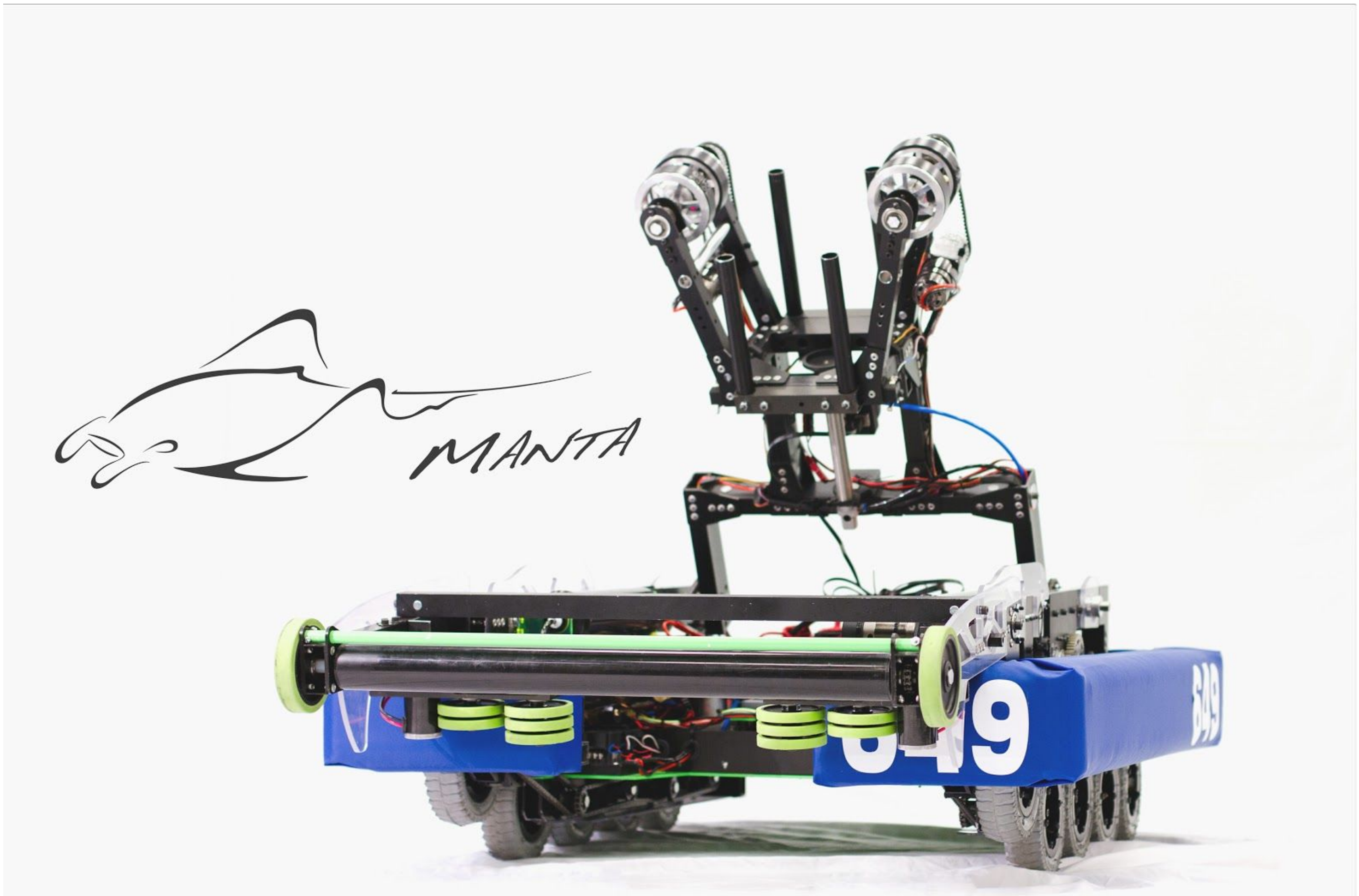
FRC Team 649: M-SET Fish



2016 Technical Binder

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Strategy

Goals

Fully defined Strategy

Coming off a 2015 season where we took an approach of making a simple yet effective robot, the team had a mentality of using this year to go all out and tackle every aspect of the game we deemed important. We wanted to spend our time flushing out ideas and making sure we had a solution to create a robot that is robust in every aspect of play.

Prototyping

Prototyping was a new idea for our team this year. Previous seasons prototyping was an afterthought as we launched heads on into design. This year we determined every system needed to go through a cycle: (1) proof of concept (2) semi-realistic proof of concept (3) Solidworks 2D design sketch (4) wooden model of final bot subsystem.

Balance Simplicity and Complexity

The design philosophy behind this year's robot was all about creating a machine that uses simple yet compact and versatile subsystems that are able to tackle every intended aspect of the game. We created a mentality that effective systems did not mean complete obsession with complexity or simplicity, but rather a balance of both simplicity and complexity to put forth a consistent design.

Initial Strategy

Game Analysis

During the first week of build, members of M-SET began prototyping and designing a game strategy, after completely reading and understanding the rules.

Through our strategy discussions, we decided our robot's primary objective should be to navigate all of the defenses. This is fundamental in guaranteeing at least 1 ranking point (RP) per qualification match by Breaching.

Outside of breaching, we concluded that scoring boulders into the high goal would determine the winning alliance in matches. So, we pursued scoring into the high goal as our secondary tele-op scoring method.

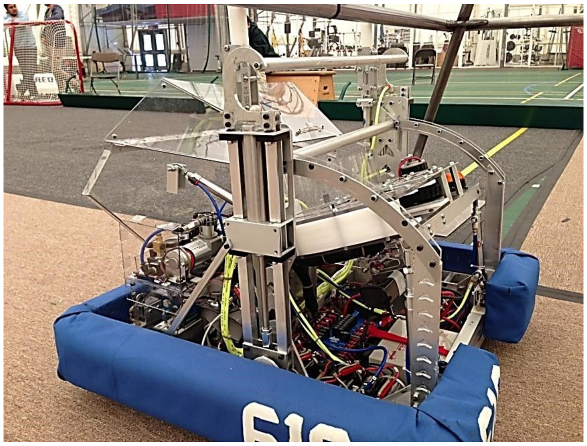
Scaling the Tower was our lowest priority, as it was a high complexity mechanism, and the additional 10 points scored could be offset by an effective shooter.

Major Design Constraints

The largest decision for our team was whether or not to attempt to fit under the Low Bar. We felt the easier High Goal Autonomous, the decreased High Goal Cycle Time, and the ability to damage an extra defense made the engineering challenge of fitting the robot under an effectively 14.5" bar worth the effort. The Low Bar is also always guaranteed to be in a set location on the field, making it a reliable way to navigate the field.

Shot Strategy and Design Inspiration

Since the goal is only 4" wider than the ball, and we can only shoot 1 ball per cycle, shooter accuracy is extremely important. To maximize consistency and accuracy, we chose to use a Park and Shoot Strategy as done by teams 548 (2012) 610 (2013) and 254 (2014) to great success.



Due to its short distance, solid wall, and protection from defense on 3 out of 4 sides, we chose to park on the Batter, against the Castle wall, to shoot.

However, we did not want to be limited to only 1 shot that may be heavily defended, so a robot requirement would be to have a minimum of 2 shooting positions.

The second shooting position we chose was a shot right at the edge of the defenses facing the front goal. This shot allowed us to have a consistent place to line up while offering us the ability to be protected from other robots, since our bumpers were in the defense zone and had not cleared into the courtyard.

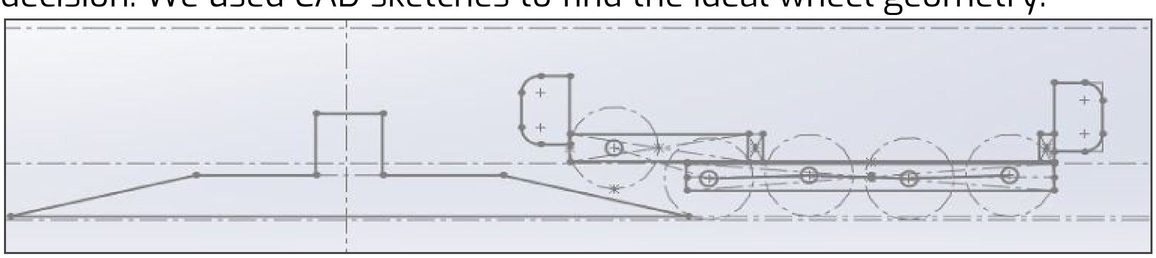
Design and Prototypes

Drivetrain Design Process

In order for the robot to navigate the defenses, especially the B and D category (passive) defenses, we needed a dependable and effective drivetrain. There were three categories in which numerous drivetrain proposals were organized into:

	Pros	Cons
Track Drive	+Effective over obstacles.	-Limited availability from manufacturers -Never tested by our team. Difficult bumper mounting.
"Rocker-Bogey" / Suspension Drive	+Always contacts the ground. +Smooth travel.	-Un-tested, never used in club's history. -Lots of moving parts - Easy to break. -Takes up a lot of space, heavy.
Pneumatic Wheel Drive	+Simple - Easy to maintain and robust. +Large footprint drives over obstacles more easily. +Deformation of wheel cushions impacts. +Space efficient.	-Bumpier ride (shakes things loose) -Geometry must be tested...extensively...to ensure robot does not high center.

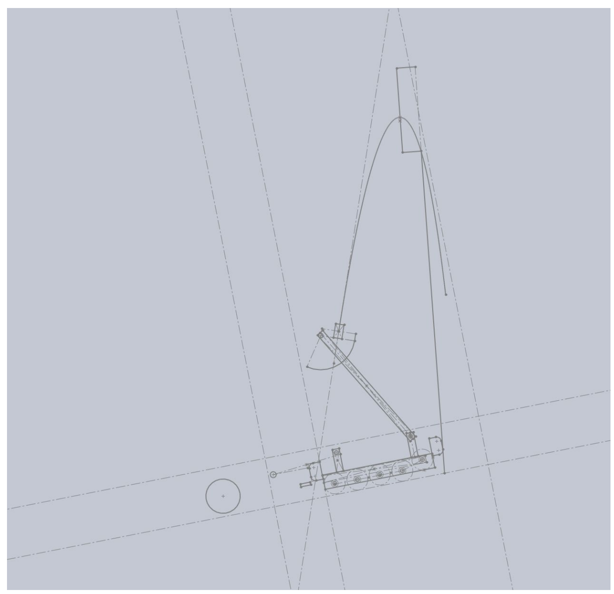
The simplicity and durability of a pneumatic wheel drive made it our final decision. We used CAD sketches to find the ideal wheel geometry:



This 2D geometry sketch allowed us to simulate the different passive defenses (moat, rock wall, rough terrain) and design a wheel configuration that allowed us to get over the obstacles without any foreseeable danger of high centering the robot on any defense.

Shooter Design Process

Design Criteria



- packages under 14"
- high point of release
- secures ball in shooter head
- adjustable angle to tune

Prototyping

We settled on a 2 axle flywheel system, which gave us great accuracy and plenty of power in a very small amount of space.
Our main decision was to shoot from the front of the robot or the back. in the end, we chose to shoot forwards, as it made the robot more driveable and packaged tighter in the robot.
Furthermore, in order to package in the 14 inch height constraint we made the decision to place our flywheels on the sides of the ball as this lowered the effective height of our shooter in the down position. With the flywheels on the side we faced the problem of the ball curving if either side spun up faster than the other. To tackle this we implemented

photoelectric sensors that counts the RPM of each flywheels and only allows us to shoot when we have reached an acceptable RPM range on each flywheel.

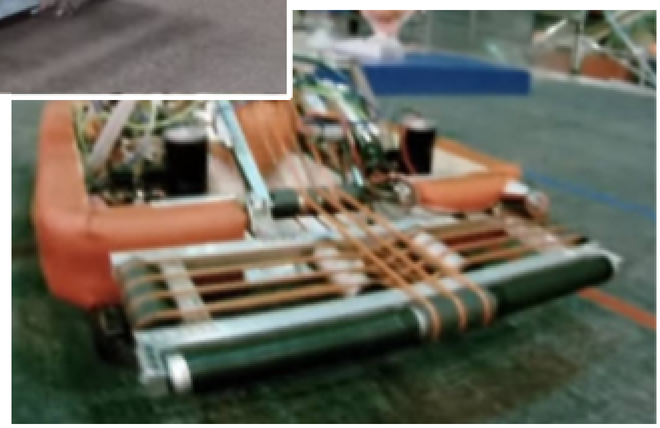
Intake Design Process

Design Criteria

- Must actuate to store inside the robot
- Centers the ball no matter the original position using horizontal rollers
- Manipulate Category A defenses
- Be as light as possible

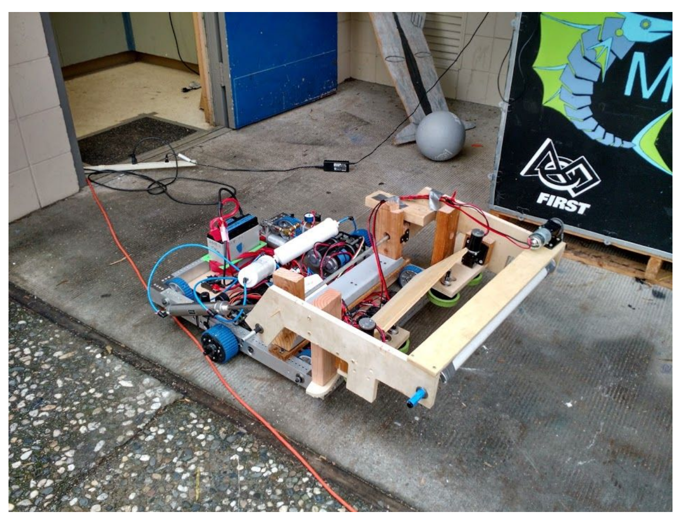
Inspiration

- FRC team 971's 2013 robot - Horizontal wheels create extremely quick intake
- FRC team 973's 2012 robot - Showcases effectiveness of unidirectional intake on a ball-based game



Prototyping

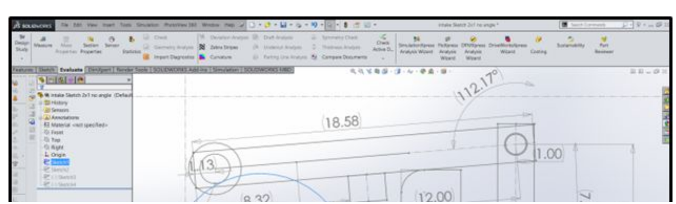
We created a wooden powered prototype to test ball compression, motor speeds, and grip materials.



This wooden prototype was iterated 3 times, with the later versions cut out of 3/4 plywood on our ShopBot.

All dimensions were taken from a geometry sketch done in Solidworks, as shown in the middle right picture.

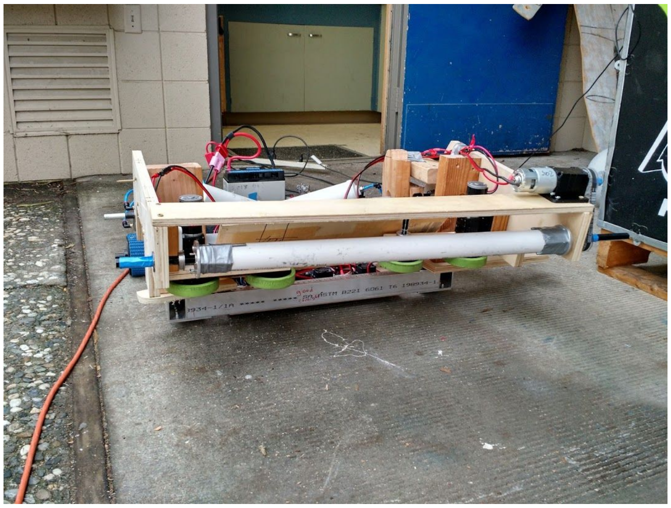
The final prototype was placed on our off-season test chassis for



drivers to test drivability of the system as well as emulate a final bot style intake to test the feeding.

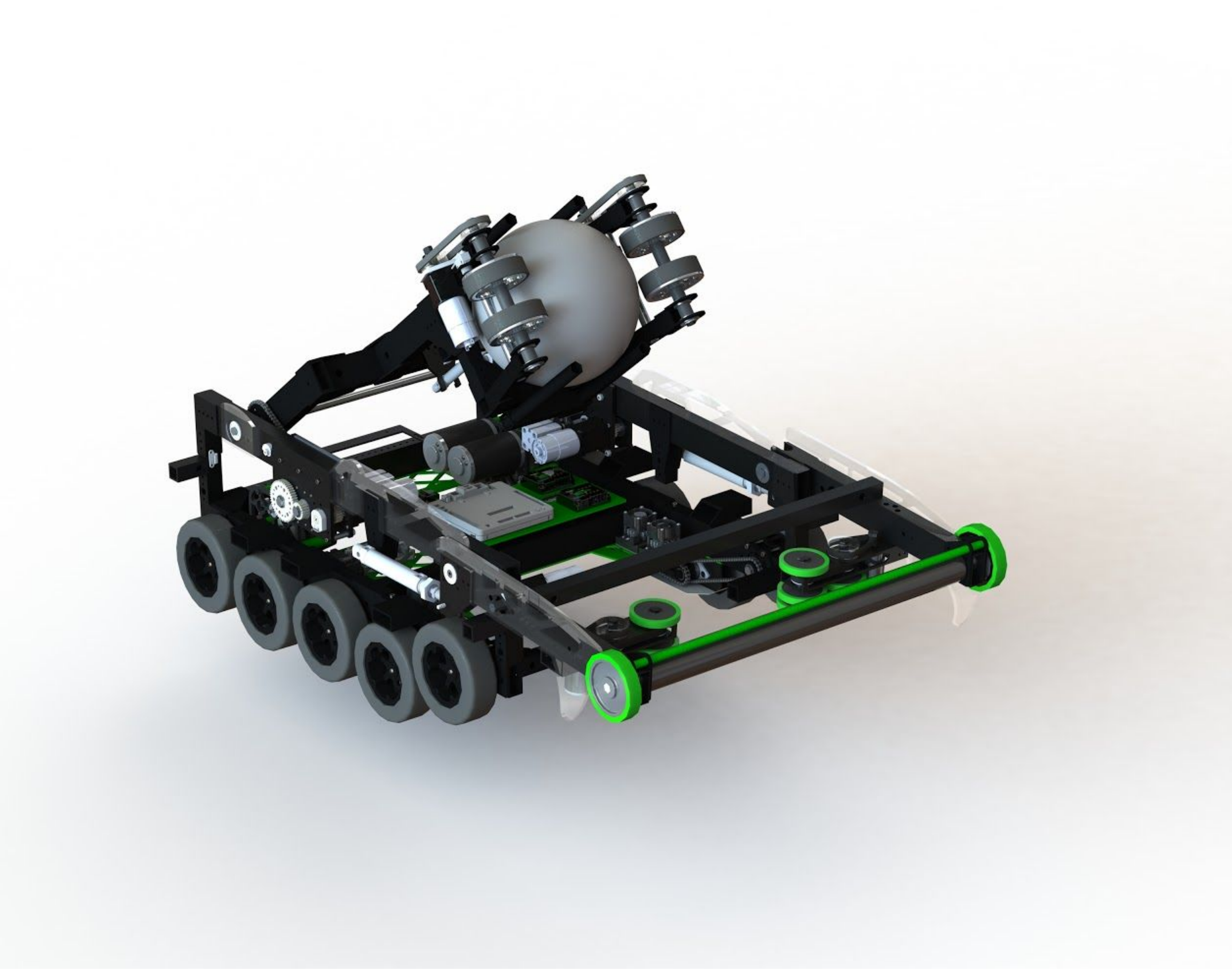
Tuning

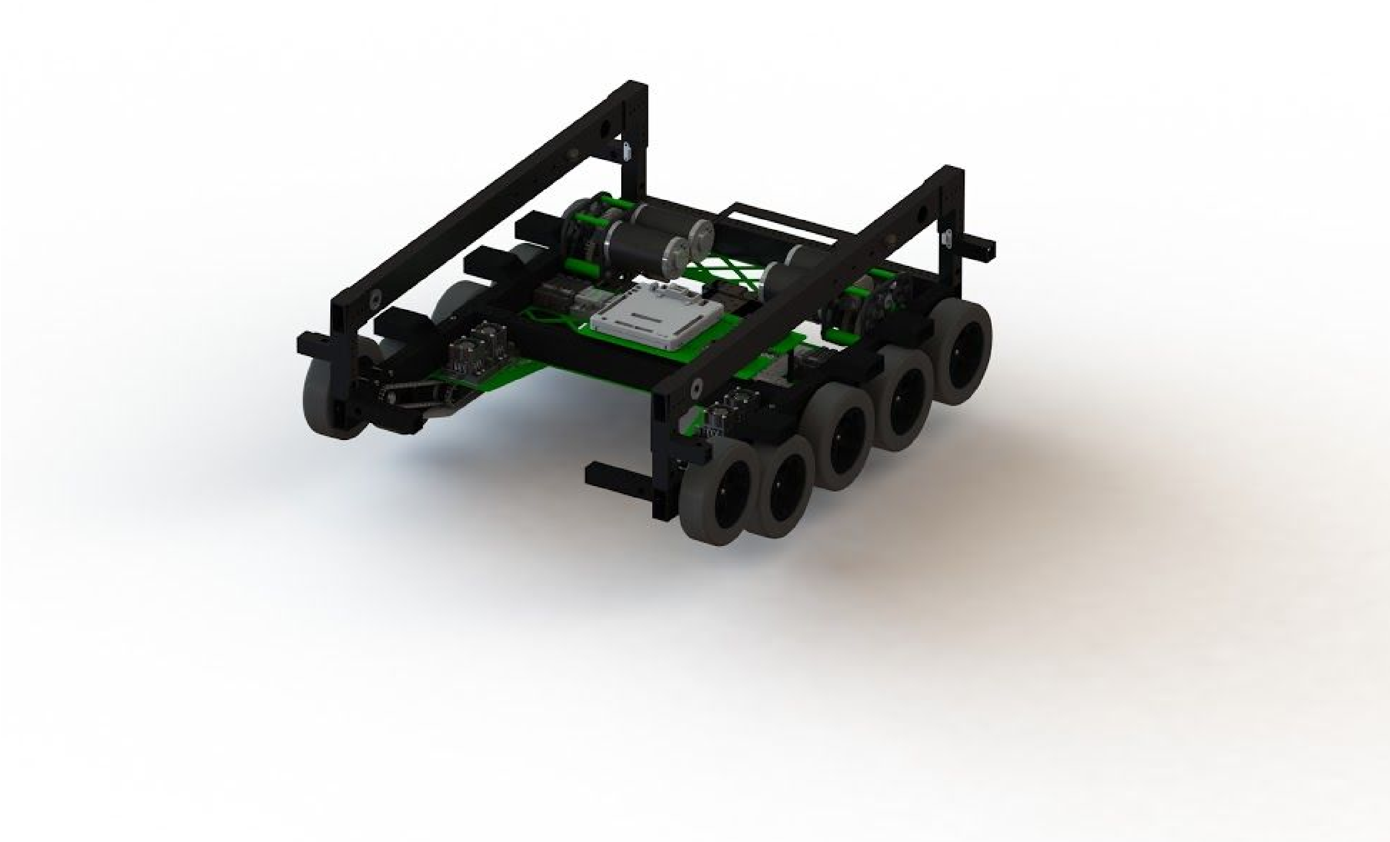
Due to the compression of the ball, the forward roller must spin at a slower speed than the horizontal wheels. On the final robot we tuned speeds with different quality balls until the intake would not jam under any circumstance. The effective speed ratio was approximately 4:1.



Final Design + CAD

Full Robot





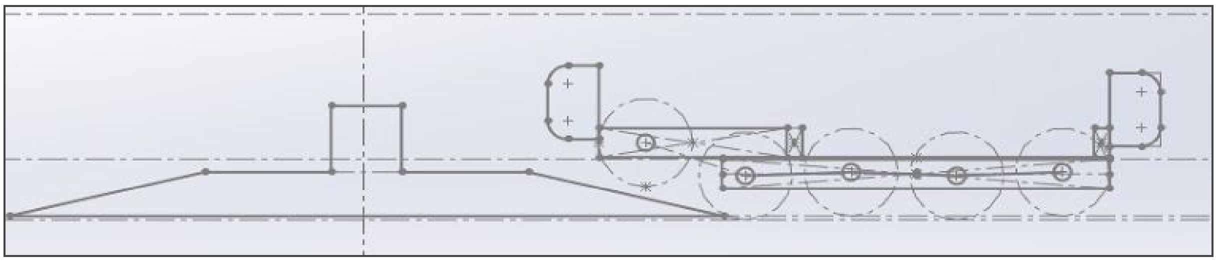
Drivetrain

Designed to be as simple and robust as possible

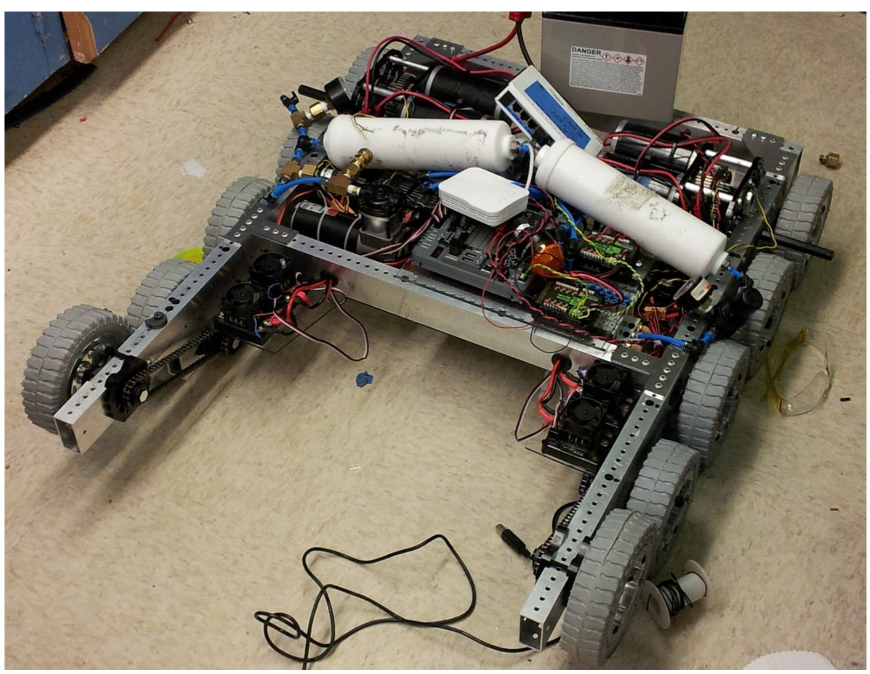
- 10 x 6" pneumatic wheels
- 6" wheels allow for easier COTS gearing
- Uses 2 CIM WCP Dual Shifting gearboxes for reliability
    - Free Speed: 8 ft/s and 15.5 ft/s
- Tensioned #25 Chain
- WCP Bearing blocks ensure bearings and axles are properly supported
- Specs
    - Dimensions: 32 in. x 27.5 in

- Weight: 43 lbs

Carefully considered Wheel Placement + Geometry to defeat all Passive defenses



- 4" of ground clearance and less than 1" spacing between wheels to prevent high-centering on obstacles
- Raised front wheel to assist going over rock wall and ramparts
- Middle of robot raised to prevent high centering on ramparts and rough terrain
  - Never has our electronics board touched a field element



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Intake

Triple Wide Intake

- Over 23" Wide; eases driver aiming - ball is possessed along entire front side of robot
- ABS roller provides optimal grip on ball without damaging wheels
- nylon shaft keeps roller light and flexible upon collisions
- powered by a 775pro and versaplanetary at a 10:1 reduction
    - Chain is run inside tube to improve packaging and keep motor weight as close to pivot as possible

Horizontal rollers centers

- 2 ⅞" banebot wheels provide strong grip on ball to redirect them into shooter
- powered by 1 BAG motor with custom 4:1 GT3 belt reduction to reduce footprint
- 2 symmetric modules allows for ease of maintenance
- tuned to provide fastest centering and avoid jamming

Outerworks Capable

- 3 ⅞" Banebot wheel rolls up portcullis
- "Fangs" extend down from intake to lower Cheval de Frise

Shooter

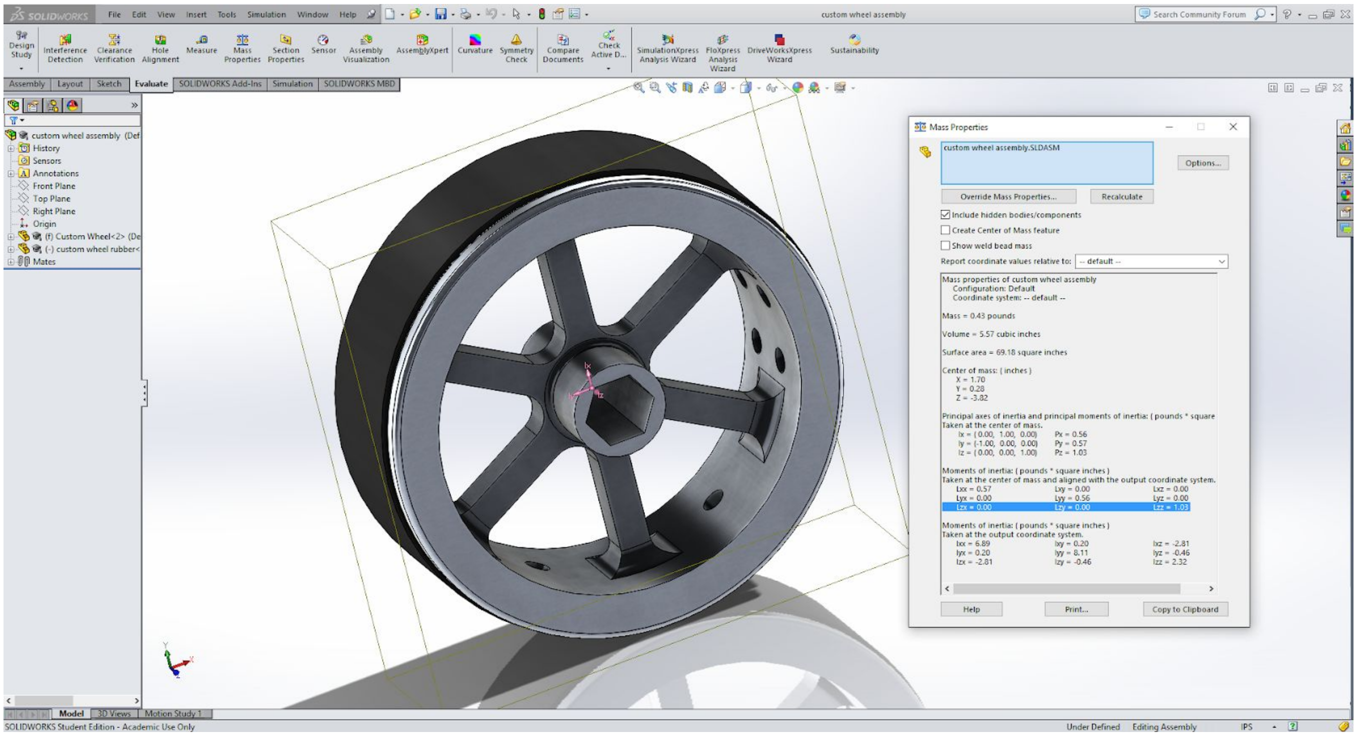
Powered by 2 775pros with a 3:1 reduction

- Spins at ~6,000 RPM
  - surface speed of ~100 ft/s or ~68.2 mph
- belt power transfer to keep weight close to pivot
- Was versaplanetary (as seen above), now custom pinion reduction with the same reduction

Photoelectric sensors allow for dynamic flywheel speeds depending on shot position and angle

Geometrically retained ball with round tubing

- Proper compression tested through prototyping
- Prevents ball from unintentionally entering flywheels while being defended and crossing over Outerworks
- Piston fed, ensures consistent entrance speed into flywheels to prevent any non-linear movement



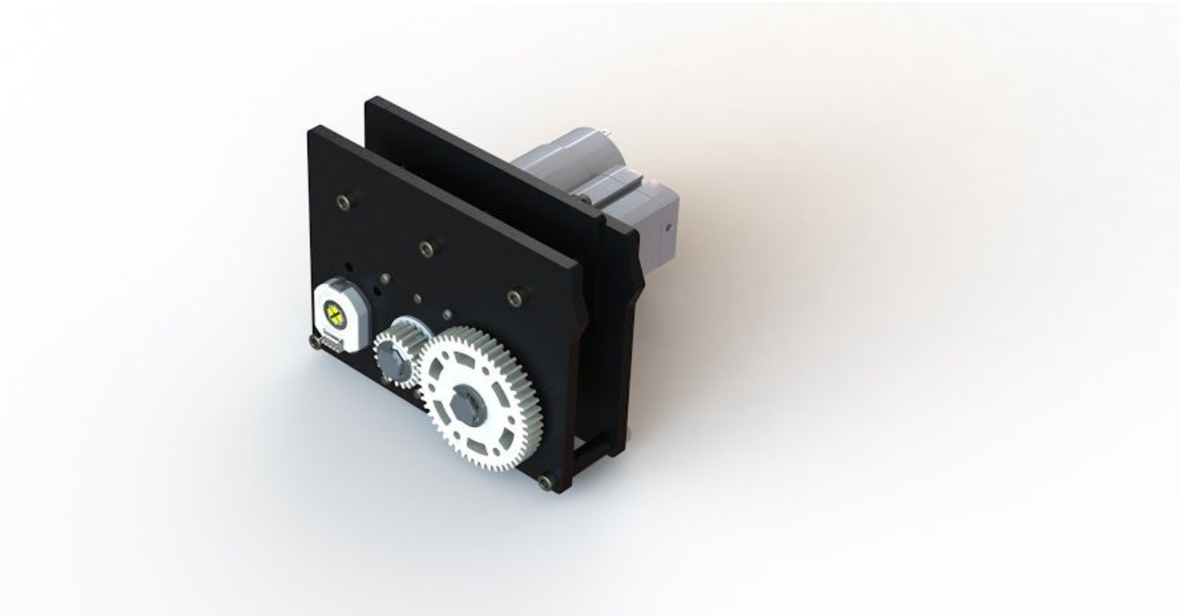
Custom Flywheels

High Moment of Inertia, Low weight, ideal grip

- ideal moment of inertia found through testing
    - Weight added to prototype until ideal shot was created
    - Used Solidworks to recreate Moment of Inertia while keeping weight as low as possible
- weighing in under ⅓ lb and a combined 3 lb-in^2 of rotational inertia
- 186 Joules of stored rotational energy

Urethane strip on wheels gives grip and durability

- 40a acrylic adhesive backed strips resist wear and attach securely



Pivot Gearbox

Custom Gearbox rotates shooter arm on pivot

- 1 x 775pro per side
- Double sprocket-driving gearboxes
- 1035:1 Overall Reduction provides 738lb-ft of stall torque, 5.84 amps per motor loaded
- Raises the 15lb arm in .87 seconds
- Custom pneumatic friction brake provides double factor of safety to prevent the claw from slipping
- Clamps around the superstructure box tubing

Software Overview

Philosophy

Goals

"The most important property of a program is whether it accomplishes the intention of its user." – Sir Charles Antony Richard Hoare (Developer of quicksort)

In the 2016 season M-SET's software team took this axiom to heart, and it has provided the foundations of a simple yet demanding goal. Our control system ought to work to enable its operators to communicate as high level of intent as possible. We worked to enable front end simplicity and intuitive functionality through layers of abstraction and forethought integration both up and down the stack (up to drivers and down to hardware).

Overview

Our 2016 control system implements many new algorithms previously unused by our team as well as strategic simplifications to systems in order to maintain both precision and consistency in semi-autonomous movements. It also incorporates more sensors than we have ever previously used: at a grand total of 17. With a larger software team than ever before M-SET has expanded not only the breadth of its sensor reach (incorporating photoelectric sensors we'd never used before) but also its code depth, using new algorithms to make use of the sensors

Why (Semi)Autonomous

To drive: to cause and guide the movement of

For us, the key word was guide. The less time a driver spends directly controlling actions of our robot the more time they can spend anticipating shifts in game strategy and other non-computable factors. We work to maximize “neglectable operations,” which is the number of unique tasks a robot operator can ignore before performance drops below some threshold. To do this our code is designed to allow drivers the freedom to communicate intent on the highest possible level, trusting the control system to follow through on their actions for them.

Semi-autonomous functions also reduce cycle time. Software control loops can decine movement completion far more accurately and well before their human counterparts. This slower response time sanctions over-travel, bounce, and multiple corrective movements - all to the detriment of efficient, smooth control.

Well tested, “fool-proof,” self controlled actions also improve safety, ensuring conflicting operations are prevented and coordinating subsystems to prevent collisions. As such, these control loops both minimize robot failures and enhance performance making them integral to M-SET’s competition goals.

Sensors

Drivetrain

- Encoders (x2)
  - For Left and Right side of robot
  - Calculates distance and velocity for autonomous distances and turning angles
- Gyroscope
  - For correcting heading error after crossing outerworks
- Potentiometer (x2)
  - Used in beginning of match as dials for selecting Autonomous start position and outerworks defense

Intake

- Hall Effect Sensor
  - Tells if Intake is deployed (down) or NOT deployed
- Limit Switch
  - Redundancy for Hall Effect Sensor

Shooter

- Photoelectric Sensors (x2)
  - Uses retroreflective tape on shooter flywheel to determine the rotational velocity. Velocity used for PID loop
- Relative Encoder (x2)
  - Mounted on Arm Gearbox to tell Angle of Shooter. Arm motion determined by PID
- Hall Effect Sensors (x2)
  - "Approaching end" (Upper / lower) warning
- Laser gate (x2)
  - Tells robot whether there is a ball in the shooter head or not.
- Nexus 5
  - Used for Vision-based Aiming
- Flashlight
  - Used as "photon cannon" for aiming. When flashlight illuminates goal, ball will go into the goal when shot

Competition Upgrades

Post-competition Reflection

During our routine post competition debrief after attending the Week 2 Central Valley Regional, we identified areas of strength and areas of growth. We found in competition that when we were all tuned we worked wonderfully and made our shots; however, this tuning was a long process that took us too far long the competition to complete. We also noticed that the robot was drastically inefficient in autonomous and tele-op modes due to poor detection mechanisms used to line up and shoot at the goal. Over the four weeks between our two competitions, we took the necessary steps to improves these areas.

Android-based High Goal Vision

At CVR, our aiming system was a flashlight on the top of our robot. While it was very effective, it was difficult to tune properly so that the flashlight aligned with the place our ball would go when we shot. It also meant that we had no form of vision during our autonomous program.

We decided our vision software needed to do the following things:

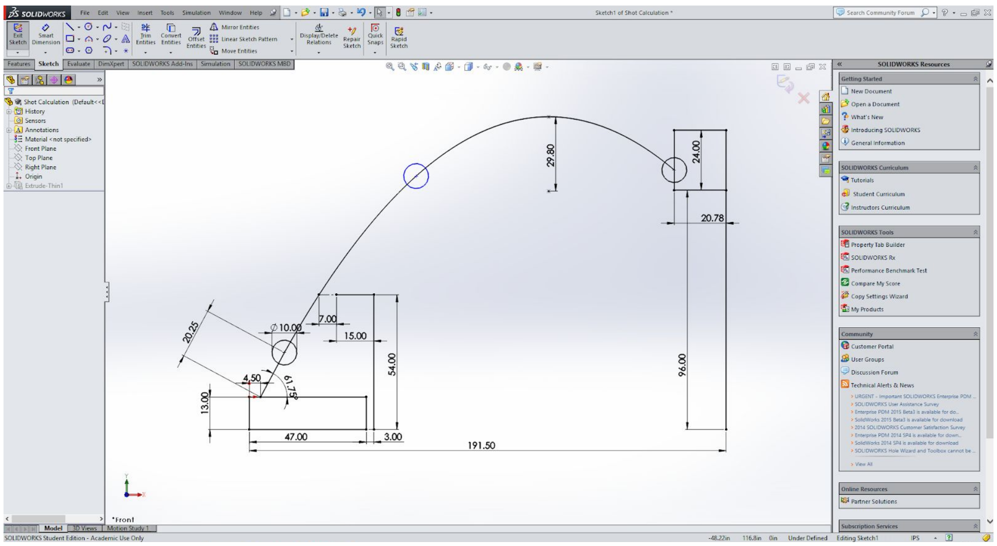
- Alert drivers if the ball will go through the goal when shot
    - Visual Cues
- Allow for accurate, vision-based autonomous shooting.
- Auto-Aim from any position on field
- Not limit driver control of aiming and shooting

After seeing the effectiveness of 254 The Cheesy Poofs vision software using an Android device, and seeing other offboard processors need power from the voltage regulation module (which is riskier considering the large bumps and changes in current draw our robot experiences), we chose to use a Nexus 5 to run our vision code.

Over-Defender Shot

During our semi-final match against 1678 Citrus Circuits, 254 The Cheesy Poofs, and 3970 Duncan Dynamics, 3970, which was cheesecaked with a 54” blocker, was able to block all of our outerworks shots. We shot 2 high goal shots as compared to our usual 4-6.

To overcome this problem, we created a unique shooting arc to shoot over a defender this a wall that is as close to our robot as possible. A drawing is below:



The final calculated Angle is 61.5, with a range down to 60.5 up to 62.0. And a forward and backwards driving range of +3.5 inches and -13.5 inches

Dropped Colson Wheels

During the competition, We found turning with our large pneumatic wheels to be less than smooth. The grip caused manual aiming to be a slow process.

We decided to replace our 4 dropped wheels on the drivetrain with 6” Colson wheels, which drastically improved our turning. We took inspiration from 1678 Citrus Circuits for this modification.

Miscellaneous Improvements

Shooter pulley swap: We replaced the VersaPlanetary reduction on our shooter flywheels with a built in pulley-pinion reduction to reduce weight.

New Bumpers: We are now using ballistic Nylon fabric and a different noodle setup to reduce the chance of bumpers tearing and the risk of pinning during defense

Larger Shooter Sprocket: to reduce the effect of gearbox slop, we are using a larger sprocket.

Larger Intake Roller Reduction: Swapping out the 7:1 versaplanetary that powered the front roller of the intakes, we placed a 10:1 on the intakes to add more torque for the portcullis wheels. This theoretically should make it easier for us to open the portcullis and allows to go through our defense faster.

MANTA