Engineering Notebook

FUSION CORPS

6672

Table of Contents

The Game

First, when learning about a new game, we look at the scoring options and robot limitations for the year. Here are our quick points

Scoring

Award	Awarded for...	AUTO	TELEOP	Qual.
INITIATION LINE	exit the infinite vertical volume created by the corresponding ALLIANCE'S INITIATION LINE any time before the end AUTO (per ROBOT)	5	-	-
POWER CELLS	scored in BOTTOM PORT	2	1	-
	scored in OUTER PORT	4	2	-
	scored in INNER PORT	6	3	-
CONTROL PANEL	ROTATION CONTROL	-	10	-
	POSTION CONTROL		20	
ENDGAME Points	HANG (per ROBOT)	-	25	-
	PARK (per ROBOT)	-	5	-
	LEVEL with 1-3 ROBOTS HANGING (per ALLIANCE)		15	
SHIELD GENERATOR OPERATIONAL	earning at least sixty-five (65) ENDGAME points			1 Ranking Point
SHIELD GENERATOR ENERGIZED	Stage 3 ACTIVATED	-	-	1 Ranking Point
Tie	Completing a MATCH with the same number of points as your opponent	-	-	1 Ranking Point
Win	Completing a MATCH with more points than your opponent	-	-	2 Ranking Point

- The teams port is on the opposite side of the field from their drivers station
- Autonomous power cell points are worth double teleop points
- Control Panel points are worth a moderate amount, especially the second position control.
- Endgame points are very valuable. If you get enough you can get a RP.
- The other RP is the activation of Stage 3. This takes a minimum of 49 balls to be shot into the ports.

Ball Handling rules

- Robots can start with up to three balls
- At no time can the robot control more than five balls

Robot size limitations

- Starting configuration max height: 45 inches
- In -game max height: 45 inches
- Low height of the trench: 28 inches

- Robots may not extend more than 12 inches past frame perimeter

Starting Location

- Robots start on the opposite side of the field from their drivers station
- Must have bumpers on the initiation line

Game Analysis and Observations

Autonomous

- This year it is a true autonomous. Because the balls are worth double, we need to try to maximize the number we can score.
- Day 1 observation is to move off of initiation line (5 points) and score three balls into the upper port. Outer goal will be fine, if we score any in the inner that will be a plus. After shooting, we will go to our own trench run and collect balls. If we have time we will shoot those balls at the upper port.

Hanging

- We see hanging as the easiest available Ranking Point. There are two ways of getting the Ranking Point. First, we can have two robots climb and the bar be level to get a total of 65 points. The other option is for the whole alliance to climb for a total of 75 points.
- Solo climbing is still valuable when none of our alliance partners can climb. Doing so from the center of the bar will ensure it stays level. To do this we need a hook on each side of the center support.
- A “buddy climb” where we can ensure that both us and a buddy can climb and stay level would be very advantageous because it would ensure that we can get a Ranking point each match.
    - Idea 1: use a traditional “forks” method to carry the partner robot. The partner can drive onto the forks and we can lift both us and them up from the center of the bar to ensure the Ranking Point. Problem: G18 prevents the robot from extending more than 12 inches out of the frame perimeter. This means that any forks we made probably would not be long enough to support another robot.
    - Idea 2: create a “buddy bar” that would extend off of our robot and provide a bar that replicates the dimensions of the bar. We could either cheesecake something onto another team’s robot or they could use their own climber on the bar. Even if they have their own climber, we may find an advantage in using the buddy bar because it would ensure we achieve a level climb
    - Idea 3: Create a similar mechanism to 148’s 2018 partner attachment method. They cheesecaked a strip of polycarbonate with velcro on it and used that, and the bumpers, to hold onto their partner.

Cycle Paths

- Roughly two options for our robot to traverse the field: through the trench or through the generator switch

- The trench is very short and not very wide, which imposes both design limitations and driving difficulties
- The generator switch does not impose height restrictions, but has a rough terrain caused by multiple, angled, 1” tall square tubes. This will slow down our cycle time, but leaves most robot sizes and design options open.
- Which path we take influences the wheels we need to use. We may need to use pneumatic tires in order to have a smooth ride over the square tubing, but they create difficulties in driving the robot.

Ports

- Lower Port:
  - 2 pts per score in auton, 1 pt per score in teleop
  - Very easy to shovel balls into with some sort of ramp, but low reward
- High Outer (Hexagon) Port:
  - 4 pts in auton, 2 pts in teleop
  - Requires a shooter
  - If the ball hits the back wall and bounces out, the score does not count at all
- High Inner (Circle) Port:
  - 6 pts in auton, 3 pts in teleop
  - Requires a shooter with very high accuracy, but high reward
  - Likely hitting this goal will be more of a wish or by-product than a necessity
- Ranking Point Stages:
  - Stage 1 requires 9 balls
  - Stage 2 requires another 20 balls and spinning the control panel wheel 3-5 times
  - Stage 3 requires another 20 balls and spinning the wheel to the correct color (which is only known by the FMS and is communicated to the robot)
  - It will require teamwork, great driving, and high shooter accuracy to accomplish this ranking point, so this RP is less important to us than the climbing RP. However, this is where the majority of regular game points will likely come from.
  - We want a wheel spinning mechanism because it the task is simple and yields a ton of points, even if it is rare we ever get to use it.

Archetypes

There are two main robot archetypes we identified this year - a trench bot, which would have a low enough overall height to be able to fit under the 28” high “wheel of fortune” or a high bot, which would extend above the 28” and go closer to the 45 inch height limit.

Trench Bot advantages

- It opens the field for cycling - you are not just limited to going through the rendezvous zone to cycle balls
- Lower center of mass which will help prevent tipping

Trench Bot disadvantages

- Harder to design
- Harder to hold balls - it will be difficult to hold 5 balls

- Will need a more complex, harder to design climber

High bot advantages
- More space to work with inside the robot
- More room to hold balls
- Easier to design
- Easier to package a climber

High bot disadvantages
- Potentially higher center of mass
- Forced to go over rendezvous zone, which will influence drivetrain decisions.

Initial Design Strategy
- We chose to go with the high bot. We will need to be wary of tipping and so must try to lower the center of mass as much as we can.
    - We will be forced to go through the rendezvous zone, which will influence our drivetrain decisions, pushing us towards pneumatic wheels
- Shooter for the high goal - if you are going to cycle balls to the other side of the field to score, you want to maximize the number of points you can get per ball. The easiest way to do this is to score into the outer port. If you are good, you can score into the inner port for even more points.
    - If we can make a shooter that can shoot across the field, from behind the “wheel of fortune”, we will be able to significantly reduce cycle times of the robot. The necessary distance traveled will be reduced by close to 30%, and coupled with not having to go over the rendevous zone barriers we will save even more time. The value of this will be discussed later in the “cycle value” section.
    - We need to examine what variables in the shooter we can alter to shoot from different distances - output velocity (shooter wheel surface speed) and hood angle seem to be the two that we can explore making variable. Variable hoods are quite complex, so that is immediately going to be harder than having the programming team alter the shooting speed.
- Turret - the advantage of a turret is that the direction you are shooting is independent of the orientation of your drivetrain. This means that you can get finer control laterally than what could be achieved by positioning a drivetrain. If you are being defended and your drivetrain is moved, you can still score. If we have this on the robot, it will have to be a closed loop control run by vision off of a limelight or something equivalent. Trying to use the turret manually is not an option
    - The turret is classified as a “want”, not a “must have” mechanism. If we are able to get it running, we think it will benefit our performance. However, it is not as high priority as something like the intake, shooter, feeder or climber etc.
- We are debating between two types of intakes - a mecanum or a wide “touch it own it” intake - this will be discussed later in the intake section
    - If we go with the touch it own it intake, we will need an “indexer” mechanism to sort the balls into a single file line in a way that they are controlled and do not jam up

- We will need a “feeder” mechanism to move balls from the intake (or the indexer if we use the touch it own it intake) up to the turret and shooter. This mechanism may have an option to index the balls if we find we need to.
    - Depending on the design we choose, this mechanism does not need to be centered on the robot. If needed, it can be slightly to the side to accomodate for any design choices. If offset, we will just need to make sure our center of mass is accounted for.

Cycle value

The value of a cycle can be analyzed in the number of points it scores per second it takes. So, for example, a 20 second cycle that nets 17 points averages 17/20=0.85 points per second. There are a few ways of increasing cycle value. First, be able to score more points. Hitting the inner port more often will immediately increase the cycle value. Second, lower the amount of time it takes to cycle. This means that shaving a couple of seconds off of a cycle, aka being more efficient with your time, will drastically help improve cycle value. When analyzed in the view of the whole game, cycle value can also account for the extra cycles it allows for, if the overall time it takes is reduced.

Once the robot is built, we will know exactly how long, in ideal conditions, it takes for us to cycle. We will need to do a lot of data collection to help us understand how we score most efficiently, which will guide how we play during matches. Below are several options we will test for their cycle value.

Mechanisms overview

Drivetrain - the most critical mechanism on the robot that is responsible for moving the robot around the field. Decisions are made based on sprint distances and field obstacles and related testing

Intake - responsible for bringing balls from the floor into the robot. Design decisions are made based on prototyping and hopper location.

Hopper - responsible for receiving balls from the loading station, reducing balls from full width to a single stream and moving them towards the feeder. Design decisions are based on loading station, example video from open alliance, prototyping and location of the feeder.

Feeder - responsible for taking balls from the hopper and up to the shooter. Must be able to control in a way that is jam free. Design decisions rely heavily on prototyping and example open alliance cad. Will expect to run several versions to reduce problems.

Turret - LOW PRIORITY will mount on top of the feeder and give ~300 degrees of motion to the shooter. Advantage is that shooting is independent of the orientation of the drivetrain. Design decisions based on feeder geometry, prototyping and triple helix example video.

Shooter - will mount on turret or, if no turret is being used, directly to feeder. Will take balls from the feeder and shoot them into the goal. Design decisions rely heavily on prototyping and turret and feeder geometry.

Climber - responsible for hooking onto the bar and lifting the robot up. Design decisions made based on the center of mass of robot, elevator components and hook design.

Drivetrain

Overview

The Drivetrain is the most important system on the robot. Without a working and reliable drivetrain, your robot is rendered useless, unable to accomplish game task and ultimately win matches. Drivetrain decisions must be well thought out and tested on game surfaces to prove their viability to compete at a high level. The first thing you have to consider when designing a drivetrain is what it will be driving on - any ground obstacles.

Field Restrictions

This year, there is only one type of ground obstacle. BOUNDARIES are 3 in. (~8 cm) wide, 1 in. (~3 cm) tall steel barriers that divide the area inside the SHIELD GENERATOR into four (4) equal sized rectangles. The only way to cross the field without going under the trench, which would limit your robot height to <28 inches, is to go over the boundaries. You must also be able to go over the boundaries when going to climb in the rendezvous zone. This means, when cycling, our drivetrain must me able to hit and go over the boundaries while at a medium-high speed. We would also like the capability to do a full 360* circle while on top of the boundaries. This will help us when maneuvering to climb and will also prevent our robot from getting stuck in any normal match play.

Drivetrain “wants”

- Utilize the Kit of Parts Chassis
- Use Falcon 500 motors for better performance, efficiency, packaging and simplified wiring.
- Be able to pass the boundaries at the minimum of half speed, preferably closer to full speed
- Be able to do “donuts” on top of the boundaries without getting stuck
- Paint it black **#allblackeverything**
- Optimize to a sprint distance based on motors, gearing and wheel size

Testing on 1/4

The day of kickoff, we immediately tested how previous robots were able to go over the boundaries. We used two robots. Our 2018 robot uses the KOP 6 inch wheels and is roughly 130 pounds. And finally our 2019 robot which uses 8 inch pneumatic wheels and weighs roughly 130 pounds.

With these robots. We did three different tests, and made observations about how easily the robot went over the boundaries, how much it shook when it did that, if it got stuck in any way etc. The first test was a from-rest crossing the boundaries. The second test we put the robot halfway on the boundaries and tried to make it spin in circles, if it could. The third test we sent the robot at full speed at the boundaries, with as much momentum as possible. The fourth and final test was we put the boundaries at a 90* angle like they are in the field and tried to cross each one in quick succession.

Observations
2018 robot (full weight, KOP 6 inch wheels)
From rest - this robot struggled slightly. The low amount of momentum it had affected its ability to get over the boundaries
Spin in circles on top. - when we did this, the robot would get "stuck" where the motors would not have enough torque to overcome the static friction between the robot when the wheels were jammed in the corner of the ground and barrier. Was not what we wanted to see.
Full speed into boundaries - we tested this with the robot going in two directions: one with the CG forward and on with the CG backward. We found that CG backward was a little better, however the drivetrain shook a lot when it went over the boundaries and the wheels took a large impact. This made us question the odds of a wheel breaking during competition.
45* angle - not much change from the full speed into the boundaries. Drivetrain did not deflect off from straight which was promising
Overall, we were not fully satisfied with the 6 in hi-grip wheels. From our tests, they did not easily go over the boundaries and, since the season is especially long this year, we were afraid we might eventually break a wheel.

2019 robot (full weight, andymark 8 inch pneumatic wheels)
1. From rest - this robot handled the boundaries great, not many problems
2. Spin in circles on top. - when we did this, the robot would slow down a little bit when a wheel was going over it laterally but it performed better than the previous robot.
3. Full speed into boundaries - The CG on this robot is pretty centered, so we did not test it from two directions. Overall, it handled the boundaries very well. The pneumatic wheels provided cushion to the robot so it did not take as much as a "hit" while going over the boundaries.
4. 45* angle - not much change from the full speed into the boundaries. Same as the last test, the drivetrain did not deflect off from straight which was promising.

Overall, we liked the pneumatic wheels more than the hi grips. The cushion they provide make the robot much more stable. We were weary of the problems we encountered last year, from this robot that we tested with, but were prepared to go solve them, having an extra years of experience on what we need to do.

Ilite Drivetrain Calculator Analysis
We use the Ilite Drivetrain Calculator to determine what gear ratio we will use for a given wheel diameter, sprint distance and motor combination. The basic premise of the calculator is reducing time it takes the robot to complete a "sprint distance" - which is the distance we think the robot will be commonly travelling during the match. We also want to know if the chosen gear ratio can be improved if it is deemed to be underperforming. Underperforming means that the robot will not be done accelerating when it hits the desired sprint distance. In gearbox, acceleration, which

is proportional to the torque output of the gearbox, and speed are inversely proportional. A robot with a low gear ratio, like 7:1 for example, will have lower torque output. This means the acceleration will be slower, but the overall top speed will be higher. The opposite of this is the gearbox that is very high, like 20:1 for example. It will have a lot more torque than the 7:1, and thus will accelerate much faster, but will have a much lower top speed. When choosing a gear ratio, we want to optimize the ratio between torque and top speed, meaning we want to optimize the gear ratio from the motors to the wheels, in order to reduce the time to the sprint distance.

Sprint Distance

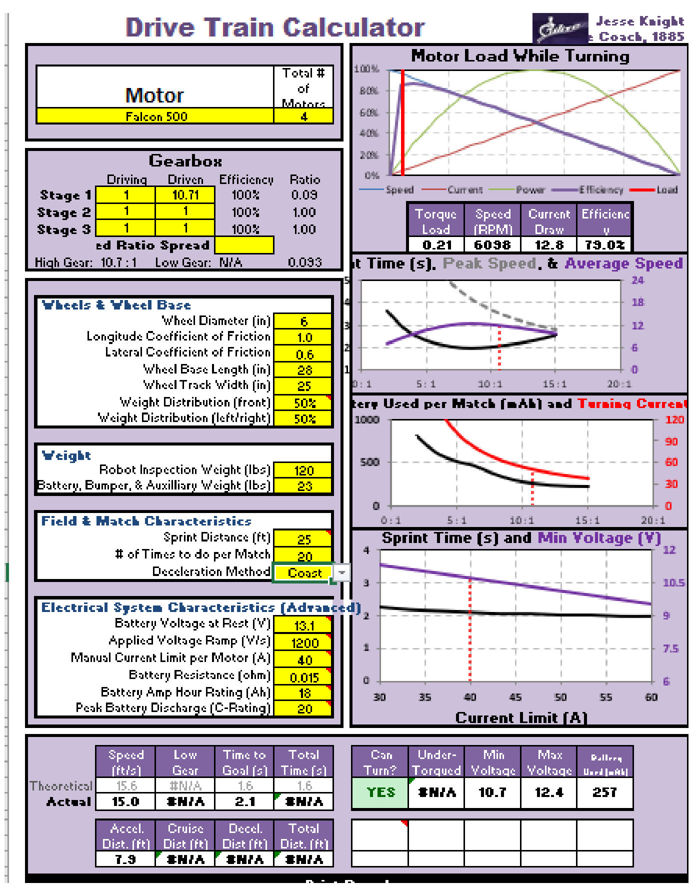
Since we do not plan on using the trench for cycling from one side of the field to another, we will have to go over the barriers in the center of the field. To go over them, we will need to slow down. This effectively limits the sprint distance of the game because we will not be able to continue accelerating over the barriers. The result of this sprint distance is a little more than ⅓ of the field (total field is 54 feet) - so roughly 20 feet.

Kit of Parts Gear ratios

- The kit of parts uses a gearbox called the “toughbox mini.” It has a swappable second stage that allows five different gear ratios to be used.
- The Kit of parts ships with a 10.71:1 gear ratio. There is one ratio above, 12.75:1 and three below, starting with 8.45:1.
- This drastically limits our gear ratio options but also

Standard KOP 6 inch wheels

- The kit of parts comes with six andymark six inch Hi-Grip wheels. We did a Ilite analysis with these wheels, the 10.71:1 gear ratio, and the 20/25 foot sprint distance
- No real benefit to the sprint time by changing gear ratio.
- No way of substantially reducing battery usage without sacrificing sprint time.
- When current limited to 40-50 amps, the minimum voltage stays far from brownout (10.7 volts is min voltage, 7ish volts is brownout)
- Basically, there is not much to optimize with this drivetrain combination, which is what you would expect for something that is used by so many teams.

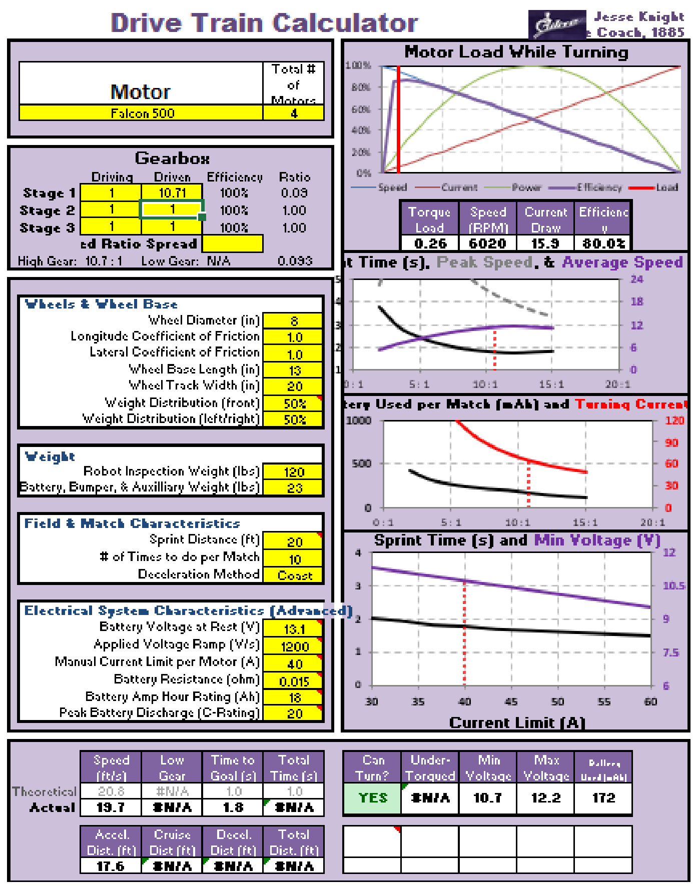


8 Inch Pneumatic wheels

There are two problems that come with 8 inch pneumatic wheels. First, the increased diameter will throw off the specs of the system and will necessitate a different gear ratio. Second, from previous experience, Pneumatic wheels drastically increase turning scrub, meaning the motors draw a lot of current when turning if there is not an adequate amount of center drop. The squishiness of the wheels makes a normal center drop practically non-existent. The first problem, the diameter difference, will be solved with the Ilite Calculator. The second problem, the scrub, will be tested with 8 inch omnis on one end of to robot to effectively halve the drive base, reducing turning current. Because we don't know the true specs of the wheels, which depend on things like contact surface, kinetic vs static coefficients of friction, lateral vs longitudinal friction etc, we will not use the output of the calculator to drive our decision making. There are too many variables that we cannot be confident in. Instead, we will test the setup in real life, seeing if it draws too much current like last year.

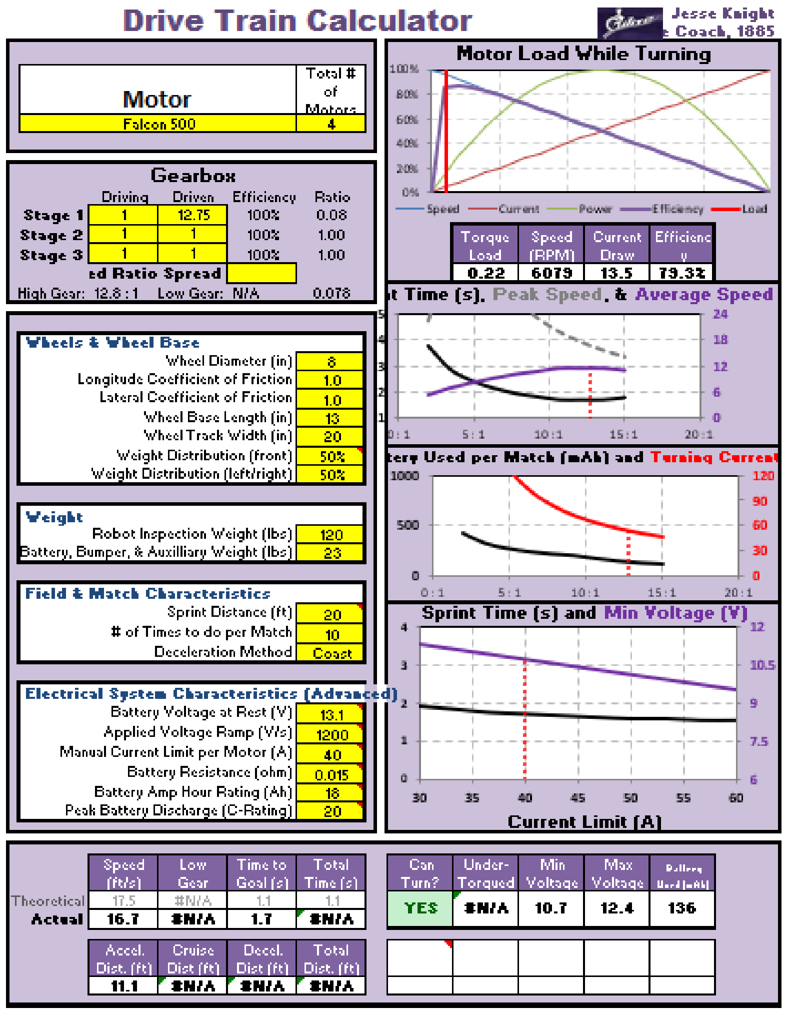
8 inch Pneumatics with 10.71:1 gear ratio

- There is not much room to optimize for the sprint duration.
- Because falcon 500s are pretty fast, top speed is very high - 19.7 feet per second. This is too high, making the robot close to uncontrollable.
- We don't know if the turning current calculation is accurate, but choosing a higher gear ratio will also lower turning current, which was one of the biggest problems we faced last year
- Acceleration distance is pretty high, roughly 90 percent of our sprint distance. Ideally, it will be closer to half because that will increase acceleration and increase short distance speed.
- Overall, it looks like we need a higher gear ratio because of the top speed, potential turning problems, and acceleration distance. The next gear ratio available for our gearboxes is 12.75:1.



8 inch Pneumatics with 12.45:1 gear ratio

- Slight improvement in sprint time versus the 10.71:1 gear ratio, but not a very noticeable change - won't drive the gearing decision.
- More controllable 16.7 ft/s top speed.
- More conservative gearing when looking at potential turning current draw, especially after related problems during the 2019 season.
- Acceleration distance is very close to 50% of sprint distance which is good.
- Overall, 12:75:1 looks good. It is more conservative than the 10.71:1 which we hope will help us with the problems we had with a similar setup the previous year.



Drivetrain sizing decisions

The kit of parts drivetrain has three sizing options they recommend. Long is 32.3” long by 27” wide. Square is 28.3” long by 28” wide. Wide is 24.3” long by 31” wide. To use the large 8 inch pneumatic and omni wheels, we must use the long configuration. This is good because based on layout sketches that is the chassis that will make our mechanisms integrate best. We will still have room to intake more than three ball widths in the front of the robot while having the length to fit our indexing, feeder and shooting mechanisms. It is also the most stable drivetrain out of all of them because it has the largest wheelbase, which we will need because of the increased low-end torque of the Falcon 500 motors.

Testing on 1/11

On January 11th, a week after kickoff, we built the chassis with the Falcon 500 motors, the 12.75:1 gear ratio and the pneumatic and omni wheels. We then ran the same four game specific tests we did for the old drivetrains and added a couple to test how the omni wheels affected the drivetrain's scrub.

We tested this robot with no additional weight (just the drivetrain), with 50 extra pounds of weight, and finally with 100 extra pounds of weight. The extra weight was positioned 2 inches backwards of the center of the drivetrain.

Note that this drivetrain has 88.21 ft-lbs of torque. Our 2019 robot had 45.61 ft-lbs and our 2018 robot had 38.21 ft-lbs. This equates to a little less than two times (1.934x) more torque from our 2019 robot and a significantly more (2.309x) than two times our 2018 robot.

2020 prototype drivetrain (40lbs, 90lbs, 140lbs 4-8 inch pneumatic wheels and 2-8 inch omnis)

1. From rest - The drivetrain did great. Its increased torque meant that it did not need a lot of momentum. We did not find any problems going over the boundaries.
2. Spin in circles on top. - We were unable to test this well, although the testing we were able to do proved it was capable. Because the middle and front wheels have a different amount of traction than the back wheels, the drivetrain does not spin perfectly around its center. Because it does not go in perfect circles, it was getting too close to the people holding the boundary down. This was not a problem we encountered with the previous two robots, but because it was able to go over the bar while turning we were satisfied with the results.
3. Full speed into boundaries - we tested this with the robot going in two directions: one leading with pneumatic wheels and one leading with the omni wheels. We were satisfied with the results in both directions, as the robot had no trouble going over the boundaries, but we will prefer leading with the pneumatic wheels for two reasons. First, the pneumatic wheels are more capable of taking the shock loads from hitting the boundary at full speed, whereas we are more wary of breaking the plastic omni wheels by leading with them all season. Second, the pneumatics provide more balance and reduce the vibrations across the whole robot. Both of these problems pose the potential of long-term damage to the robots, if we do them all season, so we will try to lead with the pneumatic wheels when we can.
4. 45* angle - not much change from the full speed into the boundaries. Drivetrain did not deflect off from straight which was promising. The pneumatic wheels made the drivetrain slightly more stable than the tests from the previous weeks.
5. Manually turning the robot to evaluate scrub - the 2019 robot, which had all pneumatic wheels and encountered a ton of turning scrub problems, is very hard to turn by hand. By testing this by manually turning the robot, we were able to guage the impact the omni wheels have on the scrub problem. When turning the robot from the omni side, with the weight on the omni side, the drivetrain turns great. We had no problem turning it just like

a normal 6 inch Hi-grip drivetrain. When turning it from the pneumatic wheels side, however, we encountered much more force. This happened when the weight was primarily on that side of the drivetrain. To avoid this problem, we will need to design our robot so that the center of mass is behind the center of the robot.

6. Analyzing current draw when turning to evaluate scrub.

Overall, we were satisfied with this drivetrain setup. From our tests, it went over the boundaries just like we wanted them to, and solves many of the problems that might have affected drivetrains similar to the previous two years' robots. There are a couple of requirements we will need to incorporate into our design to make sure this drivetrain works well, mainly the center of mass needs to be a minimum of two inches behind the center of the robot to reduce turning scrub, but we feel that we can do so.

Problems found on 2/4

On February 4th, we found that the spacers we had included between the rails of the drivetrain and the wheels did not line up correctly. This was caused by the difference in width between our omni wheels and our pneumatic wheels. This caused the frame to bow inwards slightly. We were able to clamp the frames to prevent the bowing, but then the wheels would encounter too much friction and would be difficult to turn. We decided to leave the drivetrain how it was for the time being, and resolved to address it if it ever became a problem.

Intake

Overview

The Intake system will be used to gather Power Cells from the field and into the robot. While there are several ways of accomplishing this, we will focus on a wheel-based system. There are a few things we wanted to keep in mind while developing the intake: “touch it, own it;” articulation and frame perimeter rules; bumper and chassis frame interaction; indexing; and the effects of defense. These concepts will be discussed in the following sections. All in all, we hope to design, test, and perfect (as best we can) a mechanism which effectively gathers Power Cells from the field. This is essential to competing in Infinite Recharge because we must collect Power Cells in order to score them in any of the goals. The intake does not interact with any other game task (such as the Control Panel or Generator Switch).

Intake goals and design constraints

Touch it, Own it

“Touch it, own it” refers to the intake’s ability to gather Power Cells effectively. We want our intake to collect a Power Cell into the robot as soon as it touches the ball, given that the intake is currently accepting Power Cells. We want to avoid touching a Power Cell and letting it bounce away so that the robot would have to chase it all over the field in order to collect it. Rather, we want to collect it as quickly as possible. This saves time in our cycles and also denies defensive opponents from stealing the valuable game object from us.

Articulation and Frame Perimeter Rules

The robot cannot extend more than 12 inches outside of its frame perimeter. The frame perimeter is a box around the robot created by the outside edge of the metal chassis frame. This limits how far our intake an extend from the robot. Articulation refers to the movement of the intake. This year, there are no rules about having mechanisms outside of the frame perimeter while playing on defense (although it is illegal to touch the inside of another robot, so we will have to be careful on defense). It is likely that we will simply set our intake in an upright position to start each match and allow it to fall into position once the match begins. This can be done connecting the structural arms of the intake to aluminum tubing posts on the robot with a hex shaft and ball bearings. Other ideas for articulation include pneumatic pistons which would actively deploy the intake and allow us to retract it to play defense, or a motor at the hex shaft which would do the same (just with rotational motion instead of linear motion).

Bumper and Chassis Interaction

This refers to how the Power Cell will interact with the bumpers and chassis. We have three options in regard to this. The first option is to make the bumper cover the entire perimeter of the robot, and make the intake collect Power Cells using the bumper as the bottom compression point. The second is to make a small gap in the bumper and use the chassis frame as the bottom compression point. The third is to cut a gap in the chassis with no bottom compression point, but rather using the chassis gap as a funnel (for the indexing of Power Cells).

Indexing
When collecting Power Cells, our intake is going to be wide enough to be able to collect multiple balls at a time. This poses the problem of how to order these balls in a way that they are in a single file line with space in between them. During this process, none of the power cells can squish into each other, which will “gum up” the system. The space in between the balls is especially important because it will help guarantee that this will not happen. The indexer will enable us to collect multiple balls at once and line them up in a way that is repeatable and will prevent jamming.

First Prototype

Our first prototype used the green compliant wheels to guarantee a quick intake. Two hex shafts were used to funnel the Power Cells towards the robot and over the bumper. The first bar was roughly 6 inches from the bumper (horizontally) and 8 inches off the ground, with 3-inch wheels. The second bar was 6 inches from the bumper (vertically) and ??? inches from the outside of the chassis frame (horizontally). The PVC system allowed easy movement to adjust these numbers, though there were very few adjustments (ending with the aforementioned measurements).

Advantages
Instantaneous intake. We were even able to throw balls at the intake: they would bounce off but had enough back spin to return to the intake and go over the bumper. Multiple balls could be collected at the same time as well.

Disadvantages
This intake is bulkey, heavy, and sends balls over the bumper in a straight line, regardless of spin, angle, or speed of entrance. This means we will need an indexer to correct ball placement within the robot and guide them towards the feeder in a timely manner.

Mechanum wheeled intake

This intake was not prototyped, but highly discussed. Its theoretical advantages and disadvantages are discussed below.

Advantages
Would fix the problem of indexing by collecting balls at the center of the robot before sending them over the bumper. This would mean a separate indexer mechanism would be unnecessary, and the intake itself would be much lighter.

Disadvantages
This intake would be much slower in collecting the balls into the robot and require more driver precision. It would also require us (likely) to cut a hole in the center of the chassis frame in order to allow the balls to pass into the robot (similar to Marvin from 2018 and Hal from 2019). This would greatly reduce the structural integrity of the chassis.

Second prototype

This intake is very similar to the first, but was actually used on the robot for testing and refinement. By this point, we had decided upon the green-compliant wheel intake. The bottom shaft contained 2-inch wheels, while the upper shaft had 3-inch. A hopper slope was added to the top, and a compression shield covered the bumper to increase the contact between the intake wheels and the collected balls. This entire system hinges up and down on two arms (two per side). The indexer ramp and mechanism starts right behind the shield.

Advantages

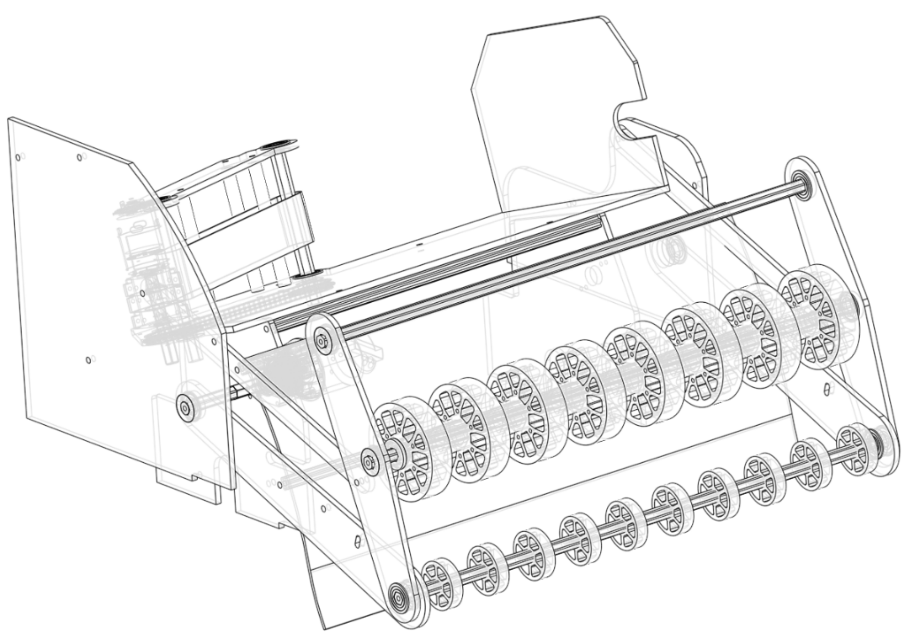
Similar to the first prototype: very quick ball collection into a hopper. Removes the most major dead zone between the bottom of the bumper and the floor. The passive hinge action allows it to start within frame perimeter, but very easily shift its center of gravity once the robot moves to passively deploy itself.

Disadvantages

Dead zone, very large and a little unstable.

From our Chief Delphi Post:

We ended up with a full width intake run by a Falcon 500, geared 3:1. The intake is on a four bar that fell forward during autonomous. We thought about adding the ability to articulate it but ultimately did not see a need. The shield on the intake prevented balls from going under our bumpers, even when moving at relatively fast speeds. The middle wheel is larger to speed balls up as they go through the intake and make sure there are no jams. The top shaft had the "car wash" (not pictured), which was comprised of string glued to the hex shaft, acting like a three inch wheel. The purpose of the car wash is two fold. First, to slow balls down so they would not shoot over the robot, which we found could happen when prototyping, and second, to act as a wheel when spinning, but as a shaft when not spinning. If we had a three inch wheel, we would not be able to easily intake from the loading station. The carwash was one of the parts of the robot that won the Xerox Creativity Award at the Plano competition.

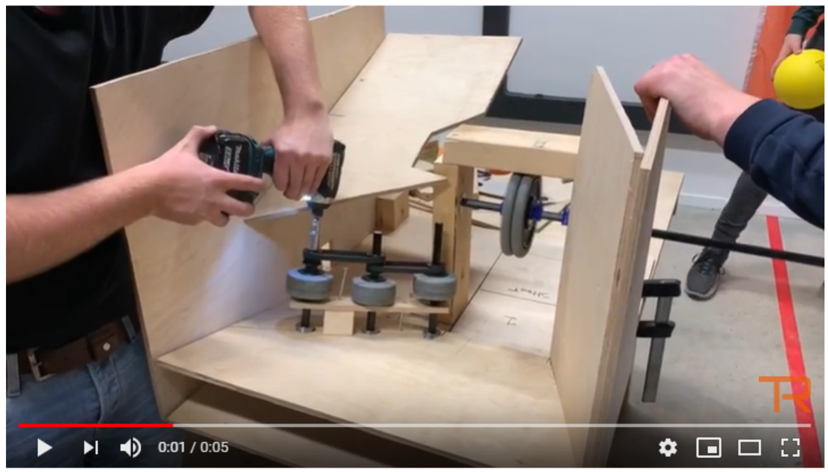


Indexer/hopper

Since we have chosen to pursue a wide intake, which will cover the entire front of the robot, we will need a way to order the balls into a single file line. Depending on how the feeder mechanism works, we may or may not need to be able to put some space in between the power cells. If the feeder is one sided, this will be much more essential. If we decide we need to incorporate an indexing feature into this mechanism, we will call it the indexer. If we find we do not need to do this, we will call it the hopper.

Inspiration

This mechanism was heavily inspired by 4481 Rembrandt's indexer prototype. The mechanism has three parts. First, a ramp that slopes down into the robot. Second, wheels or some sort of rotational mechanism that will funnel the balls to one side of the robot, and third, a top wheel that takes the balls from the indexer. We chose to use the basic idea of this design, with some modifications.



Modifications

We need to make some changes to make this idea work with our design.

- We want this whole mechanism to rotate upwards from the front edge so that we can have access to electronics on the belly pan and possibly mount the battery underneath.
- We want to try using a poly belt instead of the three colson wheels Rembrandts used to funnel the balls
- Instead of the large omni wheel, we will have it feed straight into our feeder mechanism.

First version

Now that we know what we are looking for we could start to prototype. We started by making the slope. We then started to make a plywood housing unit for the 2 wheels (4 inch compression wheels) that would guide the balls into the feeder. We then tested it using drills to see if the idea would work. Once we tested it and decided that it worked we went straight to CADing the hopper. The hopper had to mount in some way to the frame. At first we were going to use a bracket with 1 by 1 aluminum tubing however we decided later that we would just make a bracket that would attach directly to the inside of the frame. This would also be able to integrate with the intake and hold the intake motor. We decided to use a poly belt instead of compression wheels due to weight and a lack of space. To continue our progress, we needed to see the mechanism built in real life...

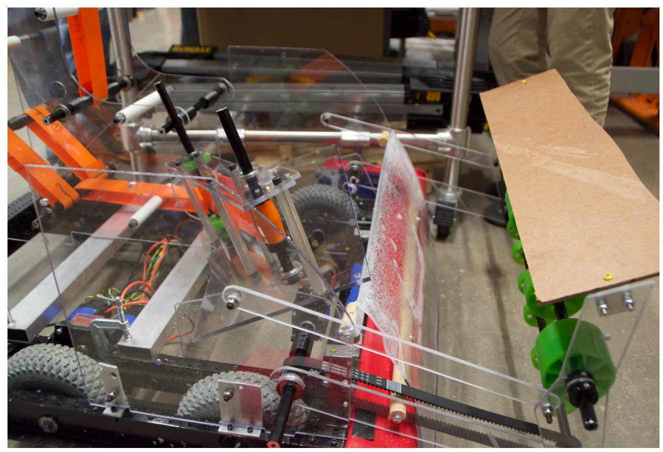
Construction

The overall construction of the hopper consists of two side plates which mount to the inner rails of the drivetrain and a piece of polycarbonate on top. On the top piece, there are holes for bearings and churros. The side plates have a churro in between them, which the hopper is connected to. In its normal state, the hopper connects to this churro and sits on top of the plates. The churro is allowed to freely rotate, which means the entire top of the hopper can rotate up to get access to the electronics below.

Once we were ready we sent the CAD to the CNC team who then turned the CAD into CAM. After some malfunctions we finally finished machining the parts. We cut the churros and the hex shaft to the correct length. We then tapped the churros and pressed the bearings into the polycarbonate. We assembled the unit and put the brackets on the frame. We then looked to see if it fit as well as the CAD had shown.

Problems from CAD integration

Unfortunately the intake and the hopper did not fit together as we had wished. The front plate of the intake would hit the front of the hopper when the intake was raised up. This meant we had to trim the front of the hopper and the front of the brackets so that the intake could move freely. We then found out that some of the measurements were wrong which caused the hopper and the feeder to not line up properly. We resolved to go back to the CAD and fix the problems we encountered.

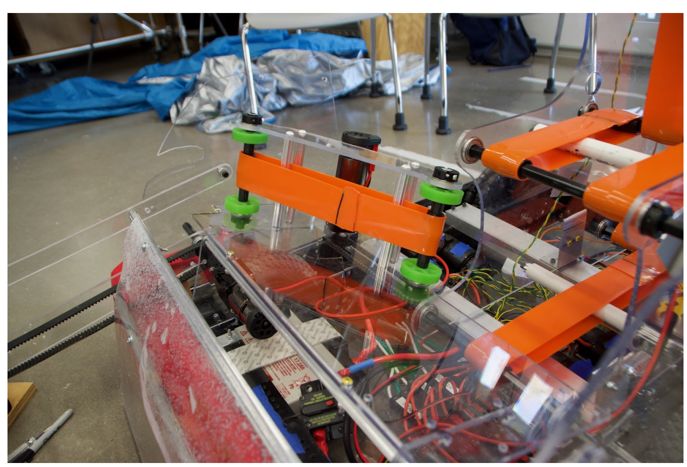


Second version

We started off by measuring the modified hopper that was not made to the correct measurements. We then started adjusting the measurements. We also realized that we needed to move the motor mount to where it was mounted on the hopper plate pointing down. Before we machined the new hopper we checked every measurement to make sure it did not interfere with the intake or the feeder.

Construction

Once we had done a thorough check we gave the CAD to the CNC team and they got the parts machined. While the parts were being machined we cut new churros including the churro we were



going to use to make the hopper open so we could access the electronics.

(More) Problems from CAD integration

Once the parts were done we assembled the hopper and put the motor system together. We discovered that we did not use an accurate center distance for the chain that drives the poly belt, meaning the chain was either too loose or was too tight we could not even put it on the hex shaft. To fix this we increased the size of the hole the motor shaft was put into and then we used one screw to act as a pivot point. We then rotated the motor until it was tight enough to not fall off. We drilled a new screw hole for the other screw and mounted the motor. We then realized that the sprocket and chain would interfere with the bracket that the hopper was supposed to mount to. We cut out the area around the chain so that it wouldn’t interfere.

Problem of losing balls

We then tested the hopper to make sure it worked. It was able to funnel the balls straight to the mouth of the feeder. The only problem left to solve was related to how it interacts with the intake system. The intake would periodically shoot balls over the hopper system. There are two ideas that we had to fix this. We can use bungee cords to absorb the energy or we could use a net to do the same. We will explore these options in the near future

Feeder

The feeder is the mechanism that will take balls from the indexer up through the turret and into the shooter. It will form an “L” shape, with a lower flat component leading to a vertical component

Design options

There are two archetypes that apply to the feeder mechanism. The first is a single belt option, with a fixed backing. This is the simplest option, but is also limited in many ways. First, because this mechanism will roll the balls against the hard backing, it necessitates the balls to be indexed. If they are not, they will have the opportunity to stick to each other and could prevent the mechanism from working.

The second archetype is a double belt option. This would have a belt on the top/front and bottom/back of the ball at all times. The ball would not roll because it would be moved from both sides. This mechanism does not need indexed balls because they will not be rolling and thus will not tend to stick to one another.

We chose to go with the double belt archetype. This will prevent many potential problems with the balls jamming in the mechanism, and, despite being harder to design and get working, will benefit the functionality of the robot.

Positioning on the robot

On top of the feeder will be the turret and Shooter, which means the positioning of the feeder will be dictated by those mechanisms so that everything is in frame perimeter. To make sure we would be okay, we used the basic mockups of these mechanisms to space the feeder away from the back of the robot, which we found was the limiting dimension. We decided to place the feeder 2.5 inches from the back.

Mounting the feeder

We found we needed to have especially strong attachment points to the feeder, because it will have a large mass (the turret and feeder) on top of it. We decided to run two 2x1 cross beams across the drivetrain to serve as attachment points, and also decided to place the outer side of the feeder on the drivetrain rail. This will allow us to use a lot of the already present mounting holes to attach the feeder mechanism.

Inspiration

We took inspiration from the team XXXX, who had a very simple dual belt design. We emulated the geometry of their rollers and the idea that we could make this mechanism out of two pieces of polycarbonate, held together with churros

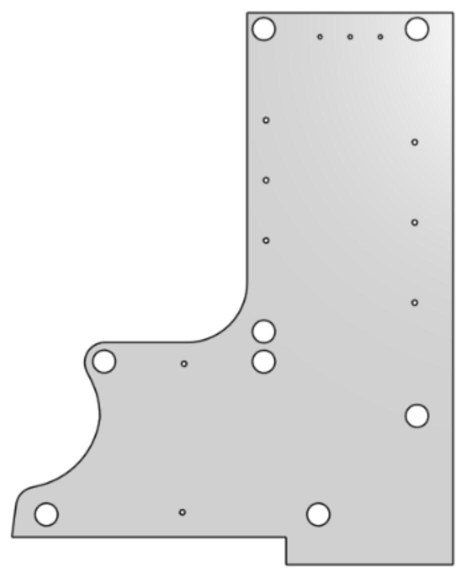
Construction and design

As stated above, we decided to make this mechanism out of two pieces of ¼ inch polycarbonate, sandwiched together with Andymark churros. We will run a combination of live and dead axles, to provide more structural integrity where it is needed.

The difference between live axles and dead axles is the relationship between their movement and the wheels that are on them.

- Live axles are set between two bearings and rotate in relation to the mechanism. The wheels on live axles do not move in relation to the axle. Live axles are very good for transferring rotational motion, as you just need to move any part of the axle to move the wheel.
- Dead axles are fixed in relation to the mechanism. The wheels on dead axles rotate independently of the axle. This enables the axle to be used as a structural member of the mechanism, but means the way of transferring rotational motion must be directly to the wheel, not just anywhere on the axle.

As stated above, the combination of live and dead axles enables us to take advantage of the ease of transferring rotational motion of live axles and the increased structural integrity that is provided by dead axles.



This is the initial design of a side of the feeder mechanism. We plan on cutting the whole part out of a single piece of polycarbonate and pressing bearings into the 1.125 inch holes. ¼-20 bolts will screw into andymark churro through the smaller bolt holes. We will include ½ inch schedule 40 PVC pipe on the andymark churro to add support to the polyurethane belting we will be using. This will make sure the belts do not flex in a way that affects the compression on the ball, which could cause balls to slip in the mechanism. The bottom cutout is there to account for the 2x1 cross beams, and will sit on top of them. The back “shelf” will sit directly on the drivetrain frame. The three bolt holes at the top are mounting holes for the turret.

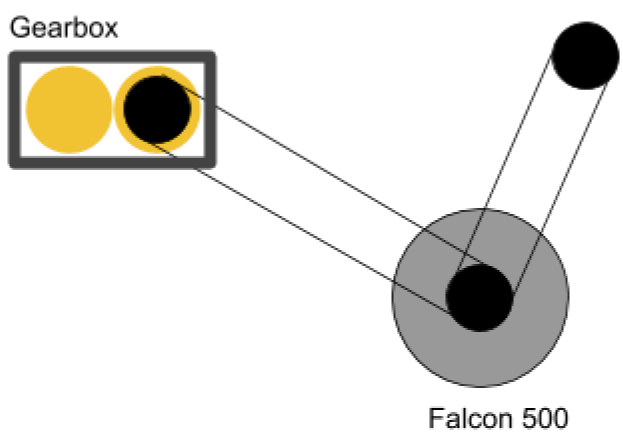
Possible indexing capabilities

If we needed to, we were able to find a way to index balls inside the feeder mechanism. Because of the dual belting setup, the primary purpose of this would not be to prevent the balls from sticking together, but rather to space them in a way that benefits the performance of the shooter. If the programming team can get the balls indexed in a way that they can just run the feeder with proper spacing in between each ball, they may be able to make it work so that the balls are more evenly spaced when shot. This would increase the accuracy of each shot.

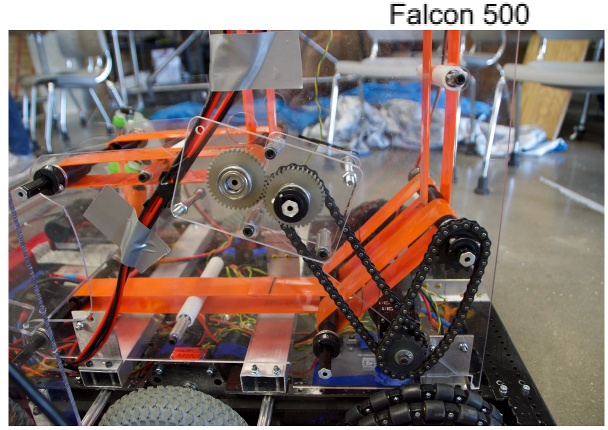
Gearbox

We want to be able to run the feeder with a single falcon 500 motor. This will enable us to have a lot of torque, which is necessary because of how much tension is in between the polyurethane belts, and enough speed so the mechanism can operate at a relatively fast rate. Additionally, the falcon 500 has a built in encoder, which makes gearbox design easier and enables the programming team to use it to help streamline the operation of the mechanism. The single motor means that we will need to invert the direction for one of the belts. The top belt must run counter clockwise and the bottom belt must run clockwise so that the ball will move up the feeder.

To do this, we have two options. The first is a section of poly cord in a figure eight pattern. Such an “infinity cord” (as one team member named it, due to its similarity to an infinity symbol) would have matched this year’s theme well, but we were afraid it might slip. We were weary of this because of the large amount of tension in the polyurethane belts, which is also one of the reasons we chose the Falcon 500 motor. The other option we have is to use a gear mesh. This will enable us to invert the direction of the top/front belt, while preventing the slippage we were afraid of in the polycord.



This was the gearbox solution we came up with. We decided to attach a versaplanetary gearbox to the Falcon 500, with two 3:1 gear ratios, and attach a double hub 15 tooth #35 chain sprocket to the versaplanetary. One side of the sprocket would run to the bottom/back of the feeder, while the other side of the sprocket would have a run to the gearbox, which would use two 42t gears to invert the direction of the rotation.



This is what the first version looked like. There were a couple of problems with our approach, which will be changed in the next version.

- The gearbox is on the left side of the feeder, on the outside of the robot. If we ever need to swap a belt, we will need to take that side of the feeder off, which means we want the gearbox and chain on the other side of the feeder.

- We cut the parts of the feeder before we figured out the gearbox solution. This means there were no CNC-ed mounting holes, so we did not have accurate Center distances for our chain. We were able to account for this with the rotation of the gearbox on the left, but not on the fixed distances on the right. In the next version, we will cut the holes with the cnc and make accurate C-C distances so our chains do not have so much backlash. We have not found this to be a problem, but we would like to make it better.

First version

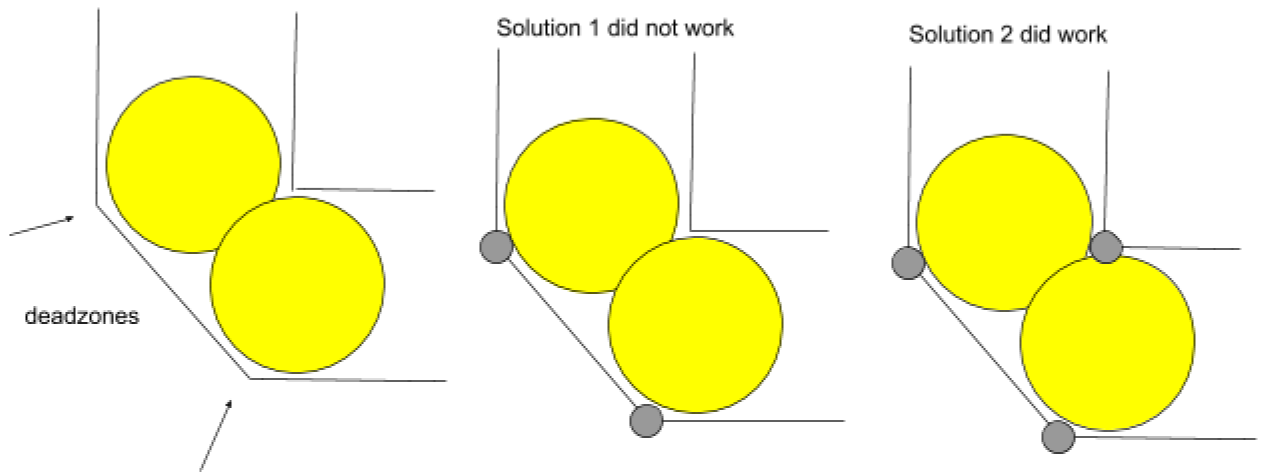
When we first tested the feeder, it worked flawlessly. We were unable to jam it due to the dual-belt system. The gearbox and chain have worked well. The shooter, with the temporary fixed mounts went on well. Overall, the feeder was relatively stable. We were able to hold all five balls. Thankfully, this does not leave a lot to fix, and our first version was a large success. However there are still a couple of things we want to change.

Problems found week of 2/9

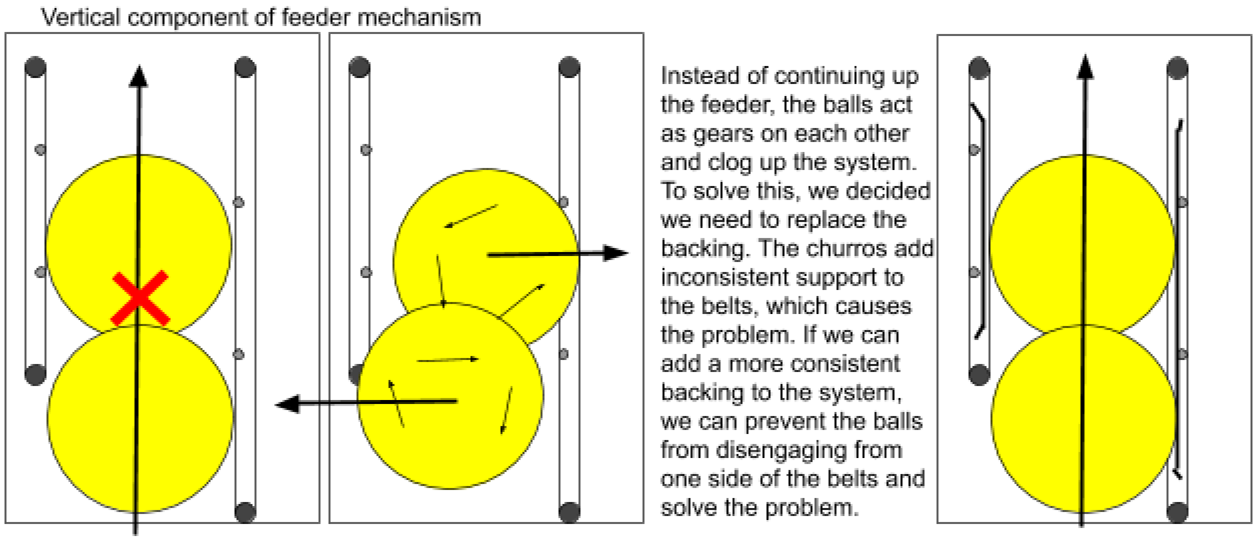
Most often, the feeder will be operated by continuously starting and stopping the belts, so that we can get as many balls into it as we can. This means that often the speed of the feeder will be low. Unfortunately, this is also the state that causes the most problems. We didn't have many problems at higher speed. We do however have a lot of problems at lower speed.

The first problem was related to the intake into the feeder from the hopper. The belts at the top are doubled, which means they are split pretty far apart. This means that we were having problems getting the balls in quickly, because there was a gap in the middle of the upper hex shaft. We fixed it by adding 2 inch compliant wheels.

The next problem was two dead zones in the corner of the feeder. One between the horizontal and the angled belts, and another between the angled and the vertical belts. This, again, is primarily caused by the dual belt setup, which reduces compression on the ball. We first tried putting the 2 inch compliant wheels in the bottom/back corners of the feeder. This barely changed anything. We then took the feeder apart again and added the 2 inch compliant wheels in the top/front corner of the feeder. This fixed the problem.



We also found the balls sometimes get pushed together for whatever reason. Most often, this happens in the vertical component of the feeder. When this happens, bad things happen. The two balls act as gears on each other. If you are looking at the robot from the left side, (it always happens in this way), the top right ball meshes with the bottom left ball (always in that orientation). The two push each other horizontally, meaning they stretch the belts and get stuck under the churros. As the belts go up, the top right ball spins counter clockwise, and the bottom left ball spins clockwise. There is not an easy way to get them unstuck when this happens. Sometimes running it in reverse can help, but not always. We found that the churros, because they created different areas of low and high support of the belts, contribute to this problem, but when all churros are removed, there is not enough tension in the belts to maintain stability of the system, and we encounter the same problem, sometimes on a larger scale because of the lack of support of the belt.



After a couple of days of trying to identify the root causes of the problem, we identified them and found a solution. First, the churros' variable support produces an opportunity for the previously mentioned gear effect. Second, the lack of support also causes the balls to disconnect from one side of the dual sided belts, which is the primary cause of the problem. The solution is to attach flat polycarbonate sheets between the stationary churros, with low friction tape, in order to provide adequate and consistent back pressure to the belts. We will use 3d printed mounts and zip ties to attach the polycarbonate to the churros.

Turret

A turret is a “reach” goal of the team. It is not one of our prioritized mechanisms, but rather one that we will work on after the basic functionalities of the robot are completed.

The advantage of a turret is the ability to shoot in a direction that is independent of the orientation of the drivetrain. We were planning on attaching a turret for the next district competition, but unfortunately the season was cut short. Will most likely be an offseason project.

Shooter

The shooter will be the primary scoring mechanism on the robot. If it is not functioning correctly or consistently, the contributed value of our robot to a given match will be reduced significantly. Because of this, the shooter is one of the critical mechanisms on the robot. In a shooting game like 2020, a robot is only as good as its shooter. One of our primary objectives is to increase the consistency of the shooter as much as possible.

General overview and design

We chose to pursue a “flywheel” shooter, which uses the same ideas of a baseball pitching machine. The basic premise is a wheel spins very fast, surrounded by a shooter hood. The ball is fed between the wheel and the hood and launched into the air. Being the most common types of shooters in FRC, this has been shown to be, when tuned in, a very capable design.

Shooter metrics

Basic terminology used when discussing shooter design

Surface speed explained

Surface speed is pretty simple - it is the speed of the shooter at the outer surface of the flywheel. When surface speed is increased, there is more energy available, in the velocity of the surface of the wheel, to transfer to the ball.

Surface speed can be defined by the equation $(RPM * 2 * pi * Radius\ (inches))/12 * 60$ Although not necessary, the 12*60 turns the stat from inches per minute into feet per second. This makes the numbers much more manageable and easy to work with.

Tractive force

Tractive force, is the force used to generate motion between a body and a tangential surface, through the use of dry friction. We want to increase the tractive force on the ball in order to transfer as much energy into the ball.

Compression

Compression is one way of increasing tractive force on the ball. By compressing the ball, the normal force between the ball and the wheel is increased. Since the force of friction is proportional to the normal force, increasing compression increases friction and thus tractive force. However, too much compression can cause the flywheel to slow down too much.

Rotational inertia

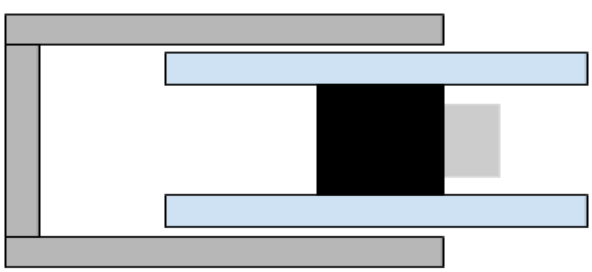
The moment of inertia, otherwise known as rotational inertia, of a rigid body is a quantity that determines the torque needed for a desired angular acceleration about a rotational axis; similar to how mass determines the force needed for a desired acceleration. The more mass on a rotating object, the more rotational inertia it has (kinda, depending on the radius). The more rotational inertia in the flywheel, the longer it takes the flywheel to get up to top speed, but it will slow down less after each shot. Additionally, if there is not very much rotational inertia in the flywheel, the flywheel will slow down significantly as it is shooting a ball, meaning the energy transferred to the ball will not be maximized.

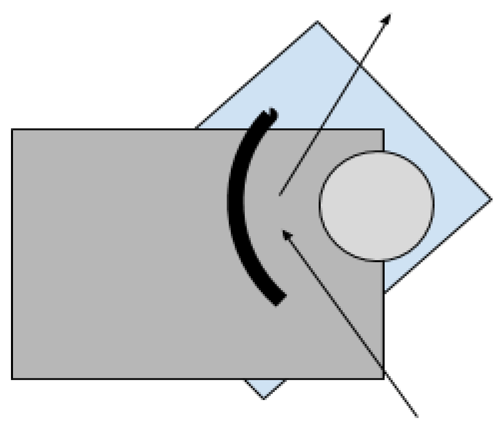
Spin Up time vs Shot frequency
Because of rotational inertia, the spin up time of the shooter is inversely proportional to the available shot frequency. In general, if it takes a long time to spin up a shooter, caused by its rotational inertia, then it will be able to shoot multiple balls in quick succession. If it does not take a long time to spin up a shooter, due to a low rotational inertia, then shots will need to be more spaced out because a larger portion of the available energy will be transferred to the ball on each shot.

Nowadays in FRC, with the available torque and speed of motors like the neo and falcon 500 brushless motors, the difference between spin up time and shot frequency is much smaller, so when the word “longer” is used, that could translate to a few seconds or less.

First prototype

The goal of our first shooter prototype was something that was easily adjustable so that we could test multiple launch angles in quick succession. It was built out of a plywood C which held two sides of the shooter. The sides of the shooter were attached to the c with bolts, held in place with squeeze clamps, making it able to easily rotate up and down.





The best specs we found were 2 inches of compression with a launch angle 19.5 degrees above horizontal. Our prototype was direct driven with a 1:1 gear ratio, but in future versions we want the ability to gear the shooter wheel up to get more speed.

Shooter wheels

We had two objectives to fulfill with our shooter wheels. First, we wanted wheels that could provide enough surface speed and tractive effort to launch the ball with the velocity that we wanted. Second, we wanted, if possible, for the wheels to act as their own flywheel. This means we would want them to be relatively heavy so that they can have a large amount of rotational inertia. Additionally, any wheels must be able to withstand the forces put on them when spinning at a max of 9000 RPM and also not damage the game pieces

On the prototype, we tested 3.875 banebots T81 wheels. These are very very cheap($3), and so were good for prototyping. However, they were relatively lightweight (thus not having a lot of rotational inertia) and took a lot of the outer coating of the balls off (Lots of lemon zest)

We elected to try the 4 inch Fairlane roller with the Space Coast products Fairlane hub. When we got them, the fairlane hub was a nice press fit, requiring our arbor press. There was minimal backlash with thunderhex shaft. The fairlane rollers were nice and heavy

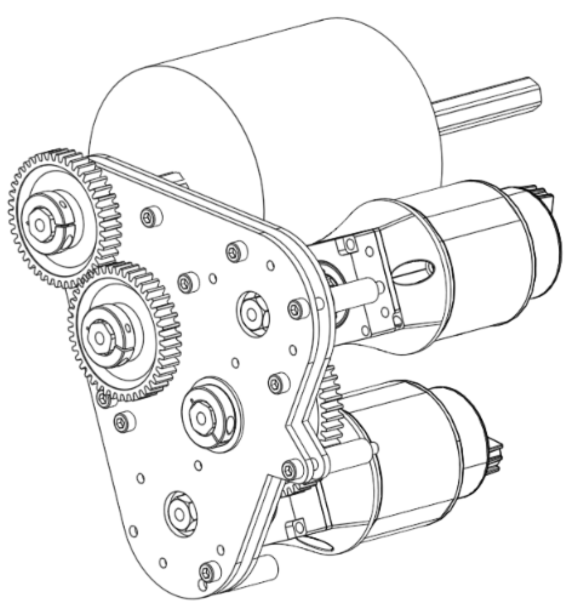
Safety wire

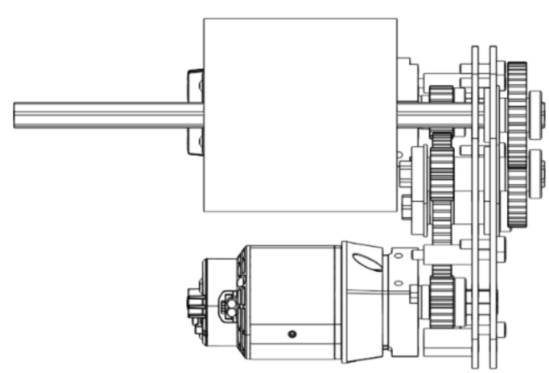
Motor placement and gearbox requirements

For our shooter, we needed to use two falcon 500 motors and connect them to the shooter shaft in some way. We also want to be able to swap the gear ratio to the shooter shaft, allowing of alteration of the “upduction”. There are also other considerations to be had, such as location of power and CAN wires, their proximity to moving parts, the limelight and overall safety of surroundings and the mechanism.

First Version

The first version we tried relied on a single gearbox with both motors in front of the shooter wheel, with the possibility of a primary shooter wheel before the main shooter wheel. On the gearbox, the two falcons had 20 t pinions, which meshed with a 60 tooth central gear. That central gear then meshed with another 20 tooth gear. On the same shaft as the 20 tooth gear was the first of a family gear mesh. These ratios: (20:60)(60:20)(X0,X1) gave a base 1:1 gear ratio. The family gear mesh, because all of the gear sets have the same center distance, can be easily swapped to change the overall gear ratio. The family gear is on the outside of the shooter for easy access.





However, there were a couple of things that made us re evaluate this design. First, it was heavy. The gearbox itself would weigh 4 lbs.. This mass was going to go at the very top of our robot, in the very back, meaning it would contribute to tipping of the robto. Therefore, we wanted to reduce the mass of this system. Second, our CNC was not yet operational. This meant that we would not have the ability to manufacture accurate parts in house, and we would have to outsource all of them. This was not something we wanted to do. Third, we did not like how close the motors were to the shooter wheels. Delamination of the shooter wheel or something getting caught in them as the spun at several thousand RPM endangered our motors and the functionality of our robot. If a motor wire got caught in the shooter wheel, we would lose functionality of one or both of the Falcon 500s. If a CAN wire got caught in the shooter wheel, our robot would be rendered dead on the field. If the shooter wheel delaminated from its hub, it could damage the $280 of motors, versaplanetaries, the limelight and anyone around it. For these reasons, we chose not to use this design.

Fixing the problems

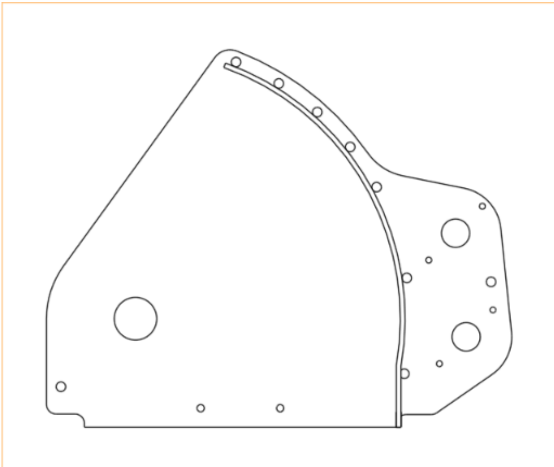
The problems of the previous design were as follows:

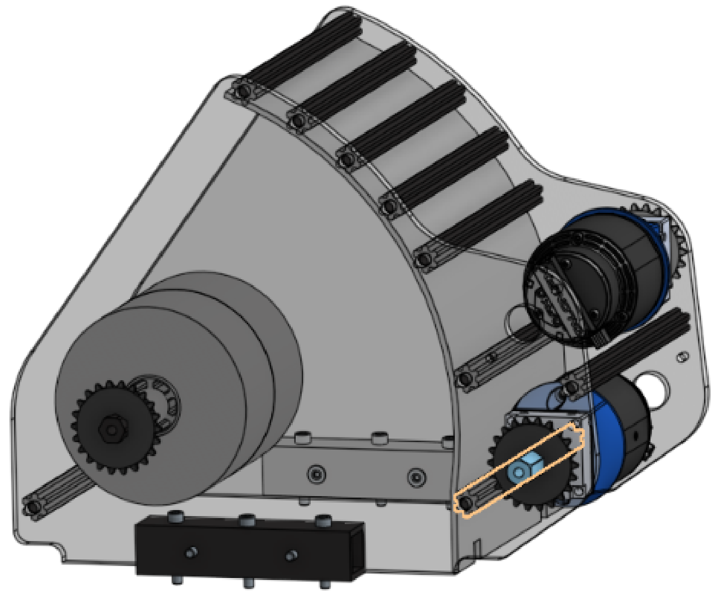
1. Too complex
2. Too heavy
3. Not easy to repair
4. High cost (both monetarily and competitively) of failure
5. Very big

To make things simpler, we decided to not use multiple gear meshes.
No or less gears would help with weight, but we also elected to not have any extra gearbox plates to reduce weight. The gearbox would have to be incorporated into the side plate of the shooter.
Simpler will make things easier to repair
Distancing the motors and CAN wires from the shooter, preferably behind polycarbonate, will solve the high failure cost.
A simpler design will help reduce size, along with some good CAD packaging.

Second Version

To solve many of these problems, we chose to put the motors in the back, behind the shooter hood. No extra gearbox plates are needed, meaning there is minimal extra weight added. Motors can be easily taken off since there is a lot of access room from the back. The motors and CAN wires are physically separated from the shooter wheels, reducing failure cost. There really isn't a way to reduce the size further. Additionally, the motors in the back counteract the weight of the shooter wheels in the front, making the shooter itself much more balanced. The motors will be connected with chain to the shooter wheel, and the C-C distance between them is optimal for three different sprocket ratios: 22:22, 22:18, 22:16. This means the ratio can easily be changed with a different chain and a smaller or bigger sprocket. The motors must be stacked vertically because they would interfere with each other.





Climbing endgame

1/5/20

After reading the game rules and point scoring, the following are the goals for the leveling climb. Note that this is based on the assumption that leveling will be challenging – but we do not yet have a sense of how sensitive the balance will be (how many inches off translate into 8 degree of tilt?). This question will need to be answered to make a more informed decision.

Goals:

- Lift and support weight of robot in under 2 seconds (max 5 seconds)
- Grab/brake to make sure robot won't slide on bar
- Maintain grab for 5 seconds after end of match (default brake or high friction)
- Be able to grab from middle of pipe (straddling center support) or on end of bar (Note that two separated grabbers would mean that weight cannot be localized at end of bar (unless push get grabbers close together – or push up on one to make all weight on other)
- Be able to reach bar no matter what height and angle (this is important if last to grab and if we need more time to complete another task)
- Be able to balance weight (move center of mass on pipe as much as 30 inches) in under seconds (max 20 seconds)

Approach 1: Frame Lifter

Life the robot using pneumatic design from last year. Hook system would be separate from lift.

Advantages:

- We know we can make this lift system work
- Using four lifting cylinders – they can be "out of the way for intake and shooter.
- If we put wheels on, (like last year) we could potentially make alignment to bar a driving task
- Support can be in tension – simply retract cylinders once hooked on pipe

Disadvantages/to figure out:

- Hook system – and clamping
- Potentially more weight since hook system separate from lift system
- How to create a balancing system (move attachment point on bar)?
- If can rotate hooking system – could align robot along either long or short-axis.
- Maximum stroke is REALLY LONG!!!!

- Space for undercarriage to life is limited and design

Approach 2: Grabber Lifter with robot balance

Grabbers extend from robot and clamp onto bar
Advantages:

- Hooks system integrated into extender system
- Balancing system
  - on robot – arms move in "channel"?
  - on bar – wheel and motor system?
  - on bar – "come along" approach?
  - Use force vectors (push up on one arm to change distribution of force)?

Disadvantages/to figure out:

- Does this get in the way of shooter? In way of spinner?
- How do we align?
  - Graspers with larger travel?
  - Extend and run into bar?
  - Sense bar location?
  - Combination?
- How do we extend grabbers
  - Pneumatic? Stroke is extraordinarily long (calcs below)
  - Telescoping poles?
  - Chain system and motors?
  - Cascading lift system?

Approach 3: Hybrid – frame lifter and Bar Grabbers

Life the robot using pneumatic extension (as in Approach 1) part way - extend a bar(s) from robot and clamp onto bar
Advantages:

- Support can be in tension – simply retract cylinders once hooked on pipe
- Lift of robot is very stable – not likely for robot to fall or swing
- Grabbers could extend from pneumatics if desired since stroke is shorter

Disadvantages/to figure out:

- Almost all of the same issues as in other methods
- More complex design
- Space and weight considerations

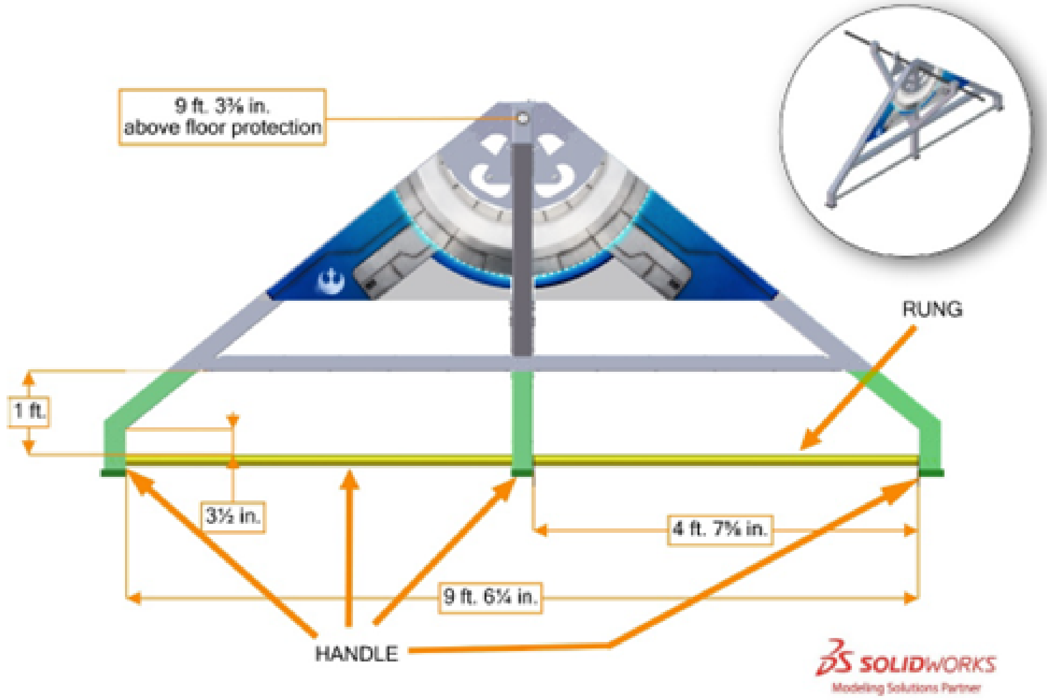
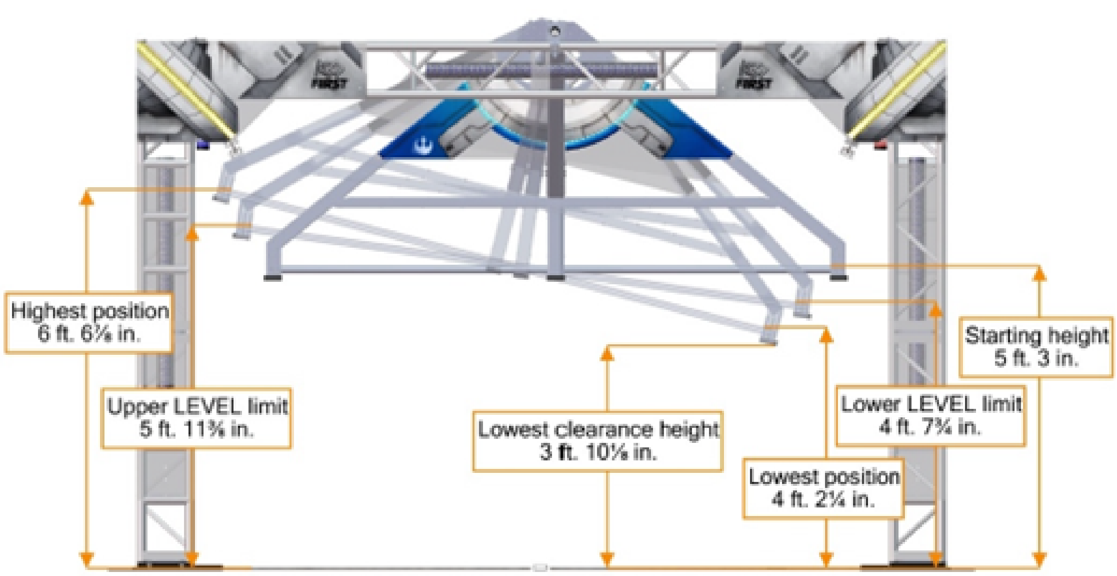


Figure 3-8 GENERATOR SWITCH

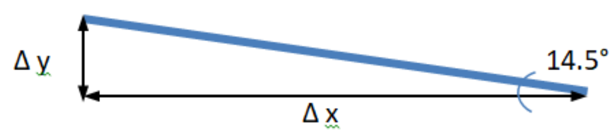
At the start of the MATCH, the top of the RUNG is parallel to and 5 ft 3 in. (~160 cm) above the floor protection carpet. The GENERATOR SWITCH can tilt and rest in different positions depending on the number and location of ROBOTS pulling on the HANDLE. For the purposes of scoring (see [GENERATOR SWITCH Scoring]), LEVEL is evaluated by the magnitude of its tilt as shown in Figure 3-9. The GENERATOR SWITCH is LEVEL if the RUNG is within 8 degrees of horizontal. Hard stops prevent the GENERATOR SWITCH from rotating more than 14.5 degrees in either direction. The rotating portion of the GENERATOR SWITCH has a weight of approximately 93 lbs. (~42 kg) and a center of mass approximately 2 ft. 2 in. (~66 cm) below the center of the shaft from which it is suspended.



Calculating worst case difference in bar height for two grabbers:

Angle is worst case of 14.5 degrees if bar is completely tipped.
Δ x represents the separation distance between the grabbers
Δ y represents the difference in height for the grabbers as a result of the angle.

Angle	Δ x (inches)	Δ y (inches)
14.5	35	8.76
	32.5	8.14
	30	7.51
	27.5	6.89
	25	6.26
	22.5	5.63
	20	5.01
	17.5	4.38
	15	3.76



Possible Robot Frame dimensions using kit of parts:
32.3” by 27”
28.3” by 28”
24.3” by 31”

Specifications:
Maximum Height of Robot = 45 inches

Bar (Pipe) diameter = 1.66 inches (approx. = 4.25 cm)

Minimum bar height = 50.25 inches
Level bar height = 63 inches
Maximum bar height = 78.625

Amount of “lift” needed: (Add 1 inch for every inch of robot height below 45 inches)
Minimum Lift = 5.25 inches
Level lift = 18 inches
Maximum lift = 33.625 inches

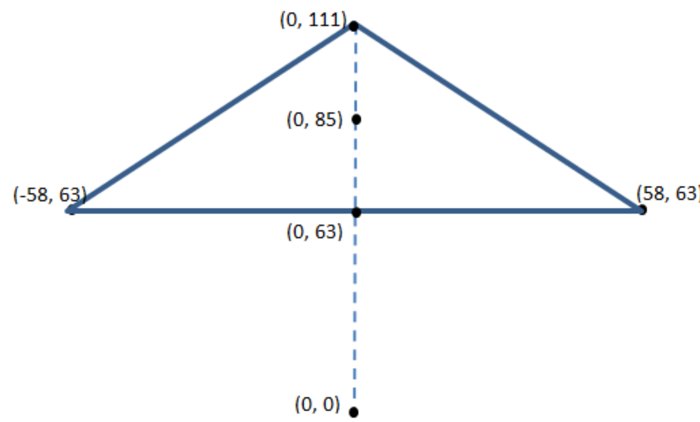
1/7/20

Determining Bar Angle:

Wrote an excel program to calculate COM of Truss with Robots, based on specifications of Truss.

Reference frame used: (in inches)

Pivot:	(0, 111)
COM of truss:	(0, 85)
Center of bar:	(0, 63)
Left end of bar:	(-58, 63)
Right end of bar:	(58, 63)



Programmed in excel:

Truss COM: 93 lbs. (0,85)

Inputs:

R1:	M1, (x1, 63)
R2:	M2, (x2, 63)
R3:	M3, (x3, 63)

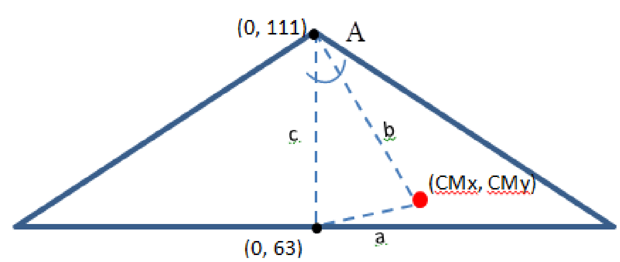
To Calculate Overall Center of Mass:

CMx = (93*0 + M1*x1 + M2* x2 + M3*x3)/(93 + M1 + M2+ M3)

CMy = (93*85 + M1*y1 + M2* y2 + M3*y3)/(93 + M1 + M2+ M3)

To Calculate Angle: Law of Cosines:

$$a^2 = b^2 + c^2 - 2bc \times cos(A)$$

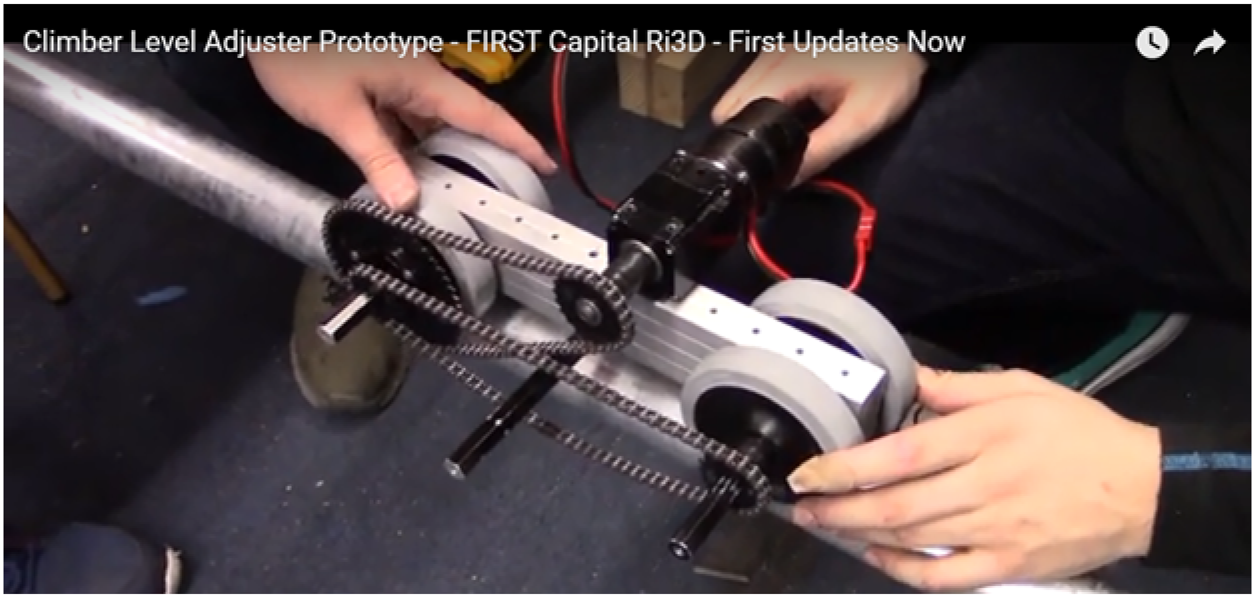


Note that this program can be used in reverse to determine where robot should be located to balance other robots already on bar. This can be solved by knowing mass of other robots and angle of bar. So if can measure angle of bar – can determine at what location to hang third robot.

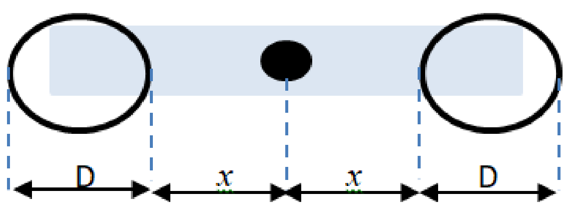
1/8/20

We confirmed the balancing program we created worked when it matched another program we found at: https://www.geogebra.org/m/aapcdzvf

Consider using a leveler as shown by Ri3D



This model they built uses 4 inch wheels



Calculation shows that to be within 8 degrees on bar:

Robot weight	Distance from fulcrum	Adjusted (-1.5 inches) for center support
135	9.29”	7.79”
140	9.23”	7.73”
145	9.14 “	7.64”
150	9.06”	7.56”
156	8.97”	7.47”

If using 4 inch wheel – this means that the shaft axis can be at a maximum 3.75” to 3.9” away. Taking worst case, the total length of the balance carriage (2d + 2x) could be: 2 x 4” + 2 x 3.75” inches = 15.5 inches. Making wheels smaller, and/or axis closer to the wheels shortens the length and gives margin.

Example 1:

- Wheels: 3.5 inch diameter
- Shaft 3 inches from wheel edge

Carriage length = 13 inches

Center of mass = 6.5 inches + 1.5 inches (half of center post thickness) = 8 inches

Robot weight	Distance from fulcrum	Angle
135	8”	6.9°
156	8”	7.15°

Example 2:

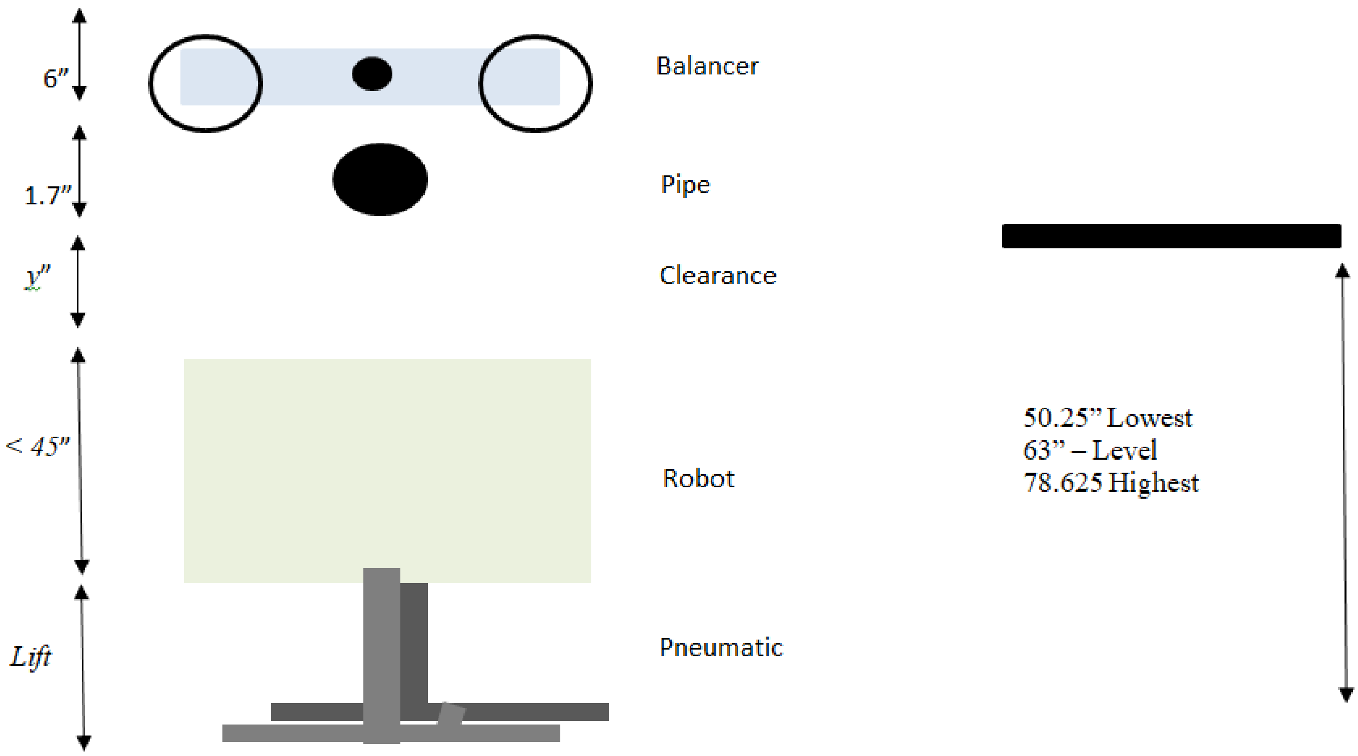
- Wheels: 3.5 inch diameter
- Shaft 2 inches from wheel edge

Carriage length = 11 inches

Center of mass = 5.5 inches + 1.5 inches (half of center post thickness) = 7 inches

Robot weight	Distance from fulcrum	Angle
135	7”	6.04°
156	7”	7.26°

Clearances:



Total Lift + Robot height > 63″ + y″ + 1.7″ + 6″
Total Lift + Robot height > 70.7″ + y″
Total Lift + Robot height > 71.7″
Total Lift + 43″ > 71.7″
Total Lift > 71.7″ – 43″ = 28.7″

For a level grab
Assume 1 inch clearance (y = 1 “)
Assume robot height = 43 inches

Total Lift + Robot height > 63″ + y″ + 1.7″ + 6″ + 3.76″
Total Lift + Robot height > 74.46″ + y″
Total Lift + Robot height > 75.46″
Total Lift + 43″ > 75.46″
Total Lift > 75.46″ – 43″ = 32.46″

For a grab 15 inches from center at 14.5 angle
Assume 1 inch clearance (y = 1 “)
Assume robot height = 43 inches

Total Lift + Robot height > 78.625″ + y″ + 1.7″ + 6″
Total Lift + Robot height > 78.625″ + y″
Total Lift + Robot height > 79.625″
Total Lift + 43″ > 79.625″
Total Lift > 79.625″ – 43″ = 36.625″

For a grab at end of bar at 14.5 angle
Assume 1 inch clearance (y = 1 “)
Assume robot height = 43 inches

Ideas:

Use lifter from base – and then use shorter lift for grabber with balancer on top of bar.

- Is lift about 20 inches from ground then need about 10 – 12 inches for balancer to be placed above bar.
- QUESTION – would the cylinders be OK holding the weight in tension?
- Another idea – what about the cylinder lifting a pole that grabs, then release air from cylinder and have load on pole instead? This would mean cylinders would have almost no load to push up (weight of rod + weight of balancer).

Using the leveler program, determined the following results:

Results from playing with leveler program yield a different perspective on what really matters. The tolerance for balancing within 8 degrees is relatively insensitive to position if you follow a few simple rules. As a result, the ability to move along the pipe is much less important than being able to get on quickly and within a pre-calculated range (as long as alliance members are not sliding.) If opponents start sliding, then the ability to be a "fixer becomes much more important.

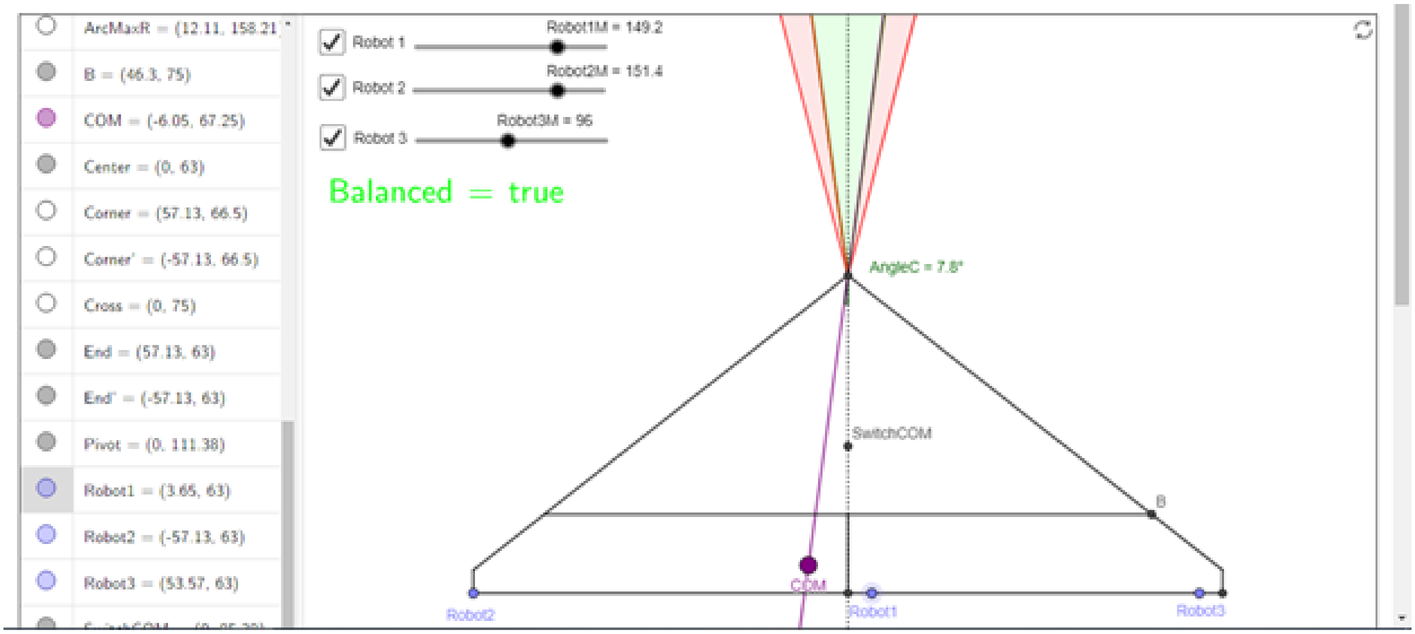
1 robot:
Center of mass must be within + 9 inches of center

2 robots: about the same weight
About 28 inches or range depending on where alliance robot is placed

2 robots: 20 lb difference in weight
Anywhere from 0 to 30 inches – (Worst if one robot is at end or at the center – best if about midway along one arm)

3 robots: about the same weight
Anywhere from not possible (two alliance robots close to each other on one side or close to middle) to about 25 inches (one near center and one on other side).

3 robots: one much lighter than other two about equal:
Anywhere from not possible (really ignorant configuration) to almost 45 inches – light at one end and heavy partner in middle



UltraSonic Sensor for bar detection in endgame

- Power Supply :+5V DC
- Quiescent Current : <2mA
- Working Current: 15mA
- Effectual Angle: <15°
- Ranging Distance : 2cm – 400 cm/1″ – 13ft
- Resolution : 0.3 cm
- Measuring Angle: 30 degree
- Trigger Input Pulse width: 10uS
- Dimension: 45mm x 20mm x 15mm