NFPA Fluid Power Vehicle Challenge

NFPA Education and Technology Foundation

Final Presentation
Murray State University
Staff Advisor – Roger Riquelme
Industry Mentor - Joshua Scarbrough
04/07/2021

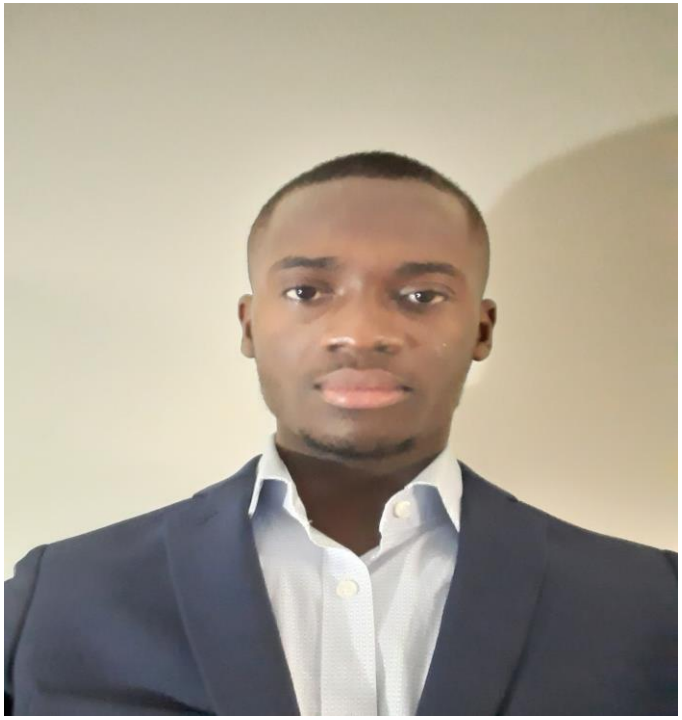
MURRAY STATE UNIVERSITY

Team Members

Roger Riquelme
Team Advisor
Instructor Murray

Team Members

Nate Heady
ElectroMechanical
Senior



Dami Ogunjimi
Electromechanical Engineering Tech
Sophomore

Team Members

Carson Elliott
ElectroMechanical
Junior

Problem Statement

To design a hydraulic bike that is driven solely on human power through the use of fluid power components in a reasonably safe manner.

Design Goals

- Redesign steering of the vehicle
- Optimize the accumulator circuit
- Regear the Human Powered circuit for a Higher Pressure/Lower Flow Rate system
- Integrate and properly utilize a pneumatic system
- Redesign power input
- Integrate Electronics
- Minimize custom fabrication

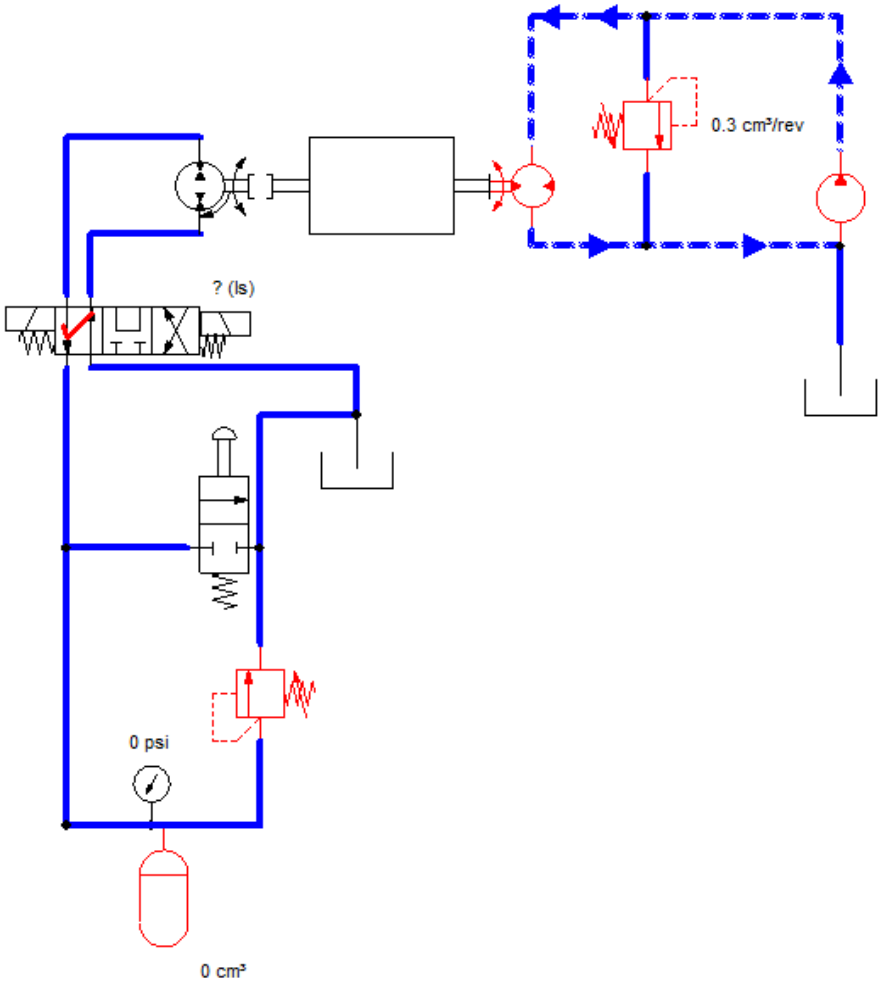
Winning Tactics: Sprint Race

- Make efficient use of our stored potential energy
  - Minimize coasting
  - Use all energy before crossing the finish line
- Control our acceleration via gear ratios and timing
  - Multi Speed gear box
- Allow for max flow rate with the D03

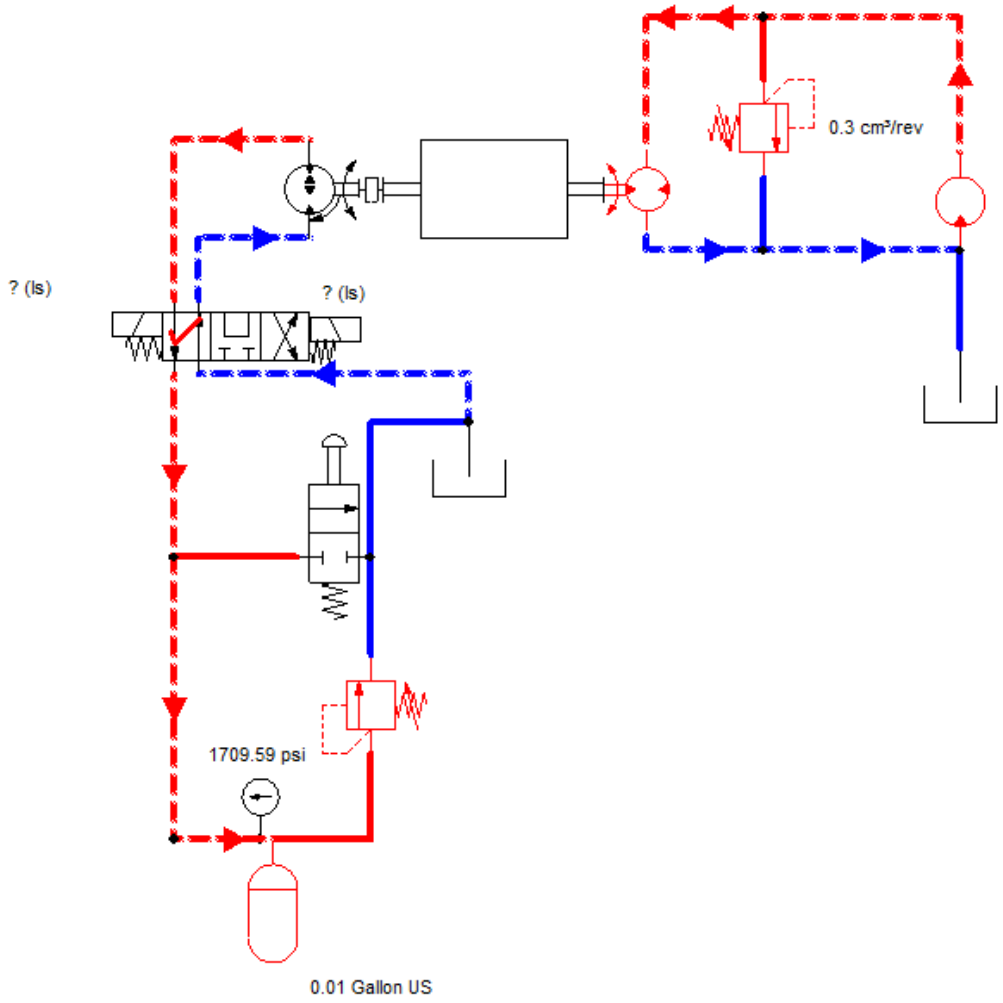
Winning Tactics: Efficiency and Lap Race

- Keep the system pressure above 1700 psi to maximize efficiency
- Make use of our 2 speed gearbox and clutch system
  - Disengaging the clutch allows us to coast after discharging the fluid in the accumulator
  - The 2 speed gearbox allows us to easily charge up potential energy after the initial discharged
  - Freewheel (ratchet) on the human powered side prevents pedals from turning while coasting

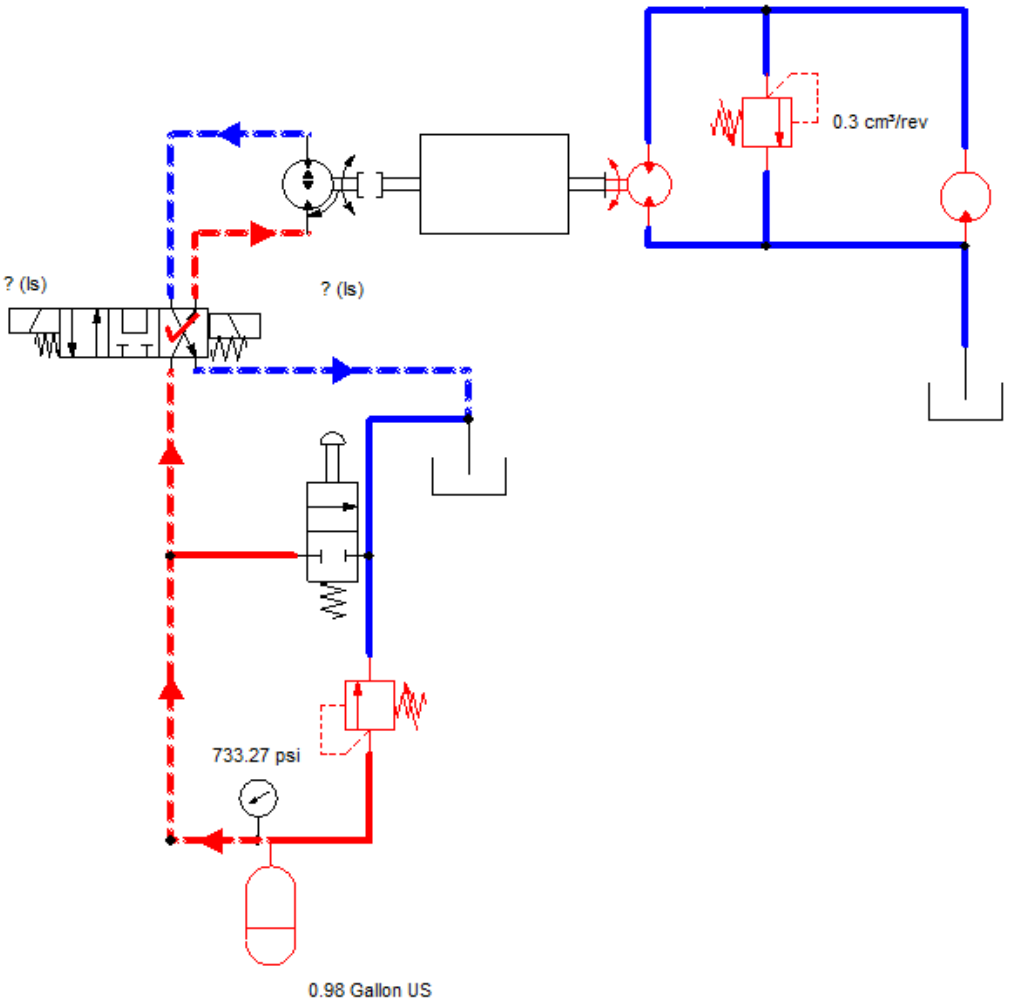
Human Powered



Regeneration



Accumulator Discharge



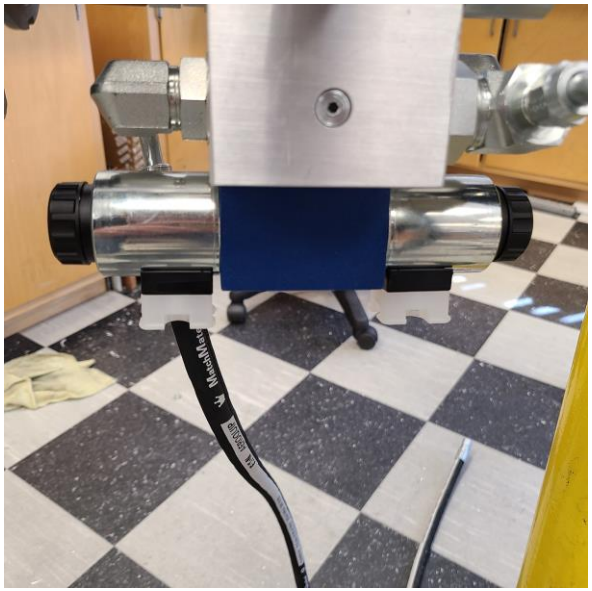
Power Input

Chain and Sprocket

- Much more efficient
- Easy to use
- Allows for a variety of gear ratios
- Easier to obtain parts
- Cheaper to buy components

Components Choices

- Our system was operating at a flow rate that was approaching the flow rate capacity of cartridge valves
- We opted for a more traditional C top D03



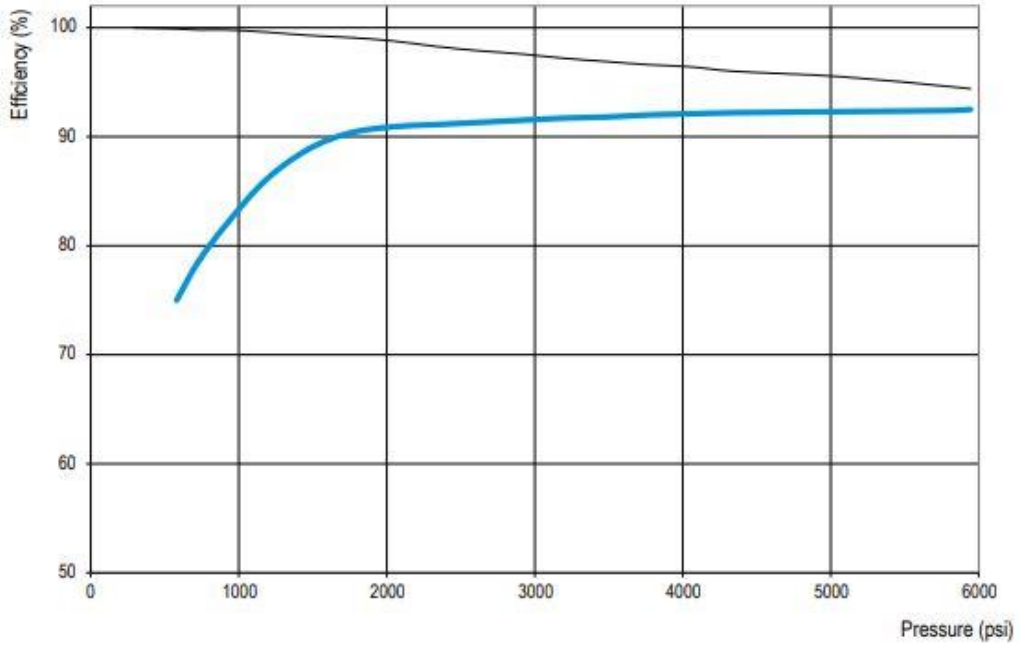
Motor/Pump Choice

- We have three piston motors/pumps
- One Hydro Leduc micropump
  - Powered by rider
  - High volumetric efficiency
  - Compact design
- Two Hydro Leduc bent axis pump/motors
  - Mounted on Regeneration and Human powered circuits
  - Very high efficiency (greater than 90% above 1700 psi)

HydroLeduc Efficiency

EFFICIENCY OF M / MA / MSI SERIES MOTORS

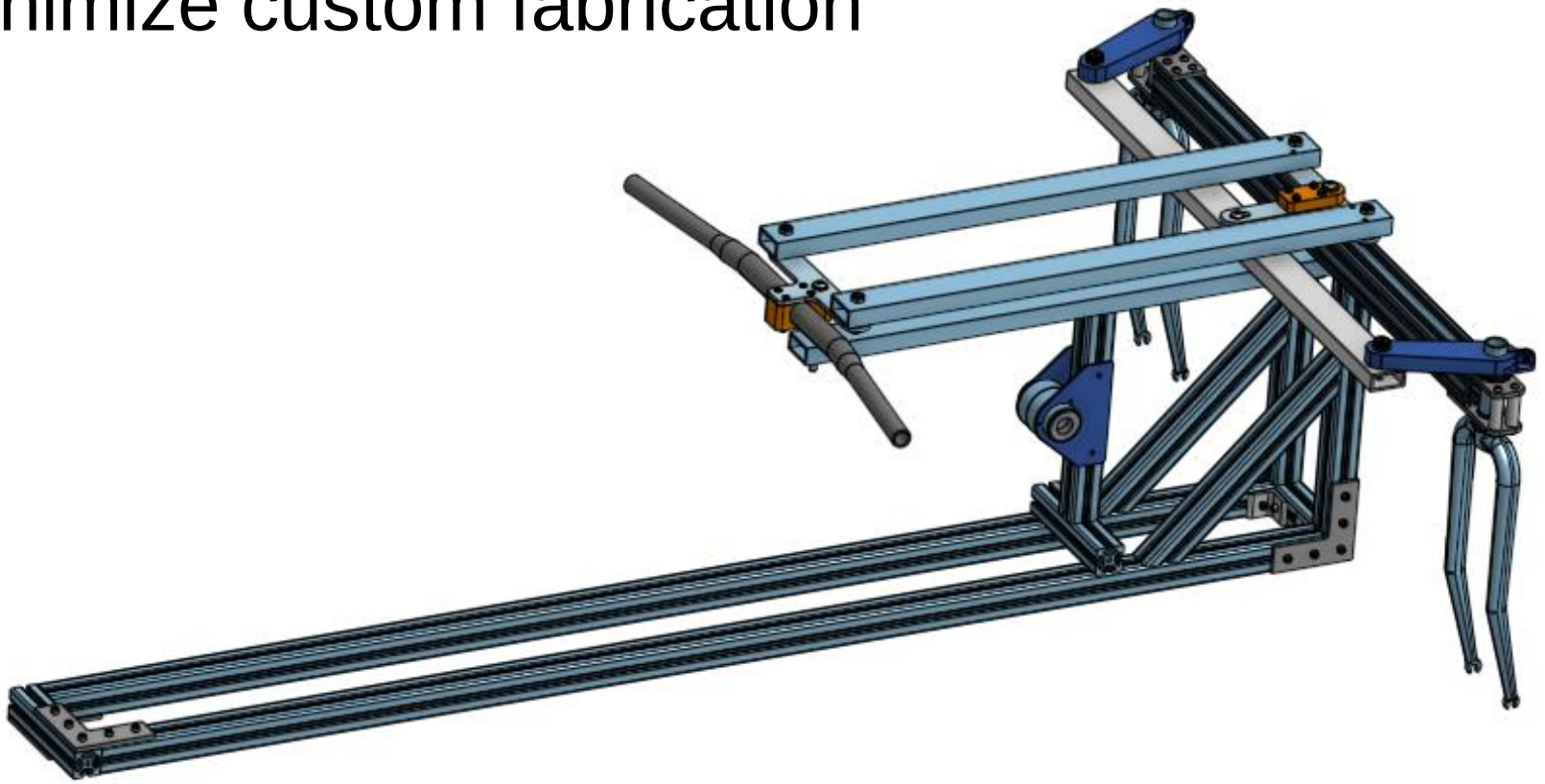
N motor = 1000 rpm
ISO46 fluid at 77° F (25°C)



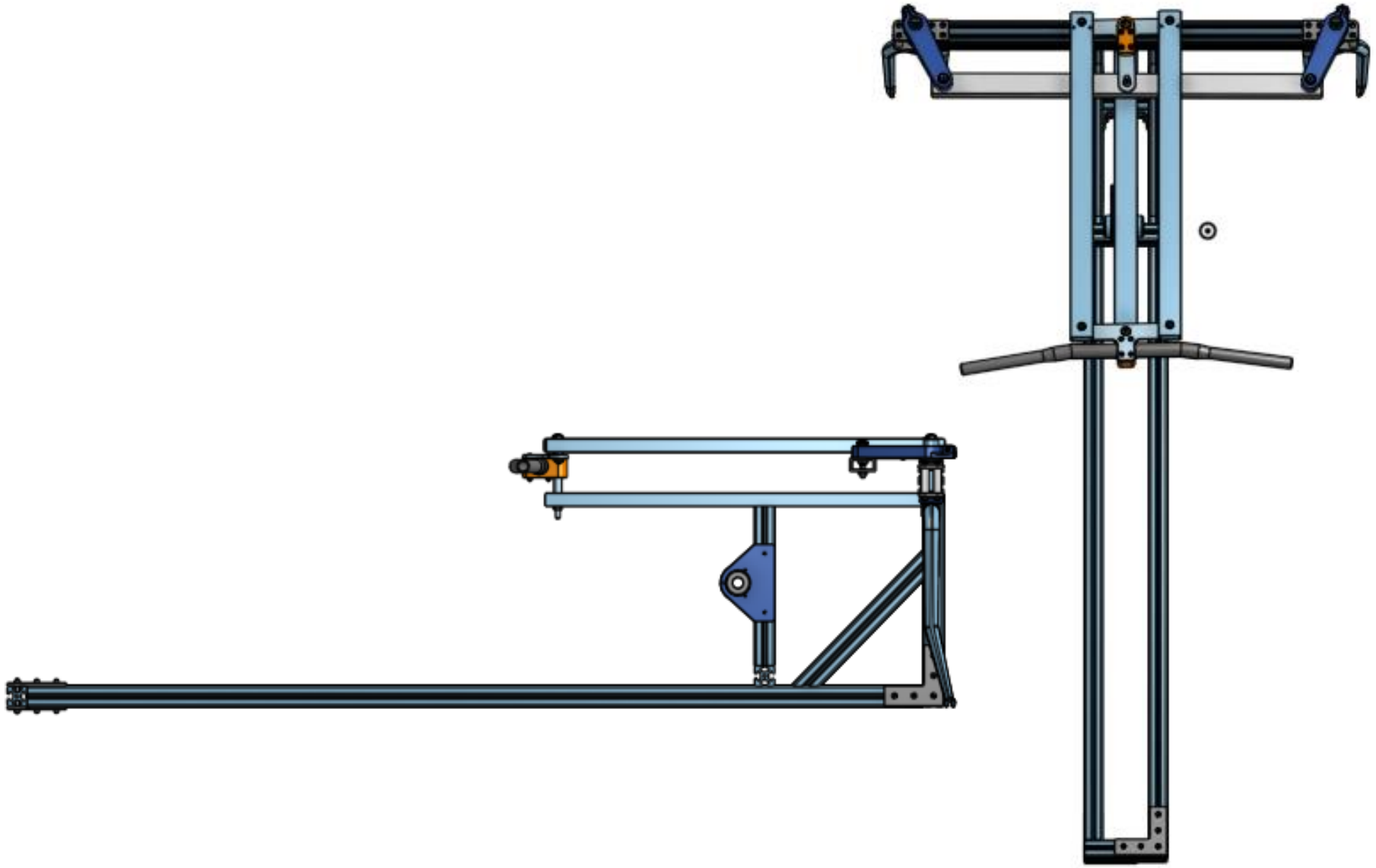
This graph is given as an indication only.
For further information, please contact our Technical Service.

Frame

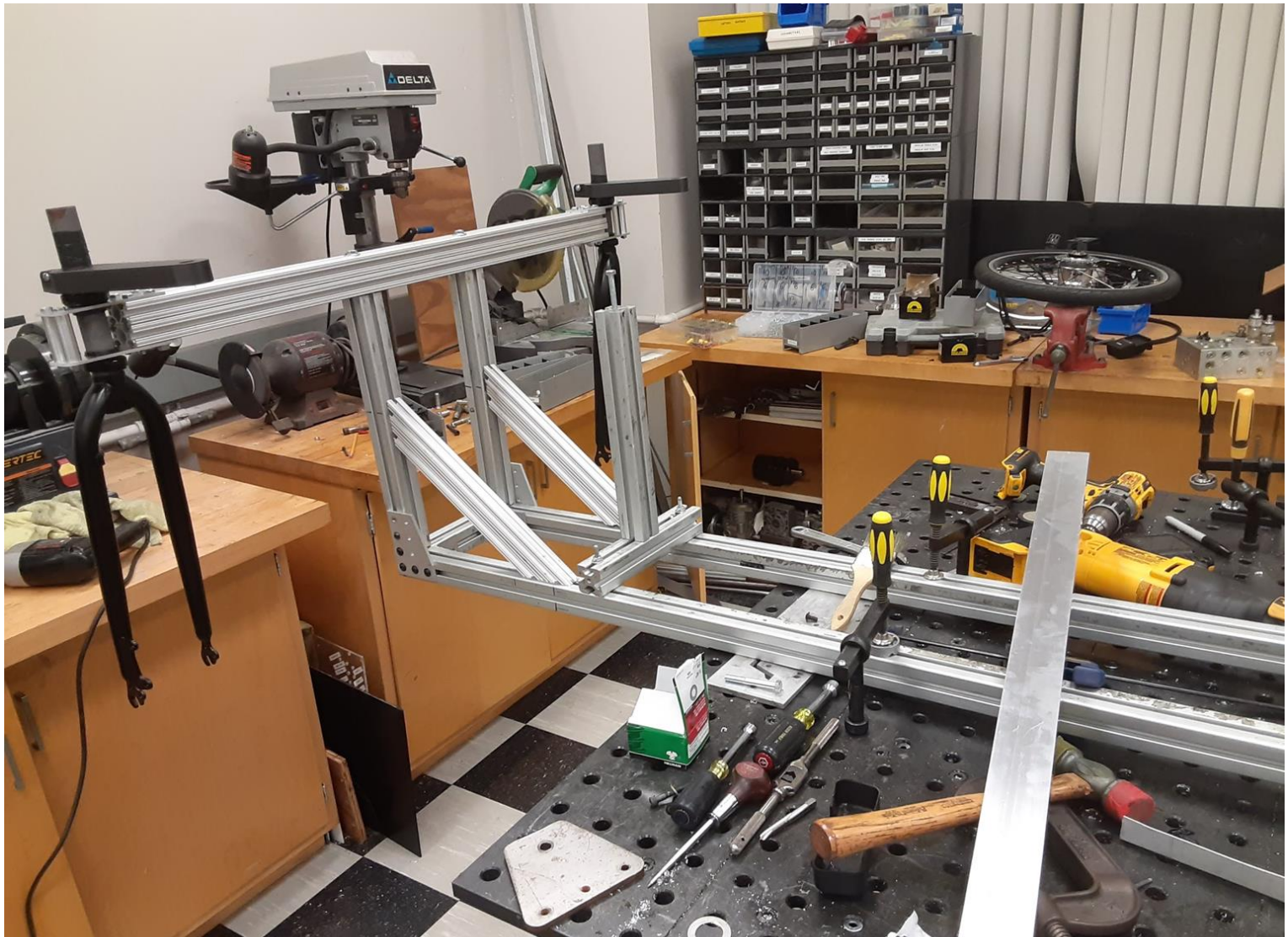
- 80-20 Aluminium
- Stability
- Minimize custom fabrication



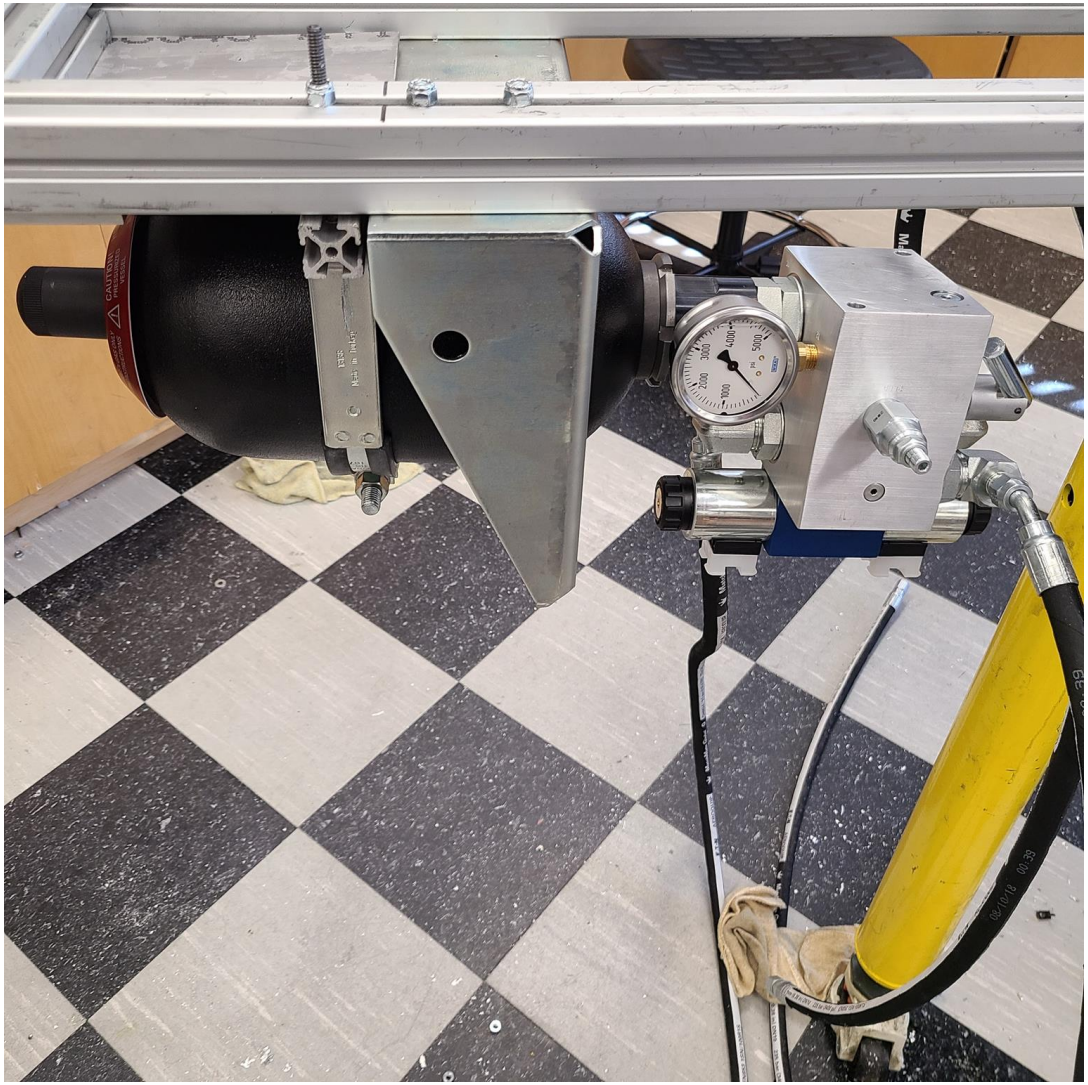
Frame



Frame Construction



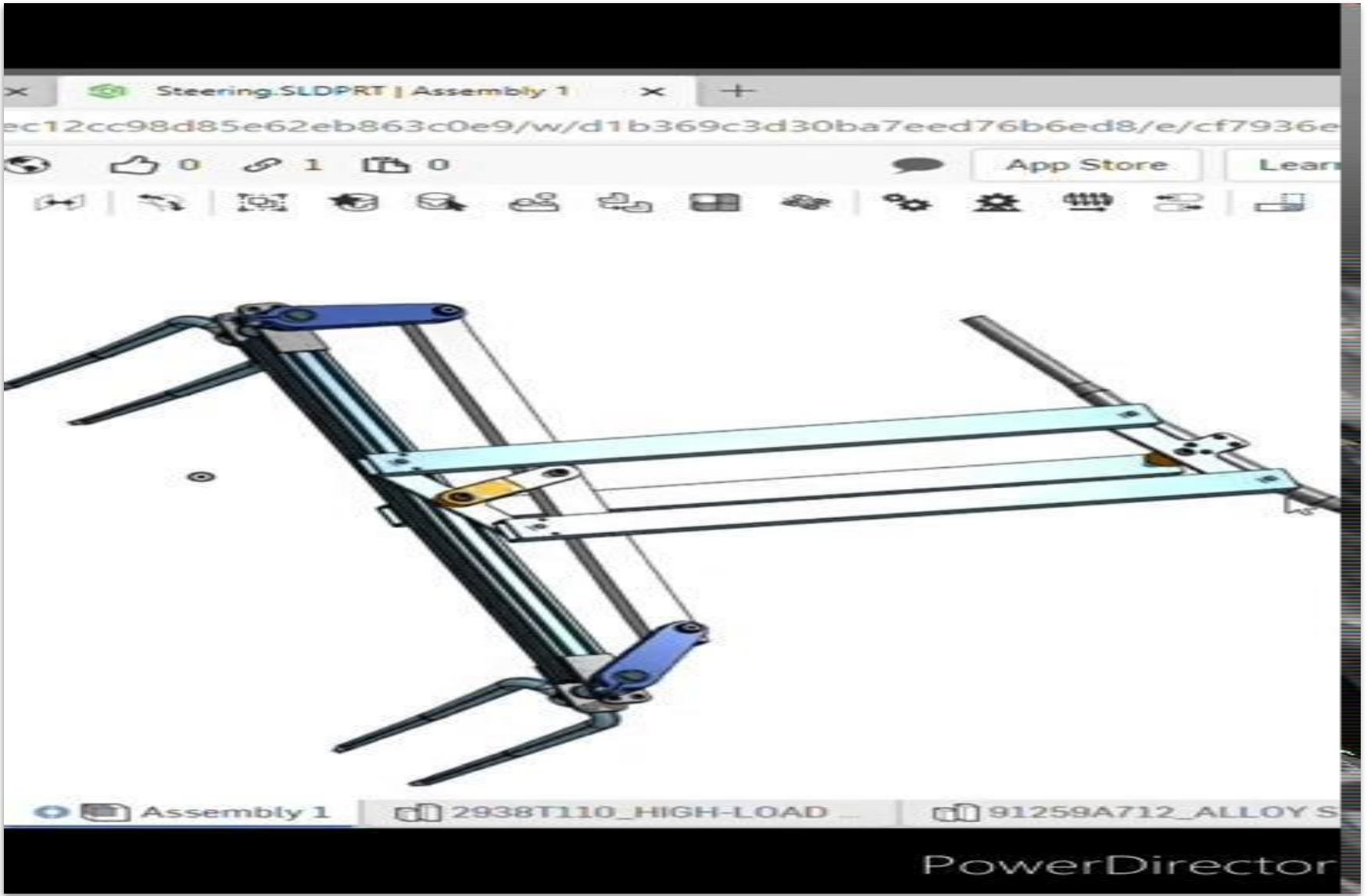
Manifold Mounting



Wheel Mounting

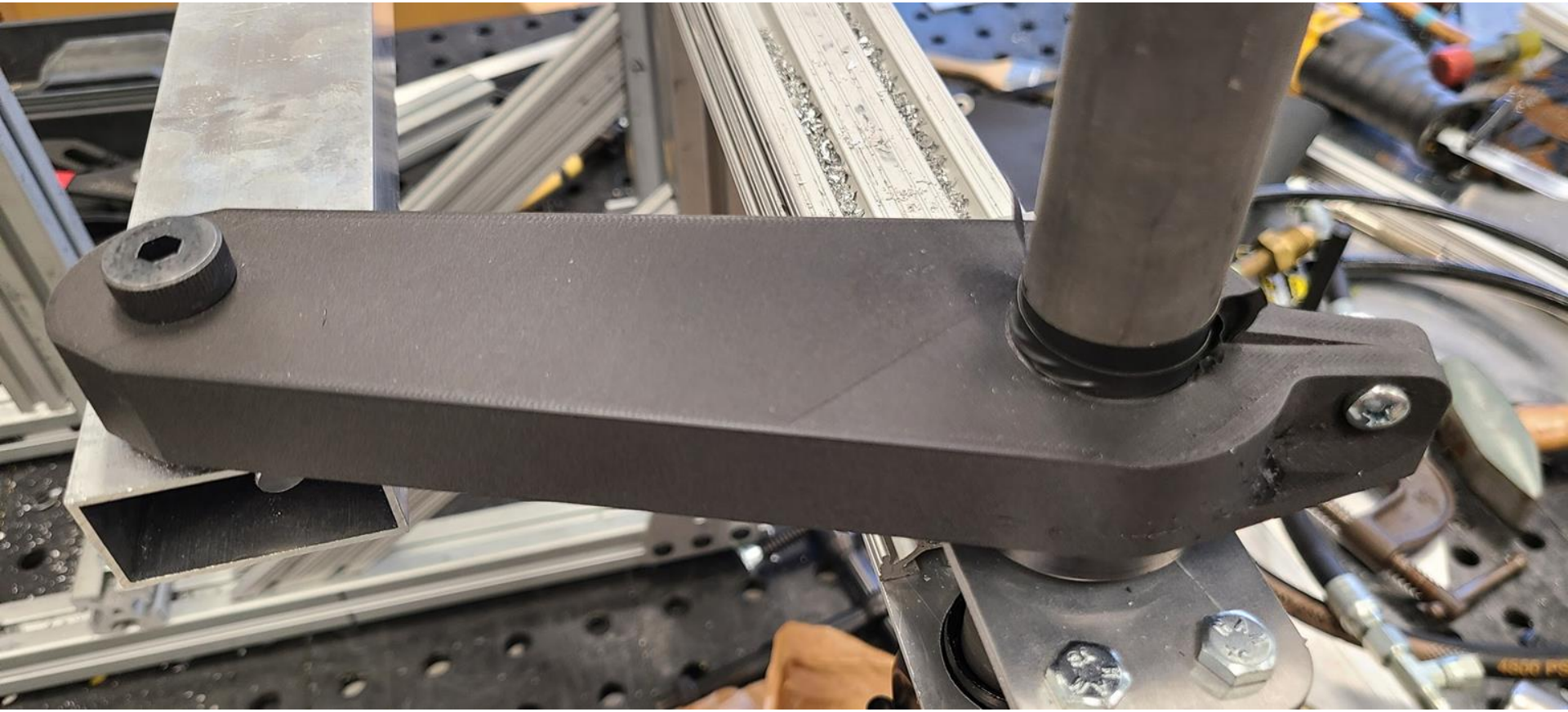
The frame as it stands now

Steering

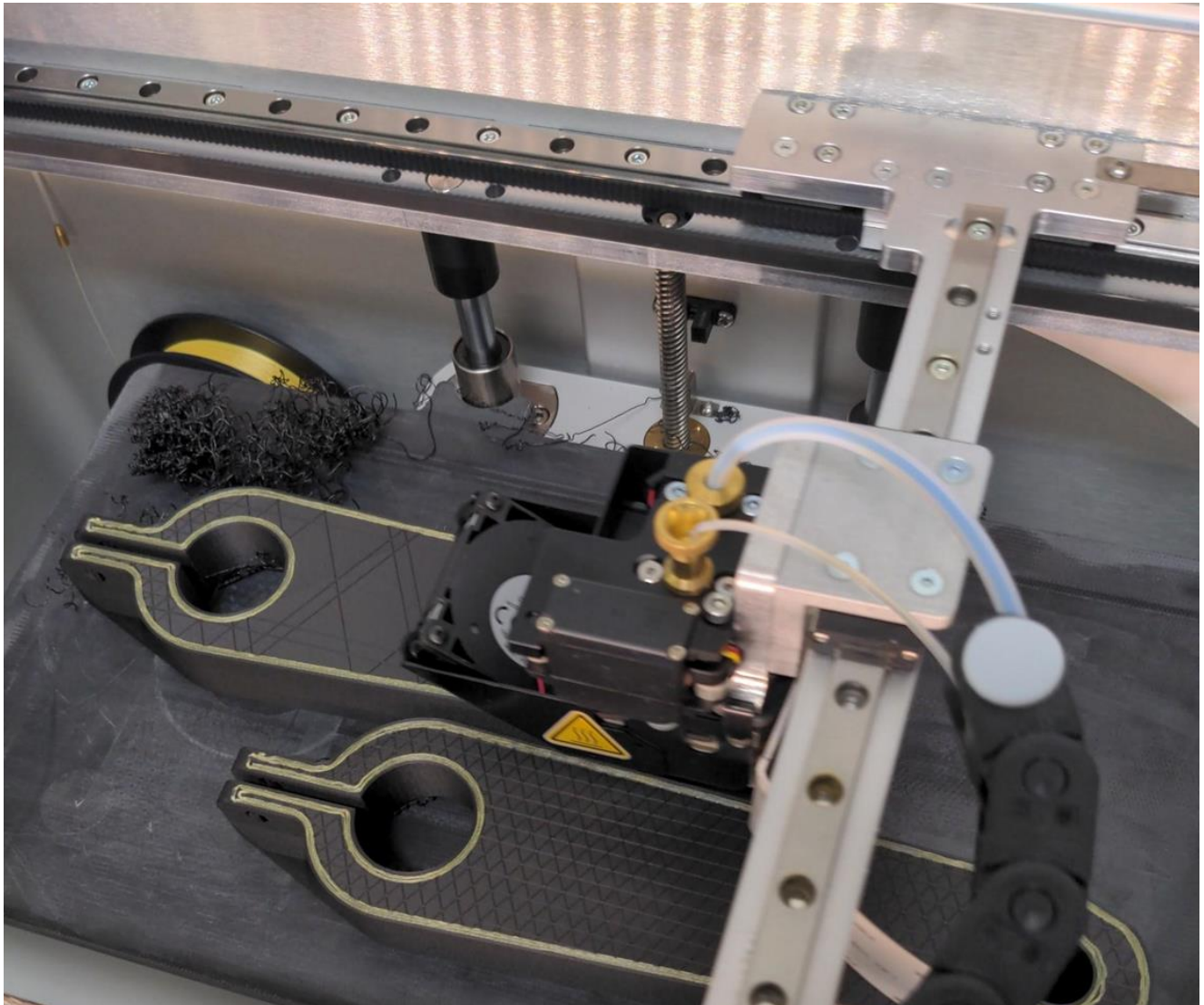

Steering.SLDPRT | Assembly 1
App Store
Assembly 1
2938T110_HIGH-LOAD
91259A712_ALLOY S
PowerDirector

Steering

Steering Linkages



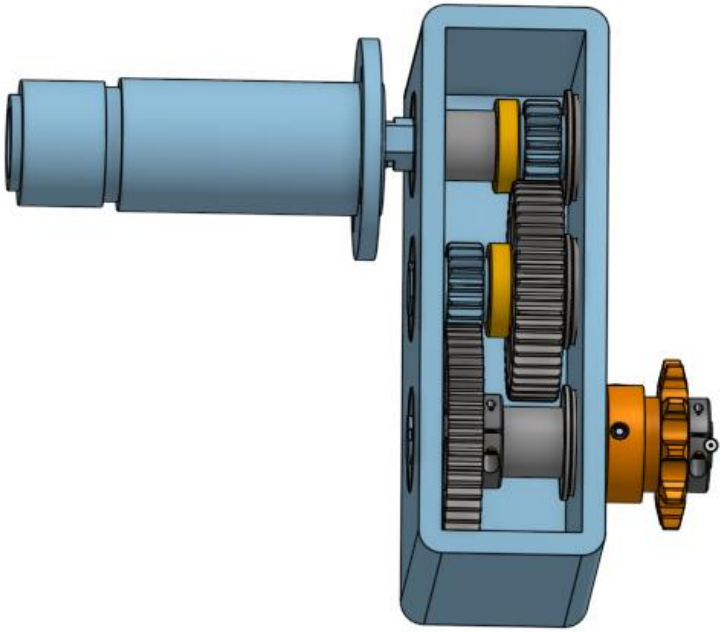
Steering Linkages

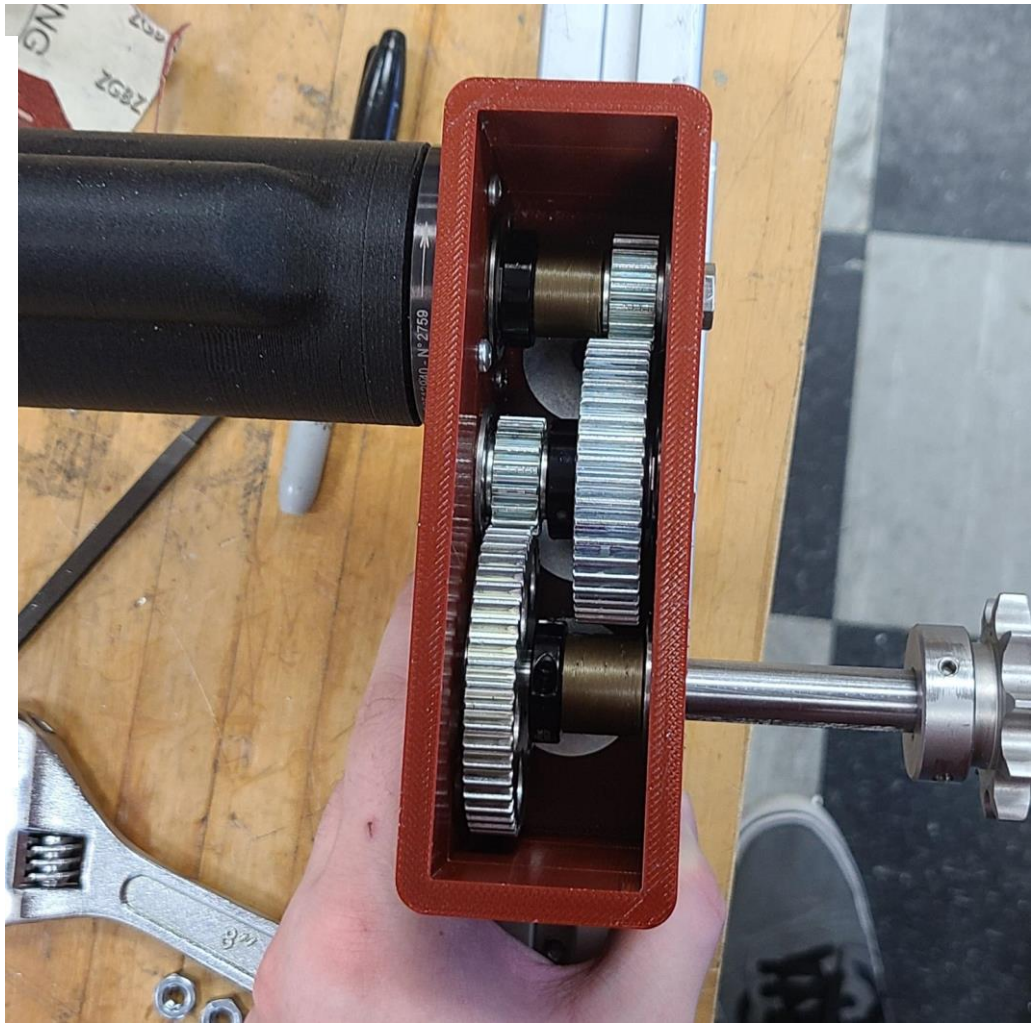


Gear Ratios

- We have 2 variable gear ratios and 1 static gear ratio
- Crank to pump gear ratio is 1:32
  - This is done so that we can get to higher RPMs with our micropump
  - This is also done to keep the gear ratio comparable to the regen circuit so that there is not a disparity in pressure

Input Gearbox



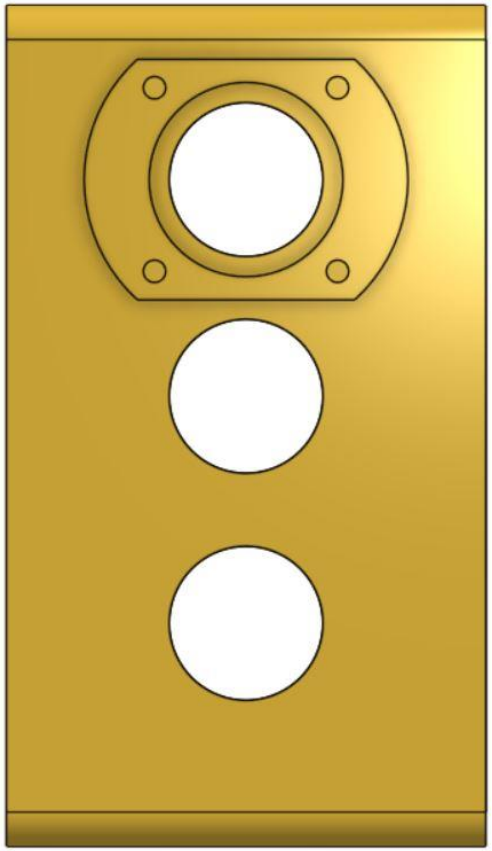


Input Gearbox

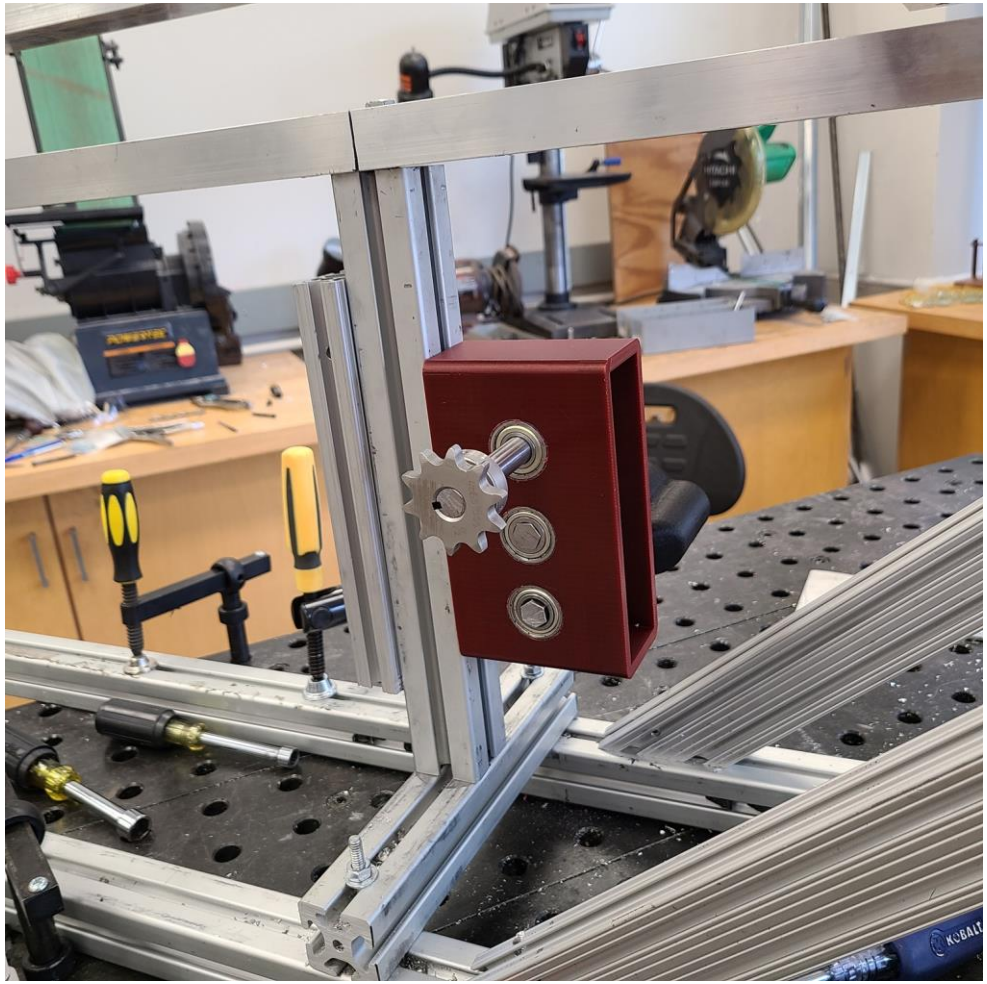
Printed successfully first time!

13-hour print at 80% infill (Afinia printer)

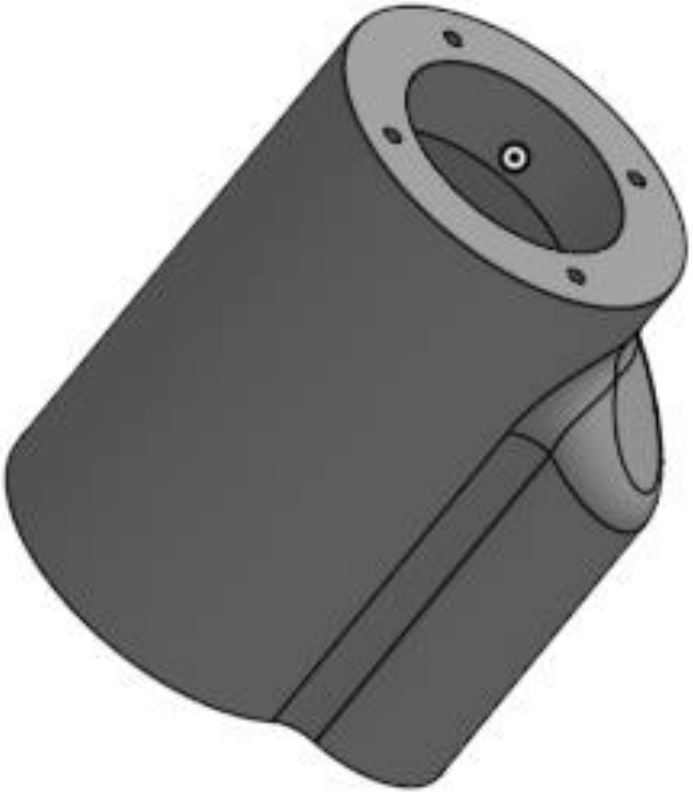
Protrusion for mounting pump housing



Mounting



Pump Housing



Pump Housing

Variable Gear Ratios

Human Power side

- We have decided to go with a cassette gear shift due to its versatility in terms of gearing options
- Minimum
  - 1:5 Gear Reduction
- Maximum
  - 1:1.1 Gear Reduction

Cassette Disk

2 Speed Gearbox

Regen Side

Minimum 1:4.78

Effective

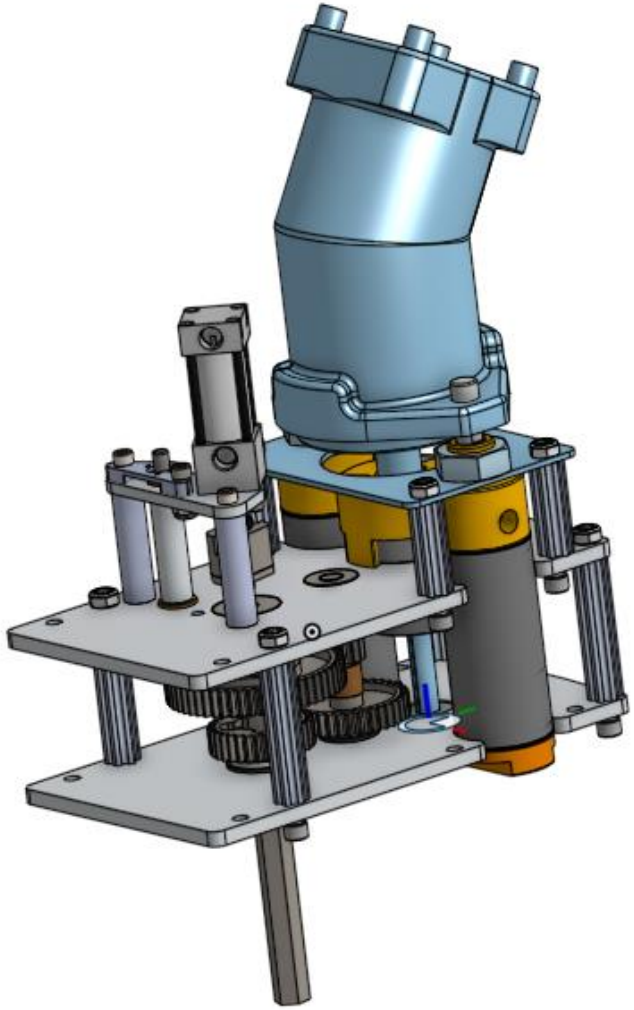
Maximum 10:1

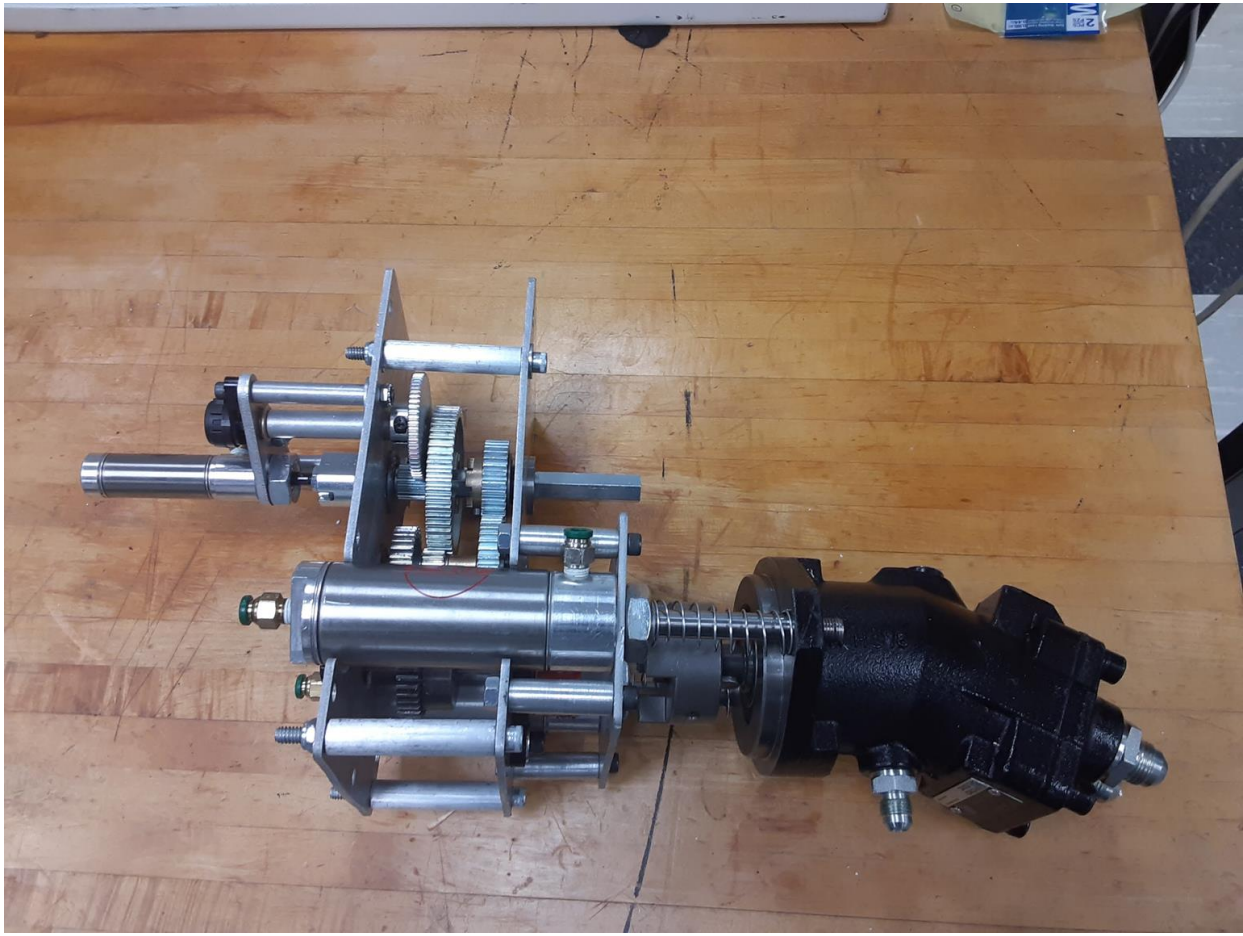
Desired Operation Speed

Pneumatics

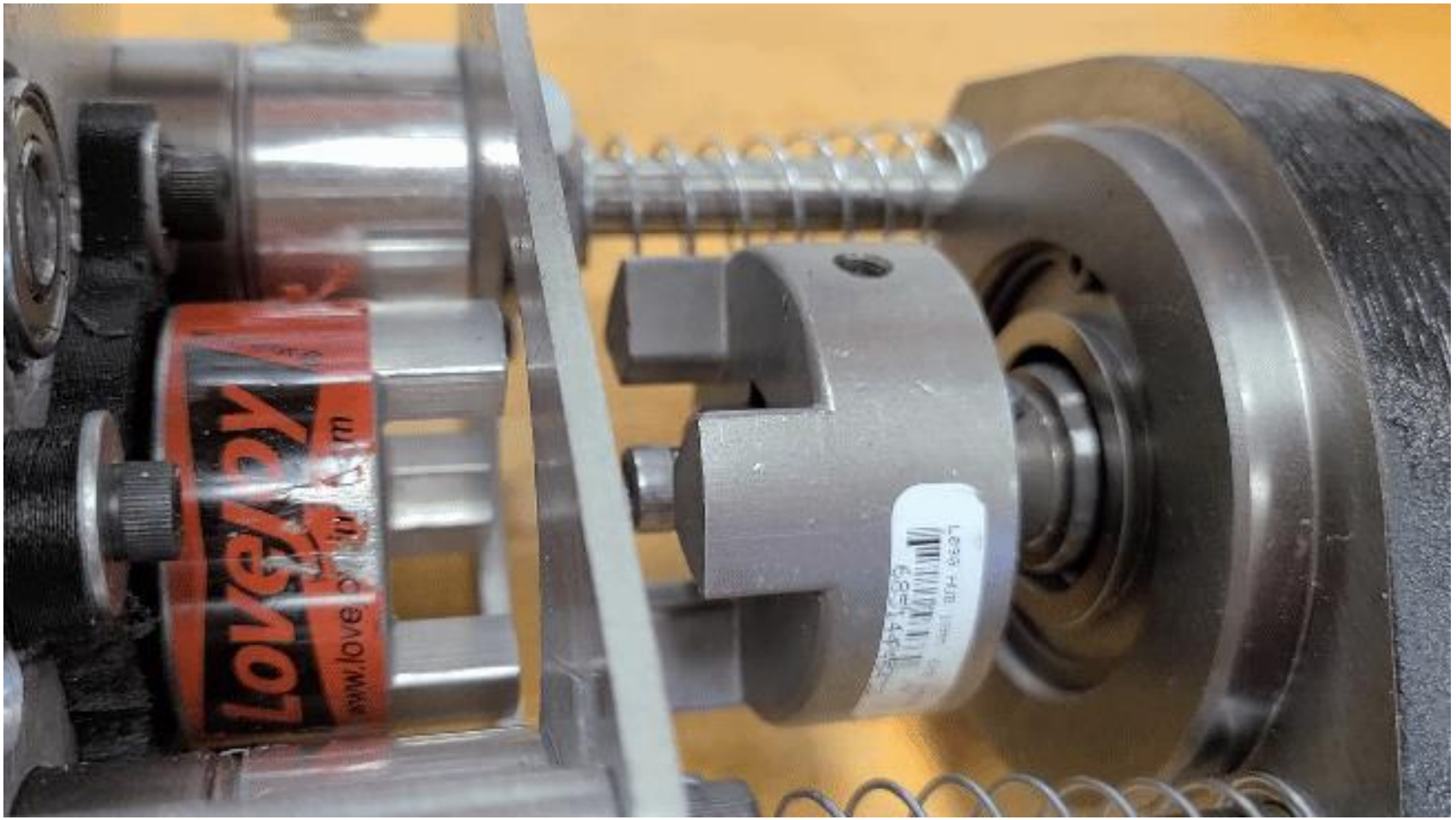
- A 2 speed gearing system that alternates between 2 gear ratios via pneumatic actuators
- The clutch is also be engaged/disengaged via pneumatic actuators

2 Speed Gearbox Design



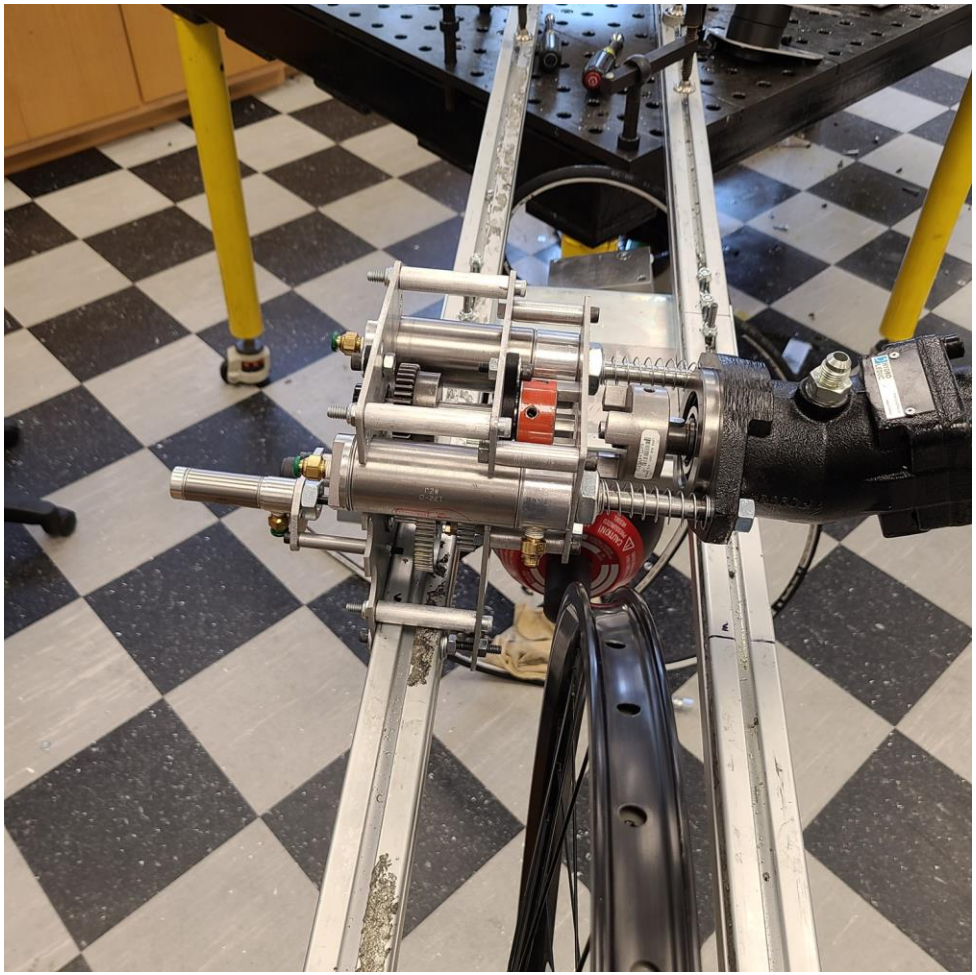


Pneumatic clutch

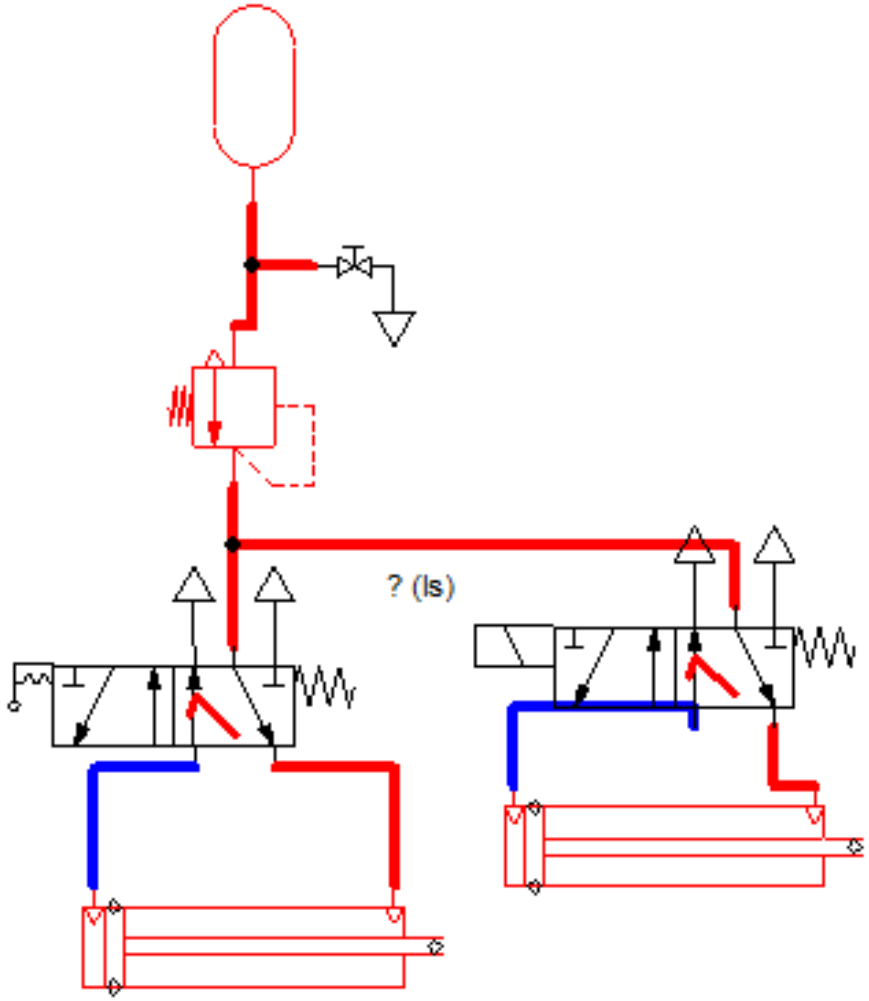


Pneumatic shifter

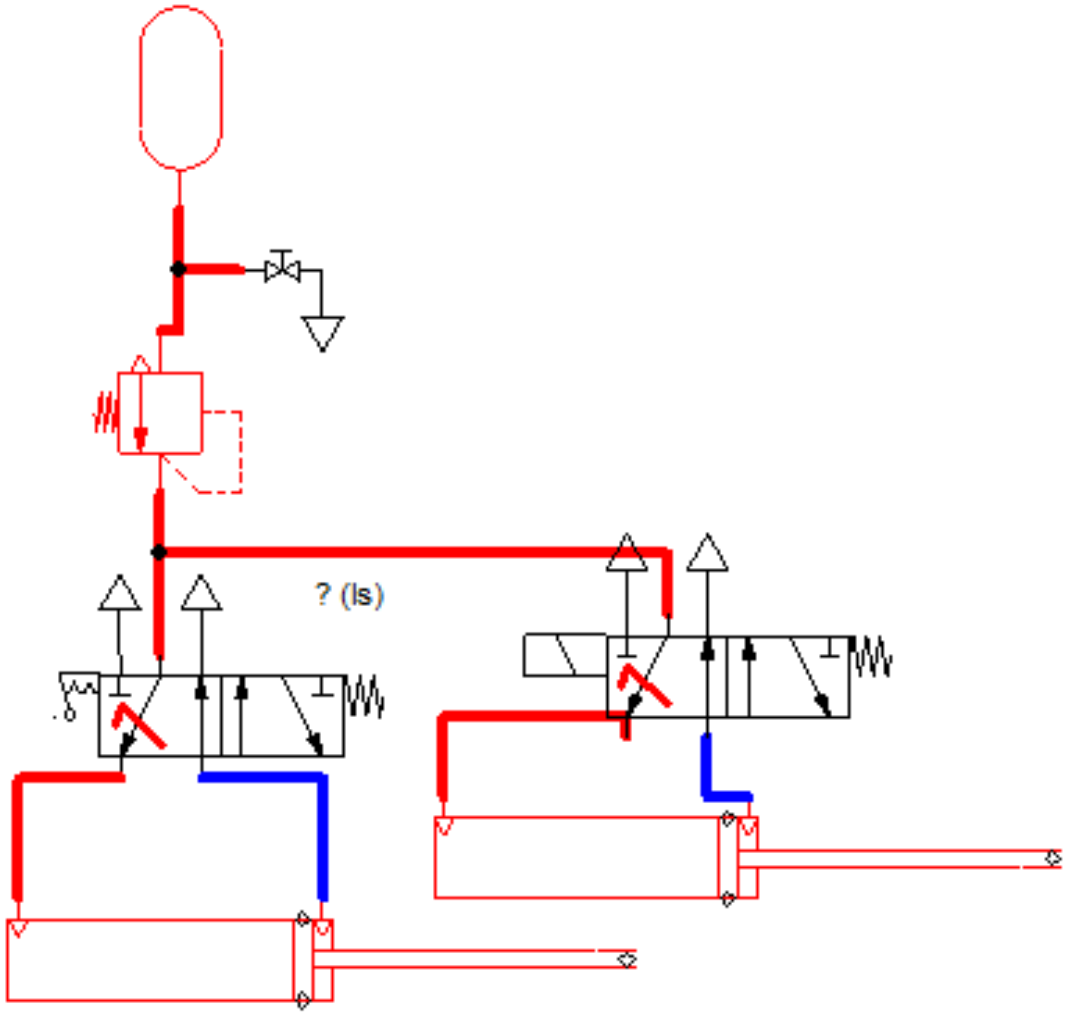
Gearbox Mounted



Pneumatic Schematic



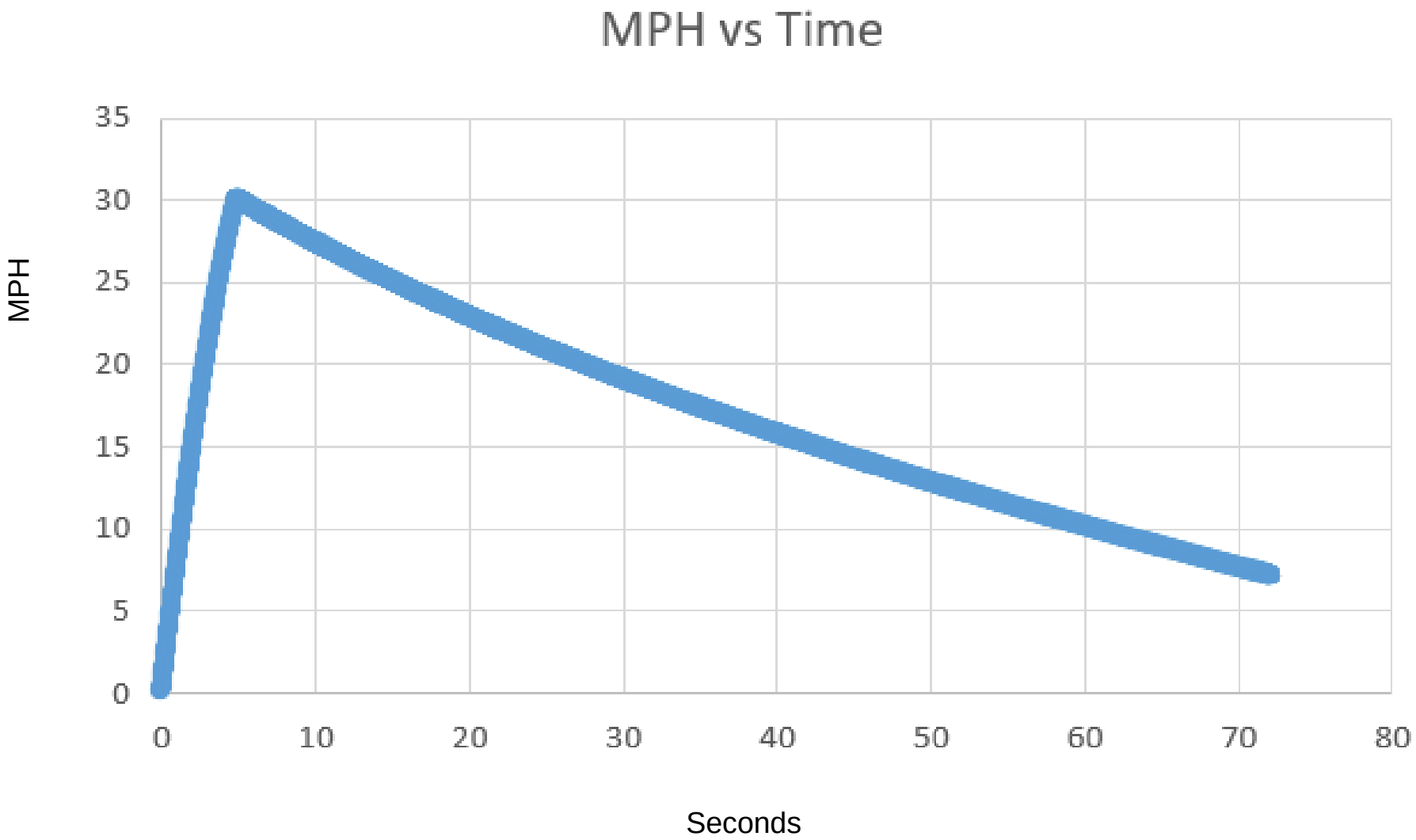
Pneumatic Schematic



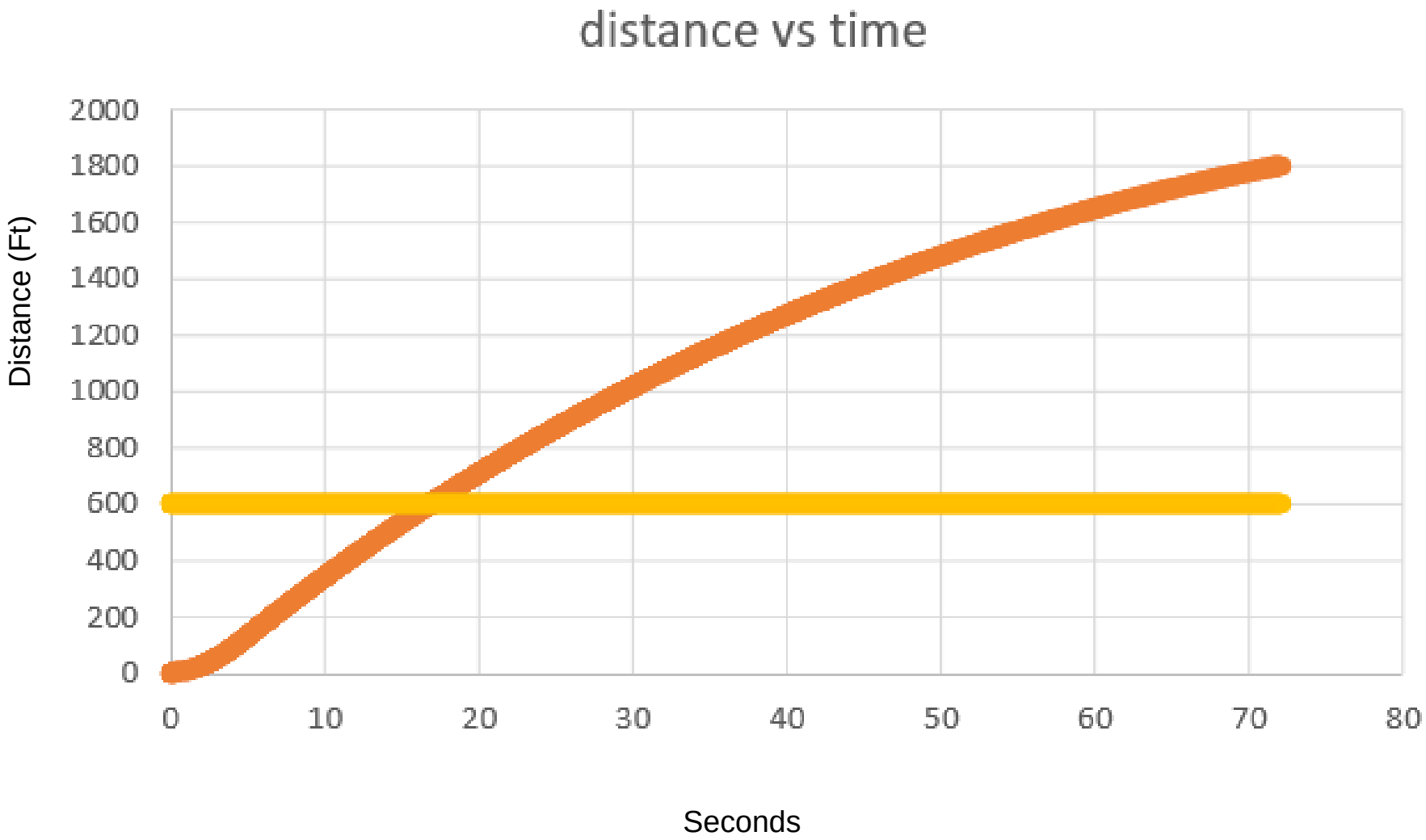
Projected Bike Specifications

Ideal Human Powered Speed: 13-15 mph
Projected Accumulator Speed : 29 mph
Bike Length: 6ft
Width: 3ft
Weight : 140 lbs

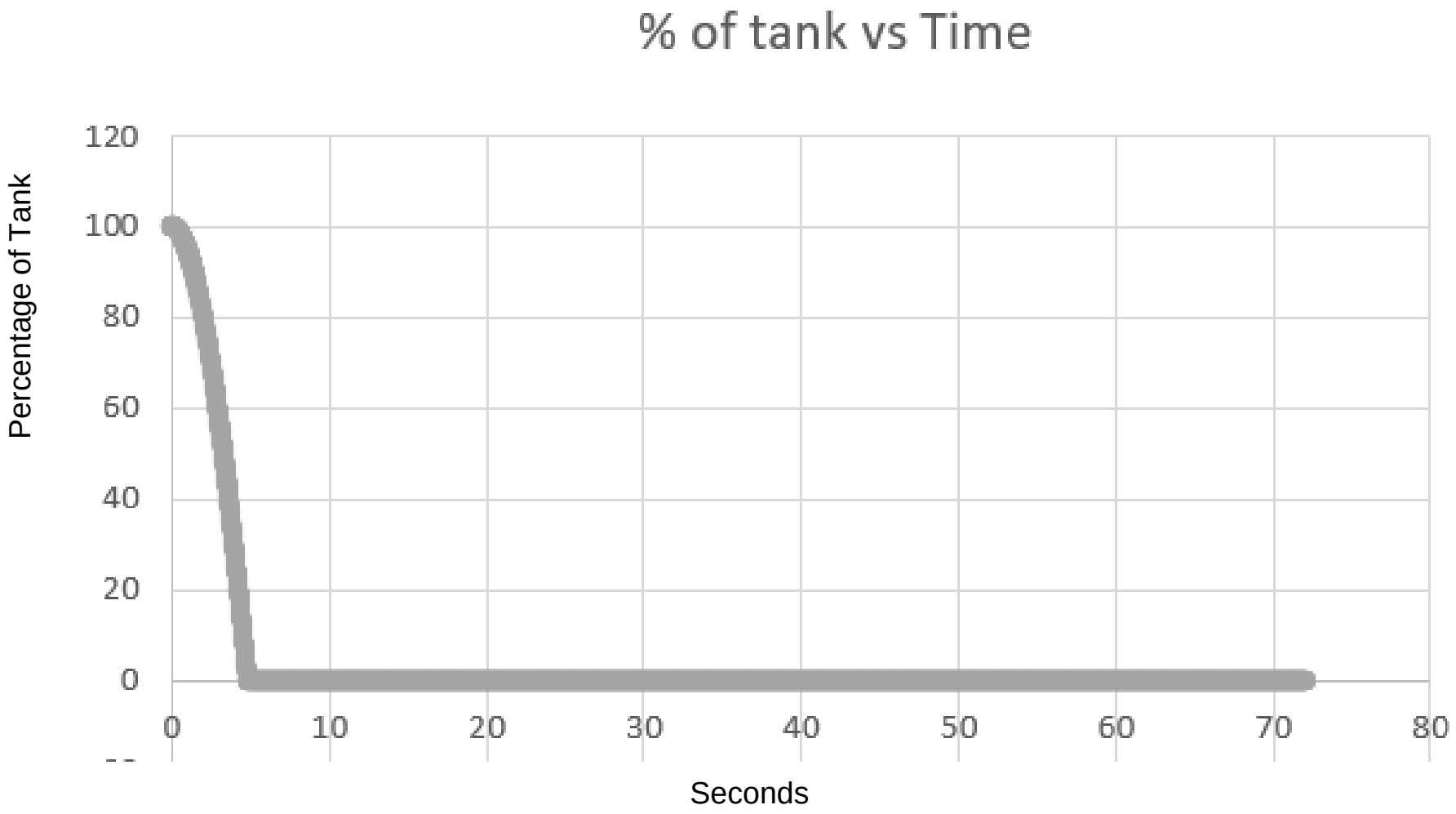
Theoretical Expectations



Theoretical Expectations



Theoretical Expectations



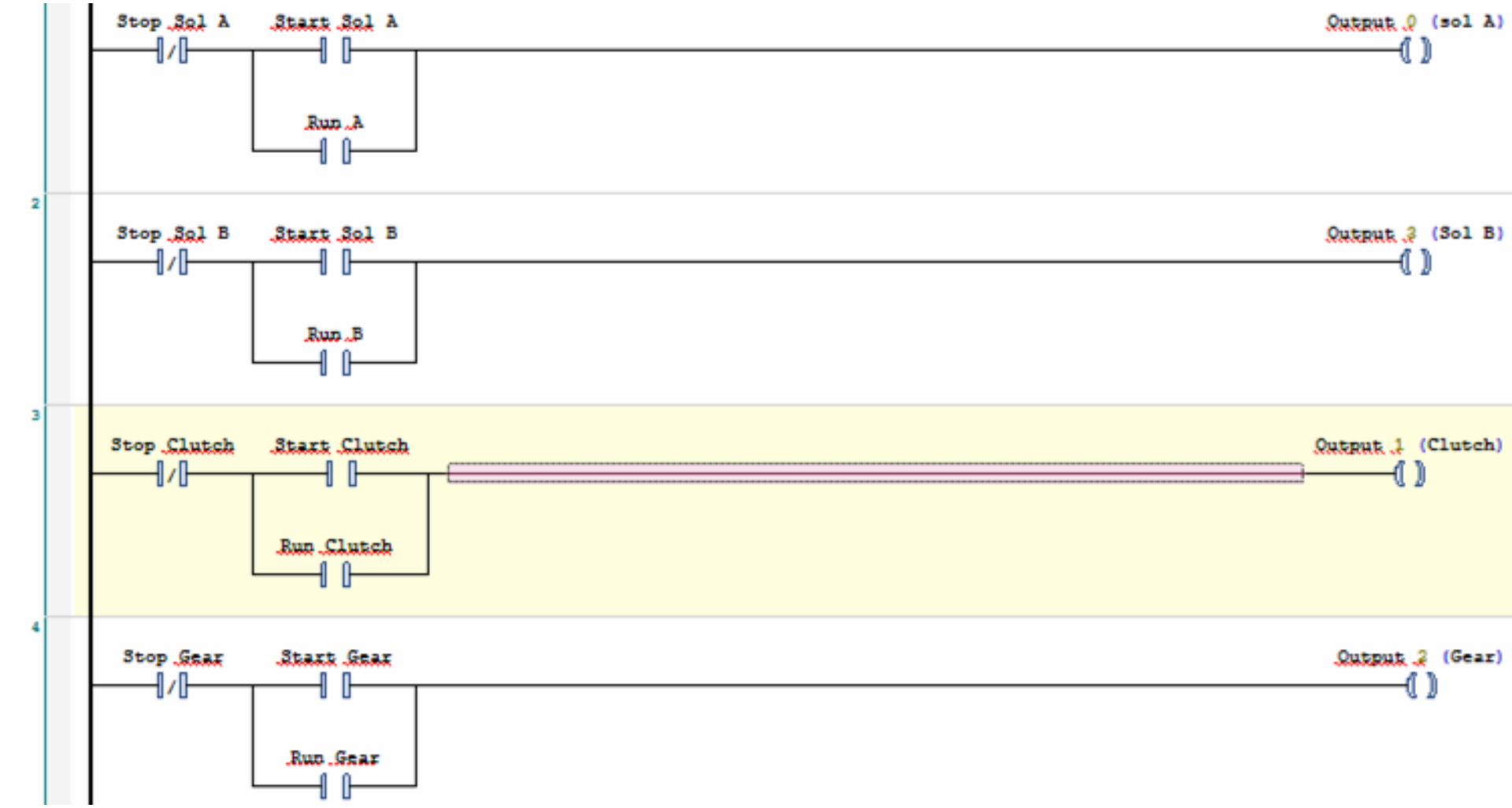
PLC Operations

- Operate the pneumatic clutch
- Operate the 2 speed gearbox
- Operate the directional control valve

Program Setup

- Button 1: Activate sol A, clutch, gear shifter
- Button 2: Activate Sol B
- Button 3: Reset/ E stop

Ladder Logic Program for PLC



PLC Program Extended

PLC Choice

- PLC Click
  - Software was available
  - Had volumes of resources used to assist in programming and layout

- 24V Power supply
  - Use battery bank
  - Batteries in series to add V

Challenges

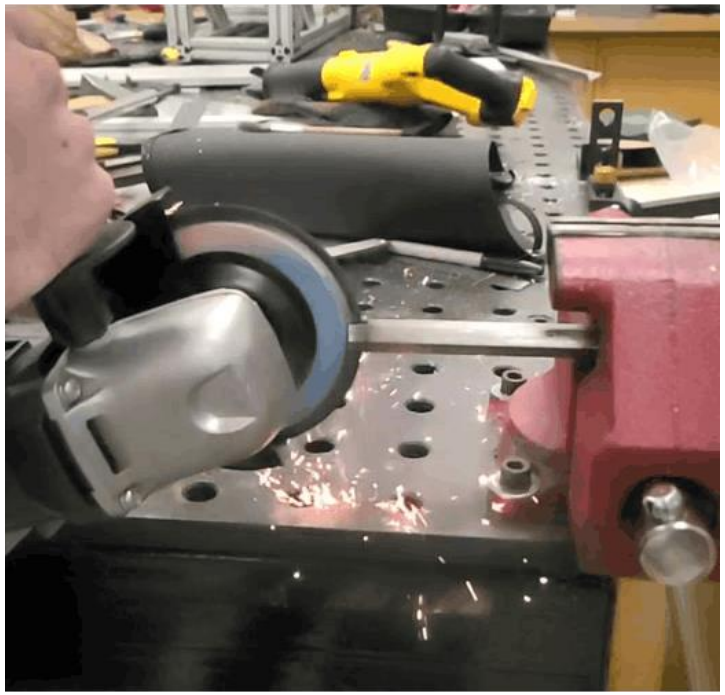
- Volunteers
  - Too few members
  - Not a lot of experienced members
  - Poor Communication
- Mechanical Components
  - Parts ordered too late
  - Focused too little on assembly
  - Not experienced with bicycle components
- Equipment Failure
- Pandemic/Covid-19 (shipping)

Learning as we go

- Efficient time management
  - Working when parts aren't physically available
- Maintaining healthy work schedule
- Supporting other team members
- Plan for different experience levels
- Teaching members while maintaining work efficiency

Practical Skills Learned

- Safe operation of equipment (i.e. drills, reciprocating saw (Sawzall), water jet cutter (WAZER), 3D-Printers, grinder)
- Equipment maintenance
- CAD Design (Onshape)
- Bicycle components
- Effective uses of different tools



Social/Teamwork Skills Learned

- Prioritization and delegation of tasks
- Learning to effectively teach each other
- Seeking collaboration
- Concise and effective communication

Machines/Software Used

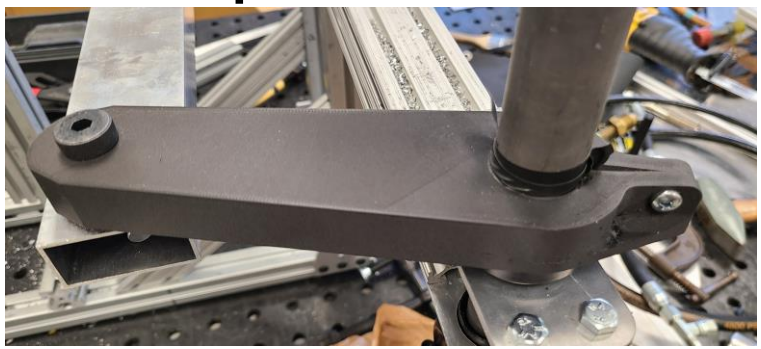
- WAZER Water Jet Cutter
- Automation Studio
- Onshape
- Afinia 3D Printer
- Markforged 3D Printer
- Basic metal working
- General hand tools
- Excel

Water Jet Cutter (WAZER)

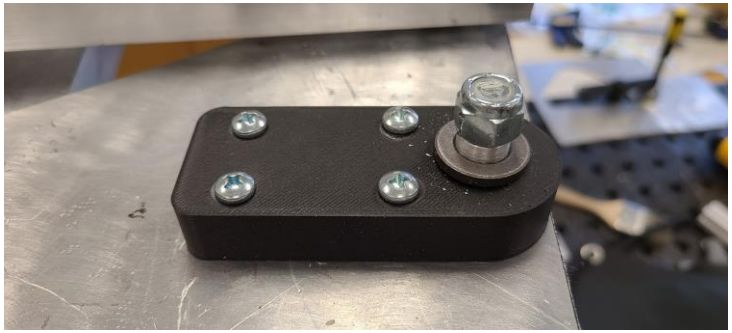
- Setup
  - Proper set up procedures
  - Proper setup of the .dxf files
  - Correctly securing material to cut bed
- Running
  - Looking for cut errors / General supervision
- Maintenance
  - Diagnosing issues
  - Fixing issues
  - Preventing further issues

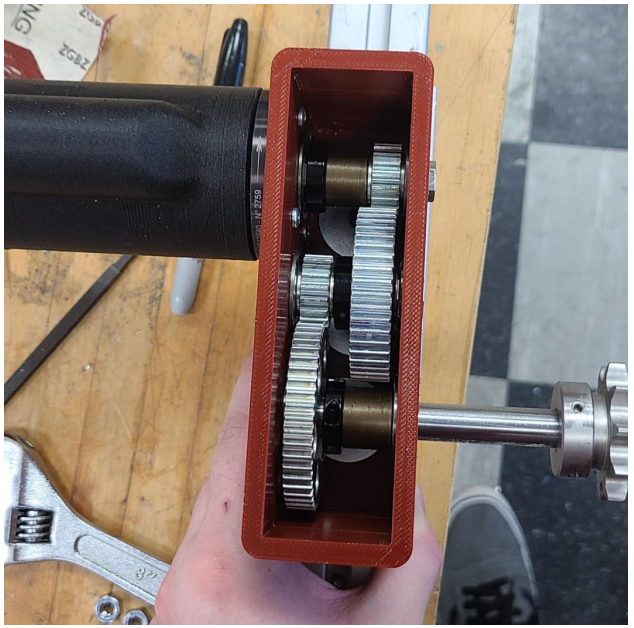
Additive Manufacturing (3D-Printing/Modeling)

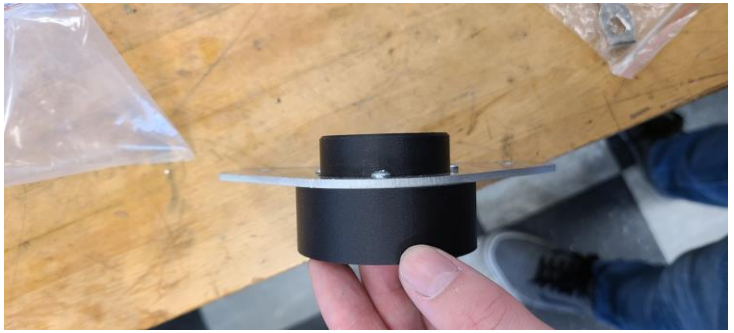
- Using Onshape
- Modeling bike parts to fit a custom bike
- Assembling parts to simulate functions
- Operating 3D printers to create 3D modeled parts with PLA, Kevlar, Carbon Fiber, Polycarbonate,and Nylon
- Altering 3D printed parts to operate with bike



Parts we designed and manufactured







Communication / Team Management

- Weekly Meetings
  - Task delegation
  - Group problem solving
  - Checkups
- Individual Meetings
  - Work 1:1 with team advisor
  - Prevented further collaboration
- Communication
  - Email
  - Text

What could be done differently

- Create CAD of the entire bike first
- Deadline for delegated tasks
- Avoid over reliance on machines (WAZAR)
- Minimize custom fabrication (almost impossible)
- Better Organization and structure
- More recruitment

What we will continue working on

- Electronics
  - Flesh out and wire PLC
- Mounting
  - Mount Motors
  - Fully mount manifold/hydraulics
  - Set up power input
- Steering
  - Add Handlebar
  - Attach wheels to steering hook
  - Finish manufacturing plates
- ***Make it race worthy!***

NFPA Fluid Power Vehicle Challenge

Thank you for your time!