Engineering Notebook

39400A

Team Number

HKAGE Team A

Team Name

Hong Kong Academy for Gifted Education

School

25/08/2023	26/01/2024	1 of 1
Start Date	End Date	Book #

V2.1 Date 6.12.23

VEX ROBOTICS

REC FOUNDATION

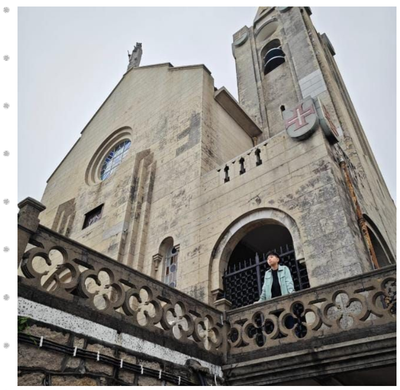
Table of Contents

Who are we?

Michael LAM Lap Yu,
Role: Team leader, builder, designer, notebooker

I am Michael Lam, a 15-year-old from La Salle College. I have joined numerous robotics and STEM related competitions in my secondary school years and I am the current captain of my school's Robotics Team, and the vice-captain of the STEAM Team. This is my second year joining the VRC competition and we claimed the Judges' Award at Spin Up last year in the HK Tech Challenge.

IAM Cheuk Nam Perry,
Role: Builder, driver, programmer



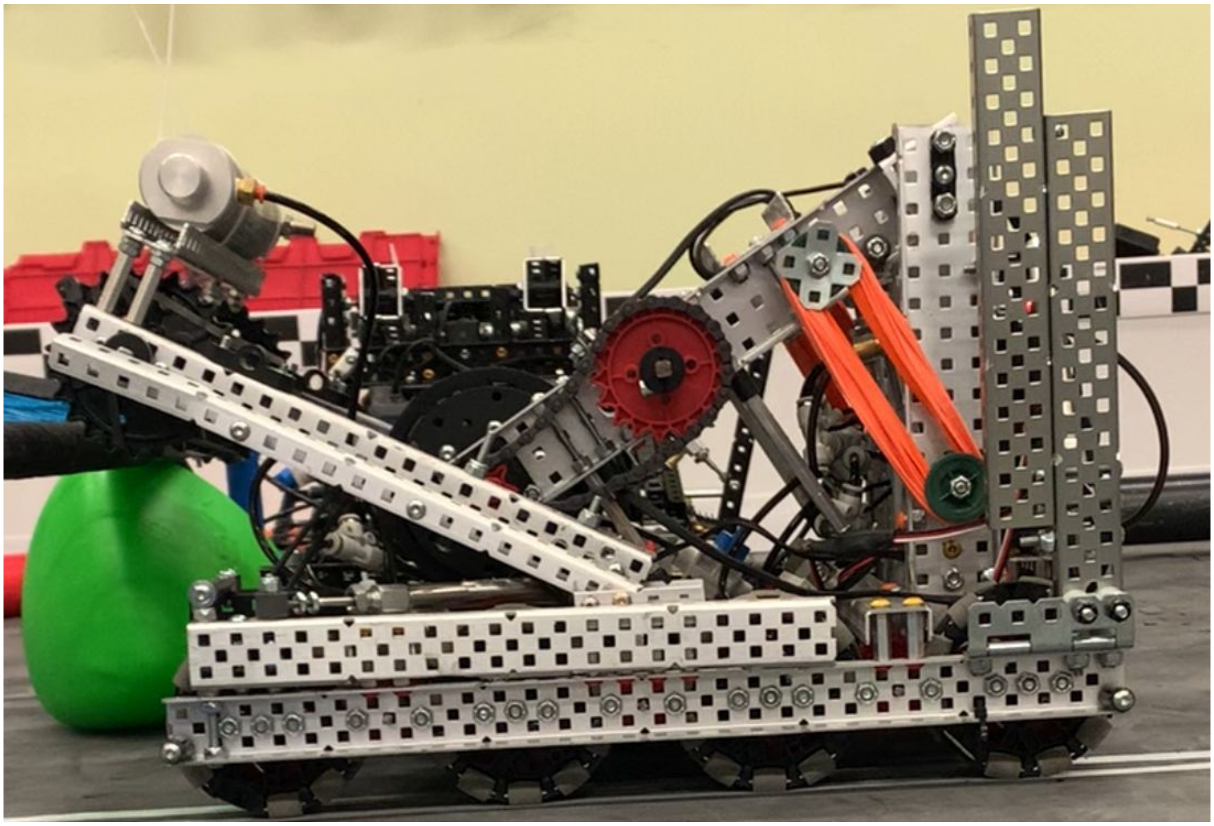
Wah Yan College, Hong Kong
Member of school STEAM club
Game Dev Artist, Graphic designer

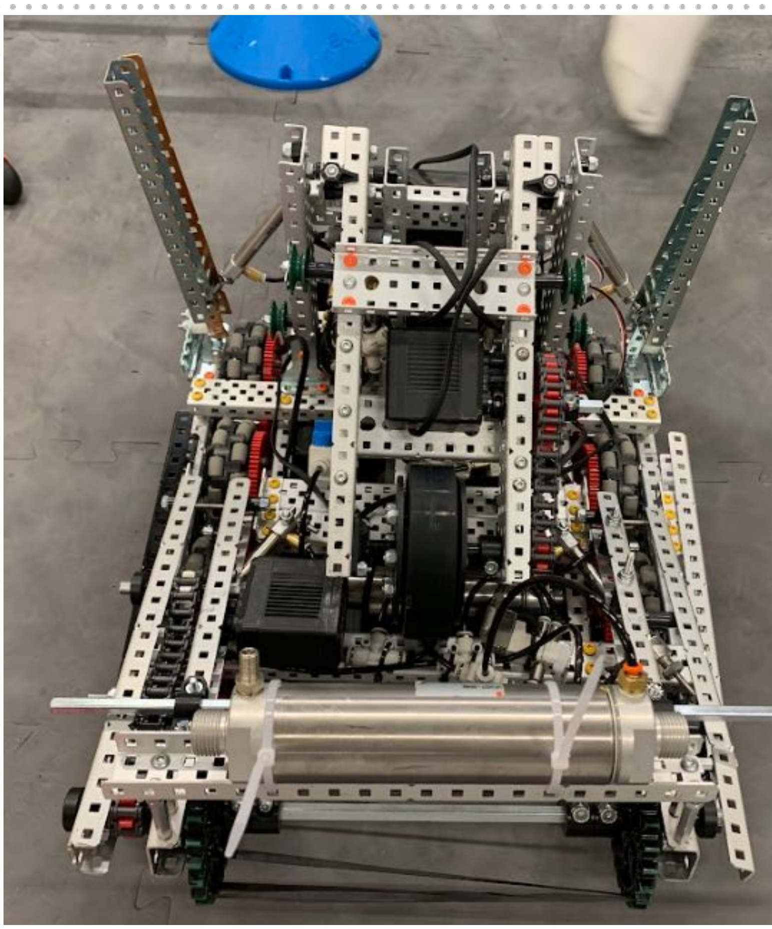
Jason Wong
Role: Builder, designer

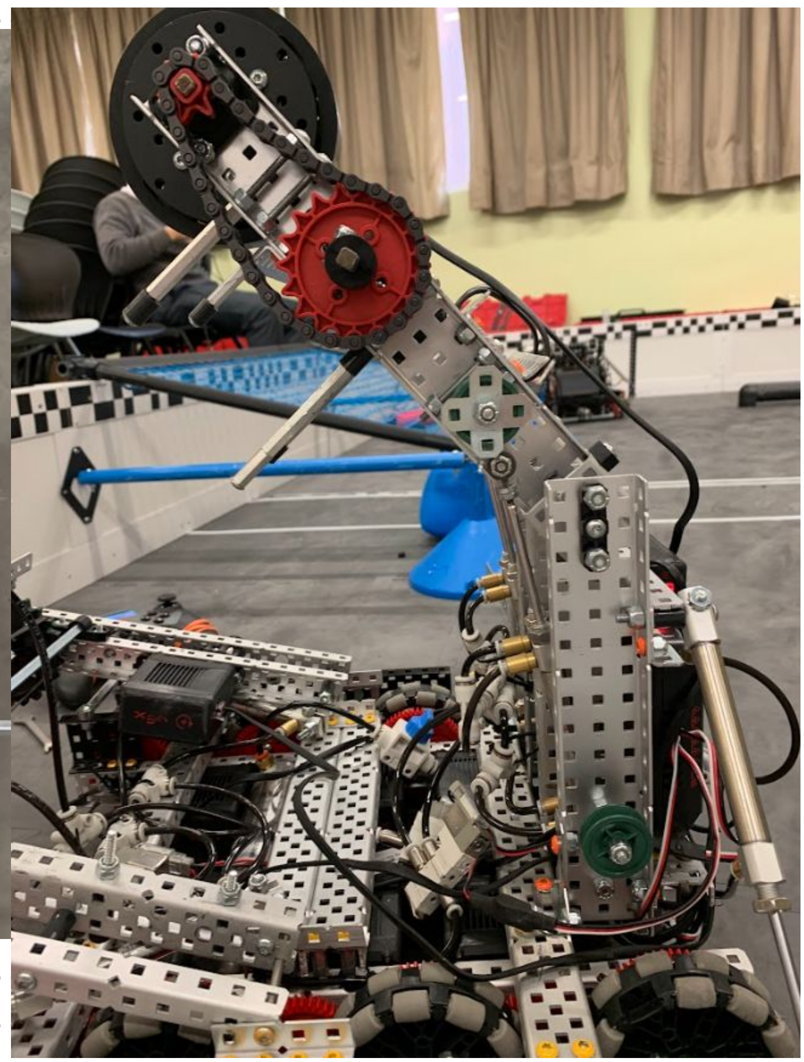
I am Jason Wong from St Paul's College. I am 15 years old now. I have tried quite a few competitions and courses about robotics and STEM in the past few years.This is my first time trying VEX competition. Cooperating with teammates and applying skills I learnt before makes me enjoy it a lot.

Section A

Final Robot and Strategy







Project Final bot - Photos

Name Michael Date Page

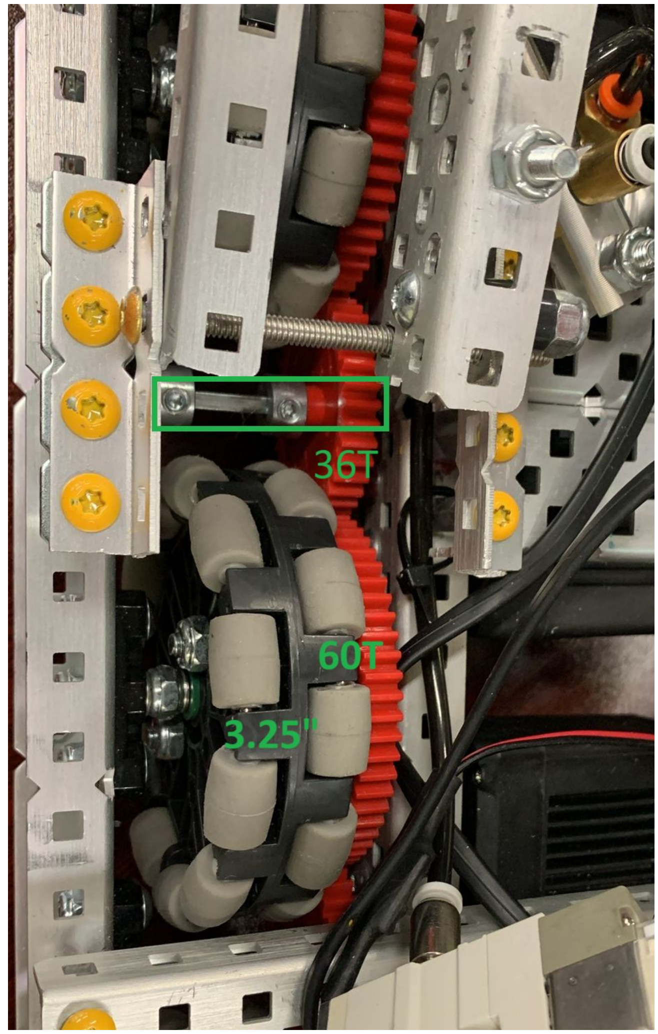
Drivetrain

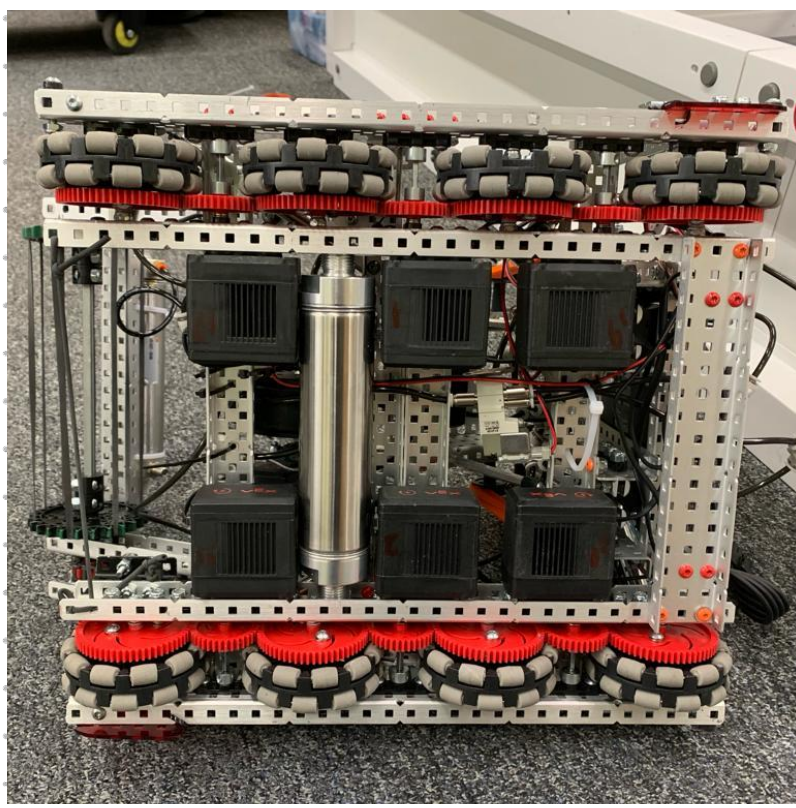
The final drivetrain design has 6 motors, all running with 600 rpm cartridges. With the 3.25 inch wheels geared 36:60 in form of motor:wheel. This gives a terminal angular velocity of 360 rpm on the wheels.

We have decided that this drivetrain is superior compared to all different designs we have this season as it gives a great balance between speed and torque.

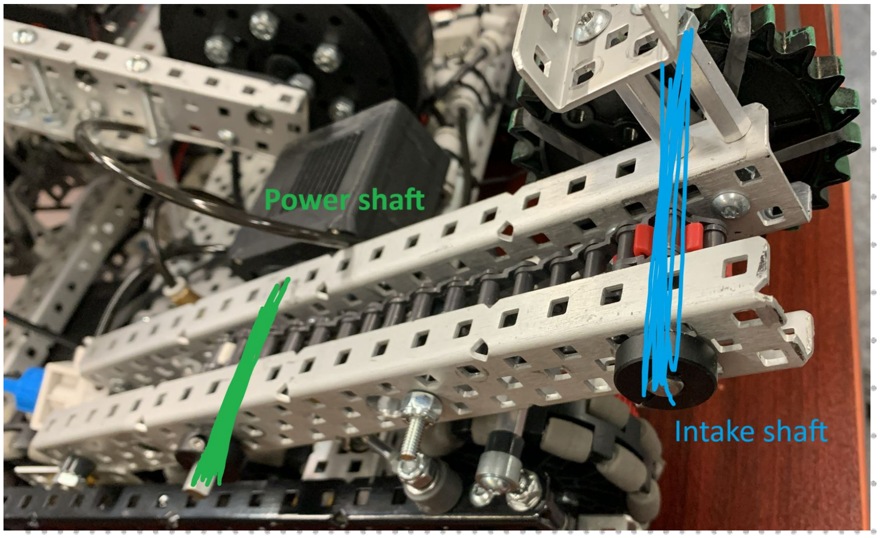
Using this configuration we can achieve 1.56 metres per second. The blend between the velocity and the torque allows us to carry out our “starve the field” strategy, which will be explained in greater details in later sections.

Having 6 motors ensure enough torque for us to push most of the robots around in the field, as well as prevents overheating and shares the load of the weight among the motors.





The drivetrain has a dimension of 30 holes in length and 27 holes in width. Compared to previous trials of making the smallest drivetrain possible, we find out that this happened to be a perfect. It is large enough to contain the triballs tight and secure inside the intake, as well as small enough to leave comfortable room for our driver to maneuver it around the field at high speeds during a game.

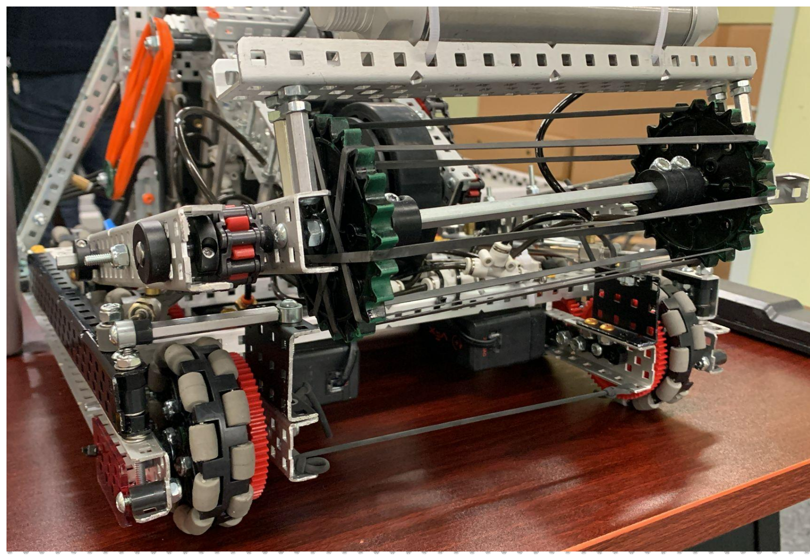


Intake

The intake is powered by one 200rpm motor geared 1:1 with 6T sprockets to the intake shaft.

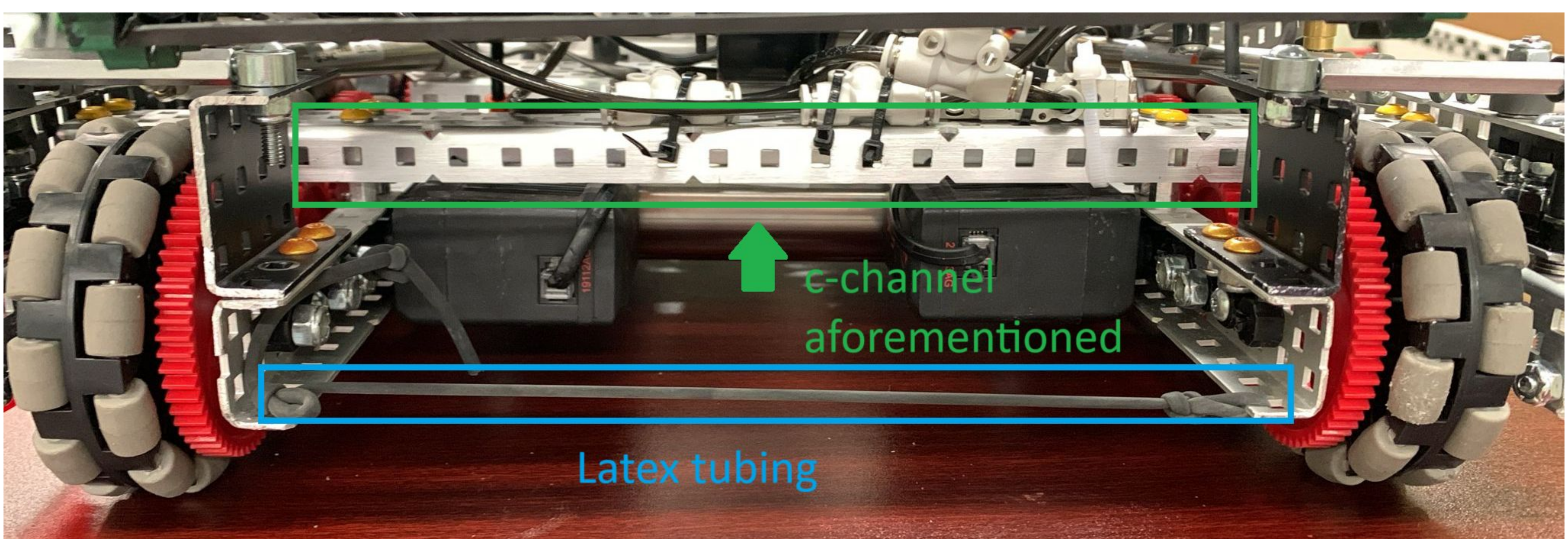
Sprockets in the intake are of 24T, we decided to use them as they are large enough to grip the triball securely as well as small enough to keep the robot more compact.

The 20-hole length of the intake also allows us to keep the angle between the intake and horizontal minimal, as it is shown crucial in scoring. It makes it easier for the goal bar to lift the intake.



We also have a c-channel to push the triball into the goal without reversing the direction of the intake, and a latex tubing to lift the triball, giving us complete control over the triball, and the ability to push the ball into the goal without reversing the motor's direction.

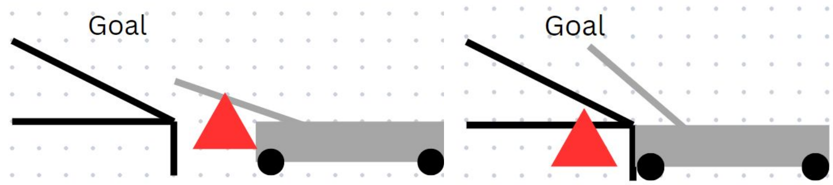
We chose the current sprocket-rubber band model over the sprocket-mesh model as it provides a much better grip and thus overall control over the ball.



Intake (continued)

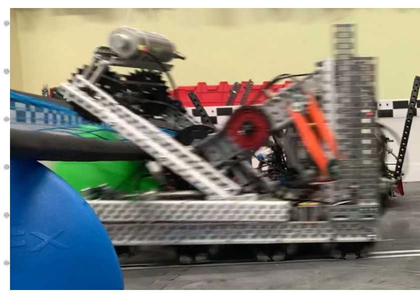
During our game analysis we have observed that intake is the most crucial part of the theme of the game this year. As a result, we have spent quite a lot of time devising a efficient yet simple intake.

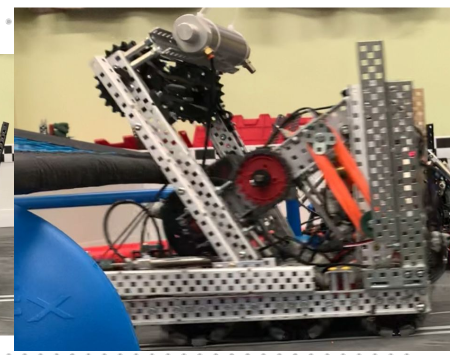
To score quickly, we need to hold on the triball tight, as well as disposing it at the goal as quickly as possible. To achieve this, we have observed that the intake's angle from horizontal plays a key part, the smaller the angle between the intake and the horizontal, the better the intake is.

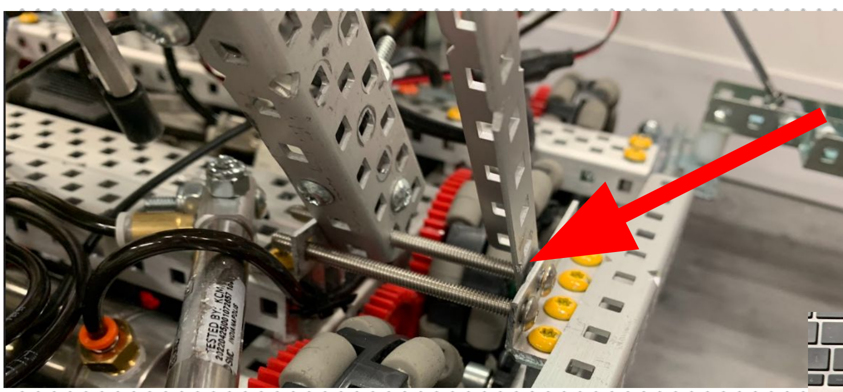


The final solution we have came up with Is shown in the figure on the right. The intake will be lifted up by the goal bar, a standoff is then used to push the intake into the goal.

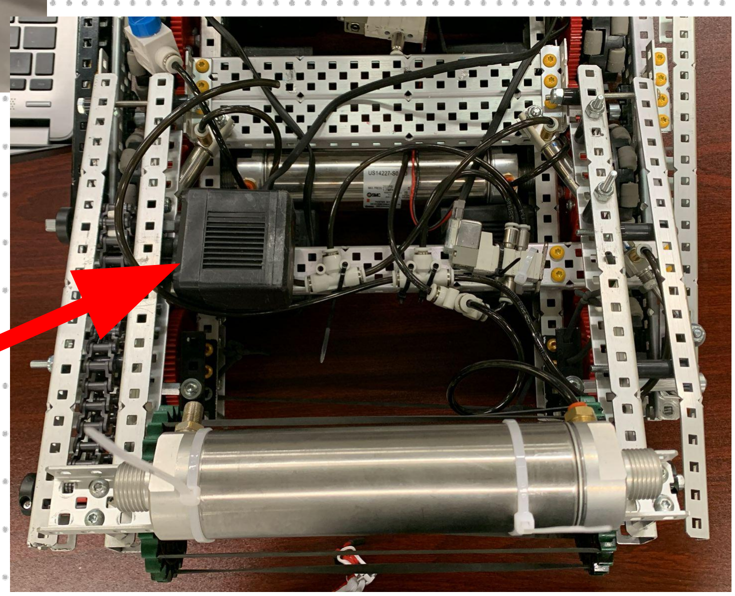
In that manner, we do not have to "outtake" the ball before pushing it in, saving us precious time and greatly eased the driver's burden.







The angle of the intake is done by adding a screw right in front of the intake c-channel, it provides a limit at which the c-channel can fall below.



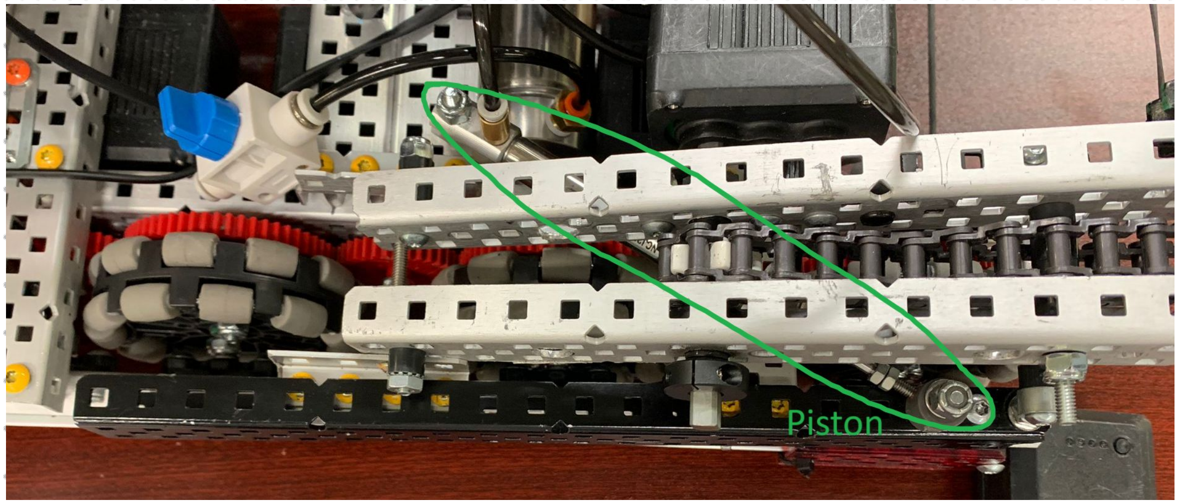
The motor of the intake is mounted close to the main body, this is done to prevent the intake from being head-heavy, which is proved to be quite obstructing. The motor, when put directly with the intake shaft causes a big imbalance between the two sides of the intake, causing bending and inconvenience when hitting the goal bar to score.

Project Final bot - Intake

Name Michael Lam Date Page

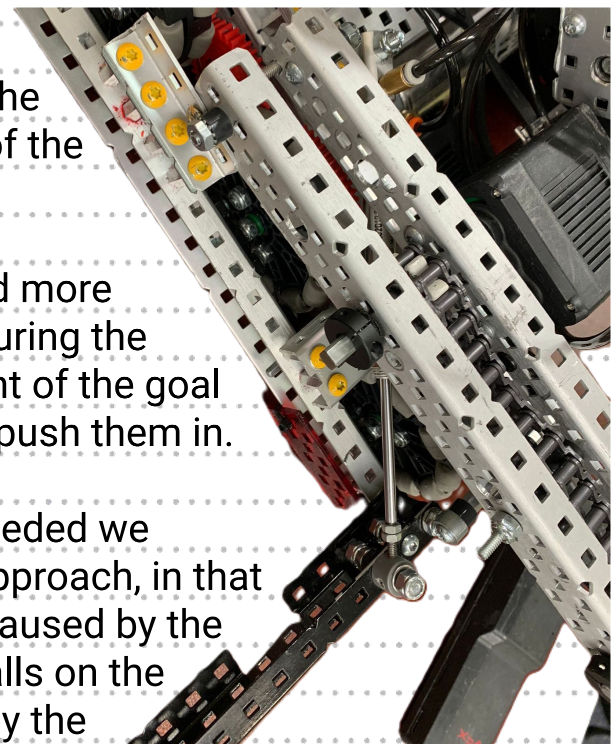
Wings

We have adopted a two-wings approach, one pair at the front and another pair at the rear.

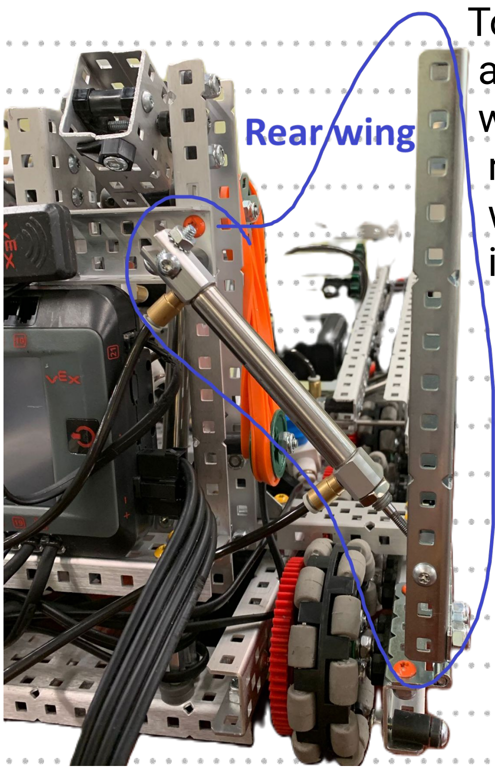


The front wings, as shown by the painted black c-channel at the right, is extended by pneumatics laterally, it provides the driver a quick and easy way to maneuver and push triballs as it aligns with the forward direction of the robot, but lacks strong support and can often be held back by the moments generated by triballs around the far parts of the wing.

Top: Front wing, contracted
Bottom: Front wing, actuated

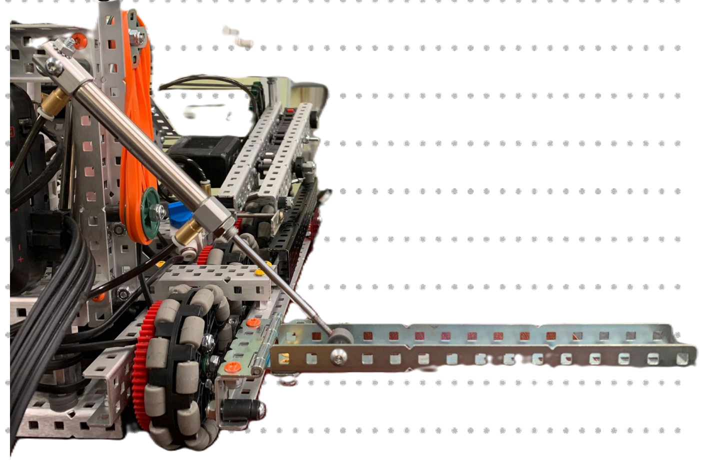


The rear wings are installed to provide a stronger and more stable pair to push around more triballs, especially during the skills challenge, where we have a lot of triballs in front of the goal and the front wings are simply not strong enough to push them in.

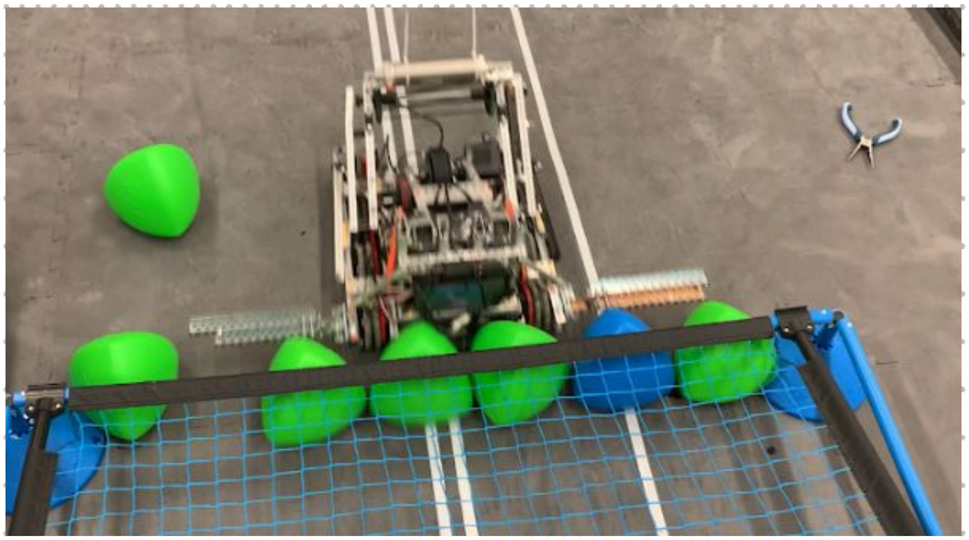


To achieve the strength needed we adopted a vertical wing approach, in that way, horizontal moment caused by the reaction force of the triballs on the wings are counteracted by the immobile hinges and screws, instead of the air pressure in the piston of the front wings.

Left: Rear wing, contracted
Right: Rear wing, actuated

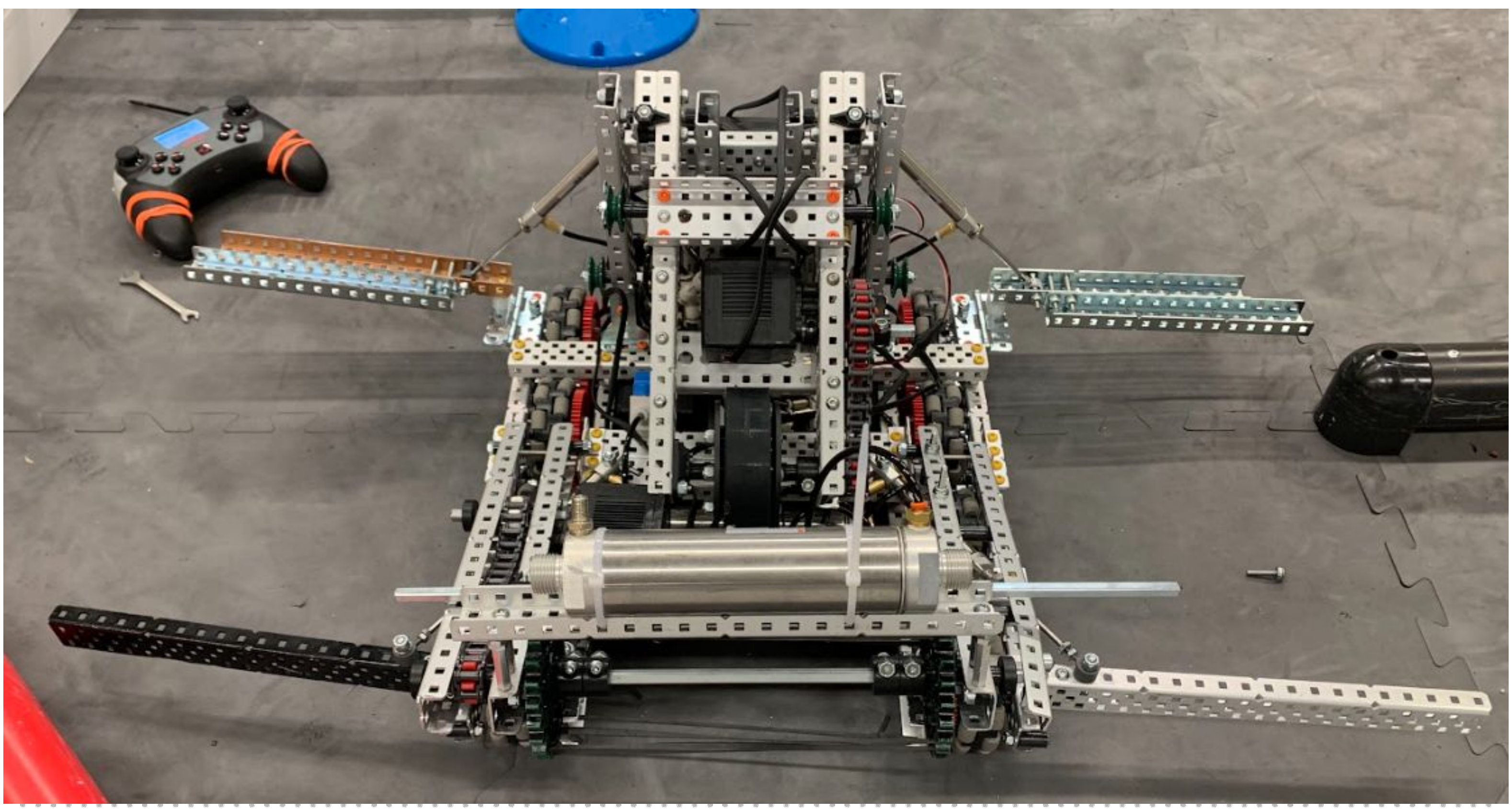


Wings (continued)



The rear, vertical wings in action.

Top: rear, vertical wings *Bottom: front, lateral wings*

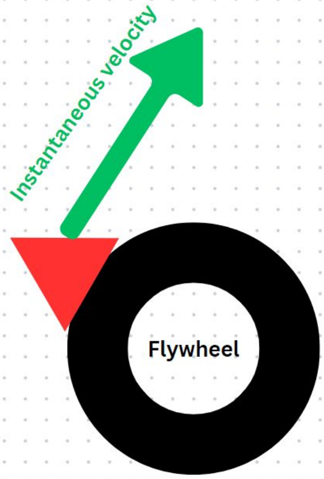


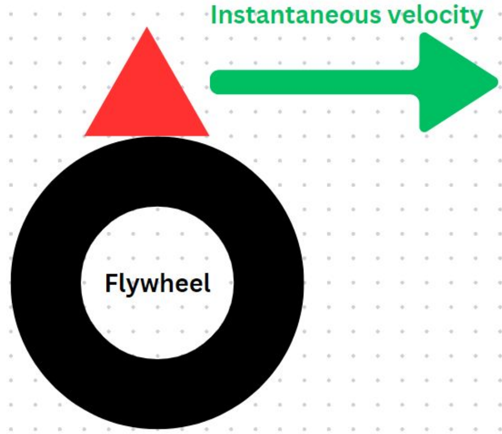
Project Final bot - Wings
Name Michael Lam Date Page

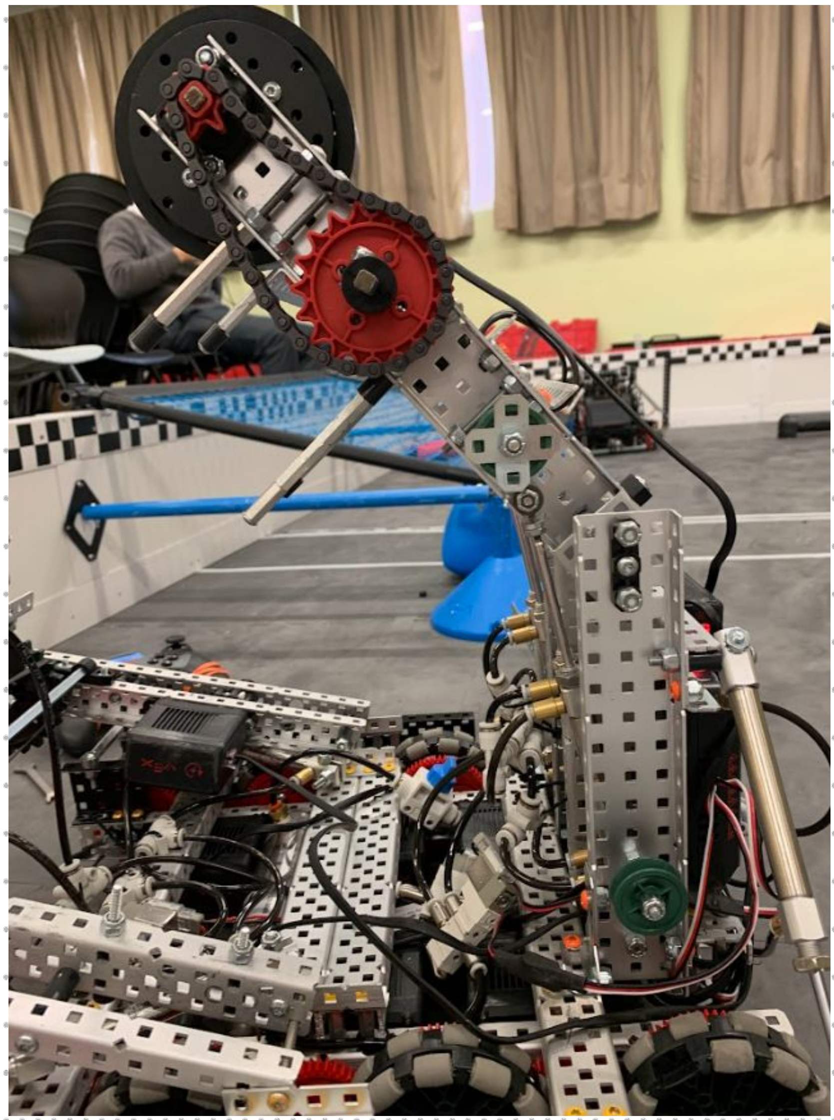
Flywheel

The shooting mechanism will only be extensively used in the skills challenge and hardly ever used in a actual game.

Therefore the main consideration when choosing a launching mechanism was the rate at which triballs can be launched, with accuracy coming second in our priorities.







Flywheel removes the limitation by the RPM of the motor in a puncher/catapult, it allows us to reload as fast as our teammates can. Another advantage of using a flywheel is that it can give different projectiles when the triball is placed at different locations around the flywheel. (as illustrated in the images above)

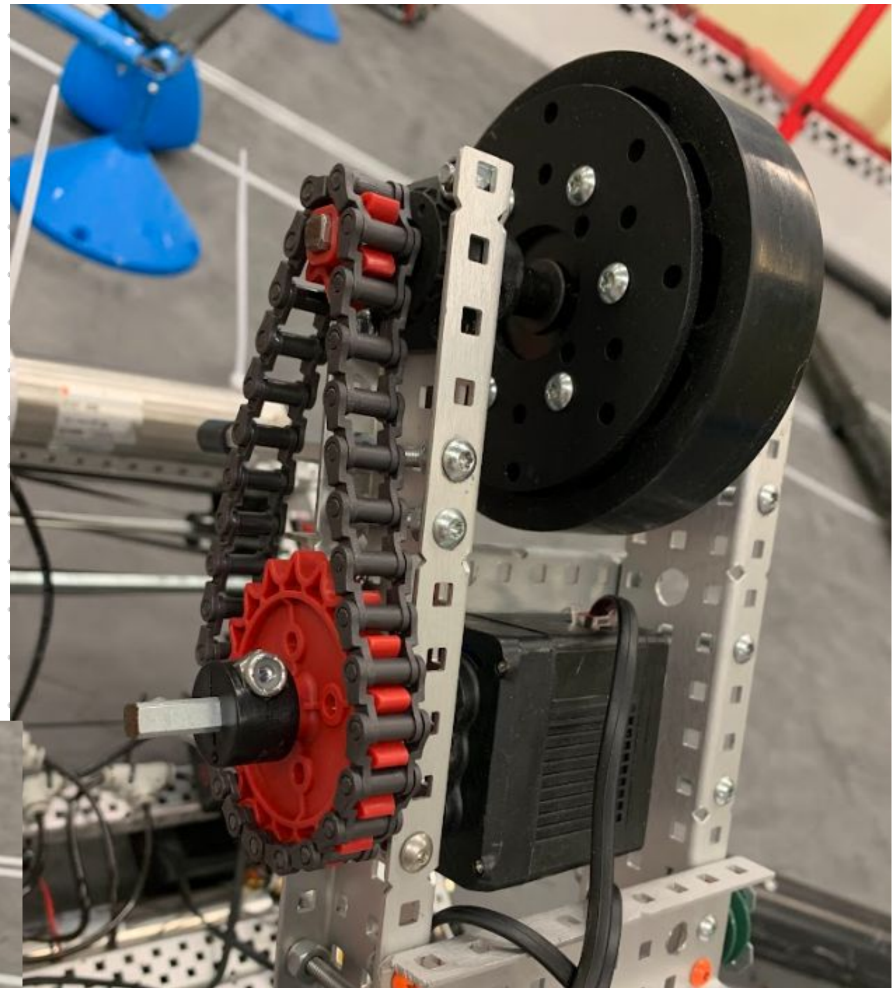
Catapult and punchers give more accurate landing spots, however, we find that not particularly helpful for our campaign as we will hardly use the flywheel in a game and the flywheel can give a more than satisfactory distribution of triballs in front of the goal in skills.

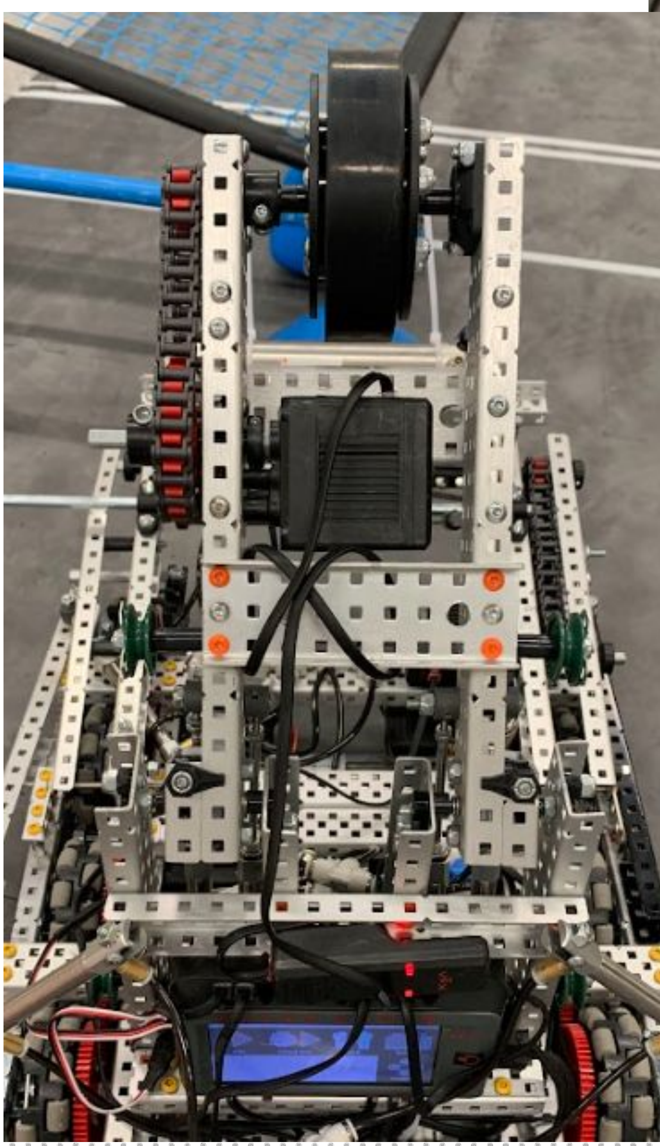
Flywheel (continued)

The black 4-inch 60A durometer flex wheels as used as they provide a strong frictional force and transfers energy to the easily with it.

Weight disks were added to increase the angular momentum of the flywheel, so the RPM can be better sustained without significant drop throughout the shooting.

The motor has a blue cartridge, and the gear ratio is 18:6, so the terminal RPM on the flywheel is 1800rpm,





which is 188.50 radians per second (* 2π/60), giving a tangential velocity of launching of 9.58 meters per second (* 2-inch converted to metres)

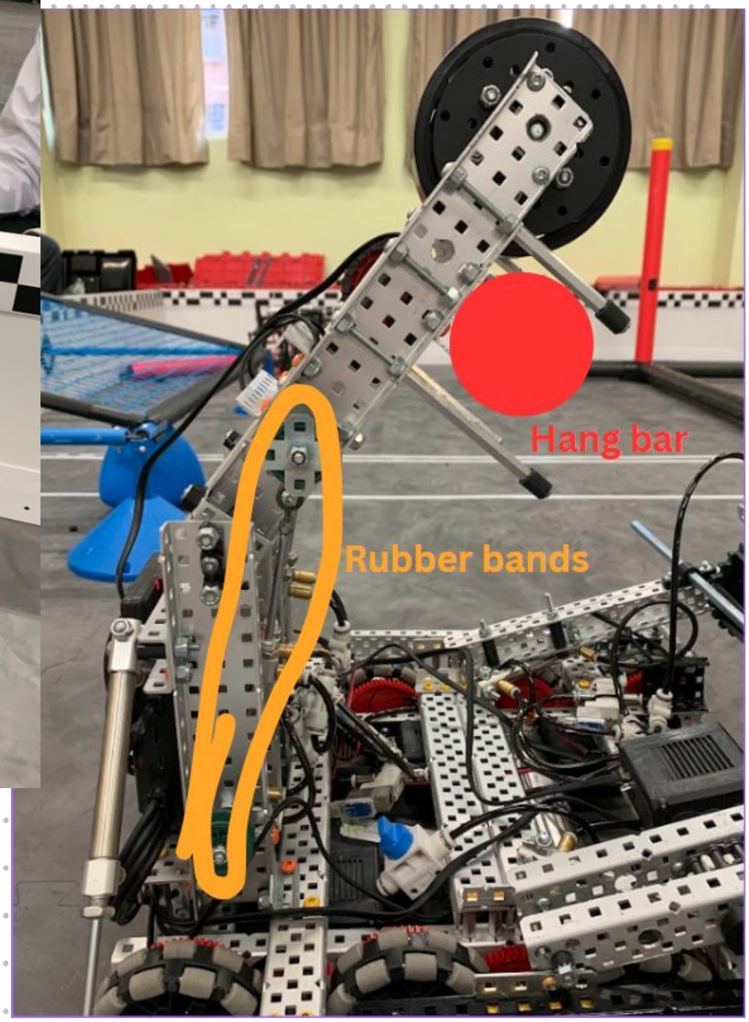
High strength shafts with ball bearings have been used in order to minimise friction.

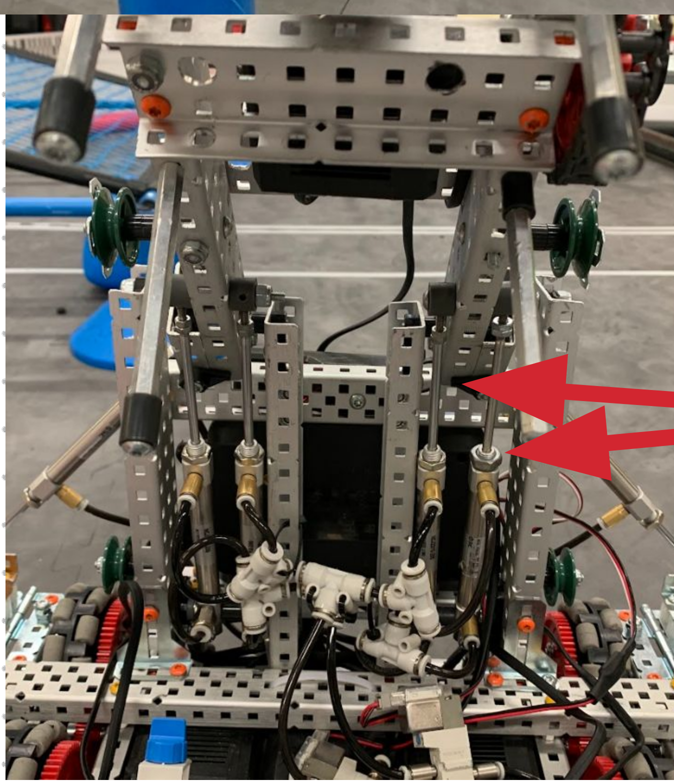
The lifted platform of the flywheel provides us a starting height of the launch, allowing us to launch a straight projectile and avoid blockers on the field.

Climber

The climber is integrated into the flywheel. Two standoffs grip the horizontal bar and four double-acting cylinders with plenty of rubber bands to provide a pulling force to lift the robot up.

Corporated with a well-balanced robot, we are able to achieve a C-tier hang.





Cylinders

Project Final robot - Climber

Name Michael Lam

Date

Page

Game strategy

Writing from my own experience from last year, I have realised that having great defensive abilities and a high-efficiency scoring method is key.

Our game strategy is simple, we will be offensive from the start of the game and gain a upperhand in the opening seconds of the match, including from the autonomous period.

After obtaining the lead, we will stay at the opponents' coloured goal, and obstructing opponents from crossing the field and scoring into the goal. While at the same time trying to keep all the triballs in open field on the other half of the field, where our alliance teammate will utilise them to score.

We will not use match loading as that will add triballs to the field, increasing the complexity and leaving the field very messy and any strategy will then be impractical or extremely complicated.

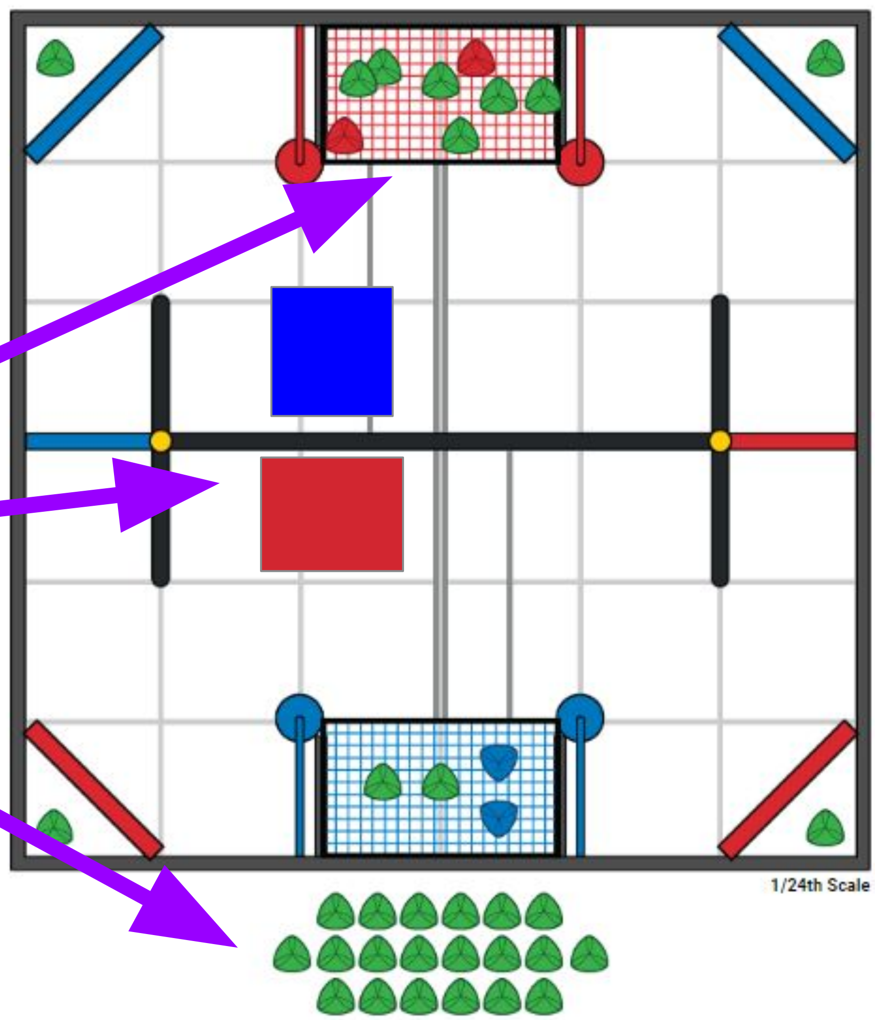
Assume we are the red robot in the field shown on the right.

Our strategy is to gain an advantage at the beginning using the triballs originally in the field. And the adopting a defensive approach, barricading entry into their own half and blocking any match loads from blue.

Early advantage

Defense

No match loads used



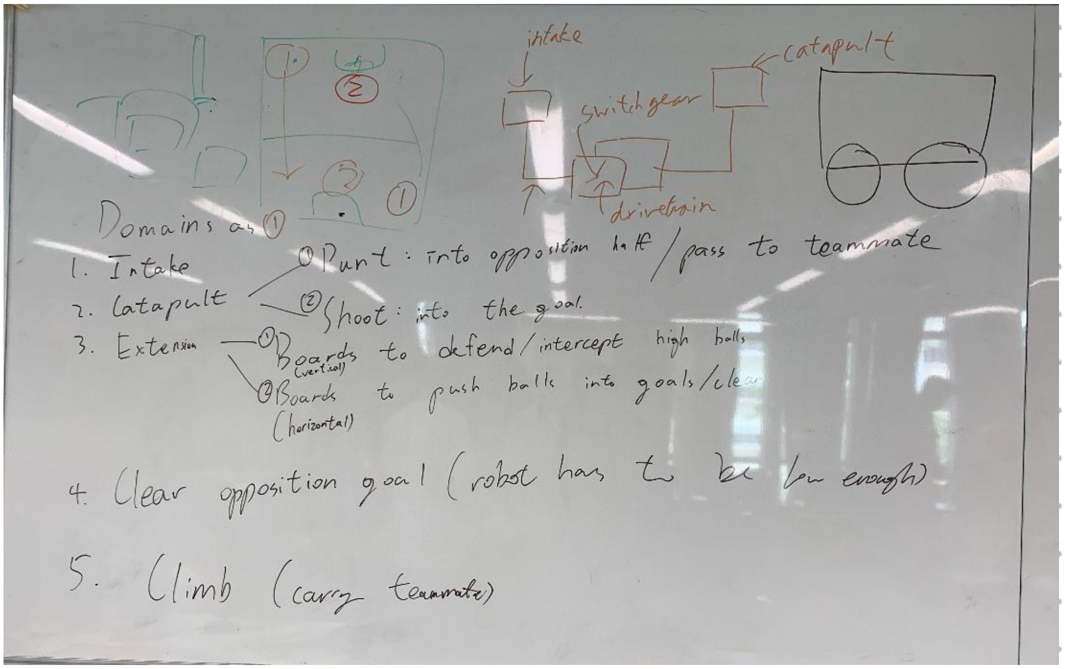
Project Game strategy - "Starve the Field"

Name Michael Lam Date Page

Section B

Along the process

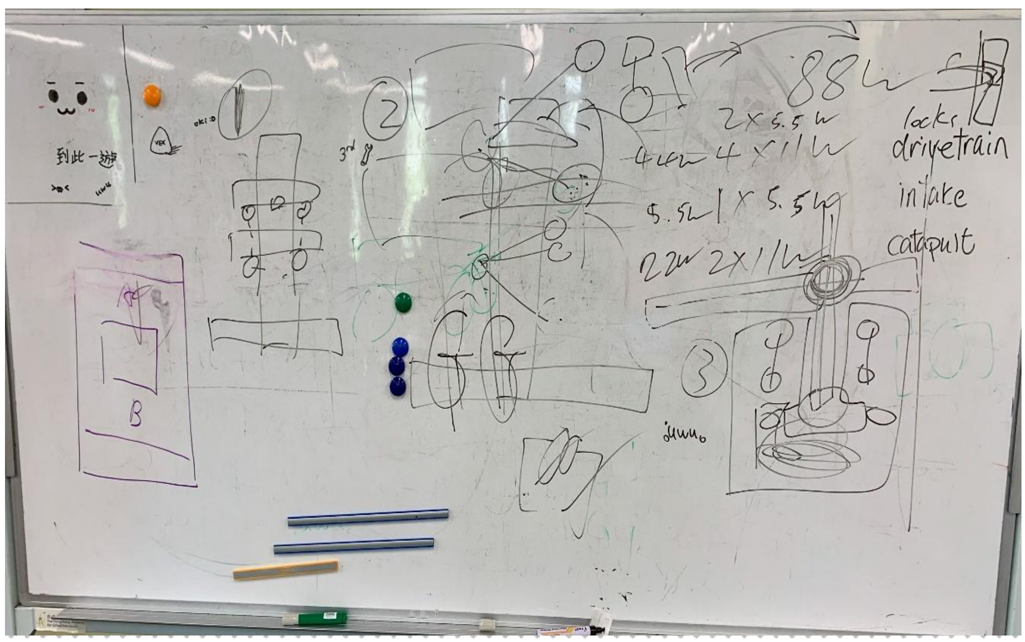
During the first meeting, we have identified the problems we have to tackle this season, identified and categorised several domains the robot contains, and did some brief brainstorming of how the output power is allocated and how we will solve different problems.



Domains we identified
1. Intake
2. Catapult – Punt&Shoot
3. Extension – Hori.&Vert.
4. Clear opposition goal
5. Climb

Three feasible methods to climb the pole.

1. Separate the chassis from the drivetrain, lift them individually and alternatively
2. Use two flex wheels Located in front of the robot
   Pros: Easier
   Cons: C.G. at the back
3. Use two flex wheels
   Pros: C.G. at the centre
   Cons: Very difficult to create a pathway to let the pole fit inside the robot



Project Problem Identification and Basic Robot Design
Name Michael Lam Date Page

Section B.1

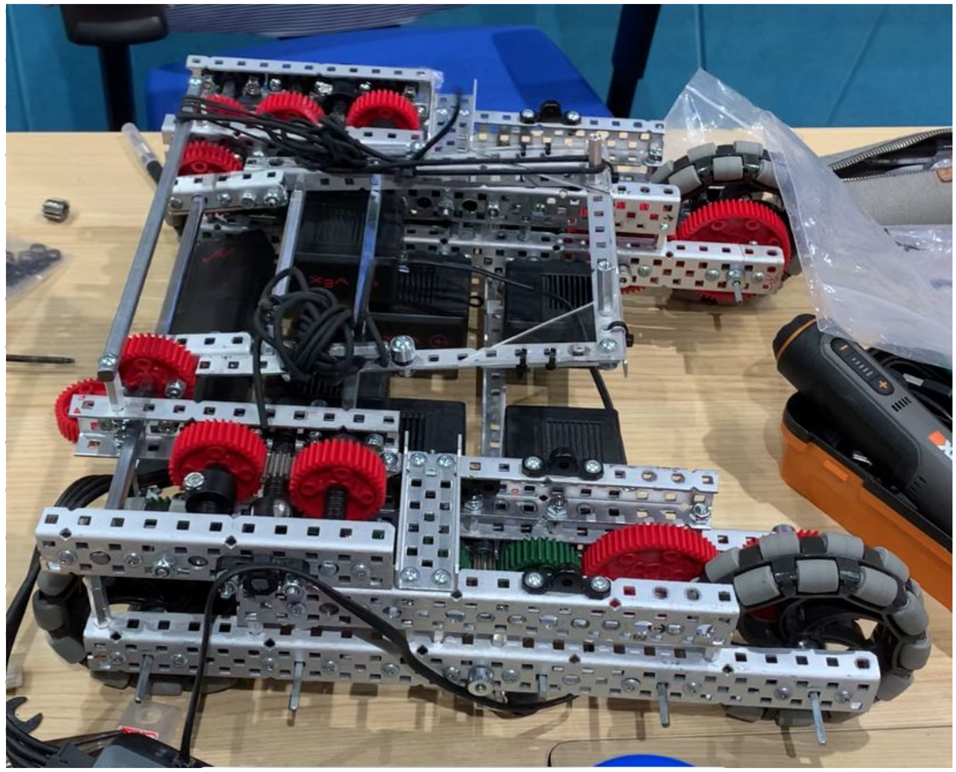
Along the process

Iteration 1

In the first iteration we have decided to make a robot that can go underneath the goal and descore the opponent when they are double-zoning.

It also contains a PTO (Power-take-off) that switches between a 22W catapult and 66W drivetrain.

The catapult was designed to shoot from the match load zone directly into the goal on the other side. It has not been implemented yet before this iteration is abandoned.



Iteration 1, with the intake take off for It.2

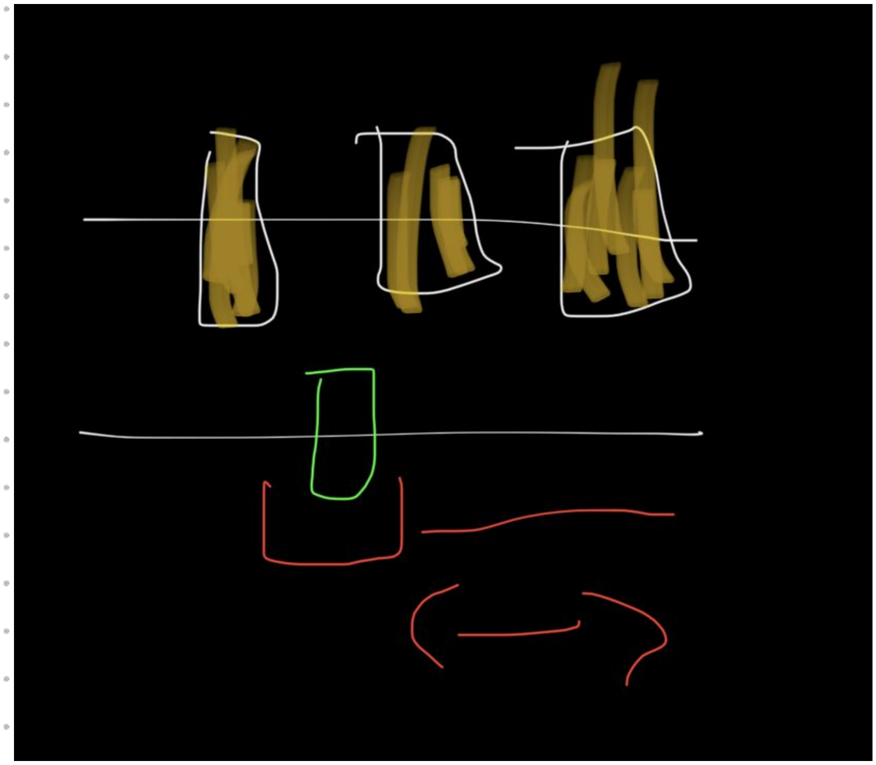
Intake was designed to be a parallelogram and is extended out by pneumatics as the robot has to be lower than the goal bars.

Drivetrain prototypes were also made and tested.

Reasons why we didn't use the Iteration 1 robot

1. We have realised that going underneath the goal would sacrifice much more than we would gain from it, especially the efficiency of the intake
2. Making such a compact robot with a PTO would be difficult to fix if anything was out of order in a match.
3. The catapult idea will certainly be blocked by robots as the projectile is too low it is impossible to shoot directly into the goal in games.
4. The drivetrain only has two 4' wheels with nothing in between, it would be very difficult for us to move across the field as moving over the barrier in the middle is almost impossible.

A hand-drawn illustration of the switch mechanism.

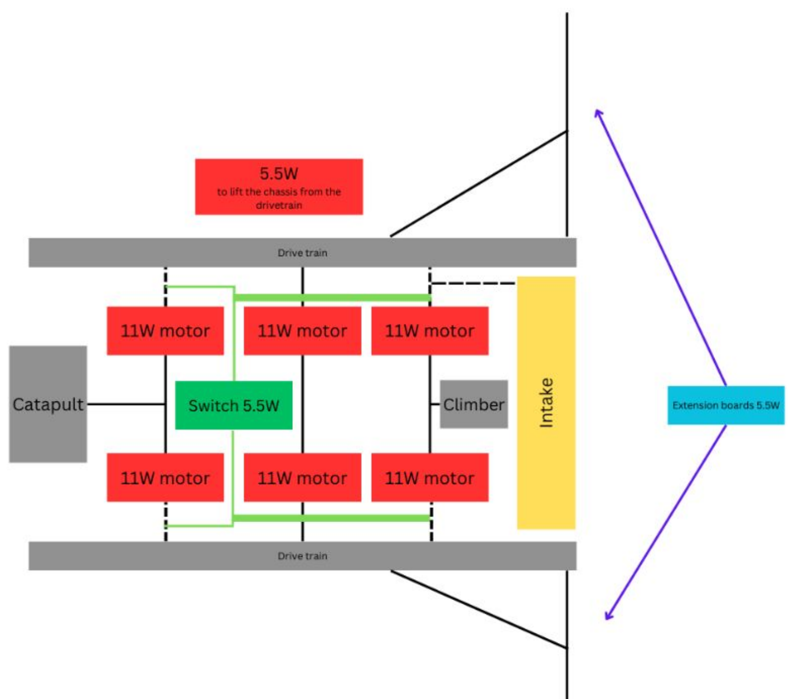


The shaft with the green gear will be the one powered by 22W.

The red one will move horizontally, connecting the green gear with different yellow gears, those yellow gear will be connected to different components of the robot.

The switch mechanism ultimately aims to reduce the number of motors we need by utilising the motors.
The catapult and intake will not be used during the entire match, which means that they will be idle most of the time, by introducing a PTO (Power Take-Off) system we can better allocate the output power and maximise the performance.

The design of the robot continued from the design yesterday.

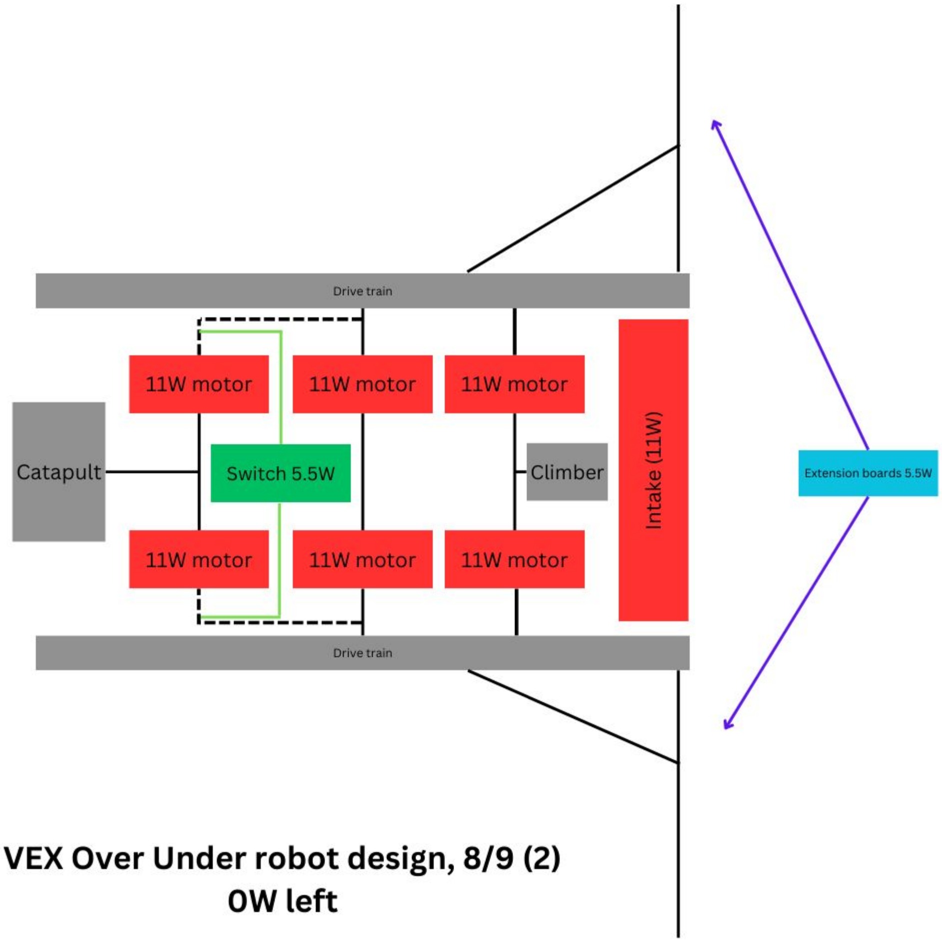


VEX Over Under robot design, 26/8 (2)
5.5W left

This new robot layout will be attempted.

Changes on the rear 22W motors are due to the fact that there are only two 200 rpm shafts on the drivetrain (as seen in the previous page).

The front 22W motors will no longer be powering the intake. That is due to the intake requires a certain amount of power to run and the rotational speed of the intake will require us to gear up before powering it, it will take up too much space and the gear chain will be complicated.



VEX Over Under robot design, 8/9 (2)
0W left

Since being able to go under the goal is one of our objectives, the robot will be lower than a triball.

The intake will be held upright, however, it can be passively pushed downwards when in contact with the goal bars.

Actual implementation of the drivetrain.

Each side of the drivetrain is 5-wide and we used 25-long c channels to reduce the size of the robot.
The gear chain is 64T(PTO)-64T-36T(powered)-12T-36T(powered)-64T-64T.
Blue cartridges with 600rpm will be used to connect to the 36T gears on each side.
The PTO will transfer power to the 64T gear at the rear of the robot.

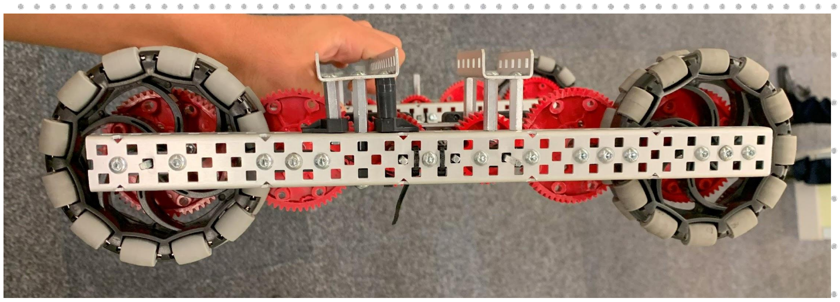
Since we do not have access to blue cartridges at this point, we have only installed the motor covers on the right side of the drive, cartridges and motors will be assembled with rubber band later.

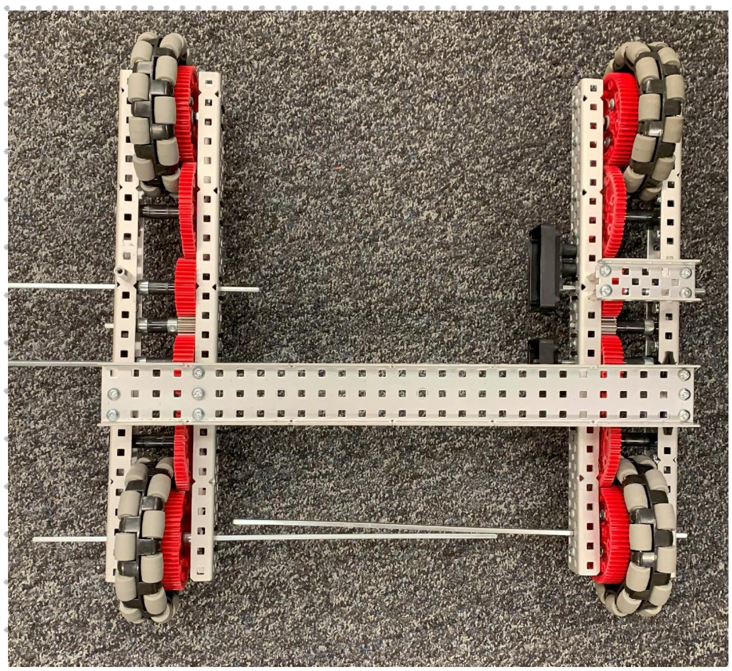
The drive will be connected by two 3-wide c channels (29 long), with the wings installed, the whole robot should be around 31-32 long.

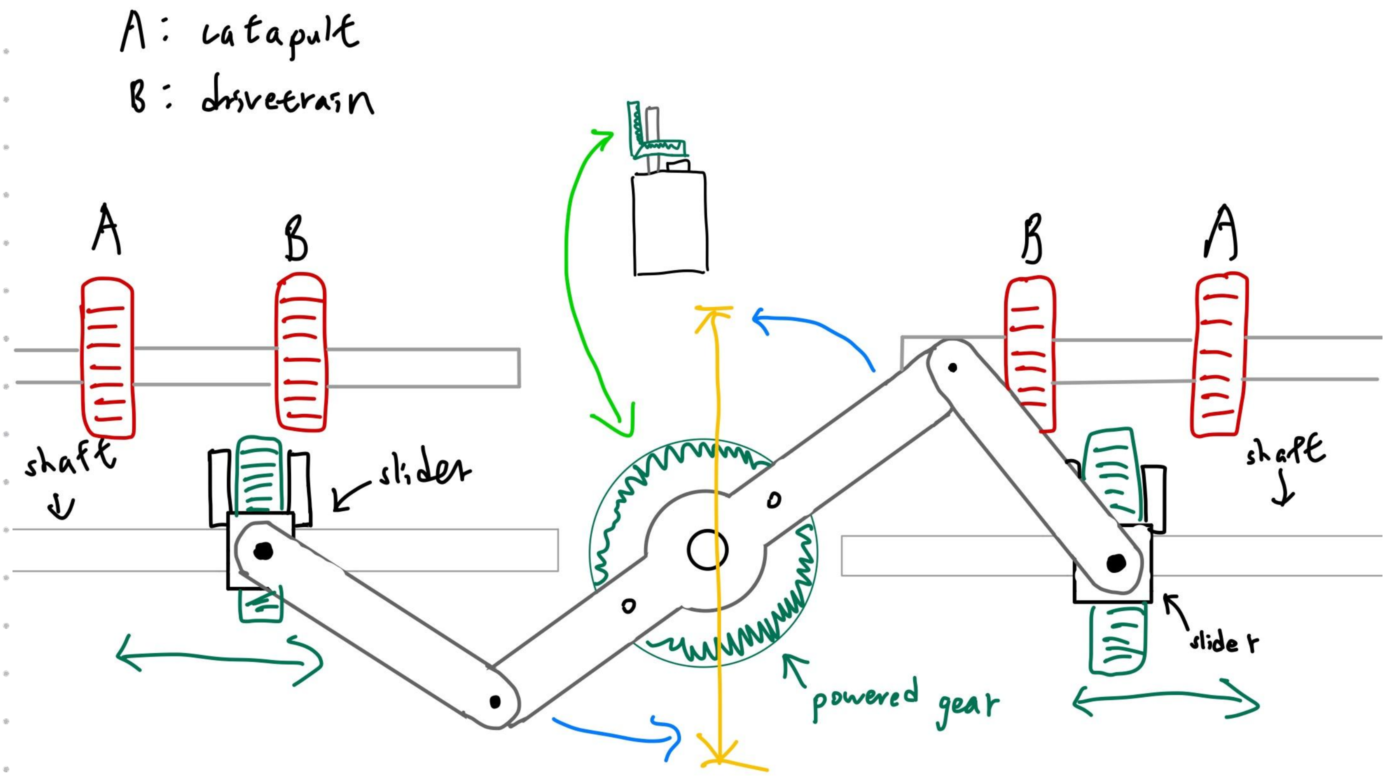
The top-left 64T gear is too wide for the robot and is now contacting the front-left omni wheel, further thinning of that gear is needed.

Some shaft bearings are compositely held in place by zip-ties and one screw (instead of two) in order to save weight but still ensure the bearings are held securely in place at the same time.

The 3-wide c channel is also boxed to the drive. By doing so the strength of the drivetrain and the robot can better cope with the weight of components above the drive.







A design of mechanism of gear switch for PTO (Power Take-Off)

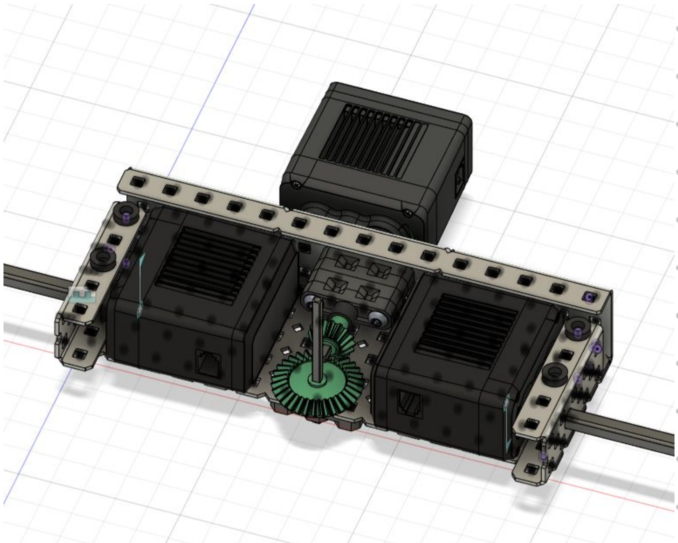
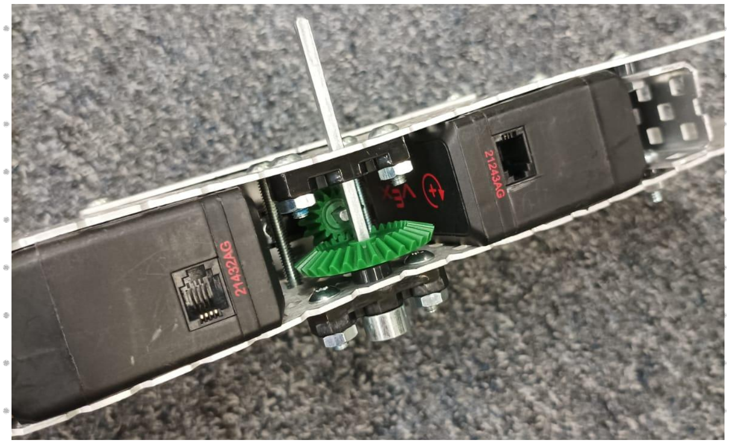
This is a linkage mechanism for converting rotary motion to linear motion. The two sliders both hold gears respectively and are connected to the powered gear in the centre by bars. By the rotation of powered gear, the two sliders will move left & right along the shafts in opposite direction synchronously.

Powered gear will be rotated to certain degree for switching between gears of catapult and drivetrain.

All the gears are beveled for smoother meshing.

Project Iteration 1 - Power Take-Off (PTO) gear switch design

Name Michael Lam Date Page

PTO prototype design (26/9)

Advantages:

- Used 4 bearings to increase the stability of the horizontal low strength shaft
- Parts are connected directly by screws(no standoffs needed), which greatly reduces the height compared to trial design B
- Modified the design so that the holes of different parts are aligned unlike trial A, which allows parts to have stronger connection
- Motors are squeezed by the upper plate and lower plate which limits its movement even if the screws are loose

Disadvantages:

- Width issue. The gear at the centre take up too much space, causing the width of the PTO increased to around 15 holes, resulting in the gear selection part and drivetrain having to be done in less than 10 holes width.

Potential issues:

➔ RPM issue. The RPM of the gear may be too slow to power the linkage for gear switching efficiently

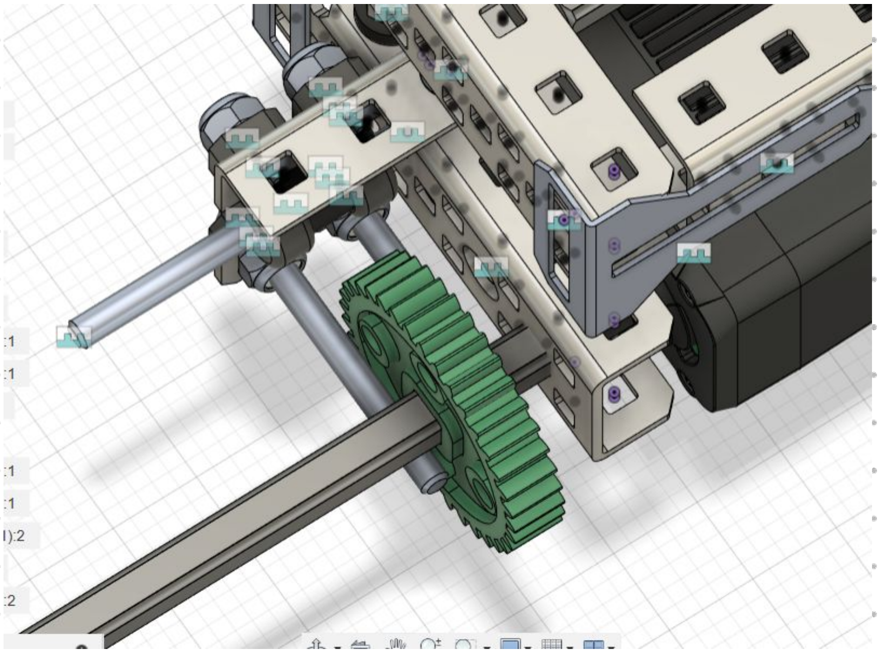
➔ Torque issue. May not have enough torque to power the linkage

Possible improvements:

➔ Move the gear to the top to minimize the width

Project Iteration 1 - PTO prototype design

Name Michael Lam Date Page



CAD of gear selector

Description:

- Similar structure to trial design B1
- Main difference between B1 and B2:
  Smaller width reduction in comparison to that of B1, but in return for an anchoring point at the bottom of the vertical shaft.

Advantage:

- Increased stability compared to trial design A, as there are support from the top to bottom for the vertical shaft

- Moderate width reduction

Disadvantage:

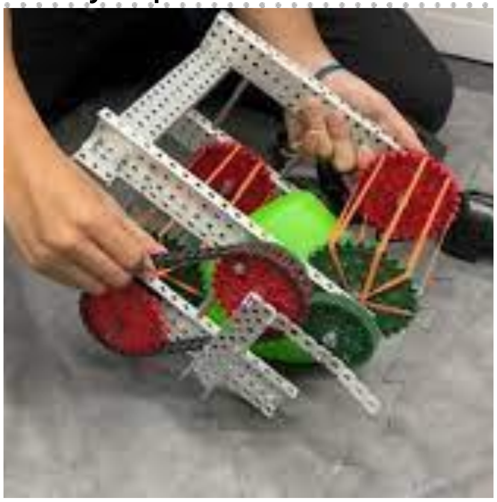
- The height of the structure is much higher, which limits the height of the cata above the PTO

- Has smaller width reduction than trial design B2. It allows smaller space for gear switching.

A sprocket intake will be adapted.

Since the triballs is taller than the goal posts, and the intake have to be taller than the ball to take them in.

That means the intake will be higher than the goal posts, which violates the crux and the synopsis of the robot.



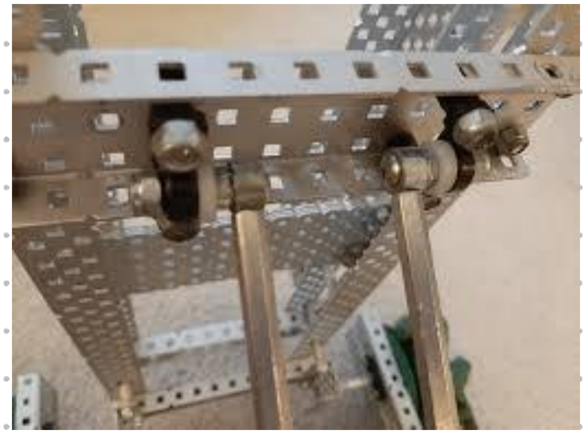
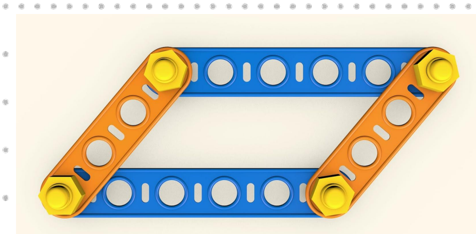


Photo credit: 4139A Botanophobia. (2023, June 3). *VEX V5 Over Under Sprocket Intake design example* [Video]. YouTube. https://www.youtube.com/watch?v=oJH_EgH0hlE

How to secure these hex drive couplers and standoffs. (2019, September 21). VEX Forum. https://www.vexforum.com/t/how-to-secure-these-hex-drive-couplers-and-standoffs/66599/8

The solution to the issue aforementioned is to held the intake upwards, in a position taller than the triballs and the goal posts **passively**.

The intake will be held like the image below, with the upper horizontal bar representing the intake and the lower one representing the drive. By using such mechanism, the intake will be held parallel to the drivetrain and can be held upright by a rubber band passively.



When the intake is in contact with the goal bars, the intake will passively bend down. Once the intake is not in contact with the bars anymore, the tension force provided by the rubber band will pull the intake back upright.

The diagram at the right will be used to act as the orange bars.

Citations:

Shafts and standoffs. (2015, November 4). VEX Forum. https://www.vexforum.com/t/shafts-and-standoffs/30774.

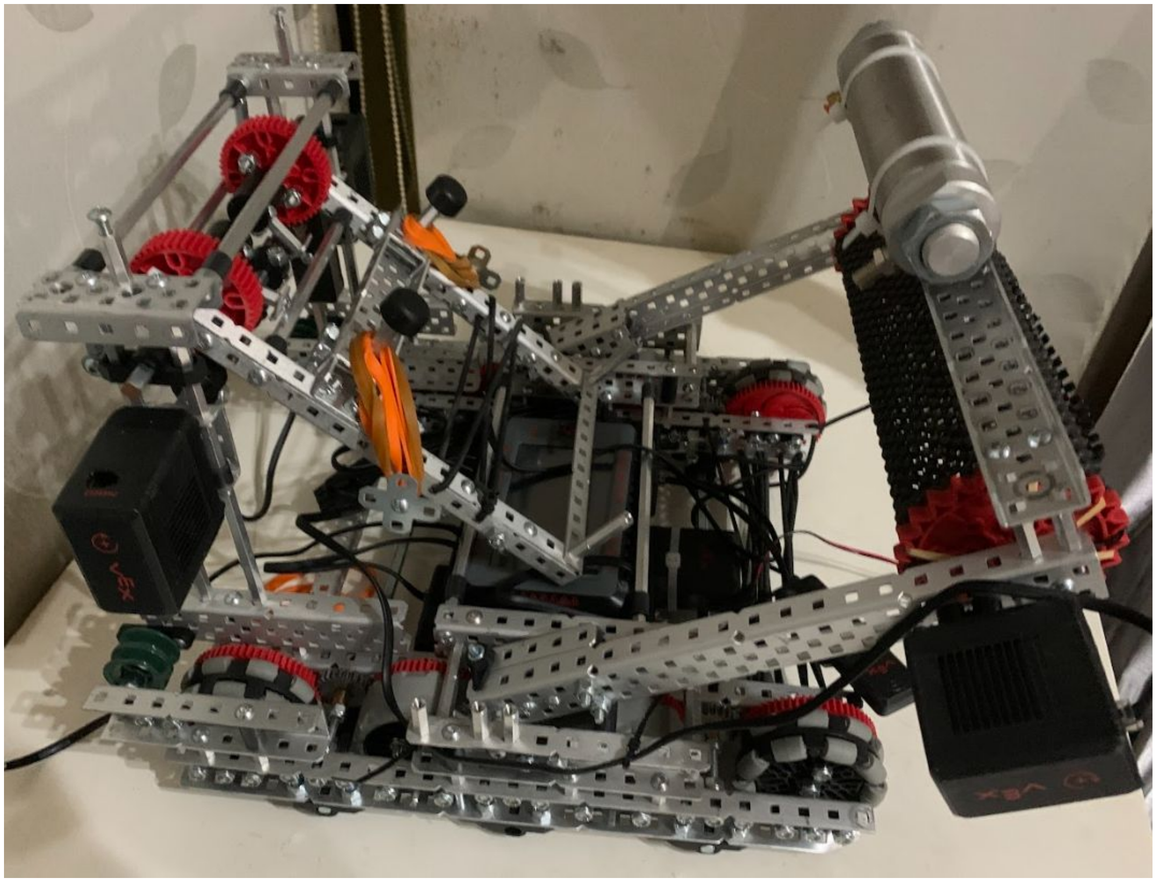
Parallelogram / etudes // mathematical etudes. (n.d.). Etudes.Ru. https://en.etudes.ru/etudes/parallelogram/6/

Section B.2

Along the process

Iteration 2

In the second iteration we have decided to make a robot focuses on the intake, as game analysis from MOA showed the absolute dominance of having a strong intake.



The intake on the second iteration was very strong, it can score without even turning on the motor, thus enabling the intake motor to spin in one direction for the entire duration of the match, increasing the efficiency and reducing complexity.

The drivetrain is rather fast, however, it showed that having a four motor drivetrain is not sufficient to sustain the whole match.

With simplicity in mind, the PTO, although undesired, was the only solution left to save the second iteration due to the overheating in the drivetrain.

A blocker was built and tested, it did went on to block a few shots, but tall robots can still get over it.

Reasons why we didn't use the Iteration 2 robot

1. We find the catapult pretty useless, due to the ingame strategy we have derived.
2. The complex, undesired PTO was brought back
3. The drivetrain has overly small 2.75' wheels, testings have shown that using those wheels it would be difficult to move over the central barrier, even with the wedge (green circular objects at the rear of the robot in the image above).

Iteration 2 robot has a direct 600rpm drivetrain on 2.75’ wheels.

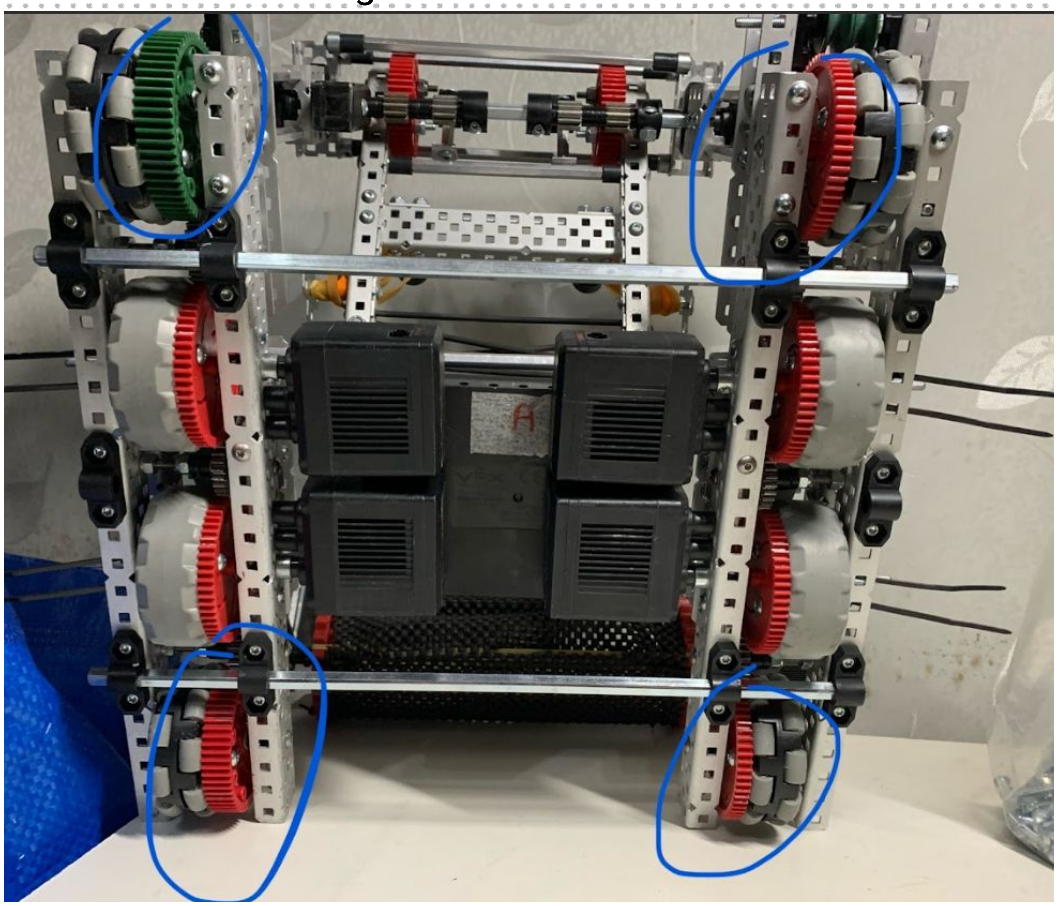
The middle two wheels are traction wheels which prevents the robot from being pushed over, which the four around the corners are omni wheels to facilitate turning.

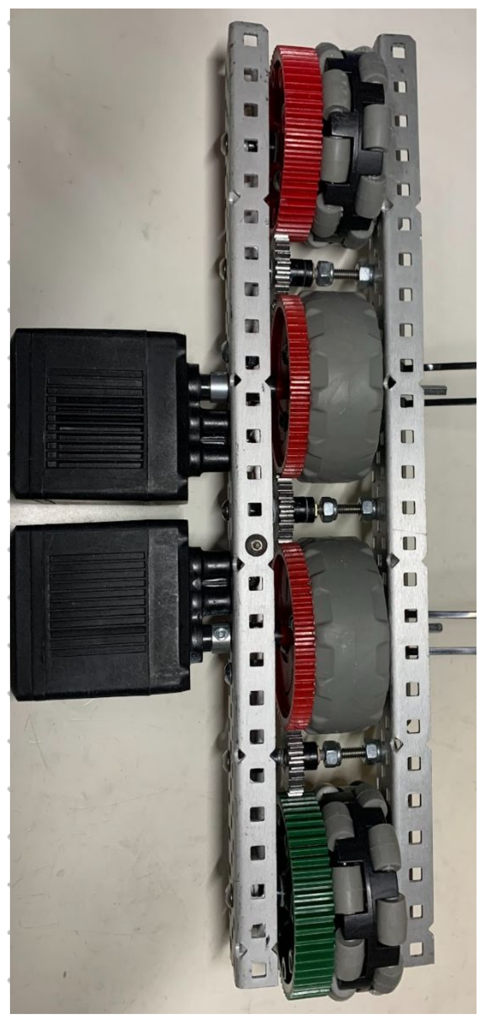
Each side of the drivetrain is chained up by 60T-24T-60T-24T-60T-24T-60T gear chain, with the 24T gears offset.

Two high-strength shafts were added to the drive to enhance the strength and ensures that it does not bend under the weight of everything above.

Tangential velocity of such drivetrain is 1.80 metres per second, one of the fastest drivetrains out there.

After testing, 4 motors cannot generate enough torque to power the robot for the whole duration of a game.





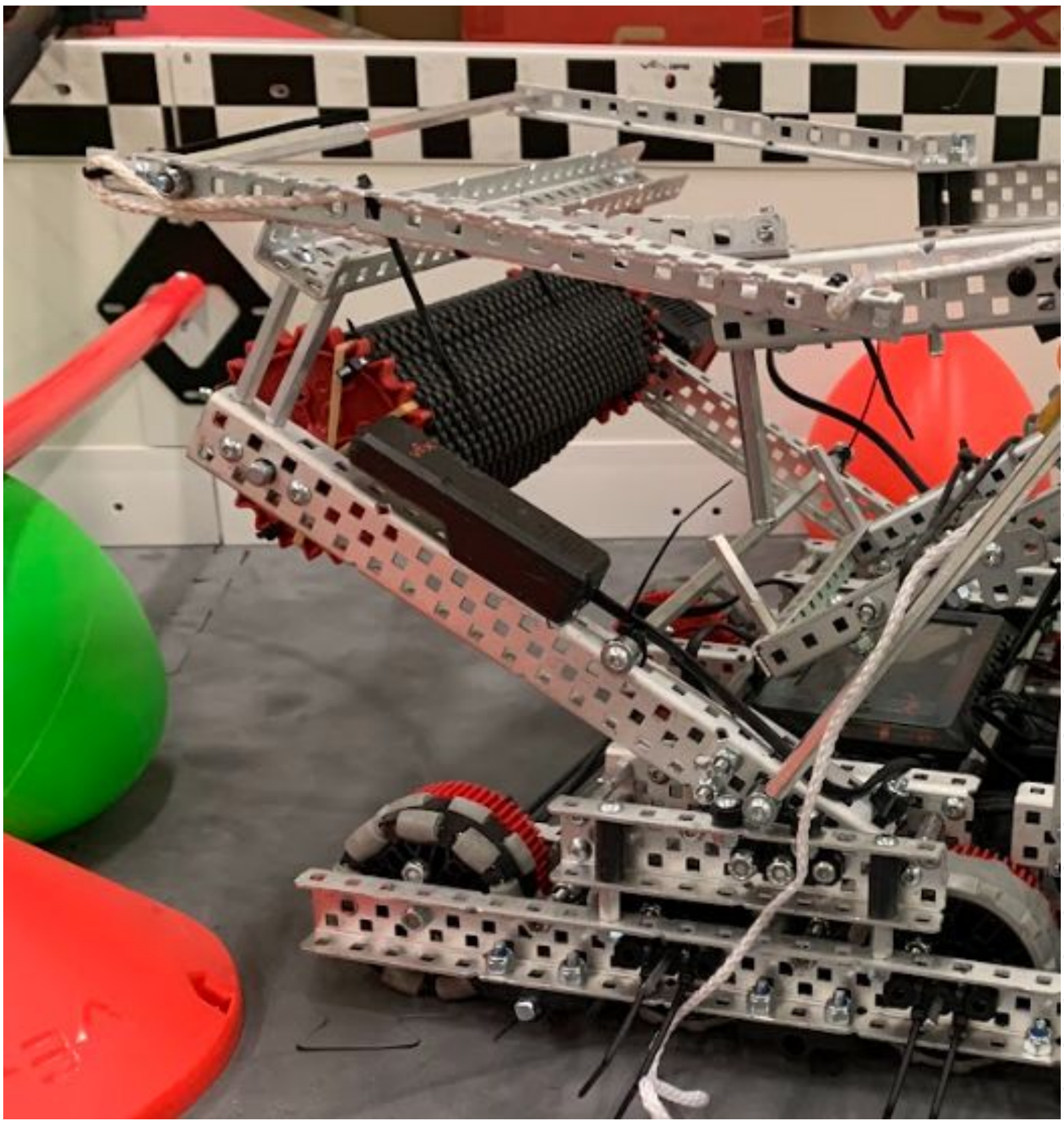
This integrates both the puncher and the catapult, the two black rubber elements are used as punchers (lower arc of projectile) and the catapult gives a much higher arc, thus avoiding some high blockers.

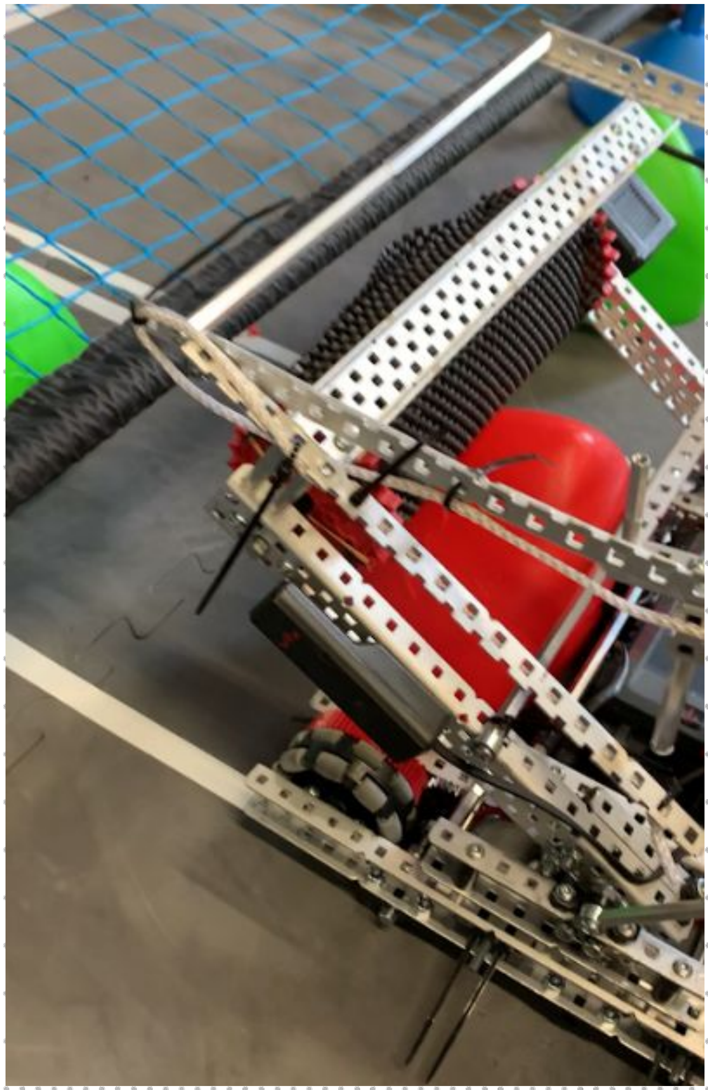
A rubber-band mash intake was adopted.

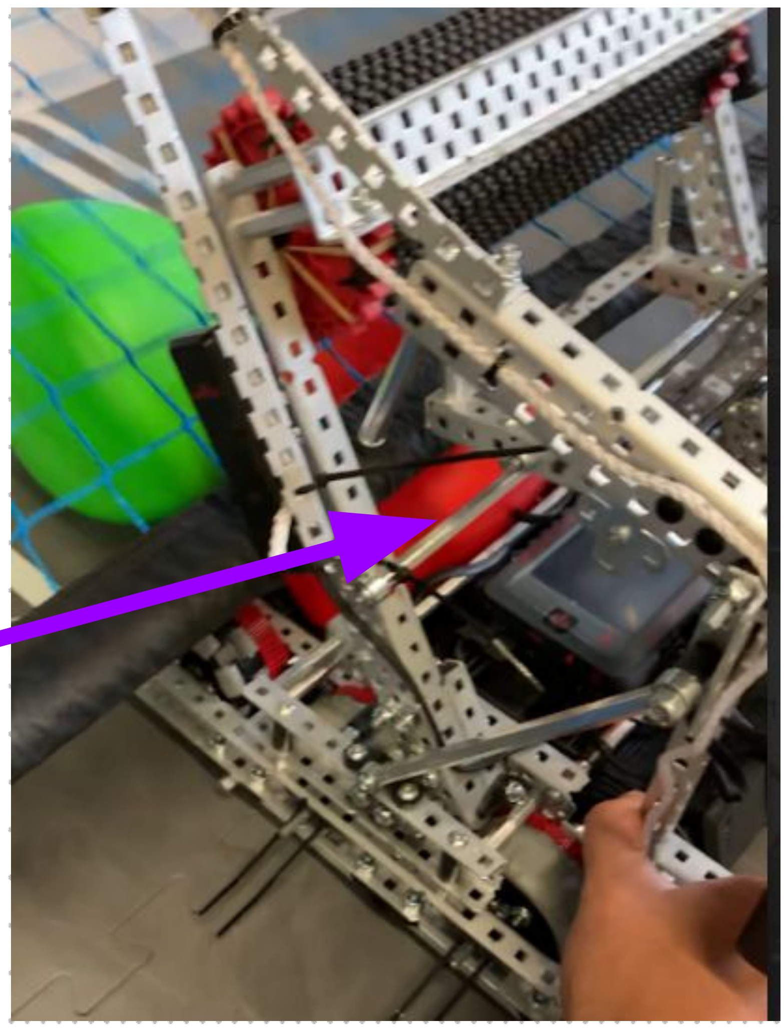
Latex tubing is used to lift the ball up from the ground so we can get complete control over the ball.

A standoff is used so that when the intake is lifted by the goal, the standoff acts as a rigid body to push the triball into the goal.

By doing so, the triballs can be **scored even when the intake motor is switched off**. The same intake idea has been carried forward to Iteration 3, the Final Robot.







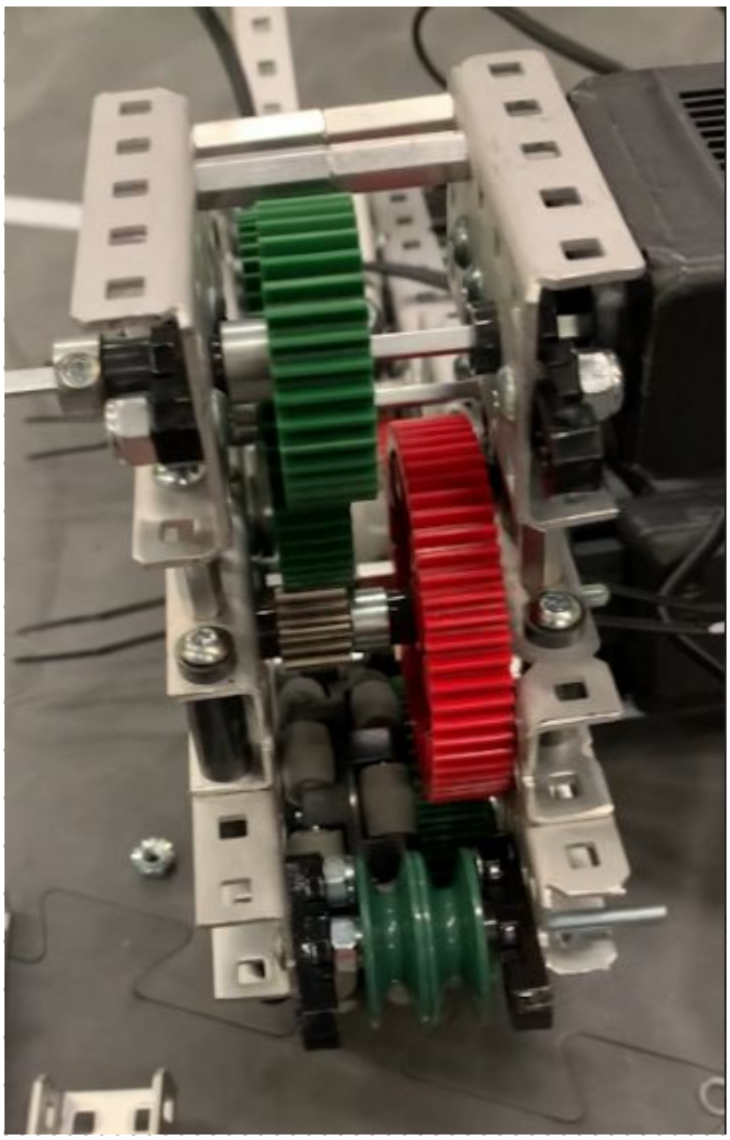
Standoff in action, pushing the triball into the goal

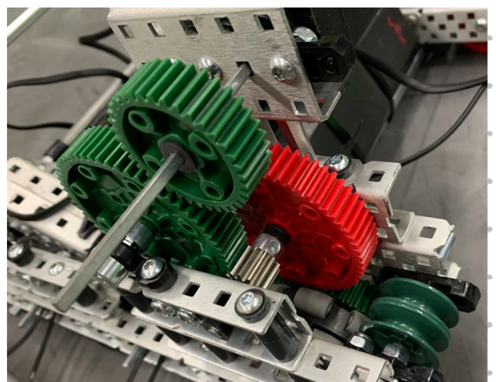
Testings have shown that the sole four motors at the drivetrain can not sustain for the whole duration of the match and overheats.

Therefore there is a need for more power to the drivetrain. We decided to install a PTO to connect the drivetrain and the catapult, as we have decided that the catapult will not be extensively used in a match.

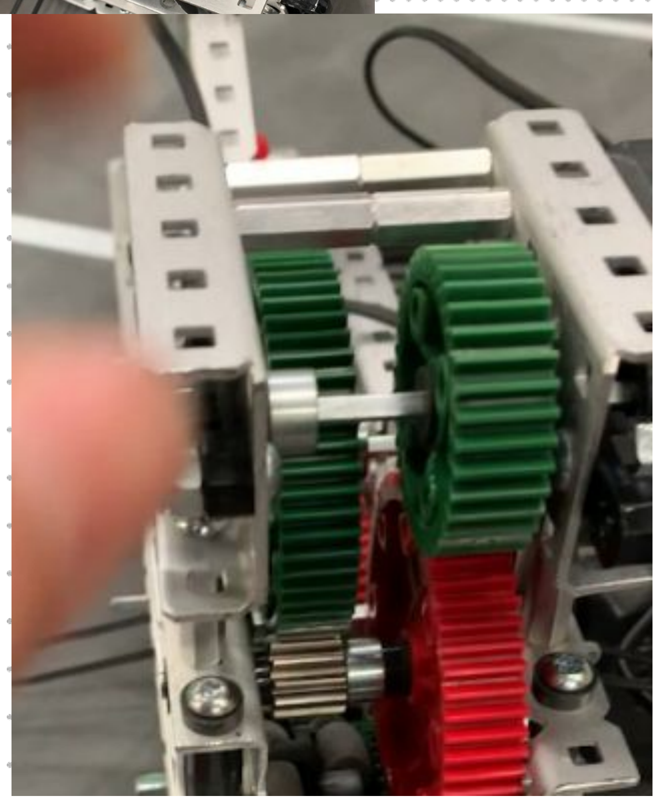
The PTO design was rather simple, the red gear is 60T, in ratio 1:1 to the drivetrain, it is connected on the same shaft to a 12T, which is connected to a 36T gear to a 200rpm motor through an intermediate offset 60T gear (just for the spacing issue).

This gearchain creates the 600rpm needed for the drivetrain from the 200rpm motor, and can be directly mounted to the cata, which used to run at 200rpm directly.





Side view of the gearchain



PTO in drivetrain position

PTO in catapult position

Project

Name Date Page

Project

Name Date Page