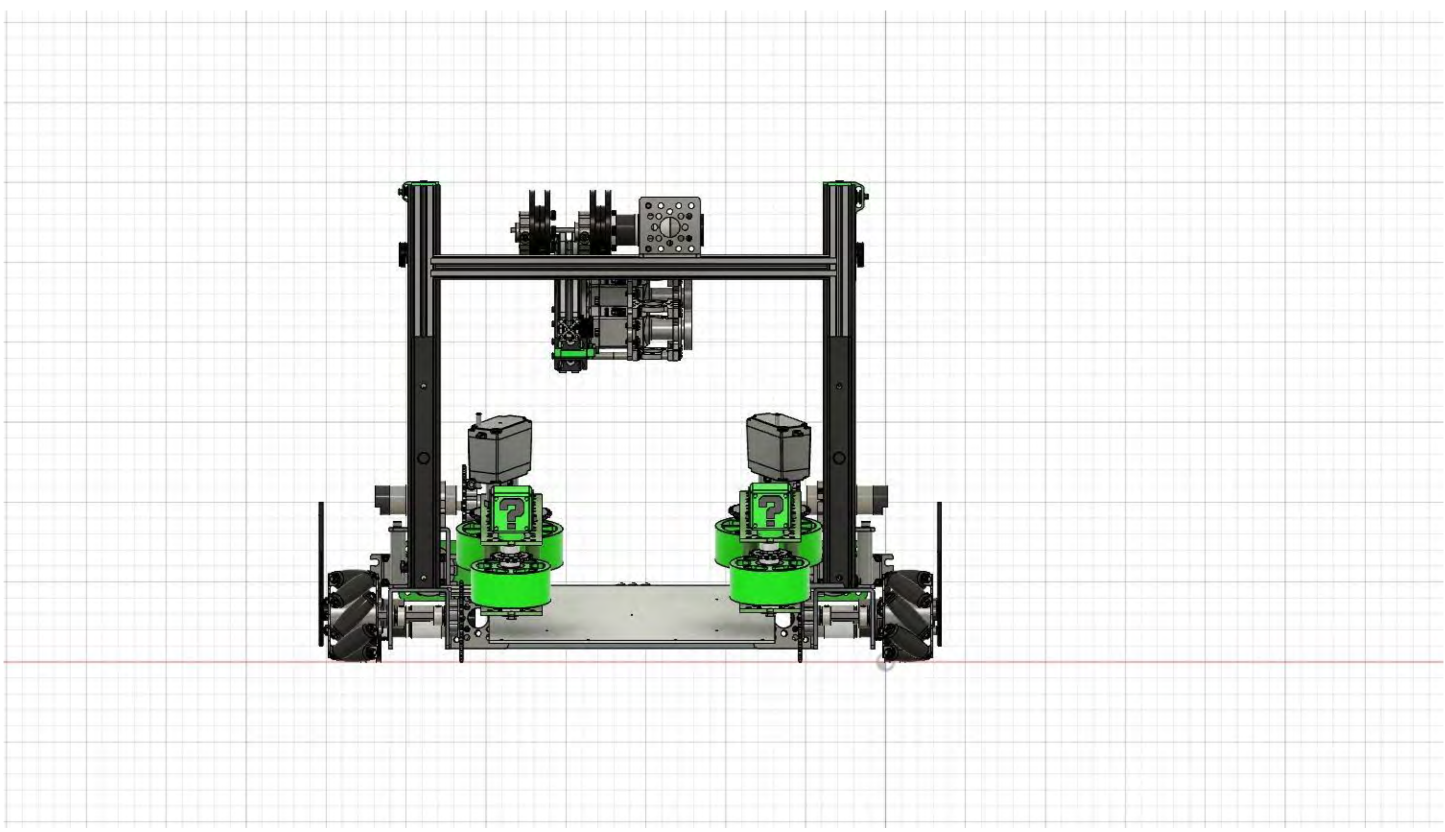

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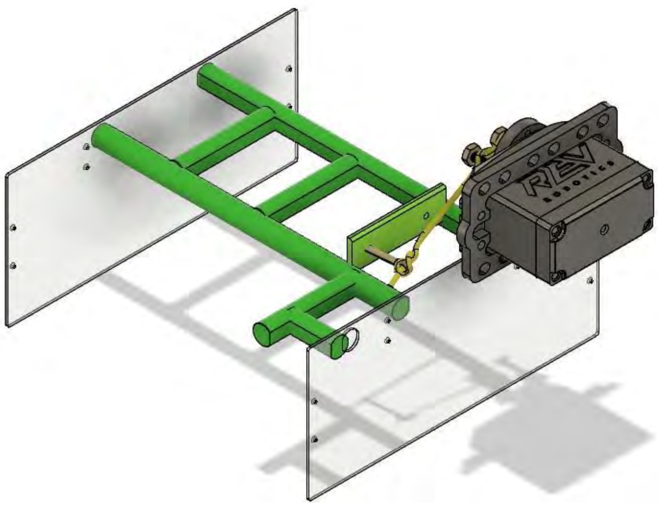
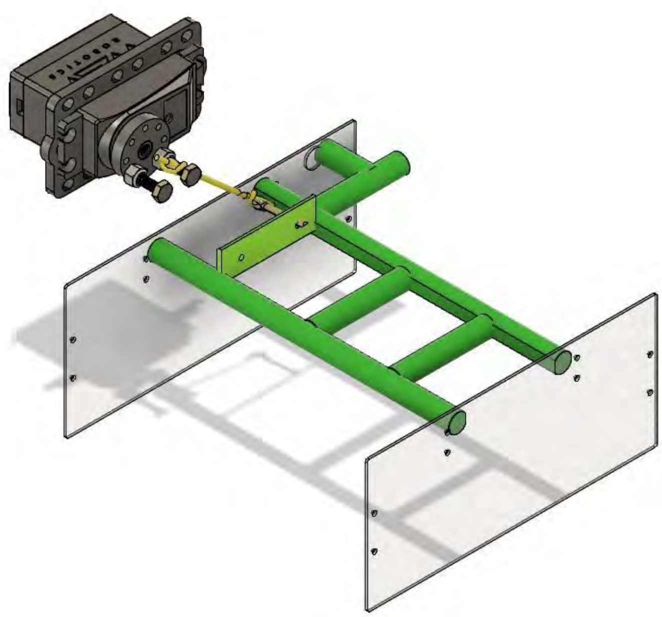
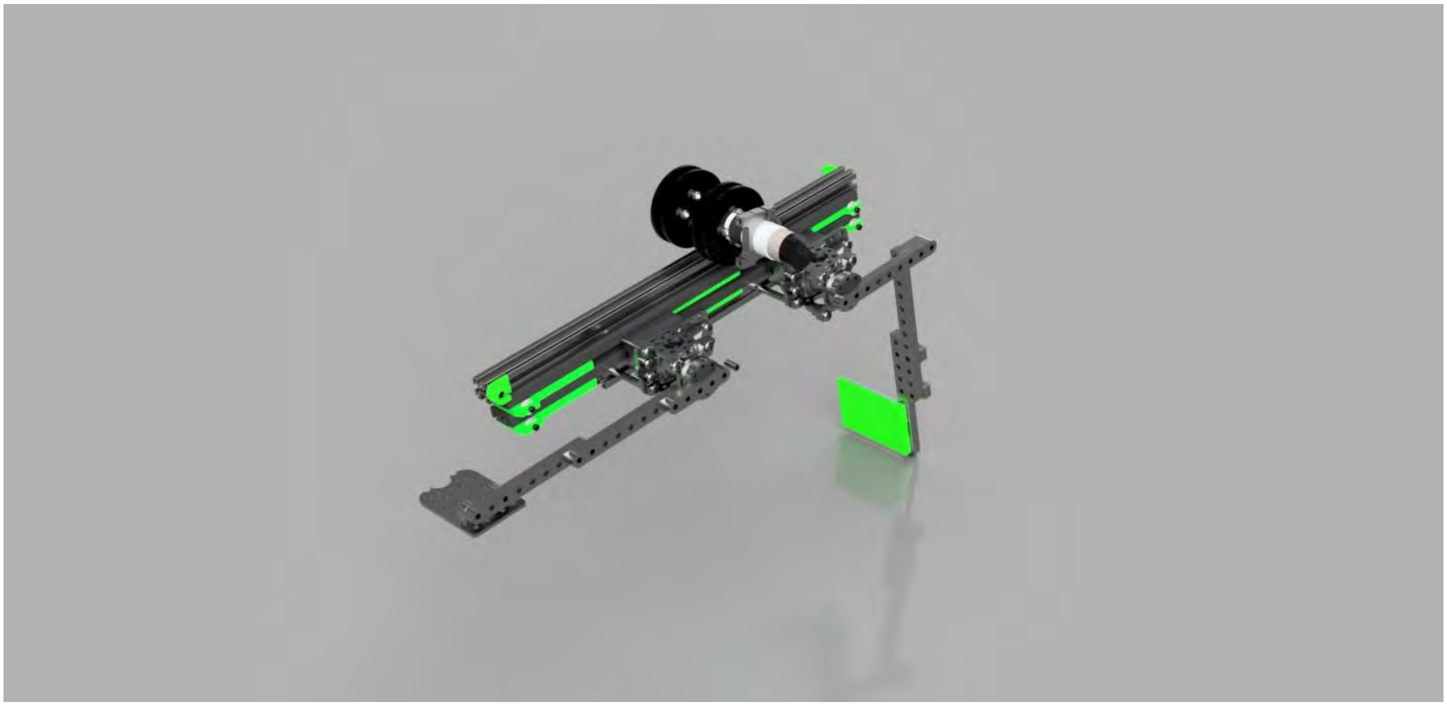
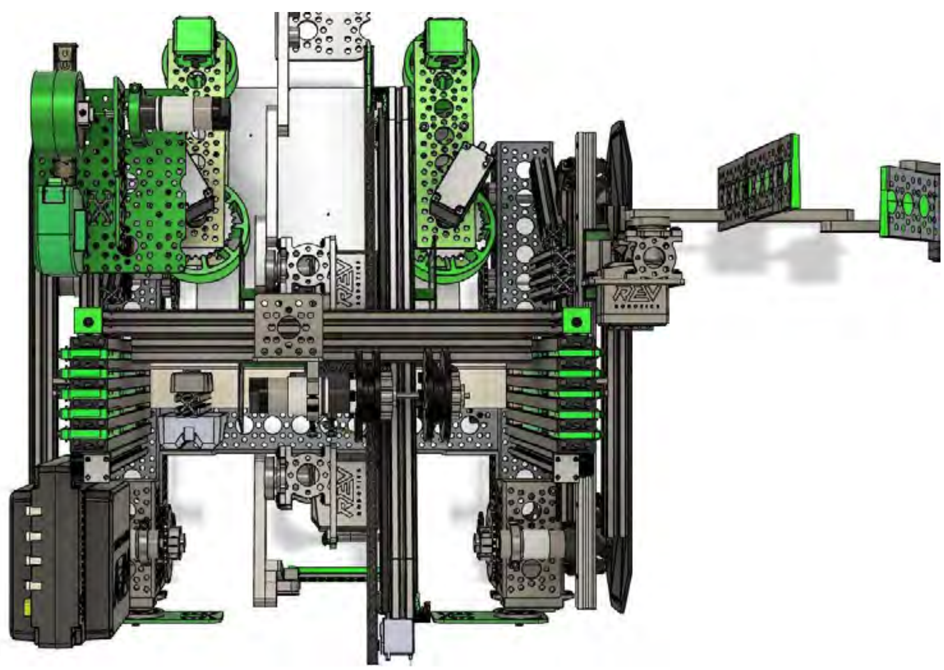




CURRENT DRIVER CONTROLLED CLAW





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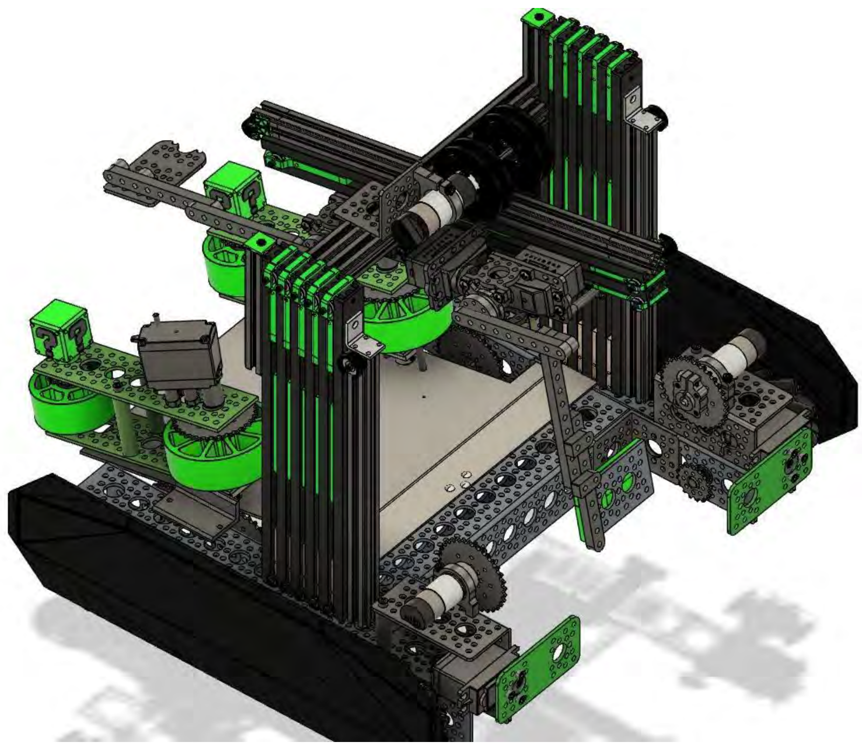

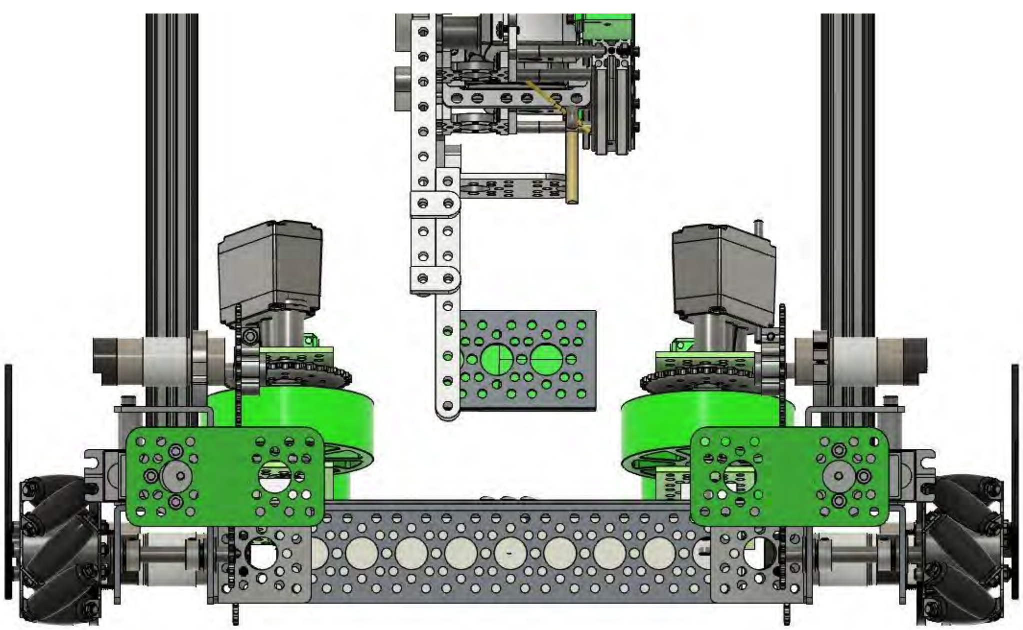

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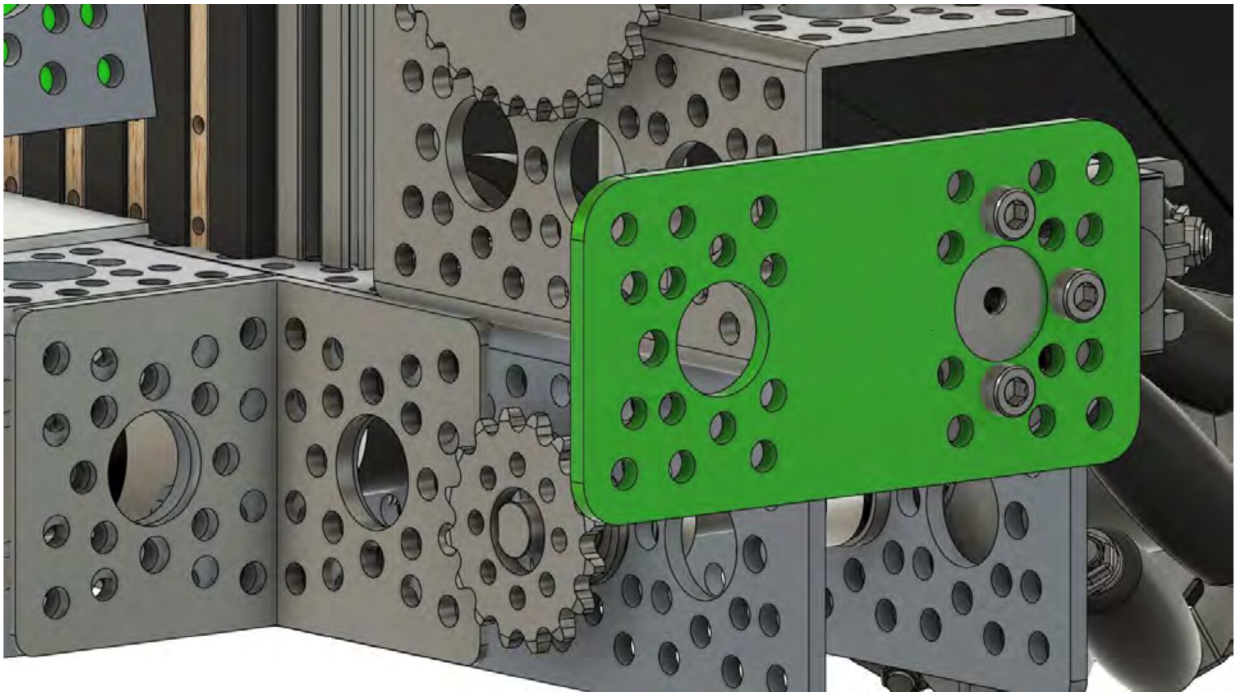

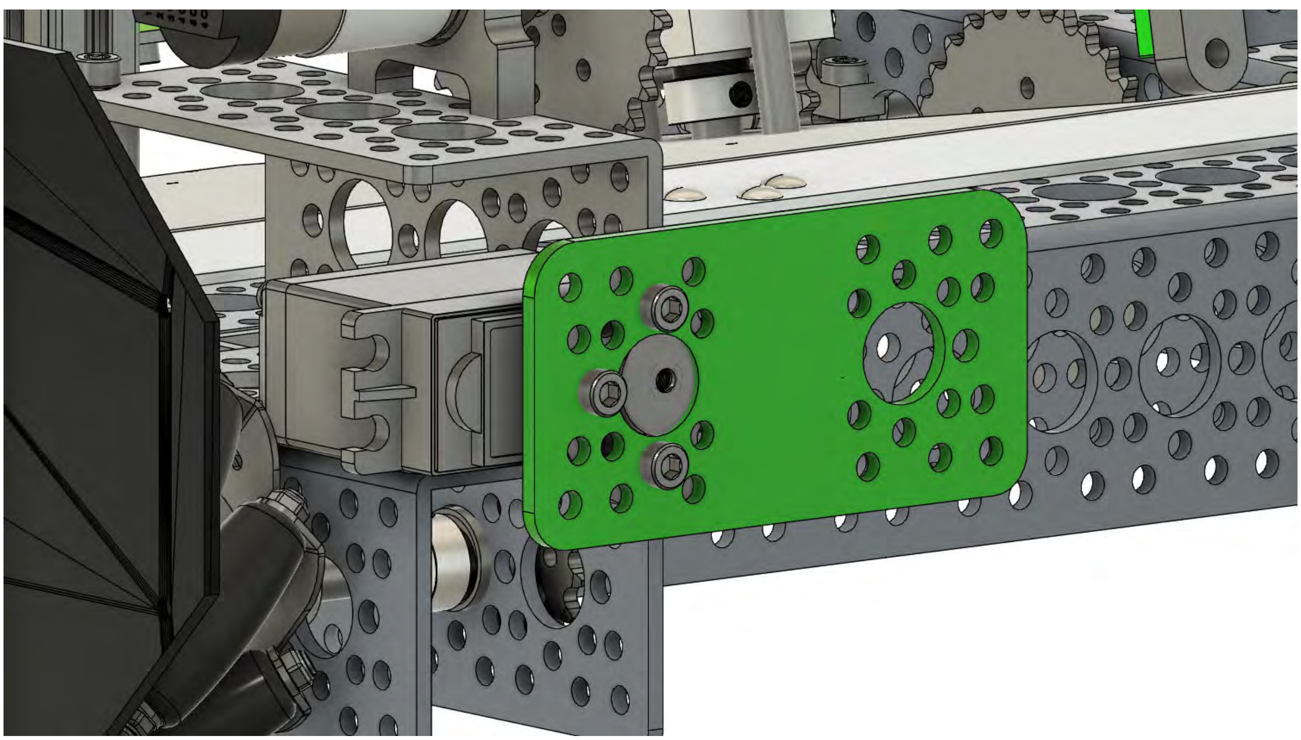

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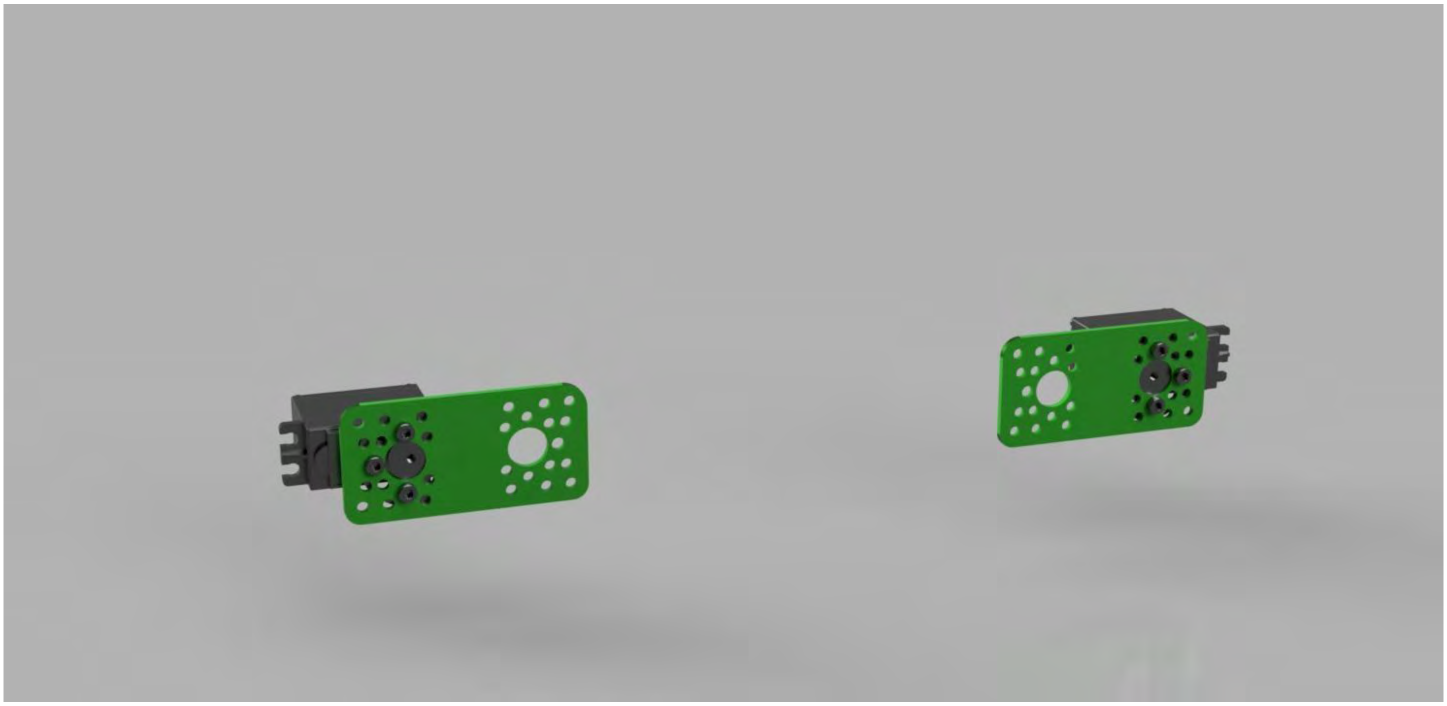
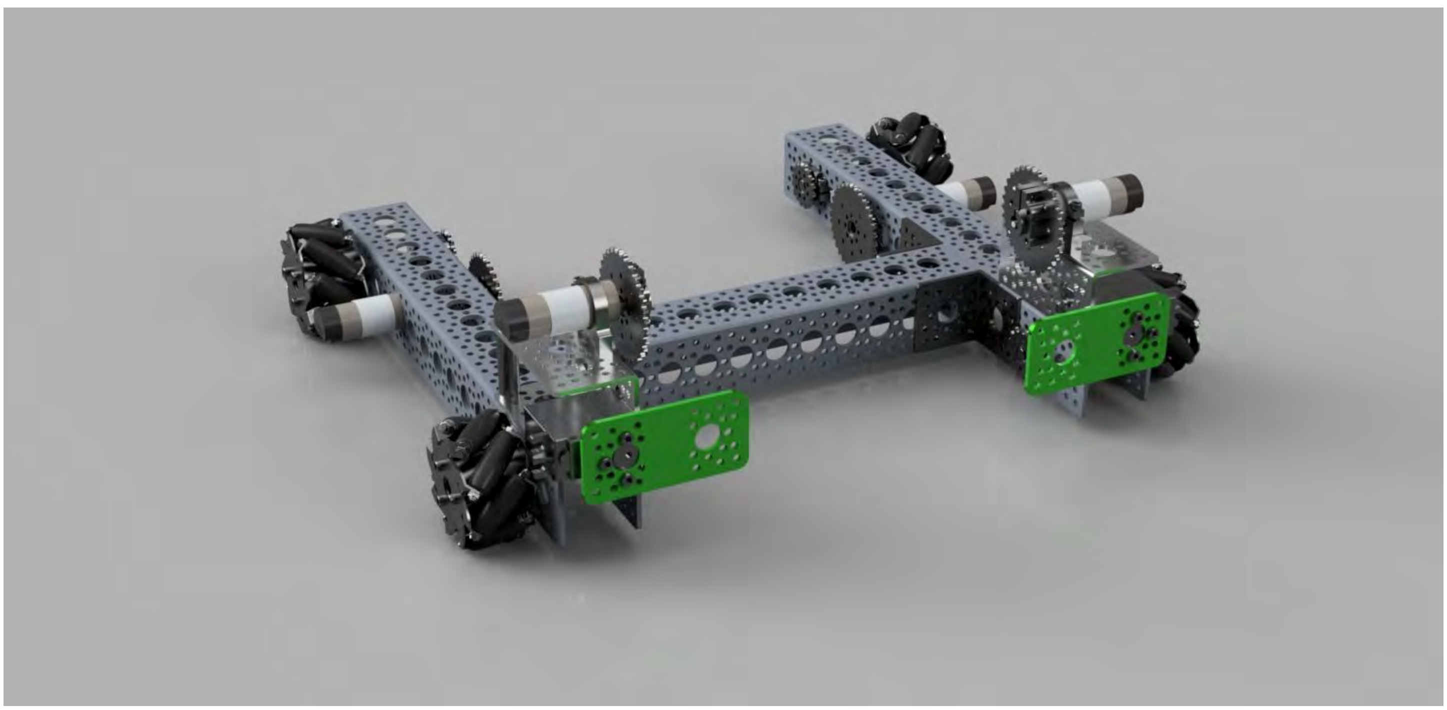
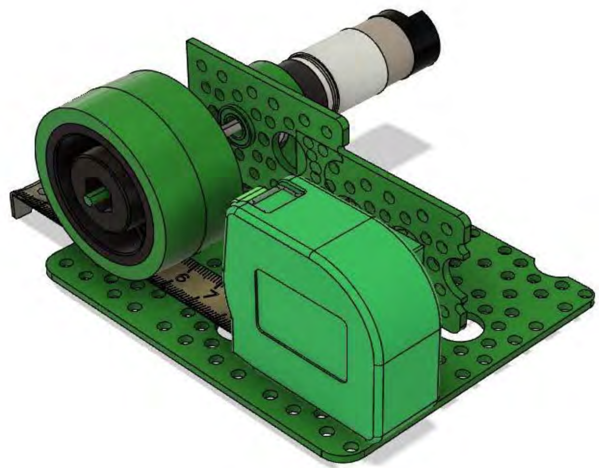
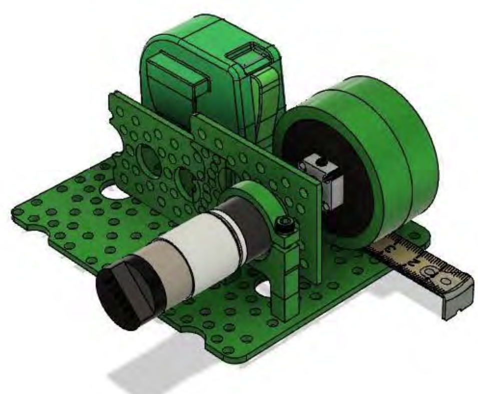
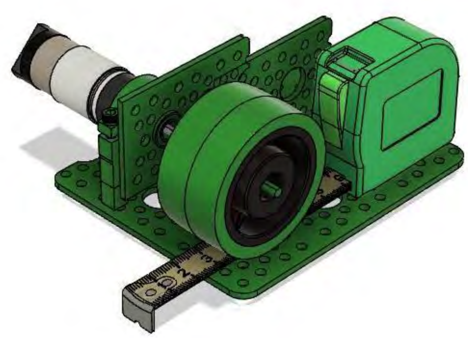




CURRENT TAPE MEASURE







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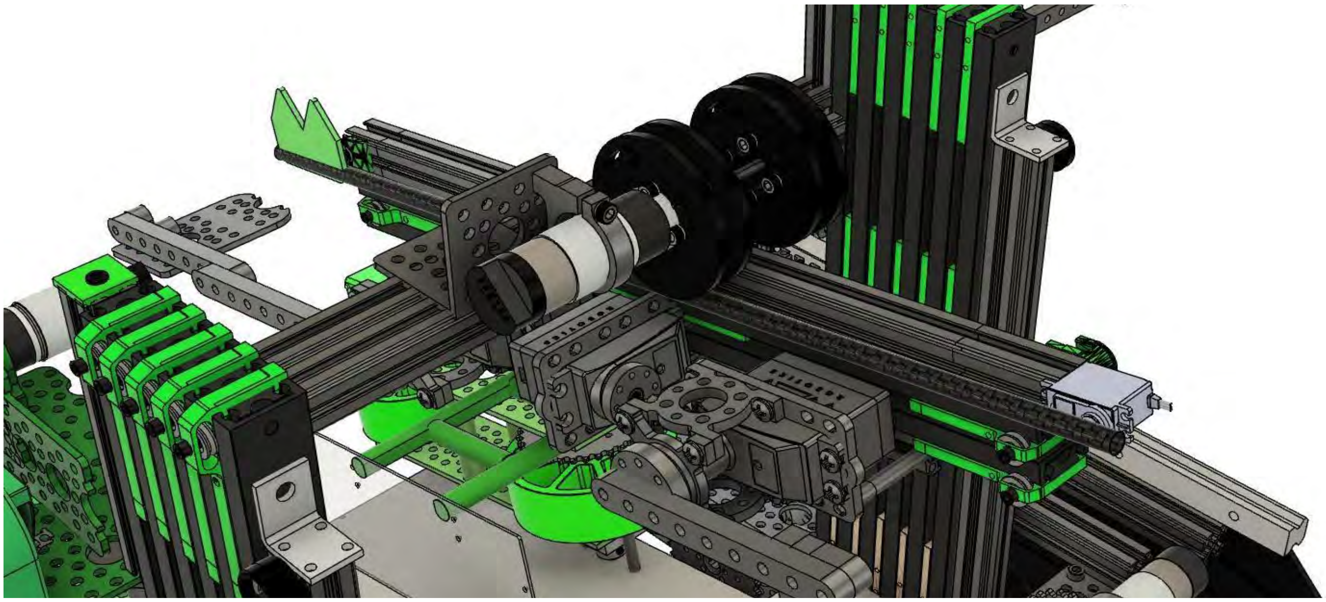

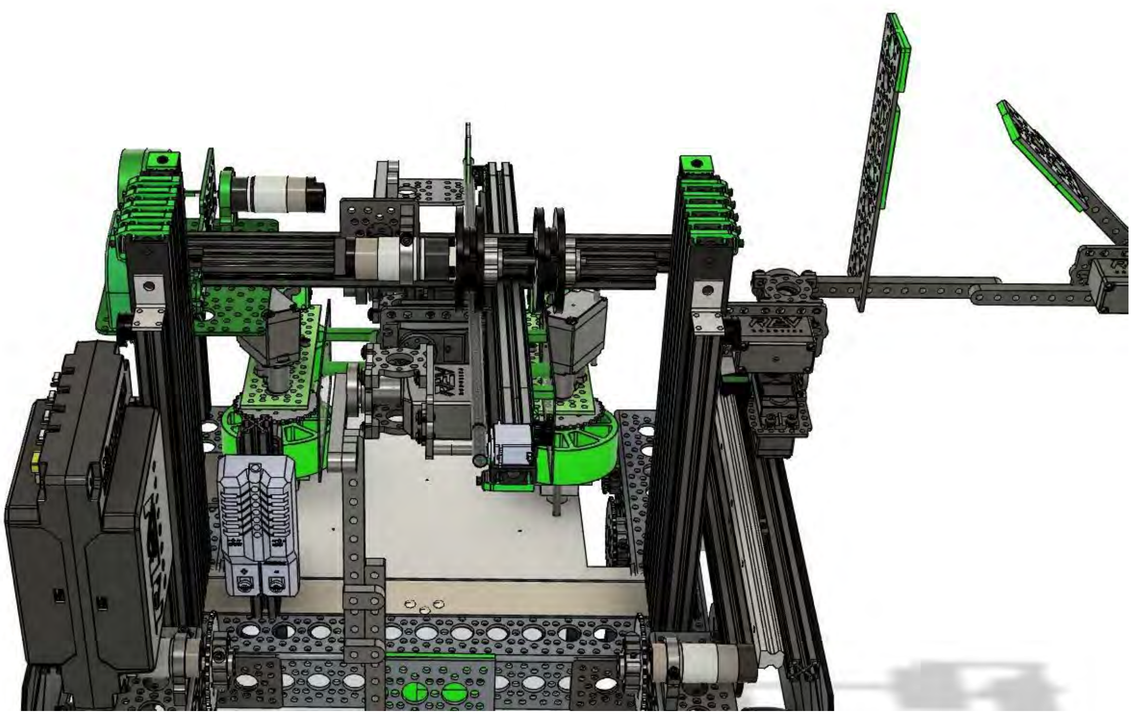

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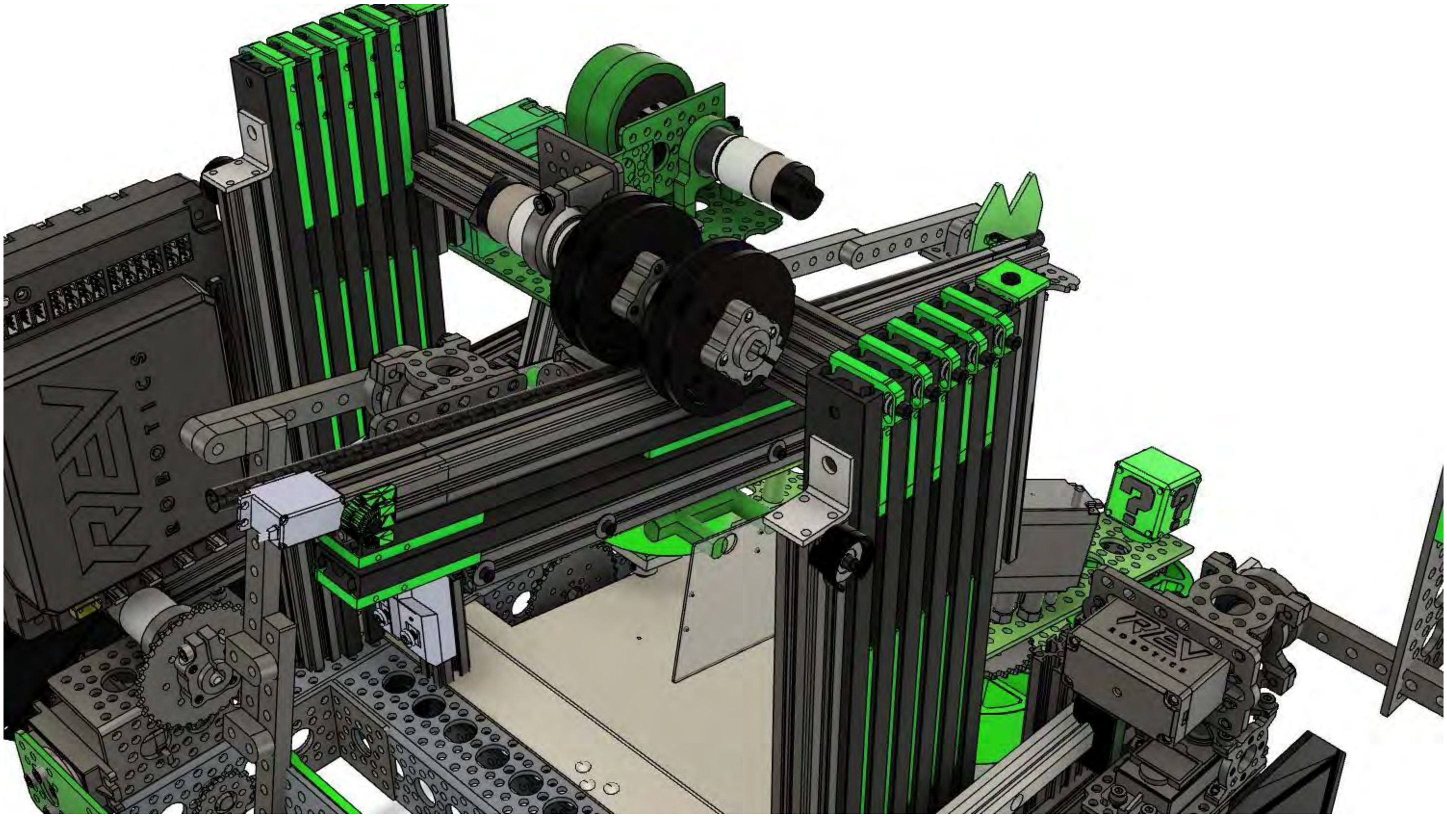
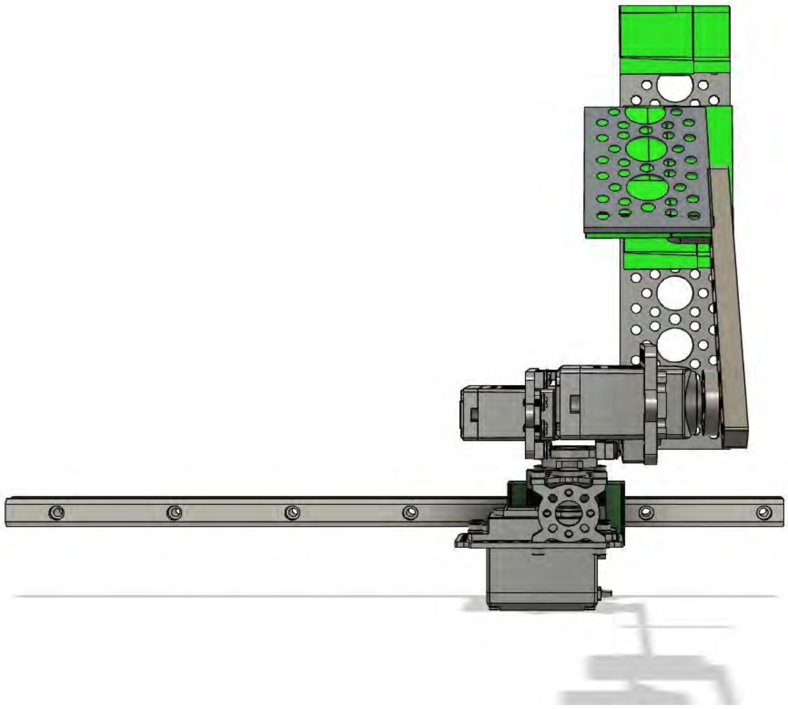
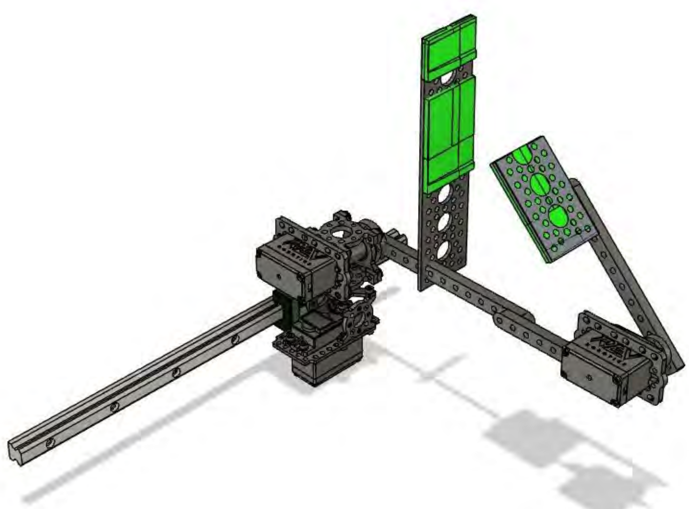


CURRENT AUTONOMOUS CLAW





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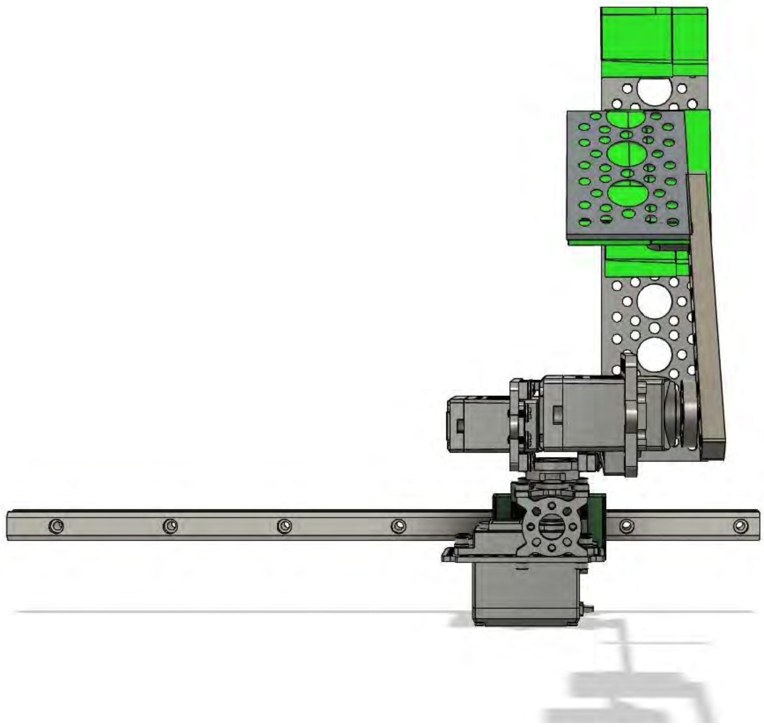

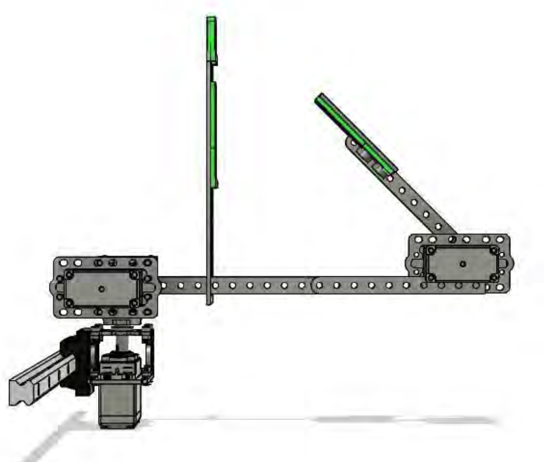

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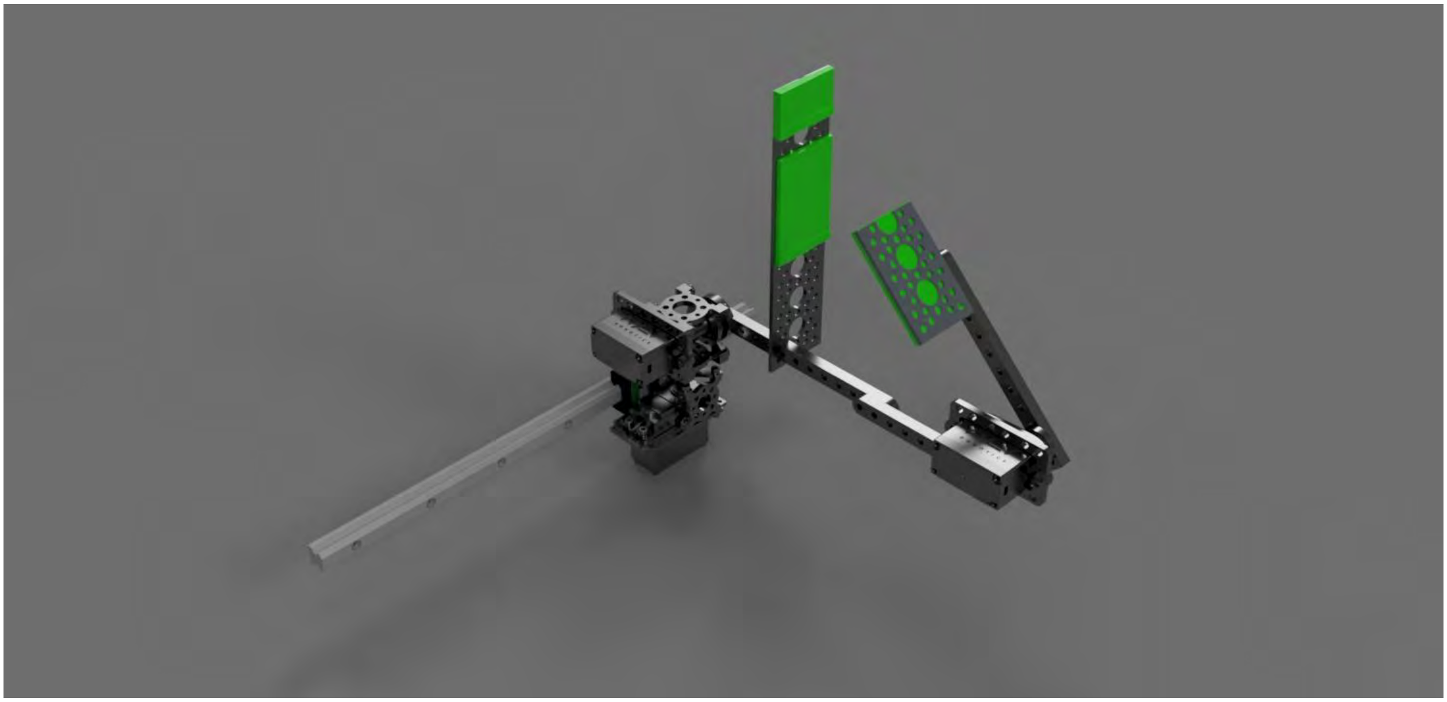
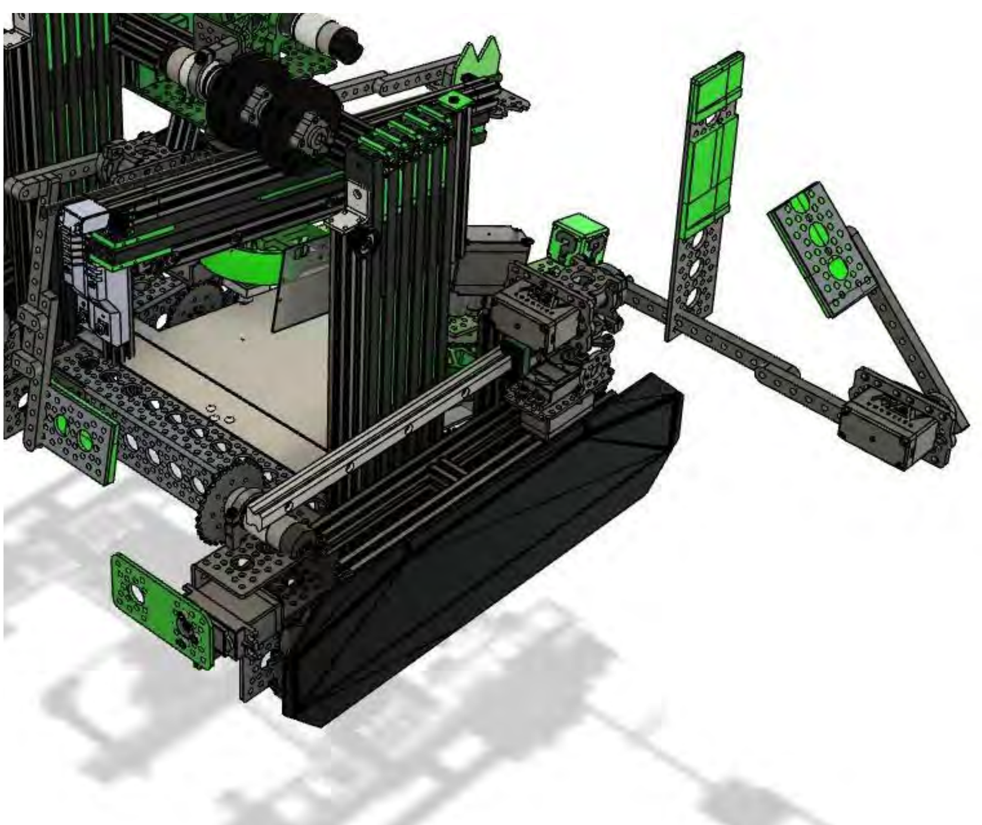
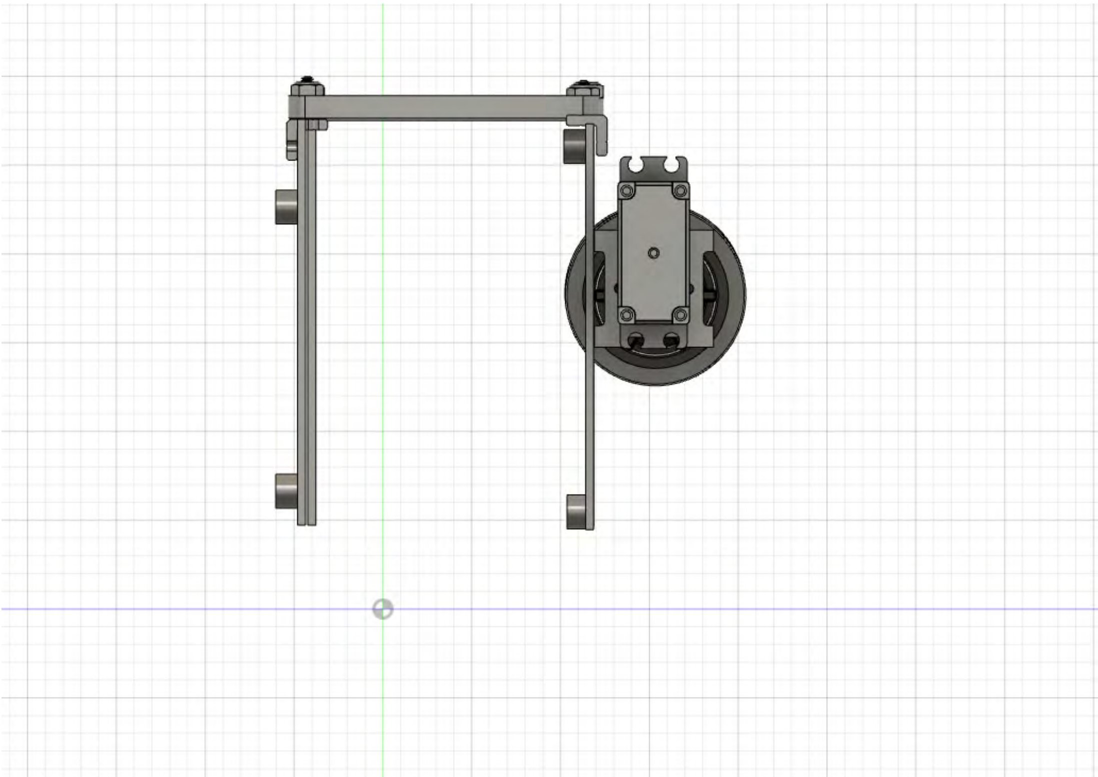
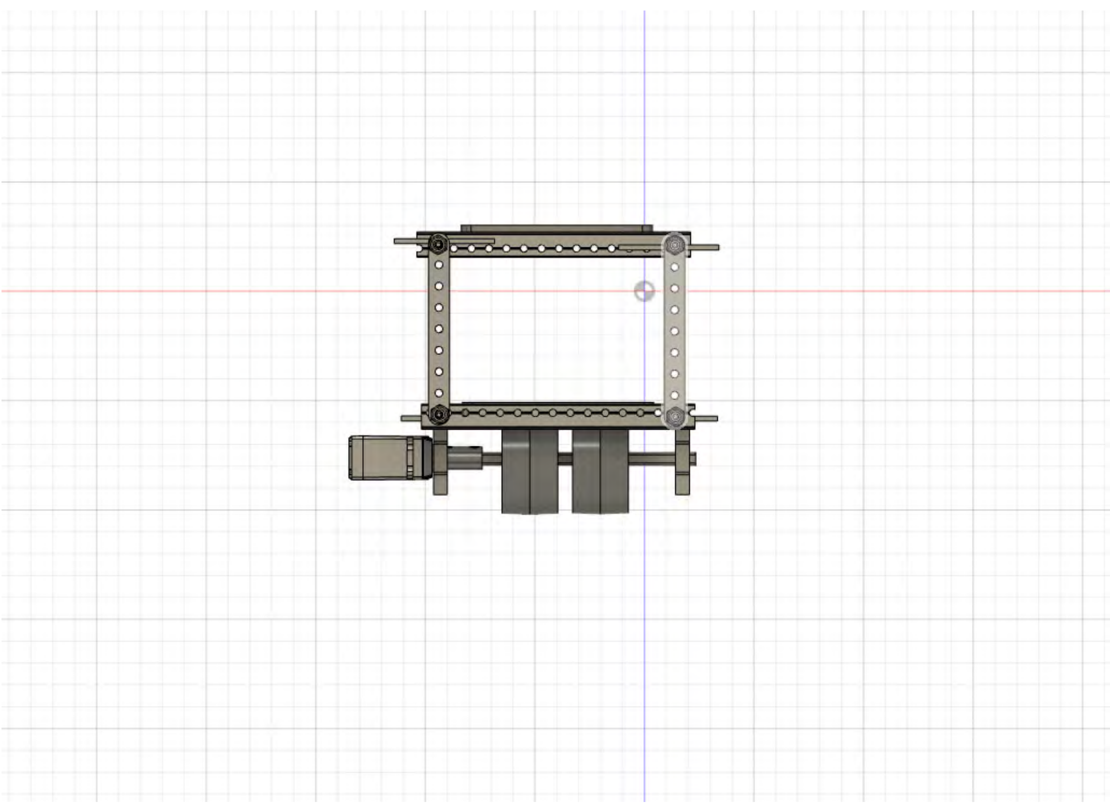




V1 DRIVER CONTROLLED CLAW





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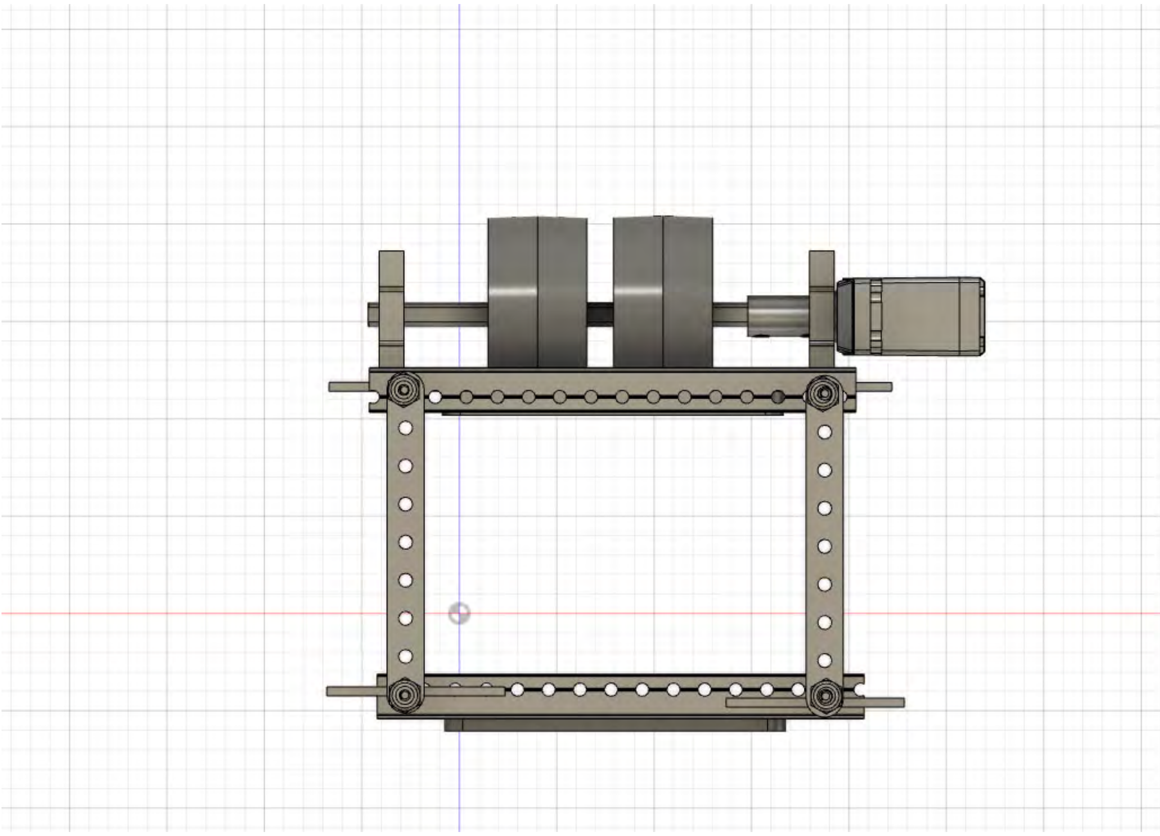

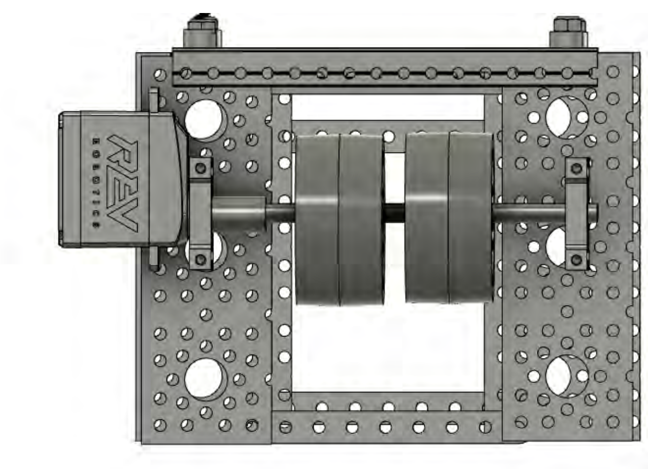

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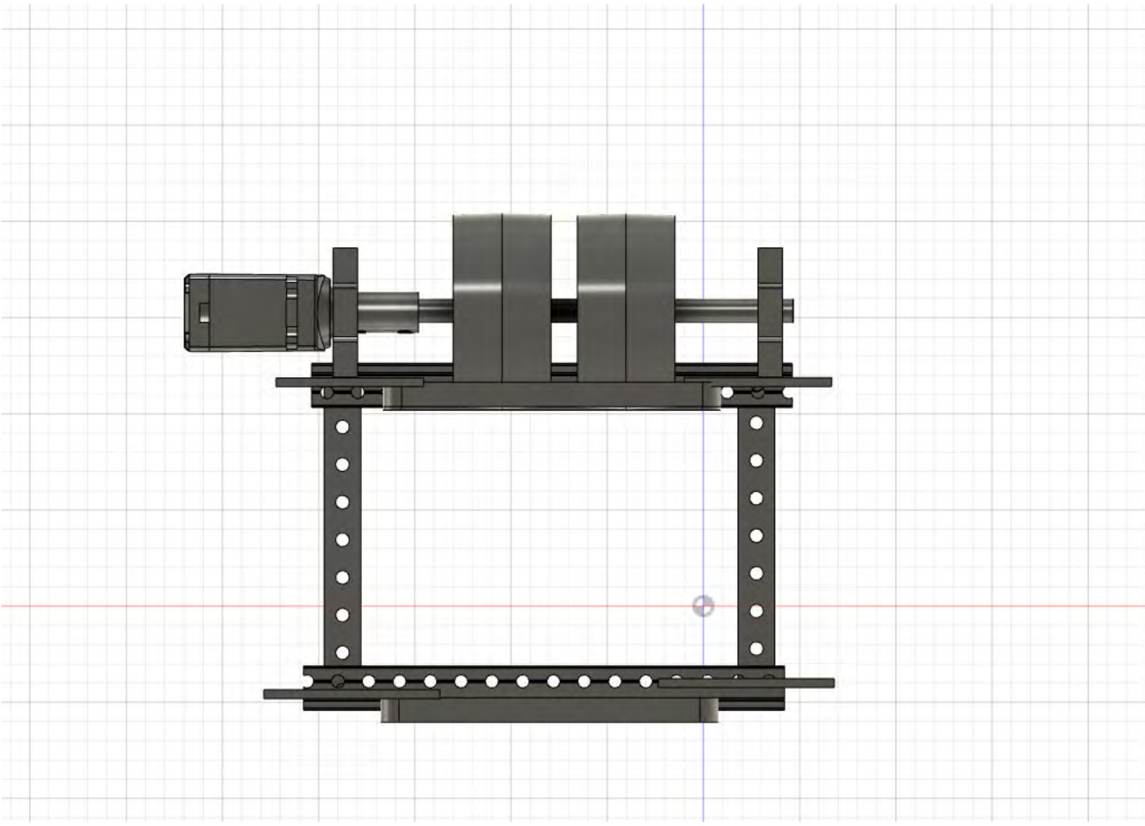
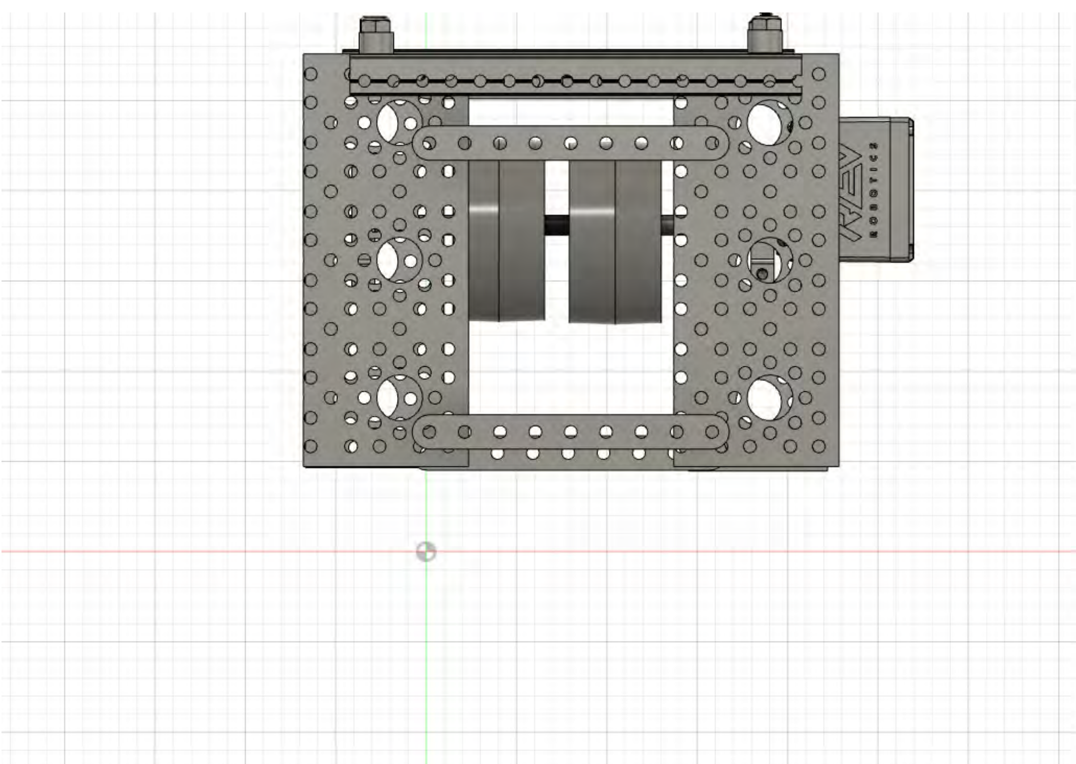
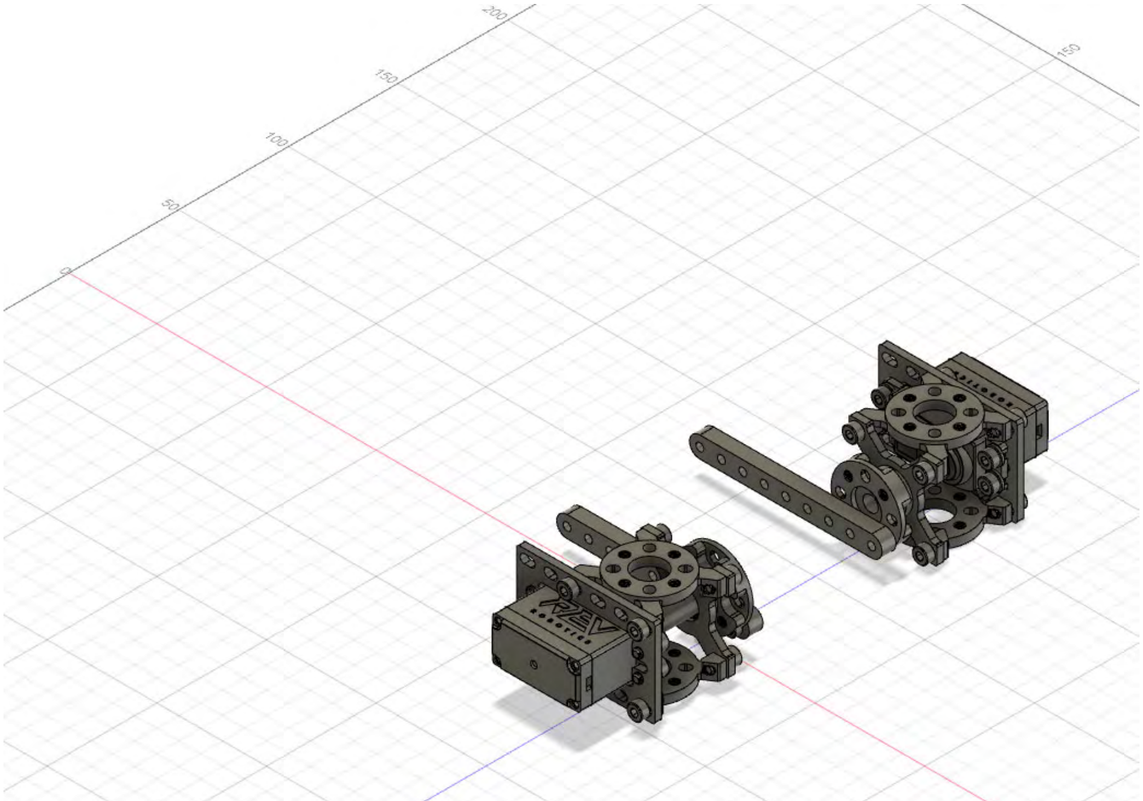
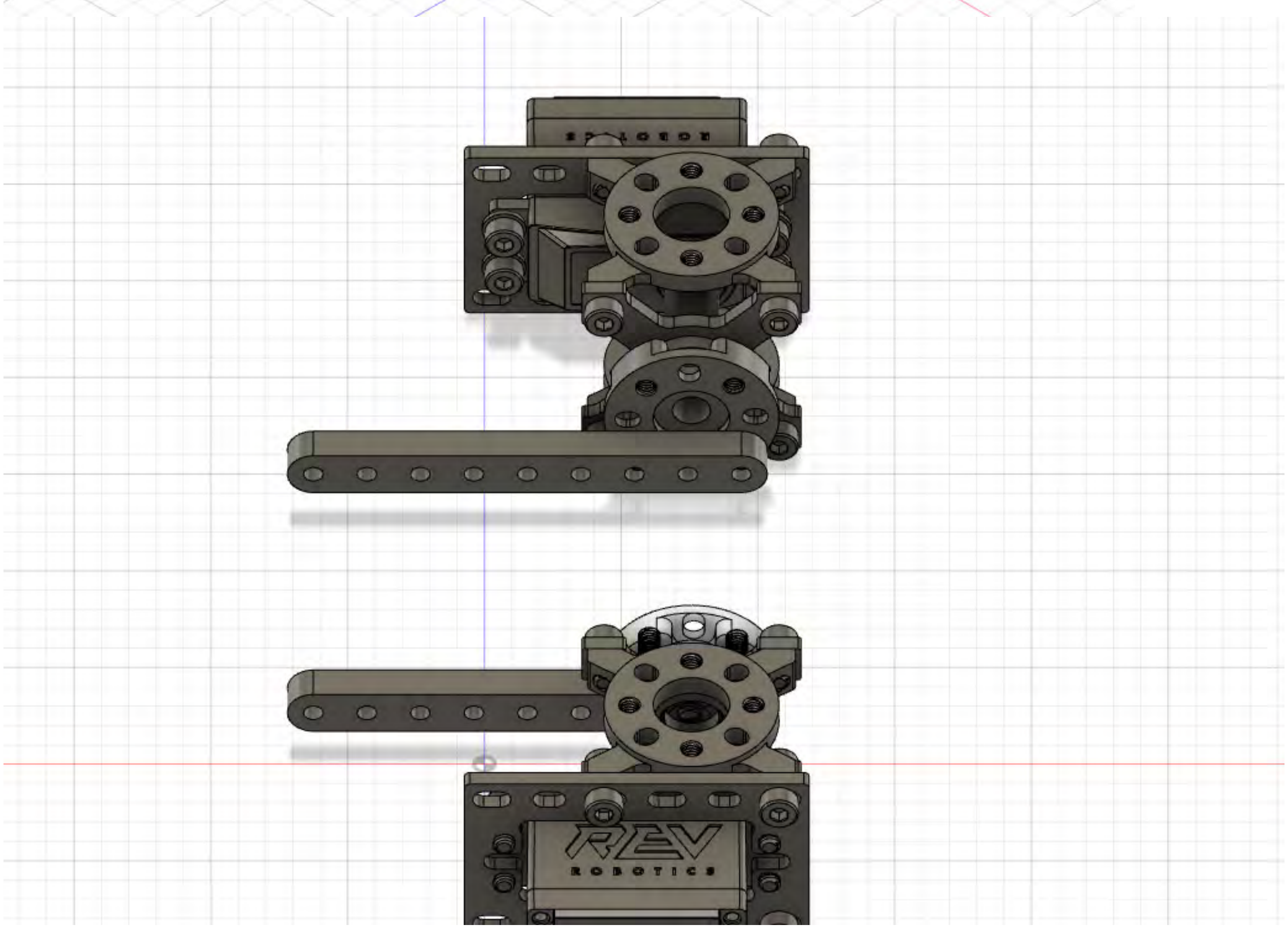




V1 FOUNDATION MOVERS





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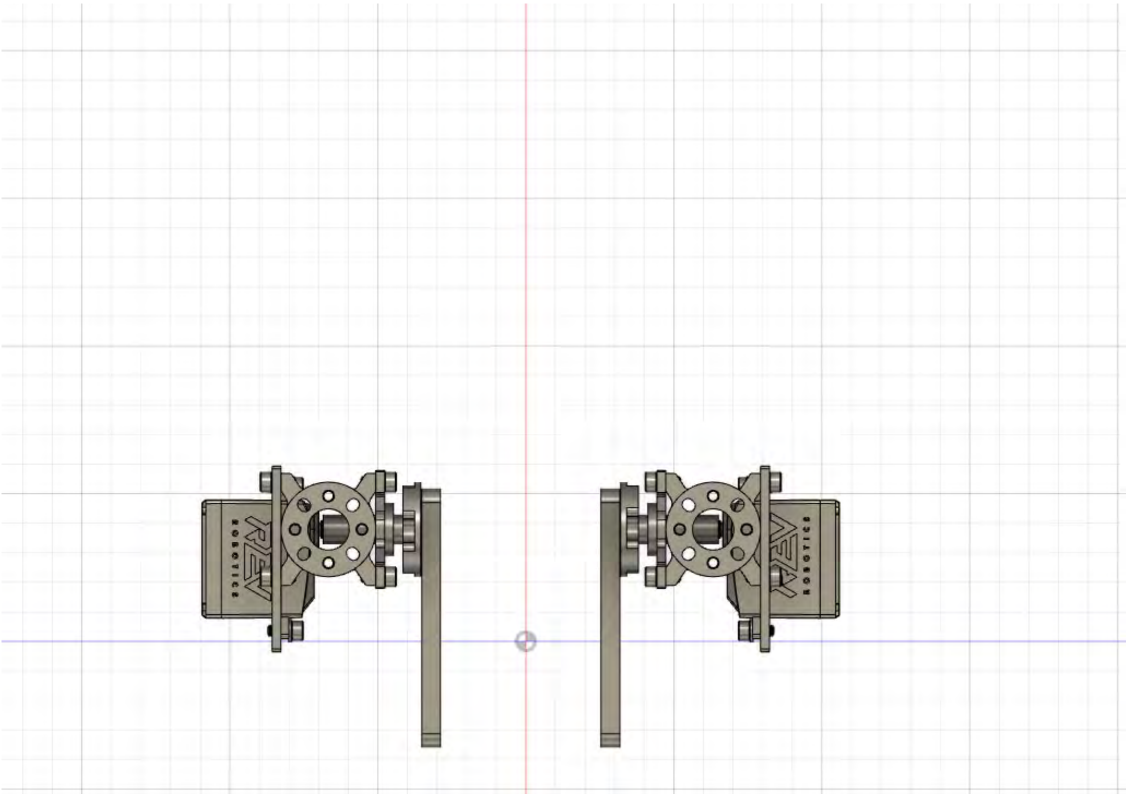

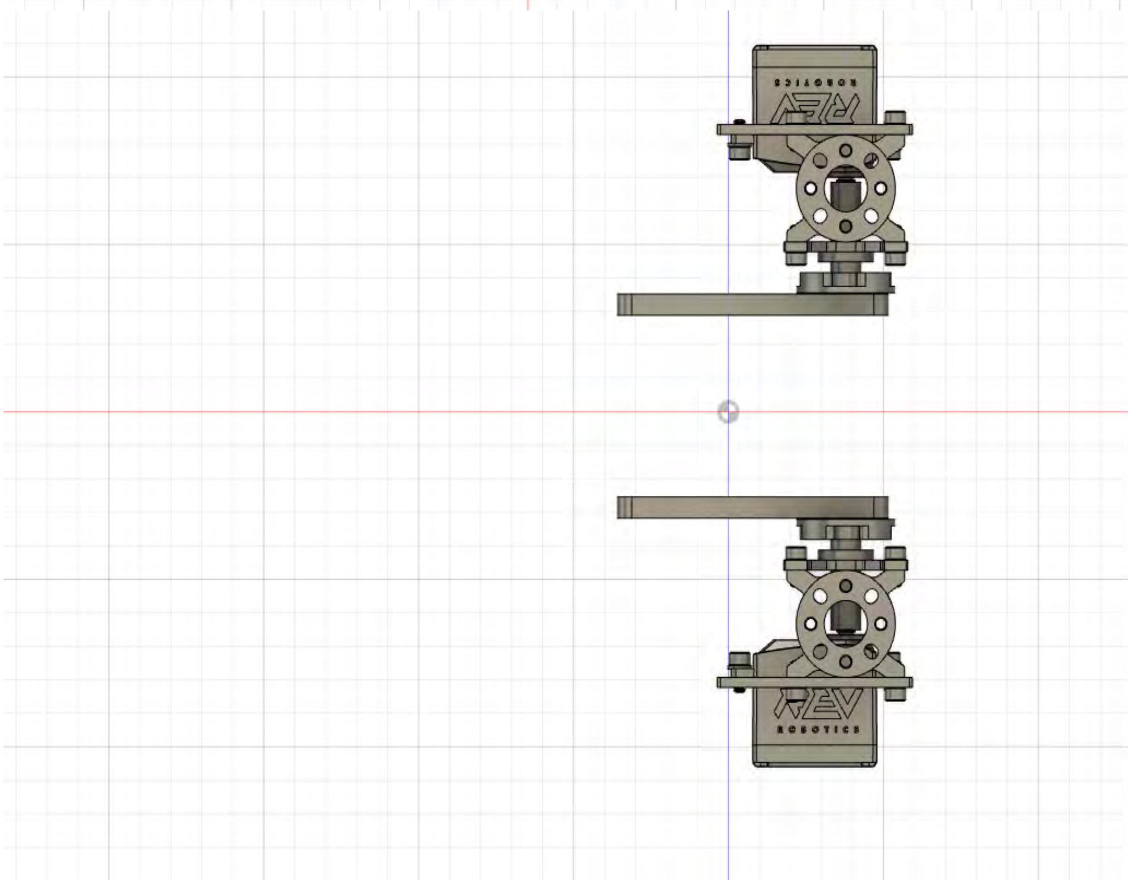

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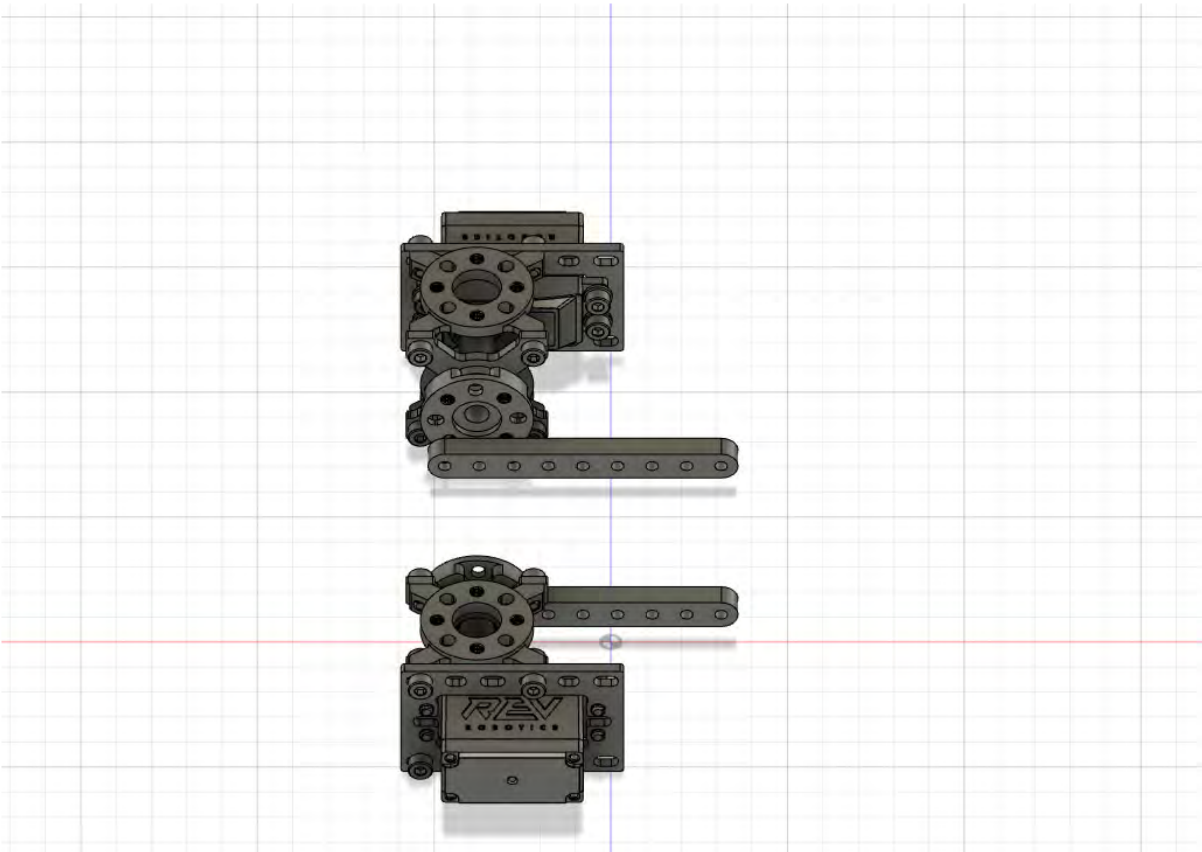

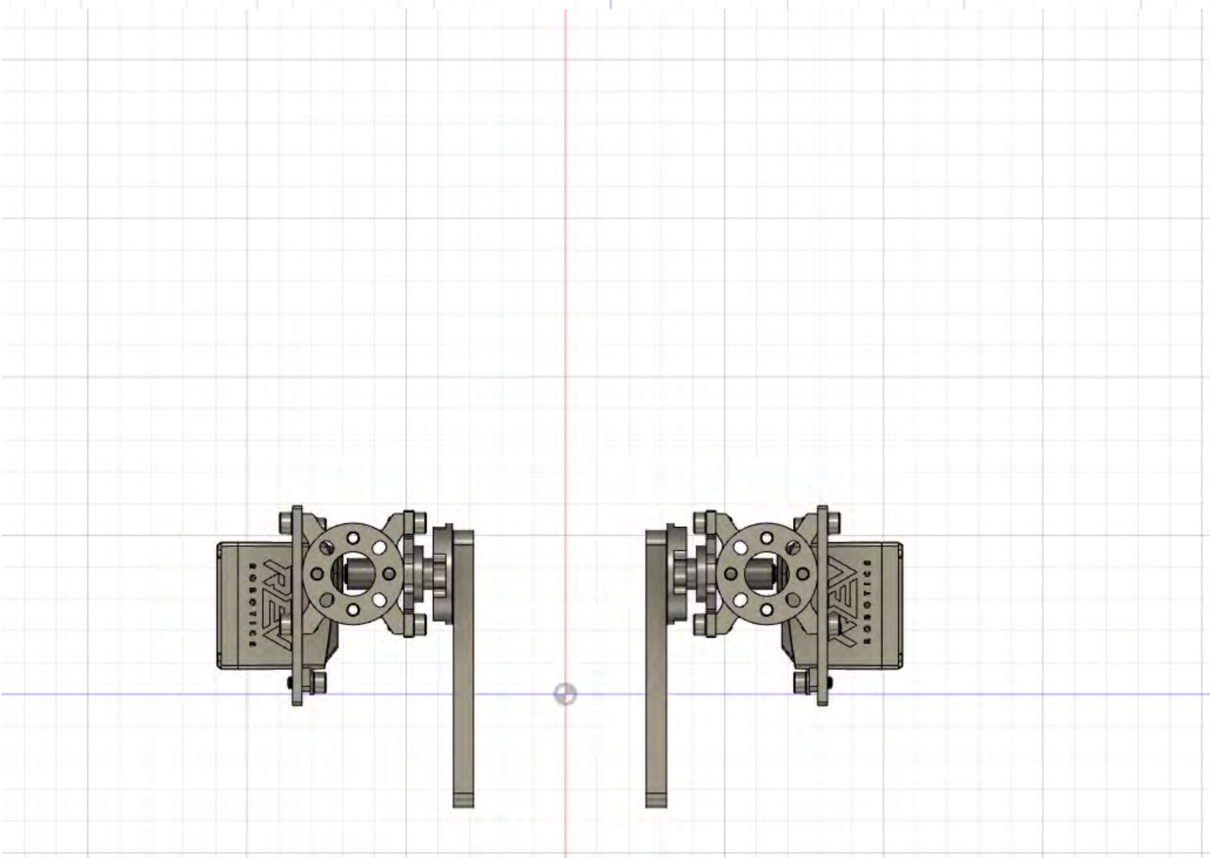

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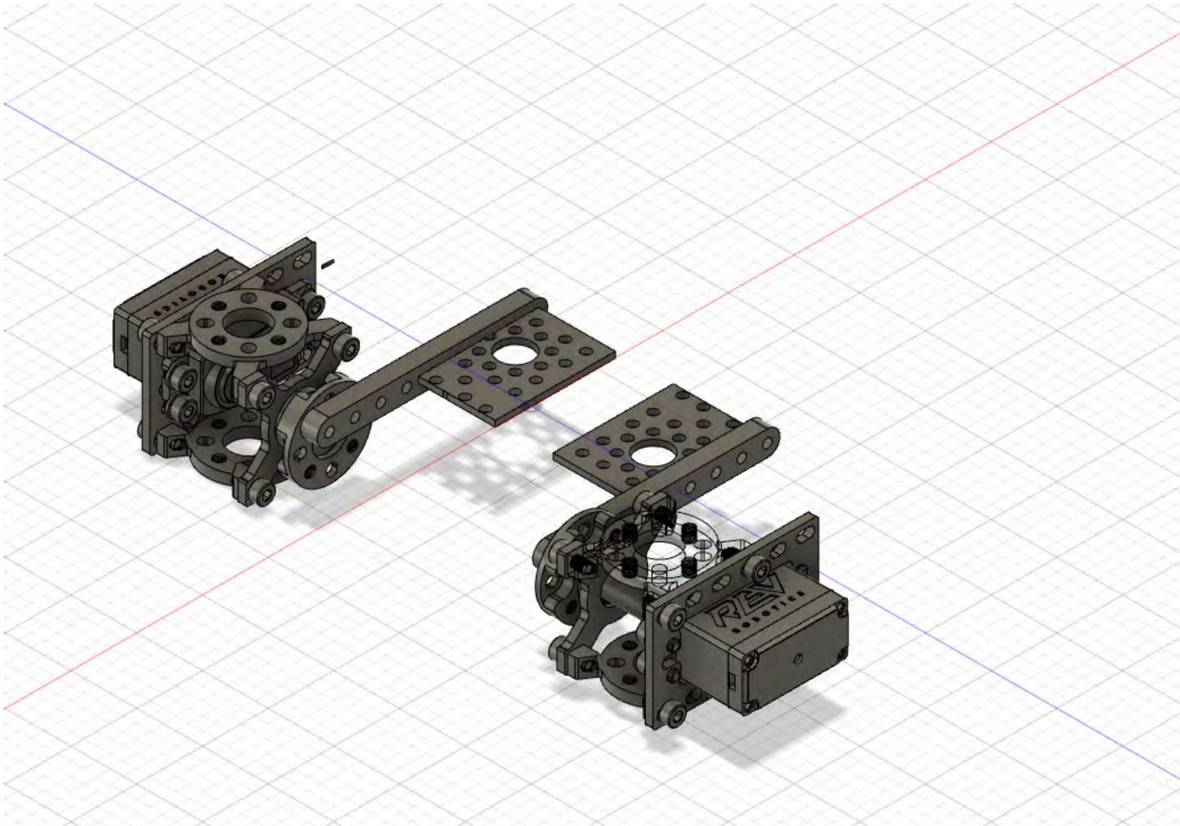

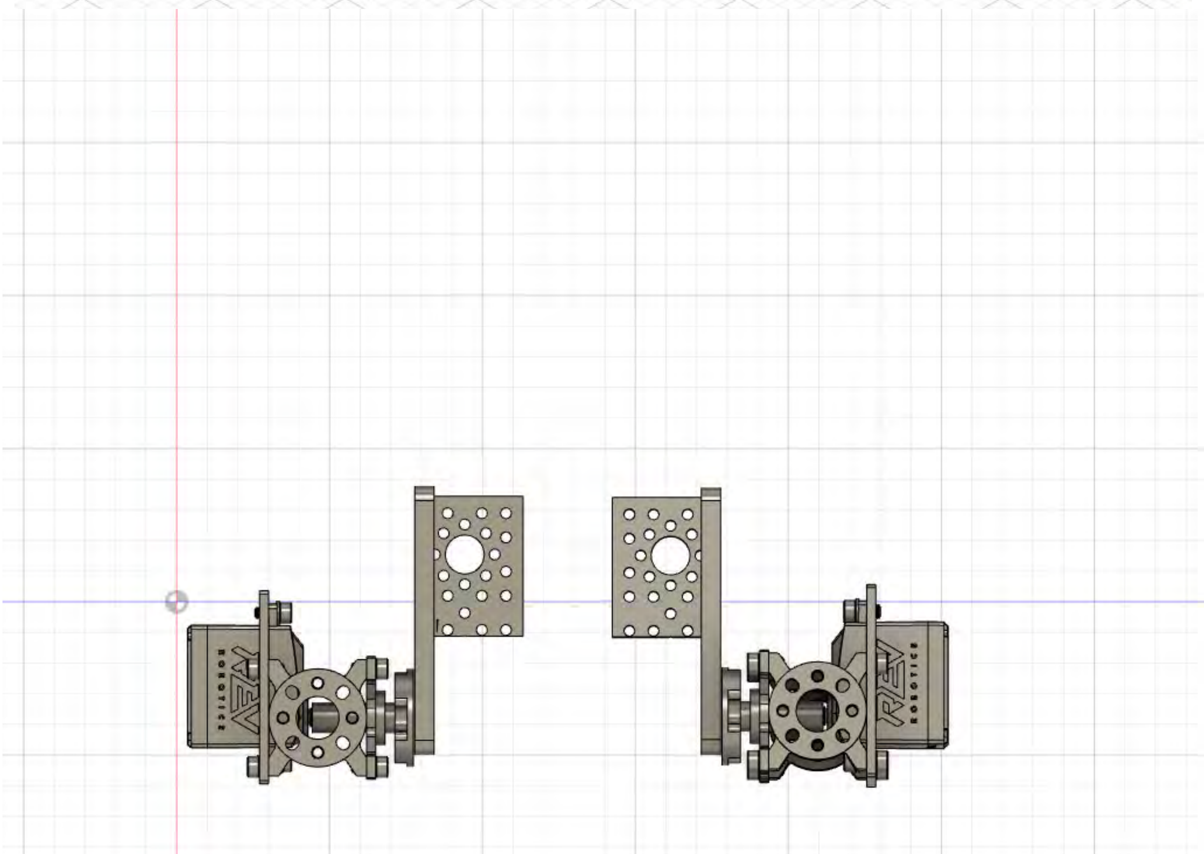

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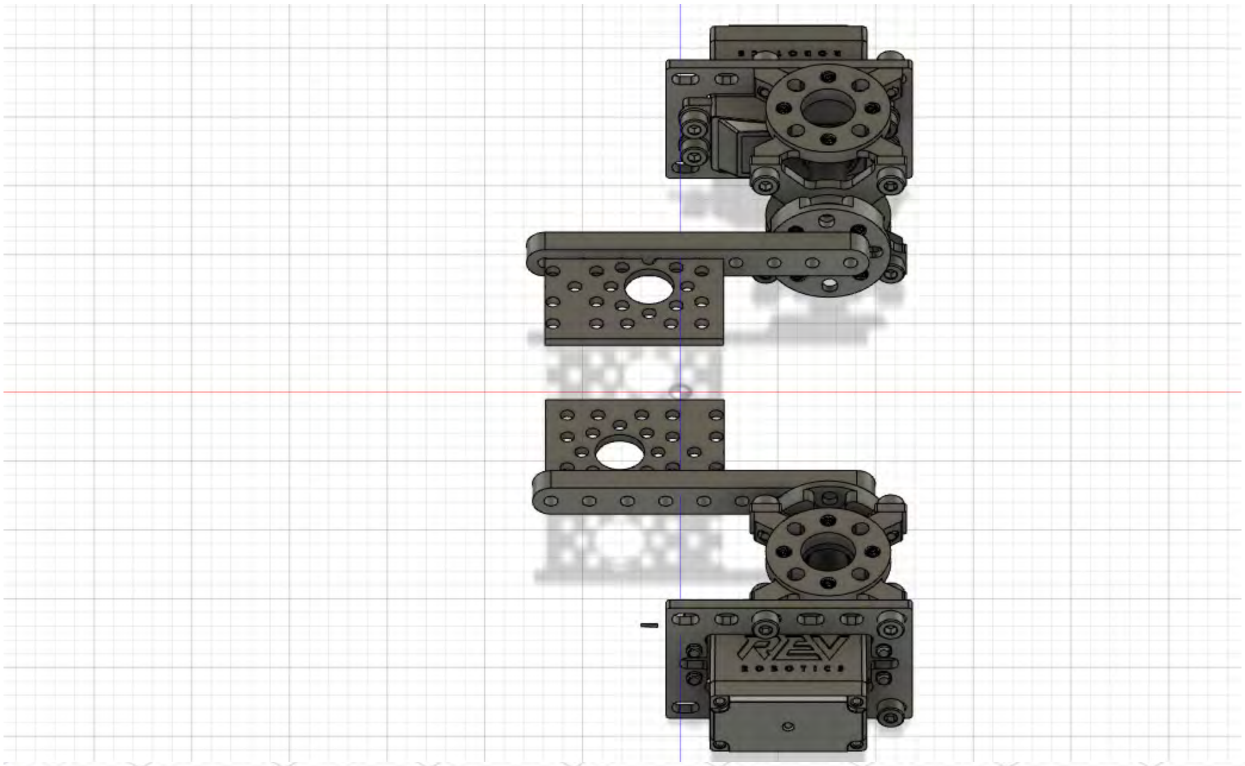

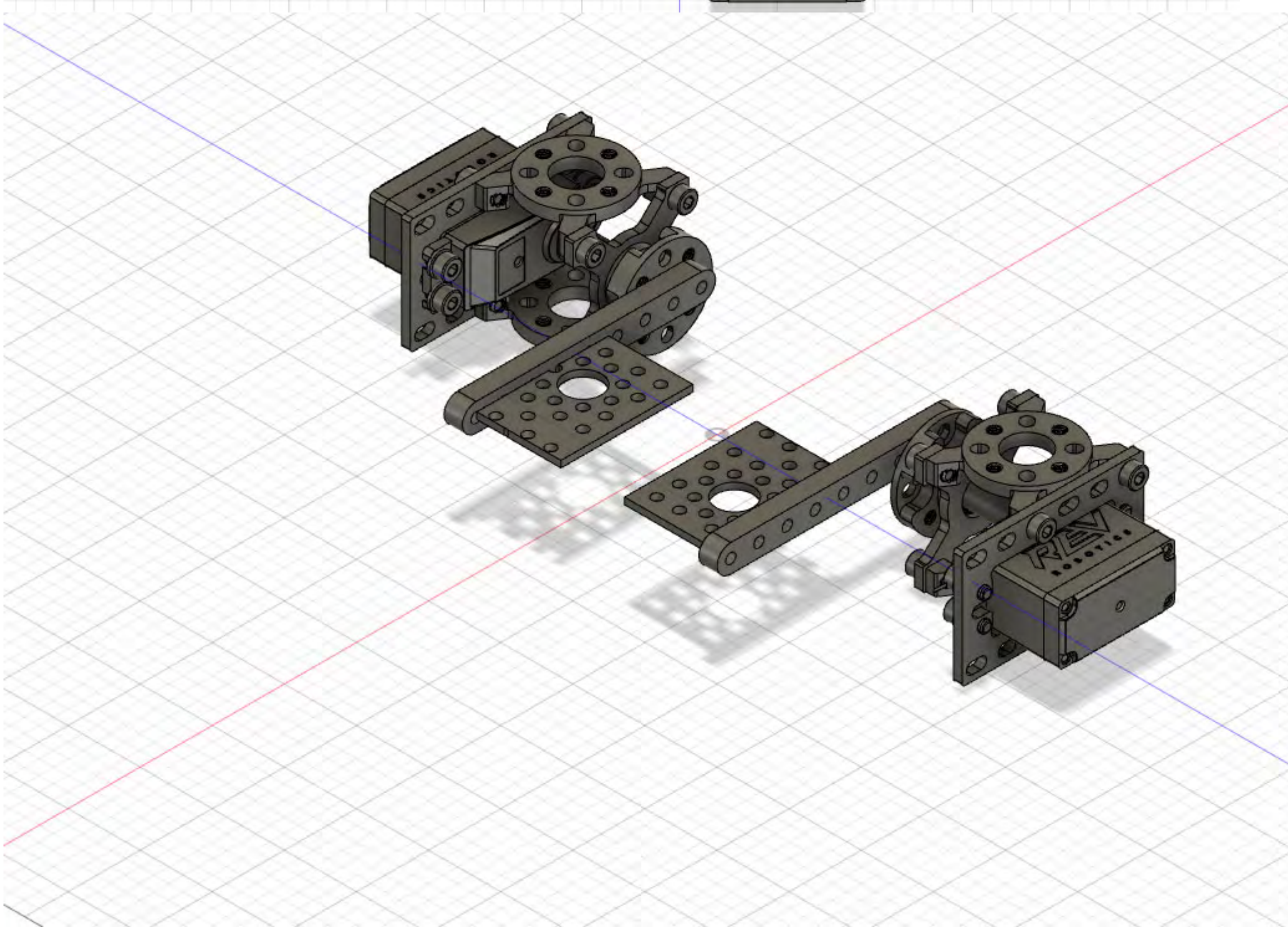

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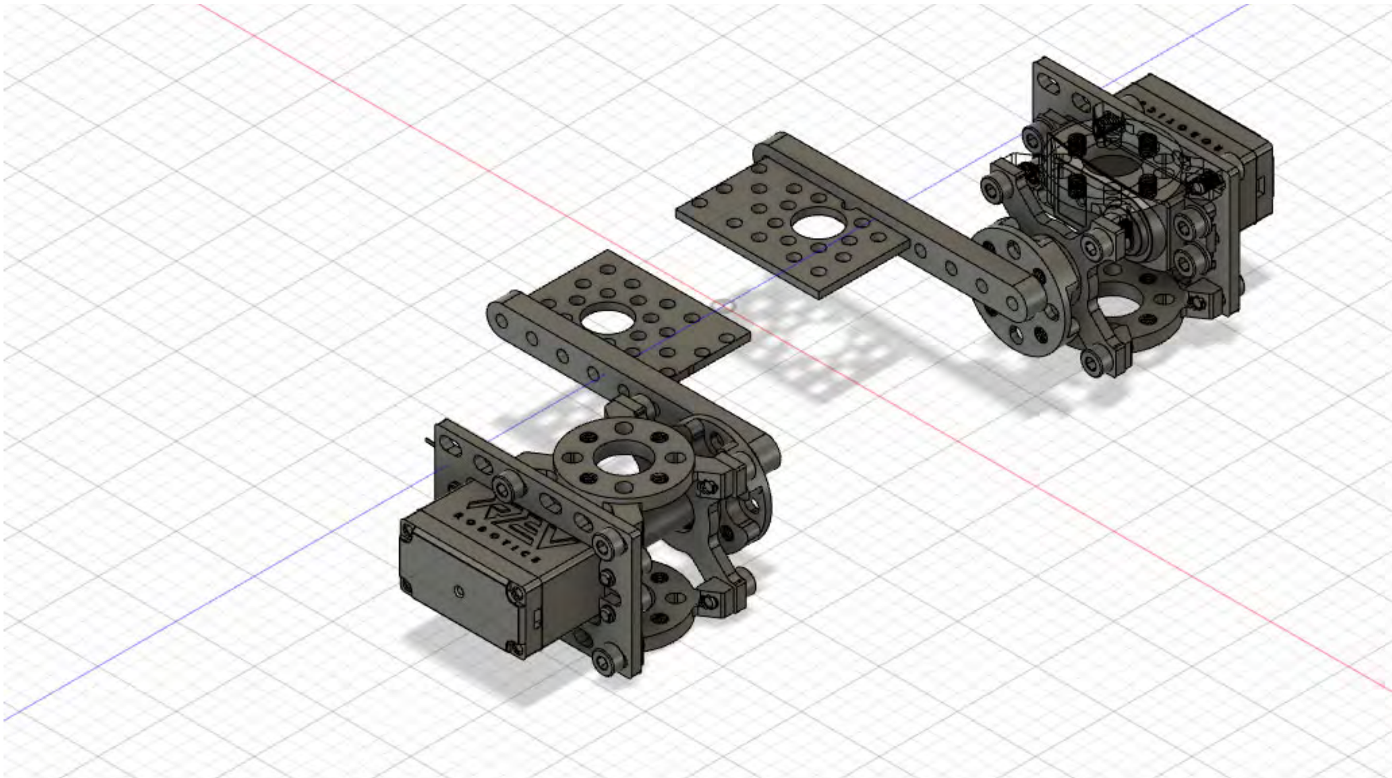
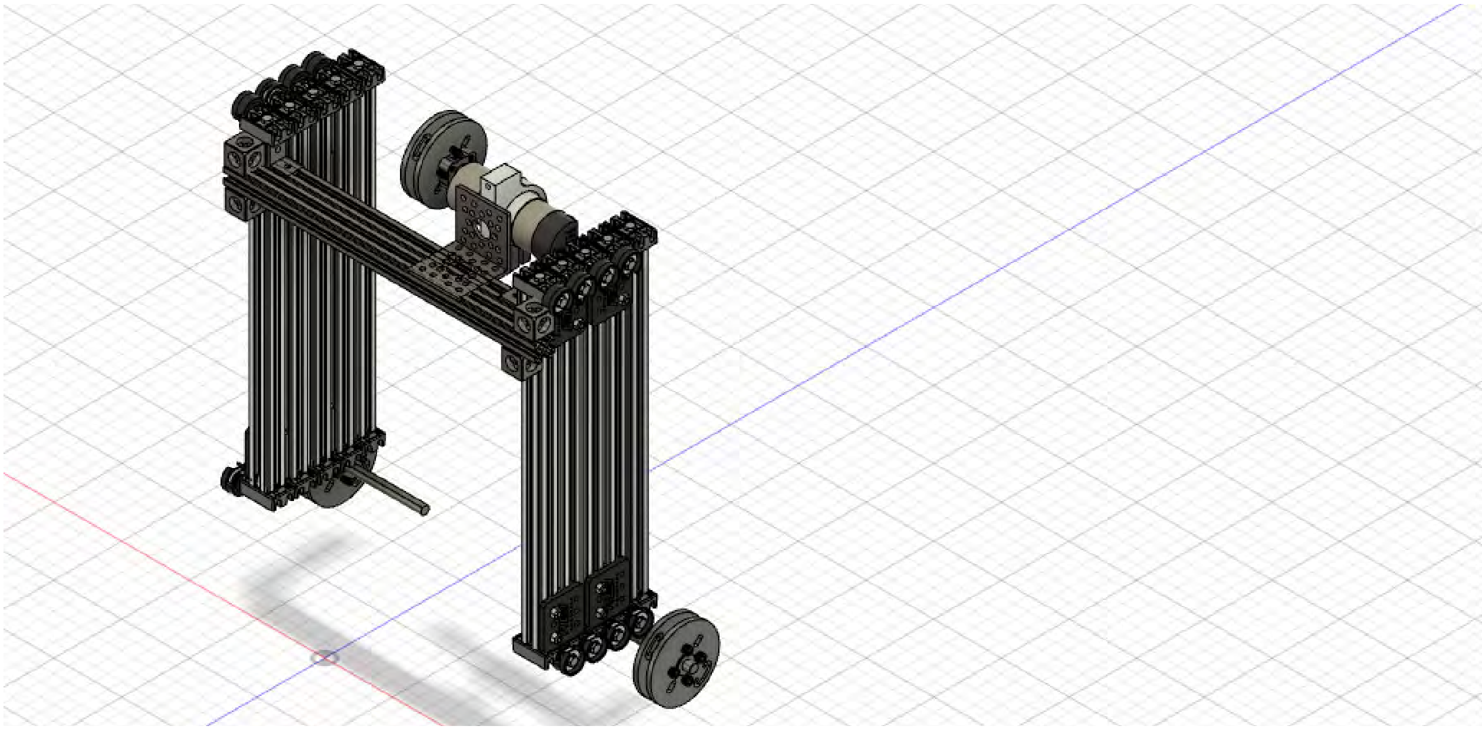
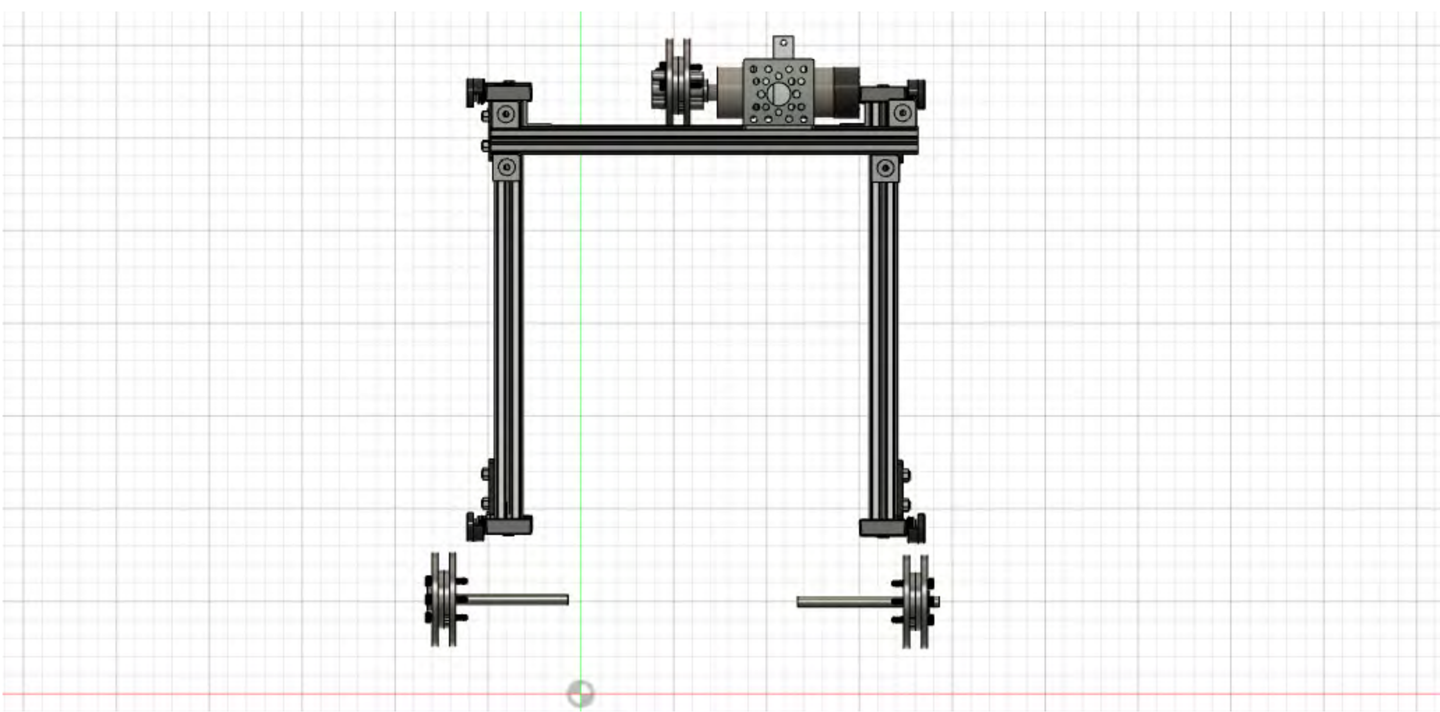


V1 VERTICAL LIFTS





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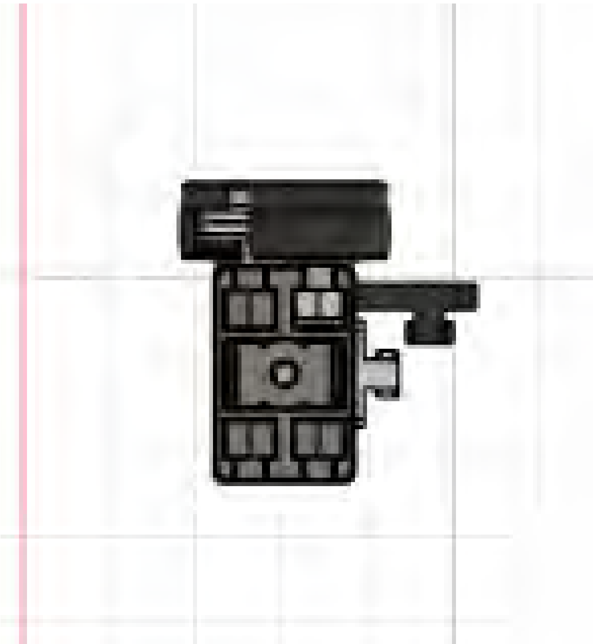

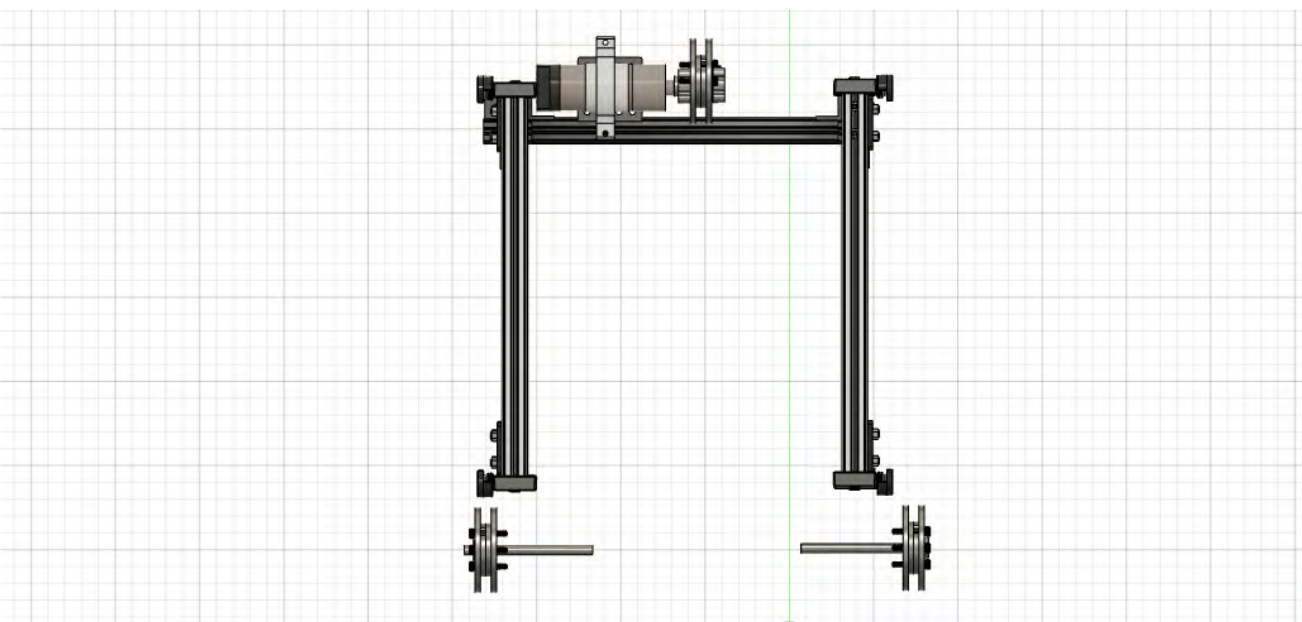

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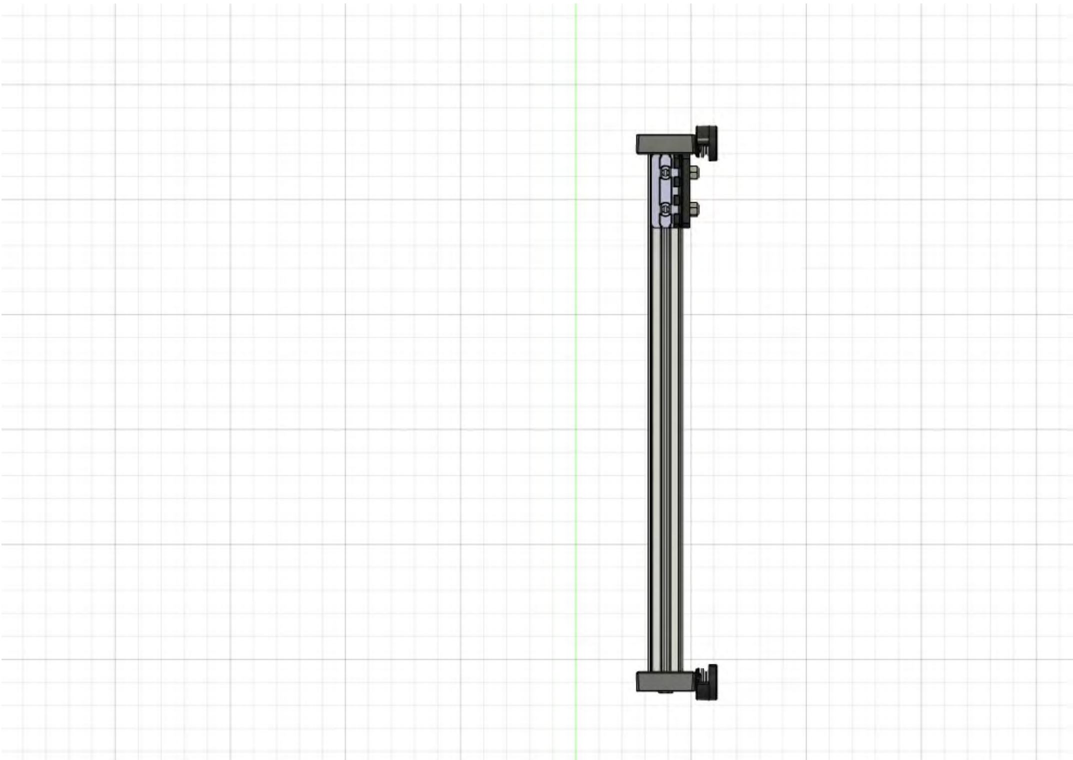

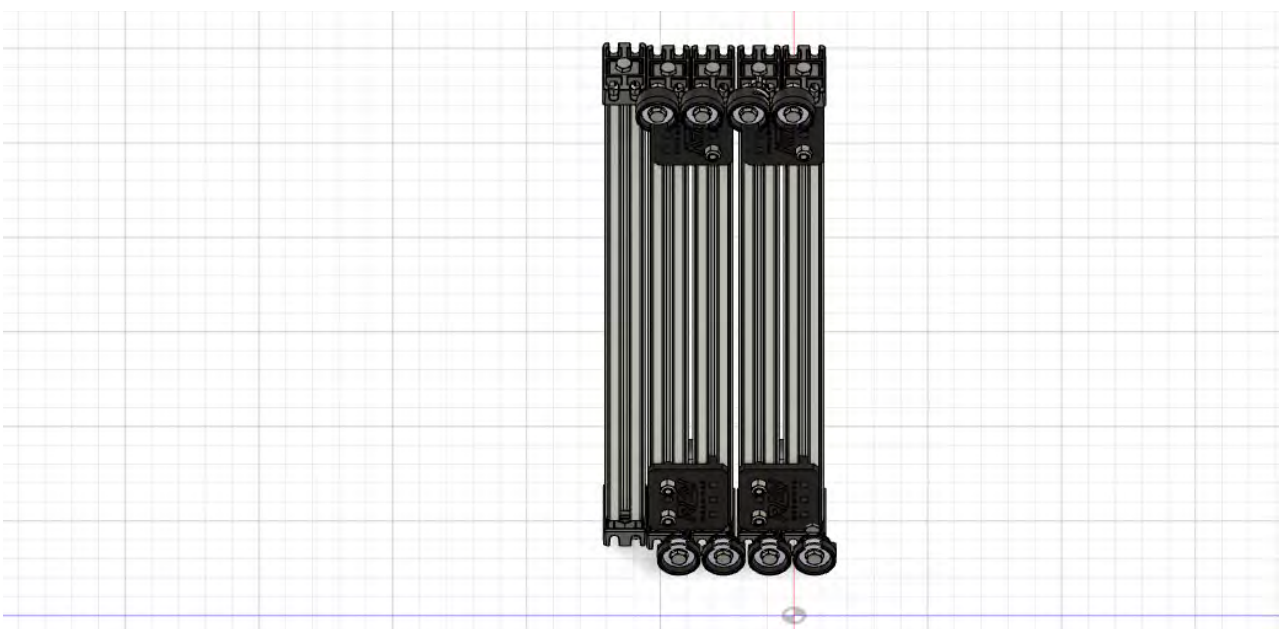

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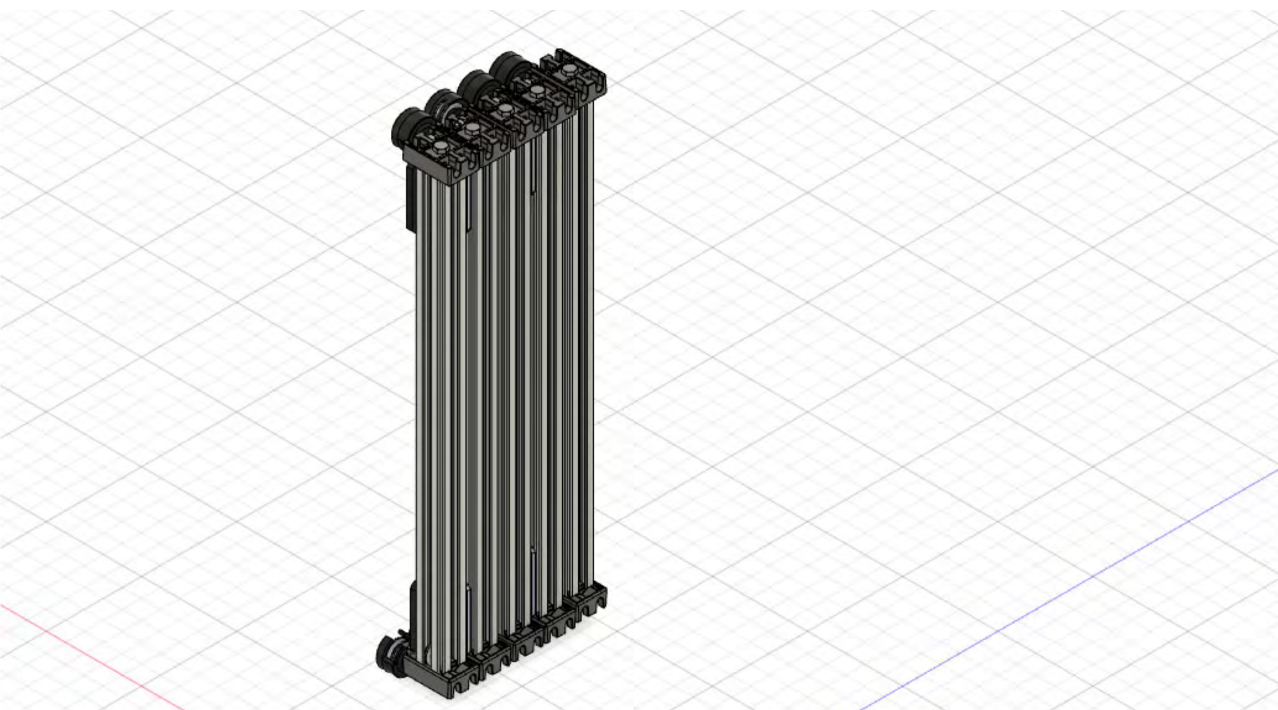

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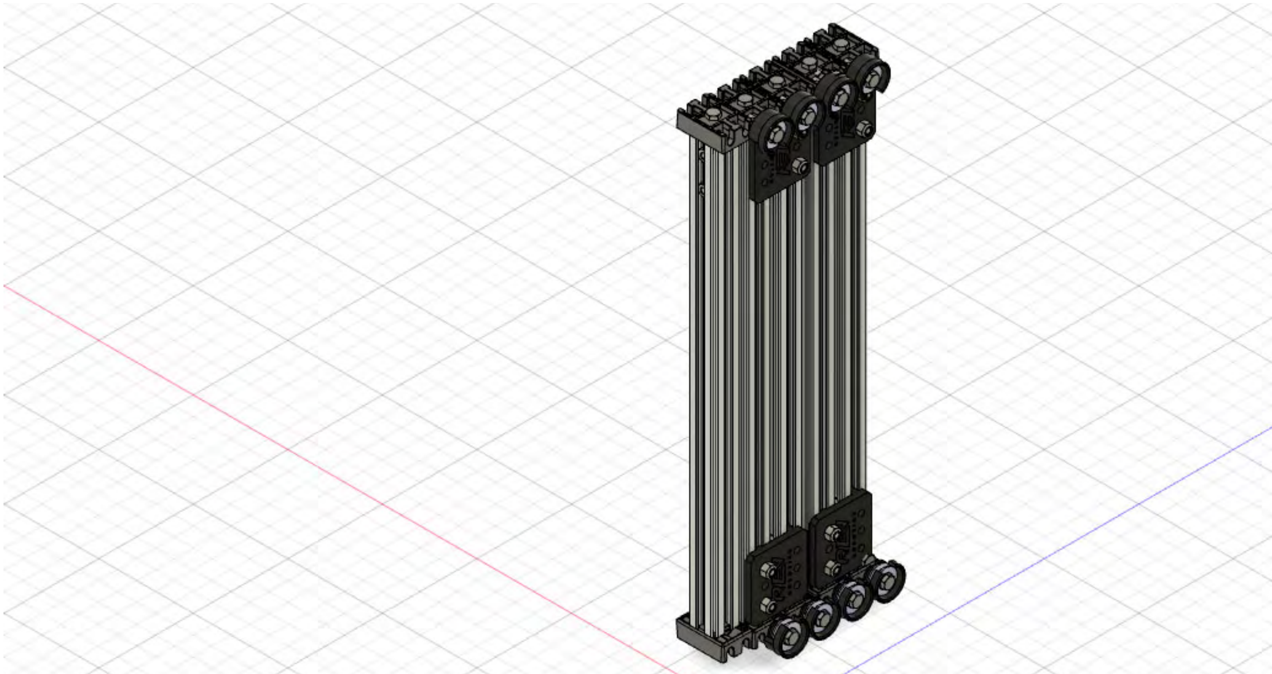
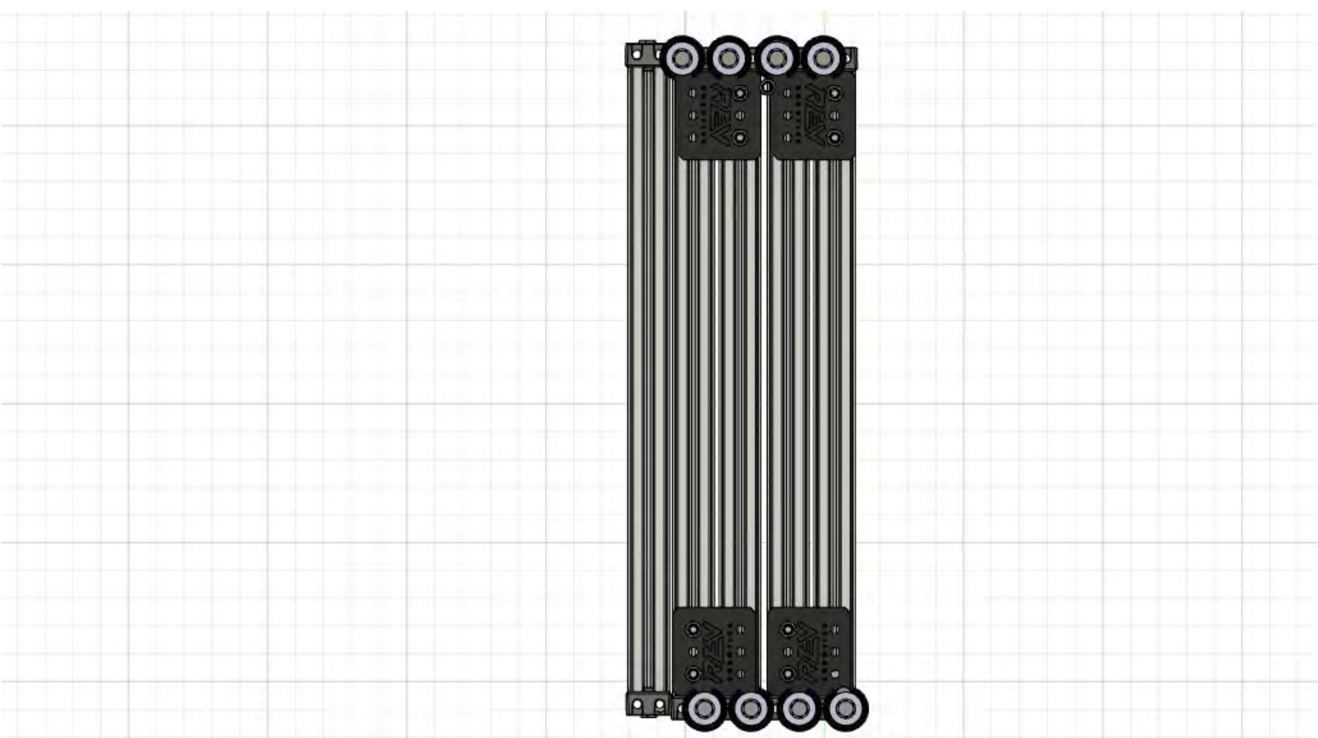
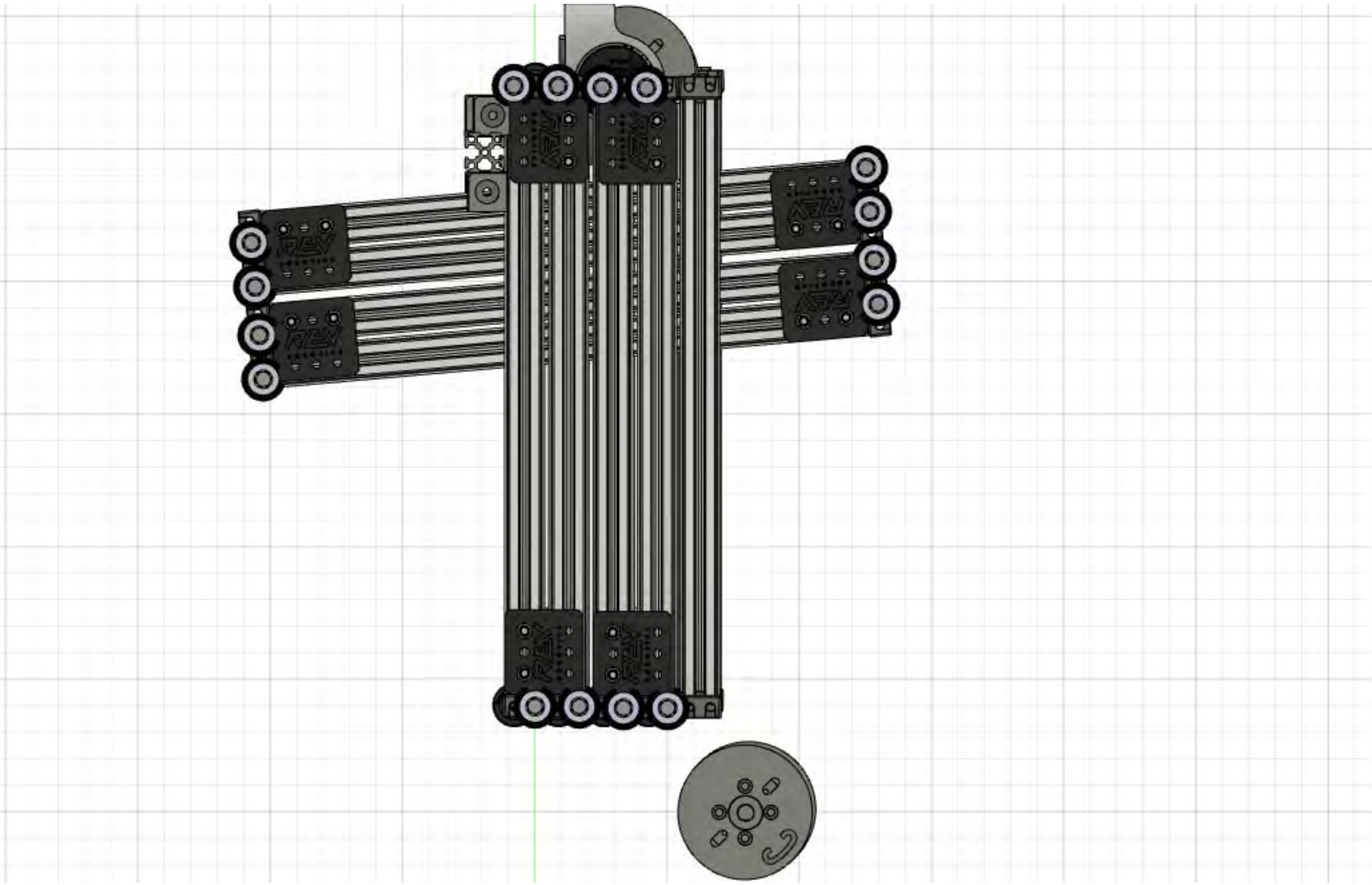
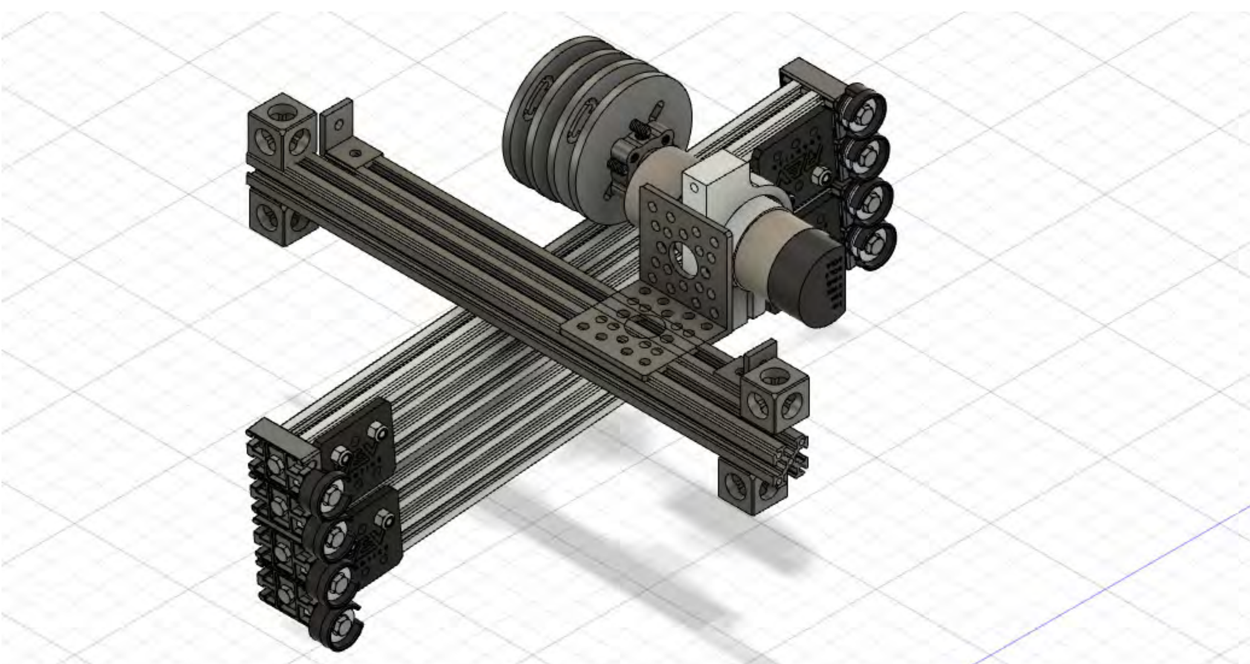




V2 HORIZONTAL SLIDES





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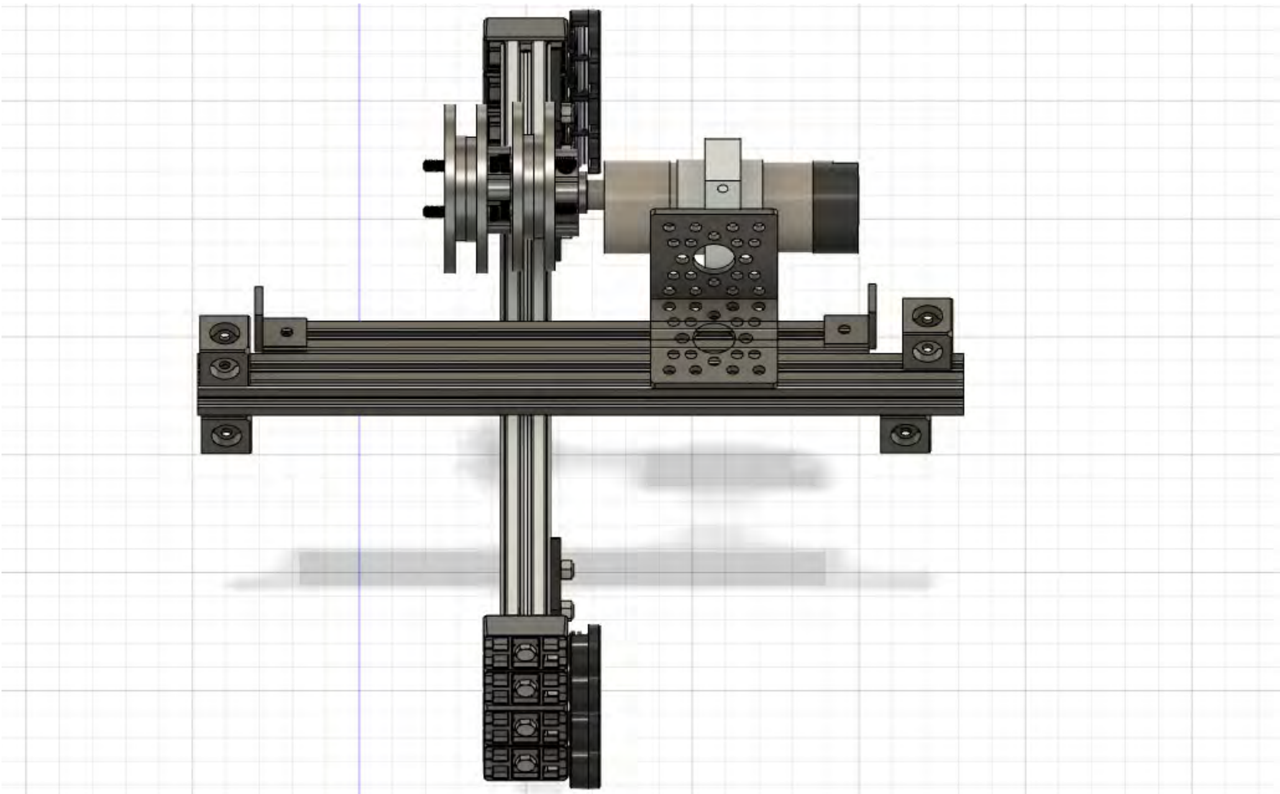

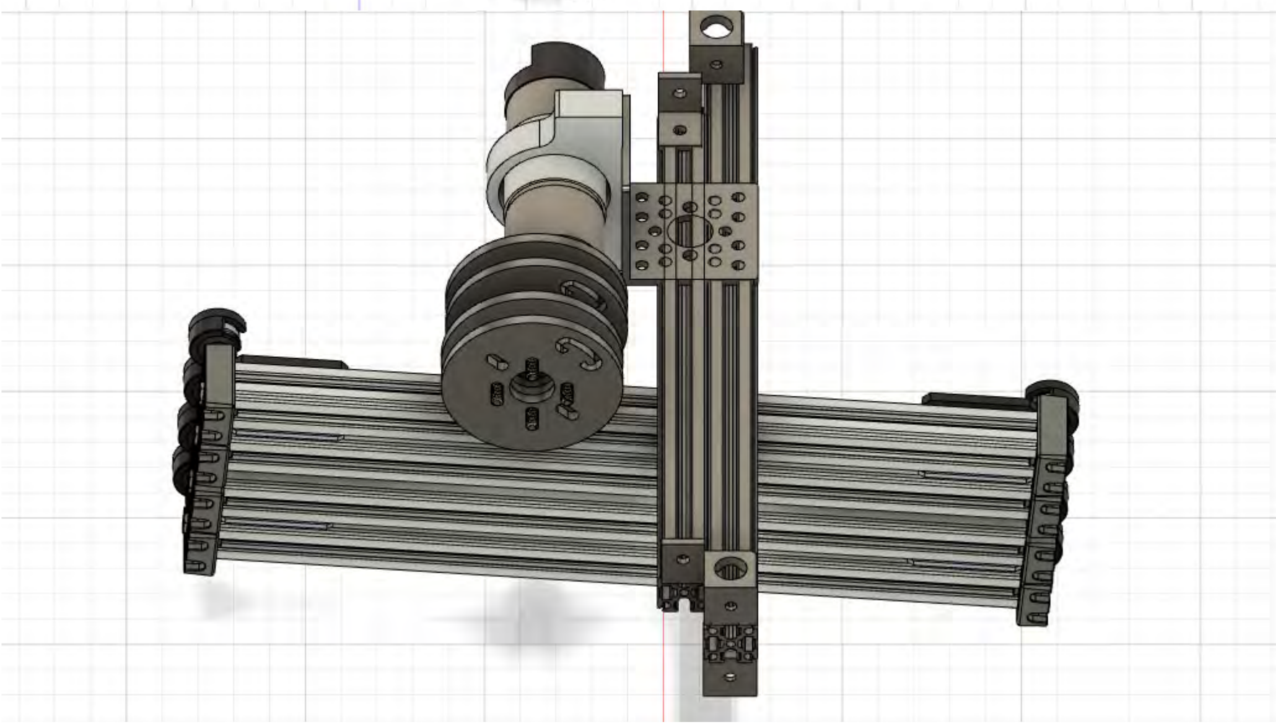

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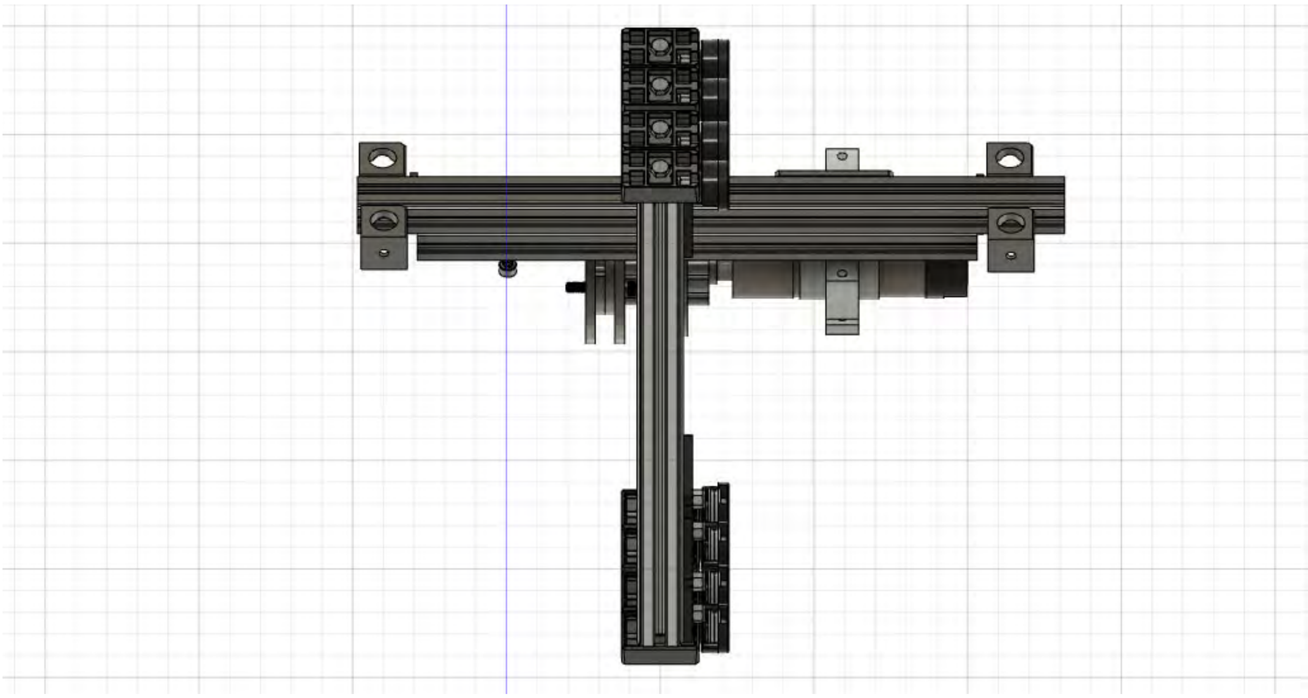
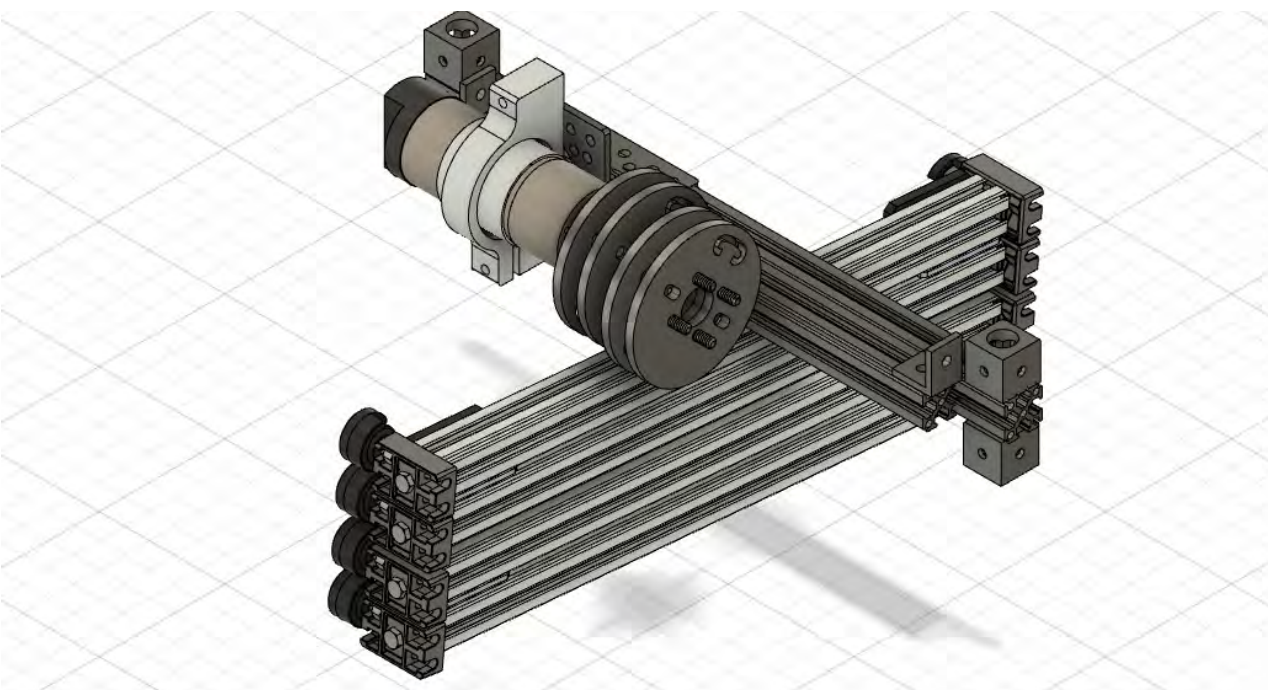
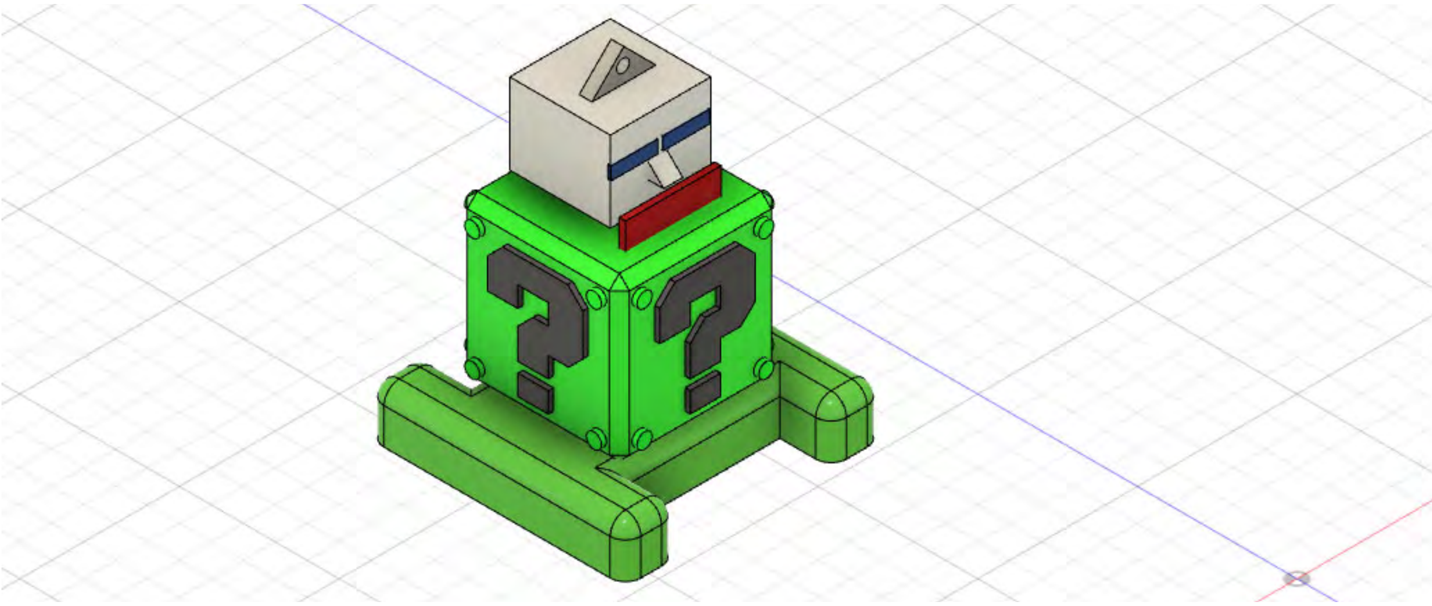
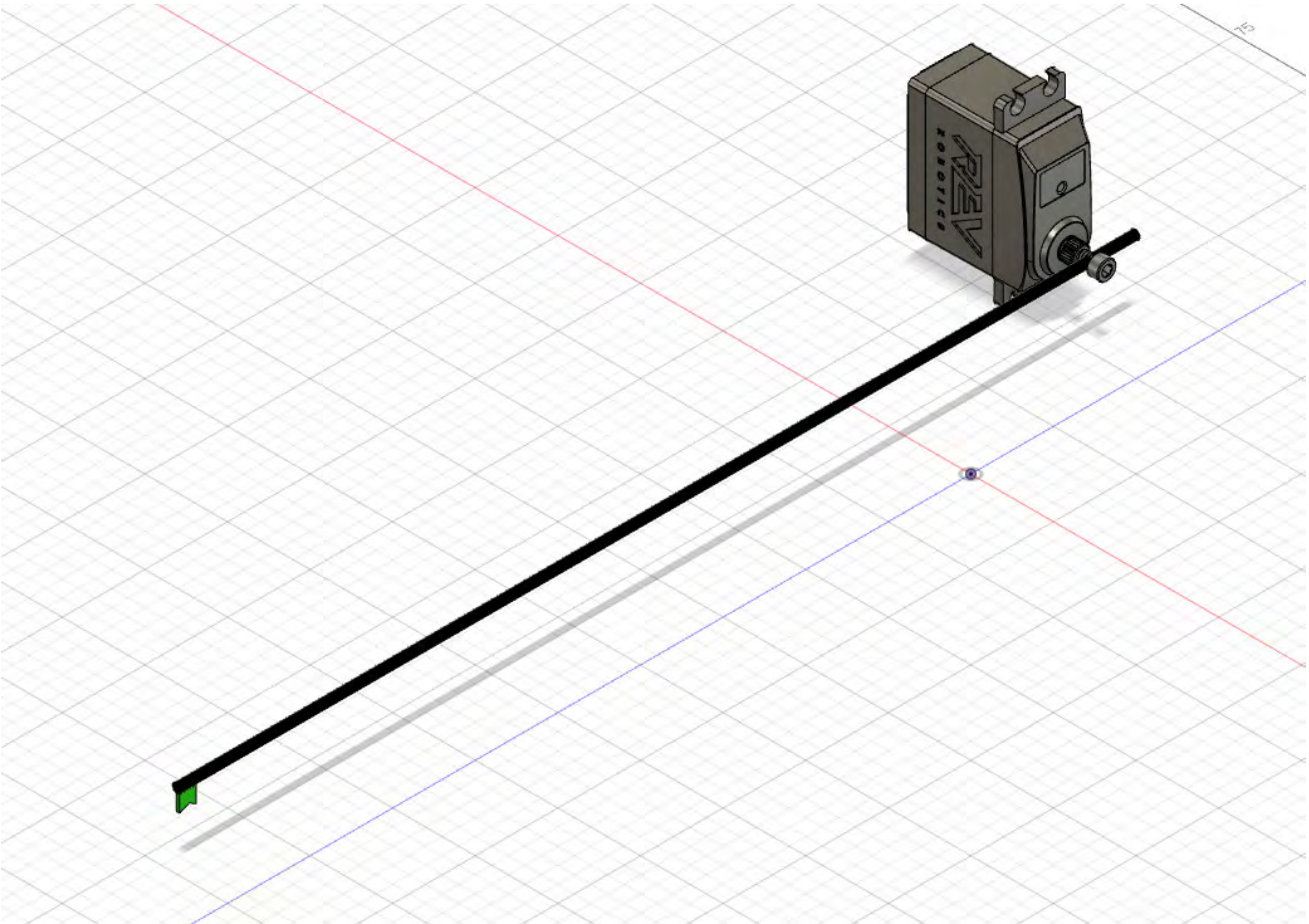




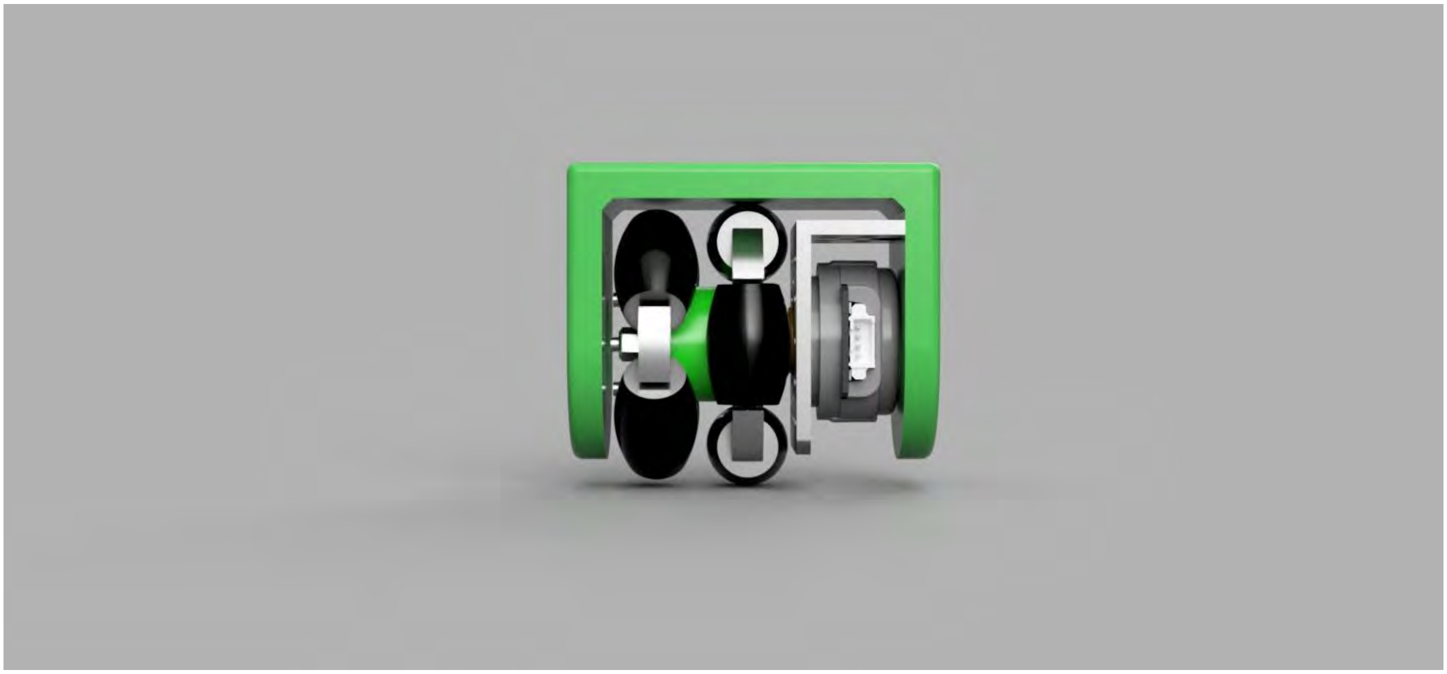
CAPSTONE V1

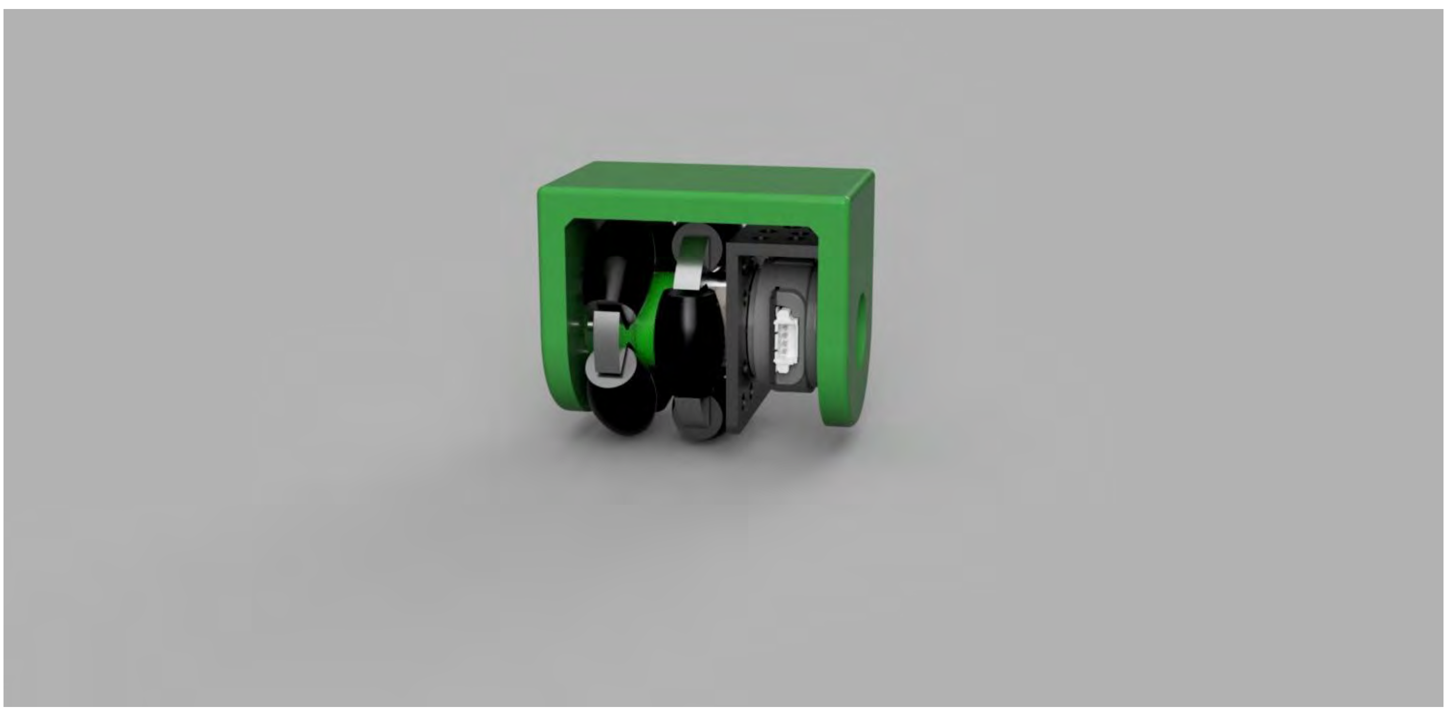


PARKING FLAG V2

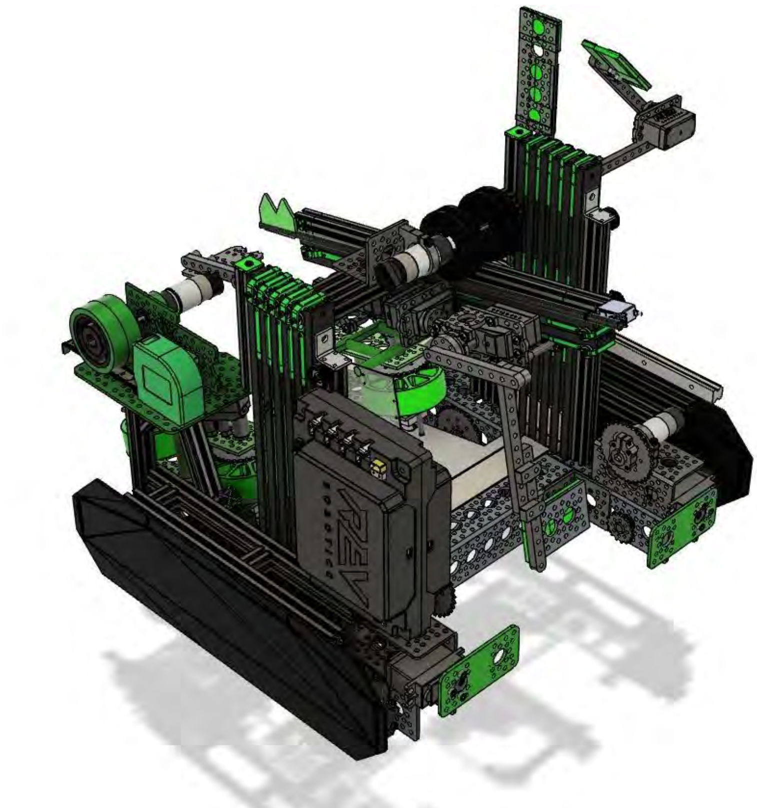


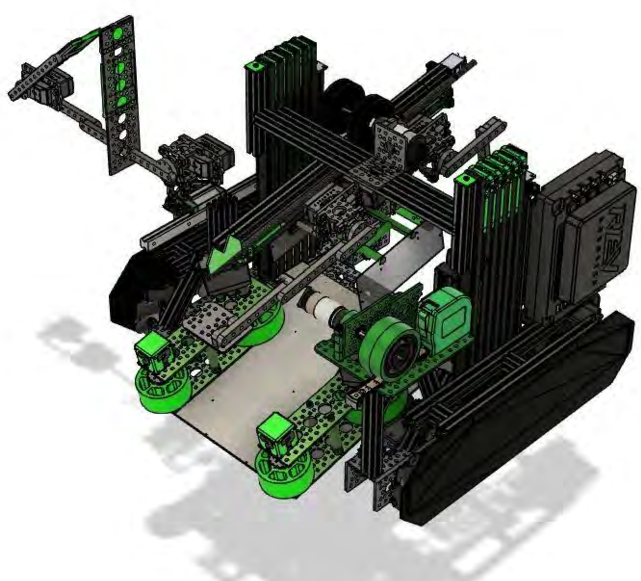
ODOMETRY



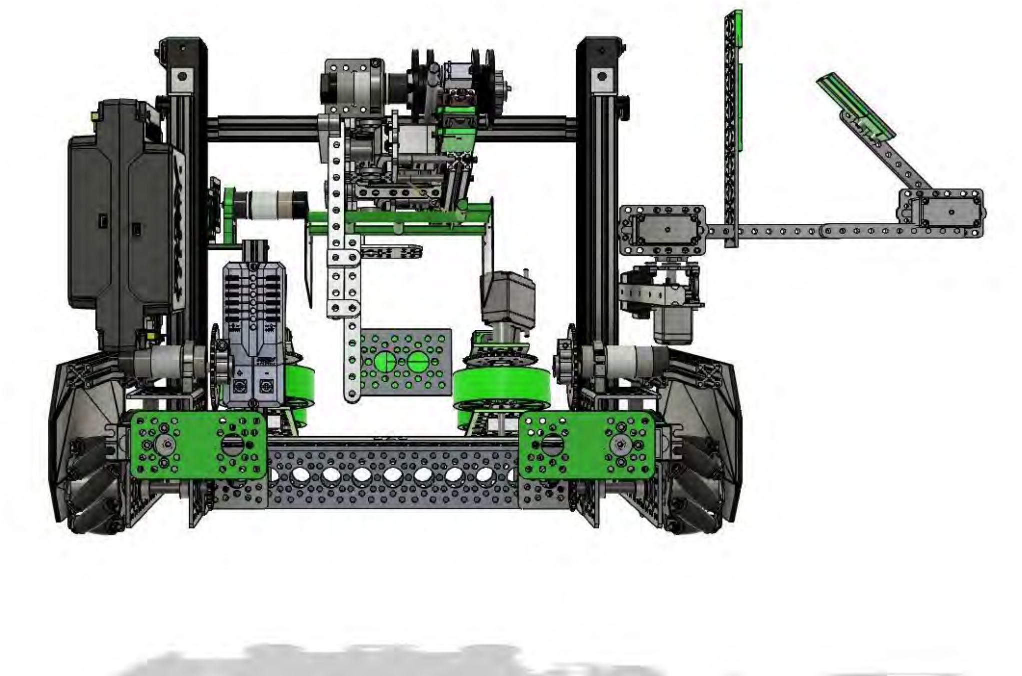


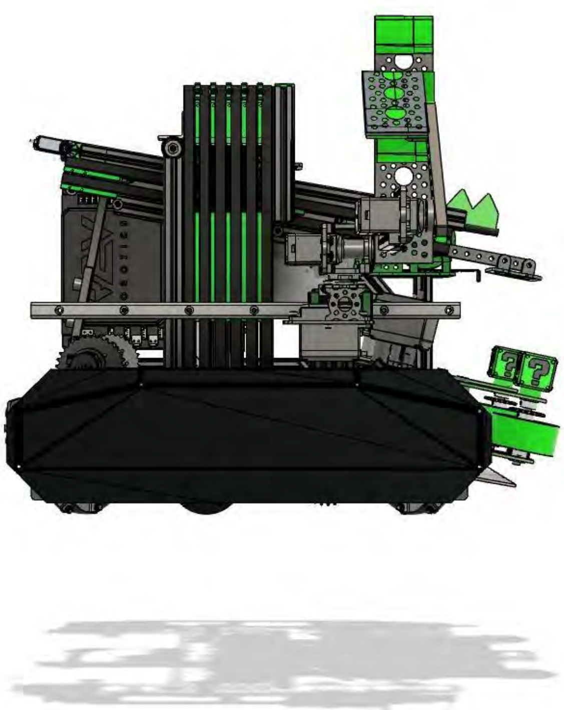
CURRENT ROBOT



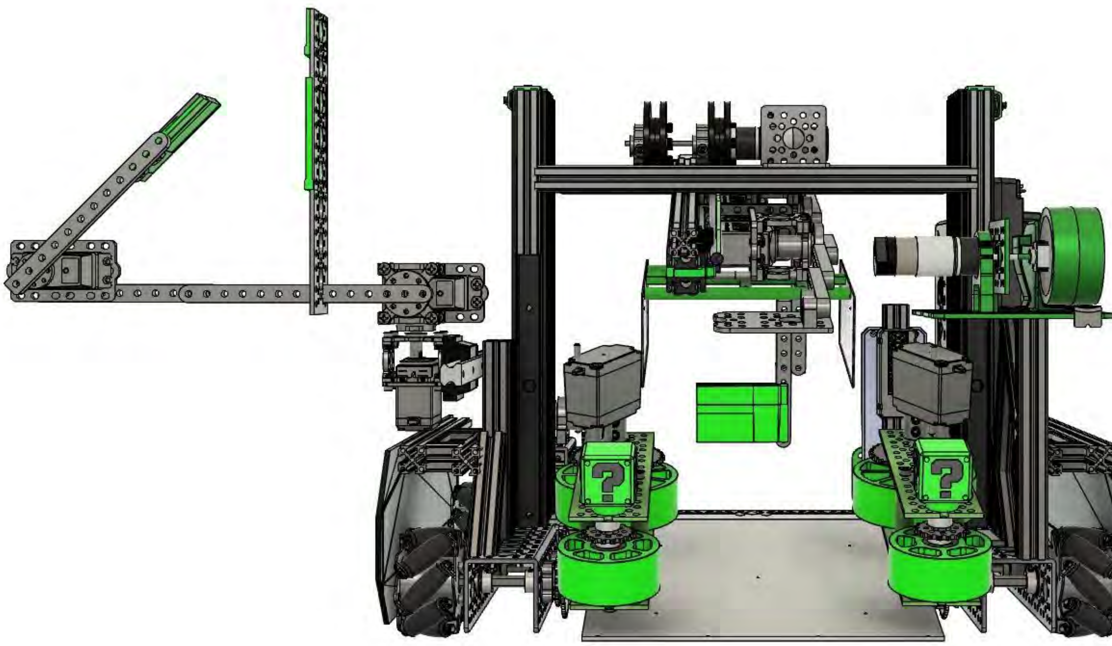


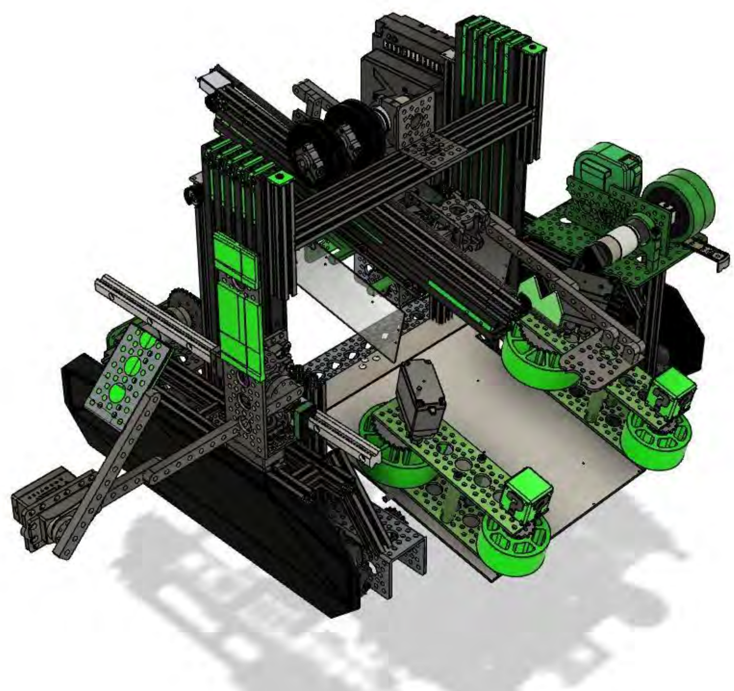
CURRENT ROBOT





CURRENT ROBOT





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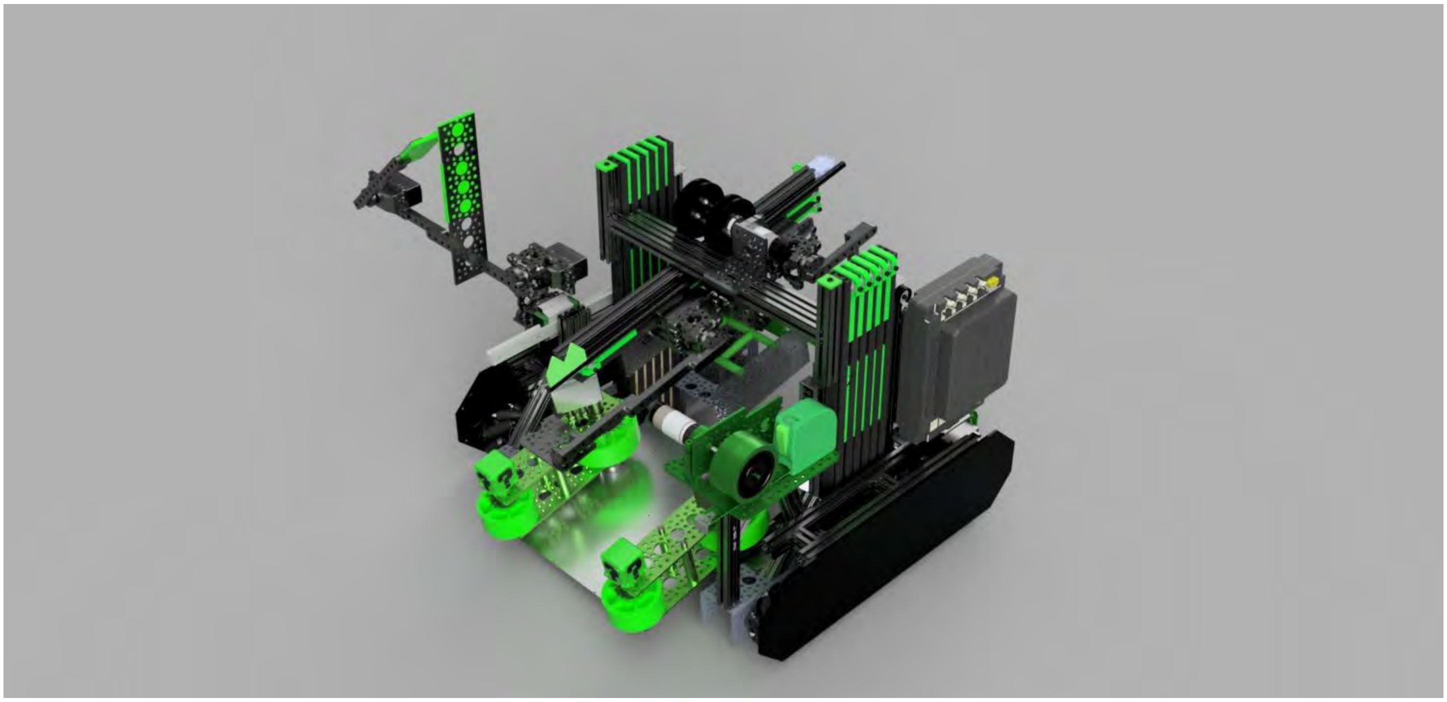
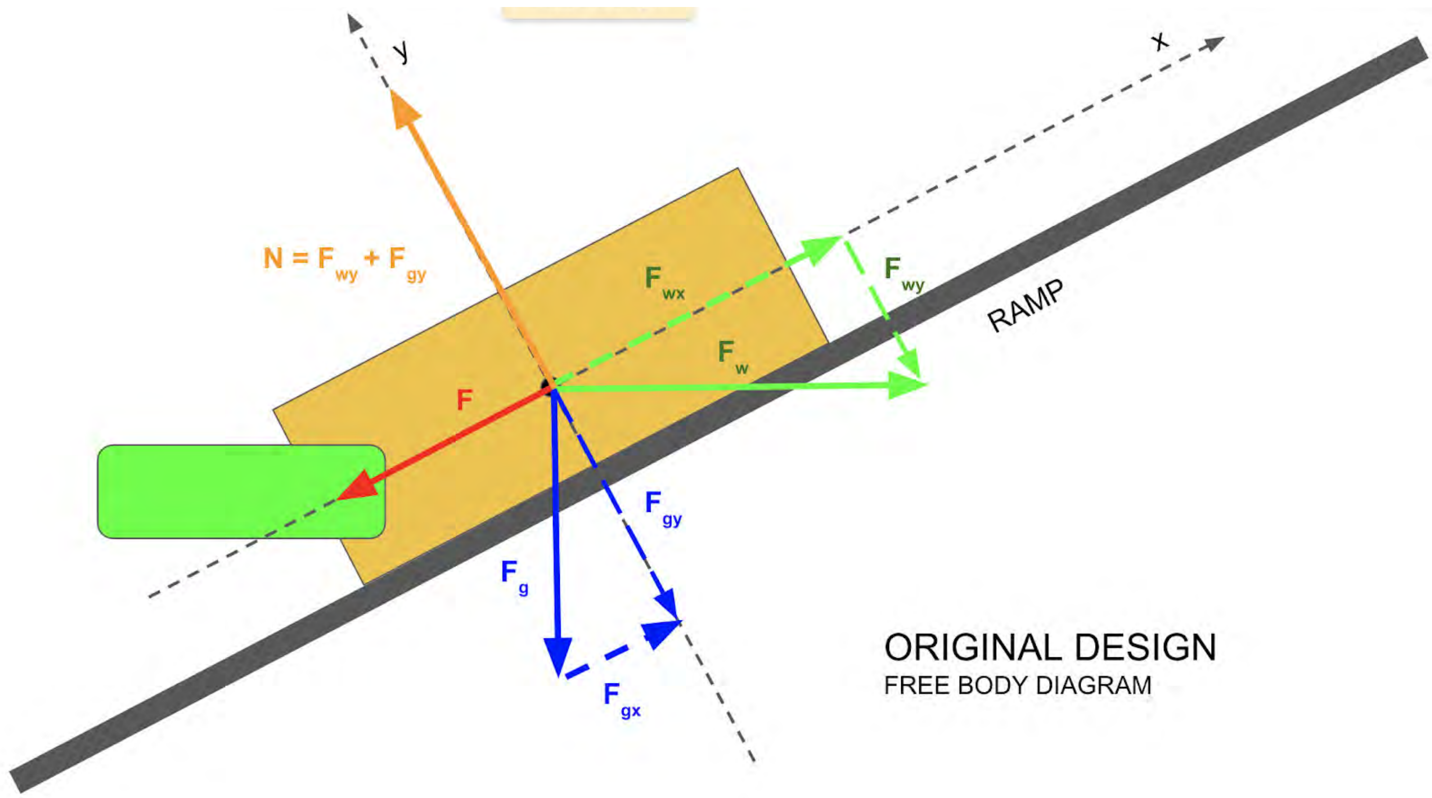


ENGINEERING CALCULATIONS

ANGLE OF THE RAMP

The incline of our ramp was too steep, and the intake wheels were too grippy and also mounted level with the ground, so there was way too much friction when intaking the stone. The following diagrams explain why.



When the wheels are not aligned with the ramp, force from the wheels is applied in the ramp direction, but also in the direction orthogonal to the ramp. This orthogonal force is wasted. But worse than that, this orthogonal force increases the frictional force on the block. Frictional force is proportional to normal force:

Loading...

Since there is no acceleration orthogonal to the ramp, the sum of the forces orthogonal to the ramp must also be zero:

Loading...

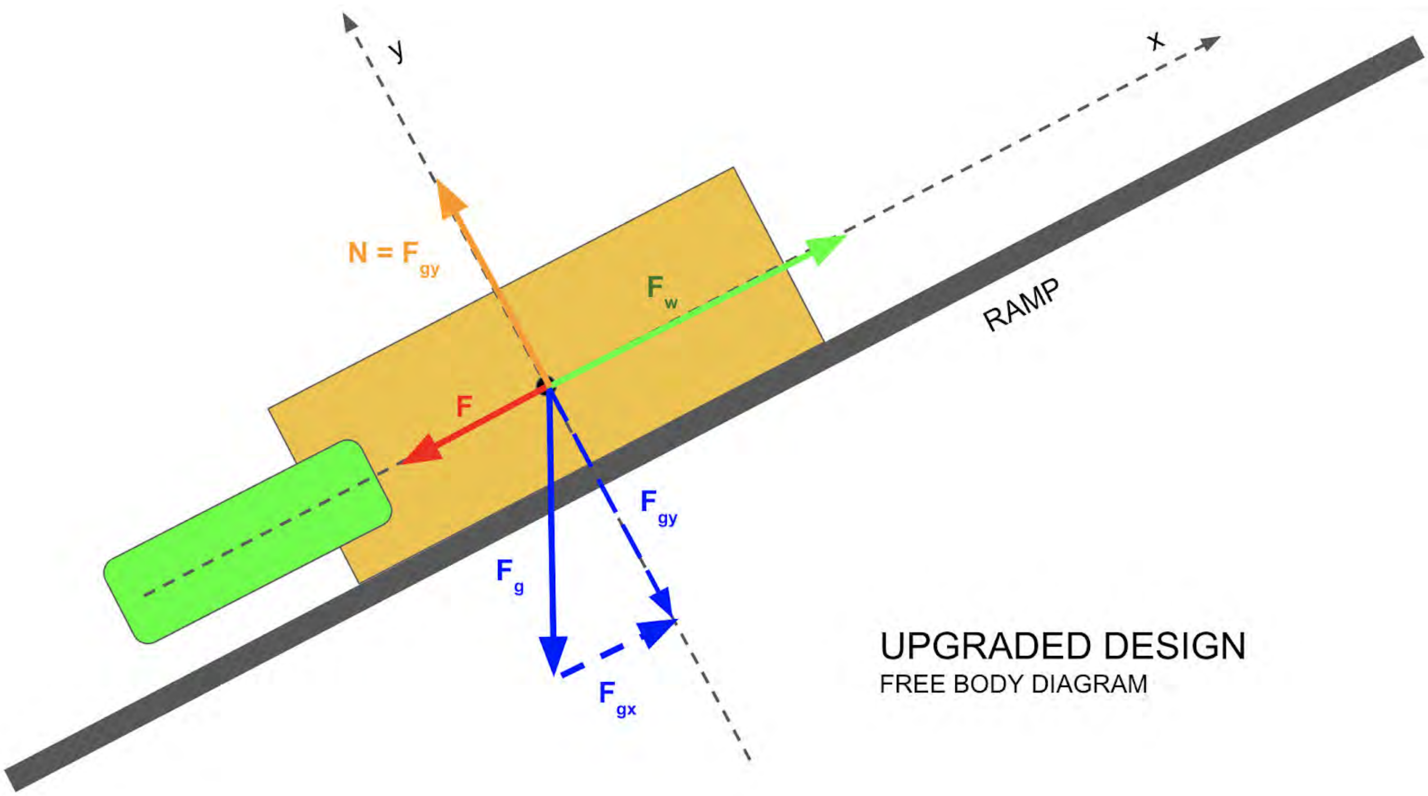
The force orthogonal to the ramp is equal to the sum of the force of gravity orthogonal to the ramp, the normal force, and the portion of the wheel force orthogonal to the ramp. Solving this equation equal to zero shows that the normal force, and thus the friction, is increased when some of the wheel force is directed orthogonal to the ramp.

Loading...

Loading...

Loading...

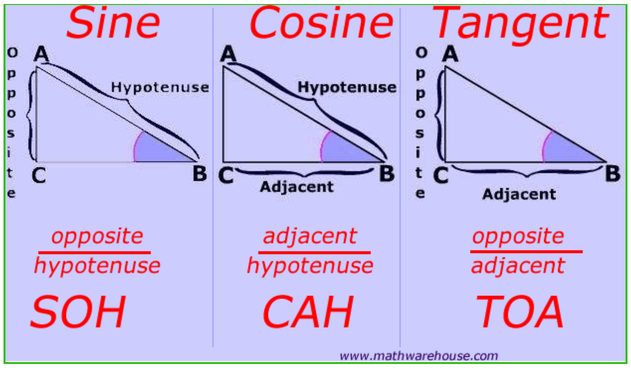
Therefore, the situation where the intake wheels are used most efficiently, and the frictional force on the block is the lowest, is when the wheels are aligned with the ramp.

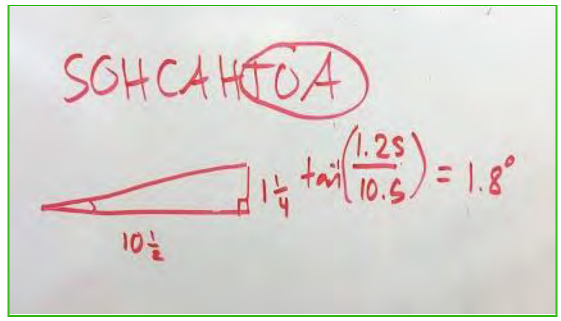


We used trigonometry to calculate the angle of the ramp, so we could then angle the wheels to that same angle.

1. We recognized that our ramp formed a triangle with the floor
2. We determined which angle we needed to measure
3. We determined which trigonometric function to use based on the side-lengths we could easily measure: **we determined tangent would be the best**

4. We measured the exact length of the opposite and adjacent sides of the triangle relative to our needed angle**: the opposite side measured 1.25in and the adjacent side measured 10.5in**
5. We plugged the measurements into the tangent equation: **tan (Loading...)** = **opposite / adjacent** = **1.25in / 10.5in**
6. We rearranged the equation and solved for theta: **Loading...= $\sin^{-1}$ (1.25/10.5) = 1.8°**
7. We then applied that same angle to the angle of our intake wheels





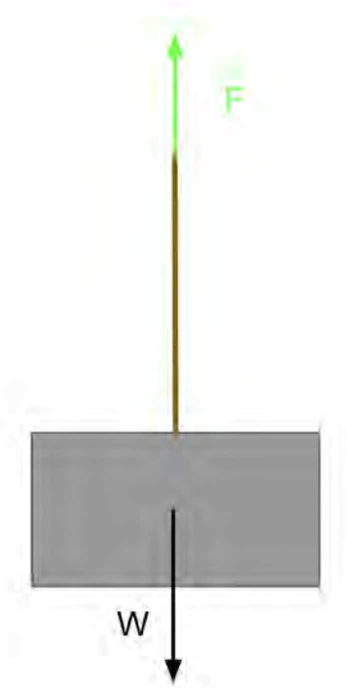
WHY PULLEYS?

We use pulleys on our vertical and horizontal lifts. Pulleys are one of the three types of simple machines:

4. Pulleys
5. Ramps (see Intake above)
6. Lever

Simple machines use mechanical advantage to multiply force. The free body diagrams below show how pulleys multiply force.

In order to lift a weight, Loading..., one has to exert a force of at least Loading...:

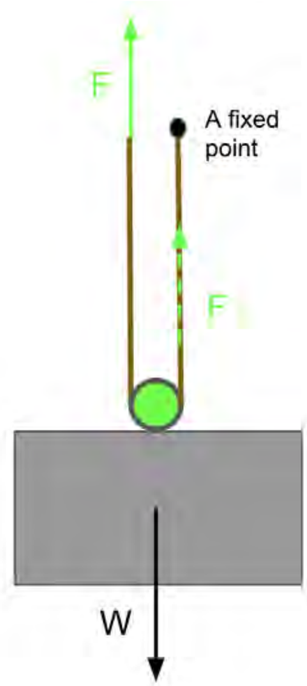


A pulley is a wheel with a rope around it. The basic rule of pulleys is that the tension, or pulling force, on the rope going into the pulley is the same as the tension on the rope coming out of the pulley. If we attach a pulley to the weight we want to lift, we can lift it with half the force, because that force is multiplied by each rope of the pulley. So, with a pulley, to lift the block the forces will be, as follows:

Loading...

Loading...

Using pulleys helps our motors lift the vertical lifts with less force, making them faster and more reliable.

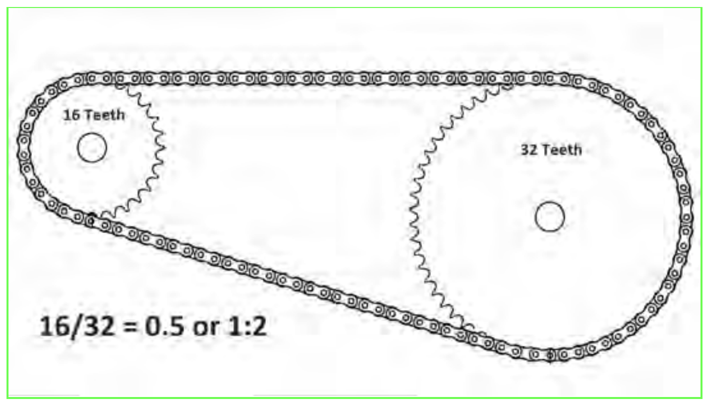


SPROCKET RATIOS

DRIVETRAIN SPROCKETS

We decided very early that we wanted to gear up all of our drive motors, thus we all learned how to calculate gear ratios.

4. Counted the number of teeth on the drive sprocket and the driven sprocket: **in our case, the drive had 32 teeth, and the driven had 16 teeth**
5. Divided the number of teeth on the driven sprocket by the number of teeth on the drive sprocket: **16/32** = **0.5 which can also be expressed as 1:2**
6. **Thus the driven sprocket (16 teeth) rotates twice for every one turn of the driver (32 teeth); because the 32 tooth sprocket is on the motor and the 16 tooth sprocket is on the axle with the wheel attached to it, our wheels spin twice as fast.**



INTAKE SPROCKETS

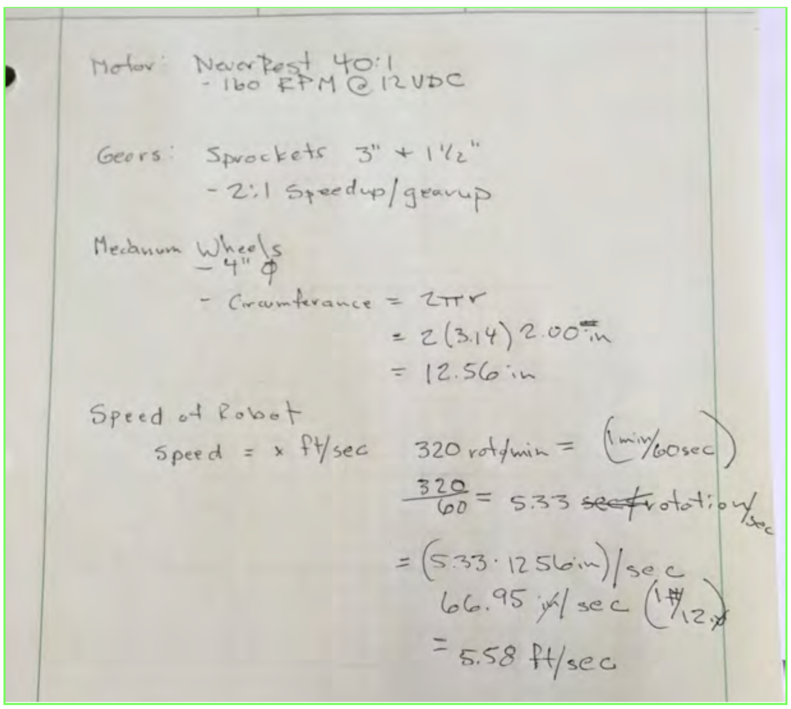
We also decided to gear up our intake, thus we calculated the sprocket ratio for the intake.

4. Counted the number of teeth on the sprockets: **we calculated the drive sprocket has 32 teeth and the driven sprocket has 9**
5. Divided the number of teeth on the driven sprocket by the number of teeth on the drive sprocket: **9/32** = **0.28**
6. **Thus the driven sprocket (9 teeth) rotates 2.6 times for every turn of the drive sprocket (32 teeth); because the 32 tooth sprocket is on the motor and the 9 tooth sprocket is on the axle with the 2 inch compliance wheel attached to it, because of this, the front compliance wheels spin 2.6 times as fast.**

ROBOT SPEED IN FT/SEC

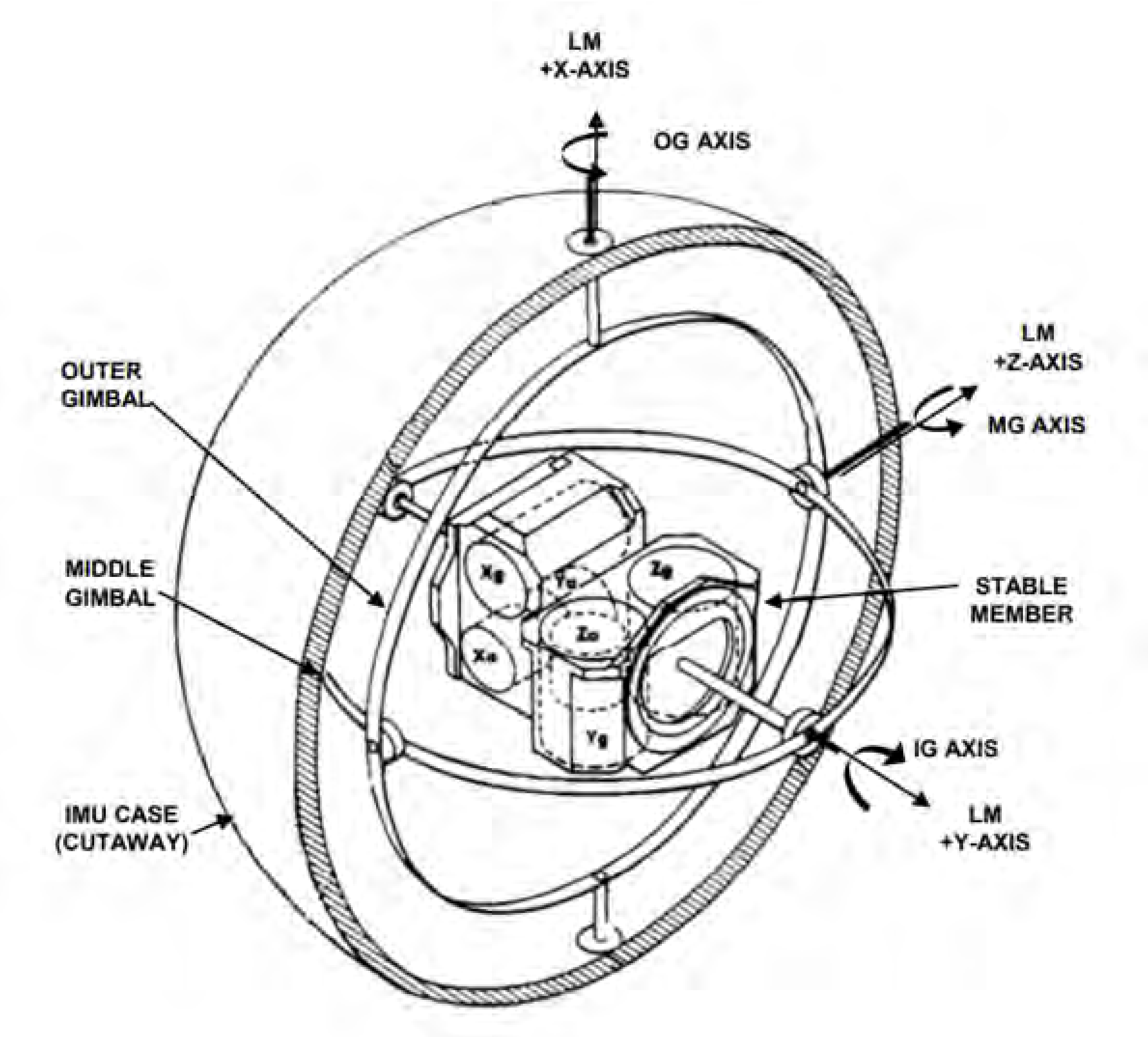
Soon after we calculated our drivetrain sprocket ratios, we decided it would be useful to know how fast our robot is. We calculated the robot's speed in ft/sec.

7. Found the rpm (rotations per minute) of the neverest 40:1 drivetrain motors: **the rmp was 160**
8. Multiplied the motor's rpm by 2 to account for our gear up: **the driven sprocket (16 teeth) rotates twice for every one turn of the driver (32 teeth), thus 2x160 = 320rpm**
9. Converted rotations per minute to preferred unit, rotations per second: **320 rotations/60 seconds = 5.33rps**
10. Calculated the circumference of our wheels using the formula circumference = 2Loading...r: **the wheel's diameter is 4in, thus its radius is 2in, when plugged into the formula, the wheels circumference = 2(3.14)2in = 12.56in**
11. Converted inches into feet: **12.56in / 1ft or 12in = ~ 1.04ft**
12. Calculated the speed of the robot in feet per second: **5.33 rotations x 1.05ft = ~ 5.58ft/sec**



WHAT IS AN IMU AND HOW DO WE USE IT?

IMU stands for Inertial Measurement Unit. IMUs are electronic devices that measure and report the angular rate and orientation of a body using accelerometers, for sensing linear acceleration, and gyroscopes, for sensing rotational acceleration. IMUs are used to maneuver aircraft, spacecraft, satellites, UAVs, and Robotiana! Below is a diagram of the IMU from the Apollo spacecraft:



Our IMU measures Robotiana's precise location to make our autonomous program more accurate.

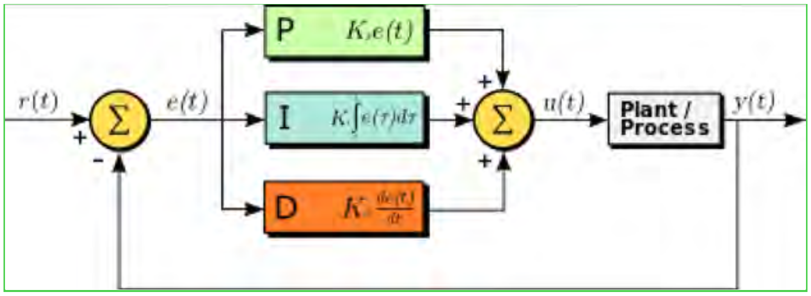
WHAT IS A PID CONTROLLER AND HOW DO WE USE IT?

"**PID** stands for **Proportional, Integral, Derivative**. The idea behind a PID controller is to take the desired state value, compare that to the actual (feedback) state value (the current gyro or IMU angle) and apply factors to the difference (called the error) that produce a proportional output value. The angle of turn is fed to the PID controller routine which measures error and produces a value (the turn power) at or near the starting (full) power. As the turn gets closer to 90 degrees, the PID routine starts to return smaller and smaller values thus reducing the power being applied and slowing the rate of turn. In theory this reduction in power and slowing rate of turn will eliminate the overshoot. The PID controller can also apply a tolerance margin that indicates when the actual value is within some percentage of the target to further control robot motors."

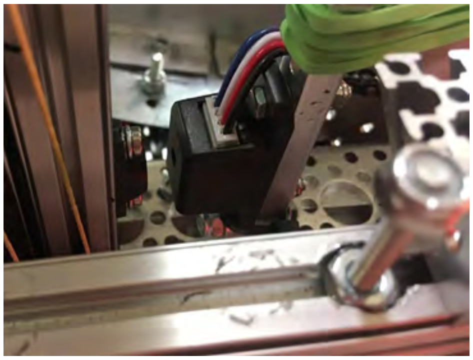
The **proportional** part of the controller applies a turn power that is based on the amount of angle error, moving the robot towards the desired angle.

The **integral** part of the controller applies a turn power that is based on the history of angle error, increasing the correction if the robot is not getting to the desired angle fast enough.

The **derivative** part of the controller applies a turn power that decreases with the rate of change of the angle, reducing overshoot.

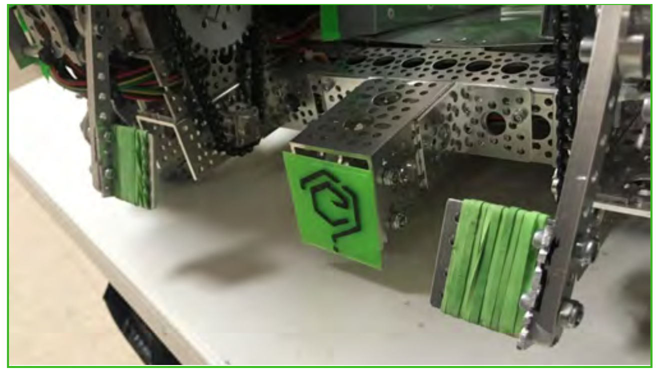


MAGNETIC LIMIT SWITCHES



The magnetic limit switch is an omnipolar momentary switch; A omnipolar momentary is a switch that will trigger when there is a certain amount of magnetic energy on either pole detected. The way we integrate the Magnetic Limit Switch on our robot is by putting them on are lifts. We have one switch on our vertical lift and one on our horizontal lift. We place magnets on our lifts, and when they are fully extended the switches sense them and stop the motor, so the lifts won't break.

STATIC FRICTION



We proved our second foundation movers are better than our first foundation movers by using physics and friction. The force between the movers and the foundation is Coulomb friction which is given by this equation:Loading...The equation means friction equals coefficient of friction times normal force. So in order to use this equation we added rubber bands to the clamps on the servos which increases the coefficient of friction. Another option we had was to add more powerful servos. Stronger servos would increase normal force but to add rubber bands was simpler.

CLEANING AND LUBRICATION PROCESS

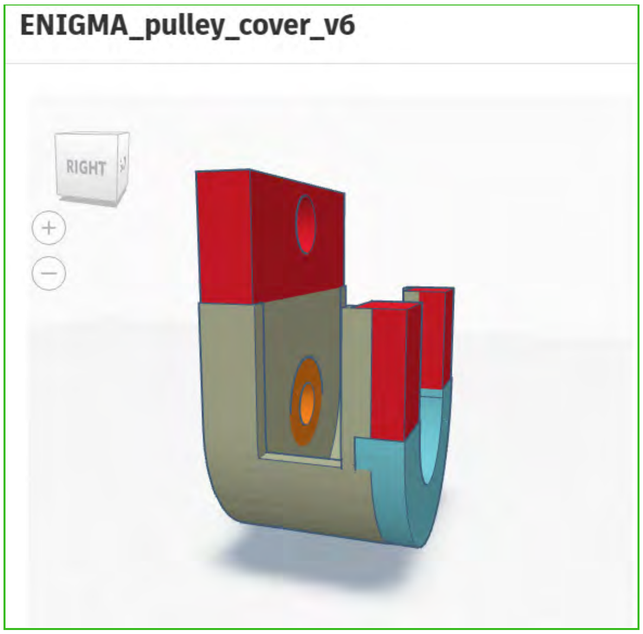
1. We clean are lifts by blowing everything out with an air compressor.
2. We clean the wheels with rubbing alcohol.
3. We evenly distribute the cleaning between each roller by rubbing each of them individually.
4. We lubricate our lifts with WD-40 to make them run very smoothly.

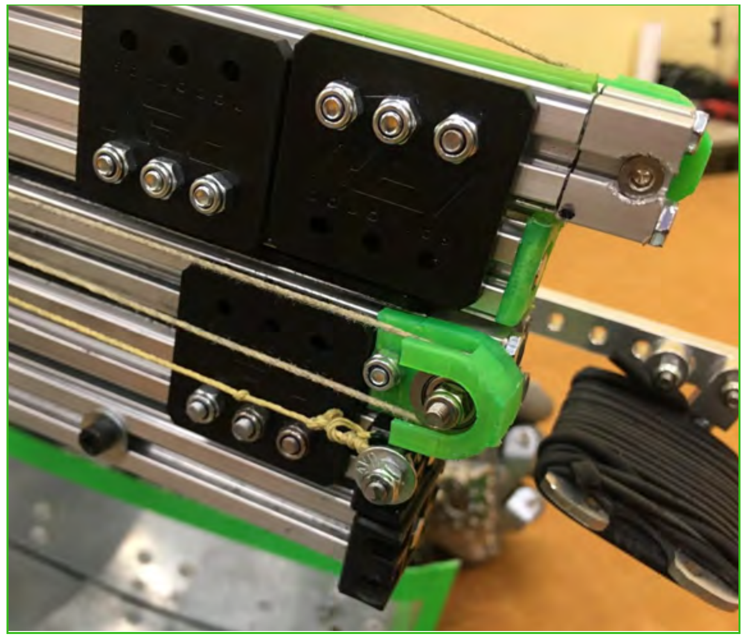
Cleaning Robotiana frequently allows her performance to be consistent.

3D PRINTING

PULLEY CAPS | DESIGNED OURSELVES

We were having issues with the rev pulley caps, as they were often bending and coming off of the pulley, so we designed and printed our own!





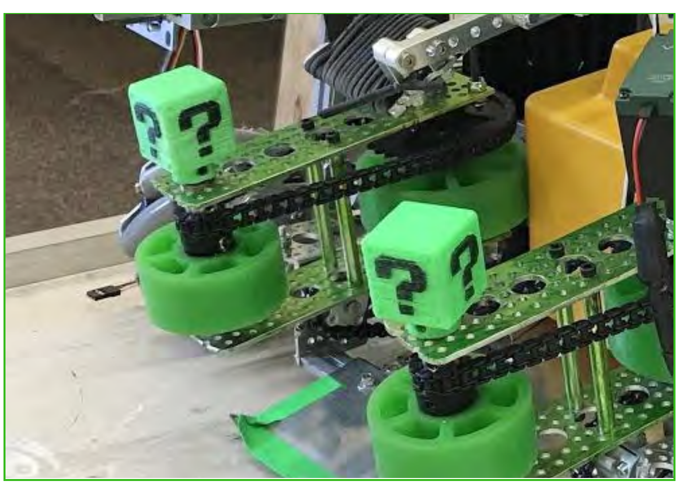
CAPSTONE KEY | DESIGNED OURSELVES

When redesigning our capstone mechanism to fit in between the claw on the horizontal slide, we had to design a key that fit in the rev extrusion so that the capstone did not swing around when preloaded.

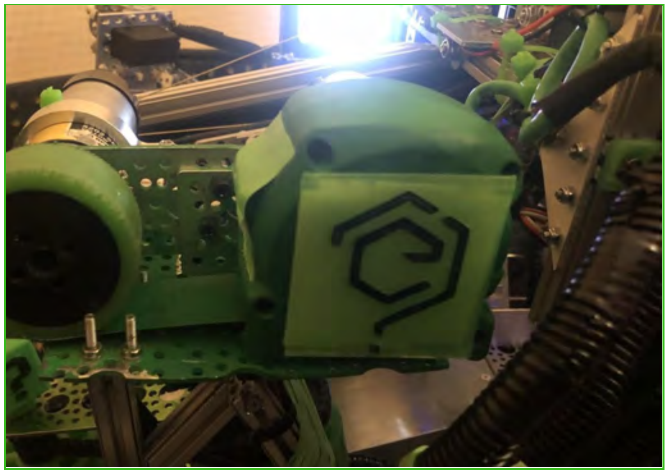
PHONE MOUNT

ODOMETRY HUBS

INTAKE QUESTIONS CUBES



ENIGMA LOGO DECORATION



LIFT CONNECTION PIECES

SAFETY PROCEDURES

(Adapted from the **FIRST ROBOTICS COMPETITION** safety manual)

STUDENTS

Be familiar with the following safety guidelines, as well as understand and follow established safety requirements applicable to your environment. Work in a safe and responsible manner, and use personal protective equipment (PPE), safeguards, and other safety equipment as required. Identify and report any unsafe or hazardous conditions to a student safety captain, mentor, and/or safety advisor. This includes work practices that may cause an accident. Lastly, always encourage safe behaviors in everyone around you.

COACHES AND MENTORS

Lead by example and practice the same safety behaviors that are expected from the students. Provide guidance and encouragement on a safe working environment, and guidance on matters of general safety, including the use of personal protective equipment including during the lifting, handling and transportation of robots as detailed in this manual in team work spaces as well as at events. Utilize hazard based safety engineering principles with team members to eliminate or minimize identified hazards to a suitable level.

SPECTATORS

Spectators attending FIRST competitions should follow the same footwear rules as participants. If substantial close-toed shoes are not available, they may enter the pit area as long as they remain in the pit aisles. Spectators that do not meet the footwear requirement for participants, as described above, are not allowed inside individual team pits or in any location where robots are being worked on.

SAFETY CAPTAIN

Encourage your team to display positive safety behaviors at all times. Provide support for any safety questions or concerns that may arise. Seek guidance, as appropriate, from mentors. Conduct safety inspections of the general work site, especially the robot construction area. This also applies to the pit station during competition events. Know where to find and become familiar with the Safety Data Sheets (SDS) and related emergency procedures. Coordinate, deliver, and track safety training for the individual team members as well as team wide

safety procedures. It is suggested that teams bring their training log and procedures to events and continue to make comments about infractions and/or areas of continuing improvements.
At FIRST events: Lead the FIRST culture of safety as an event safety ambassador by maintaining Safety. Advise those around you of safe practices in line with these procedures and escalate to your mentor if support is required. Have a safety plan for each event so that in the event of an emergency, all team members know procedures to follow to ensure everyone's safety. This would include a meeting spot to gather as well as a list of participants to assure everyone is safe.

GENERAL SAFETY PRACTISES

Follow safe work practices, including safe use of all tools and personal protective equipment (safety glasses, shoes, gloves, hearing protection, etc.). Maintain a healthy attitude regarding safety. Always walk and work in a controlled and thoughtful manner. Keep full control of the robot at all times.

Be especially careful around high-speed rotating components, both on and off the robot. If you are putting a high-speed rotating component on the robot, make sure the component is designed to be used the way you are using it.

Take special care when working above normal height or ground level. Be careful using tools that generate heat, such as heat guns and soldering irons.

Be aware of objects that may be in the vicinity of the heat source and may catch fire. Also, be aware that these tools often retain heat after being shut off, and should be set down only on appropriate surfaces.

TOOLS

Do not use a power or machine tool without a coach/mentor present or if you do not have proper training. All students should receive training for all power and machine tools.

Before using any tool, check to see if it is in good condition. Don't use defective, dull, or broken tools. Don't put them back on the shelf; remove them from service and notify the safety captain and mentor so the tool can be replaced or sent for repair.

When using a tool, place the work on a bench or hard surface rather than in the palm of your hand. When using knives/blades, direct your cutting strokes away from your hand and body and be aware of those around you. Wear gloves when appropriate.

Store sharp-edged or pointed tools in a safe place. When carrying tools, cover the point or any sharp edges with shields. NEVER carry unshielded tools in your pocket. Don't leave tools on overhead work surfaces. They may fall and strike someone below. Store equipment in a location where it will not create a safety hazard or get damaged.

Provide safety guards for power tools where required. Never use any equipment without safety guards in place. Notify your safety captain and mentor of any broken or defective equipment, and take it out of service until repairs are made.

ELECTRICITY

Proper use and respect for electricity is paramount. Inspect your equipment cords and extension cords routinely to ensure they are in good condition. DO NOT "daisy chain" – plug a power strip into another power strip. This could cause the potential for fire of electric shock due to overloading of the circuit. Avoid the following electrical power supply setups to prevent overloading: extension cord plugged into another extension cord, extension cord plugged into a power strip, multi-device receptacle plugged into a power strip or extension cord.

EYE AND FACE PROTECTION

There are several forms of eye/face protection available to provide protection from related hazards, including safety glasses with side shields, goggles, and face shields. Inspect equipment for damage each time it is worn. Wear eye protection in the following situations: when performing any work on the robot including grinding, drilling, soldering, cutting, welding, etc. when there is a risk of exposure to flying particles or chemical exposure (such as splashes, splatters, and sprays).

At FIRST events, wear eye protection: anywhere in the pit station including walkways and team pits, in the vicinity of the arena, including the playing field, on the practice field, any area posted with signs requiring the use of eye protection (such as the machine shop).

Safety glasses and protective eyewear are designed to provide a shield around the entire eye to protect against hazards such as splashes of liquids, burns from steam, compressed air, and flying wood or metal debris. To prevent injury, all individuals in the pit area, the practice field area and the arena must wear safety glasses or protective eyewear that is ANSI-approved, UL-Listed, CE EN166 rated, AS/NZS certified or CSA rated. Only lightly tinted yellow, rose, blue, and amber tints are FIRST approved. Reflective lenses are prohibited; your eyes must be clearly visible to others. The use of anything other than ANSI-approved, UL-Listed, CE EN166 rated, AS/NZS certified or CSA rated eye protection is prohibited.

Prescription Glasses If you wear prescription glasses that do not have a marked safety rating, you must wear rated safety goggles over them to achieve adequate protection. If you wear marked safety rated glasses, you may use ANSI-approved, UL-Listed, CE EN166 rated, AS/NZS certified or CSA rated side shields. Safety rated glasses, side shields and frames can be identified by markings stating the standard that they

HAND, EAR, AND FOOT PROTECTION

Hand protection is designed to protect against heat, electrical, chemical and mechanical hazards. Use proper gloves and mechanical tool guards for the application. FIRST Robotics Competition participants should work with their mentor to ensure the selected glove is the correct one to use for each activity. For example, wear chemical-resistant gloves when handling chemicals. Check your gloves for proper size, absence of cracks and holes, and good flexibility and grip before you wear them.
Hearing protection devices should be available, such as earplugs, where there are objectionable/questionable sound levels. At events, hearing protection is often available at pit administration. A mentor can provide assistance in evaluating high-noise tasks and determining appropriate hearing protection devices.

Participants, when engaged in FIRST activities, must wear shoes that completely cover the entire foot. Shoes must be substantial and have closed-toes and heels to protect against foot injuries, regardless of work location. Flip-flops, sandals, mules, lightweight slippers, etc. are not acceptable when working on or near the robot.

OTHER PREVENTATIVES

Other Preventatives Ensure that team members or mentors are not wearing ties, loose clothing, jewelry, hanging key chains or similar when near or working on moving or rotating machinery so as to avoid the potential risk of draw in to rotating parts. In the case of individuals with long hair, this risk should be mitigated by tying back or covering long hair.

TRANSPORTING THE ROBOT

Ensure all transporters are wearing appropriate PPE (safety glasses at a minimum are required. Make sure the robot is safe to move. Are all parts of the robot secured? Is the robot powered off? Is anyone still working on the robot? Before lifting, hold a short discussion to determine the direction and path you will be lifting. Ensure that the areas and paths are clear of debris and hazards.

WORKSPACE SAFETY

Ensure stacked items at least 18" below sprinkler heads, stacks are stable and secure against sliding and collapse, heavy or bulky items are stored below shoulder level, floors are free of slipping and tripping hazards, all light fixtures are functional, and illumination level is sufficient for the detail of work performed.

AT COMPETITIONS

At events, the pure anticipation and excitement can sometimes overshadow common sense and safety fundamentals. One safety area teams sometimes overlook is the need to wear appropriate clothing when working on or being around robots. In addition to the ANSI-approved, UL-Listed, CE EN166 rated, AS/NZS certified or CSA rated safety glasses required for eye protection, FIRST highly recommends that team members and mentors: refrain from wearing dangling jewelry or loose, baggy clothing near the robots; tie back long hair so that it will not get caught in the robot or other machinery;

To gain entrance to the pit, every person will have to wear a pair of safety glasses or safety rated prescription glasses with side shields. Don't leave all safety glasses or side shields in the pit. Be sure to bring a few pairs with you, so someone from your team can enter the pit and get the safety glasses for all other members. Use safe lifting, handling and transportation techniques around the robots at all times.

PIT SAFETY

Control access to your pit station. Keep the work area neat and orderly. Properly use power strips. Do not 'daisy chain' (plugging power strips into one another) or overload the rated capacity of the power strip. Keep the aisle immediately outside your pit station clear for pedestrians and robot transit. Participants and spectators should be wearing approved personal protective equipment, PPE, in the pit at all times.

Teams may not build any structure to support people or items for storage over the top of the work area in their team pit station. Team structures, signs, banners, or displays cannot be higher than 10 feet above the floor. Securely mount team pit station signs, banners, and displays. Be aware of your neighbors. Alert them if there is a hazard in your pit or near theirs.

Maintain a clean, neat, and orderly pit station at all times. Maintain a clean floor in and around your pit station and properly store tools. Take proper care of batteries and battery chargers. Maintain tidy storage of personal belongings and equipment.

Children twelve and under must have a person eighteen (18) or older with them at all times. Child strollers and baby carriages are not allowed within the individual pit stations.