Drivetrain Technical Report

2018

Drivetrain

FROG FORCE 503 | 2/14/18

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DECIDING THE ARCHITECTURE

In order to decide what type of drivetrain to use this year we had to take into account and factor in multiple different elements of this year's game. Most importantly we had to account for how we assumed that the game will be played. With the increased reliance on saving time this year we already knew that speed was going to be a big factor. In addition, due to the precarious nature of placing the Power Cubes in just the right spot, maneuverability was also going to be a key factor. Keeping these two constraints in mind we created a Pugh Matrix which helped us decide the drivetrain style to use based on its characteristics and their importance in this year's game.

TABLE 1: DRIVETRAIN PUGH MATRIX

	Weight	Tank	Swerve	Holonomic	Tankonomic	OmniTank	H-Tank
Speed	6	6	5	1	4	5	4
Scrub	4	2	6	6	6	4	6
Agility	6	2	6	6	6	4	6
Weight	2	6	3	5	2	4	1
Space	3	5	6	3	2	4	1
Defense	3	6	4	1	4	5	4
Programmability	2	6	1	3	3	5	3
Time	2	6	1	2	2	5	3
Maintenance	2	6	5	3	2	4	1
Totals :		**137**	**140**	**104**	**120**	**133**	**115**

- In contrast to last year, the weights were decided by common consensus rather than averaging values. This was used in order to provide more friendly numbers without outliers significantly changing the outcome of the Pugh Matrix
- The drive options differed from last year in the regard that we were willing to try out combo drivetrains in which the robot would be able to switch between drivetrains. (e.x tankonomic would switch in between tank drive for speed, and holonomic for positioning).
- The ratings for the individual categories were 1-6 (for the 6 tank drive options) and these were also chosen by group consensus for similar reasons as the weightings.
- After going through the Pugh Matrix, swerve was given the highest overall score. However, due to our team's relative inexperience with swerve construction and maintenance, we chose the next best, tank drive.

GEARBOX AND RATIOS

This year, similar to previous years, we wanted to use a VEX WCP gearbox. The team has had a good history with them and therefore feels very comfortable. In addition to comfort, we decided to use the VEX WCP gearbox because it fits all of our needs and had various different gear ratio options.

DECIDING ON A GEARBOX AND GEARBOX REQUIREMENTS

- This year we decided that a dual speed gearbox would be beneficial for having speed and defending against the opposing alliance.
- We used a spreadsheet calculator to determine acceleration, current draw, speed, slippage, and voltage versus time (http://www.chiefdelphi.com/media/papers/3038, Hill Drivetrain Simulator)
  - The group put in different gear ratio combinations in order to determine the best ratio for this challenge.
  - Last year, we assumed that the drivetrain itself was around 10 lbs, this year we used last year's drivetrain (as we would end up creating a very similar drivetrain) and measured to get the actual weight of the drivetrain therefore improving the accuracy of our calculations.
- Packaging was an important factor this year but unfortunately we were not able to find a smaller gearbox that satisfied all of our needs.
- One of the key elements that was desired this year was a Power Take-Off (PTO). Therefore we also had to look for a gearbox that was able to support PTO.

HIGH GEAR SPECIFICATIONS

- Goal Speed – 20 ft/s
  - The group felt that we wanted a speed faster than last year and in addition, saving time was even more paramount in this challenge since points is all dependent on time.
- Current Draw Goal – ≤100 amps
- Final Ratio – 6.25:1

LOW GEAR SPECIFICATIONS

- Goal Speed – 10 ft/s
  - Considering the challenge in addition to the fact that we wanted a significant amount of pushing force, as well as being limited to certain ratios for the gearbox, this speed was the most reasonable.
- Current Draw Goal - ≤100 amps
- Final Ratio – 12.85:1

POWER TAKE-OFF

- Since for our PTO we were wanting to support 2 robots (us and one more) we had to take into account the strain that would be on the gears while climbing.
- After talking to our Game Specific Design team we decided that a 1:2 ratio would be sufficient lifting strength and speed.
- Because the pre ordered gearbox does not come with a 1:2 PTO gear we had to custom design our gearbox plates and specially modify some parts of the gearbox in order for it to work cohesively.
- Current Draw Goal - ≤100 amps
- Final Ratio - 1:2

GEARBOX MODIFICATIONS

- Removed 32 tooth PTO gear and replaced with an 84 tooth gear.
- Had to mill out 84 tooth gear to accommodate for dog gear clearance
- Designed Gearbox Plates to accommodate for new center to center distance of 84 tooth and 42 tooth gear
    - Also added mounting point for Intake System
- Custom lathed 3/8” hex shaft for center axle to have space for a second 42 tooth gear
- Added a 42 tooth gear to interface with PTO gear

CHART 1: LOW GEAR PERFORMANCE

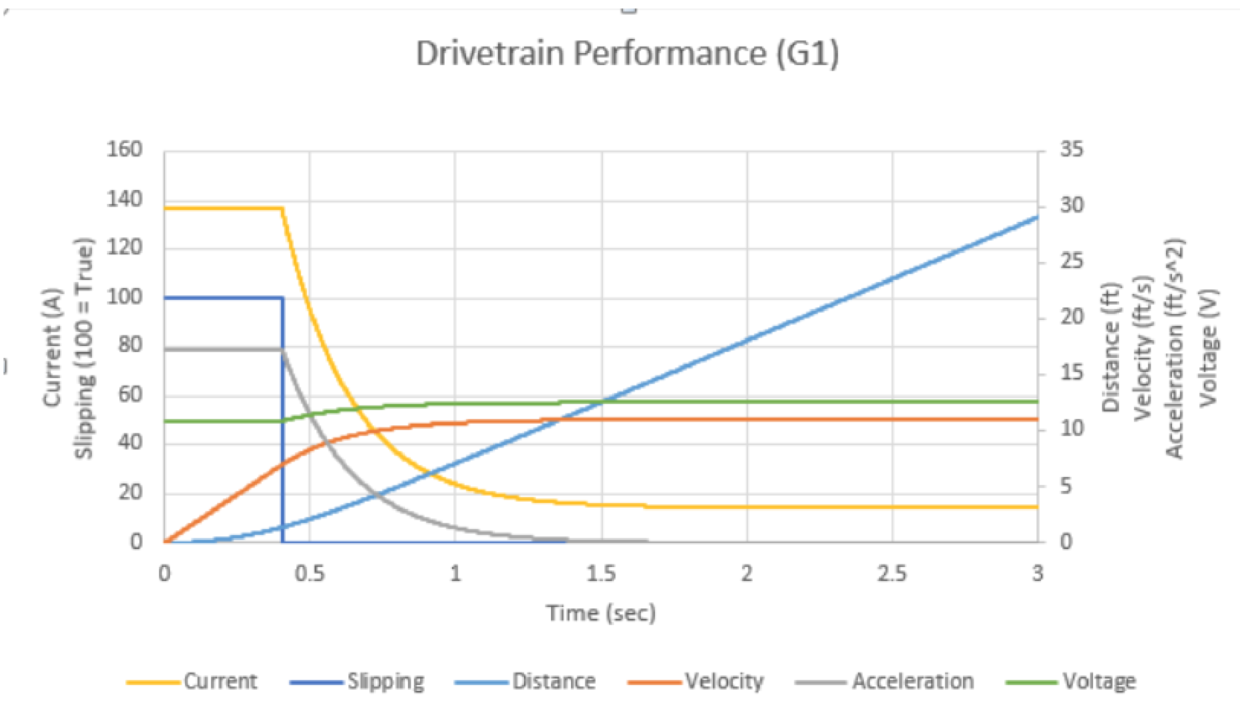


CHART 2: HIGH GEAR PERFORMANCE

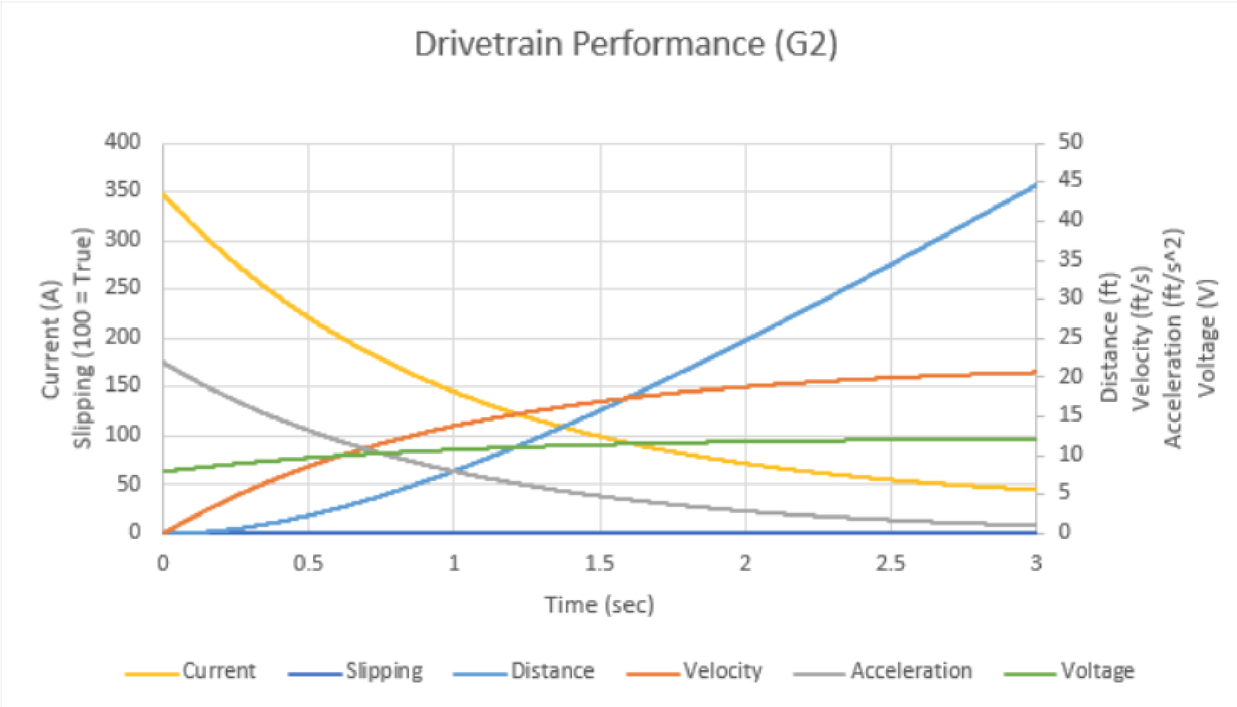


CHART 3: PTO PERFORMANCE

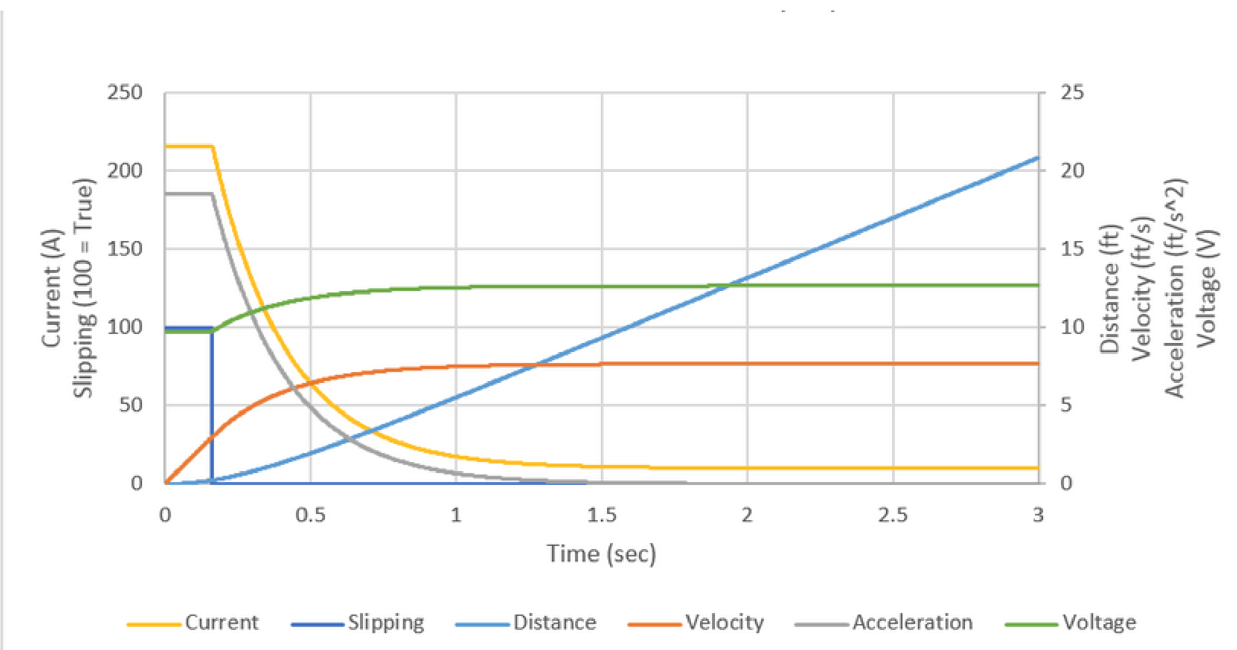


CHART 4: DRIVETRAIN INPUTS

1	Kro	8.3	lbf	
2	Krv	0	lbf/(ft/s)	
3	Kf	0.82		Drivetrain Efficiency
4				
5	d	6	in	Wheel Diameter
6				
7	M	130	lb	Robot Mass
8	uS	0.804	1.2	Static Coefficient of Friction
9	uK	0.603	0.9	Kinetic Coefficient of Friction
10				
11	Rcom	0.013	Ohm	Circuit Resistance from batt to PDB (inc. Batt Rint)
12	Rone	0.002	Ohm	Circuit Resistance from PDB to motor
13	Vbat	12.8	V	Fully charged Battery Voltage
14				
15	Vspec	12	V	Motor Specification Voltage
16	Tspec	4.841	N-m	Combined Motor Stall Torque
17	Wspec	5310	RPM	Combined Free Speed RPM
18	Ispec	262.5	Amp	Combined Motor Stall Current
19				
20			Efficiency %	Gear Ratio
21	Motor 1:		100%	1
22	Motor 2:		100%	1
23	Motor 3:		100%	1
24				
25	dt	0.001	sec	Time Step
26				
27	G1	12.85714286		Gear Ratio (Can also mod A20 in Unit Conversions)
28	G2	6.25		Gear Ratio (Can also mod A21 in Unit Conversions)
29	Vmax1	11.05	ft/s	
30	Vmax2	20.64	ft/s	
31	Spread	2.06		
32				
33	LSR	3811		Low Speed RPM to Shift
34	HSR	1853		High Speed RPM to Shift
35	VmaxShift	20.63	ft/s	

FIGURE 1: VEX GEARBOX

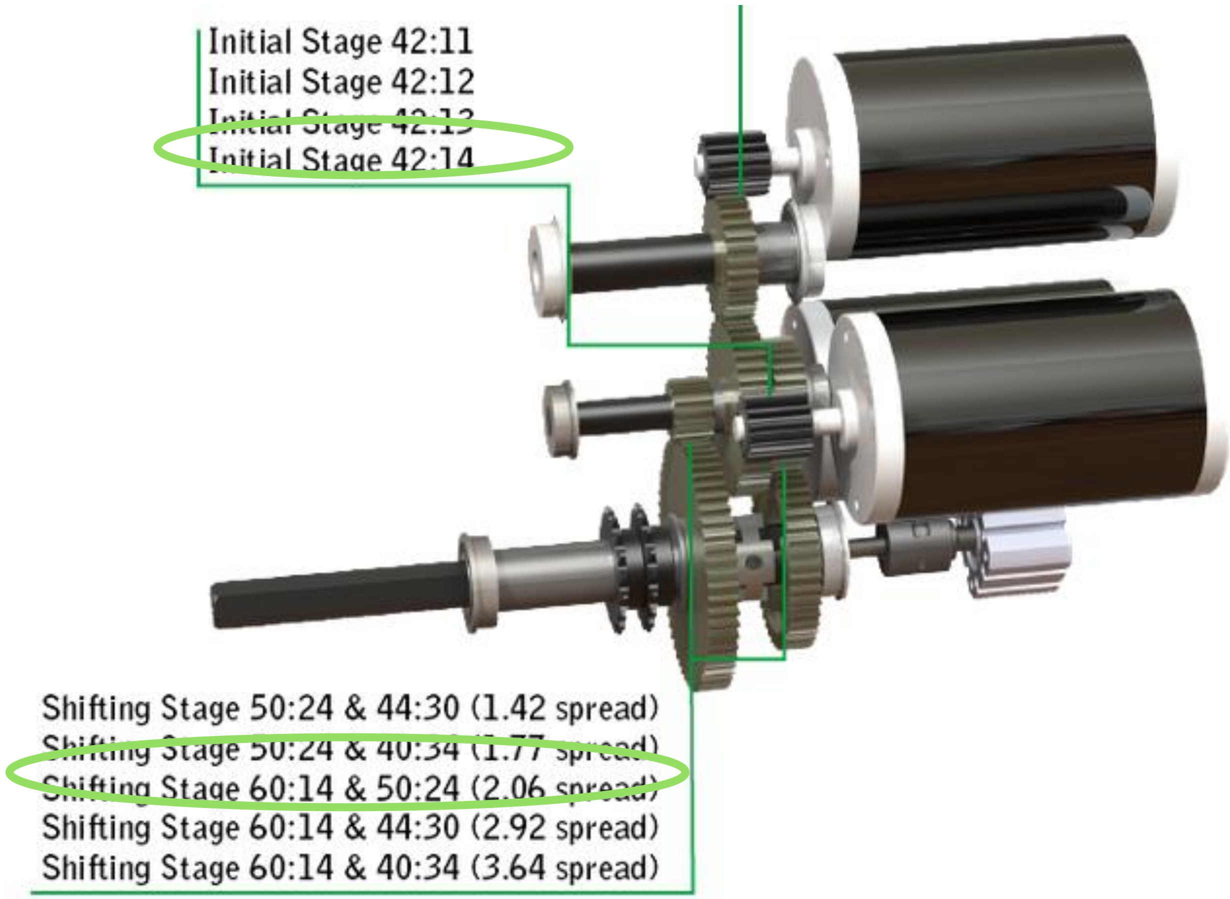
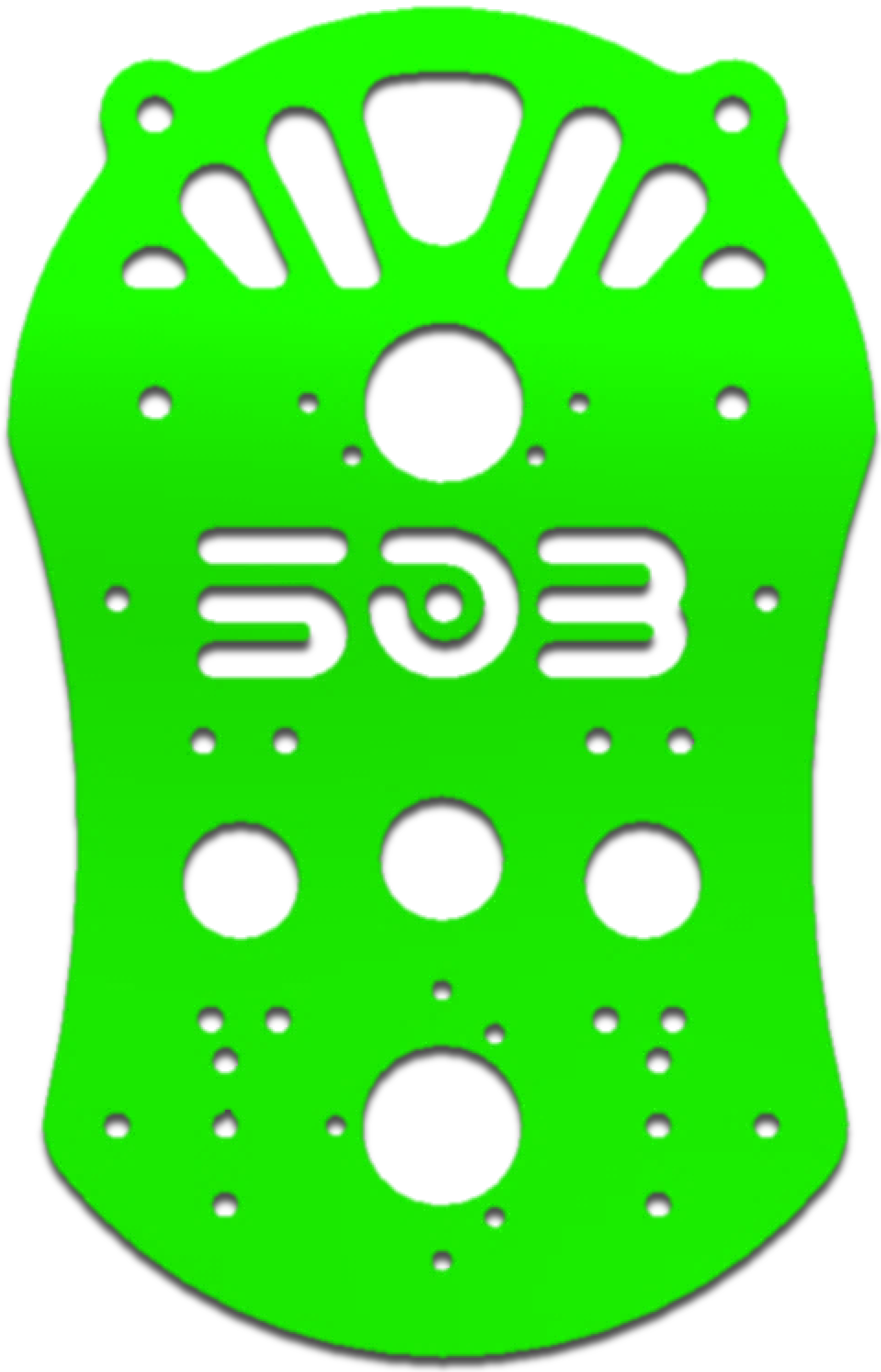


FIGURE 2: GEARBOX PLATE



WHEEL SELECTION

WHEEL REQUIREMENTS AND GOALS

- High coefficient of friction to provide sufficient traction when driving and defending
- High precision when pivoting the robot to place Power Cubes
- High Durability
- Stable Robot (no rocking)
- Low scrub

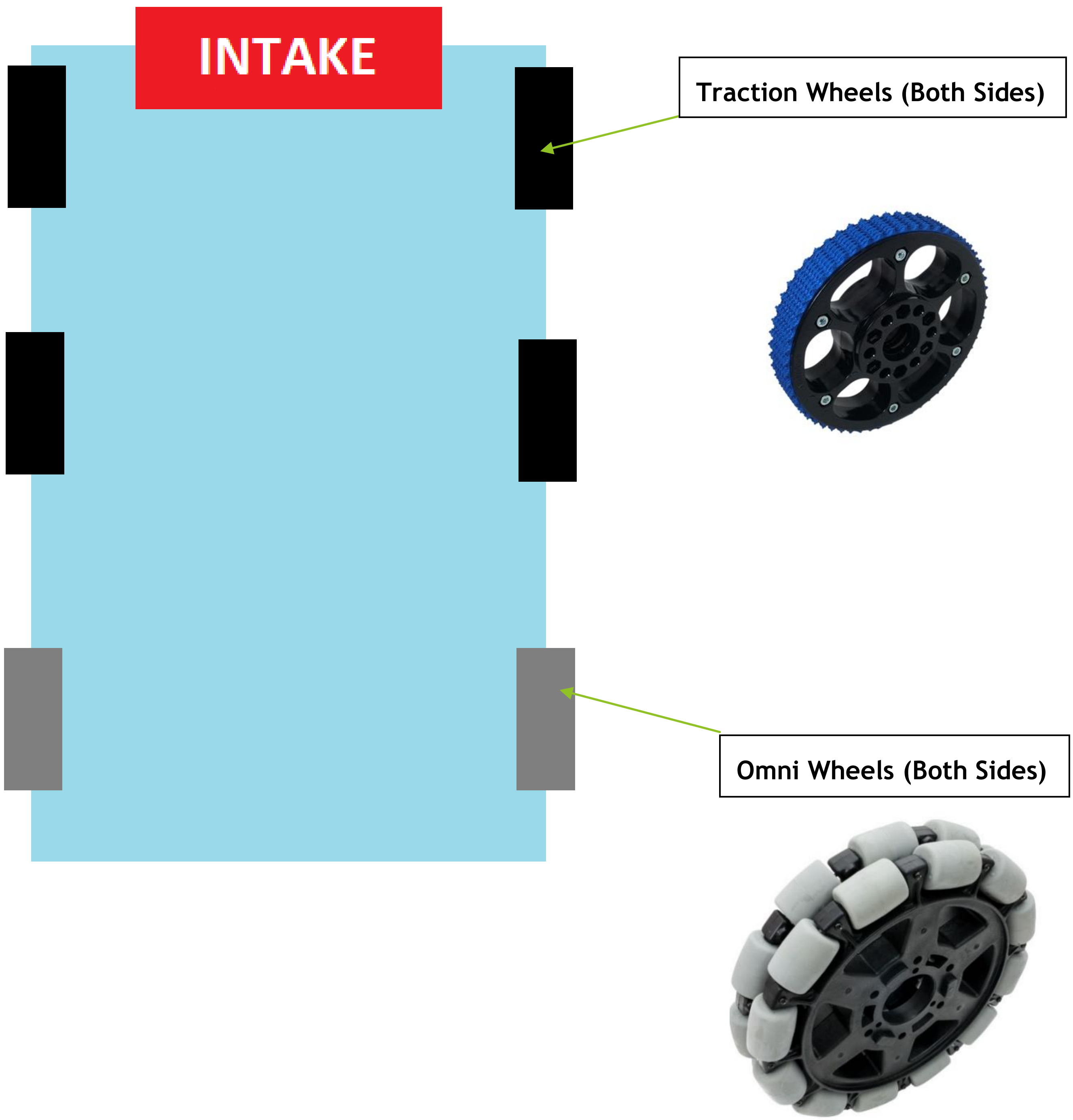
POSSIBLE SOLUTIONS TO GOALS AND REQUIREMENTS

- Nitrile tread to provide traction
- Omnidirectional (Omni) wheels to provide maneuverability
- 4” or 6” Wheels
- Aluminum or Plastic Wheels

FINAL DRIVETRAIN SOLUTION

- 6” Wheel Diameter
  - Provide ample clearance for ramps
  - Assists in getting the high speed that was desired in this game
- 3 Wheels on either side of robot
  - Very stable and reliable drive system
- 4 Blue Nitrile Traction Wheels
  - Placed in the center and front of the robot
  - Provide traction
  - Bring the pivot point of the robot forward which is beneficial to place Power Cubes on Switches and Scale
  - High Durability
- 2 Omni Wheels
  - Assist in balancing the robot
  - Push center of turning to the front of the robot
  - Allow for more precise turning and therefore placing of Power Cubes
- Gearbox Location
  - Gearbox located in the front of the robot
  - Allows space for a robot to climb on top of us
  - Very little loss of power transmission to the wheels with a West Coast Drive and sprocket system.

FIGURE 3: DRIVETRAIN LAYOUT



ENCODERS

- Unlike last year, we used magnetic encoders this year. The reason that we switched over is because last year we had problems with slippage and the magnetic encoders are much more accurate.
- Instead of having the magnetic encoders in a separate location we decided to put them on the driven axle in order to get an accurate reading of the robot velocity.
- One important consideration we had to make when designing the encoder mounts were enough space for the chain.
  - During testing we found a flaw and in order to fix that we decided to add an option to drive our omni axles. In doing so we forgot to account for the chain width in the mounting system. Our solution to the problem was to use a lathe to trim down our Male-Female Hex Standoffs, this added enough clearance for both sets of chain without a major redesign.

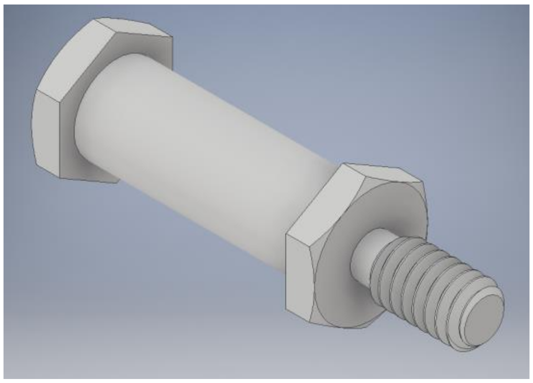
COMPONENTS USED IN ENCODER ASSEMBLY

- ¼-20 UNC Threaded Male-Female Hex Standoffs, Modified
- ¼-20 UNC Castle Nut
- CTR SRX Magnetic Encoder
- Custom Polycarbonate Encoder Mounting Plate

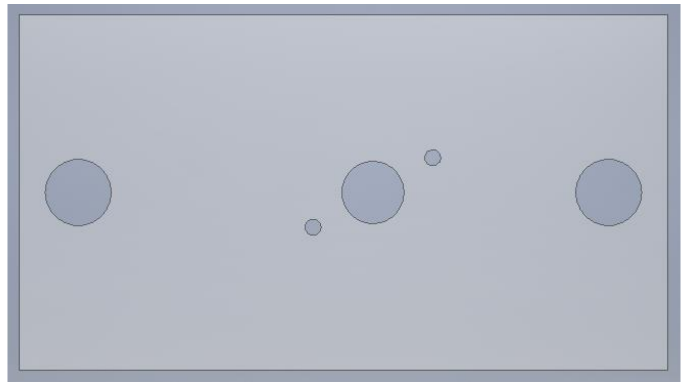
ENCODER PLATE SPECIFICATIONS

- 1.5” x 2.75” x .125" Polycarbonate Sheet
- 2 3/8” Clearance holes for 1/4-20 Standoffs
- .265” Clearance Hole for .25” diameter magnet
- 2 .069” Holes for CTR SRX Magnetic Encoder Mounting Bolts

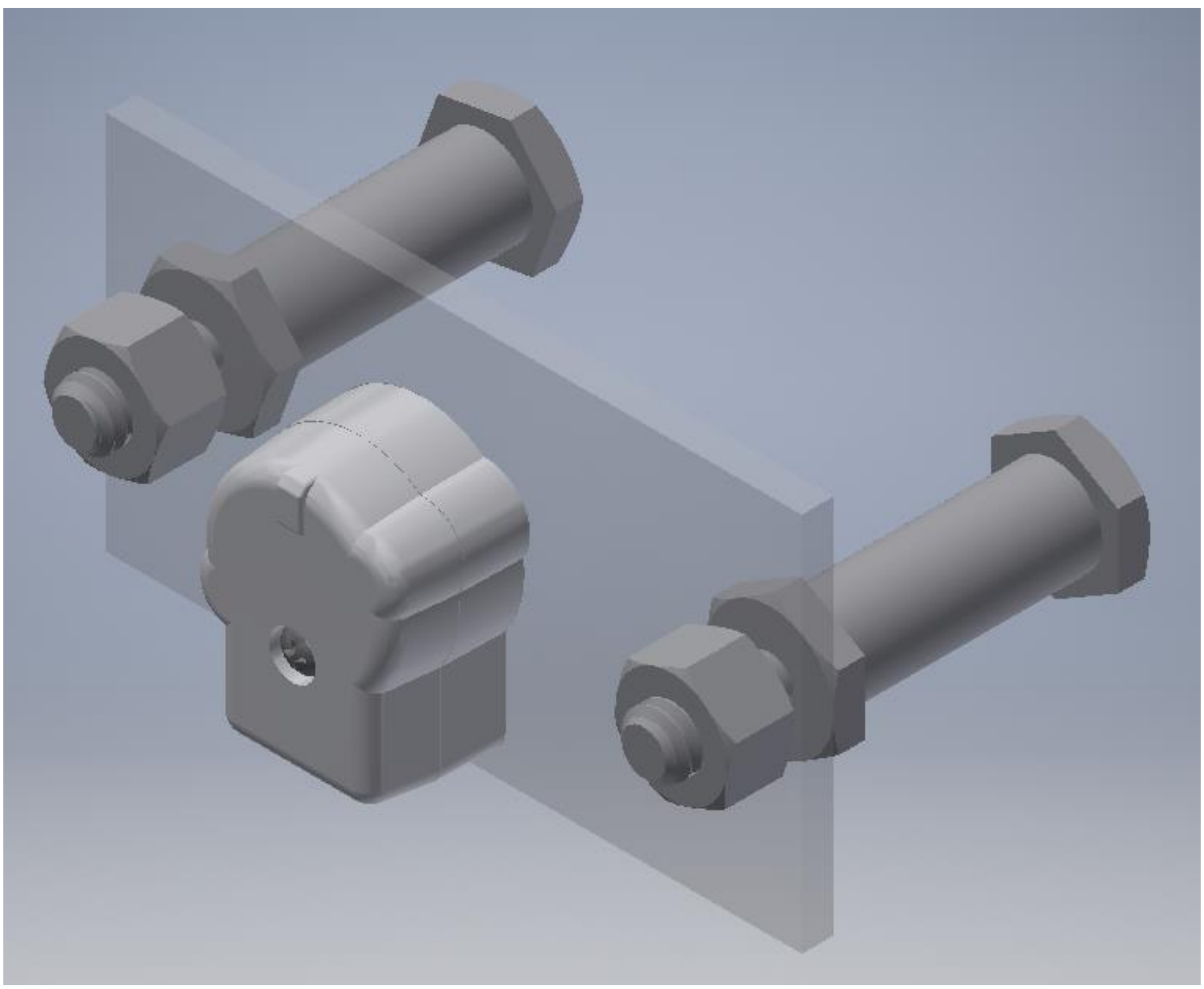
FIGURE 4: ENCODER MOUNTING SYSTEM AND PARTS



Modified Hex Standoffs



Encoder Mounting Plate



Encoder Mount Assembly

CHAIN TENSIONING SYSTEM

- Original plan was to not use a tensioning system this year. We expected to achieve this by calculating the chain length exactly for the center to center distance between the two sprockets. If this distance turned out to not be a whole number, we would slightly adjust the center to center distance.
- Due to machining, the center to center distance was slightly less than what we had calculated and therefore there was sag visible in both chains from the gearboxes to the center axles
- The Game Spec team had a gearbox, for another system of the robot, that was mounted around our chain and we decided to use one of their spacers to mount a pulley that would push the chain taught.
    - This method, while not the most elegant, is the most effective and simple route that we had possible to us.

PULLEY SPECIFICATIONS

- Manufactured from Delrin rod for high durability and low friction
- 0.4" width, 1” diameter groove for the chain to ride inside the pulley
- 0.8" Overall width – minimizes volume taken up by chain tensioner while still having material that won't be too flimsy
- 1.2" Overall Diameter
- .2” width, .8” shoulder to provide built in offset from chassis rail

FIGURE 5: TENSIONER PULLEY

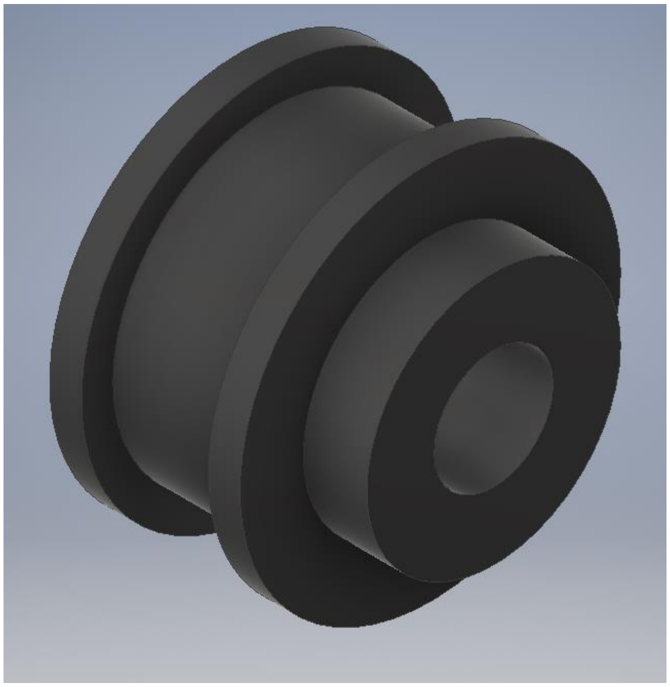


FIGURE 6: FULL DRIVETRAIN ASSEMBLY