# Robotics Projects

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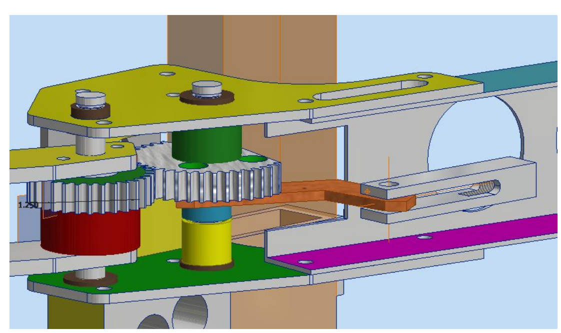
2015 FRC Robot - “Junky Monkey”

# Robot Hardware Design

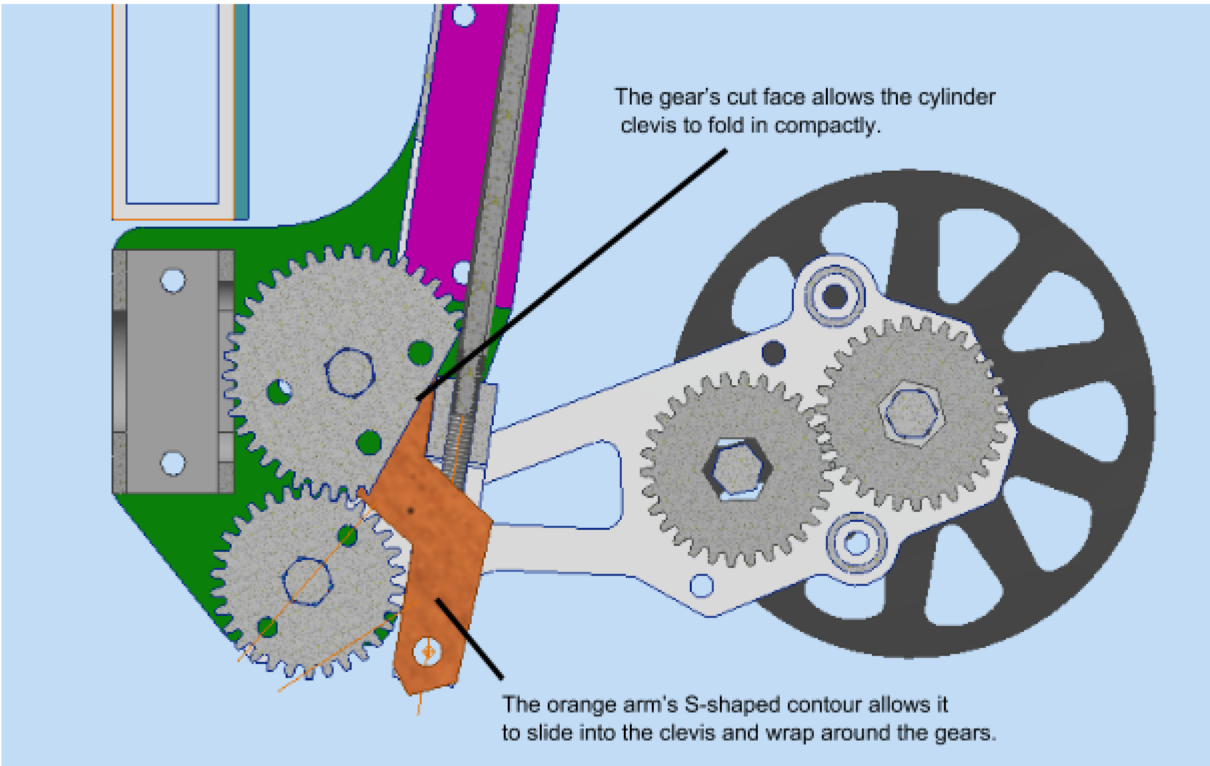
### Tote Collector (2015)

To reach totes on the field and bring them into the robot, I designed two collector arms with powered traction wheels. However, I wanted these arms to also remain within the robot's travel configuration between matches so that we would not have to remove and re-assemble them before every match. I decided to sweep the arms back into the robot frame perimeter using pneumatic cylinders to manipulate the arms quickly into two positions. To retract the arms within the travel configuration and extend them to the location of the totes during the intake cycle, I calculated that the collector arm would have to travel approximately 160 degrees. From force analysis on the cylinder, however, I determined that the cylinder acted most optimally over a stroke less than or equal to 120 degrees, because in this range, the linear distance covered by the cylinder would effect a larger change in angle. To convert the 160 degree sweep of the collector arm to such an acceptable stroke angle for the cylinder, I used a gear augmentation of 4:3.

The cylinder clevis couples to an arm that is attached to the 40-tooth gear. The 40-tooth gear drives the 30-tooth gear, unfolding the attached collector arms over a 160 degree sweep.

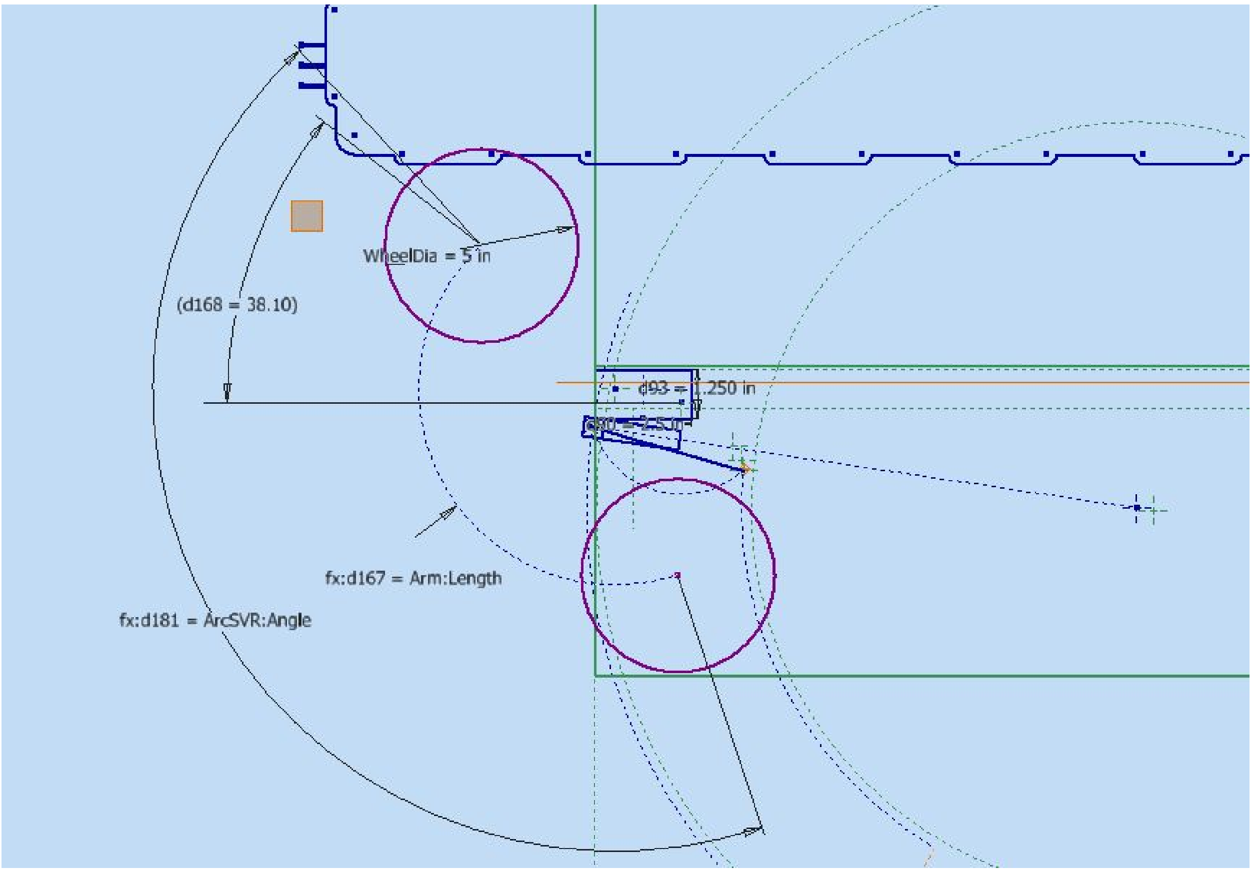


The collector arm in its extended position




When the collector arm is retracted, the cylinder is extended and its clevis fits snugly next to the gears.  I identified component interferences using Autodesk Inventor and then cut the gears and shaped the orange plate to make the assembly fold compactly.

In Autodesk Inventor, I used our desired initial and final positions of the collector wheels on the robot to plan the compact arrangement of the collector's different components. I also used Autodesk Inventor's interference analysis and motion constraint tools to locate material overlaps and make sure that the design would remain compact while still functional.




The geometry sketch that I used to trace the arm as it moved between its extended and retracted positions.

After our first regional competition in Orlando, I wanted to improve the collector to center the totes and containers more precisely.

Through experimentation and mathematical analysis, I found that the largest source of inefficiency and weak intake was a tractive counter-force that served to splay the collector. During operation, this reduced the collector wheels' pinch force on the game pieces, often preventing them from being sucked into the robot.

$$F_{pinch} := 5\ \mathbf{lbf} \qquad L_{arm} := 5.05\ \mathbf{in} \qquad \theta := 30 \cdot \frac{\pi}{180}\ \mathbf{rad}$$

$$T_{arm} := F_{pinch} \cdot L_{arm} \cdot \cos(\theta) = \boxed{21.867\ \mathbf{in} \cdot \mathbf{lbf}}$$

$$\boxed{\mu := 2}$$

$$F_{traction} := \mu \cdot F_{pinch} = 10\ \mathbf{lbf}$$

$$T_{reactive} := F_{traction} \cdot \sin(\theta) \cdot L_{arm} = \boxed{25.25\ \mathbf{in} \cdot \mathbf{lbf}}$$

Using PTC's MathCAD software, we laid out the input parameters, $L_{arm}$ and μ, and the torque ($T_{reactive}$) generated by the forces on the collector wheels

In the first iteration of the collector design, I had assumed that wheels with higher tractions would be preferable, as they would have more traction on the game pieces. My calculations now showed, however, that wheels with higher μ-values instead caused the reactive torque to be greater, which detracted from the collector's operation. I tested several wheel models with varying coefficients of friction, ultimately selecting gray rubber-tread wheels over *Sure-Grip* wheels as the optimal choice for our design.

We stiffened the compliant *Sure-Grip* wheels by
adding custom 3D-printed inserts

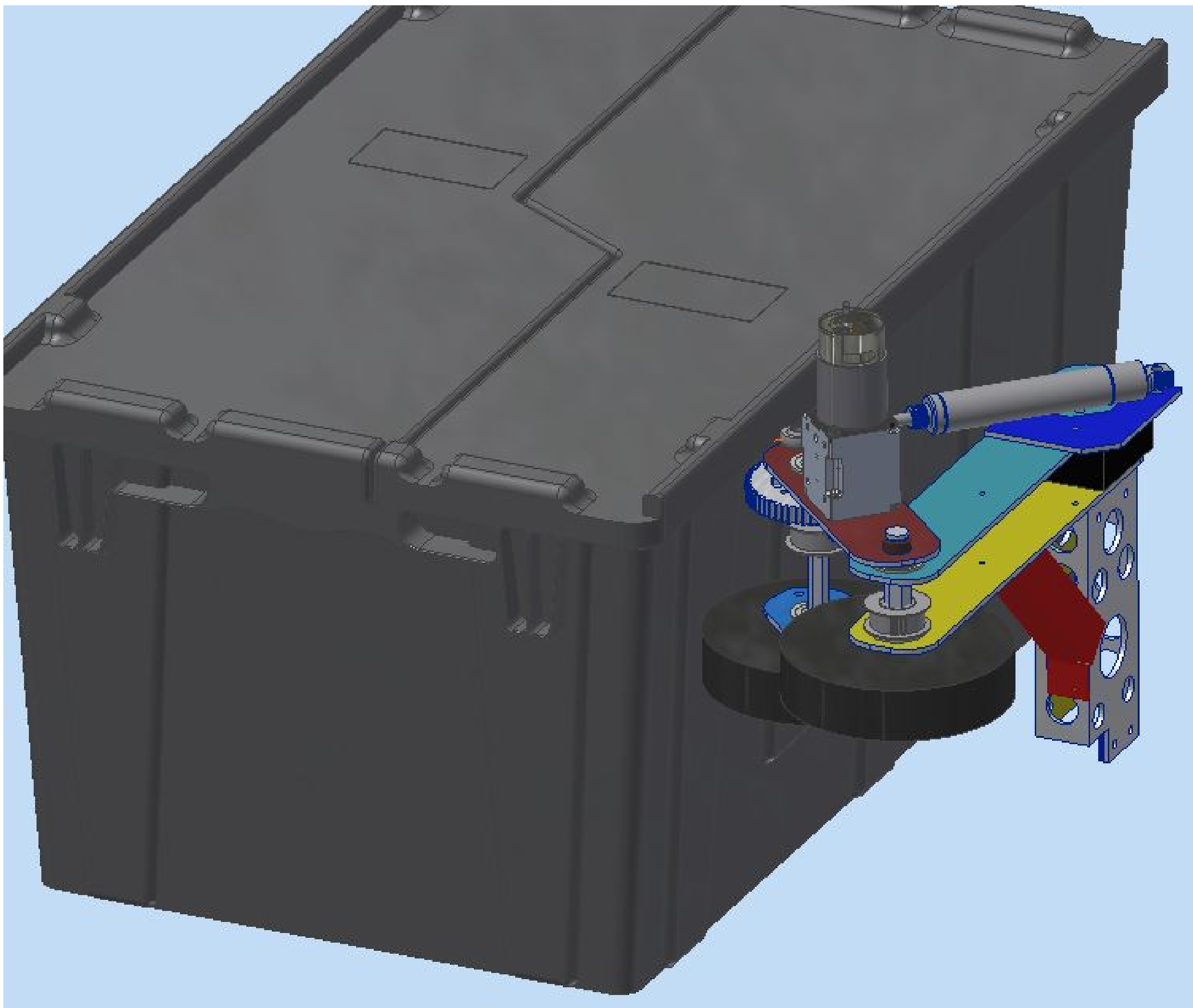
We prototyped a lower coefficient of friction wheel
by taping the *Sure-Grip* wheels in gaffer’s tape

We ultimately selected the rubber-tread wheels
for their moderate coefficient of friction

I tried many different wheels, both modified and in their stock configuration, to find the optimum compliance and traction.

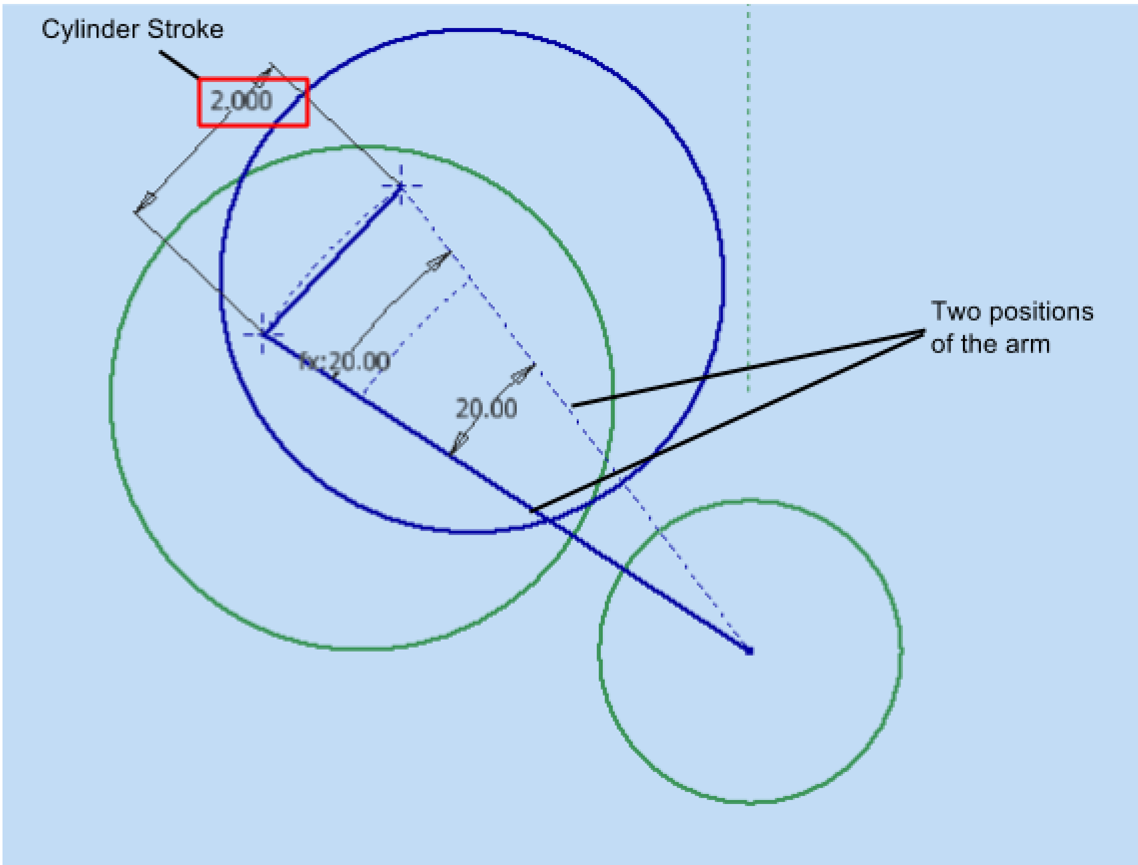
# Tote Collector V2 (2015)

Over summer, I decided that I could improve the collector design even more by taking advantage of the reactive torque on the arm.  By moving the arm's pivot point forward of the wheel, I changed the direction in which the reactive torque caused the arm to swing.  Instead of swinging away from the tote during intake, the arm would now swing into the tote, increasing compression and thereby speeding up the intake cycle.



An Autodesk Inventor CAD model showing the collector pulling in a tote

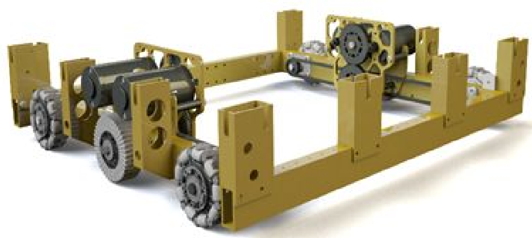
I used Autodesk Inventor to trace the path of the collector arm as a pneumatic cylinder pulled it between two positions.  In a CAD sketch, I defined the cylinder's stroke and different dimensions of the arm.




A geometry sketch I created to show the collector arm's two positions

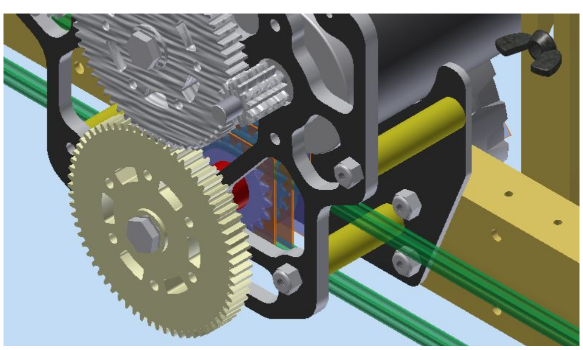
# Funky Drive (2014)

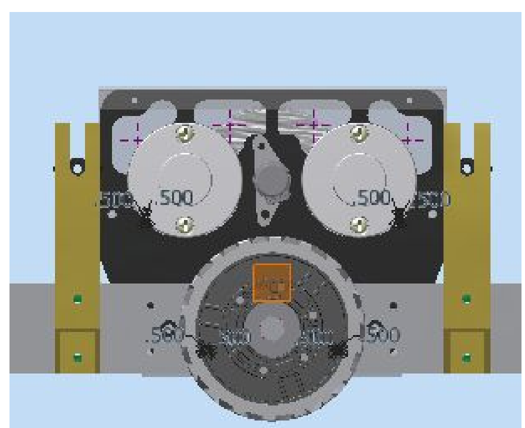
The 2014 robot's drivetrain, trademarked *Funky Drive* provided a combination of traction, easy turning, and a stable shooting platform.  A conventional "west coast" drive has its center wheels dropped, which reduces the resisting force on the outer wheels, allowing for ease of turning.  After analysis of this year's gameplay, however, the drivetrain design team realized that the robot base needed to be stable to perform accurate and consistent shooting.  This required the robot's wheels to be placed along the same line.  Thus, the solution that we reached was to utilize omni-directional wheels (omni-wheels) on the four corners of the robot, which have perpendicular rollers to reduce turning friction.



CAD render of Funky Drive

One of Funky Drive's key design features was its inverted over-wheel gearbox.  I flipped the motors that powered the drivetrain over the wheels so that they hung facing outside the robot.  This saved precious space inside the robot, and made room for the robot's electronics.  To allow the motors to hang above the wheels, I added an intermediary gear between the pinion gear on the motor and the large gear on the gearbox's output shaft.  Doing so allowed me to position the motors above the wheels while maintaining the overall reduction of the gearbox, the ratio of the pinion gear's teeth to the output gear's teeth.

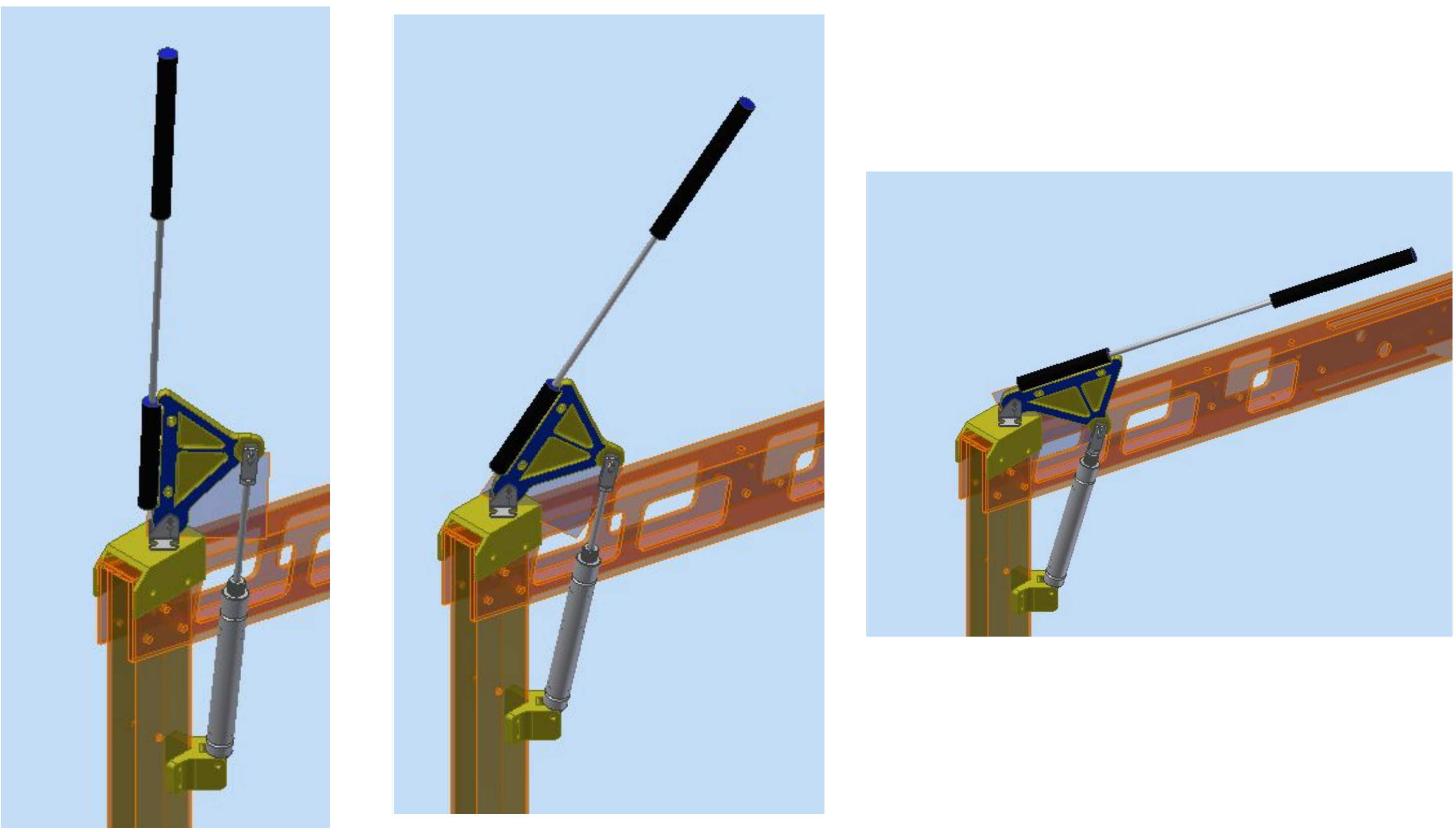




The gearbox's motors hung over the wheels, and were offset by an intermediary gear

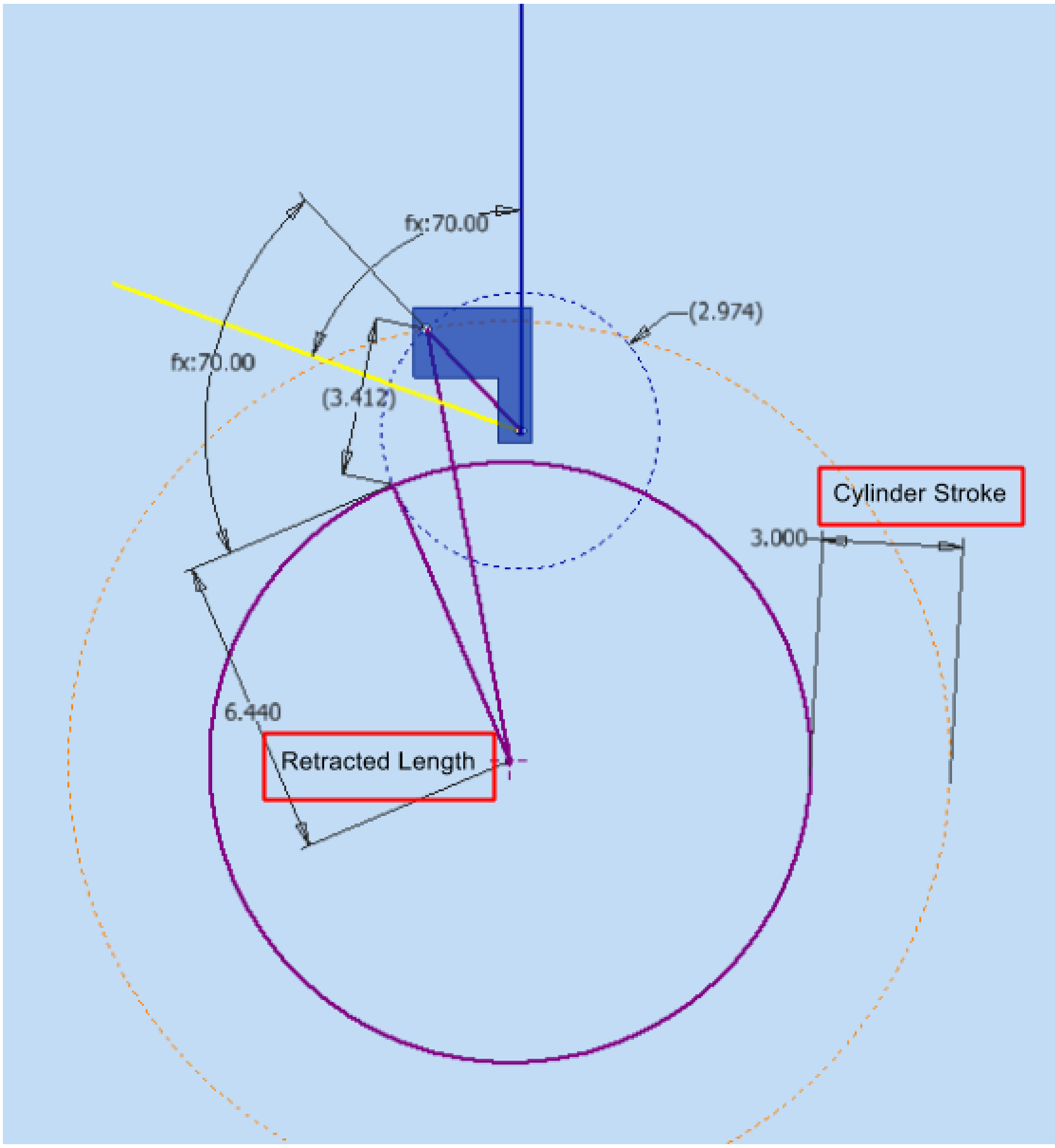
# Ball Trapper Mechanism (2014)

The 2014 robot, Funk Cannon, shot a large two-foot diameter ball into a goal six feet off the ground.  As it moved around on the game field, Funk Cannon cradled the ball between its two catapult arms.  To maintain possession of the ball while the robot was jostled by opponents, I designed a pair of “Ball Trapper” arms to clamp down on the ball and prevent it from moving.



As the cylinder retracted, the ball trapper’s fiberglass arm swung from its extended position to clamp down on the ball

The Ball Trapper Mechanism used a pneumatic cylinder to pull down a fiberglass rod.  When the cylinder was extended, the arms were clear of the catapult, and the robot could fire the ball into the goal.  When the cylinder was retracted, the arms were forced down onto the ball, and this compressive force held the ball in on the catapult.




To determine the position and stroke of the pneumatic cylinder, I created a geometry sketch in Autodesk Inventor.  The sketch allowed me to trace the path of the ball trapper arm as it moved between its two positions, and showed me the effects of changing the cylinder's stroke.

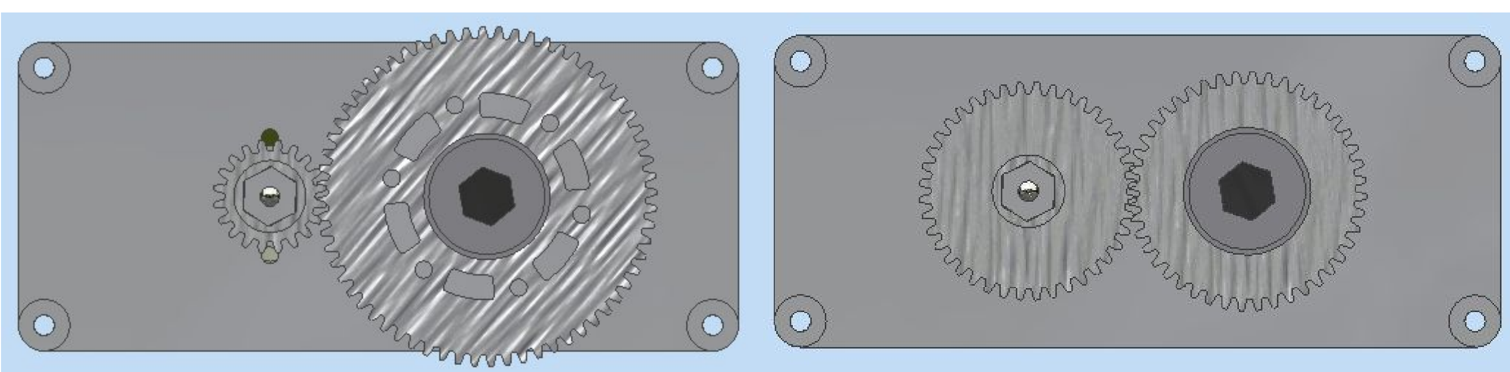
# Prototyping Gearbox (2013)

I designed a prototyping gearbox to facilitate subsystem prototyping in the build season. The prototyping gearbox could be configured for a variety of speed reductions, and had a standard mounting pattern to allow students to attach it to different prototypes over the course of the season.

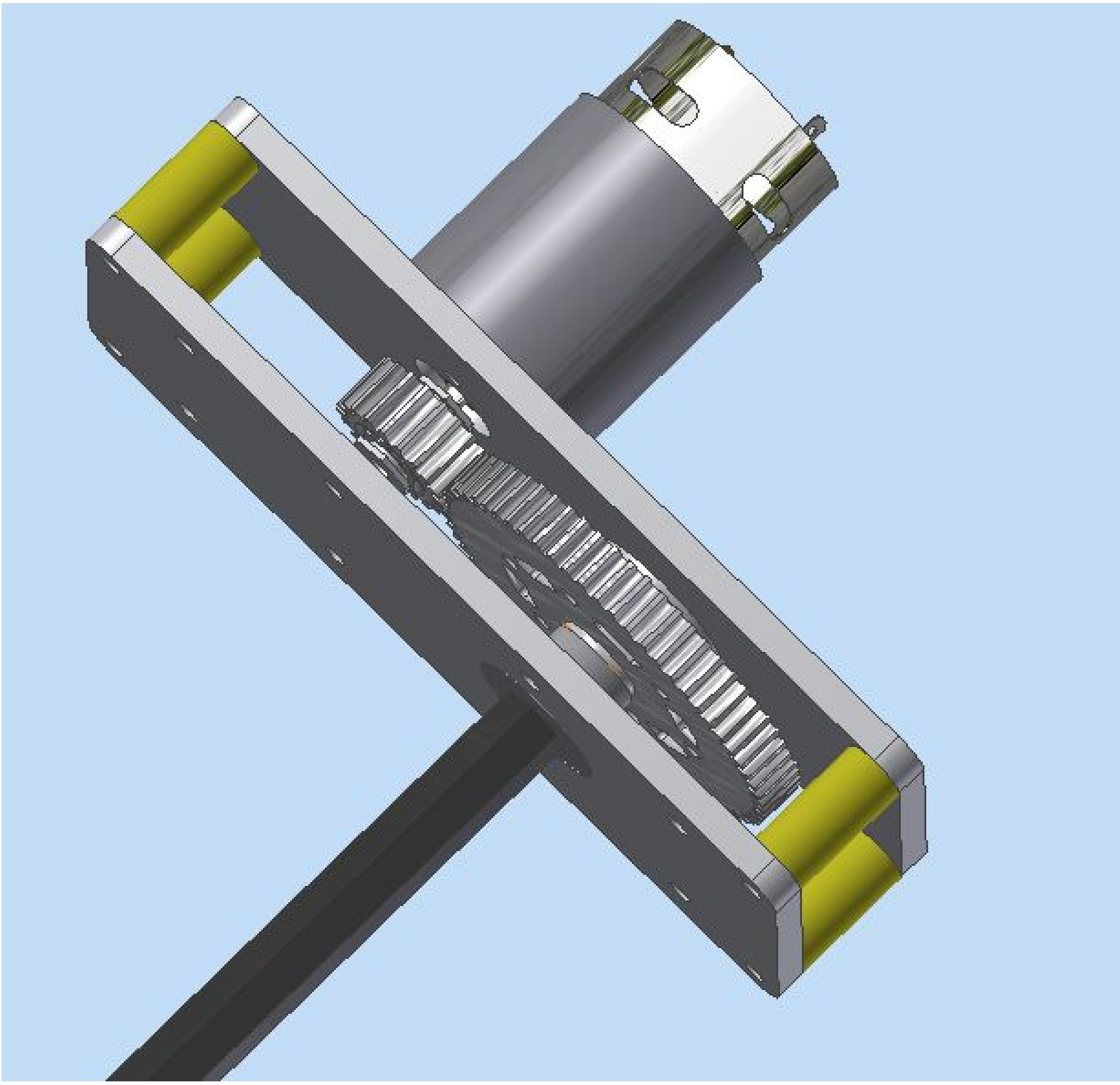
Distinct pairs of spur gears will have the same center-to-center distance if the sum of the spur gears' teeth in both pairs are the same, because the sum of the gears' pitch diameters will remain constant. By analyzing the VexPro spur gear selection, I determined that the tooth-sum of 84 fit the largest number of gear pairs.

| | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q | R |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | **Teeth** | **12** | **14** | **18** | **20** | **24** | **30** | **34** | **36** | **40** | **44** | **48** | **50** | **54** | **60** | **64** | **66** | **72** |
| 2 | **12** | 24 | 26 | 30 | 32 | 36 | 42 | 46 | 48 | 52 | 56 | 60 | 62 | 66 | 72 | 76 | 78 | 84 |
| 3 | **14** | 26 | 28 | 32 | 34 | 38 | 44 | 48 | 50 | 54 | 58 | 62 | 64 | 68 | 74 | 78 | 80 | 86 |
| 4 | **18** | 30 | 32 | 36 | 38 | 42 | 48 | 52 | 54 | 58 | 62 | 66 | 68 | 72 | 78 | 82 | 84 | 90 |
| 5 | **20** | 32 | 34 | 38 | 40 | 44 | 50 | 54 | 56 | 60 | 64 | 68 | 70 | 74 | 80 | 84 | 86 | 92 |
| 6 | **24** | 36 | 38 | 42 | 44 | 48 | 54 | 58 | 60 | 64 | 68 | 72 | 74 | 78 | 84 | 88 | 90 | 96 |
| 7 | **30** | 42 | 44 | 48 | 50 | 54 | 60 | 64 | 66 | 70 | 74 | 78 | 80 | 84 | 90 | 94 | 96 | 102 |
| 8 | **34** | 46 | 48 | 52 | 54 | 58 | 64 | 68 | 70 | 74 | 78 | 82 | 84 | 88 | 94 | 98 | 100 | 106 |
| 9 | **36** | 48 | 50 | 54 | 56 | 60 | 66 | 70 | 72 | 76 | 80 | 84 | 86 | 90 | 96 | 100 | 102 | 108 |
| 10 | **40** | 52 | 54 | 58 | 60 | 64 | 70 | 74 | 76 | 80 | 84 | 88 | 90 | 94 | 100 | 104 | 106 | 112 |
| 11 | **44** | 56 | 58 | 62 | 64 | 68 | 74 | 78 | 80 | 84 | 88 | 92 | 94 | 98 | 104 | 108 | 110 | 116 |
| 12 | **48** | 60 | 62 | 66 | 68 | 72 | 78 | 82 | 84 | 88 | 92 | 96 | 98 | 102 | 108 | 112 | 114 | 120 |
| 13 | **50** | 62 | 64 | 68 | 70 | 74 | 80 | 84 | 86 | 90 | 94 | 98 | 100 | 104 | 110 | 114 | 116 | 122 |
| 14 | **54** | 66 | 68 | 72 | 74 | 78 | 84 | 88 | 90 | 94 | 98 | 102 | 104 | 108 | 114 | 118 | 120 | 126 |
| 15 | **60** | 72 | 74 | 78 | 80 | 84 | 90 | 94 | 96 | 100 | 104 | 108 | 110 | 114 | 120 | 124 | 126 | 132 |
| 16 | **64** | 76 | 78 | 82 | 84 | 88 | 94 | 98 | 100 | 104 | 108 | 112 | 114 | 118 | 124 | 128 | 130 | 136 |
| 17 | **66** | 78 | 80 | 84 | 86 | 90 | 96 | 100 | 102 | 106 | 110 | 114 | 116 | 120 | 126 | 130 | 132 | 138 |
| 18 | **72** | 84 | 86 | 90 | 92 | 96 | 102 | 106 | 108 | 112 | 116 | 120 | 122 | 126 | 132 | 136 | 138 | 144 |

I defined the spacing between the motor and the output shaft of the gearbox as the center-to-center distance for a VexPro gear pair with a sum of 84 teeth, 2.1 inches.

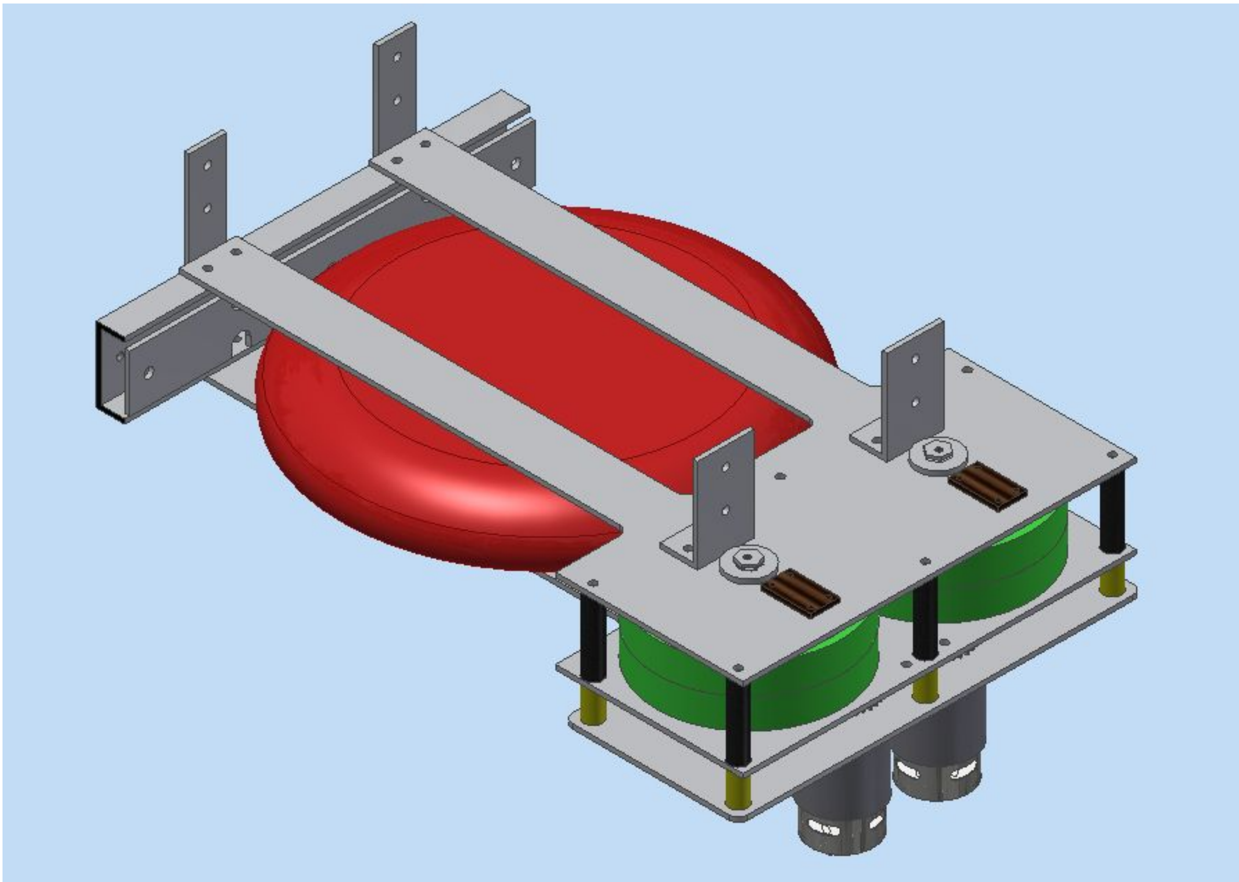


Two different gear pairs with a tooth-sum of 84 teeth



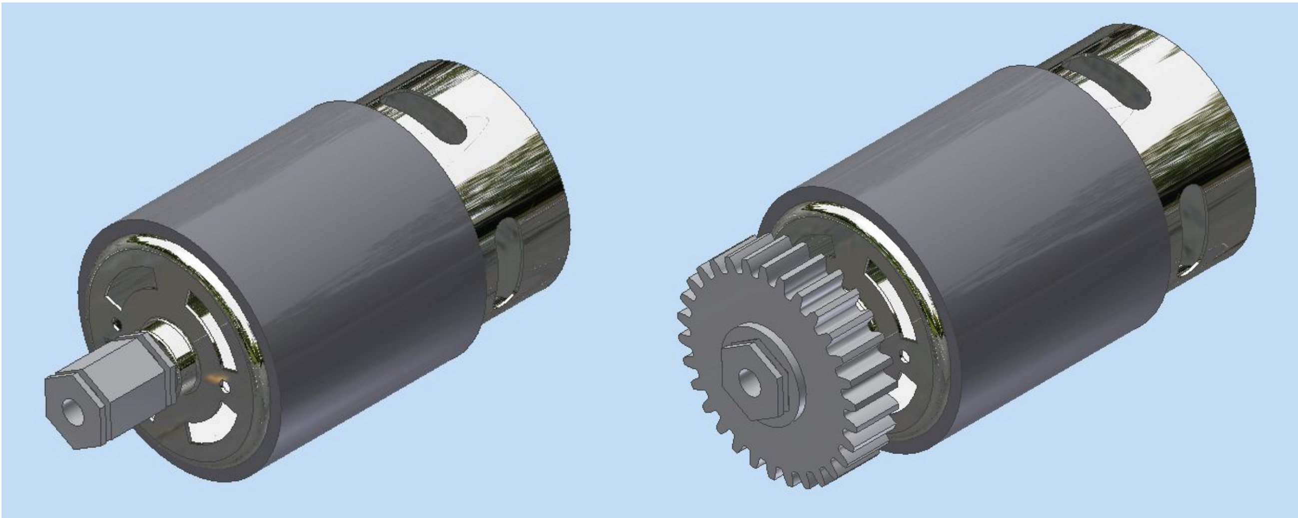
The prototype gearbox was driven by a Banebots RS-775 motor, which drove a ½” hex output shaft

# Improved Frisbee Shooter (2013)



Before our offseason competitions in Fall 2013, I improved the frisbee shooter on our 2013 robot, Ultimate Funky Object, to make it more efficient.

In the first design iteration, the frisbee shooter was powered by two planetary gearboxes from VexPro. The planetary gearboxes drove a second stage of spur gears, which in turn spun the shooter wheels. This system was inefficient, because it was made up of too many gear stages, but was designed as such because there was no easy way to couple the Banebots RS-775 motors, which had small output shafts, to the VexPro spur gears, which came with ½" hex bores. The planetary gearbox was an easy solution because of its ½" hex output shaft.

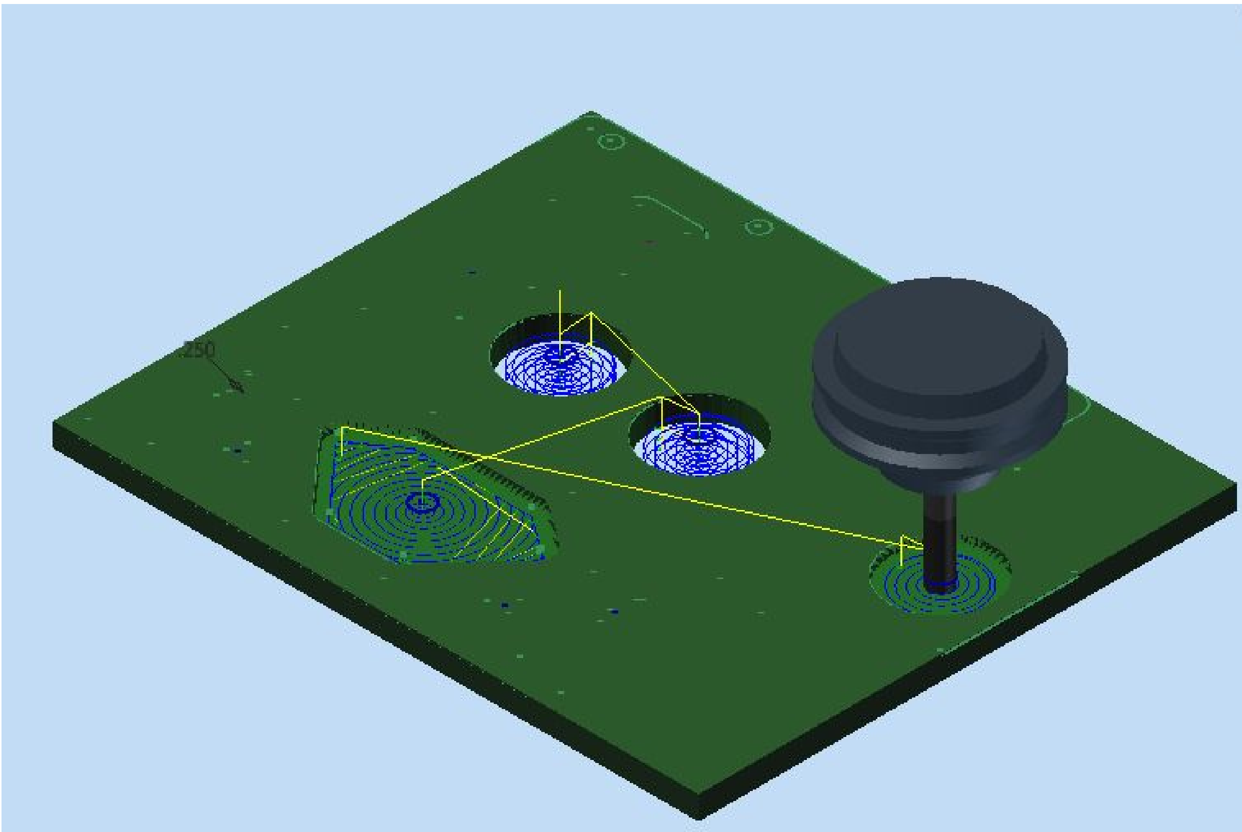


RS-775 motor with custom hub.  The gear was held on the hex hub by two e-clips.

I improved the efficiency of the gearbox by coupling the RS-775 motors to the spur gears through a custom hex hub.  Press-fit onto the motor shaft, the steel hub allowed me to remove the planetary gearbox and replace the two stage reduction with a single spur gear reduction. The new gear assembly not only made the frisbee shooter more efficient, but also made it lighter.

## HSMWorks CAM for Autodesk Inventor (2014-2016)

I introduced the team to HSMWorks CAM, and have used it with my peers to create CNC Mill G-Code for numerous parts.




Simulation of a milling operation in Autodesk Inventor

I decided to start using HSMWorks CAM because it was integrated with the Autodesk Inventor CAD environment. I could create CAM procedures for parts in the same window in which I modeled those parts, and could easily change features of the CAD model without having to re-create the CAM processes.

In my senior year, I led the fabrication team in making the CNC machining process more efficient. Making use of the Tormach CNC mill's tool offset and heights table features, we developed a standard tool numbering process that made tool selection easier and less time-consuming. As one of my largest overall efforts defining a process for the team to follow, this project proved useful in the 2016 build season, in which students were able to completely fabricate all the parts for the robot in a matter of just two weeks.

# Additional Links

Team Website: http://lynbrookrobotics.com/

Team Newsletters: http://lynbrookrobotics.com/?act=newsletters

Team 846 Promotional Video: https://www.youtube.com/watch?v=Qn4FnvVNFAI

Funk Cannon 2014 Robot: https://www.youtube.com/watch?v=92IbHU0Z76I

Ultimate Funky Object 2013 Robot: https://www.youtube.com/watch?v=jmdET56tukM

Team Blog about All Things Robot: http://becauserobots.org/