14365 Build Section

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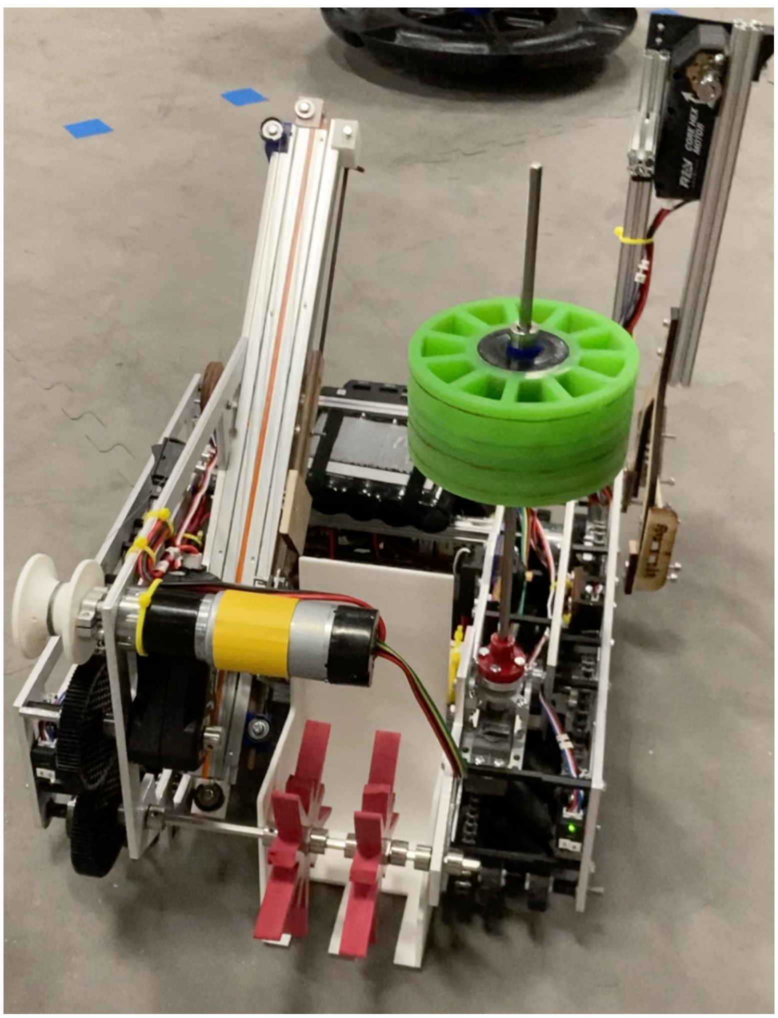
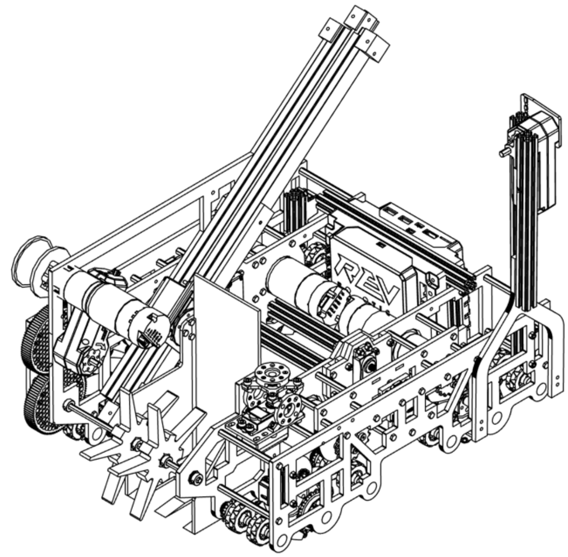
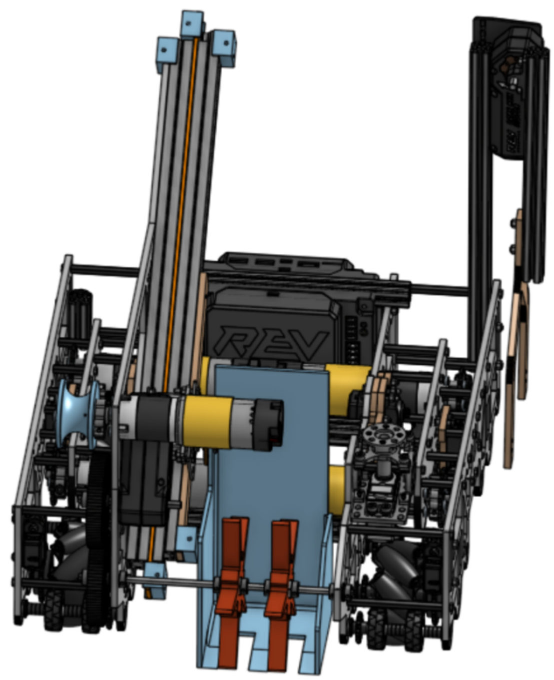






General robot notes

Constraints

Size Maximum base size of 14x14 inches. This has 2 great benefits – the small size allows us to skirt around many of the obstacles around the field, so (even though we are able to handle the obstacles) we do not have to, and it allows us to add small mechanisms that can overflow the edges without violating the maximum size.
Maneuverability We have used Mecanum wheels in the past and have grown comfortable with the superior maneuverability afforded by the multi-directional driving, so decided to stick with them.
Access Obviously we have to get into the space behind the obstacles, so we wanted a robot that could both go around the obstacles and go right over them, hence our auxiliary wheel system.
Speed & torque Each year we have massively increased our speed potential, this year we are using 435 RPM GoBilda YellowJacket motors as our drive motors, connected to our primary wheels with a 1:1 ratio. We have discovered this is the highest speed we can go while staying within the YellowJacket family while still having enough torque to move our robot around easily.

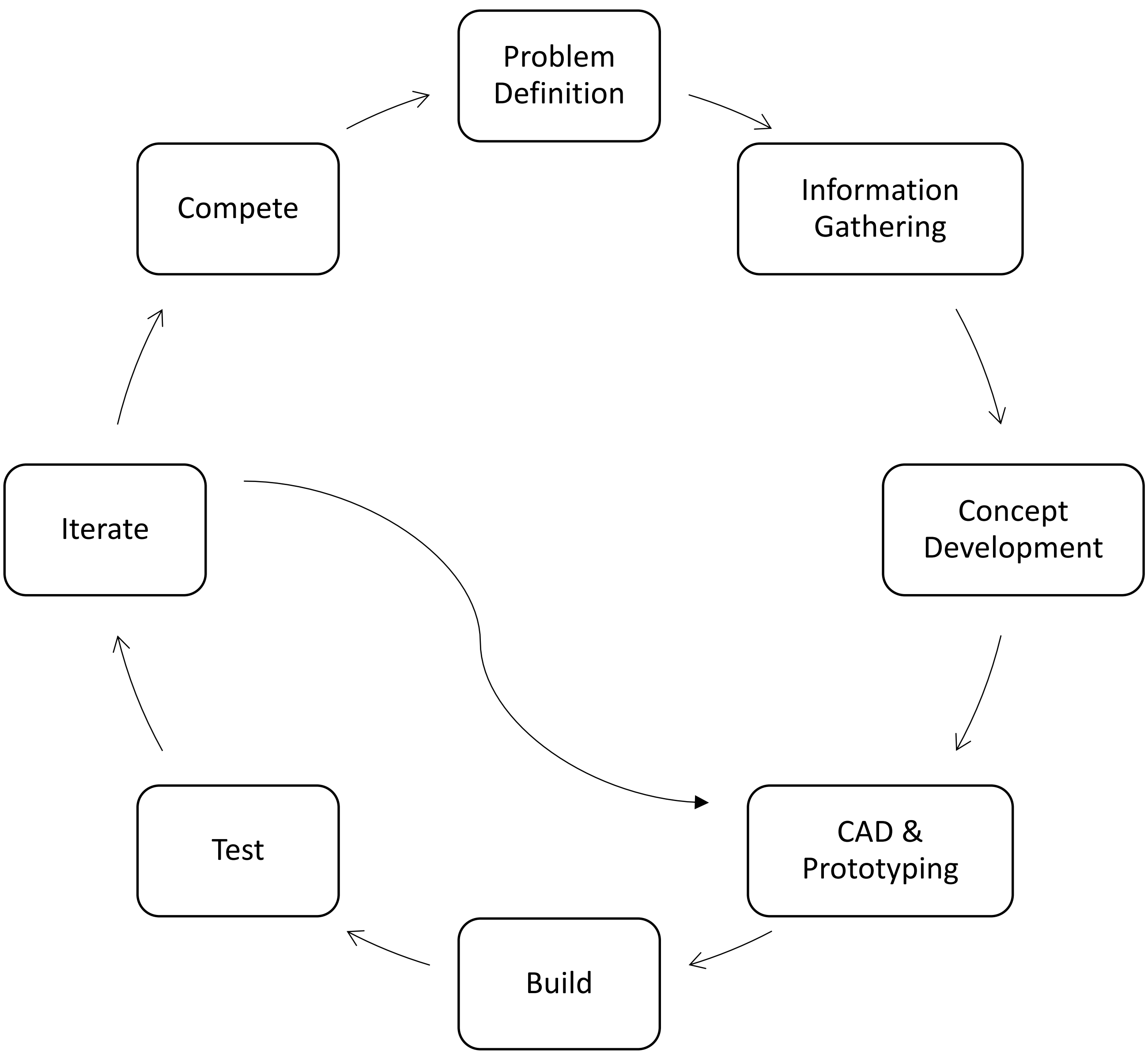
Notable items

Our drivetrain is 100% custom designed and prototyped in-house (see *Iterative Design*) and was sent off for laser cutting out of .187” 5052 Aluminum.

Our robot has been completely replicated in CAD this year, enabling us to easily extract accurate measurements for the development of new systems, print build instructions and schematics, and generate attractive imagery for marketing and notebook purposes.

The Design Process

Our team follows a slightly modified Engineering Design Process as we assess, brainstorm, prototype, iterate, and compete. We use this process for everything we do on our robot, from initial prototyping to programming to finalizing all of our designs. This systematic approach to everything we do as a team helps to ensure what we create are to the highest standards while also being efficient with time and resources.



The Design Process (continued)

Problem Definition – Our initial understanding of the task we are attempting to solve. On our team, this often comes as watching the game reveal animation and our first look at Game Manual part 2.

Information Gathering – Getting a more in-depth understanding of the challenge through thoroughly reading GM2, and using the one-page game description to plot each task based on point value and perceived difficulty, giving us a roadmap of our priorities. Read more about this process in our game strategy section.

Concept Development – Regardless of position on the team, every member is given a stack of note cards and a pen to draw a brief sketch of their ideas for how to solve each task. Once an idea is chosen or developed, the team discusses the mechanism, pros and cons, and assess the build, programming, and driving complexity.

CAD & Prototyping – All of our systems are designed and built out of cardboard before we begin using any "real" materials or open our CAD software. This process of "cardboarding" helps us to envision if our idea is able to be turned from the 2d sketch on a note card to a 3d 100% scale object. Once cardboarding is finished, the mechanism will be designed in OnShape, our CAD software. If any digital fabrication is necessary we then send the file to our laser cutter or 3d printers, and if the system is to be built by hand, we use the CAD drawings as reference.

Build – The relatively short phase after prototyping where we turn our hand-made, fragile prototypes and turn them into sturdy, production-quality components.

Test – Our systematic approach to making sure our hardware and software work as expected. Before a mechanism is marked as "complete" it must accomplish the task 9/10 times, and before the mechanism is marked "tournament ready" it must work 10 out of 10 times.

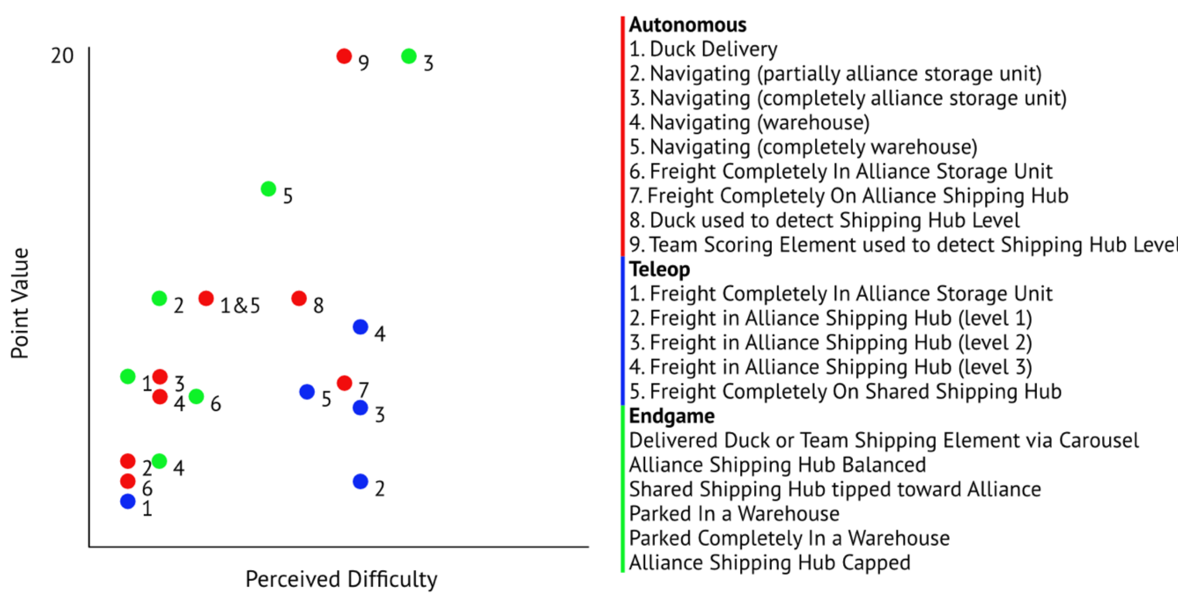
Iterate – If a test does not go as expected, our constraints change, or our strategy changes, it often requires a new system to be designed or modifications to be made to the current mechanism.

Compete – Our chance to perform and show off what our creation can do, while also collecting metrics that can be used as our next *problem definition*.

Team-led Brainstorming

Regardless of job or seniority, each team member is given note cards to draw their ideas on how to solve issues, then we discuss each idea individually, decide on the most feasible, then combine features to produce the best possible mechanism while involving as many ideas as possible. This leads to simple but reliable systems.

The team discussing initial thoughts as we organize the challenges after kickoff



Our analysis of the missions, plotted by point value vs perceived difficulty.

Cardboarding (prototyping)

Before we ever start working with “real” materials, each large mechanism on the robot is completely built of cardboard. While unorthodox, this practice has helped our team massively by forcing us to completely nail down the building technique of the system at hand, while also helping to weed out logic issues in the design that would be harder to fix on stronger materials.

We begin cardboarding immediately after the initial design on paper, and before CAD. Our cardboarding process precedes CAD for many reasons, but the main ones are having a physical 3d object in front of the CAD screen helps to eliminate issues, and it allows our entire team (especially those who don’t know how to use CAD) to be involved in the prototyping process, allowing us to move faster.

Picture needed

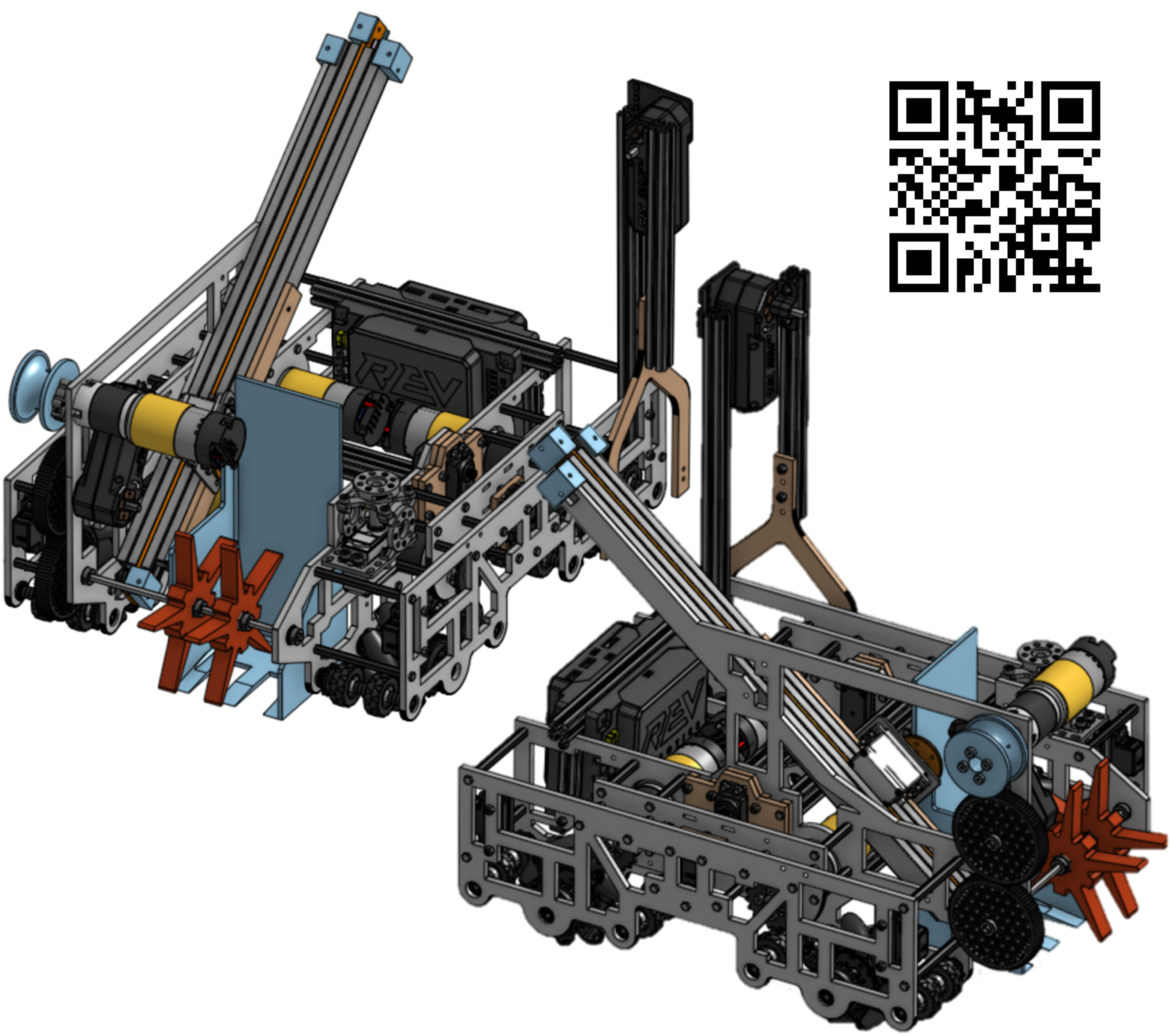
CAD

Our team has selected OnShape as our primary CAD software. Its web interface and cloud-based workflow make it easy to use on a wide range of devices, and the relatively simple interface and low barrier of entry makes it easy for us to more members of the team involved in CAD.

We don’t just use CAD for parts that have to be digitally fabricated (3d printed or laser cut), we also use it on almost every mechanism for recordkeeping and as a reference for building/rebuilding the mechanism.

This year, for the first time, our entire robot has been modelled in CAD.

Explore our 3d robot at http://go.scdrobotics.org/pZhFyN



Iterative Prototyping

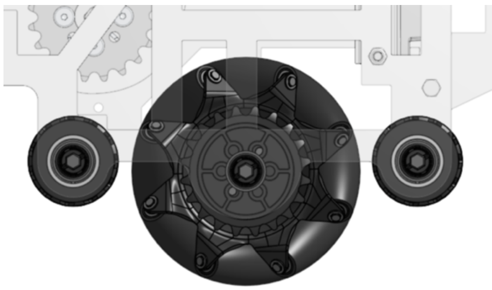
We use many iterations of prototypes to test our mechanisms, making small improvements to each. This unique process allows us to see the real effects of our changes. Our iterative process is helped greatly by our laser cutters and 3d printers in-house, allowing us to run multiple prototypes in a single day.

A great example of our iterative prototyping process is our drivetrain. Some with major, breaking changes, and some with holes moved (literally) tenths of millimeters, we have had a total of 14 drivetrains, 12 of which were at one point, fully drivable bases. This process of making minor changes and testing them in the real world helps us to account for certain mechanisms and principals that are hard to simulate. For example, while using the mathematically proper center distance for the sprockets for our chains, the chains were all way too loose for accurate control, so we moved the sprockets slightly further apart, tightening the chain to perfection.

Picture needed

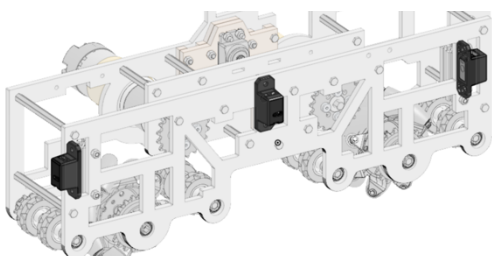
Systems Reference

Auxiliary Wheels



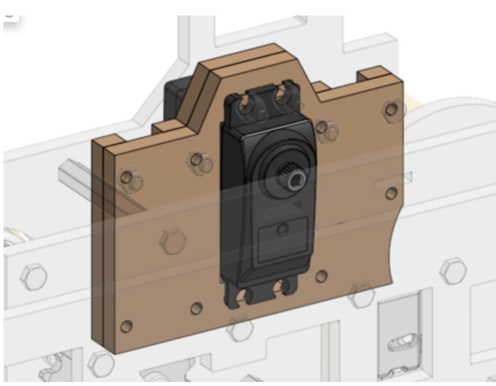
We use a set of Auxiliary wheels in front and behind each of or REV Mecanum Wheels to help ensure we can safely make it over the obstacles without risking getting stuck, while also not sacrificing the superior maneuverability that mecanum provides. Chains (not pictured) drive the small auxiliary wheels off the main Mecanum wheel, driven in turn by our drive motors.

Distance Sensors



An array of 8 distance sensors (2 forward, 2 back, 1 left, 1 right, and 2 bottom) help our software know exactly where the robot is at any given moment, backing up our IMU-driven position tracking, as well as help determine if the robot is going over the obstacles, in which case the IMU tracking has to be reset.

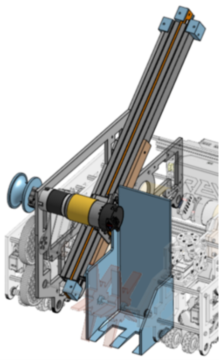
Provisions for Dead Reckoning



Although not yet implemented, we have included a mechanism to hold a dead reckoning system as part of our future-proofing. Because of the obstacles, we have designed our dead wheels as sleighs that can be retracted into the body of the robot to protect them.

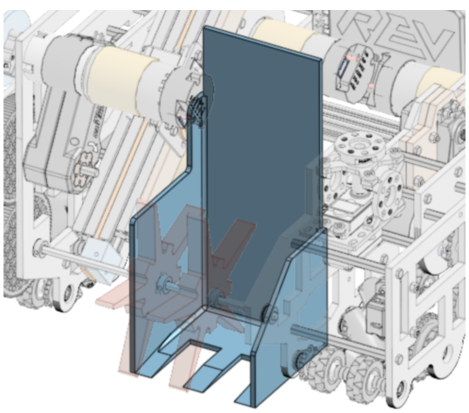
Systems Reference (continued)

Delivery Mechanism and Linear Slide



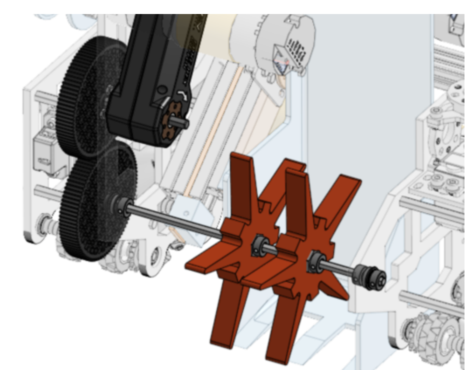
Driven by 2 layers of Misumi SAR340 linear slides, the delivery mechanism is a multi-purpose system that brings scoring elements from the input to the shipping hubs. The delivery mechanism has 2 parts: the linear slide and the bucket. The bucket is connected to a servo, allowing us to control its position on the route up, as well as letting us dump the scoring elements.

Delivery bucket



The bucket has the task of holding our scoring elements as they are being brought up the slide for scoring. Due to the small overall size of the robot, we had to figure out how to work a 9x9 cm structure into an 11x5 cm space, so we had to add cutouts for our intake wheels, as well as a large cutout on the corner. The tall back allows us to deliver into the lower layers of the scoring element while also reaching the highest layer with the help of our long linear slide.

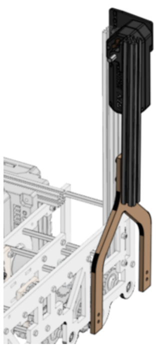
Intake



We use 2 modified entrapption stars to grab the shipping elements. We experimented with the unmodified stars, but discovered that the more concentrated points would grab the elements then push them back out once more came in contact, so we cut off every other ‘spike’ and it worked far more reliably.

Systems Reference (continued)

Arm



The arm mechanism is a simple solution for picking up and delivering our Team Shipping Element. While still under heavy development, our Team Shipping Element has 2 sticks that reach out opposite each other, and the ‘wishbone’ shape on the arm easily nestles in and keeps the shipping element under control while we manipulate it.

Bill of Materials

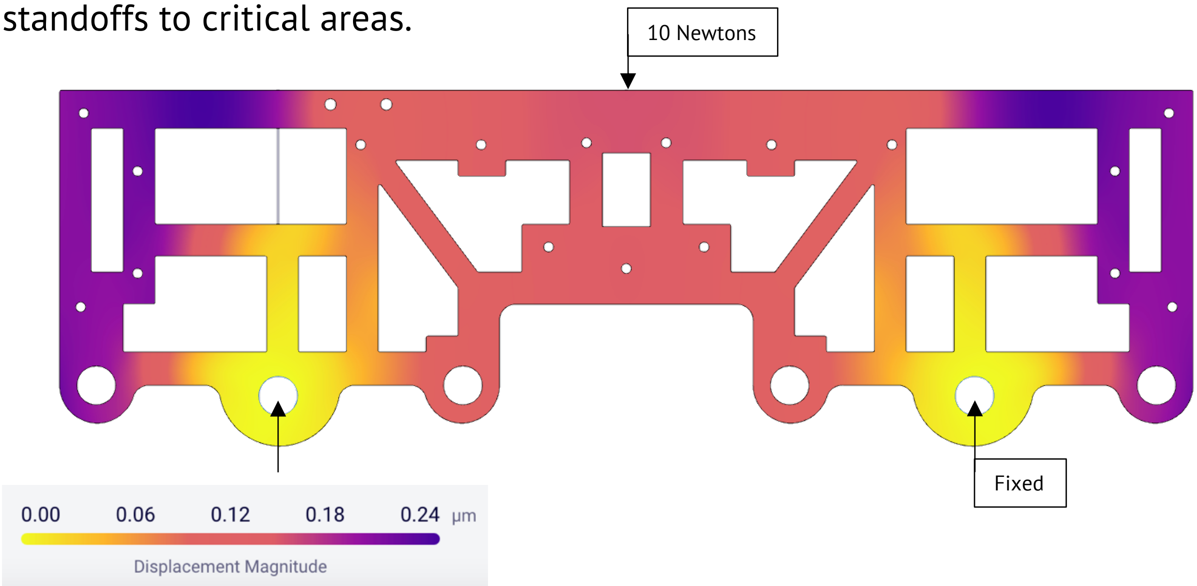
Qty	Item
	GoBilda 5202 Motor
4	↳ 435 RPM
1	↳ 223 RPM
2	REV Core Hex Motor
1	GoBilda Torque Servo
1	GoBilda Speed Servo
2	REV Smart Robot Servo
8	REV 2m Distance Sensors
1	REV Control Hub
1	REV Expansion Hub
	Drivetrain panels
1	↳ Boom side inner panel
1	↳ Arm side inner panel
2	↳ Outer panel
2	↳ Motor panel
	REV 3m Standoffs
8	↳ 30 + 40mm (combination)
12	↳ 25mm
11	↳ 40mm
6	↳ 15mm
	REV 3m Hex Bolts
100	↳ 8mm
5	↳ 16mm
16	↳ 10mm
15	↳ 20mm
8	↳ 25mm
	M4 x .7 Socket Head Bolts
20	↳ 10mm
20	↳ 8mm
5	Flat countersunk head machine screw #4-48 x 0.25

56	REV Nylock Hex Bolts
6	GoBilda 6mm Bore Clamping D-Hub 0.770" Pattern
4	ServoCity 1/2" Bore 0.250" Pitch Acetal Hub Sprocket 20T
	Retractable Dead Reckoning wheels
2	Servo rail bracket
2	Outer straight bracket
2	Outer fit bracket
2	Main holder bracket
	NOTE: the dead reckoning system is not yet deployed, but the sled is in place *NOTE: we are using 2 REV Smart Robot Servos in this mechanism, but they are included in the servos section.*
80	REV 3mm Spacer
4	1.5mm Spacer
4	15mm Spacer
26	REV 5mm hex to 8mm round bearing insert
26	REV 8mm Flanged Bearing
16	REV 30mm Traction Wheel
4	REV 75mm Mecanum Wheels (2 left, 2 right)
4	REV Universal Hex Adapter V2
12	REV 10 Tooth #25 Sprocket
4	REV 20 Tooth #25 Sprocket
12	REV 5mm x 75mm Hex Shaft
1	REV 5mm x 200mm Hex Shaft
1	GoBilda 1910 ServoBlock (24 Tooth Spline)
2	Misumi SAR340
1	Connector board for slides
1	Connector board for slide to servo
1	REV 15mm Metal Flat Servo Bracket V2
1	REV Aluminum Servo Horn
1	3d printed bucket
5	3d printed slide caps
1	3d printed spindle (linear slide pulley)
2	REV 90 Tooth plastic gear
9	REV Slim Shaft Collar
2	½" x .25" Ultrahex Shaft

1	REV Plastic Motion Bracket
1	REV 15mm Hex Pillow Block
1	Custom Wishbone bracket

Challenges & Solutions

Torsion & Shear Our final drivetrain panels are .187” thick and made of Aluminum, but our original panels during the prototyping process were made of wood, so the substantial forces resulted in warping of the wood, resulting in looser connections. Long-term, our solution was to transition to metal. Short-term, the solution was drilling extra holes and connecting extra standoffs to critical areas.



Tight chains We originally used the mathematically “correct” center distance for the sprockets on the chains on our drive system. After discovering that this did work, but was too loose and had too much play to make a reliable autonomous, we did some testing with slight extra space to tighten the chain. This tightened our chains, but left us with a new issue: they are extremely hard to install. Our solution for the tightness issue was not a design change but a workflow advancement. Previously, we would attach the chain to the sprockets, then to the shaft, but now we connected the chain to the sprocket, then, an off-center screw would help lever it over the shaft and fall into place.

Challenges & Solutions (continued)

Intake consistency Our original entrapption stars would initially grab the shipping elements, but once the next prong came around, it would pinch the element and shoot it away from the robot. We solved this by just cutting off every other prong.