FRC 2017 Steamworks – Gear Floor Pick Up Mechanism Design

CS450HO – Robotics Design and Fabrication Honors

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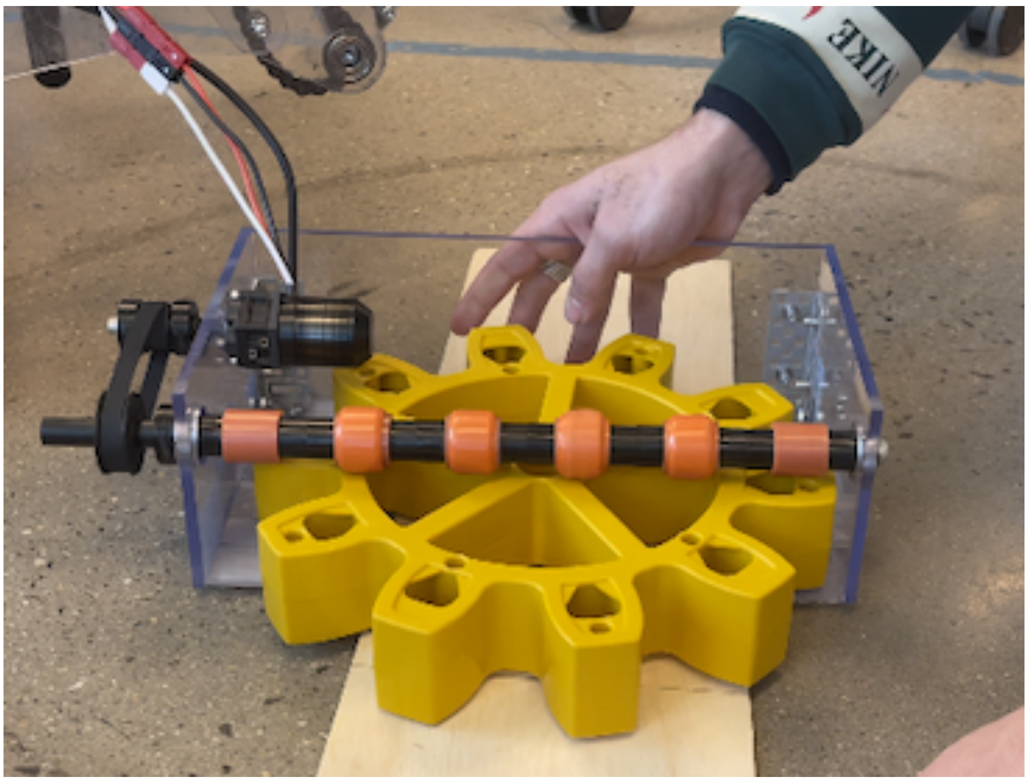

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Introduction

The objective of this project was to design and manufacture a contraption that could intake gears as seen in the 2017 FIRST Robotics Competition Steamworks challenge. The FIRST Robotics Competition, or FRC, is an annual international high school robotics competition that allows participants to delve deeper into designing and producing machines that can complete certain tasks. A component task of the 2017 Steamworks challenge was to intake polypropylene gears that were placed on the field floor efficiently. These gears measured 2 inches thick, 11 inches in diameter, and weighed around 18.4 ounces. The contraption was solely the intake mechanism, as the drivetrain was already manufactured. The project team had no material, part, or weight/size constraints.

Strategic and Functional Requirements Design Analysis

Steamworks Gear Intake	
Strategic Requirements and Limitations	Functional Requirements and Limitations
Intake the yellow gear quickly and efficiently	Intake should have little to no fumbling with the gear
Intake should be versatile and able to retrieve gears in different configurations	Intake must be able to take gears in front different angles and from different parts of the field
Intake should be able to withstand impacts from other robots	Intake should have a sturdy structure and have good grip on the gear
Priority Ranking	
Intake should be stable and consistent in intaking the gear	
Intake should be able to intake in different scenarios	
Intake should be able to handle being hit by other robots	

Figure 1: Strategic & Functional Analysis Spreadsheet

The purpose of this strategic and functional requirements design analysis is to identify factors that must be considered during the design and manufacturing process prior to beginning the planning process. This helps eliminate incorporating inefficient and ineffective design pieces.

Before sketching and assembling the intake in Onshape, a computer aided design software, the design team listed several strategic and functional priorities to address.

The strategic and functional priorities included:

- The intake should be systematic and consistent; if the intake contacts the gear, it should be able to intake it without fumbling
- The intake should be able to handle a variety of situations; the intake should be able to operate no matter where the gear is on the field or if it comes in at a certain angle
- The intake should be able to withstand impact from other robots and maintain possession of the gear

Initially, the design team devised and sketched an intake that would grab the gear using a claw. However, there were predicted issues with consistently grasping gears from different angles. In addition, there were foreseen issues related to dropping the gear when hit by other robots. Thus, the design team formulated an intake that uses rollers to grip and roll the gear into the intake. Originally, the team wanted to use two rows of rollers, but eventually deemed it unnecessary, as the intake was designed to not completely encase the gear. This second prototype is the one that the design team decided to execute and manufacture.

Computer Aided Design Process

CAD is an acronym for computer-aided design. Onshape is a computer-aided design software system that has many functions and tools that allowed the design team to use it to create a digital model of the parts and assembly of the intake.

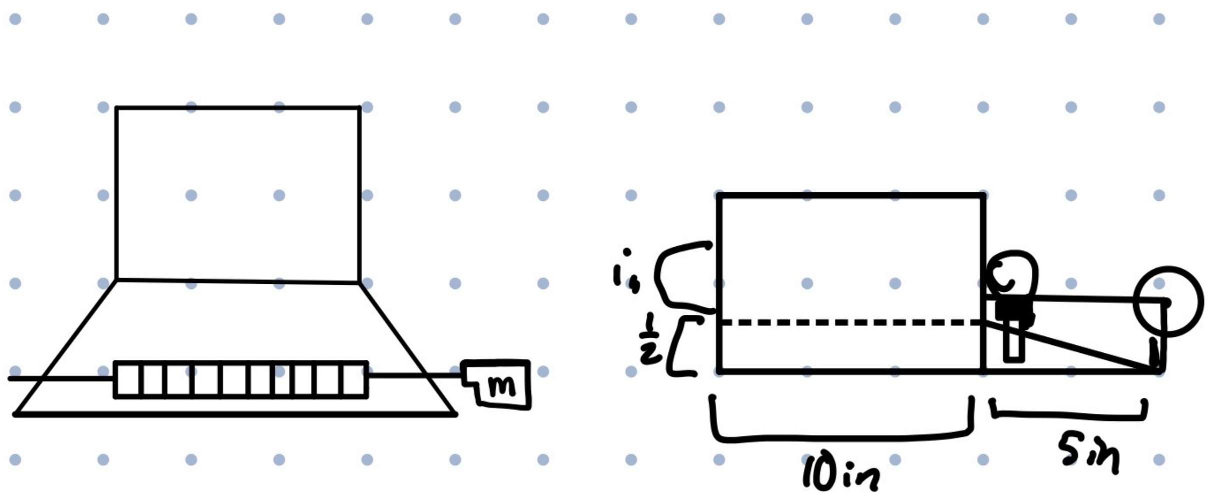


Figure 2: Preliminary Sketches of Intake Ideas

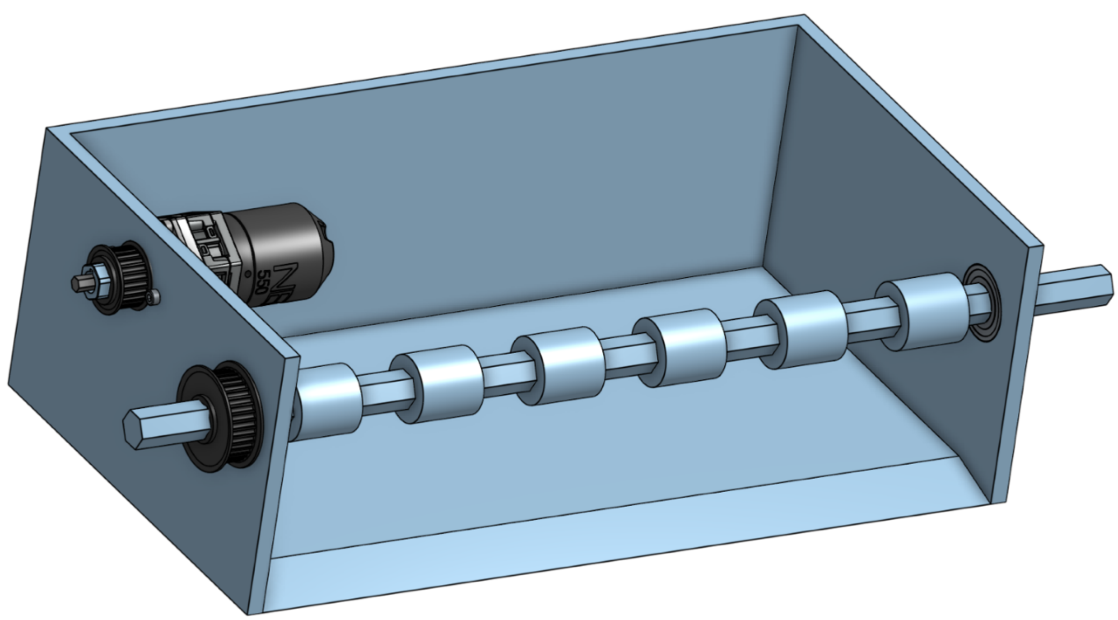


Figure 3: First Perspective of Final Render

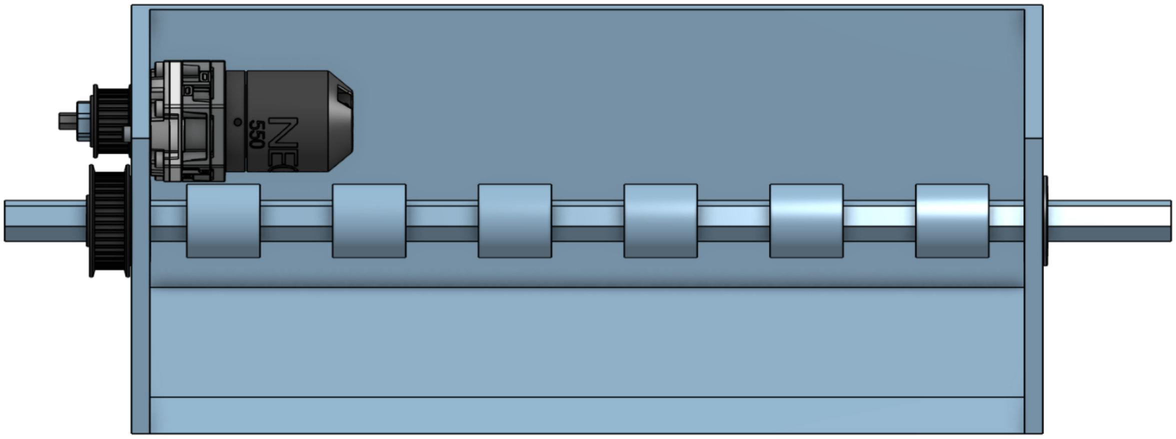


Figure 4: Second Perspective of Final Render

During the part modeling process, the design team started with the frame of the intake. The inclining base allowed the gear to slide smoothly into the intake. The walls were extruded to ¼" to ensure that they would be sturdy enough to contain the gear and were located further apart from each other than the diameter of the gear. Four holes were extruded from the left wall and a single hole was extruded from the right wall to allow spaces for the bearings and screws to be inserted. The shaft was created as an extruded hexagon (which was created using the inscribed polygon tool). The design team fabricated a single roller and used the linear pattern tool to create more of them and space them evenly in a line. The bearings, pulleys, and motor parts were imported from MKCAD, an Onshape library of FRC parts created by FRC Team 1836.

During the assembly process, a variety of mates were used. The bearings were revoluted with their respective holes and the shaft revoluted with the two bearings. The rollers were slider mated and offset with the shaft. The motor parts were grouped, and the screws were fastened through two of the holes that were extruded from the left wall. The pulleys were cylindrically mated to the shaft.

Manufacturing & Assembly

The manufacturing team used a variety of machines and tools to create a physical model of the intake. The following written descriptions detail the use of machines and issues that the manufacturing team encountered. The images depict the progression of manufacturing and assembly, the final assembled intake, and the Bill of Materials.

The machines used include:

- Hand-Held Belt Sander

The hand-held belt sander uses a motor to continuously move a looped sheet of sandpaper. The manufacturing team used the hand-held belt sander to create the inclining lip of the base part.

- CNC Router

The CNC router is a computer-controlled cutting machine that can cut a variety of material. The manufacturing team used the CNC router to cut the two side pieces and the back wall with precise measurements.

- 3D Printer

The 3D printer uses a heater to melt filament to make a desired three-dimensional object. The manufacturing team used the 3D printer to create two PLA carbon fiber pulleys.

- Dremel

The dremel is a handheld sander that rotates a small cylindrical tube that is covered with a sheet of sandpaper. The manufacturing team used the dremel to make the hole for the motor large enough for the motor to be able to rotate.

- Drill Press

The drill press is a machine that uses a rotating drill bit to bore holes in the material. The manufacturing team used the drill press to drill eight holes for the rivets.

- Hand Rivetter

The rivet gun is used to expand the head of the rivets to hold them in place in a hole. The manufacturing team used the hand rivetter to fix eight rivets into the side walls to the back wall.

- Vertical Bandsaw

The vertical bandsaw uses a vertically rotating toothed blade to cut through a variety of materials. The manufacturing team used the vertical bandsaw to cut the base sheet of polycarbonate.

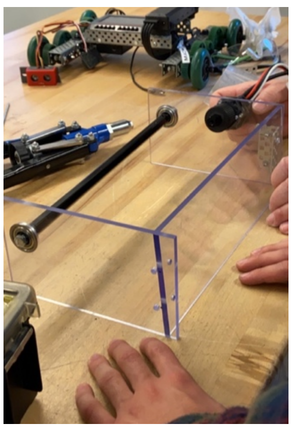
- Horizontal Bandsaw

The horizontal bandsaw is very similar to the vertical bandsaw in that it uses a rotating toothed blade, but the blade is dropped so that it cuts horizontally. The manufacturing team used the horizontal bandsaw to cut the metal shaft.

- Tap

A tap is used to create threads in softer metal tubes and shafts. The manufacturing team used the tap to create threads for bolts in the shaft.

Even with the assistance of all these machines, the manufacturing team encountered several issues during the production and assembly process, particularly due to human errors. One problem that the manufacturing team encountered was that the shaft was too short because they did not account for the small distance required between the pulley and the bearing to allow the pulley to rotate. The manufacturing team had to recut and retap another shaft, which was time and material consuming. Secondly, due to measurement inaccuracies, the holes that the manufacturing team drilled for the rivets did not allow the walls to be flushed when bracketed, so they had to be redrilled, which was very time consuming. Something that the manufacturing team did not anticipate was that extra-long rivets had to be used to go through the quarter-inch layer of polycarbonate, the bracket, and the washer. Finally, if the manufacturing team could redo this project, they would fix the problem with the rollers being too small and the base not being completely flushed to the ground. Both of these problems were fixed using tape, though this would not be practical in a competition season as tape is not a durable adhesive for heavy-duty intakes.



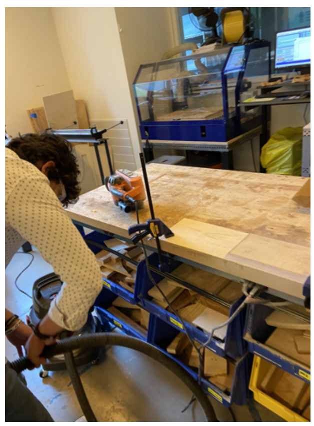


Figure 5: Orienting the Intake Wall

Figure 6: Cleaning Up Polycarbonate Shavings

Figure 7: Practicing Intake with Rollers

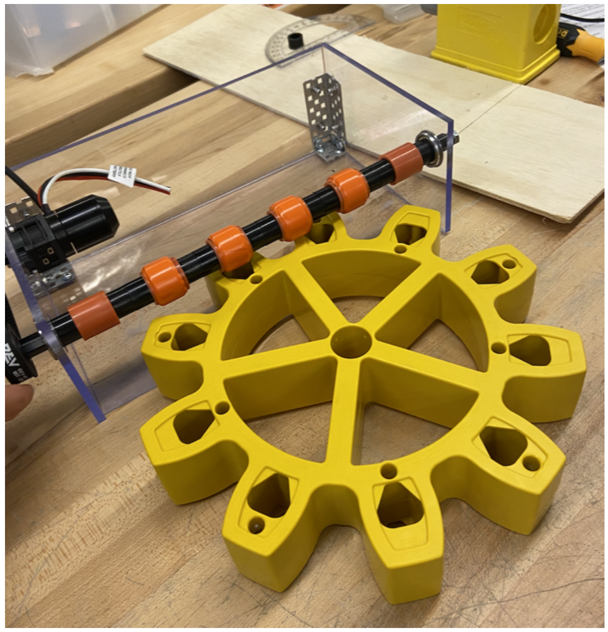


Figure 8: Final Assembly

Part Number	Name/Description	Price	Quantity	Total Price	Vendor and Link	
SKU#: 217-2737	Clamping Shaft Collars (1/2" Hex)	$4.99	3	$14.97	Vex Robotics	https://www.vexrobotics.com/shaft-collars.html?q=&locale.name=English
SKU#: REV 21-1651	NEO 550 Brushless Motor	$25.00	1	$25.00	Vex Robotics	https://www.revrobotics.com/rev-21-1651/
SKU#: 217-3261	Acetal Spacers (1/2" Hex; 1/2" Thick)	$5.99	2	$11.98	Vex Robotics	https://www.vexrobotics.com/vexpro-spacers.html?q=&locale.name=English
SKU#: REV 21-2024	1" Grip Wheel - 1/2" Hex Bore	$3.00	6	$18.00	Vex Robotics	https://www.revrobotics.com/1in-grip-wheel-0in5-hex-bore/
SKU#: 217-4006	1/2" Thunderhex ID (Flanged Bearing)	$4.99	2	$9.98	Vex Robotics	https://www.vexrobotics.com/pro-bearings.html?config=273-1279,274-1284,275-1287,276-1297
SKU#: 217-4017	1/2" Hex x 0.201" ID Thunderhex (36")	$15.99	1	$15.99	Vex Robotics	https://www.vexrobotics.com/thunderhexstock.html
				$95.92		

Figure 9: Bill of Assembly

Testing Setup & Results

To test the final assembly, the design team used a pre-made drive-base and control system from the 2020 BB2 Robot from Team 7407 to control the motor. The intake was placed on a thin piece of wood to create more friction between the ground and the gear, and the intake was slid along the ground to imitate the way it would travel in a competition.

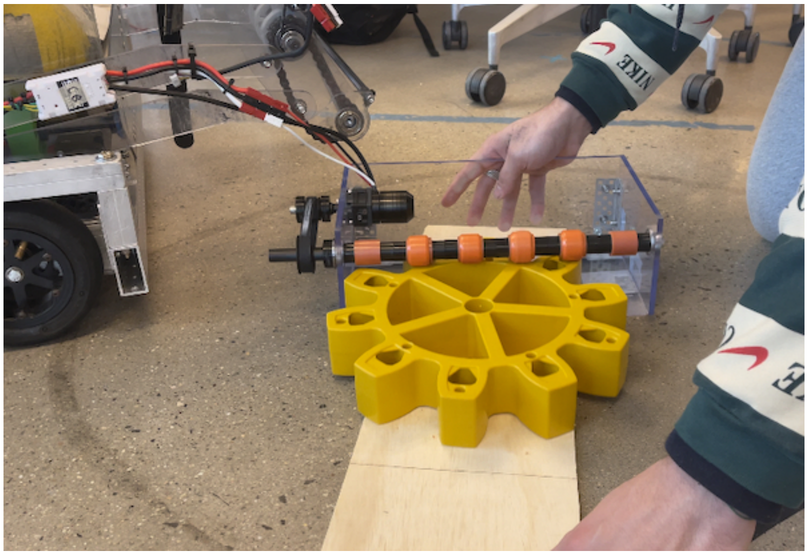


Figure 10: Testing Final Assembly

Through the testing process, the team identified certain strengths and weaknesses.
Strengths:

- The intake was efficient and smooth, and the rollers rarely skid over the gear.
- The polycarbonate material was sturdy and did not move, even when the gear entered the intake at a relatively high speed.
- The speed of intake was fast enough to be considered efficient, but not too fast to the point where the gear would damage the polycarbonate upon impact with the back wall.
- The base piece was sanded so the incline was gradual and did not cause the gear to skip as the intake slid under the gear.

Weaknesses:

- Because the manufacturing team had to wrap the rollers with duct tape to make them thick enough to contact the gear, the rollers were not all of the same diameter, so the intake could be inconsistent at times.
- Also, the manufacturing team did not wrap the outside-most rollers, which made it difficult for the intake to retrieve gears that entered at an angle.
- Because the base piece was attached to the rest of the assembly by corner brackets located on the back wall, the front of the piece was flimsy and not flushed to the ground. The manufacturing team temporarily fixed this problem using tape (again), but the tape did not offer much support either. Regardless, the intake was able to successfully roll in gears.

In future trials, the team would use the following iterations to resolve some of these weaknesses.

The team would:

- Add brackets along the left and right side of the bottom plate so that the structure is more reinforced, and the base won't lift off the ground as the gear is on its way in.
- Either lower the bearing hole so the rollers make contact with the gear or add tape to the outmost wheels as well.
- File down the incline on the base plate a little more so the gear's path is smoother.

Date	Structure	Observations
11/18/2021	Basic box assembly; rollers on the shaft do not have tape; the base is supported only by the corner brackets; the intake is being powered by a drill	The gear is too short that it doesn't make contact with the rollers
11/18/2021	Basic box assembly; elevated the front of the base so that the gear would make contact with the rollers; rollers have no tape; the intake is being powered by a drill	The gear rolls into the intake at an acceptable speed quite smoothly
11/19/2021	Basic box assembly; used duct tape on the middle four rollers to make them thicker so the gear touches them; intake is being powered by a drill	The gear was a bit choppy on its way in, and the front of the bottom plate lifts a little bit as the rollers makes contact with the gear, which contributes to this choppiness
11/19/2021	Basic box assembly; used duct tape to tape the base at an angle where the gear is able to slide in from the ground, but will not lift as the gear is being rotated by the rollers; intake is being powered by a drill	The gear was able to make contact with the roller without lifting the base; the intake was smooth and quick without damaging the polycarbonate of the back part
11/19/2021	Basic bx assembly; duct tape remains where it was in the previous trial; the intake is being powered by the BB2 control system	The intake was able to roll the gear in smoothly off the ground without going too fast and the front of the intake was secure (didn't move)

Table 1: Testing Data Table

Conclusion

The purpose of this project was to allow the design and manufacturing team to explore the CAD, production, and assembly processes of the FIRST Robotics Competition. Specifically, by using a component of the 2017 competition prompt, students were able to explore the different functions of CAD through Onshape.

Through the manufacturing and assembly process, students learned how machines work and reached a level of proficiency when operating with them. Specifically, the design team learned to make shapes, extrusions, and patterns using Onshape. In addition, the team learned to import pieces from the MKCAD Library and used a variety of mates to virtually assemble the prototype. Using a variety of computer-controlled and manual machines, the team was able to create a physical intake, using their CAD blueprint as a guide. Overall, the teams learned to problem solve and devise creative solutions to the design challenges.

During the testing period, the manufacturing team was able to identify problems with the intake and how to resolve them. Most issues that were encountered were human errors, including mismeasurements and insufficient planning on how to attach the side, back, and base pieces. In the future, the team will focus on remembering all the mechanical logistics and be more cautious when manufacturing.

The following are three major lessons that the team learned and a few pieces of feedback for next year!

Lessons:

- Lesson 1: Having an accurate CAD prototype to base the actual measurements and steps of assembly can be very helpful. Manufacturing and assembly take a few days, so it is easy to forget measurements and the orientation of the parts. Thus, being meticulous when doing CAD can pay off in the long run.
- Lesson 2: It is beneficial to consider all the design possibilities because it allows for the exploration of different ways the challenge can be solved. For example, the team originally considered using a clamp to pick up the piece but decided to use rollers because they are more reliable and consistent. Coming up with multiple prototypes in early stages fosters the selection of the best possible way to approach a challenge.
- Lesson 3: Teamwork is incredibly valuable. Not only does it make the production process much quicker, but it can also make the work much more fun as well. Teamwork fosters positive connections between teammates and opens more perspectives.

Feedback:

- Feedback 1: This project was very enjoyable for the team. Towards the end of the build season, the camaraderie grew stronger and more productive, which was wonderful to experience. Promoting and ensuring teamwork is an important aspect of this project, so the team hopes that this will be emphasized in future years!
- Feedback 2: During the beginning of the build season, most groups were unproductive. Towards the end, teams were rushing to finish their construction and were very stressed out about completing the project. It would be optimal if the season is more organized in terms of time distribution in the future!

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