Robo Raiders
FTC 7129

"Show yourself in all respects to be a model of good works, and in your teaching show integrity, dignity, and sound speech that cannot be condemned." Titus 1:7-8a

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Motivate: Team Summary & Business Plan

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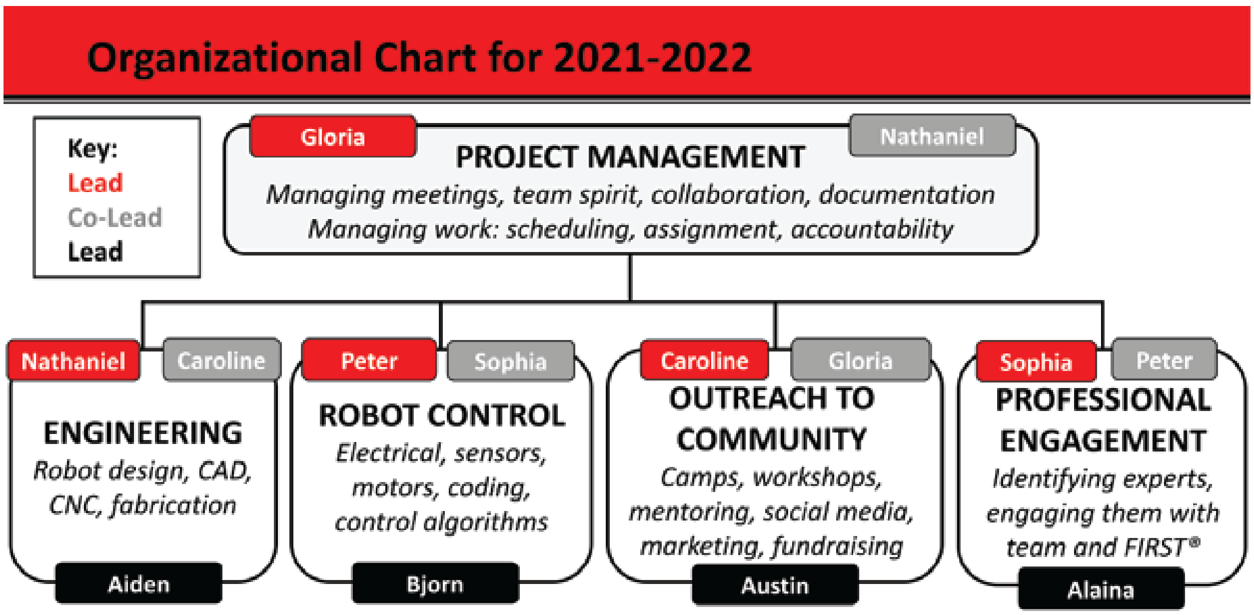
Aiden (9th), Sophia (11th), Austin (9th), Caroline (10th), Nathaniel (11th), Gloria (11th), Peter (10th), Alaina (9th), Bjorn (9th)

3 Juniors, 2 Sophomores, 4 Freshmen



Team Organization

Our team is organized into five subteams and a project management team to keep everyone on task and accountable. There are at least two members in each area to ensure all the tasks are completed and knowledge is passed on.

Sustainability

- We use a buddy system to pair experienced members with rookies in each subteam area. This prevents knowledge from being lost, trains rookies, and provides rookies with someone to answer questions.
- Experienced members, mentors, and alumni teach team members new skills during training sessions in programming, CAD, fabrication, marketing, and more.
- This year we recruited 4 rookie members with interests in areas our seniors from the previous year were involved in.

Finances

Total income: **$11,900**

Total Expenses: **$4,700**

Season Goals

Goal	Result
Be an effective, well-rounded team displaying a Christ-like demeanor	- Received 2nd place Inspire Award at qualifier - Assigned technical & professional roles to each member - Rookies paired with buddy for learning - Teamwork lessons and exercises as needed - Prayer supporting all meetings and events
Be intentional about spreading FIRST in our community and in non-FIRST organizations	- Received 3rd place Motivate Award at qualifier - Weeklong robotics camp for 72 students - 3 10-week robotics classes for 26 students - 1 radio interview and 3 newspaper articles - 5 robot demonstrations
Develop inventive, resourceful programs and programmers	- 5 members attended Java class - 4 code reviews from 2 experts - 4 members programmed parts of robot code - 8 sensors and 8 automated features in robot
Create an innovative and competitive robot that efficiently balances form, function, and aesthetics	- Built 2 robots to provide extra learning - 2nd robot ranked #5 of 20 at Qualifier - Rapid and consistent scoring in Alliance Shipping Hub - Rapid and consistent scoring of Ducks in End Game
Establish, strengthen, learn from, and build relationships with professionals	- Received 2nd place Connect Award at qualifier - Added 2 new team mentors - Added 4 new alumni and professionals as advisors to team - Held 15 reviews and training sessions by professionals on CAD, programming, fabrication, graphic design

Motivate: Outreach Summary

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11,400+ People Reached
630+ Hours Invested

Weeklong FLL Summer Camp

We hosted a **student-led** summer camp for kids ages 6-13 teaching classes at 4 different levels of FLL. In total, we reached **72** students.

Helped Form 2 FLL Teams

Through teaching summer camp, we helped start **2** FLL teams. We were able to **mentor one** of these teams and teach them programming, game strategy, and season planning. We gave each of them Spike Prime robot kits.

5 FLL Classes at Local Co-op

Over the course of 2 semesters, we **taught 2 different levels** of FLL programming classes over 10 weeks, reaching 27 students. **2 FLL Explore teams were started** the following semester as a direct result of the classes.

- Taught 1 FLL Explore class using advanced WeDo
- Taught 1 FLL Challenge class using EV3
- Co-led 1 FLL Explore class using simple WeDo
- Helped start 2 FLL Explore teams

5 Public Robot Demonstrations

- YMCA
- PE Field Day
- Men's Club
- Local Chilifest
- Sci-Fest at St. Louis Science Center

At these demos we demonstrated robots to students and families and encouraged them to become involved with STEM. Impacted **6,800+** through these demos.

Students driving robots at PE Field Day

Sharing FIRST at KFUO Radio Interview

Event	People Impacted
PE Field Day Demo	50
YMCA Demo	84
Presentation at FTC Webinar	300
Summer Camp	72
Mentoring FLL Team	7
Mentoring FLL Team #2	2
2 We-Do Class: Fall	6
FLL Class: Fall	8
Fall Fest Demo	721
FLL Qualilfier Volunteering	200
Radio Interview	1,500
2 We-Do Class: Spring	12
SciFest	3,075
Zion Men's Club Presentation	12
Newspaper Articles (3)	5,400

KFUO Radio Interview

We were interviewed on the 30-minute Coffee Hour program to talk about our robot, team,and season. Through this, we promoted FIRST to**1,500+** listeners.

Presented at FTC Virtual Webinar

We were able to present at an FTC team's virtual webinar to **50** different FTC teams, reaching **500+** people.

FIRST Volunteering

48 FIRST volunteer member hours

- FLL Qualifier: judge, scorekeeper, judge assistants
- FTC League Meets 2-3: Helped set-up and tear down

Published 3 Newspaper Articles

Our local newspaper published 3 different articles **written by team members**. Each article promoted FIRST and reached **5,000+** people each time.

Social Media with 5,600+ Views

Instagram, Facebook, Twitter, YouTube, and team website.

Motivate: In-Person Summer Camp

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Quick Facts:

- Reached **70+** children
- 5 day camp with morning and afternoon sessions
- Team-written curriculum
- Taught 4 robotics platforms including a new Spike Prime level
- Helped form 2 FLL teams, which we have mentored

Three Levels of Classes

Using **team-written** curriculum, we taught **three levels** of classes. **WeDo** robotics (2nd-4th grade) taught the basics of FLL Explore programming. **Robotics 1** (4th-8th grade) taught how to program NXT robots to move forward and backward, turn, and use the color and ultrasonic sensors. In the morning of **Robotics 2** (5th-9th grade), we taught the basics of EV3 programming. In the afternoon, we taught the basics of Spike Prime programming.

Purpose and Impact

Through this summer camp, we hoped to engage with the community, help local students gain an interest in STEM, and start at least one FLL team. From this summer camp, we reached over 70 children and **two FLL teams started**. We also posted daily updates on our social media platforms to show what students were learning.

Sponsored Water Bottles for Campers

We had a local Orthodontist reach out saying they would like to sponsor water bottles for all our students at the end of our camp.

Water bottles sponsored by Amazing Smiles Orthodontics

All morning students

Nathaniel helping WeDo robotics students

Robotics 1 students measuring reflected light with NXT robots

Robotics 2 morning students building EV3 attachments

Robotics 2 afternoon students programming Spike Prime robots

All afternoon students

Used $2,000 Grant to Help 2 Teams

We gifted a Spike Prime robot kit to each of the FLL teams that started from our summer camp. We bought the kits with a $2,000 grant. We continue to mentor one of the FLL teams and helped them prepare for their Qualifier competition.

Training Team Members

In order to continue teaching robotics summer camps, we make sure to **include rookies** in the planning and teaching of each class. Because we had only four returning members this year, our **rookies planned and taught Robotics 2** in addition to helping teach the other levels of classes.

Discussions & Team Thoughts

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Organization

We use ClickUp and Slack to help us organize tasks, keep team members accountable, and communicate within the team.

We create meeting agendas to ensure each team member knows the plan for the day, who's leading which activity, and who's documenting what.

We schedule our time between League Meets and competitions to ensure everyone knows what tasks need to be accomplished before each event and what steps we need to take to reach our goals.

6/1/21 - YMCA Demo Planning

Attended: Aiden, Alaina, Austin, Bjorn, Caroline, Gloria, Nathaniel, Peter, Sophia

Tasks:	Person in charge:
1. YMCA Demo Planning	1. Caroline
2. Follow Up with Rookies' Documentation	2. Nathaniel
3. Team Contract Discussion	3. Mr. Davis
4. Purchase Approval Discussion	4. Gloria
5. Pick Dates for Church Tour and Build Day	5. Gloria

Schedule:
3:00-3:05 Opening/Prayer/Check ClickUp
3:05-3:15 YMCA Demo Planning - Nathaniel
3:15-3:20 Follow Up with Rookies' Documentation - Sophia
3:20-3:40 Team Contract Discussion - Peter
3:40-3:45 Purchase Approval Discussion - Austin
3:45-3:50 Pick Dates for Church Tour and Build Day - Gloria
3:50-4:00 Break!
4:00-4:30 Drive Train Project
4:30-6:00 Java Class
Garage Work
Test Mini Bots
6:00-6:05 Closing/Prayer/Tasks for next Meeting

Meeting Minutes:

YMCA Demo Planning - Nathaniel

Purpose: To finalize the little details for the YMCA demo on Friday.
Decisions made: We decided:
- Peter or Nathaniel will be leading the "what is a robot?" discussion first, with a rookie, maybe leading it later
- Sophia will be drawing a cat to help kids understand coding
- Caroline will be giving an overview of the demo bots before the kids run them
- Nathaniel will be driving Annatar
- Peter will be making sure Annatar works well before the demo

References: See Appendix pg. 2 for in-depth planning and schedule.
What's Next?: Pack things up and get ready to demo at the Y.

Page 21 of Meeting Minutes in Notebook

Team Members' Concise Thoughts

Gloria: Throughout this season I have learned so much in areas of leadership, robot design, outreach, and fabrication.

Alaina: I have gained knowledge in engineering principles, CAD designing, and time management, as well as how to collaborate effectively in a team setting.

Nathaniel: My time on the team has taught me many important leadership skills and given me ideas for career paths in video editing or graphic design.

Caroline: FIRST allows me to communicate with professionals and leaders in a mentor to student setting, helping me gain confidence and learn a great deal.

Aiden: This year I have learned a number of new skills like how to CAD, use the CNC machine, and much more.

Peter: This year I have learned how to work with others as well as how to allow others to work with me.

Bjorn: I have learned everything I know about programming, designing, and building robots.

Austin: FIRST has taught me the importance of Gracious Professionalism, and it is something I could use in any career field I choose.

Sophia: I have learned so much about the design process and engaging with professionals. The team environment has prepared me for working well in business team environments.

12 Different Professionals
11 Design Reviews

We have improved our CAD, programming, strategy, robot design, and wiring through design reviews with STEM professionals. We have also benefited from GitHub, Adobe, and team building training sessions. These have improved our team members' skills and strengthened our team.

Acquired 2 New Mentors

- Our mentor introduced us to a Cyber Warfare Officer with whom we shared FIRST and who eventually became our mentor. He has mentored us in coding, along with management development. He also became a regular FIRST volunteer.
- We welcomed a Mechatronics and Robotics Engineer who is a FIRST alumnus. He has further improved our robot design and game strategy.

Engaged in Ansys Software Demo

Dr. Reni Raju, a representative from Ansys, one of our sponsors, met virtually with our team. He explained the Ansys Discovery simulation software and how we can use it in our team. We were able to share FIRST with him.

Jared Phillips, John Deere technician, giving feedback on our robot

Steve Bleymaier, Vice President, Global Strategy and Government Sales, Brig Gen (Ret), USAF teaching project management

Professionals

1. **Marketing Manager**
   - Team Building Training
2. **Vice President, Global Strategy and Government Sales**
   - Goal Setting, Project Scheduling
3. **Computer Science Student at Rose Human Institute of Technology**
   - GitHub Training, Code Review
4. **Software Engineering Student at Liberty University**
   - Adobe Illustrator Training, Display Board Assistance
5. **Mechatronics and Robotics Engineer**
   - Robot Design and Strategy Improvements
6. **Software Developer**
   - Strategy Improvements, Code Assistance
7. **John Deere Technician**
   - Systems Review, CNC Assistance
8. **Electrical Engineer**
   - Wiring Design Improvements
9. **Mechanical Engineering Student at Cedarville University**
   - CAD Improvements, CNC Assistance
10. **Computer Science Student at Cedarville University**
    - CAD Improvements, Code Assistance
11. **Engineering Student at Valparaiso University**
    - Strategy Review, CAD Assistance, Robot Design Improvement
12. **Cyber Warfare Officer**
    - Programming Assistance, Code Revew, Management Training

Robot Design: Design Journey

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We use a six step, iterative process when designing and fabricating our robots, including using it twice. We designed our first robot, Maximus, for Leagues 1-3 and Maximus Prime for Qualifier and States. We repeat or rewind to earlier steps when needed to keep improving our design.

1. Define Needs and Criteria

The first thing we do when the game is released is to develop a game strategy from which to define our robot needs and criteria. We calculate the probable points per second for each scoring method to guide our decisions towards the most points in available time. With the game strategy established, we can identify what the robot will need to be successful.

2. Brainstorm Ideas

We seek ideas for the different subsystems that can meet the stated needs. We search for ideas and generate our own. From ideas for different subsystems, we create several overall robot concepts. We then score concepts according to criteria for each subsystem. We remove concepts that don't fit our game strategy.

3. Prototype and Test

The best concepts are then prototyped and tested so we can get data to use in evaluating them.

4. Select Concept with Decision Matrix

With the data collected from prototyping, we use our decision matrix to select the concept to use. More on our decision matrix can be found on page 9.

5. CAD

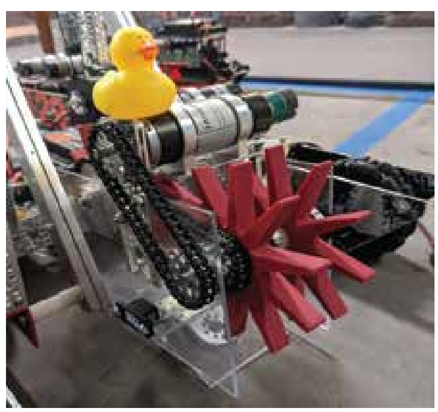
System envelopes are created to allocate space to each subsystem. The subsystems are then modeled using Fusion 360 CAD software and integrated into a whole robot design.

6. Fabricate Robot

From our CAD, we created custom parts using our 3D printer and CNC machine. We also are learning to use our mentor's laser cutting machine. This year we have over 25 custom parts on our robot. We then use CAD to direct team members who fabricate the rest of our robot.

Collection Design Journey

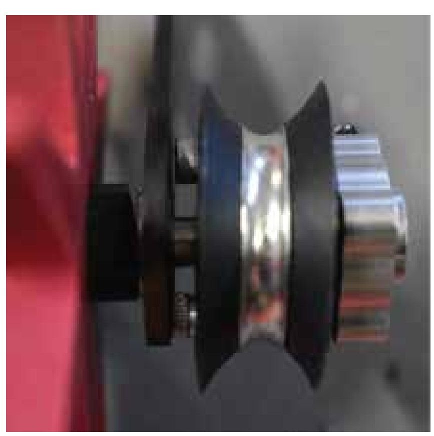
Early prototyping



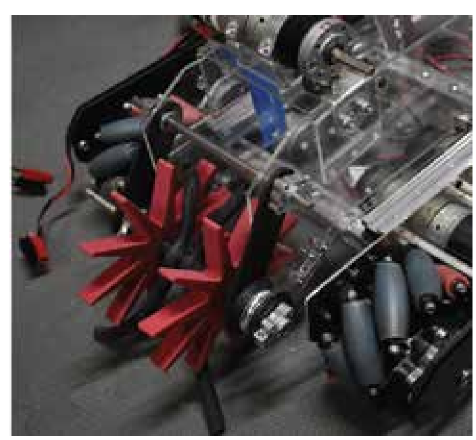
Robot 1 iteration

Robot 2 CAD

Robot 2 assembling



Robot 2 3D printed pulley shield



Current robot 2 iteration

Robot Design: Strategy

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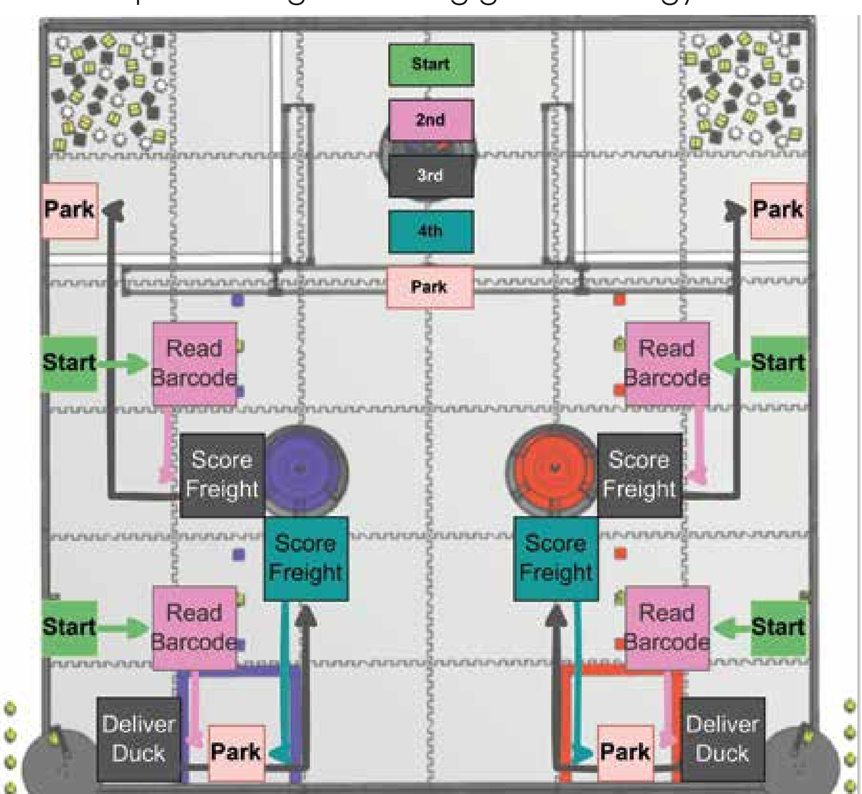
At the start of the season, the team analyzed probable points and time to score for many different types of scoring. Probable points and scoring efficiency identified the best types of scoring for our strategy. From this we selected a game strategy (highlighted in green) for the first meet and for later meets.

League meet 1-3 robot

Qualifier robot

Scoring Method	Points	Probability(%)	Time	Probable Points	Efficiency
Autonomous					
Carousel: Delivering a Duck Autonomous	10	0.9	3	9	3
Robot In Storage Unit	3	0.9	3	2.7	0.9
Robots Completely In Storage Unit	6	0.6	5	3.6	0.72
Robot In Warehouse	5	0.9	4	4.5	1.13
Robot Completely In Warehouse	10	0.8	6	8	1.33
Freight Completely In Storage Unit	2	0.85	2	1.7	0.85
Box on randomized level using duck	10	0.6	6	6	1
Box on randomized level using shipping element	20	0.65	6	13	2.17
Teleop					
Freight Completely In Storage Unit	1	0.83	9	0.83	0.09
Freight On Alliance Shipping Hub – Level 1	2	0.8	6	1.6	0.27
Freight On Alliance Shipping Hub – Level 2	4	0.78	6.5	3.12	0.48
Freight On Alliance Shipping Hub – Level 3	6	0.75	7	4.5	0.64
Freight On Shared Shipping Hub	4	0.8	6	3.2	0.53
End Game					
Duck or Team Shipping Element Delivered	6	0.95	4	5.7	1.43
Alliance Shipping Hub: Balanced	10	0.7	6	7	1.17
Shared Shipping Hub: Unbalanced	20	0.5	6	10	1.67
Parking In Warehouse	3	0.95	3	2.85	0.95
Parking Completely In Warehouse	6	0.92	3.3	5.52	1.67
Capping: each Team Shipping Element	15	0.65	9.5	9.75	1.03

Our plan for the season was to use two different robots. Our first robot was used to develop ideas, give rookies design and building experience, and give us time to successfully design a more competitive robot that completes a higher scoring game strategy successfully.



Qualifier Autonomous paths

Autonomous Strategy

We developed two autonomous routes to avoid interfering with our alliance partner. We read the barcode and deliver the pre-loaded freight into the corresponding Shipping Hub level. We can either deliver ducks and park in the Shipping Container or park in the Warehouse.

Teleop Strategy

Score freight onto top level of Alliance Shipping Hub or Shared Shipping Hub depending on alliance partner's preference.

End Game Strategy

Score all ducks from Carousel and park in Warehouse.

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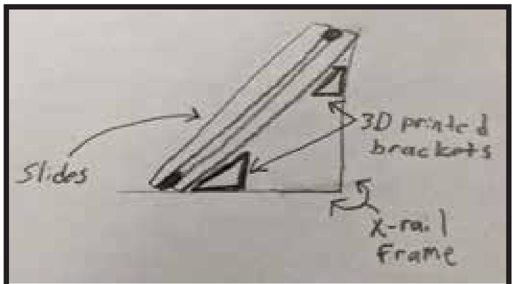
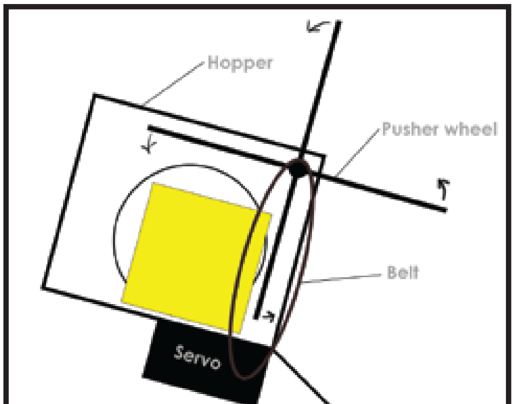
- We use Fusion 360 to generate system envelopes, design subsystems, integrate the subsystems, and create custom parts to be 3D printed or cut on the CNC or laser cutter machines.
- We try to CAD everything on our robot before we start building. This ensures all the subsystems work well with one another.

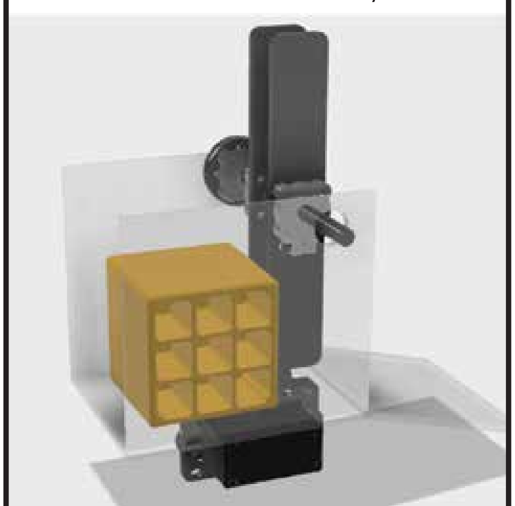


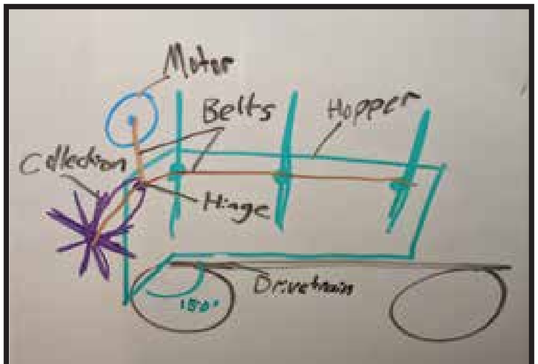
Sketch of lift idea


CAD of lift

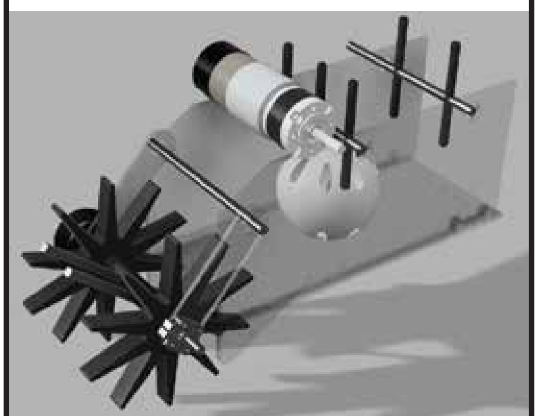


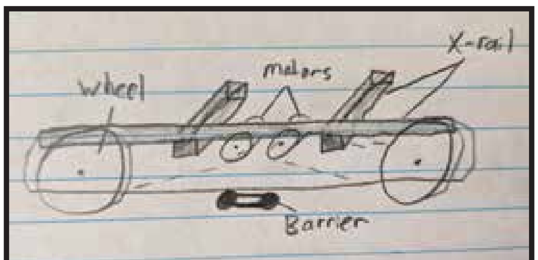
Sketch of delivery


CAD of delivery



Sketch of collection and transfer


CAD of collection and transfer

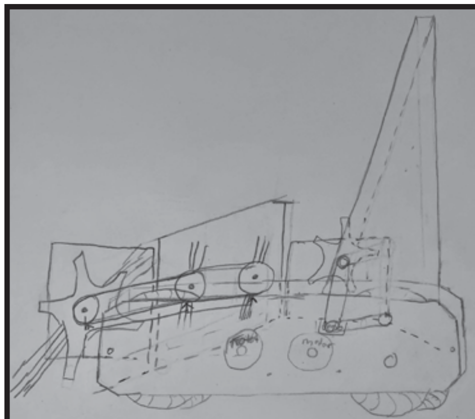


Sketch of drivetrain


CAD of drivetrain

Shown are sketches we made early in the season as well as how these sketches have been brought to life in CAD. We drew out almost all of our subsystems before designing them to have a better idea of how they may come out. All of the subsystems on this page are systems we have found work best for our strategy, and we are currently using them on our robot. The CAD of our robot is the current version.

5 CNC parts
12 Laser cut parts
40 3D printed parts


Sketch of full robot


Full robot CAD

Robot Design: Problems, Analyses & Calculations

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Collection	Be able to bring in all blocks	Be able to bring in balls	Be able to bring in ducks	Bring in one at a time	Performance	Innovation	Easy maintenence	Servo/motor usage	Speed	Take up <25% of space	Durability	<2 inches of error	Total
Weight	3	3	2	3	3	2	2	2	2	2	2	2	
Side rollers w/star	3	9	9	9	3	9	3	3	3	1	1	9	148
Side rollers w/ compliant	3	9	1	3	1	3	3	3	3	1	3	1	84
Top roller w/pivot	9	9	9	9	3	3	3	3	3	9	3	3	162
Top roller star	9	3	9	9	3	9	3	3	3	9	3	3	156

Decision matrix used to decide on collection mechanism on the final robot

For our decision matrix, we assign each criterion a weight, either 1, 2, or 3, then we rate each concept against the criteria on a 1, 3, 9 scale. From there, the weight assigned to the criteria is multiplied by the rating number for the criterion. The largest sums of products identifies the best concepts (highlighted in green). We did this for subsystems including the drivetrain, collection, transfer, lift, and delivery.

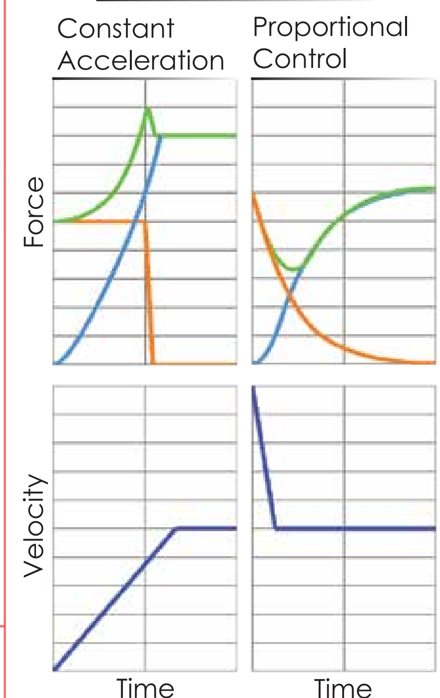
The decision matrix shown above was used to determine the best collection system. Since the "top roller with pivot" earned the highest score, we tested it further and decided to use it.

Analyses

Analysis in Fusion 360 showing a low safety factor for possible drivetrain plate design cut from MDF on the laser cutter

- We used Fusion 360 and sponsor, Ansys Discovery softwares to simulate stress on our inner drivetrain plates to see what material would work best.
- From the analyses, we saw that neither MDF nor plywood cut on the laser cutter would be strong enough to support the robot, considering 1/8-inch thickness.
- We decided to cut the inner drivetrain plates on the CNC out of aluminum.

Carousel Speed



Initially, we used constant acceleration to get the carousel to the desired speed. At this speed, the sum of radial and tangential forces (see green line) exceeds that to keep the duck on the carousel. We decreased acceleration for carousel speed to keep the duck on the carousel.

For a short period of time, the carousel can be rapidly accelerated without the duck flying off. We then decrease the power to the level that maintains the desired carousel speed. Throughout this process, we keep the sum of the centripetal (radial) and tangential forces below that which launches the duck.

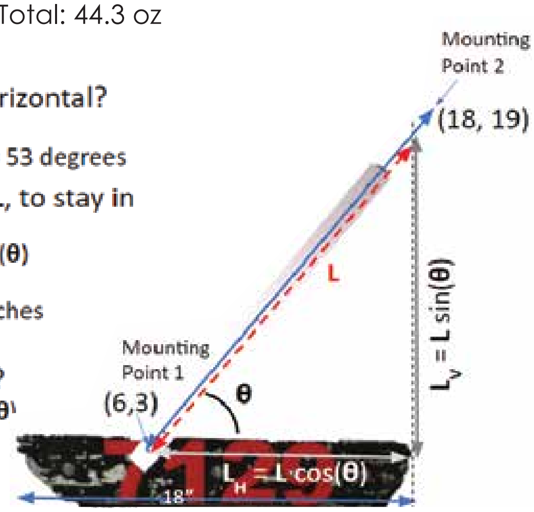
Calculations

We used trigonometry and calculations to determine angles of transfer and lift mechanisms. In addition, we used torque calculations to find motors for collection, lift, and capping.

Lift weight:
MiSUMi Slide = 8.5 oz x 4 = 34 oz
Delivery = 5.6 oz
Freight = 4.7 oz
Total: 44.3 oz

Force needed:
F = (W + L) sin (B)
Sin (B) = 23/23.8 = 0.97 in
(W + L) = (44.3 oz) (0.97 in) = 43 oz-in

- **What is the angle of the slider from horizontal?**
  $\theta = \arctan[(Y_2 - Y_1)/((X_2 - X_1)]$
  $\theta = \arctan[(19 - 3)/(18 - 6)] = \arctan(1.33) = 53$ degrees
- **What is the greatest retracted length, L, to stay in horizontal limits?**
  Note that $\cos(\theta) = L_H / L$, so $L_H = L\cos(\theta)$
  Horizontal limit: $L\cos(\theta) + 6 = 18$
  $L = (18 - 6) / \cos(\theta) = 12 / \cos(53) = 19.9$ inches
  Choose 18" slider
- **How high is top of retracted 18" slider?**
  Note that $\sin(\theta) = L_V / L$, so $L_V = L\sin(\theta$
  Max height $= L_V + 3 = L\sin(\theta) + 3$
  Max height $= (18)\sin(53) + 3$
  Max height = 17.3 inches



With help from mentor, Dr. Davis, we found the optimal sliders angle on robot #1.

Robot Design: Freight Collection & Transfer Systems

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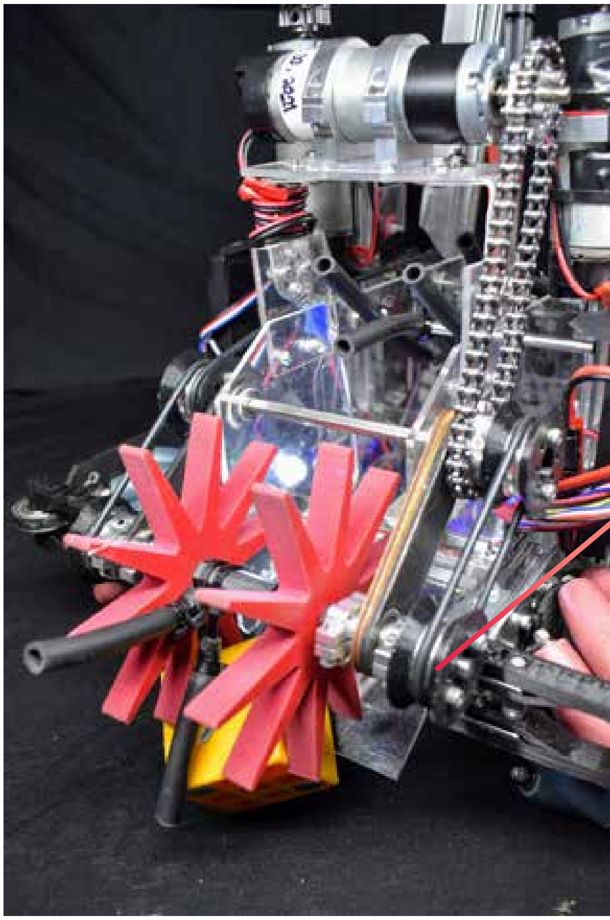


Current collection System

Collection Features

- We use two star wheels with surgical tubing between to grab and collect freight from many different angles
- A 20:1 motor powers both the collection and transfer. A 1:1 chain goes from the motor to the first axle while O-ring belts power everything else.
- The collection is able to fold down beyond the front of the robot to allow greater reach and be able to reach down to ducks and up to balls.
- 3D printed wedges on the side of all O-ring pulleys prevent belts from slipping off.

3D printed wedges, as mentioned above

Collection Needs

- Take less than 1 second to collect
- 3 inch wide range of collection
- Be able to collect all shapes and weights of freight
- Be able to collect no more than 1 freight at a time
- Fit in space allocation
- Easy maintenance
- Use only 1 motor

Surgical tubing able to reach past star wheels

Transfer Features

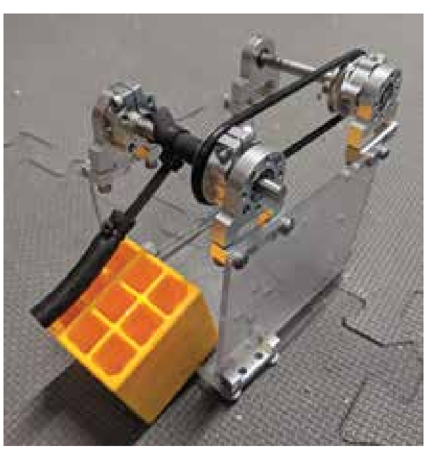
- We use two sets of surgical tubing in sync with each other to move freight.
- The surgical tubing is long enough to reach to the level of the ducks, but flexible enough to move the blocks and balls.
- The transfer is powered by the same motor as collection with O-ring belts connecting the two.

Transfer Needs

- Take less than 1 second to transfer any freight
- Be able to move all types of freight
- Be able to fit all types of freight
- Fit in space allocation
- Easy maintenance
- Use 1 or fewer motors

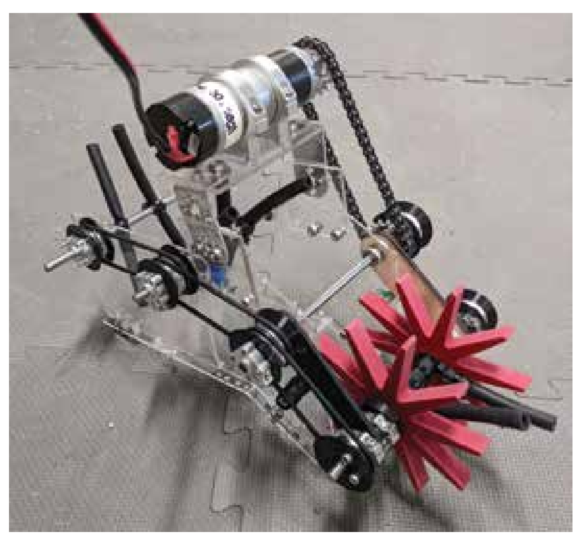
Prototypes

We prototyped many different designs for our collection mechanism. From the tests, we found that star wheels and surgical tubing worked the best. We combined the two in our final design.



Top beater bar with surgical tubing

Side mounted compliant wheels



Collection and transfer systems built and detached from robot

Robot Design: Lift System

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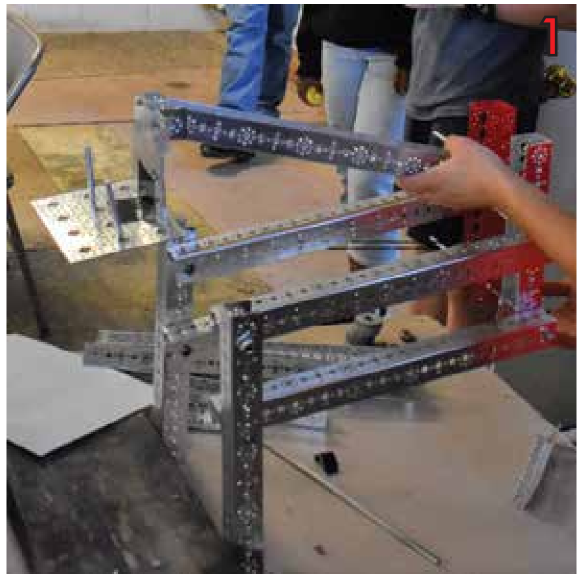
Prototypes

We prototyped a few different designs for a lift system including a double four-bar linkage as shown in the picture on the near right. Due primarily to space and complexity, we decided to use MiSUMi slides.

On our first robot, we put the slides at 60° as shown on the far right picture. The slides reach from the ground at the front of the robot to the top of the Shipping Hub at the back.

On our second robot, we put the slides at 75° to match the Shipping Hub and allow us to score easily on all levels.



Prototype of double 4-bar lift

Single angled slide on 1st robot

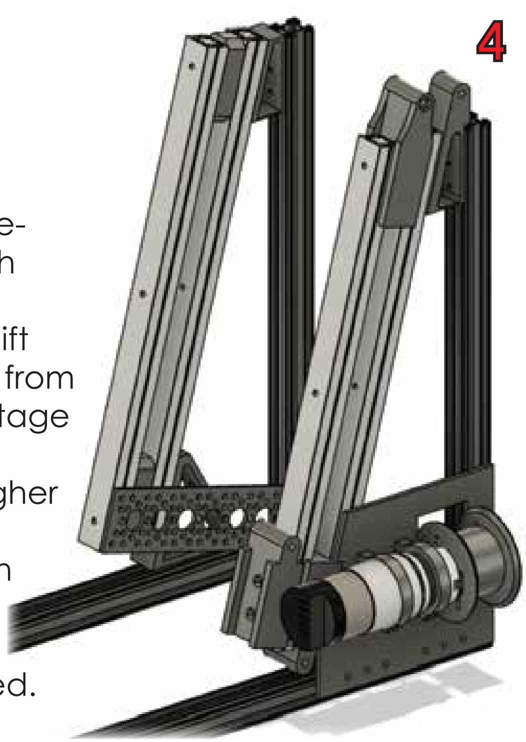
Lift Needs

- Be able to reach all Shipping Hub levels
- Have space for delivery between slides
- Reach taller than top of Shipping Hub
- Be strong enough to lift all weights of freight + shipping element
- Take less than 3 seconds to reach full extension
- Less than 1 inch of wobble at full extension
- Use no more than 3 slides
- Fit in space allocation
- Easy maintenance
- 2 or fewer motors

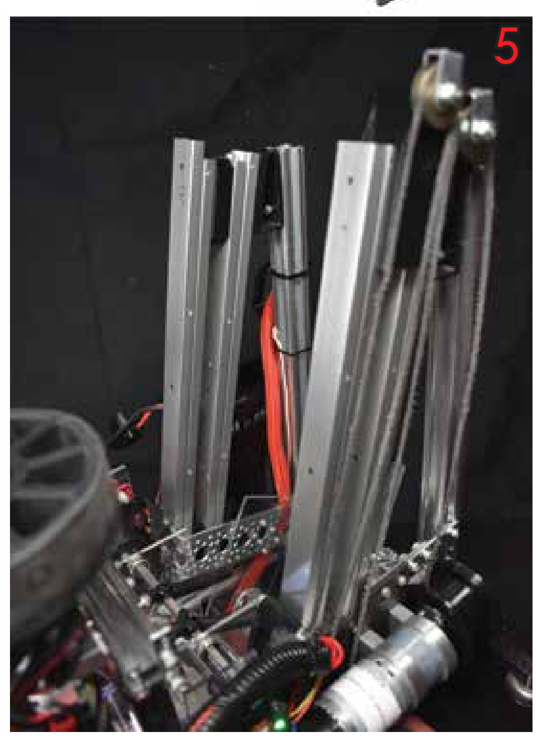
Original design of lift system before CAD review showing laser cut panels holding 16 inch MiSUMi slides horizontally. This design did not work well because the slides were too tall the way they were mounted. If we shortened the slides to 12 inches and added another section, then there would not be room for the delivery between. Through a CAD review with an engineering student, we decided to stack the 12 inch slides vertically on top of each other as shown below.

Features

- We use 2 roughly 12 inch telescopic MiSUMi slides on each side
- One 40:1 motor powers the lift with continuous string going from the motor spool to bottom stage of slides.
- 23 inch reach (able to lift higher than top of Shipping Hub).
- Attached to X-rail frame with 3D printed pieces to allow easy movement forward and backwards when desired.



Lift CAD



Final lift design

Robot Design: Delivery System

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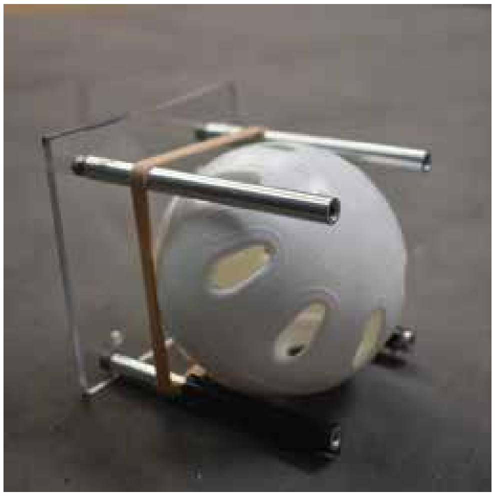


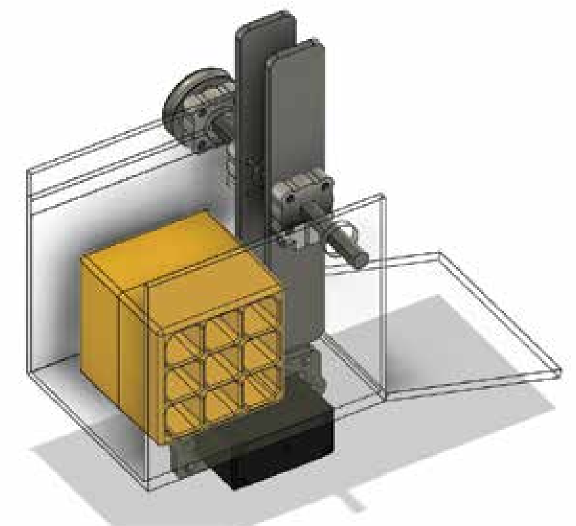
Rough hopper prototypes to flip over and score freight

Prototypes

Initially, we prototyped bucket-like hoppers that can hold freight and flip over to score freight.

Next, we made a system that would have fingers to push the freight out.

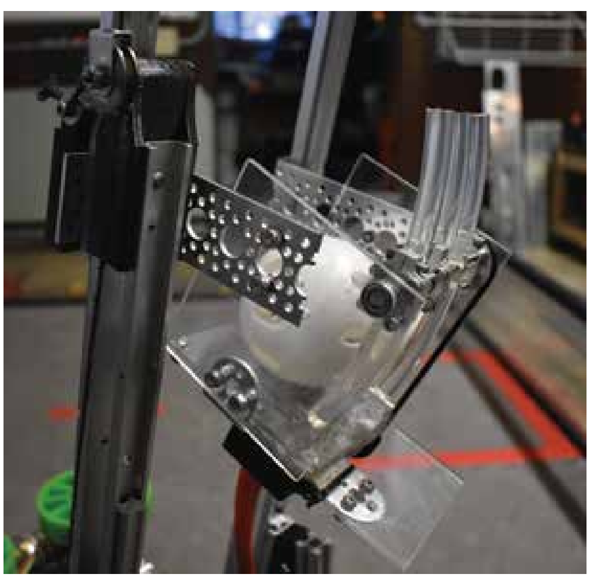
Finally, we decided to use gravity to get the freight out of the hopper and fingers to hold it in and release it when desired.



Delivery CAD

Delivery Needs

- Take less than 1 second to score any freight
- Be able to hold all types of freight
- Deliver on all levels of Shipping Hub
- Release freight smoothly
- Fit in space allocation
- Easy maintenance
- Use 2 or fewer servos



Current lift mechanism

Problems and Solution

Throughout the design of the delivery, we struggled with finding a material to use that could hold the freight inside the hopper. We looked at using something bendable like cut star wheels or surgical tubing, or something rigid like a pattern plate. Through a design review, we found polycord, a nice blend of the two. It is bendable and grippy enough that freight can be pushed out easily, but rigid enough that it holds the freight in.

Different ideas we had to hold freight in.

Features

- The hopper is attached to the lift with two pattern plates bent at a 90°.
- Clear polycord holds the freight inside the delivery and rotates to let freight slide out.
- One servo is attached with a belt going to an axle with the polycord.
- 3D printed pieces on the O-ring pulleys ensures the belt cannot slip off.

Robot Design: Drivetrain System

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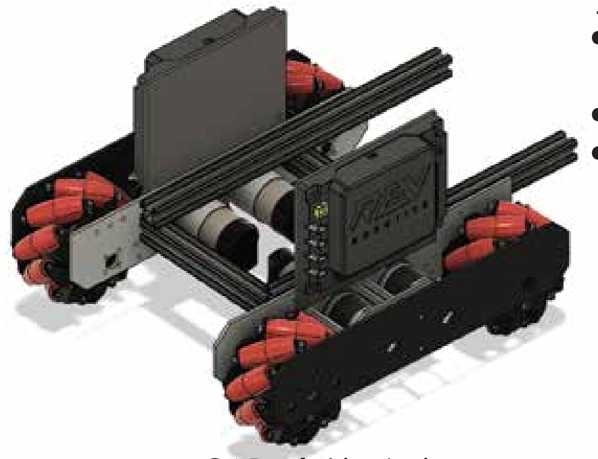


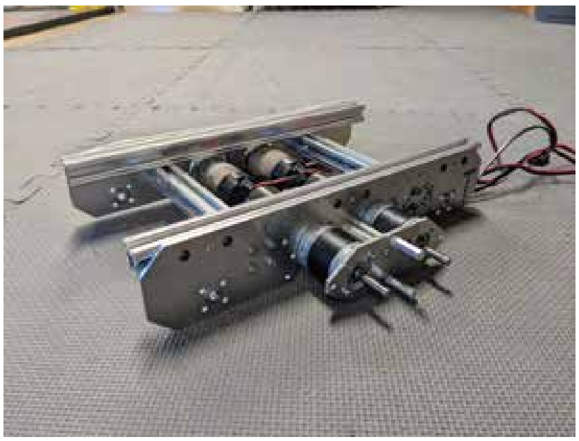
CAD of drivetrain

Features

- 12x12 inch Mecanum drivetrain enables the robot to fit between barrier and wall.
- The divetrain plates are high enough to easily cross the barriers.
- 4 20:1 motors are chained to 4 wheels preventing slippage and giving great acceleration.

Drivetrain Decision

To decide on our drivetrain, we made a list of pros and cons of a Mecanum and Tank drivetrain. Ultimately, we decided to use a Mecanum drivetrain because it is more reliable when crossing the barriers and is easier to maneuver than a tank, especially between the barrier and wall.



Drivetrain being assembled

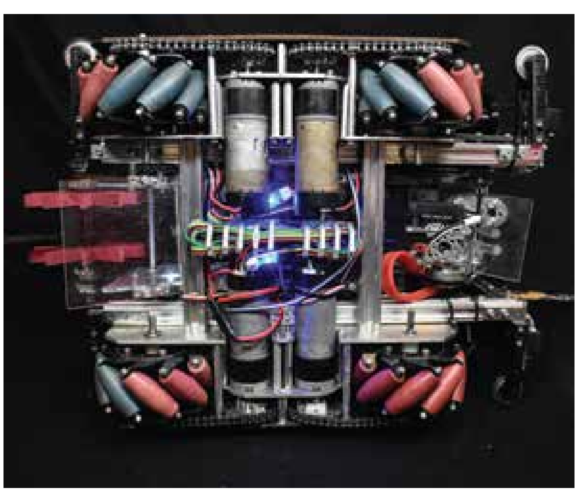
Drivetrain Needs

- Easily fit between barrier and wall
- Able to cross barriers
- Able to cross the field in 2 seconds
- Able to score in Shared Shipping Hub consistently
- Ability to store all 4 motors underneath
- Room for wires
- Fit in space allocation
- Easy maintenance

Progress of drivetrain with chains

Drivetrain Design Implementations

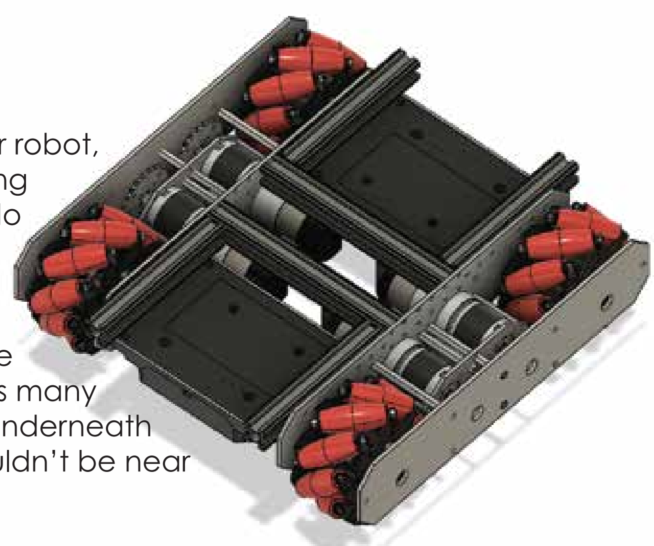
We originally designed our drivetrain to be connected by x-rails mounted on top of the motors. However, after a CAD review with an engineering student, he suggested moving the x-rails to the side of the motors so that freight doesn't have to get as high on the robot.
Another suggestion was to move the REV Hubs from underneath the x-rails and mount them to the side of transfer. This would leave room at the top for collection and transfer.
We implemented both suggestions, which has improved our robot's design tremendously.



Bottom of current drivetrain

Wiring

Soon after finishing our robot, we struggled with wiring and the best way to do it. With help from mentors, we cleaned up our wiring by using cable carriers and wire ducts. We re-routed as many wires as we could to underneath the robot so wires wouldn't be near moving parts.



Original drivetrain design

Robot Design: Innovations

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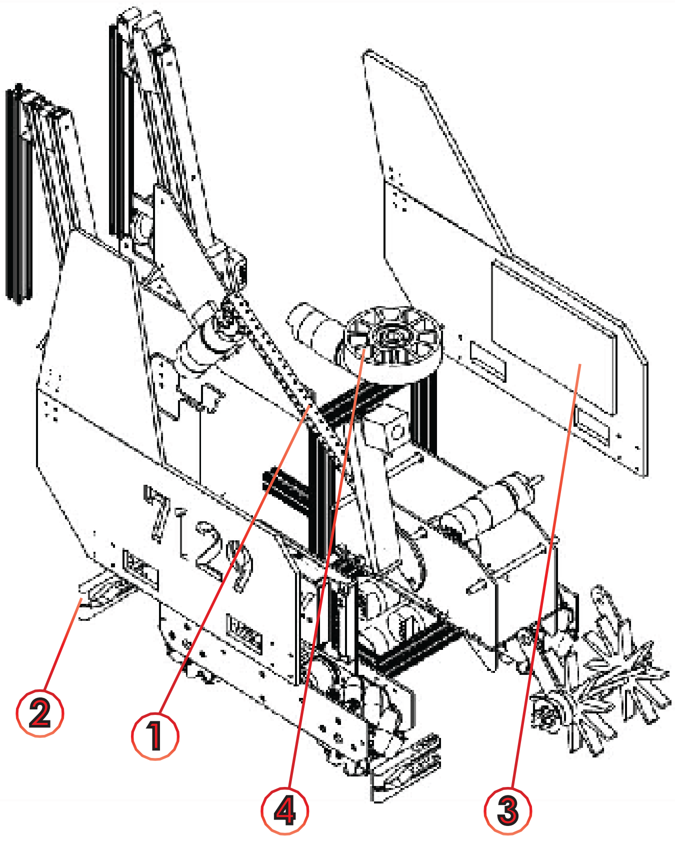
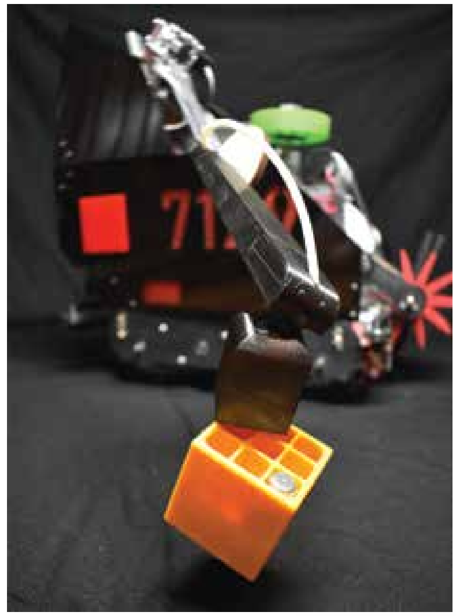
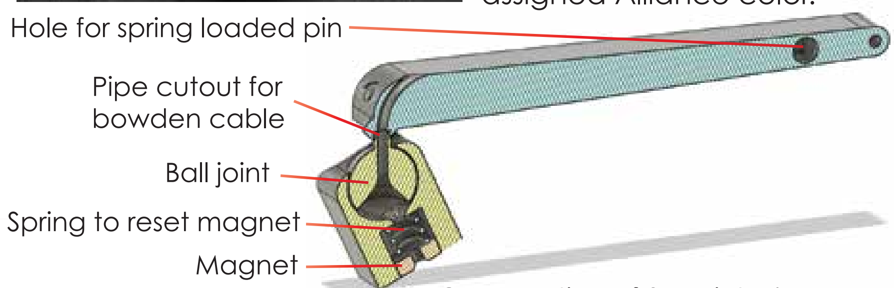


Exploded wire-frame view of robot CAD

1 Capping/SSH Block Scorer



An innovative arm allows us to cap in End Game and score heavy blocks in Teleop. The end of the arm is 3D printed. It pivots down at the beginning of a match and locks in place with a spring loaded pin. A magnet on the end of a bowden cable going through the middle of a ball joint allows for flexible pick-up and precise release of the TSE or freight. The angled arm and motor assembly can be quickly mounted on the robot side needed for our assigned Alliance color.



Cross section of 3D printed arm

2 Wall Alignment Wheels

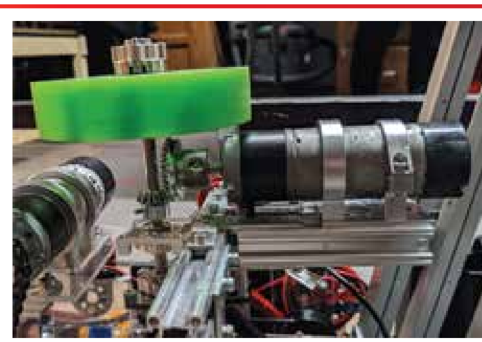
One wall alignment wheel is mounted near each corner of our robot. This allows the driver to easily follow the wall to prevent getting stuck on the barrier. Our robot can strafe to the wall and run along it easily.

Below are iterations of the 3D printed holder for the bearing (wheel) to go on. The far left iteration was made for a smaller bearing that would not work. The piece in the middle accounted for that and added material to go on top of the mounting piece for added strength. The last iteration was thicker and printed at a slight angle so it cannot shear on the print lines.

3 Side Panels

We designed our side panels to be functional and aesthetically pleasing. Our side panels function as a wiring protector and robot shield, while looking awesome. We designed the side panels to be easily removable. Three 3D printed pieces allow each side panel to slide in and out easily. Lights shine out from the robot to help the robot drivers know whn freight has been collected.

4 Carousel Spinner



We use one 20:1 motor powering a 2:1 bevel gear attached to a compliant wheel. Originally, we had two motors powering one wheel each, but we needed an extra motor for capping. We decided to use only one motor for the Carousel in the middle. The motor is mounted horizontally so as not to interfere with the transfer system. When designing the carousel spinners, we put a beam under the motor to act as a handle for the robot.

Robot Control

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Programming Team

We program the robot with Android Studio, using GitHub to share code. With many new programmers, this year we have put an em - phasis on training. We have done this by holding programming lessons, training sessions and attending a fifteen week java course by Bayer, one of our sponsors. We have frequent reviews with professionals to further devolep our knowlege.

Autonomous

- Sense team shipping element with webcam using openCV
- Maneuver around the field using proportional speed controlled encoder drive and gyro turn functions
- Raise lift accurately using an encoder

Teleop

- Automatic alignment with REV Hub IMU
- Field centric driver code
- State machine for automatice delivery to any level
- Lights to indicate if the hopper has freight

Proportional Speed Controled Gyro Turn

```
void IMUTurn(float targetAngle, String leftOrRight,
                int maxSpeedAngle, float minSpeed) {
        imuTimer.reset();
        while (((LinearOpMode)opMode).opModeIsActive() && currentHeading < targetAngle) {
            // Updating our current heading while turning
                currentHeading = (angles.firstAngle);
            // Calculating the motor power. 'minSpeed' is the slowest speed to turn at.
            // 'maxSpeedAngle' is how many degrees of the angle it will turn without slowing down
                float power = Math.max(Math.abs(currentHeading-targetAngle
                                                    /maxSpeedAngle, minSpeed)
                                                                            );
            // Break from the loop if we have reached our target
                if (Math.abs(currentHeading) < Math.abs(targetAngle)) {
            // Turn left or right based on which was was entered by the user
                if (leftOrRight.equals("left") || leftOrRight.equals("l")){
                        leftDrivetrain.setPower(-power);
                        rightDrivetrain.setPower(power);
                } else {
                        leftDrivetrain.setPower(power);
                        rightDrivetrain.setPower(-power);
                }
        }
    // Stopping the motors once we completed our turn
        leftDrivetrain.setPower(0);
        rightDrivetrain.setPower(0);
 }
```

State Machine for Automatic Delivery

```
switch (liftAvailability) {
        // If one of the dpad buttons is pressed, begin raising the lift
    case LOW:
        if (opMode.gamepad2.dpad_down ||
                opMode.gamepad2.dpad_left
            || opMode.gamepad2.dpad_up) {
            liftM.setPower(1); liftAvailability = LiftAvailability.RAISING;
        }
        break;
        // If the lift has reached it's target position, begin delivering
    case RAISING:
        if (liftM.getCurrentPosition() > liftTargetHeightTicks) {
            liftM.setPower(0); deliveryS.setPosition(50);
            genericTimer.reset();
            liftAvailability = LiftAvailability.DELIVERING;
        }
        break;
        // Once we are done delivering, close the servo and lower the lift
    case DELIVERING:
        if (genericTimer.seconds() > 1 &&
            liftAvailability == LiftAvailability.DELIVERING) {
            deliveryS.setPosition(0);
            liftM.setPower(-1);
            liftAvailability = LiftAvailability.LOWERING;
        }
        break;
        // Once the lift reaches the low position, stop the motor
    case LOWERING:
        if (liftM.getCurrentPosition() < restingPositionTicks) {
            liftM.setPower(0);
            liftAvailability = LiftAvailability.LOW;
        }
        break;
```

Sensor Controlled Indicator Lights