Engineering Notebook
Team 8346A

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Team 8346A: *The Lads*
St Helena School, Colchester

A showcase of Team 8346A's knowledge and skills in designing, building, and programming a competitive robot constructed for the VEX Robotics Competition 2021-2022 season, *Tipping Point*.

Contents

1 Introduction

1.1 Team statement

8346A ("The Lads") is a team of two Year 11 students from St Helena School in Colchester, Essex, Seb Jensen and Damian Rusecki. This will be the team's second year participating in the VEX Robotics Competition, having accumulated experience with various VEX Robotics design platforms in the 2019-2020 VRC season and from the VEX IQ Challenge. Previously members of 17089A in the VEX IQ Challenge, the team competed at the UK National Championships twice before progressing to the V5 system.

The competitive VEX Robotics programmes, offered by the Robotics Education and Competition Foundation, continues to engage the team with a variety of challenges to overcome. It is a unique programme and offers opportunities unlikely to be encountered otherwise; the team are unanimous in the benefits of the programme and appreciate the STEM-links embedded throughout.

Accompanying their participation in the VEX Robotics Competition, 8346A dedicates a significant portion of their season volunteering within the community. Students new to the robotics design platforms have been mentored by both team members and there is considerable involvement in VEX IQ Challenge events. The team have hosted RECF qualifying regional events for up to 30 teams as well as travel to other regional events to offer assistance.

8346A is looking to achieve its best results in the 2021-2022 season, and hope you will see this reflected in the engineering notebook - a showcase of the team's knowledge and skills in designing, building, and programming a competitive robot.

1.2 Profiles and roles

Seb Jensen

Seb started with VEX IQ in Year 6 with the 2016-2017 Crossover season. Ever since, Seb has been building robots, attending events, volunteering at events and even organising them. Since transitioning to the VEX EDR platform, he has began to host qualifying VIQC events for up to 30 teams. He is the programmer of the team, focusing on autonomous and innovative means of making driver control more efficient.

Damian Rusecki

Damian started with VEX IQ in Year 7 with the 2017-2018 Ringmaster season. He has since been working with Seb, progressing with them into the VEX Robotics Competition. He's a talented builder and quick to come up with solutions to tackle the challenges set each seasons. Consequently, he will be focusing on building the robot this year and developing strategies for application on the field.

1.3 Engineering design process

The engineering design process influences the team at every step of the season, helping us to keep organised and work efficiently. It will be adapted and referenced by 8346A in the digital engineering notebook throughout the season. The largest part of the design process is the continual iteration of the cycle, and this will be demonstrated over the course of the season in our digital engineering notebook.

The engineering design process is not something done once. We will be working through the stages throughout the season to tackle a large number of challenges from design to game strategy.

1.3.1 Ideate

The process of ideation requires an understanding of the challenge, exploring it and defining the goals with specification, and then formulating solutions. Every challenge has many solutions, although some are obviously better than others, and we as a team need to find the most efficient solution meeting specifications and time and effort constraints.

Part of ideation is exploring how others have tackled the challenge. We make use of and cite a plethora of online resources where other teams facing similar challenges share their approaches. We can take on board and consider their experience as if it were our own, and when we discover a new solution, we will endeavour to share this with the competitive robotics community.

We will need to produce specifications for the solution for the challenge. This focuses on what the solution will accomplish, before describing how this will take place. Both design constraints and functional requirements will be considered, and specifications should be ranked based on wishes, preferences, and demands. After doing so, we can determine how we will approach the challenge by listing a variety of solutions and selecting the most appropriate.

1.3.2 Implement

This is where the team takes one or more of their concepts from the previous stage and produces functional versions of them. In doing so, we can see how each concept functions in 'real life' and interacts with the rest of the robot and its environment. We will have made an educated choice, often with a decision matrix, and will be able to proceed with implementing our chosen solution to the robot.

We will document the implementation of the solution and our initial findings before any significant testing which is to inevitably follow.

1.3.3 Evaluate

At this point, we will have implemented a solution and will be able to gather valuable data about how effective it is. We will be able to determine where or not the final implementation performs as expected and fulfils the specifications. Ideally, we should know how the robot will function and perform before we take it to a competitive match.

Should the solution not meet the demands set out in the specification, we will return to stage 2 to implement an alternative solution presented in the process of ideation.

1.3.4 Keywords and steps

1. Understand
2. Explore
3. Define
4. Ideate
5. Prototype
6. Choose
7. Refine
8. Present
9. Implement
10. Test
11. Iterate

1.4 Notebook

Typeset with LaTeX using Overleaf for its included Git and version-control functionalities. The notebook is split into cycles for clear and chronological organisation. One cycle is the period of time until the forthcoming competition; the lengths of such will vary considerably. You can find a table of contents at the beginning of the document.

Documenting each session and advancement is a collaborative effort between Seb and Damian.

2 Cycle 1

We are registered to compete in a regional tournament at Greig City Academy in London on 6 November, 2021.

2.1 Game outline

Date	13 September, 2021
Documented by	Seb Jensen
Verified by	Damian Rusecki

The 2021-2022 VEX Robotics Competition season, Tipping Point, is played on the 12 foot by 12 foot VEX field with 4 teams per tournament match, 2 for each alliance, red and blue. This game features elements of gameplay similar to previous VRC seasons, such as In The Zone. Consequently, we will be able to harness the knowledge and experience of previous VRC teams to aid us as we iterate the design process. The aim of Tipping Point is to score as many points as possible by manipulating the game elements, more so than the opposing alliance to win the match.

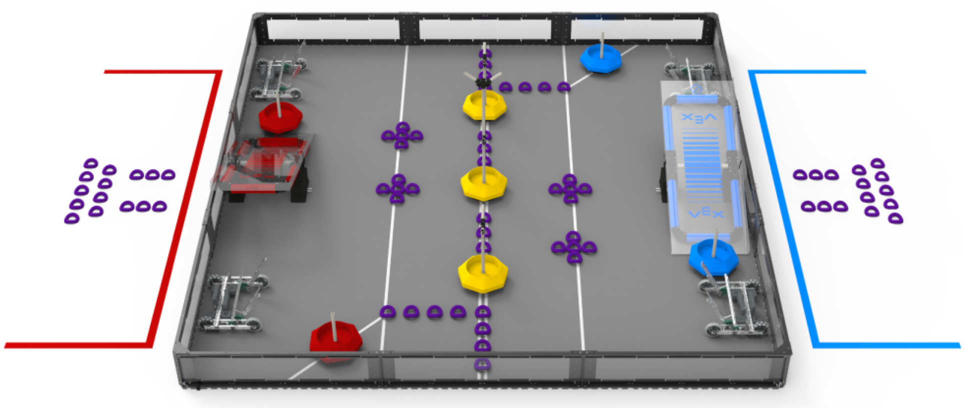


Figure 1: field layout for Tipping Point

2.1.1 Game elements

- 72 rings
- 3 neutral mobile goals
- 4 alliance mobile goals
- 2 alliance platforms

2.1.2 Scoring points

Objective	*Points*
Each Ring Scored on a Neutral Mobile Goal High Branch	10 Points
Each Ring Scored on any other Mobile Goal Branch	3 Points
Each Ring Scored in a Mobile Goal Base	1 Point
Each Mobile Goal Scored in an Alliance Home Zone	20 Points
Each Robot that is Elevated	30 Points
Each Mobile Goal that is Elevated	40 Points
One Ring scored on / in each Alliance Mobile Goal and a Cleared AWP Line in Autonomous	1 Win Point

2.1.3 Game format

VEX Robotics Competition Tipping Point can be played in 2 ways at the MS/HS level. This is unchanged from previous seasons.

Tournament matches Tournament matches form the bulk of qualifying events we will be participating at. These are formed of 4 teams, two in the blue alliance and two in the red alliance. The aim is to win by scoring more points than the opposing alliance.

Some competitions will offer practice matches, others will not. These precede the qualification matches which are featured at all RECF qualifying competitive events. Qualification matches feature a 15 second autonomous period in which the robots carry out a program, followed by a 1:45 driver control period operated by a single driver.

Each team will play several times in pursuit of WP, AP, and SP, described as follows, and which determine their place in the qualifying rankings.

- **WP** Win Points
  First basis of ranking teams
  - Two WP awarded for winning a qualification match
  - One WP awarded for tying a qualification match
  - Zero WP awarded for losing a qualification match
  - One WP is awarded upon earning the Autonomous Win Point
- **AP** Autonomous Points
  Second basis of ranking teams
  - Six AP is awarded for winning the autonomous bonus in a qualification match
  - Three AP is awarded for tying the autonomous bonus in a qualification match
  - Zero AP is awarded for losing the autonomous bonus in a qualification match

- **SP** Strength of Schedule Points
  Third basis of ranking teams
  - Equivalent to the score of the losing alliance in a qualification match
  - When tied, both alliances receive SP equivalent to the score

After all qualification matches are played, final rankings are determined prior to alliance selection. The highest ranking teams select their alliance partner first, to which the recipients of the invite must accept or decline. Finals matches are then played in a classic elimination bracket format with a blend of Best of 1 and Best of 3 games depending on the event format.

Robot skills Robot skills are less commonly offered at events, and are different to how tournament matches are played. It is important to be able to maximise our opportunities where the skills challenge is offered and that requires an understanding of how this format differs from tournament matches.

Matches are 1 minute long and there are both driver skills matches and programming skills matches, requiring driver-only and autonomous-only control, respectively. Robot skills matches are scored differently to the primary game, and this is something we will be investigating in later sessions.

2.2 Challenge specification

Date	15 September, 2021
Documented by	Seb Jensen
Verified by	Damian Rusecki
Engineering design process	Define

- Critical - The robot *must* achieve this criteria
  - Maneuver mobile goals around the field
  - Place rings upon small alliance mobile goals
- Preferred - We *would like* the robot to achieve this criteria
  - Reach low branches (2̃2 inches)
  - Get mobile goals elevated on platform for 40 point bonus
  - Win autonomous bonus for six AP with 15-second auton routine
- Wishes - *Minor additions* we would like to *consider*
  - Get robot elevated on platform for 30 point bonus
  - Reach highest branches (4̃0 inches)

Figure 2: alliance and neutral mobile goals

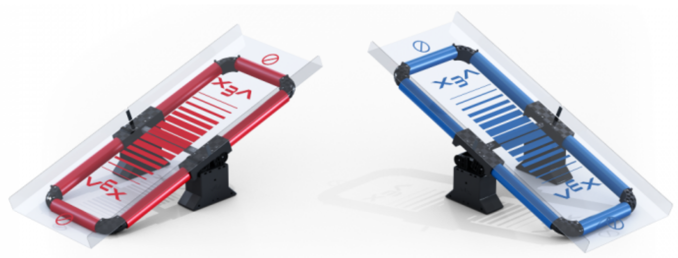


Figure 3: alliance platforms

2.3 Initial ideation

Date	16 September, 2021
Documented by	Seb Jensen
Verified by	Damian Rusecki
Engineering design process	Ideate, explore, choose

2.3.1 3D printing elements

St Helena School has numerous 3D printers available, and we were able to utilise one of these to print a ring. CAD files for VEX Robotics Competition Tipping Point can easily be obtained through the VEX Robotics website. A .STEP file of the full game field can be downloaded, and we extracted a ring from the file and had it set up to print.

Due to their shape, we had to print the rings in two halves before glueing them together. The rings, as shown below, are not flat, and this full object would have been considerably more complex to print.

Figure 4: a 3D printed ring

2.3.2 Exploring

VEX Robotics Competition seasons begin and end around April each year, however, we only began our season on the 13th of September. Consequently, there is a plethora of community robot designs and game strategies already published online. A particularly useful resource is the official VEX Forum, and team members have made significant use of this site in previous seasons to give and get help.

Hero bot VEX Robotics publishes a 'hero bot' for each season. These are robots (with instructions included) designed to take on the season's challenge and play at a relatively low competitive level. We opted for a hero bot for the 2019-2020 season, which was met with mild success, and we'll be considering it as a starting point for further development.

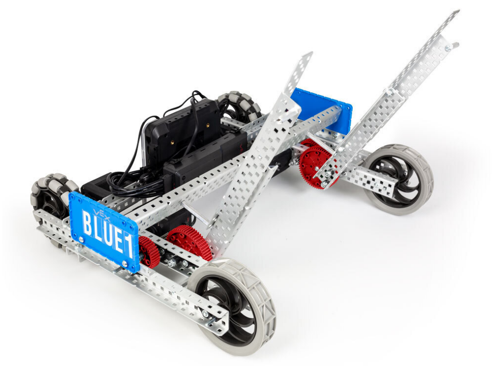


Figure 5: *Moby*, the 2021-2022 Hero Bot

This robot design focuses on manipulating mobile goals only, and so a game strategy would need to be designed around such limited capability. It meets only one of the critical criteria set out in the specification, which is to manoeuvre mobile goals. It would prove to be excessively tedious to manipulate rings in that it would require the rings to be carried on the arms, and this does not seem intended.

It is also worth considering that this robot should easily get atop of the alliance platform to elevate itself for 30 additional points at the end of the game. As it can move the mobile goals, it may be possible for this design to score the 40 point bonus for a mobile goal elevated on the platform. The robot could mount the platform while carrying a mobile goal to achieve this, and in doing so would satisfy two additional criteria listed on our specification.

DR4B with ring intake and passive mobile goal intake Demonstrated initially by 2616J in their R13D reveal video, this design, as pictured in the figure below, features both a ring intake attached to a DR4B and a passive mobile goal intake. Consequently, this design would satisfy most, if not all, of our criteria listed in our design specification.

The defining characteristic of this robot design and its accompanying strategy is the "Double Reverse 4 Bar", otherwise known as a DR4B. It is named as such due to the construction consisting of two 4-bar arm mechanisms, the bottom of which is reversed, that have been coupled. Mobile goals are manoeuvred with a passive intake attached to the back of the DR4B; rings are stored in a container attached to the top of DR4B.

To collect rings there is a conveyor intake system at the base of the robot. This guides the rings up a lift and into the container atop the DR4B. In order for rings to be deposited successfully, the DR4B must be in its lowest position. Following this, the container is lowered above a branch and the robot reverses to remove the rings from its intake.

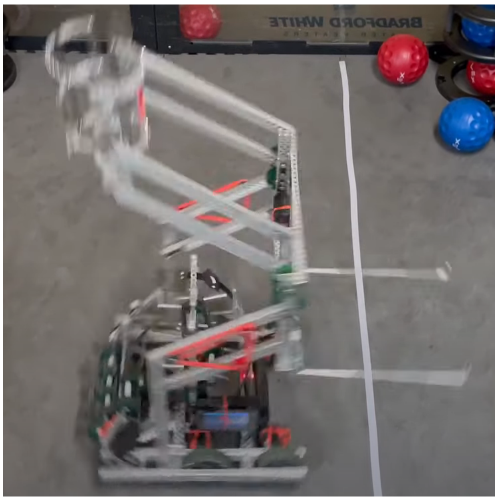


Figure 6: 2616J demo, DR4B extended, mobile goal intake deployed

Despite satisfying all our requirements on paper, we may experience some issues regarding structural integrity. 2616J's demonstration of this design is a "RI3D", suggesting that less time would have been spent during the planning phase. Most notably, the passive mobile goal intake may need to undergo considerable refinement to reliably manoeuvre mobile goals without tipping and other such issues.

4 bar with mobile goal intake This design, previously constructed, tested, and published by 38141B, focuses on the movement of mobile goals across the game field. It achieves this through the use of a 4 bar lift complemented by a claw mechanism at the end. This design serves as an intermediary between the Moby starter hero bot and the considerably more sophisticated DR4B + ring intake design.

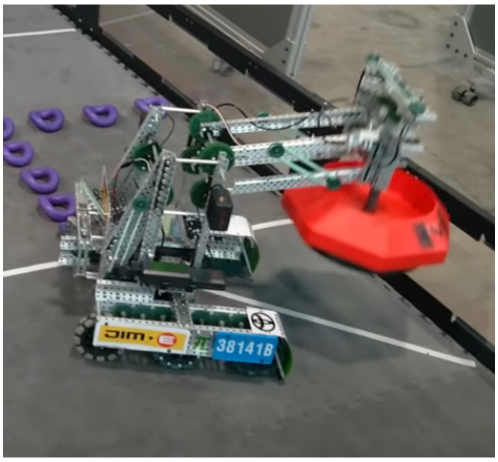


Figure 7: 38141B's application of a 4 bar and mobile goal design

The only time this robot would be capable of collecting and possessing rings is at the beginning of the match with the preload. Otherwise, this robot's only means of scoring is by collecting and elevating alliance and neutral mobile goals. This, however, still makes for valuable game strategies - elevating five mobile goals on the alliance platform scores 200 points in total. This would be accompanied by 3 (relatively insignificant) points for depositing the preload rings in the base of an alliance goal.

Importantly, this design's reliance on the mobile goals around the field poses a large disadvantage. In the last 30 seconds of the driver control period, otherwise known as the 'endgame', platforms are protected and cannot be touched by the opposing alliance's robots. By this point, this robot would have little impact on gameplay as it cannot go and steal elevated mobile goals from the opposite platform. This rule reads as follows:

> **<SG3>** - Platforms are "safe" during the endgame. During the last thirty (30) seconds, Robots may not contact the opposing Alliance's Platform. For the purposes of this rule, contact is considered "transitive" through other Robots and Scoring Objects. For example, contacting an opposing Robot who is contacting their own Platform would be considered a violation of this rule.

In terms of the challenge specification previously laid out in the engineering notebook, this design would satisfy both critical demands. It's ability to place rings on small alliance mobile goals is questionable due to it only being possible with the preload, however, it does meet this criterion. This robot cannot interact with any branches, but could possibly win the autonomous bonus with a routine crafted for this design.

What is a "RI3D"? A RI3D is a "robot [built] in 3 days". RI3Ds are challenges undertaken by numerous teams participating in the VEX IQ Challenge and VEX Robotics Competition. The challenge is not just limited to three days either, with some teams attempting to build functioning and competitive robots in just under 24 hours.

8346A has no plans to take on the RI3D challenge, at least for this design cycle. We may revisit this idea later as the season progresses, but we will be maximising the time available to us to prepare a functioning robot for our first competition on the 6th of November.

2.3.3 Selecting a solution

Specification	*Points Value*
Demand	1 Point
Preferred	2 Points
Wish	3 Points

Although the above method of weighting each specification category may initially seem nonsensical, we believe that a design is much better if it can satisfy wishes/non-critical criteria in the specification. We don't choose to weight demands more greatly as these are expected to come as standard.

Design	*Critical*	*Preferred*	*Wishes*	*Total*
Hero Bot	1 of 2	2 of 3	1 of 2	8 pts
DR4B w/ Ring Intake, Passive Mogo Intake	2 of 2	3 of 3	2 of 2	**14 pts**
4 Bar w/ Mogo Intake	2 of 2	2 of 3	1 of 2	9 pts

The second of the three solutions matches all of the criteria laid out in our challenge specification; we will be proceeding with this design for our first robot design and strategy.

2.4 Drivetrain construction

Date	21 September, 2021
Documented by	Seb Jensen
Verified by	Damian Rusecki
Engineering design process	Explore, choose, implement

2.4.1 Selecting a drivetrain design

There are numerous drivetrain designs for the team to choose from; the most common two designs for drivetrains are the 2- and 4-motor standard drives. These standard designs feature two and four motors, respectively, which are perpendicular to the drivetrain structure.

We have opted for a 4-motor standard drive design due to its superior force and speed capabilities. It is important to note that a maximum of 8 VEX V5 motors can be used on the robot for it to remain competition-legal. Although this design uses half of that allocation without even considering the rest of the robot yet, we consider the bonus of using the power of four motors to be highly beneficial. We can then dedicate the rest of the motor allocation to the DR4B mechanism and ring intake.

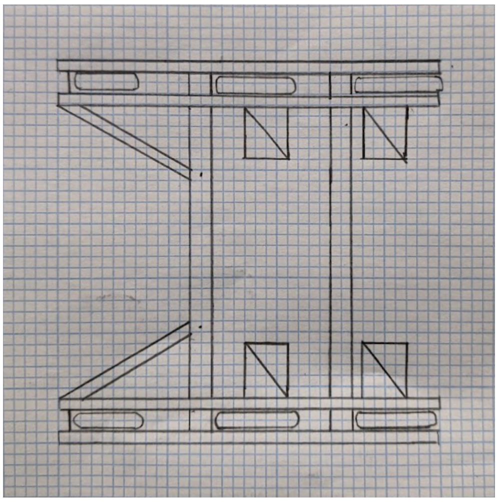


Figure 8: a top-down sketch of the drivetrain design

On either side of the drivetrain are three wheels. It is fronted by 2.75" wheels which are not driven by any motors. They have been included in the design to assist robot stabilisation for when the DR4B mechanism is fully raised. The back two wheels on either side are 4" wheels, which are driven by the motors and will be responsible for the robot's movement. All wheels used are of the 'omni' variant - they are all equipped with smaller rollers on the edge of the wheel to allow for lateral movement. We will not be able to make full use of this functionality as we are not using an X-drive or H-drive, however, it will increase manoeuvrability and agility on the field.

Figure 9: omni-directional wheels offered by VEX

2.4.2 Alternative designs

2- and 4-motor standard drives are not the only options for drivetrain subsystems. The aforementioned X-drive and H-drives are both alternatives. These designs, along with the mecanum drive design, allow the robot to strafe both left and right. Despite their unparalleled manoeuvrability on field, these designs can lack in force and speed, or require an additional motor (H-drive), which is why we have not pursued them.

H-drives are the same as 2- and 4-motor standard drives, however, they're accompanied by a fifth wheel perpendicular to the other four in the centre of the drivetrain. X-drives are unique in that all four wheels are at a 45 degree angle to the frame on all four corners. Mecanum drives require specialised mecanum wheels from VEX, however, they permit diagonal motion on field.

2.5 DR4B construction

Date	27 September, 2021
Documented by	Seb Jensen
Verified by	Damian Rusecki
Engineering design process	Prototype

With the construction of a functioning drivetrain completed and implemented, we have now moved on to developing the Double Reverse 4 Bar mechanism. Despite looking particularly sophisticated, this is, in fact, a relatively simple mechanism to implement, as it is simply formed of two 4-bar arms linked by a middle section.

Damian has been working on its construction, beginning with the middle section that will link the two 4-bar arms. We are aiming to have the robot be able to score rings on the high branches of the highest mobile goal, extending upwards after deployment at the start of the match.

Figure 10: a DR4B design with a prototype cup holder attached

To be able to manoeuvre mobile goals around the field, Damian is adding two beams to the rear of the DR4B on hinges. This means, to be able to stay within the required dimensions at the start of the game, these beams can be folded up. After the DR4B is raised, these will deploy and fold down in order to slide underneath the overhanging outside of the mobile goals. Consequently, when the DR4B is raised again, we will be able to lift the mobile goals to move them around the field and place them atop our alliance platform.

Figure 11: 100 RPM cartridge offered by VEX Robotics

Furthermore, we have used motors with a 100 RPM cartridge as opposed to the standard 200 RPM cartridge that is included. VEX Robotics' motors are modular in that they can be opened to be able to swap cartridges. They offer 100 RPM, 200 RPM (included), and 400 RPM cartridges, all for different use cases. The 100 RPM cartridges rotate much less, but this is a consequence of their higher internal gear ratio, increasing torque. Substantial torque is necessary to allow the lift to raise. On the other hand, a team might use the 400 RPM cartridge for a flywheel, and these cartridges have been particularly useful in previous seasons where balls needed to be flung to toggle posts.

2.6 DR4B construction

Date	30 September, 2021
Documented by	Seb Jensen
Verified by	Damian Rusecki
Engineering design process	Implement

We have finalised the construction of our DR4B lift and prepared to mount it to the drivetrain for testing. Both 4-bar arm mechanisms have been attached to the central gear section of the DR4B and we've braced the lift with a triangular pattern. Bracing larger lifts like DR4Bs is often necessary to support them and allow them to raise with the use of motors only. We've added protruding screws to attach rubber bands in a triangular pattern on the bottom 4-bar. If necessary, we can also brace the top section.

The lift is attached to the front of the robot and, when lowered, rests on the wheels at the back of the robot. Our aforementioned solution to manoeuvre mobile goals around the field has also been implemented at the back of the robot. At this stage, however, we are unable to test if it will be sufficient to lift one of these mobile goals, and will be one of the first things investigated in testing, beyond the basic robot functionality.

The next steps will be to construct our ring intake; this will need to integrate directly with the cup that will sit at the top end of the DR4B. A roller mechanism will take in rings to be picked up by our chain lift, supported by a polycarbonate sheet backing. These two components will be independent of the lift. However, the cup for collected rings to sit in will be directly attached to the DR4B and will need to be designed to fit within size regulations at the start of the match.

Despite being the most prominent mechanism on the robot, the DR4B was relatively simple to implement and is now pending testing once we complete the other subsystems.

2.7 Ring intake construction

Date	5 October, 2021
Documented by	Seb Jensen
Verified by	Damian Rusecki
Engineering design process	Implement

The ring intake system is formed of three critical components:

1. Roller intake
2. Chain lift
3. Ring cup

2.7.1 Roller intake

The roller intake is crucial, in that it effectively 'sucks' the rings into chain lift. As the robot approaches rings across the field they are immediately taken in by a rotating roller to make the collection process seamless. This eliminates the tedious activity of having to push rings into the field perimeter in order to get them into the chain lift. We are making use of the clear polycarbonate sheet flags from the VEX Robotics Competition *Turning Point* season to help guide the rings into the chain lift.

The roller intake and chain lift are operated together, with the power from the motor also rotating the chain to move the chain lift.

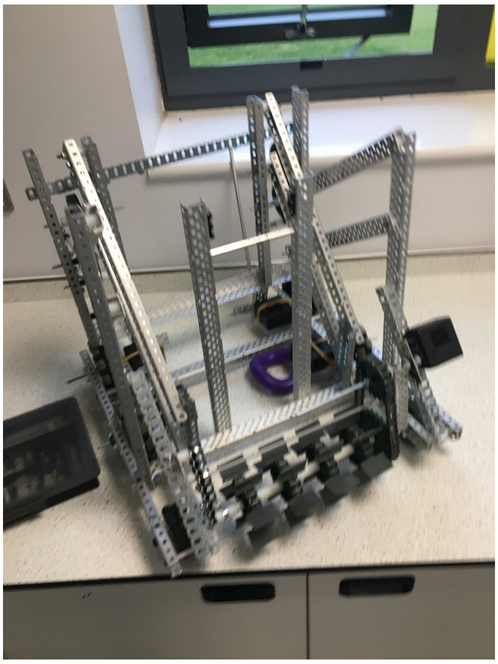


Figure 12: our design for a roller intake

2.7.2 Chain lift

After the rings have been collected by the roller intake, they are lifted to the top of the robot by the chain lift. We have attached standoffs to the chain that stick through the middle of the ring and carry them up the lift. This mechanism is backed by a polycarbonate sheet to prevent the rings from falling off the back of the robot and becoming inaccessible. We are, however, limited in the amount of polycarbonate we are allowed to use on the robot.

We purchased an A3 sheet of the material and have cut that into two sections. These cover both the bottom and upper sections of the chain lift and are attached at the back after having drilled two holes in them to fit screws. At the bottom of the robot we have had to bend the aluminium c-channel in the centre to accommodate for the polycarbonate sheet.

It is important to note that once we have the robot in a state that it can be programmed, the motors will rotate at a significantly higher speed than what we are able to test with by manually moving the chains to raise rings and test the system. We will need to account for this in extra testing.

Figure 13: our chain lift for elevating rings into the ring cup

2.8 Ring intake construction

Date	5 October, 2021
Documented by	Seb Jensen
Verified by	Damian Rusecki
Engineering design process	Implement

The ring cup is part of the robot we've been able to work on and be able to implement later, as opposed to having to construct it on the robot. We'll be looking to add this to the top of the DR4B in the next session as we have finalised the DR4B design today.

We're using the polycarbonate sheet as shown below at the rear of the chain lift to support the rings as they are moved up the lift.

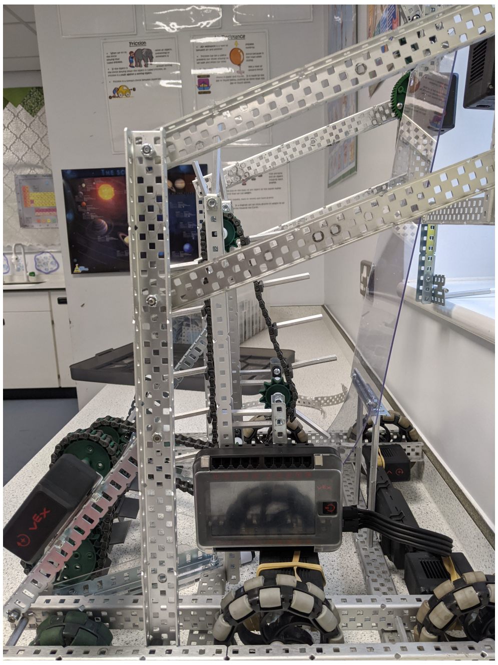


Figure 14: a cut-down sheet of polycarbonate

We'll be interested to see how efficiently the chain lift functions after the robot is (hopefully) fully functional. We aim to be able to test it by the end of this first school term. This means we will be working towards a deadline of 22 October.

2.9 Testing and evaluating

Date	15 October, 2021
Documented by	Seb Jensen
Verified by	Damian Rusecki
Engineering design process	Test, evaluate

We are using VEXcode V5 Pro to program the robot in C++. I (Seb) have created a standalone driver control program that can be used to test. We have tested the functionalities of the following subsystems:

- Drivetrain
- DR4B
- Roller intake
- Chain lift
- Ring cup

2.9.1 Drivetrain

Criteria	*Pass*	*Notes*
Forward motion	Pass	
Turning on spot	Pass	
Turning in motion	Pass	
Supports robot weight	Pass	No considerable flexing

2.9.2 DR4B

Criteria	*Pass*	*Notes*
Raises beyond initial state	Fail	
Reaches high goal height	Fail	Failed due to first criteria

2.9.3 Roller intake

Criteria	*Pass*	*Notes*
Intake	20/20	Passed 20 of 20 times tested
Transition to chain lift	16/20	Passed 16 of 20 times tested, occasionally stuck with little gap between plastic and standoff

2.9.4 Chain lift

Criteria	*Pass*	*Notes*
Transition from roller intake	16/20	Passed 16 of 20 times tested, occasionally stuck with little gap between plastic and standoff
Ring elevation to top of lift	19/20	Passed 19 of 20 times tested, fell off back polycarbonate sheet
Ring ejected from lift	20/20	Passed 20 of 20 times tested

2.9.5 Ring cup

We have opted against spending any further time in implementing the ring cup due to the critical failure of the DR4B mechanism.

2.9.6 Conclusion

We have categorically determined that the current robot design we are finalising has failed to meet some of the criteria we laid out in the challenge and design specification. We will be discussing an urgent plan of action at our next meeting. It has been agreed that we would prefer to make any reasonable modifications to ensure the robot is capable of scoring points consistently as opposed to having more capability but only being able to score points half of the time.

2.10 Revised robot design

Date	18 October, 2021
Documented by	Seb Jensen
Verified by	Damian Rusecki
Engineering design process	Ideate, implement

The root cause of our troubles lies with the DR4B mechanism we implemented. We have acknowledged that the competition is on the 6th of November and our school half-term holidays are very soon, leaving us with very little time to make any large modifications to the current design.

As such, we have discussed and chosen to remove the DR4B mechanism in favour of a very simple arm that will be inspired by the Hero Bot we investigated when originally choosing designs. The arm should tilt one of the small mobile goals and allow us to score rings on the top using the same chain lift system.

Damian focused mainly on constructing and implementing the near arm mechanism, while I was able to take off the polycarbonate sheet that was being used for the chain lift. For the 2 bar arm lift, we were still able to use the 100 RPM motor cartridges for the sake of torque.

He was quick to complete the design due to its overwhelming simplicity, as you can see in the figure below. Once done, Damian and I worked to reinforce the drivetrain as we determined it would be relatively high-maintenance during the tournament. We added wider steel and aluminium c-channels, ensuring its design is a lot more robust and reliable. Self locking nuts have been used as opposed to keps nuts to keep it secure.

We are confident that this modification will allow us to score a large number of points consistently as opposed to having a DR4B that would have proven difficult to work with.

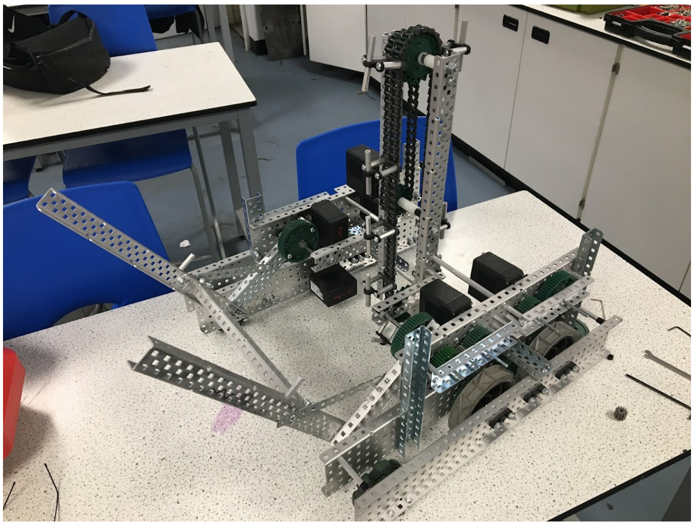


Figure 15: the DR4B has been removed and a 2 bar arm lift constructed

2.11 Autonomous routine

Date	21 October, 2021
Documented by	Seb Jensen
Verified by	Damian Rusecki
Engineering design process	Define, ideate, implement

To ensure we still are able to satisfy a desired criterion laid out on our challenge specification earlier last month ("contribute to winning autonomous bonus with 15-second auton routine"), we have set out on programming a very simple autonomous routine.

As has been previously detailed, a tournament match is formed of a 15-second autonomous period at the beginning, followed by one minute and forty five seconds of driver controlled teleoperation. You can gain an additional six points for the match (as well as six AP) by having the highest score by the end of this period.

We are using VEXcode Pro V5 to program the robot which is a tool officially supported by VEX Robotics. It will allow me, Seb, as the programmer to code in C++, which I have used for other projects involving microcontroller technologies. It is contained within the same Monaco integrated development environment that professional programmers use in the industry. There are alternatives, such as VEXcode Blocks for V5, which creates a more accessible graphical means of programming a robot, but these options lack features and do not prove suitable for us.

Our strategy is simple - launch forwards to the centre line of the field, rotate the front mobile goal lift, and return back to our home zone. This will count for 20 points by the end of the autonomous period if executed successfully. Provided we position the robot correctly at the start of the match, we will be able to run this very simple routine from any starting point. This results in added flexibility with our alliance partner.

By making an effort to program this, we will be able to score against other teams who have not. It is a straightforward program, but we will just need to iteratively test it when we have access to a full-sized field on the day.

```cpp
int main() {
  vexcodeInit();

  // Setting up the mobile goal lift motors
  Lift.setStopping(hold);
  Lift.setMaxTorque(100, percent);

  // Set timer to 0, to time the duration of the following routine
  Brain.Timer.reset();

  // Drive towards the centre line of the field
  Drivetrain.driveFor(forward, 1190, mm);

  // Reduce speed for last distance, to prevent momentum from knocking away mobile goal
  Drivetrain.setDriveVelocity(25, percent);
  Drivetrain.driveFor(forward, 100, mm);

  // Reset drivetrain velocity for subsequent driver control period
  Drivetrain.setDriveVelocity(100, percent);

  // Pick up mobile goal, reverse to home zone, reset lift positioning
  Lift.spinFor(reverse, 45, degrees);
  Drivetrain.driveFor(reverse, 800, mm);
  Lift.spinFor(forward, 45, degrees);

  // Print time taken to complete autonomous routine
  Brain.Screen.print(Brain.Timer.value());
}
```

Figure 16: autonomous sequence

To ensure both myself and Damian can easily refer to specific parts of the program and understand what they do in future, I am extensively using commenting. This is an industry standard practice to ensure code maintainability and increase accessibility for members of teams inexperienced with programming.

2.12 Programming for competitions

Date	4 November, 2021
Documented by	Seb Jensen
Verified by	Damian Rusecki
Engineering design process	Define, implement

VEX Robotics Competition tournaments are run with additional hardware to communicate with robots, enabling the organisers to trigger autonomous and driver periods as well as disable robots when the match comes to an end. All this gear is encompassed by the 'VEXnet Field Controller Kit' and is standard at every qualifying VRC event.

When we come to the field, we have to plug our controller into a driver interface. This is connected to the device running the tournament to start and stop the matches. To allow our robot to run the 15-second autonomous routine that has been programmed already, we need to ensure that the program is compatible with the hardware.

This is simple to set up with a competition instance in the code. From there, we need to add functions for pre-auton, auton, and driver control. The pre-auton function is called when the controller is connected to the driver interface and the program is run.

This code also works if you are not plugging into the driver interface. If you are not at a competition, the program will jump straight to the driver control section.

On the next page is an example of this code, and I have already implemented the 15-second autonomous routine to start at the beginning of the match.

```cpp
competition Competition;

void pre_auton(void) {
  vexcodeInit();

  // Setting up the mobile goal lift motors
  Lift.setStopping(hold);
  Lift.setMaxTorque(100, percent);
}

void autonomous(void) {
  // Set timer to 0, to time the duration of the following routine
  Brain.Timer.reset();

  // Drive towards the centre line of the field
  Drivetrain.driveFor(forward, 1190, mm);

  // Reduce speed for last distance, to prevent momentum from knocking away mobile goal
  Drivetrain.setDriveVelocity(25, percent);
  Drivetrain.driveFor(forward, 100, mm);

  // Reset drivetrain velocity for subsequent driver control period
  Drivetrain.setDriveVelocity(100, percent);

  // Pick up mobile goal, reverse to home zone, reset lift positioning
  Lift.spinFor(reverse, 45, degrees);
  Drivetrain.driveFor(reverse, 800, mm);
  Lift.spinFor(forward, 45, degrees);

  // Print time taken to complete autonomous routine
  Brain.Screen.print(Brain.Timer.value());
}

void usercontrol(void) {
  // Code to be run when the driver control period begins
  while (1) {
    // Code to be continually run throughout driver control

    wait(20, msec); // Reduces resource wastage
  }
}
```

Figure 17: autonomous sequence for competitions

Comments have been retained and I have also added comments in the driver control function just so others viewing the code understand its purpose while it is empty.

2.13 Competition review

Date	8 November, 2021
Documented by	Seb Jensen
Verified by	Damian Rusecki
Engineering design process	Review

A look at our performance at the regional competition at Greig City Academy in numbers:

- 9th of 19 teams in qualification matches
- Finished as quarter finalists in the elimination bracket
- 4 wins, 0 ties, 4 losses
- 5 autonomous wins
- Total SP: 575
- Highest score: 157

That's the quantitative data - but how does that translate to our experiences?

Well, we had a successful day with a lot the team can be proud of. Despite the considerable set-back observed when we tested and evaluated our initial design, we were still able to compete in all of our qualification matches. We reaped the benefits of a robot we knew we could rely on to consistently score low points, rather than have a temperamental design that was only able to score highly half of the time.

We were the first team to arrive at the venue, giving us plenty of time to use the practice field by ourselves. With this, we perfected the autonomous routine I programmed before the competition. We only had to make a couple of adjustments to measurements before it was working consistently. We were able to win the bonus six points in five separate matches for having the highest score at the end of the 15-second autonomous period. This was mostly the case when our alliance partner had a similar autonomous routine, or where our opposition had none.

We were proud to have achieved four wins out of the eight games we played, especially considering the high total strength of schedule points. This meant that our opposition was strong on average and yet we were still able to counteract their ability. By the end of qualification matches, we had placed ninth out of the nineteen competing teams.

However, our successes did not continue through to the elimination bracket. This is largely due to how the higher seeded alliances are matched with the lower seeded alliances, and as such we were promptly eliminated in the quarter finals.

We just could not compete with the robots that had the capability to lift mobile goals onto the alliance platform and then park on it. These are worth 40 and 30 points, respectively. This quickly makes for a lead in a match that cannot be rivalled by a robot like ours, limited to small mobile goals on the floor.

It is important that we do not see this as a failure, though - rather, it is a part of the engineering design process and we must now iterate our process once more. We will designate the lifting and balancing of mobile goals on the alliance platform as a target for improvement and will reflect that in our next robot specification. We intend to shake up the design of our robot considerably in the coming months before our next competition.

In this evaluation, we have already laid out our strengths and weaknesses from the tournament, and in doing so we have also established some targets. We look forward to what we are able to achieve next time round. After all, there's always room for improvement.

3 Cycle 2

Our next competition is at our own school, St Helena, on 15 January, 2022.

3.1 Revised specification

Date	12 November, 2021
Documented by	Seb Jensen
Verified by	Damian Rusecki
Engineering design process	Define

In the review of our performance at our first competition at Greig City Academy in London we identified our inability to balance mobile goals on the alliance platform and have possession over multiple of such to be our main areas for improvement. We have decided to re-evaluate our robot specification, now that we have seen the more prominent strategies and responses to the design challenges posed by this season's game.

There is greater emphasis on being able to lift up mobile goals. There is also the inclusion of our desire to be able to manoeuvre two mobile goals simultaneously to reduce the amount available for the opposing alliance to take control of. Some criteria from the original robot specification laid out in our first cycle has been removed having seen its insignificance in the region at the competition.

Our successes in terms of programming were also great to see at the competition - we won the bonus six points in five of the eight matches we played. As such, we have elevated this from being a desired feature to one that is a necessity. In doing so, there will be a focus on ensuring we maintain that performance and expand our capabilities.

- Critical - The robot *must* achieve this criteria
  - Maneuver mobile goals around the field
  - Get mobile goals elevated on platform for 40 point bonus
  - Contribute to winning autonomous bonus for six AP with 15-second auton routine
- Preferred - We *would like* the robot to achieve this criteria
  - Get robot elevated on platform for 30 point bonus
  - Place rings on small alliance mobile goals
- Wishes - *Minor additions* we would like to *consider*
  - Reach low branches (2̃2 inches)

3.2 Selecting a lift mechanism

Date	16 November, 2021
Documented by	Seb Jensen
Verified by	Damian Rusecki
Engineering design process	Explore, choose

We have elevated the priority of a criterion on our robot specification. Namely, the ability to raise mobile goals and balance them on the alliance platform for a 40 point bonus. Doing so should result in a massive boost in the points we can score in a match, without having to rely so much on our alliance partner as we did at the competition at Greig City Academy. At that competition we saw a lot of focus on being able to lift mobile goals, making this a strong strategy to target.

There are various lift designs that we could target. We, of course, still have the simple 2 bar lift on the reverse of the robot. This new lift mechanism will complement our pre-existing lift and will consolidate our ability to manoeuvre (multiple) mobile goals across the field. In today's session we investigated three as detailed below.

3.2.1 Scissor lift

A scissor lift is built, as demonstrated below, with overlapping beams that open and close like scissors, hence its name. The more bars added, the more 'stages' the lift has and, of course, the higher it can reach. It extends with two or more motors on either side of the lift rotating across a track. The closer the motors get to the stationary end, the more the lift will extend.

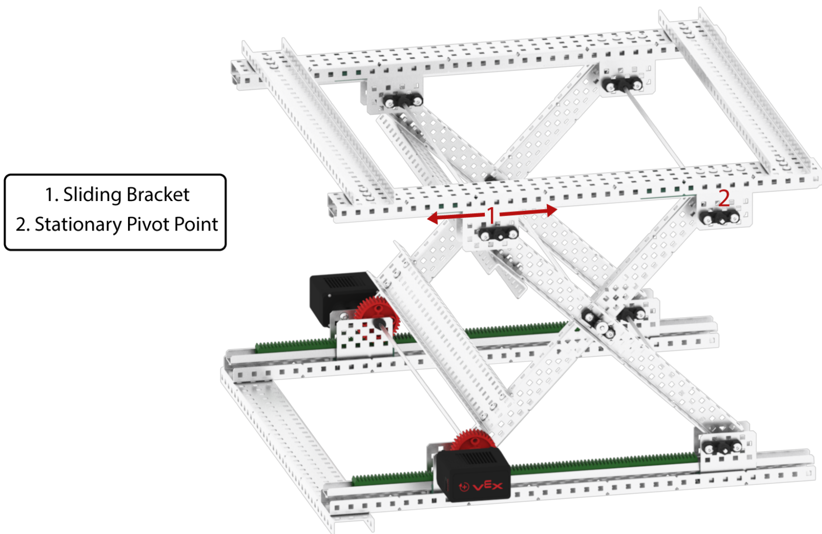


Figure 18: example of a scissor lift (source: VEX Knowledge Base)

The most compelling reason to utilise a scissor lift design is down to the positioning of weight on the robot. As the lift extends directly upwards, it helps the robot to remain stable and not begin to tip, or in other words, "wheelie", as the momentum pushes the robot once it stops. It is also very collapsible, making it very compact. You can create a high extending scissor lift fit in much less space than a DR4B design.

Scissor lifts, however, require precise calibration for them to work effectively; both sides of the lift must be synchronised in their movement. Otherwise, the lift will start to bend while it rises. Furthermore, while the heavy centralised weight of the design would be good in preventing any tipping, it would make it very difficult for us to climb and balance on the ramp. This is a desired criterion on our robot specification.

3.2.2 Four bar

The four bar design is arguably the simplest of the three we're detailing. It is constructed of two sets of parallel bars which have a synchronised up and down movement. The design ensures that the attachment at the end of the lift remains parallel to the structure.

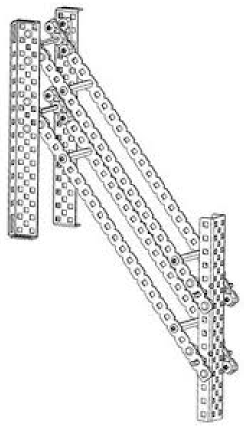


Figure 19: example of a four bar lift (source: VEX Forum)

The main advantage of this design is its ease to build, while being particularly useful in how the attachment (we plan on adding a clamp of sorts) remains parallel to the rest of the robot's structure. The design is very reliable, and once constructed, will require minimal maintenance, less than the other two designs.

The main disadvantage of the four bar is how the centre of gravity then extends outwards, making it more likely to tip when the robot drivetrain is stopped suddenly. There will be no reasonable way for us to recover our robot if it tips in the middle of a match and then we will not be able to assist our alliance partner. Additionally, the simple design means that the height at which it will be able to extend to will be limited.

3.2.3 Six bar

The design of a six bar is largely the same as that of a four bar lifting mechanism. It is merely an advancement of such and achieves the same with the attachment remaining parallel to the structure at all points.

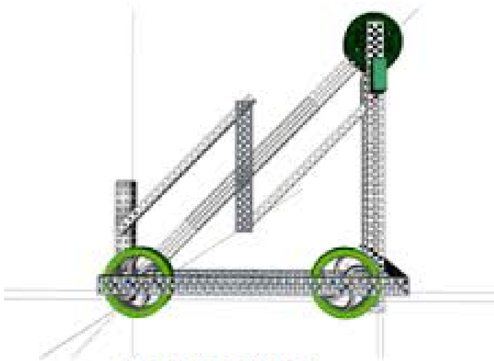


Figure 20: example of a six bar lift (source: VEX Knowledge Base)

The advantages of a six bar and four bar lift are shared mostly. The only difference is that a six bar lift will be able to reach higher. It is still relatively easy to build and once it is, is particularly low maintenance and reliable.

The issue of the centre of gravity is exacerbated on a six bar lifting mechanism, though. As it is able to extend further forwards, there will be an increased risk of our robot tipping in the middle of a match. To raise a six bar lift we will need more torque, which will require increasingly complex gearing as well as the use of two 100rpm red motor cartridges. It will also be important to ensure that the same force is applied to both motors simultaneously to avoid bending and stresses.

* * *

We are not considering the double reverse 4 bar design that we originally pursued. While it was discussed, we thought the above designs to be much more desirable in their own respects. It would not be appropriate of us to attempt a design that we could not guarantee would bring us success, and is not very common across the UK.

3.2.4 Selecting a lift mechanism

Having investigated the three aforementioned lift designs, we determined that the most logical pathway would be to pursue a four bar mechanism.

- It is very easy to build, and we have used four bar lifts in the VEX IQ Challenge in the past. We are acquainted with this design.
- We can rely on the design to work consistently. Once it is built there will be little maintenance that we will need to conduct between matches.
- The end of the lift will remain parallel to the structure at all times. This will be especially beneficial in getting mobile goals to balance on the alliance platform.

We have chosen this design over the others, because:

- It is not as heavy as a scissor lift, meaning that we will be able to drive the robot onto the ramp to balance. The centre of gravity is also not as far out as an extended six bar, meaning that the likelihood of tipping is, while still present, lessened.
- Scissor lifts require plenty of maintenance and precise tuning to ensure they operate effectively and reliably. We need to be able to expect consistent results.
- A six bar lift is constrained more by the initial 18 inch cubed starting constraints and besides, we don't believe we'll need the extra height offered by such a design.

3.3 4 bar lift construction

Date	19 November, 2021
Documented by	Seb Jensen
Verified by	Damian Rusecki
Engineering design process	Implement

In today's session we began the construction of our new four bar lifting mechanism. We decided this would be the optimal design in the last session, when we also investigated the potential of a six bar and scissor lift. We don't envision that the process of constructing this lift will take more than 2 sessions, which is one of the reasons why we decided to pursue this design. It will also be reliable and low-maintenance from its construction and after we test it.

We added some additional aluminium c-channels across the robot to maintain its robustness and structural integrity. This is because the chain lift that remains is the only thing that connects both sides of the robot together. The result is a more well-built drivetrain that should hopefully be less prone to damage and such.

This session we focused on the upwards extending beams from either side of the drivetrain and Damian was able to finish this component of the design. We are going to be using the red 100rpm cartridges to ensure the motors have enough torque to raise properly, as well as high strength shafts to make our design more effective.

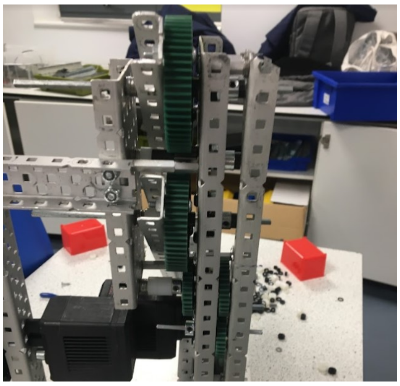


Figure 21: the initial progress on the four bar lift design

The motor will likely sit at the bottom of the gears and Damian will be using gearing that promotes high torque. Hopefully, we will even be able to lift up the heaviest, tallest neutral mobile goals that have the high posts. With this, we should be able to counteract any opposition that employs a design and strategy targeting the highest posts. A gear ratio designed for more torque will have a smaller gear driving a bigger gear.

We are pleased with our progress and hope to be on track to complete it in the next session. As part of our new plans to test each new addition iteratively, we will be programming and then testing and evaluating the design once it is complete and in a usable state.

3.4 4 bar lift construction

Date	23 November, 2021
Documented by	Seb Jensen
Verified by	Damian Rusecki
Engineering design process	Implement

Damian finished the construction of the four bar lift mechanism today. We were able to resume promptly due to the design being particularly simple and made considerable progress within a short period of time. By halfway through our session there was already one half of the arm itself constructed - you can see this in the figure below. There was a motor at the bottom with a 100rpm high-torque cartridge with a gearing solution designed to promote torque.

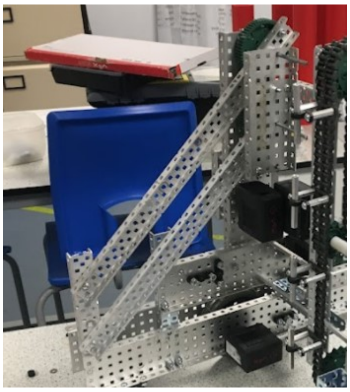


Figure 22: bars attached, parallel at the end

There has been plenty of mention of torque throughout this engineering notebook, but what does that actually mean? In its simplest form, torque is the rotational force. And in this instance, it is a motor's force when moving a gear. We can increase the torque with a 100rpm cartridge offered by VEX Robotics. Another means of doing this is by having smaller gears drive much larger ones. This means the gears rotate more slowly and results in more force when lifting up a mobile goal. High torque will be necessary to be able to manoeuvre the tallest neutral mobile goal with the high branches.

We are confident that our lift will work effectively and it should not need any additional bracing, although this is something that can be implemented with tension banding. This is where we use elastic bands to reduce the force and power needed from the motor for it to raise. It is spread across the lower and upper beams of each arm with the elastic bands, and this also means that the motors will not overheat from being overworked. While they would return to safe temperatures eventually, it is not sustainable to keep the motors working to the extent that they repeatedly overheat.

In the next session I will program the robot. We will then be able to test it and apply our iterative testing approach. We are confident that this lift will work mostly the first time, unlike what we saw when we tried implementing a DR4B design the first time round. Any issues or areas for improvement will then be quickly identified and promptly addressed.

3.5 4 bar lift programming, testing

Date	13 December, 2021
Documented by	Seb Jensen
Verified by	Damian Rusecki
Engineering design process	Implement, test, evaluate

In the last session we completed the design of our four bar lift mechanism. It is not yet fully implemented, though. To achieve this, we will need to program its functionality and then test it. Iterative testing is all part of our process to be able to rapidly cycle through the engineering design process. Keeping a quick pace will ensure that we are able to make effective and impactful changes on the fly for positive competitive outcomes.

Programming a lift is a simple affair - VEXcode Pro V5 is fully equipped with motor group functionality for our needs. As this lift requires two motors, one on either side of the robot, the motor group feature in our programming environment means we can set up and then engage multiple motors. This is immensely beneficial and has saved me a lot of time in programming the lift.

VEXcode Pro V5 has an interface for setting up motors. In that same interface, their functions can be easily bound to sets of buttons on the controller. It is necessary to add them this way for VEXcode to recognise them when you add your own instructions in the code, but it does mean that basic controller functionality can be set up on the fly.

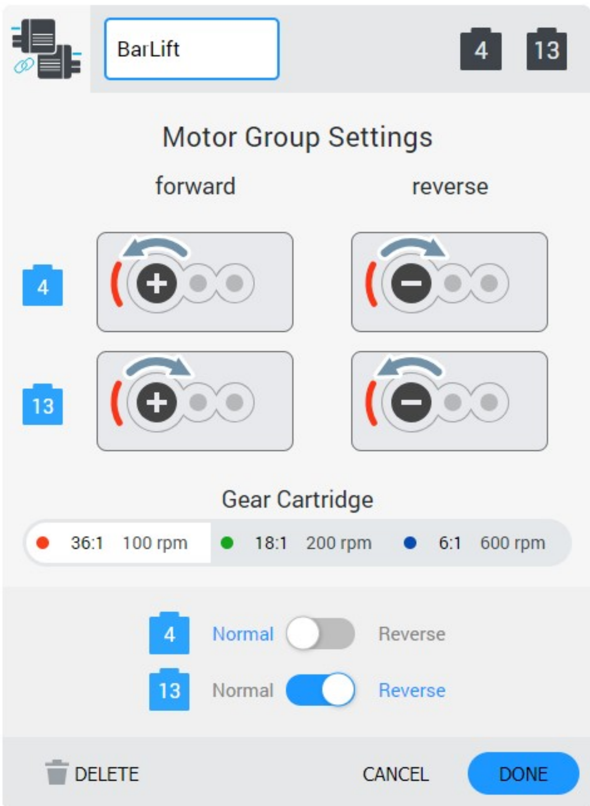


Figure 23: VEXcode Pro V5's motor configuration interface

It is also necessary to manually configure the motor group driving our four bar lift. This includes ensuring that the maximum torque value is set to 100 percent and that the maximum velocity value is the same. While this might seem excessive, the high torque gear ratio that we opted to utilise means that the lift will not elevate as quickly as would originally seem.

```
BarLift.setMaxTorque(100, percent);
BarLift.setVelocity(100, percent);
BarLift.setStopping(hold);
```

What is also important is the configuration of the motor group's stopping mode. The V5 motors are smart in that they can allow the gears to coast down, brake, or be held in their current position. Without setting the motor group to hold as also shown above, the arm would fall back down to its starting position when a button on the controller is not held down. This would make it difficult for Damian, the driver, to control the robot and keep mobile goals in our possession, ultimately leading to a loss of points.

3.6 Mobile goal clamp design

Date	16 December, 2021
Documented by	Seb Jensen
Verified by	Damian Rusecki
Engineering design process	Explore, implement

With the completion of the four bar lift mechanism, we, in today's session, turned our focus towards the attachment that would complement such. We were able to build this promptly and complete its integration in the same session, bar programming.

The design is simple and originated from Damian. It makes use of standoffs being mounted on the side of an aluminium c channel. This bar is driven by a motor that has been geared for optimum torque. We have also configured the motor to hold when not engaged by the driver which further allows us to grip onto the side of the mobile goal.

We make use of the 'bowl' in the middle of the mobile goal for this to be effective. As the protruding standoffs are rotated downwards, they hold onto the inside of the base of the mobile goal to grip it. Once gripped, we are able to raise the four bar arm lift that we programmed and tested in the last session.

With this design we will be able to satisfy what is now a critical criterion on our revised robot specification, that being the ability to raise and elevate mobile goals for 40 point bonuses. Considering this was the predominant strategy at the competition we attended at Greig City Academy, we should have a better chance of competing. We hope to see this effort reflected in large competitive gains at the upcoming competition.

Programming will be very simple and similar to the four bar lift. We don't anticipate that programming our entire robot and ensuring all systems are functional will take too much time. We aim to start this in the next session when we return back from our Christmas holidays. After programming the bot we can begin to test it fully once more.

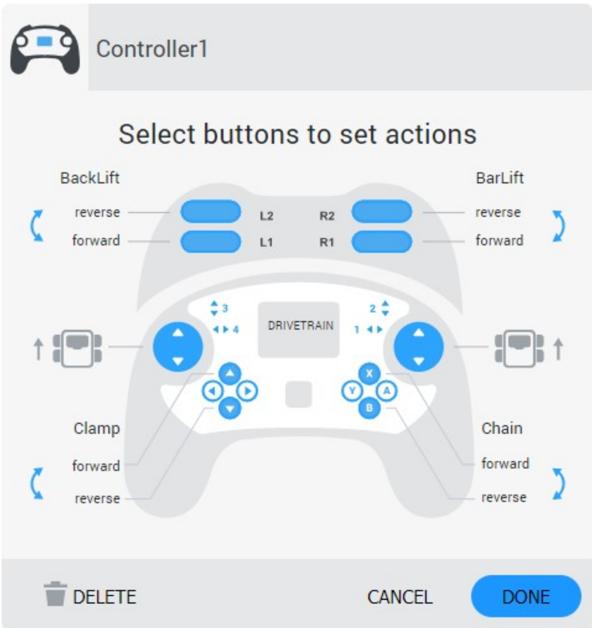
3.7 Robot programming

Date	6 January, 2022
Documented by	Seb Jensen
Verified by	Damian Rusecki
Engineering design process	Implement

We returned from our Christmas holidays with a complete robot in need of programming so it can be tested. This is what I spent today's session achieving in preparation for our next and the upcoming competition. We have not changed the way we program our robot and are still using VEXcode Pro V5.

As has been previously documented, this software features an intuitive means of configuring motors and electronics connected to the brain. You just select the device, allocate its port, and configure it where necessary. For example, it is very easy to reverse a motor from within the same set of menus.

Controls can also be hastily configured from within a similar graphical interface. By clicking on each set of buttons on the controller diagram you can toggle between the available motors. VEXcode has this functionality built in and allows you to get your robot on the move with little time and effort.



We are going to be using the same autonomous code from our last competition, as we have maintained the two bar lift design on the rear of the robot. I have also set up a couple of motor settings, such as the motor 'hold' stopping mode on the four bar front arm to ensure the robot keeps the lift in place when not engaged by the driver.

In the next session we will be testing the robot and comparing it to the specification we laid out while reviewing our performance at Greig City Academy in November.

3.8 Robot testing

Date	10 January, 2022
Documented by	Seb Jensen
Verified by	Damian Rusecki
Engineering design process	Test, evaluate

The robot underwent a series of tests to evaluate its capabilities in time for the competition this coming weekend. Some of the criteria is carried forward from the full systems test we conducted before the last competition to ensure a base level of consistency and repeatability. We programmed the robot earlier this week.

3.8.1 Drivetrain

Criteria	*Pass*	*Notes*
Forward motion	Pass	
Turning on spot	Pass	
Turning in motion	Pass	
Supports robot weight	Pass	Might benefit from more structural support

3.8.2 Four bar lift

Criteria	*Pass*	*Notes*
Raises beyond initial state	Pass	
Reaches to ramp height	Pass	
Reaches to ramp height while carrying mobile goal	Pass	Initially required a bit more bracing

3.8.3 Clamp

Criteria	*Pass*	*Notes*
Rotates to hook onto mobile goal	Pass	May be too slow for the competition
Maintains grip as four bar lift raised	Pass	Must ensure it is fully locked in the first instance

3.8.4 Two bar rear lift

Criteria	*Pass*	*Notes*
Raises beyond initial state	Pass	
Elevates mobile goal off the floor	Pass	

3.8.5 Conclusion

We are very satisfied with the outcome of our testing this session and we are excited to see how the robot will perform on the field in a competitive environment. All of our main systems are functioning well due to our thorough attention to detail during construction. The only takeaway might be the suboptimal speed at which the clamp mechanism rotates, and I intend to amend this by adjusting the programming to accommodate a higher-velocity, less-torque mode, perhaps in the form of a macro.

The last changes to the program will be made in the coming days with the deadline being the competition itself on Saturday. As it is being hosted at our own school, this will provide us with more time in the morning to use the field and prepare ourselves. Following the competition we will meet and write up a competition review and reflect on our progress this cycle.

3.9 Macros and controller functionality

Date	13 January, 2022
Documented by	Seb Jensen
Verified by	Damian Rusecki
Engineering design process	Refine

I have quickly come in afterschool for an impromptu session to investigate how we can resolve the issue of the slow-moving clamp. It is particularly problematic because it will allow other teams to snatch mobile goals from us while we are trying to grab them. This has the potential to cost us a lot of points, so that's why I'm looking at programming a macro specifically for this competition.

But first - what is a macro? Well, it will allow for the robot to execute a series of pre-programmed instructions at the click of a single button. Another macro might also encompass using a button as a 'shift key', modifying the functionality of others while held. In this case it is a matter of pressing a button once to have the clamp grip onto a mobile goal and then another for it to release.

The current issue lies with how we have to emphasise the torque and strength of the motor to firstly be able to grip the base of the mobile goal and then keep it held while the four bar lift elevates. My plan of action is to implement additional controller functionality in the form of a macro to temporarily increase the speed at which the clamp rotates and sacrifice its strength. This should reduce the time it takes to get into a position where it can grip, and then revert to the initial configuration to finish the procedure.

Another button will do the opposite, allowing the driver, Damian, to be able to release the mobile goal a bit quicker, although this is arguably less important.

```
void toggle_clamp(std::string direction, int deg){
  if(direction == "forward"){
    // Low torque, high velocity for 90% of the turn
    Clamp.setMaxTorque(50, percent);
    Clamp.setVelocity(100, percent);
    Clamp.spinFor(forward, (deg * 0.9), degrees);

    // High torque, low velocity for remaining 10% of the turn
    Clamp.setMaxTorque(100, percent);
    Clamp.setVelocity(50, percent);
    Clamp.spinFor(forward, (deg - (deg * 0.9)), degrees);
  }
  else if(direction == "reverse"){
    // Low torque, high velocity for 90% of the turn
    Clamp.setMaxTorque(50, percent);
    Clamp.setVelocity(100, percent);
    Clamp.spinFor(reverse, (deg * 0.9), degrees);

    // High torque, low velocity for remaining 10% of the turn
    Clamp.setMaxTorque(100, percent);
    Clamp.setVelocity(50, percent);
    Clamp.spinFor(reverse, (deg - (deg * 0.9)), degrees);
  }
}
```

The code is shown above, and I have clearly annotated it with comments in VEXcode so that others can easily understand what it means and how the robot will execute it. I have used functions to achieve this, parsing arguments to ensure compatibility in the future. If I need to make adjustments or rotate the clamp only by a specific amount (perhaps for use in autonomous routines) then I can do so easily by adjusting the parameters.

3.10 Competition review

Date	16 January, 2022
Documented by	Seb Jensen
Verified by	Damian Rusecki
Engineering design process	Review

Much like our last competition, we'll start by evaluating the numbers:

- 4th of 17 teams from qualification matches
- Finished as semifinalists in the elimination bracket
- 7 wins, 0 ties, 1 loss
- 3 autonomous wins
- Total SP: 556
- Highest score: 187

If we considered ourselves successful at our last competition then we can easily say we put in an amazing performance at our own competition at St Helena. There are widespread improvements across the board with the only notable drop being in autonomous period wins due to strengthening competition. Many teams have seen the importance of the initial 15-second autonomous period in each tournament match, and when two opposing robots are programmed to snatch the centre mobile goal it can be likened more to a tug of war.

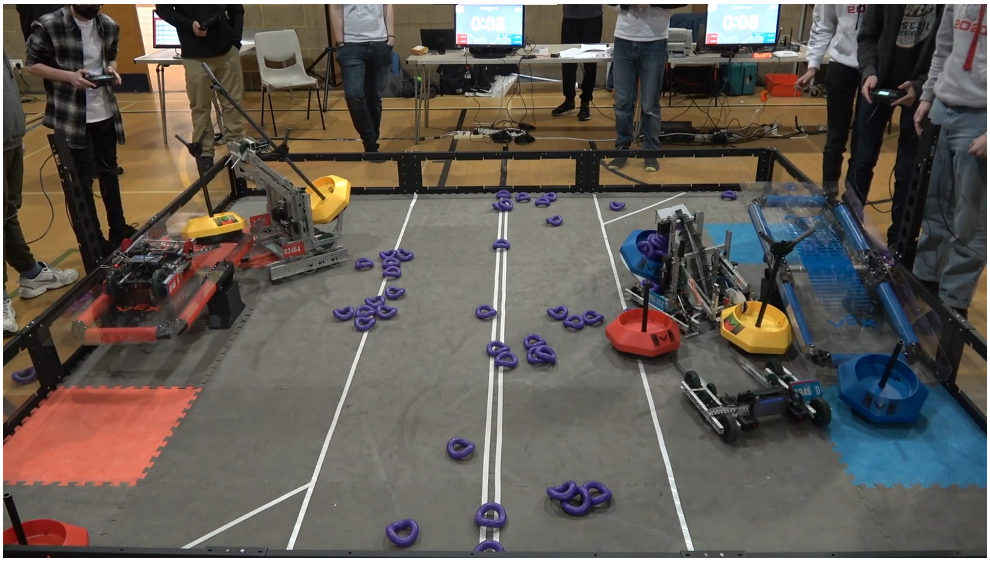
We played eight qualification matches, preceded by a single practice match. Our total strength of schedule points is comparable to the 575 from the last competition, indicating that we have grown also with our competition. For example, if we had made significant gains against our competitors, the total SP would have been lower. This is because the opposing alliance would have scored less in each match, reducing that value. It is good to see that we are able to keep up with other teams in the region.

Being the school hosting the event meant that we were able to get in and start practising immediately with all the fields open to us. Other schools didn't start arriving until after roughly half eight. This meant we could refine our autonomous routine which used the same back lift that we did for the competition at Greig City Academy. We benefited greatly from having access to practice fields.

We found ourselves being able to compete with more of the robot designs we encountered at Greig City Academy. Specifically, it was our newfound ability to elevate and then balance mobile goals on our alliance platform that gave us a new competitive edge against the rest of the competition that had not adopted such a strategy. Our clamp was still too slow for our liking, though, so we'll look into how we can adapt this in future. Perhaps, this will also entail a rework of our lifts to make them faster and to improve their structural integrity.

Another improvement is our finishing position in the elimination bracket. This time we were able to advance from the quarter finals to the semi finals. These marginal gains are what we need to make use of as over time our ability will slowly but surely improve and develop as we learn more about the game and our opposition. We hope to match this performance in our next competition, or perhaps improve upon it and make it to the finals.

Our main issue stemmed from the clamp. That, and the inability to deposit rings on the poles of the low alliance mobile goals. We are outlining these as key improvements we want to make in time for our next competition. We're hopeful and excited to undertake the next step in our engineering and design journey in this year's VEX Robotics Competition season.



4 Cycle 3

We are now working towards the worlds qualifying tournament that will be taking place at Haberdashers' Boys' School on Saturday 5 March, 2022.

4.1 Drivetrain rebuild

Date	20 January, 2022
Documented by	Damian Rusecki
Verified by	Seb Jensen
Engineering design process	Understand, explore, define, ideate

Post-competition, an immediate issue we encountered consisted of our robot having very little traction, slow drive and inability to park on the ramp. Due to the unavailability of pneumatics, we had to provide a motor for each motorised function of the robot which at the time consisted of; 1M clamp, 1M conveyor, 2M bar lift, 2M back lift, and 2M drivetrain. After discussing our issue with members of a VEX forum, we were suggested to change our drivetrain to a 4M base at the very least. Our previous design consisted of a very heavy robot and therefore put a lot of strain on the motors, hence causing us to have a slower drive. After discussing ideas with the team, we came up with the idea of Using 1M for the bar lift and 1M for the backlift. This would mean we would then free up 2M that we could use on the drive.

After thinking of a solution, we then began researching robots that had the capability of parking on the ramp at the end of each match and always noticed that the robots used omni-wheels rather than standard wheels, considering that they have more traction than the standard wheels. Since we had 200rpm motors for our drive, we were limited to using a 1:1 gear ratio in order for us to have the option of parking on the ramp in-game. Another solution that could help us with parking could be the use of 100rpm red cartridge motors instead in order for us to gain more torque and have a more successful balance attempt when attempting to drive up the ramp.

A final issue we encountered with our drivetrain was the inconsistency of making contact between the wheels and the ramp. We found that this was due to the supports of the wheels- consisting of 5-hole-wide c-bars blocking access to the ramp and hence stopping us from achieving a successful balance. To resolve this issue, we once again explored the successful parking robots and saw that omni-wheels were positioned much closer to the front and back of the bot to prevent the issue we had with our own. After having all of the ideas down, we decided to perform iterative testing during our constructive stage of the challenge, making sure we position the drivetrain omni-wheels correctly to enable access to balancing.

4.2 Drivetrain rebuild

Date	24 January, 2022
Documented by	Damian Rusecki
Verified by	Seb Jensen
Engineering design process	Prototype, choose, refine

After conducting our research we decided to go for the same dimensions we had with our previous robot which was 35 holes in length. We proceeded to use the 5 hole wide c-bars in order to sustain the stability of the robot as in the previous robot that proved itself to be very robust. To make it easier to adjust before settling on a certain design, we used keps nuts to hold together the structure of the drivetrain and during production, tested whether or not the drive would be capable of driving up the ramp. Almost instantly a difference was noticed when the omni wheels gained more traction and the 1:1 gear ratio to the 200 rpm motors provided more torque. We were almost immediately capable of driving up the ramp if placed in a pre-positioned setup on the end of the ramp.

However, if driven normally, we saw that the c-bar once again blocked access from getting up the ramp. After a few adjustments and more iterative testing, we finally managed to position the omni wheels along the length of the robot in a way to stop the c-bars from preventing access to park and had a consistent drivetrain which now meant we could determine it to be our final concept and could work on producing a much more stable and detailed drive. A factor that we had not yet considered is the weight of the robot, especially if we plan to possess 2 mobile goals in our mechanisms, which would only add more weight and could quite possibly become a factor affecting our ability to balance. If this plan does not work when the robot is completed, we will consider using 100 rpm motors instead of our current 200 rpm ones to provide us with more torque to be capable of balancing within matches.

4.3 Drivetrain rebuild

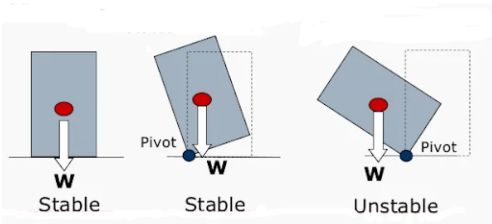
Date	27 January, 2022
Documented by	Damian Rusecki
Verified by	Seb Jensen
Engineering design process	(Iterative) testing

The drivetrain, now being built to detail and secured with lock nuts, is ready its own testing, in which the robot undergoes tests such as; conformity to size specifications, motor placement, and an evaluation of the overall structural integrity of the robot.

Firstly, we tested the width and length of the robot to verify it fits in the specified 18″ by 18″ by 18″ size specifications which ended up in verifying the required dimensions. We measured to a total of 17.5″in length and 17.8″ in width. Measuring height was at this point unnecessary due to the robot having no installed mechanisms on the top of the drive. Due to frequent problems with dimensions in previous seasons and competitions collectively, we made ourselves a rule of keeping the mechanical top of the robot within the current area of the drivetrain itself.

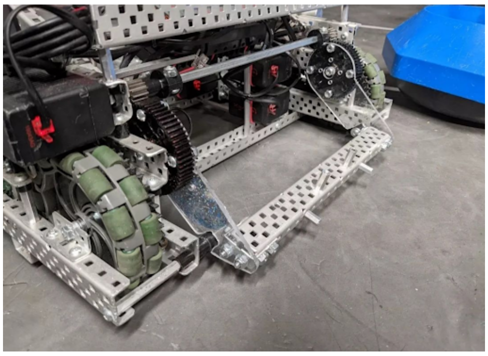
We then proceeded to verify that the motor placement and gearing would not get in the way of other parts of the robot and tried to make sure the motors were mainly situated to the centre of the drivetrain so we could maintain the area centre of gravity towards the lower central area of the robot to prevent tipping. Our current gearing of 84 toothed, 1:1 gear ratio from the wheels to the motor helped centralise the motors and therefore gave us more room at the front and back of the robot for the clamp and back tilter.

Finally, we analysed the general structure of the robot, one test of which consisted driving full speed at a wall and even after sounding like an absurd idea, was a necessity if we were to be sure of our drivetrain's strength. This would verify that no damage would be sustained if we were to be rammed into or driven into a game wall, meaning that we would not need to worry about damage to our robot. We were capable of driving at full speed around the testing area without tipping either direction due to our 12″ wheel base. This inability of tipping was subject to change when we would begin implementing heavier mechanisms onto our robot, that could alter our centre of gravity and could cause the build up in momentum to enable our robot to "wheelie" if we were to fast-stop whilst driving at full speed which was something we could only test at the final stages of robot production. However, we are confident that our robot has no possible means of tipping at its own accord due to the inability of our robot's centre of gravity to pass the line of pivot and tip into a motionless position.

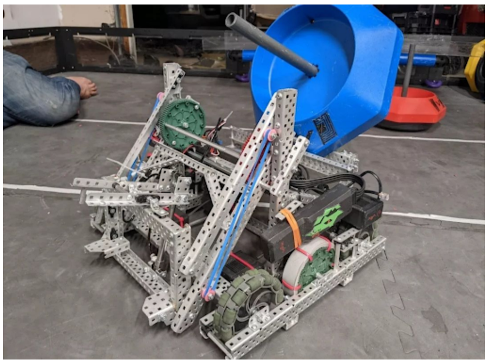


4.4 Jessie lift planning

Date	31 January, 2022
Documented by	Damian Rusecki
Verified by	Seb Jensen
Engineering design process	Understand, explore, define



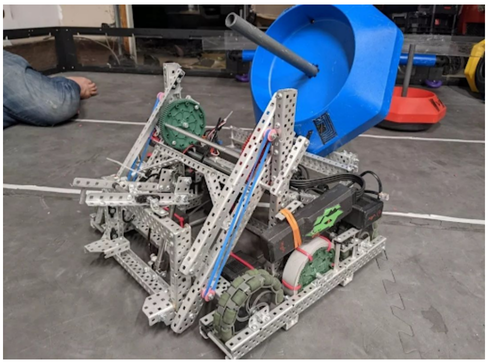
Due to issues with our back lift/tilter during our St Helena competition, we realised that having two separate motors controlling L tilters would often unalign the tilters so that the mogos would not lift at the correct angle, or lift at all. This caused us to begin searching for alternative design and solutions to the issue and needed something compact to fit within the size limitations of the bot. That is when we came across a non-competing American team that had designed a tilter that was compact, could use 1M and lock the mobile goal in its place, making it practically impossible to remove by other teams.



To use a 1M tilter, we would need to use high strength shafts to prevent bending of low strength shafts and be able to support the weight of a mobile goal. We will also need to use a stronger gear ratio which will use a 1:7 gear ratio to increase torque and have the capability of lifting a mobile goal. If we do so, we will sacrifice the speed at which it lifts the goals but it will also provide a very strong, protective and working method of ring deposition.

4.5 Jessie lift prototyping

Date	4 February, 2022
Documented by	Damian Rusecki
Verified by	Seb Jensen
Engineering design process	Ideate, prototype, choose



After analysing and exploring the idea of the jessie lift, we began working on a basic prototype of the design. Due to our unavailability of polycarbonate sheeting, we were limited to using flat steel sheets from the VEX kits to build a similar concept based off of the polycarbonate seen in the images in the previous entry. Soon after constructing the prototype, we attached the design to the back of our robot and noticed that it was a very compact design which was a major benefit to our robot's scale and made it easier to fit within the size specifications. Something else we had a look at was the different angle at which the standoffs were positioned which if understood correctly would mean that the jessie lift would need to rotate more to pick up the mobile goal (mogo) which could be an issue later on during testing.

Soon after fastening the jessie lift to the back of the robot, we ried testing out the lift without the use of a motor to power the mechanism, instead using our hands to spin the gear and make sure the mobile goal would position correctly when lifting to dispense rings. When testing out the contraption, we were happy to record that the standoff design worked very effectively in securing the mobile goal on the lift and would not be easy to remove with an ordinary clamp by other oppositions. Unfortunately however, we noticed that the centre of rotation was too far from the mobile goal and consequently rotated the goal to an undesirable angle and height which lifted past the 18" height limit which meant we would not be able to deposit rings. Soon after some brainstorming, we came up with a few deas, one of which was to shorten the distance between the gear and the standoffs hook, which would proportionally reduce the distance between the goal and the centre of rotation, meaning that we would need to rotate the gear less to lift the goal and also lift it at the required angle to be able of depositing rings.

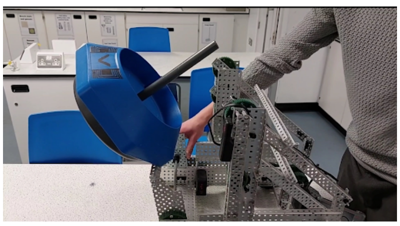


Figure 24: our first prototype in action

4.6 Jessie lift refining

Date	8 February, 2022
Documented by	Damian Rusecki
Verified by	Seb Jensen
Engineering design process	Refine, test

We began removing the flat sheets of steel from the VEX kits and instead began attaching the standoff hooker to the gear themselves to severely reduce the distance between the goal and centre of rotation. This would supposedly allow us to dispense rings at the desired angle.

After making the planned changes, we once again tested our results which proved themselves very worthy of tilting the mobile goal at the optimum angle for ring stacking. After the manual test, it was time to conduct a motorised test that included attaching a motor and gearing up the mechanism to test out how the robot would function with the new addition. The gearing ratio we went for was an immediate decision for torque to make sure the robot could lift the mobile goal without losing power or being inefficient at its role. After programming a simple up/down function, we were able to start testing the new mechanism and found that it worked very precisely and effectively. The mobile goal would lift to the correct position for future ring dispense and was unable to be pulled away with our hands.

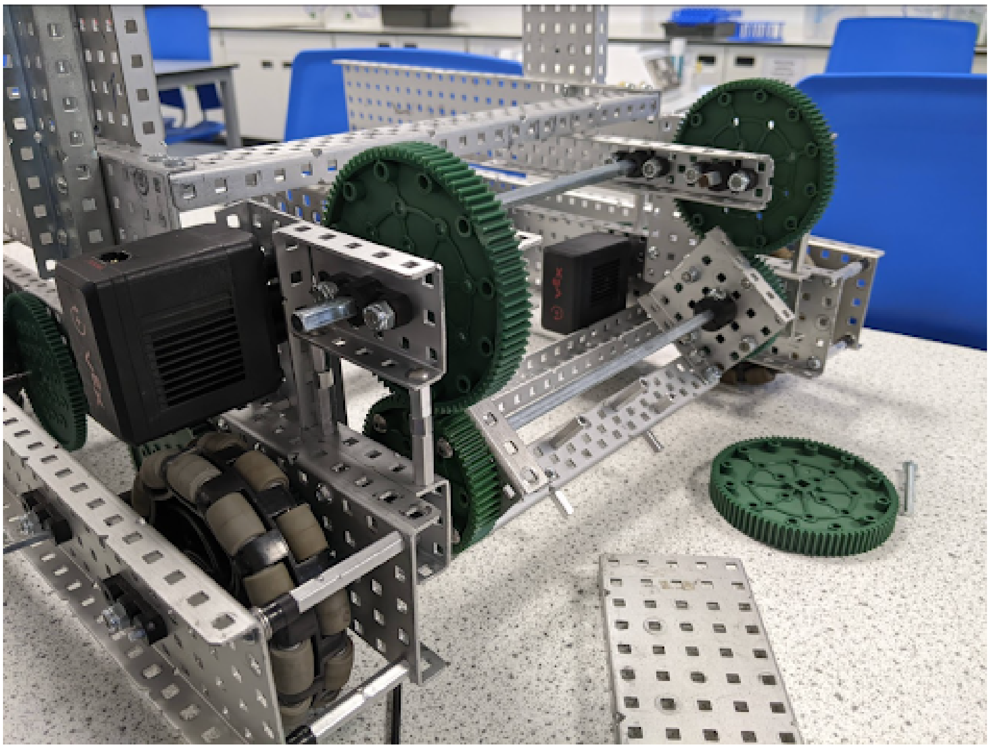


Figure 25: our refined jessie lift design

4.7 4 bar lift planning

Date	10 February, 2022
Documented by	Damian Rusecki
Verified by	Seb Jensen
Engineering design process	Understand, explore, define

It is now time to begin planning the most important mechanism on the robot, the 4 bar lift. Even though this is a very basic build, it was important to build it correctly for maximum bar lift advantage. Our last bar lift had used 2 motors which as explained before was planned to be reduced into a 1 motor bar lift. To do this, we would need to switch to high strength shafts instead of using the low strength shafts to prevent them from twisting and snapping. We would also have to change the gear ratio for more torque in order to be able to be able to lift. Reducing the 4 bar lift into 1 motor will also free up a motor, meaning we will have enough motors for the clamp and ring conveyor for future builds.

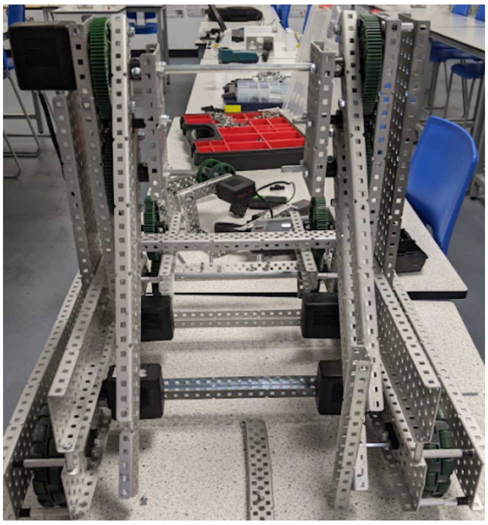
The concept of a 4 bar lift is very simple, a 12 tooth gear is directly connected to the motor, to the top and bottom of that gear, larger gears such as 84 tooth gears are connected to the small gear which increases torque due to the number of rotations a small gear must complete for one full rotation of the 84 tooth gear. Both 84 tooth gears are connected to a c-bar parallel to the other c-bars and when motorised, will fulfil the concept of a 4-bar lift. These lifts often have bracing located from the left to right of the bar lifts in order to increase stability, reduce tension and prevent the bars from becoming unaligned.

On a lot of 4-bar lifts, we saw that bar lifts with one motor had elastic bands positioned on the sides of the bar lifts. After doing some research on the reasoning behind this, we gathered that this technique reduces tension on the motors. The bands need to be placed at 2 points where the abounding is close together when raised up, but far apart when the bar lift is lowered.

4.8 4 bar lift experimenting

Date	14 February, 2022
Documented by	Damian Rusecki
Verified by	Seb Jensen
Engineering design process	Ideate, prototype, choose

Whilst planning out our design of the bar lift, we had the idea of using longer c-bars for height advantage. This would let us reach up higher with our bar lift compared to other teams. This would give us an advantage of being able to keep possession of mobile goals away from reach of other teams. To do this however, we would need to move back our gearing for the 4-bar lift in order to make sure it would fit within the size specifications.



We decided to create a prototype of the arm fit straight into the robot in case the prototype worked well enough for our plan. We used 30 hole long c-bars for the arms and set up the required gear ration. Since we were using high strength gears, we needed to make larger holes in the pieces we used as the standard holes are much too small for the high strength shafts. In order to create the right size for the holes, we used a size 8 drill bit and drilled into the metal, filing off any imperfections that could affect the rotation of the shafts.

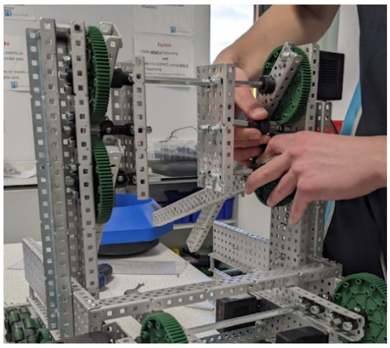
After constructing the prototype, we noticed some issues that we would like to fix during our next session. One major issue was that the motor was incapable of lifting the arm. This was because the motor was accidentally connected directly to the 84 tooth gear instead of the 12 tooth gear which posed issues for the lift. Another issue was the 12 tooth gear constantly popping out of the gear connection which was an issue as it would then stop the bar lift from operating efficiently or operating at all.

4.9 4 bar lift refining

Date	15 February, 2022
Documented by	Damian Rusecki
Verified by	Seb Jensen
Engineering design process	Refine, test

After noting issues with our 4-bar lift prototype in the last entry, we began working on them the next session we had and refined the bar lift until it worked perfectly. Firstly, we had to remove the motor from its current position and move it down to direct the power of the motor to the 12 tooth gear in order for the torque to make a difference and raise the bar lift. For us to do this we had to remove the gears that took up a lot of time.

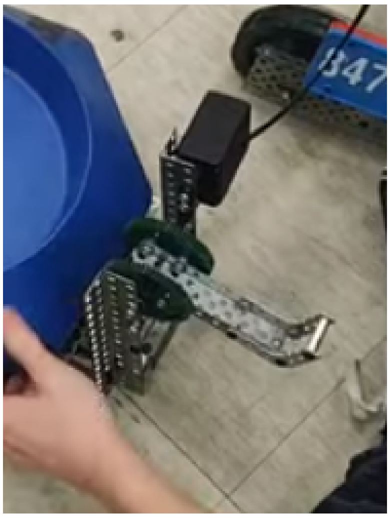
Eventually, we finished the task and while the gears were off, we decided to change our drill bit to a size 9 as we notice that the issue making the 12 tooth gear pop out was because the hole we drilled before was not centred and the gear was at an angle which created tension and made it pop out.After drilling the hole, we replaced all of the pieces back to how they were before and added aluminium plated on either side of the gears to make sure they would be held in place and not ruin the gearing by popping out.



Now it was time to make a motorised test and after connecting the motor to the brain, we were pleased to see that the bar lift worked very well and the torque was working efficiently. However, we had to think ahead and realised that the motor would be put under much more pressure when we added our clamp and had to pick up mobile goals and would be subject to overheating which could damage our motor. This is why we added our tension bands later in during the building process closer to the final outcome to test how the bar lift would operate without the bands.

4.10 Clamp rebuild

Date	17 February, 2022
Documented by	Damian Rusecki
Verified by	Seb Jensen
Engineering design process	Understand, explore, define

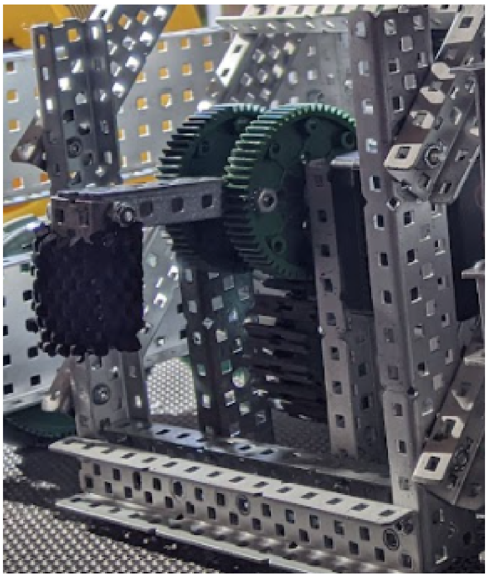


After analysing our previous clamp design, we saw many issues with the design, including the very high gear ratio that caused our clamp to get a hold on mobile goals very slowly and was a major disadvantage when playing against teams with fast clamps which meant we would often not have possession of any mobile goals. We also added standoffs below our original clamp which would very often get in the way of removing mobile goals from our clamp when trying to dispose of them onto our ramp.

After doing some background research on clamp designs, we found a very efficient, fast and easy to build L-clamp. This clamp is seen to use absolutely no gear ratio and is directly connected to the motor for a fast clamp time. We saw that this would be very beneficial compared to our last clamp due to its speed and would give us an advantage over our opponents by getting hold of mobile goals before them. Based on the video, we saw that the clamp was a very robust mechanism that could maintain control over mobile goals even during intense shaking which only meant it was obvious to use the design.

4.11 Clamp rebuild

Date	22 February, 2022
Documented by	Damian Rusecki
Verified by	Seb Jensen
Engineering design process	Ideate, prototype, choose, refine, test



Eventually after deciding to use the clamp design primarily researched, we began to work on a prototype. This followed the exact same design as in the video. However, instead of using corner pieces, we used a c-bar due to the unavailability of the pieces. And seemingly worked just as well as the L-clamp design we were basing our clamp off of.

After constructing our prototype, we had the idea to wrap the front part of our clamp in VEX anti-slip mats to help grasp onto the mobile goals much more securely by reducing slip and increasing friction.

Due to the ease of building the clamp, we had time to refine the clamp as required and only had to change the gears to smaller ones to prevent the large ones from getting in the way of a possible conveyor in the future.

To test, we experimented with using every kind of goal, alliance goal, small neutral goal and tall neutral goal. During this we were also able to get more testing done with the bar lift and realised that the bar lift after sometime did indeed overheat the motor as predicted. This meant we had to add the tension bands in the end and made a large difference without overheating and was able to lift all sized goals. The clamp proved itself very effective and held a very strong grasp on the mobile goals. It was also very fast in clamping which was a very successful accomplishment.