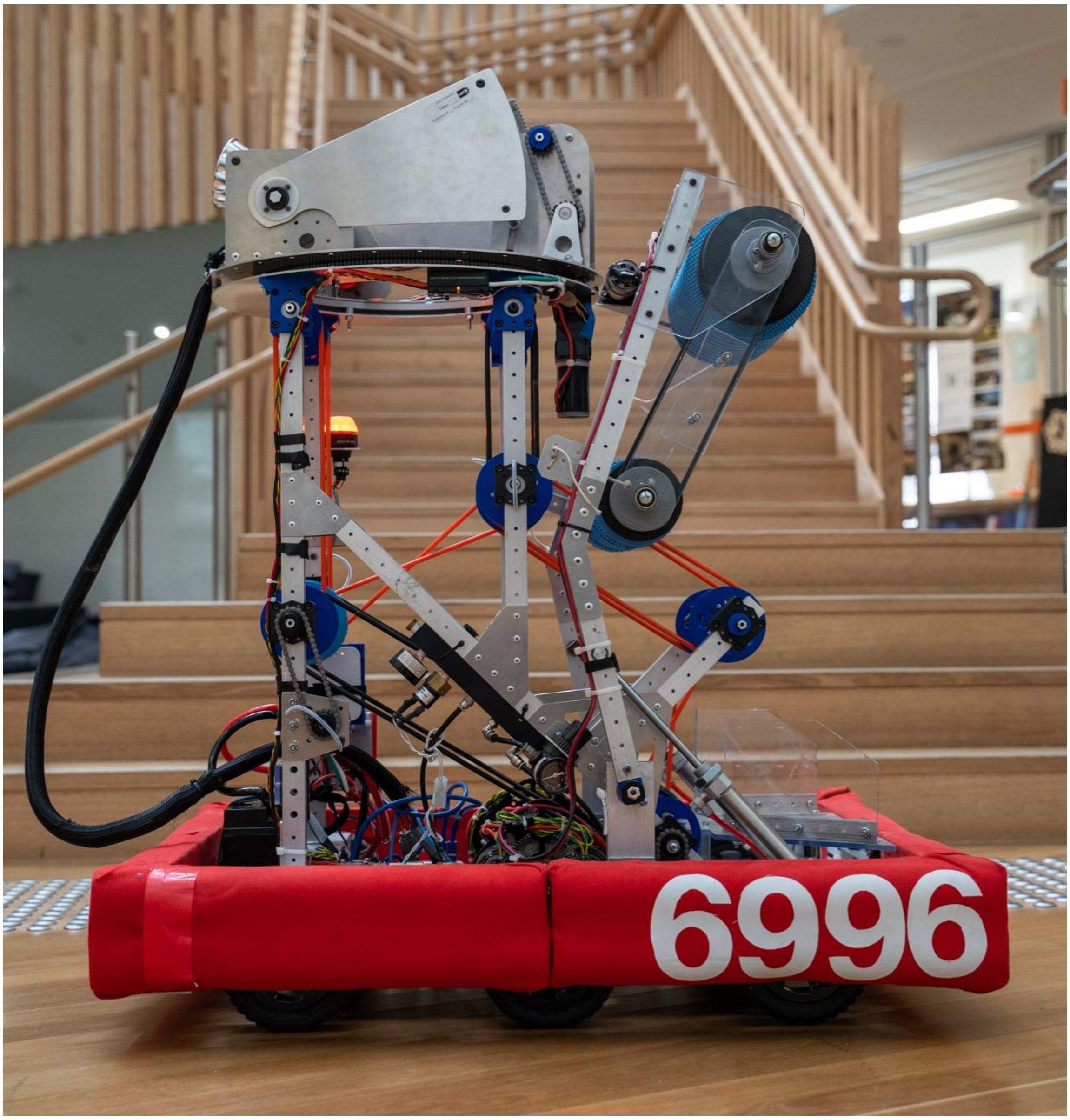
Team Koalafied #6996: Off-Season Robot Design 2022



Introduction

This document describes the design of Team 6996 Koalafied's 2022 Rapid React robot. The Onshape CAD for this robot can be found here. Due to COVID pressures we designed this robot to compete in the offseason Melbourne Robotics Tournament rather than the normal competition season.

The robot consists of the following subsystems:

- Drivebase - a standard centre drop 6 wheel tank drive
- Intake - an over the bumper intake with two rows of foam rollers.
- Indexer - a polycord transfer system
- Shooter - a variable hood, single flywheel turreted shooter
- Climber - a double sided rotating arm climber that was largely designed, but not built

We have tried to summarise the reasoning behind the design and also how the design intent was expressed in the CAD. Note that in practice there was, of course, some iteration of the design, although not as much as we would have liked. Also note that some details of the final build are not in the CAD, such as shaft spacers, shaft collar and details of the wiring.

For any enquiries about this design please contact teamkoalafied@gmail.com.

Design Goals

We intended to build a robot with the capability to pick up balls from the ground, shoot balls in any direction with a turret, and climb to any of the rungs. We took a very experimental approach to our design as we did not intend to compete in an in-season event.

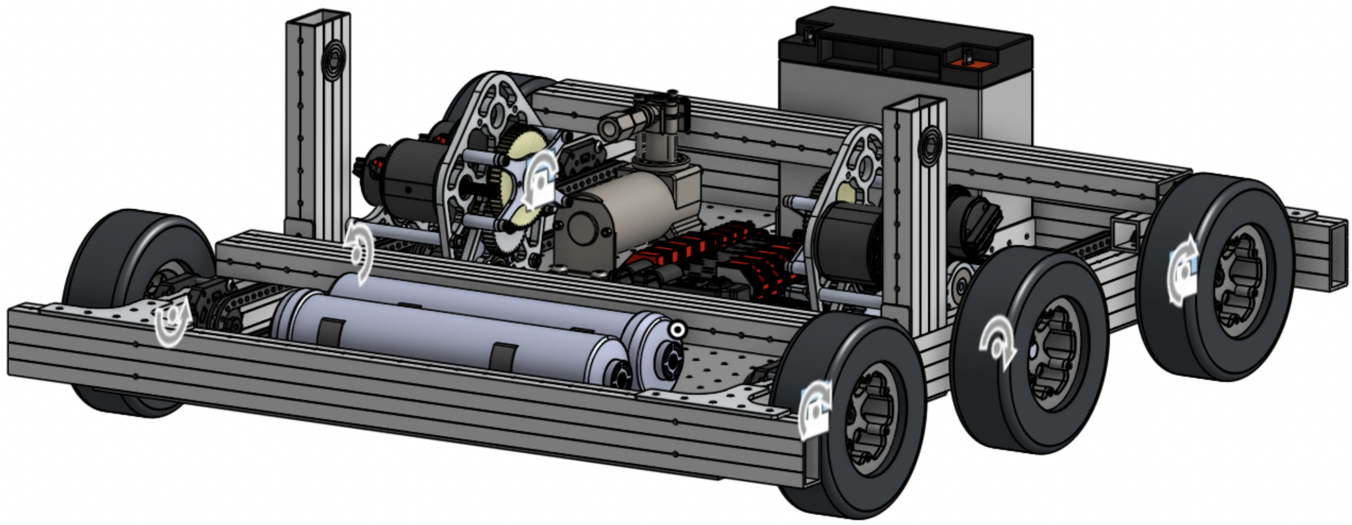
CAD Notes

The basic geometry of the design can be seen in the **Master** parts studio.

- The **Ball Path Sketch** is used to design a **Ball Path** part, which then drives the design of all the subsystems that manipulate the ball.
- **Intake Sketch** shows the design of the intake.
  - It has a 6" outer roller and a 4" inner roller, with a 7" gap between them to prevent the 9.5" ball from getting through.
  - The extended intake position has the front roller contacting a ball on the floor below its top and the inner roller contacting the top of the ball as it goes over the bumper.
  - The retracted intake position brings the whole intake inside the frame perimeter. Note that to avoid other subsystems the inner roller pivots through intake side arms.
- **Climber Sketch** shows the space to be taken by the rotating arm climber to be able to reach over the mid rung by 2".
- **Shooter Sketch** shows the space allowed for the shooter. As the turret will be circular the 19" space also represents the width of the shooter across the robot.

- **Kicker Ball** shows the position of the ball as it leaves the indexer and enters the shooter. The design does not actually use a kicker as the indexer carries the ball until it touches the shooter flywheel.

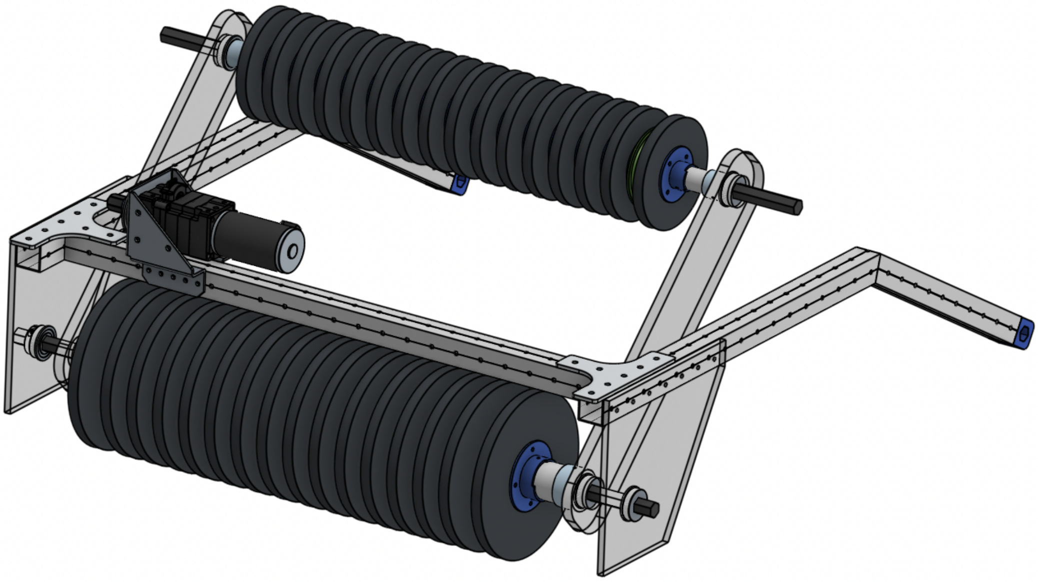
Drivebase



Our drivebase was very similar to the one fielded in the 2020 competition. It is designed to be simple to assemble, manoeuvrable, and have high acceleration rather than top speed.

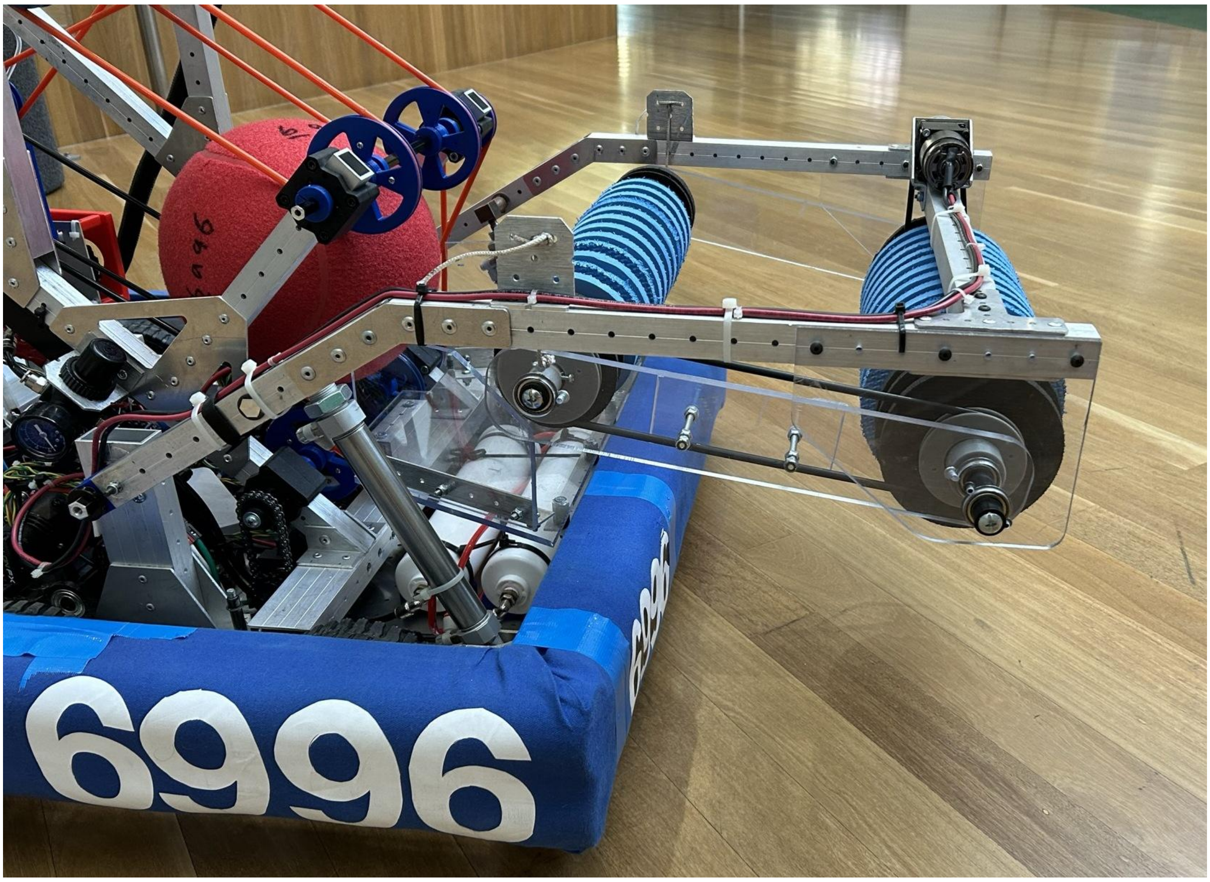
- West Coast Drive style design driven by centre mounted WCP flipped gearbox run by 2 falcons on either side.
- 1/8" Centre drop achieved with Vex clamping bearing blocks. In previous years we've used a CNC router to produce the rails, but reverted to bearing blocks given unsatisfactory results with chain tensioning and easy assembly of bearing blocks.
- Bellypan simple grid hole pattern in 2.5mm aluminium sheet. This provided flexibility in electronics/pneumatics mounting.
- Battery mounted between crossbeam and end rail. This was merely a convenient position, not particularly optimised for centre of gravity.
- The chains were tensioned appropriately with cams not reflected in the CAD.

Intake



The intake was heavily inspired by the #118 Robonauts design. Given we started building our robot later in the year we decided to copy many elements of it. It particularly stuck out because of its interesting foam rollers and 'over the bumper' design.

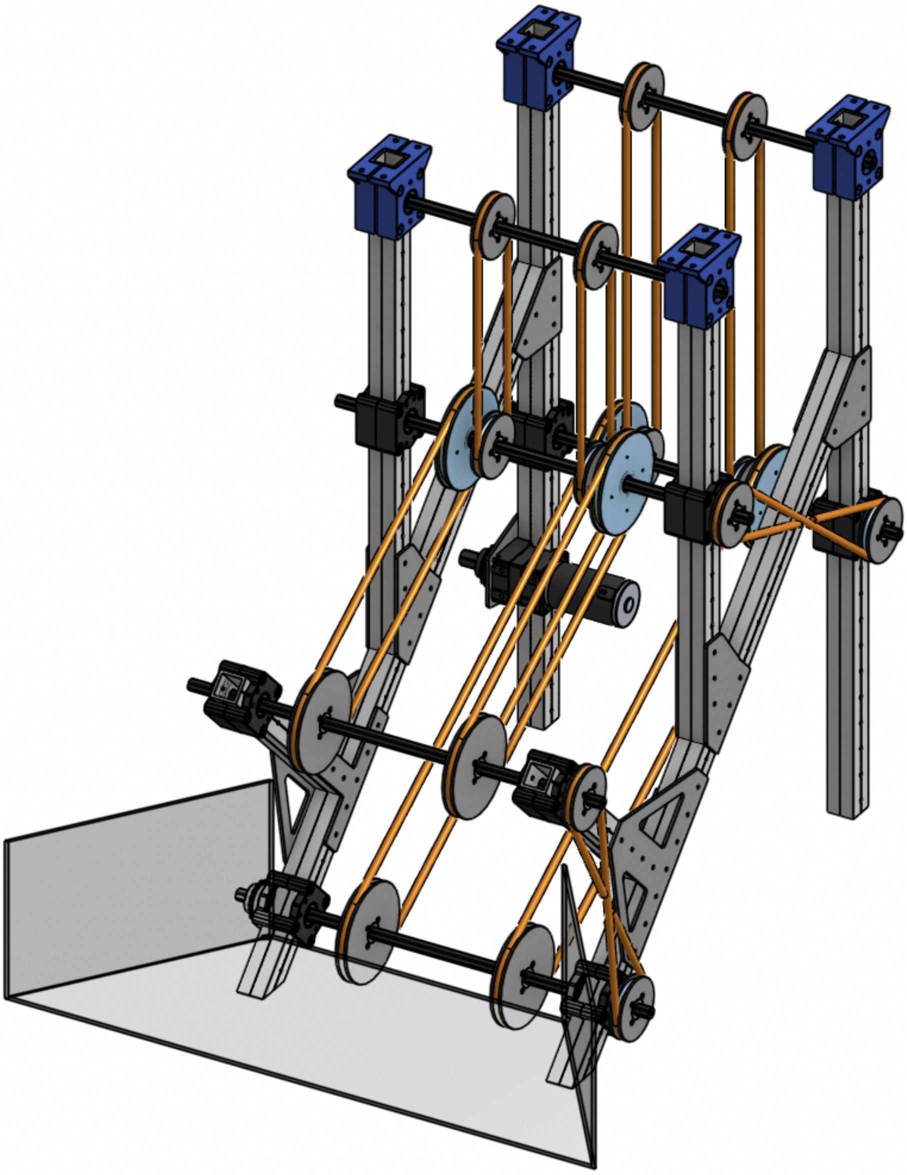
- The rollers were made from 9.5mm EVA mats, which were sold as camping/gym mats. (specifically these ones). They are cheap, light and provide good grip on the ball.
- Power was transferred from the motor to the front roller and from the front roller to back roller using a 6mm polycord belt. Polycord slips more easily than a timing belt or chain, but can be cut to any given length and mounted with 3D printed pulleys, enabling versatility in our design
- The roller shaft used PVC pipe, with a short section of 0.5" hex shaft mounted in the end with a 3D printed mount, to interface with 0.5in flanged hex bearings. The foam rollers were secured to the shaft with 3D printed hubs that are held together with cheap self tapping screws. Each hub slots into adjacent ones to secure and space the foam rollers. The end hubs are secured to the shaft with more self tapping screws. Utilising PVC pipe, foam rollers, and 3D printed parts made the intake very light despite its large size.
- During competition an improvised polycarbonate shield was added to the intake to prevent the ball knocking the polycord off the pulley. This proved to be an effective and simple solution to this problem. This design change is not reflected in the CAD.



Motor Calculations

Intake roller target speed is usually estimated to be twice the maximum robot speed, which should mean the ball is still pulled in when driving at it fast.
Max robot speed is approximately 13ft/s, so the intake speed targetted 26ft/s
For 6” rollers that means a roller speed of 26ft/s(PI*0.5ft) = 16.5rev/s = 993 RPM.
We used a 775 Pro motor (as we had spares) which has a free speed of approximately 1900 RPM.

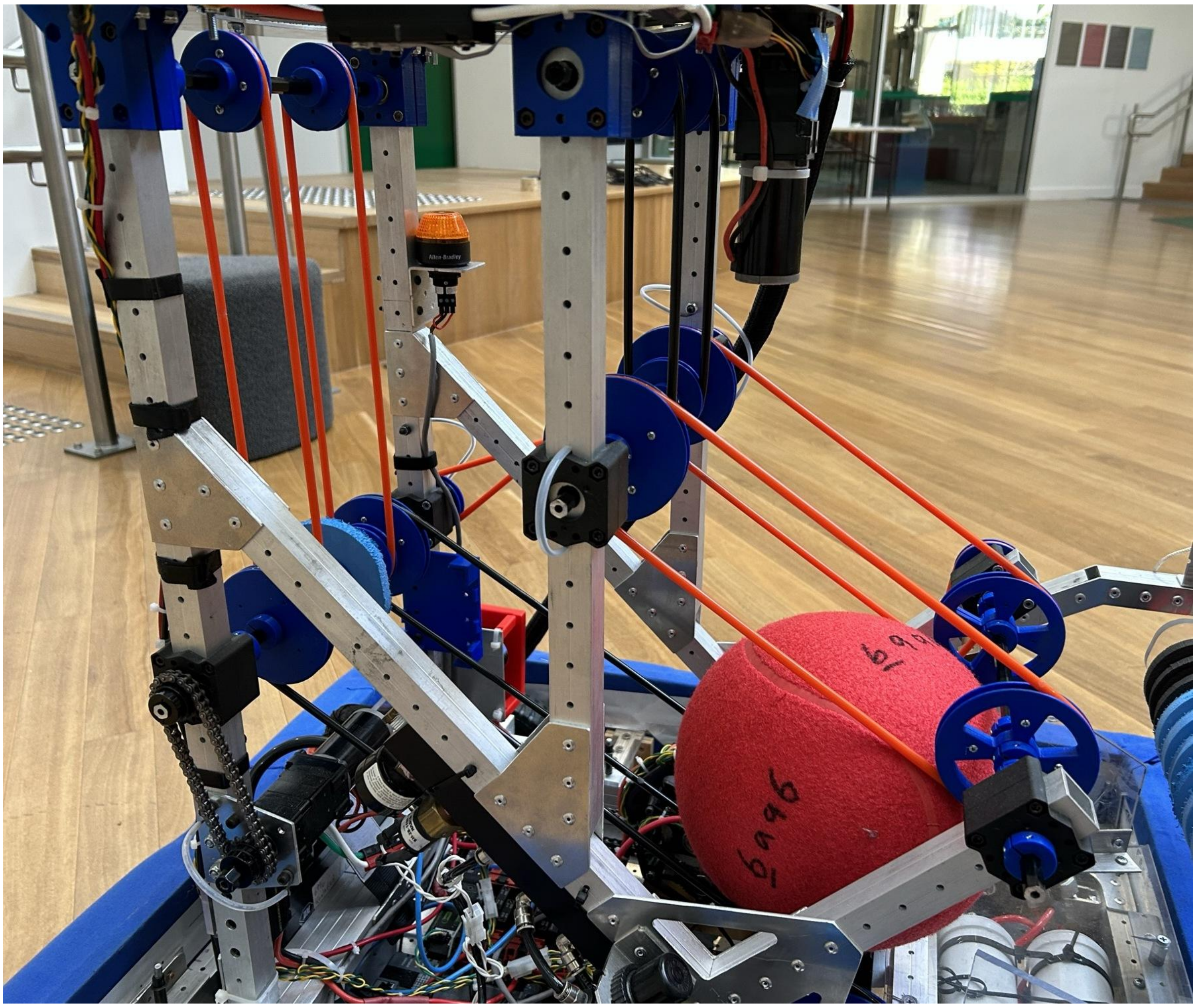
Indexer



The indexer is designed to carry balls from the intake to the shooter reliably. The size of the indexer was designed to allow the shooter to shoot balls over a climber design we had in mind. It also had to provide a constant speed to the balls entering the shooter to ensure consistent shots. We intended to do this without a ‘kicker’ like in our 2020 robot to enable a simpler design.

- Polycord was a very effective choice for ball transfer– it was able to grip the balls well, and was simple to cut to the appropriate length and mount with 3D printed hubs.
- The indexer was divided into two sections that were independently controllable. This allows us to run the bottom half constantly when intaking balls and then run the top and bottom half only to feed the balls into the shooter. It is possible to have sensors and run the indexer only when a ball is detected but this is more complex and requires careful tuning (our Infinite Recharge robot worked like this)

- In practice there was a gap in the grip of the ball between the two stages of the indexer. During testing we added an additional passive foam roller in this gap to ensure the ball didn't get stuck. That proved to be a very effective solution.
- On the middle shafts there are pulleys from the top and the bottom of the indexer that must operate independently. This is managed by having the pulleys for the bottom half spin freely on the shaft using thunderhex bearings.
- The two sides of the indexer must rotate in opposite directions. This is accomplished using polycord pulleys outside the indexer frame with a belt that crosses over. At the relatively low speeds involved this presents no issues.
- The indexer frame involves a lot of triangles making it very rigid front to back. The front top roller shaft is supported by a cantilevered extrusion, so a very large gusset is used in this case. Originally, a plate to stiffen the design side to side was planned, but it was found to be fine without it. We also opted to use thin wall extrusion given its lighter weight.
- Given the intended height of the indexer and that the robot may only control two balls, there was plenty of space within the indexer.
- The transmission of the balls from intake to indexer was handled passively by a polycarbonate sheet joined by gussets to create a funnel towards the indexer entrance. Given the speed of the balls this approach was more than sufficient. The details of this setup are not depicted in the CAD.



Motor Calculations

Approximate index speed 24” in 1s. For 2” diameter rollers means
$\omega = v/r = (24/0.5)/2.5 = 19\, rad/s = 183\, rpm$

From the JVN Calc sheet a linear mechanism with 2” pulleys and a Bag motor with 1:50 reduction gives 27.6”/s which is about right.

CAD Notes

The details of the indexer are laid out in the **Indexer** part studio. It has two critical sketches.

1. **Kicker Plan Sketch** - this is a top down view that lays out the position of the shaft, the small pulleys (for the top section), the large pulleys (for the bottom section), the transfer pulley (to transfer power from one size of the indexer to the other). The key parameter is PulleyCompression, which is the distance the pulleys push into the ball on both sides.
2. **Indexer Profile Sketch** - this is a side view of the indexer that lays out the positions of the 6 shafts. The sizes of the pulleys and the position of the shaft compared to the ball are projected from the plan sketch into this one.

In the **Indexer** folder there are 3 subassemblies for the 3 types of indexer shaft (top, middle, bottom). Using a number of simple subassemblies makes the CAD much easier by keeping each assembly simpler (we should have done this for the shooter).
Note that the Kicker Plan Sketch is used in the assembly to position the pulley. This is done by creating a mate on the sketch point in the middle of the pulley and then mating the pulley to it. This is a really easy technique for placing parts at a special position on a shaft (much easier that mating to the end of the shaft and offsetting the mate). When building the robot 3D printed shaft collars were used to hold the pulleys in place. They are cheap and are stong enough in this case. By tweaking the position of the pulleys in and out the force on the ball can be tweaked, although this was not really required.

The overall indexer is put together in the Indexer Assembly.

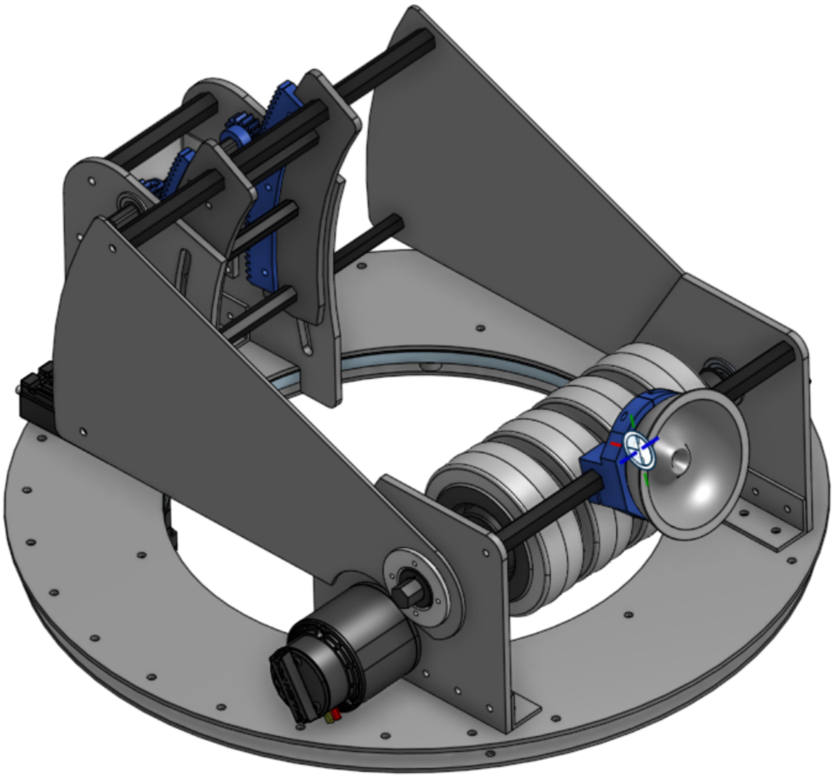
Design Points

- The top and bottom pulleys must be different sizes otherwise they would need to be on top of each other on the middle shaft to grip the ball in the same location.
- The small pulleys are used at the top because space is tight where the indexer meets the shooter. Also having the larger, and hence wider spaced, pulleys at the bottom should help with gathering the ball into the indexer from the intake.
- Note that in the Kicker Plan Sketch you can see that the ⅜” shaft almost touches the ball. In fact it will just touch because it is hex, but that does not matter because of the flexibility of the ball.
- Examining the Indexer Profile Sketch shows that the indexer still has a good grip on the ball that the Mate Indexer Top. Note that the inner ball circle at the top of the sketch is a projection of the ball section at the plane of the top rollers. Looking also at the Shooter Profile Sketch in the Shooter part studio shows that the ball only has to

move 0.332” up from the Mate Indexer Top position until it hits the shooter wheel. Note that the shooter geometry is based on a heavily compressed (8.1”) ball, when first contact is made with the roller the ball is the full 9.5” diameter. The end result is that the indexer should easily be able to feed the ball into the shooter.

- On the shared shaft the larger bottom pulleys rotate freely. There is a thunderhex bearing embedded in the middle of the pulley, between the two printed halves.
- Looking at the shooter there is 0.758” distance from the Mate Indexer Top to the underside of the Turret Base Plate. This distance is shown in the Indexer Profile Sketch (simplified to 0.75”) and the top pulleys have a 0.25” clearance to the bottom of the turret. Close spacing here is key to getting the ball to feed into the shooter wheel.

Shooter

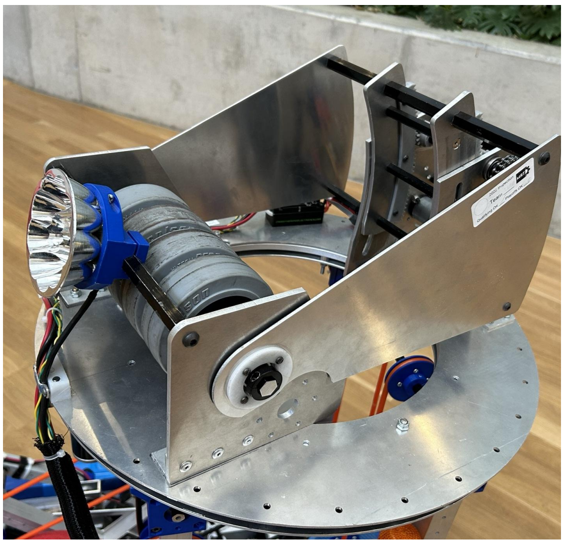


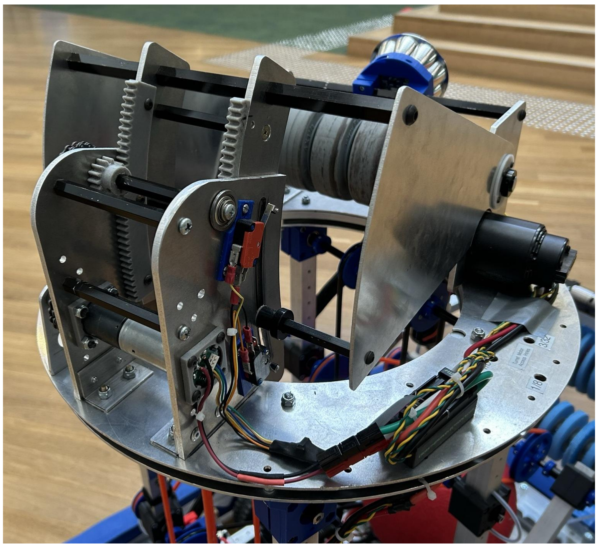
Given our success with a shooter for our 2020 robot, we wanted to try pushing the design further by adding a variable hood and turret. One mentor sourced a 'lazy susan' bearing, similar to this one from Amazon, which we largely based our turret design around. Ideally we also wanted automatic targeting, given the complicated operation of a shooter with both variable hood and turret, and its success in previous competitions. Ultimately, the shooter is the most complex mechanism due to the multiple degrees of freedom for the turret and variable hood angle.

- The shooter itself used four 4" colson wheels, running from a single Falcon 500 motor, geared up by and 1.5 ratio. This design was almost identical to our 2020 Infinite Recharge robot, except that this new design uses 1 Falcon, rather than two.
- The lazy susan bearing proved to be an inexpensive, compact, yet highly effective part for this purpose. A 3D printed gear was produced and mounted in 4 sections to the bearing– this gear was driven by a small 3D printed gear attached to a bag motor. This method was very effective, simple, and cheap given the slow speeds and low forces involved. The turret achieved a 340 degree range of motion, and used limit switches in either direction to ensure safe operation in case soft-limits failed.
- The hood consists of a fixed rail and a variable rail that slides upward to adjust the exit angle. We used teflon tape between the rails to reduce friction. The pin that runs in the slot was machined from hardened steel and was one of the few special parts on the robot (produced by our expert machinist mentor).
- The variable hood was driven with a 3D printed rack and pinion setup. This proved to be an effective and simple setup. It was driven by a Johnson Electrics PLG motor

due to its compact size and low power requirement (but also because we had one spare from the Kit of Parts, and were operating on limited funds).

- An umbilical supplying motor power, control, and the targeting camera ran on the outside of the turret, down the indexer frame.





Motor Calculations

The shooter is geared with 36T to 24T GT2 3mm pitch timing pulleys. The 24T pulley on the shooter hex shaft is a metal one (from Vex). The 36T is 3D printed from PLA and mates with a 14T pinion on the Falcon, which gives a very robust connection. Using the WCP Belt Calculator - 36T and 24T pulleys, 70T belt, gives 2.351” centre distance

Turret gear is 25 to 234. For a full revolution in 2s we need 30rpm * 234/25 = 280 RPM
For a BAG motor that's a gear reduction of 47:1, so we used a 50:1 versaplanetary gearbox.

For the hood the design requires only about 2 rotations of the sprocket for the full range of motion. So to travel the full range in 0.5s required 240 RPM. The Johnson Electrics PLG motor free speed is 410 RPM. We could have added reduction in the chain link, but instead just ran it at half speed.

CAD Notes

The shooter parts studio is very complex, with 40 parts. Ideally we would have broken it up further, but the parts reference each other in complex ways such that it is hard to separate them. The design starts with the shooter profile sketch, which shows the path of the centre of the ball through the shooter. To allow for compression of the ball we use a ball diameter of 8.1" instead of the true size of 9.5". This is a different approach to the indexer where we used the full ball diameter and placed the pulleys inside the ball. Both methods gave designs that worked. Note that we did build a prototype of the shooter with just the rails and wheels and our final design had the same rail to wheel distance.
The CAD shows a large Lazy Susan Washer part that gives a gap between the bearing and the moving Shooter base plate. In practice we did not use this, but instead used normal washers at each bolt to create the spacing.

Climber

Our climber was not built, but we intended to build a climber similar to Team #846. It seemed an elegant design that was within our capabilities. We made a preliminary design but decided not to pursue it given time constraints.

Reflections on the Design

A note: many issues with our design stem to the lack of iteration in our mechanisms. This is partly because our team was operating with substantially reduced numbers, limited time and was ‘re-learning’ a lot of robot building with mentors missing. A lot of ideas for ‘prototyping’ simply ended up becoming our final design– the best example of this being our intake. We also had a lot more tolerance for experimenting with new, experimental designs than in a normal competition year, with highly variable outcomes from this approach.

- In hindsight power transmission would have been more appropriately accomplished using timing belts, even though it is more limiting in design, their use would limit issues associated with polycord belts insufficiently slipping on their pulleys and occasionally slipping off.
- During competition this intake also broke on numerous occasions due to a collision while the intake was deployed. In hindsight, this part should have either been much smaller (and thus less leverage to break), or able to compress into the robot frame when hit (such as the four bar link designs many teams utilised).
- A 3D printed tube insert was also used to enable the intake to pivot into the robot frame– in hindsight this would’ve been better accomplished with bearing blocks directly into the stronger aluminium intake arm given the substantial forces around this point. Whilst intended initially for prototyping, given the rushed time replacing this part was an oversight.
- The robot was unnecessarily top-heavy given the lack of climber. With appropriate initial planning (and more reasonable expectations), we should have more quickly come up with either a simpler, achievable climber design (like our 2020 robot), or cut it from our timeline much earlier altogether enabling us to design a substantially shorter indexer
- This particular shooting challenge was not well suited to balls with backspin. Part of the reason we were not able to realise this promptly is the difficulty in producing an accurate replica of the true field element. Further investigations into other teams’ design process would have likely also prompted us to design a hood which mitigated backspin to some extent.

Our robot had a few highlights, we thought were notable:

- The lazy susan bearing for the turret was highly cost effective. Lots of teams used much fancier, more expensive bearings, yet our’s had no issues given the low loads and was easily available.
- 3D printing the gear surrounding the lazy susan bearing was also very effective. Other teams used very expensive/complex milled aluminium pieces, but the 3D printed gear was more than appropriate in this scenario and substantially lower cost.
- The 3D printed rack and pinion hood was also very effective, low cost, and quick. Relatively low effort for a hood, and use of PLG Johnson motor made the entire system very compact.
- Foam exercise mats were a cheap and very effective intake material. Only very occasionally had issues, but often not the fault of the material. Some issues with durability, but not an issue given the low cost and effort to replace.