



FAMU-FSU
College of
Engineering

Team 501

Tribometer in Spacelike Conditions

Engineering Design Day 240404



Team Introductions



Branham Channell
Materials Engineer



Cobi Johnson
Systems Engineer



Madison Retherford
Mechatronics Engineer



Javier Ibanez
Structural Engineer



Joshua Wesley
Computer Hardware Engineer



Sponsor and Advisor



Dr. Brandon Krick



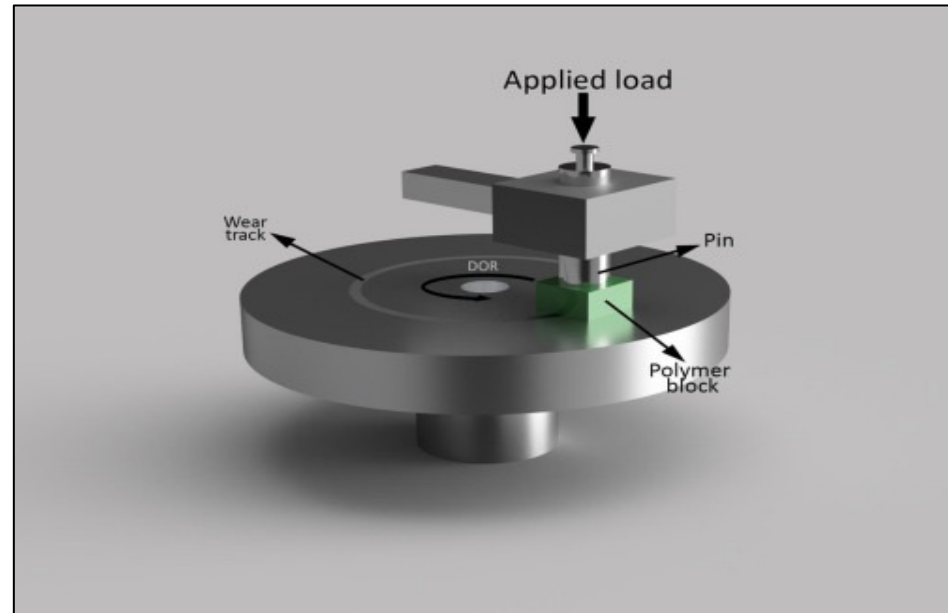
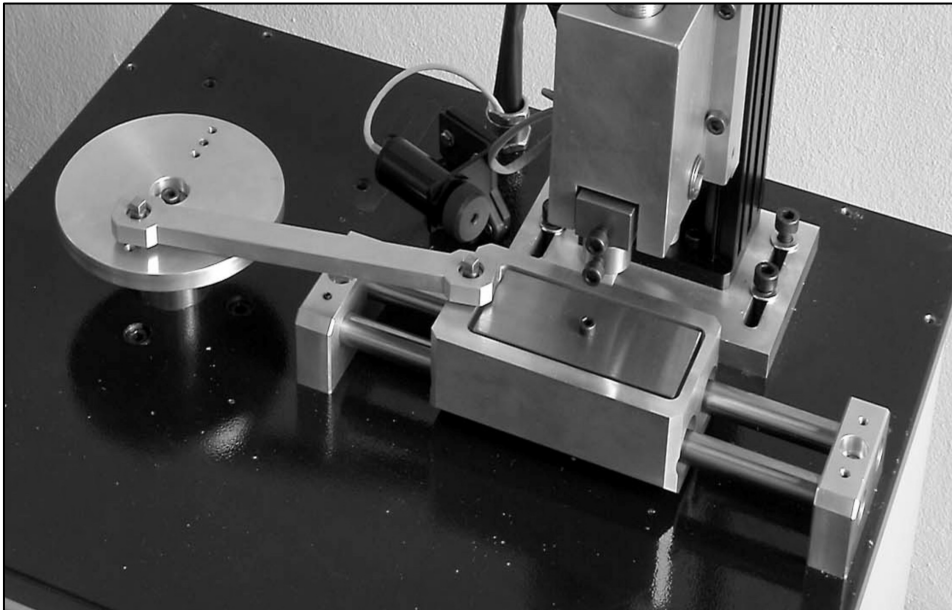
Objective

The objective of this project is to design, develop, and implement a system that enables the simultaneous testing of multiple samples within a vacuum chamber using a tribometer. This system aims to increase testing throughput and enhance overall efficiency while maintaining prior accuracy and control.



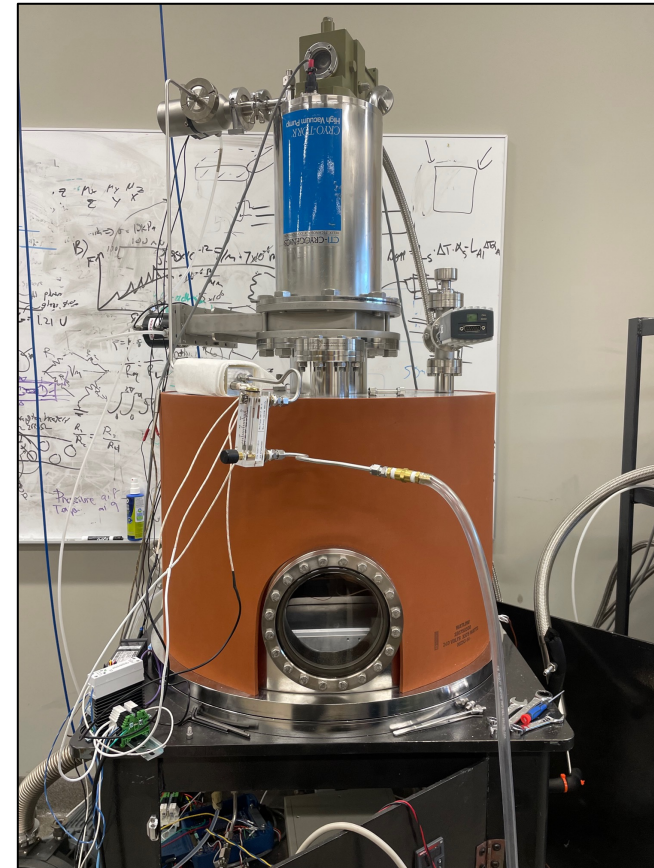
What is a Tribometer?

Tribometers measure quantities such as coefficient of friction, friction force, and wear volume on two surfaces in contact by simulating friction in controlled conditions.



AME's Vacuum Chamber

- Developed to be compatible with the tribology lab's bell-style high-vacuum chamber.
- It can reach pressures as low as 1.5×10^{-6} mbar.
- It takes approximately 12 hours to reach high vacuum.

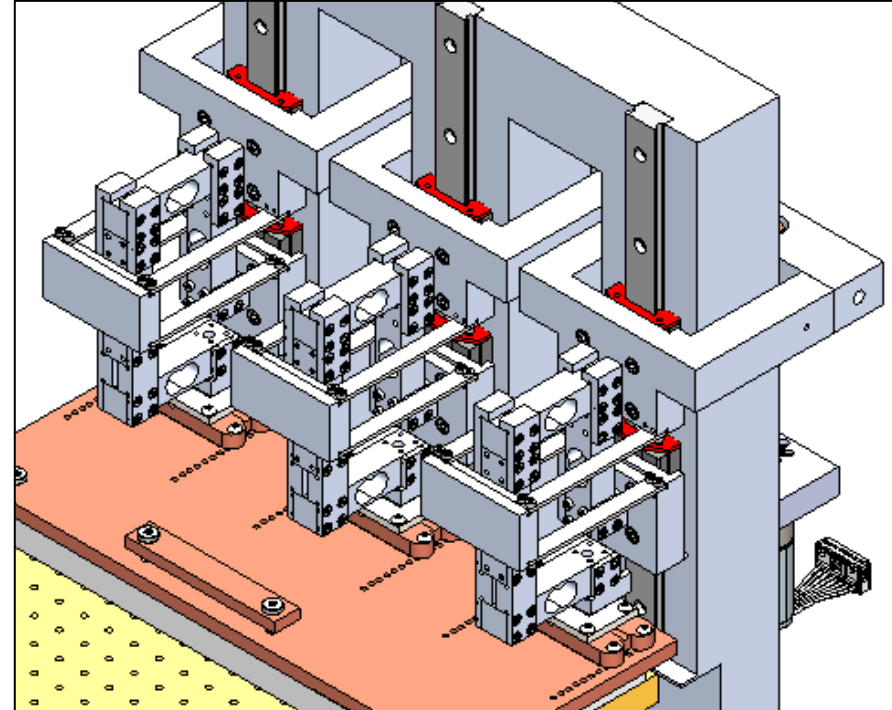


Key Goals

Test multiple samples

Control parameters

Operate in spacelike conditions



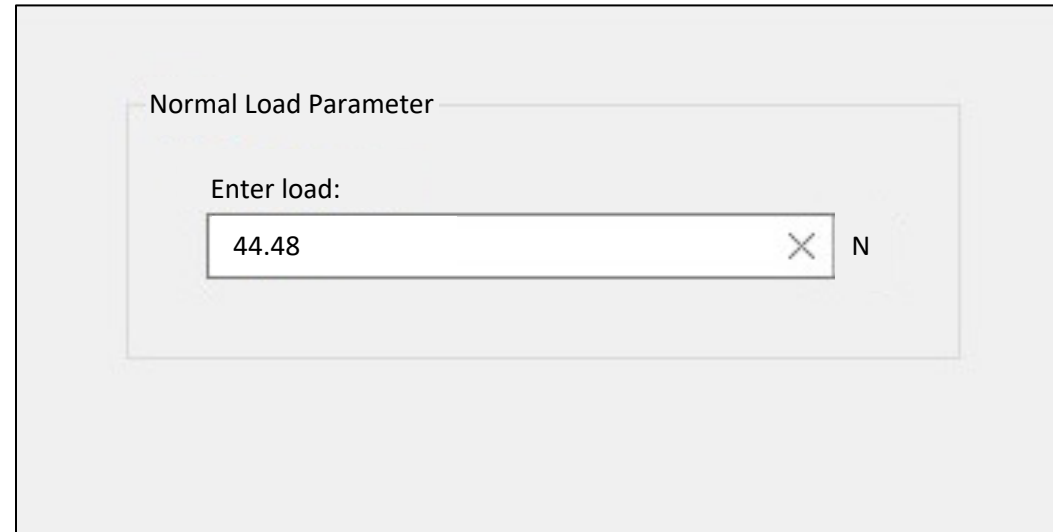
Key Goals

Test multiple samples

Control parameters:

- -200C to 200C
- Max 100 N normal load

Operate in spacelike conditions



Normal Load Parameter

Enter load:

44.48 X N

The screenshot shows a software window titled "Normal Load Parameter". Inside the window, there is a label "Enter load:" followed by a text input field containing the value "44.48". To the right of the input field is a small "X" icon and the unit "N".

Key Goals

Test multiple samples

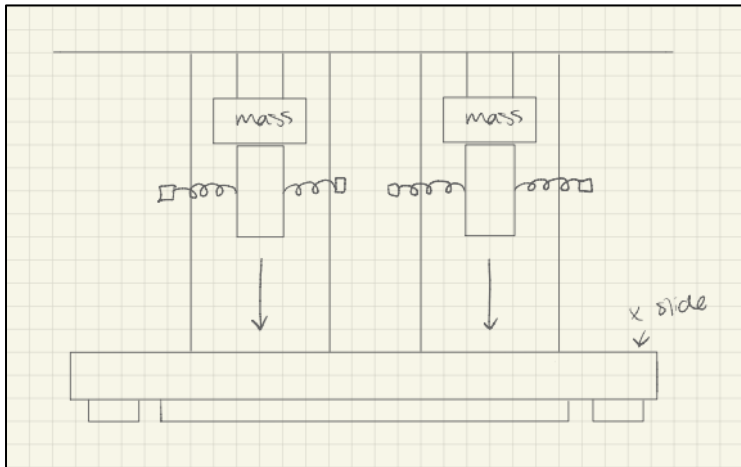
Control parameters

Operate in spacelike conditions



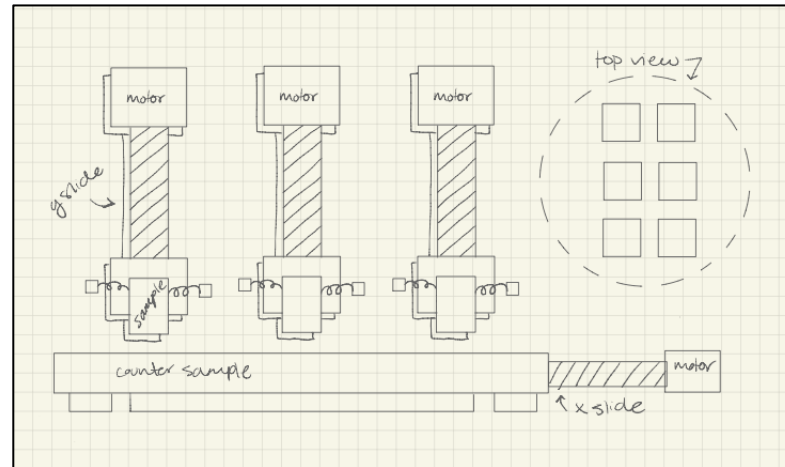
Concept Selection

Rank 1



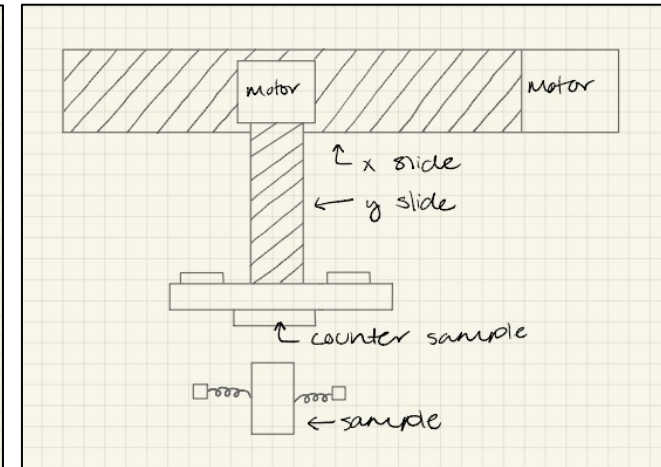
Weights to control normal load

Rank 2



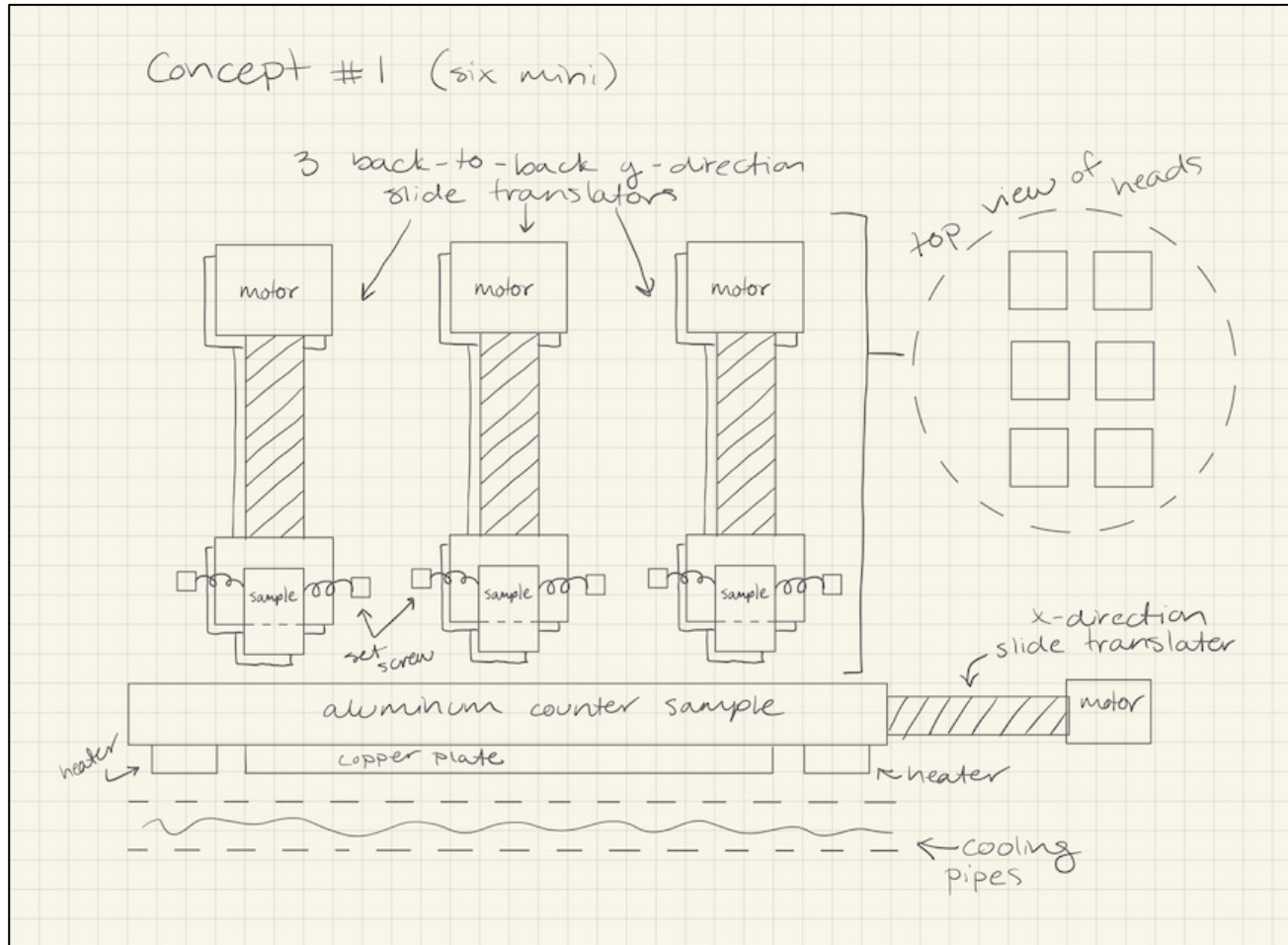
6 mini tribometers

Rank 3



Inverted tribometer

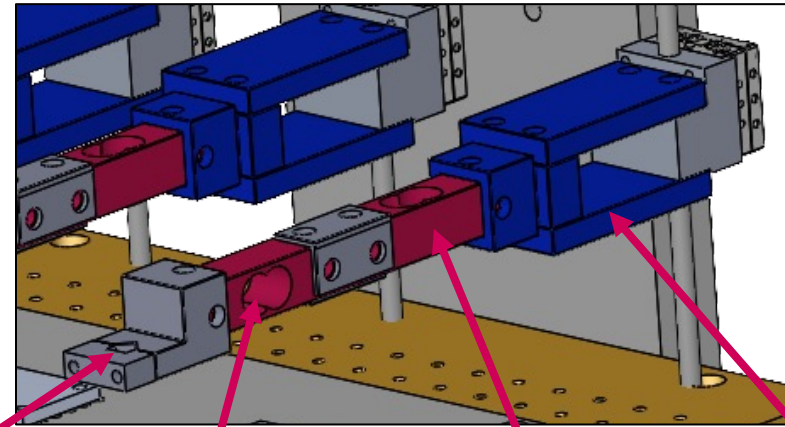
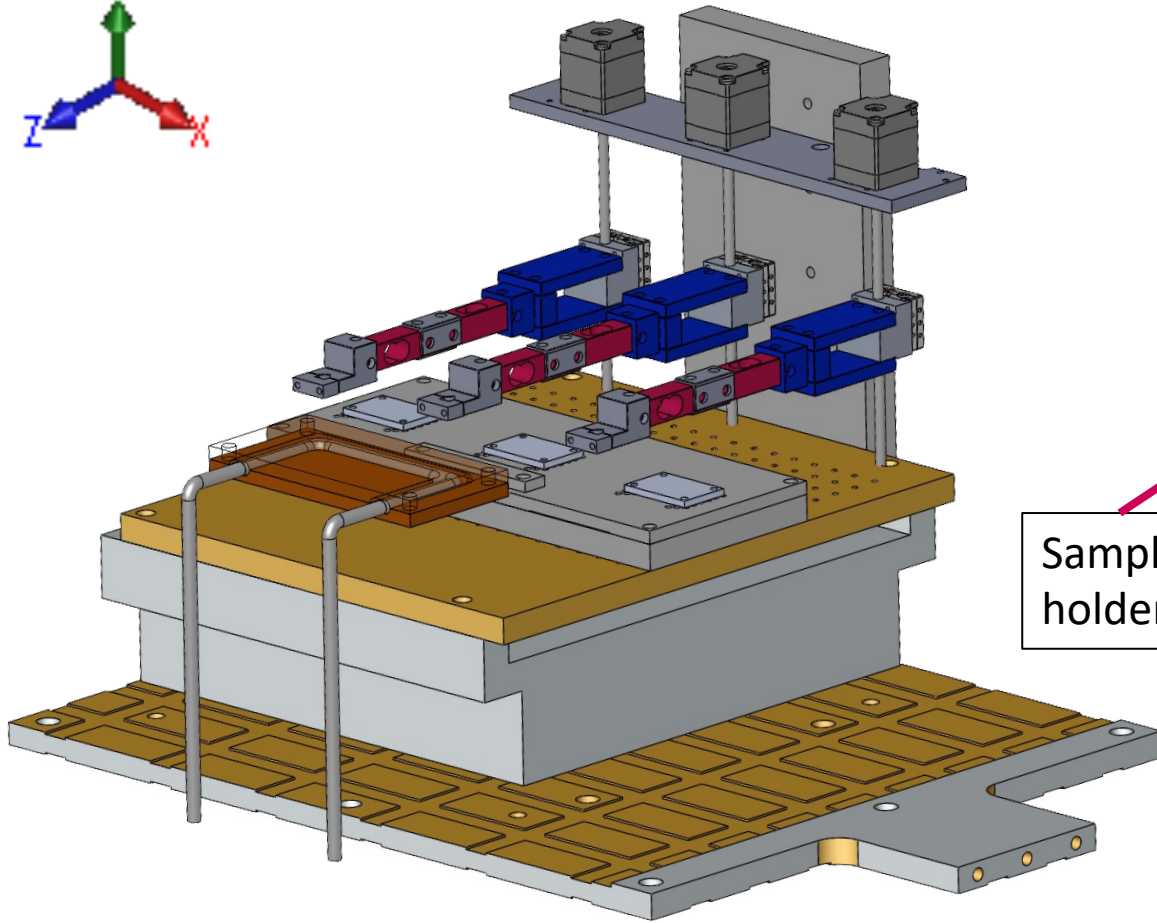
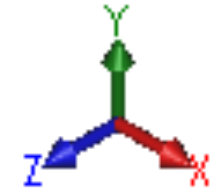
Final Concept



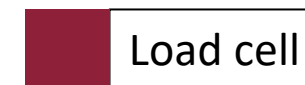
6 mini-identical tribometers.

CAD Design: Iteration 1

Large moment in the z-direction.

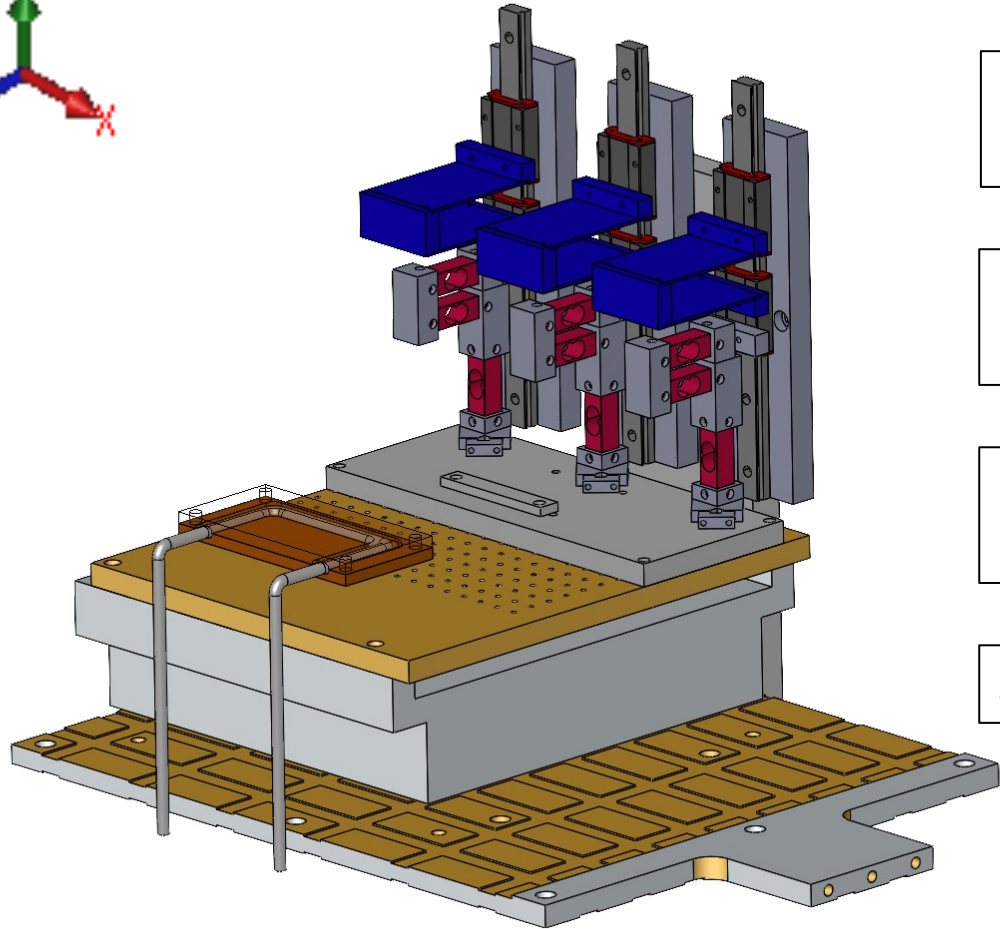
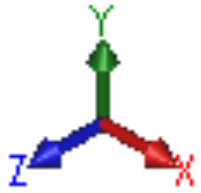


- Sample holder
- Normal force load cell
- Friction force load cell
- Leaf spring assembly



CAD Design: Iteration 2

Large moment in the y-direction.

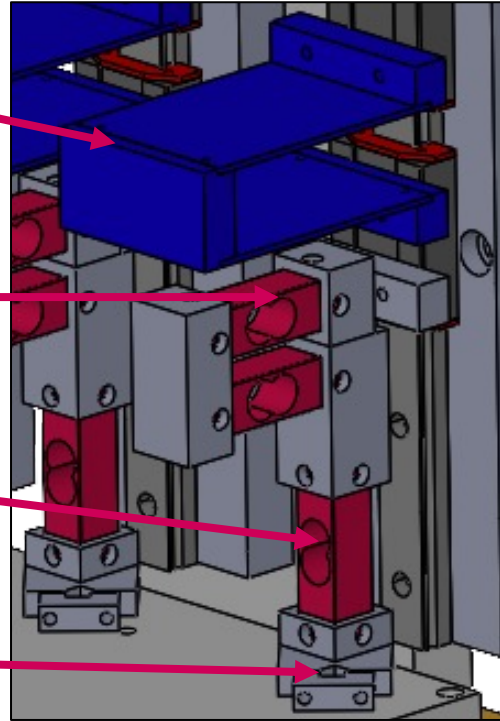


Leaf spring assembly

Normal force load cell

Friction force load cell

Sample holder



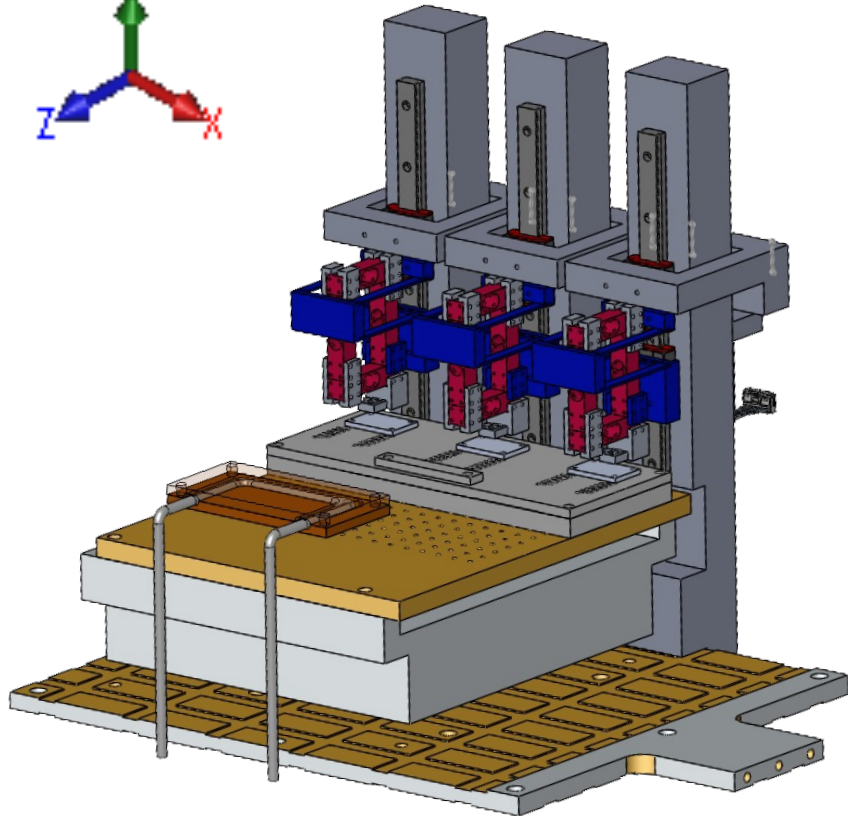
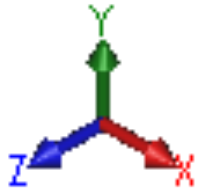
Load cell

Leaf spring



CAD Design: Iteration 3

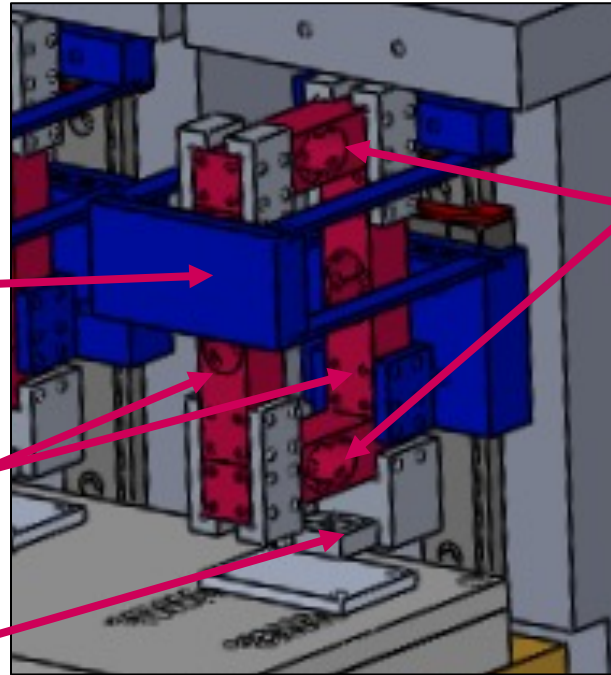
Load head needed revision.



Leaf spring assembly

Friction force

Sample holder



Normal force

Load cell

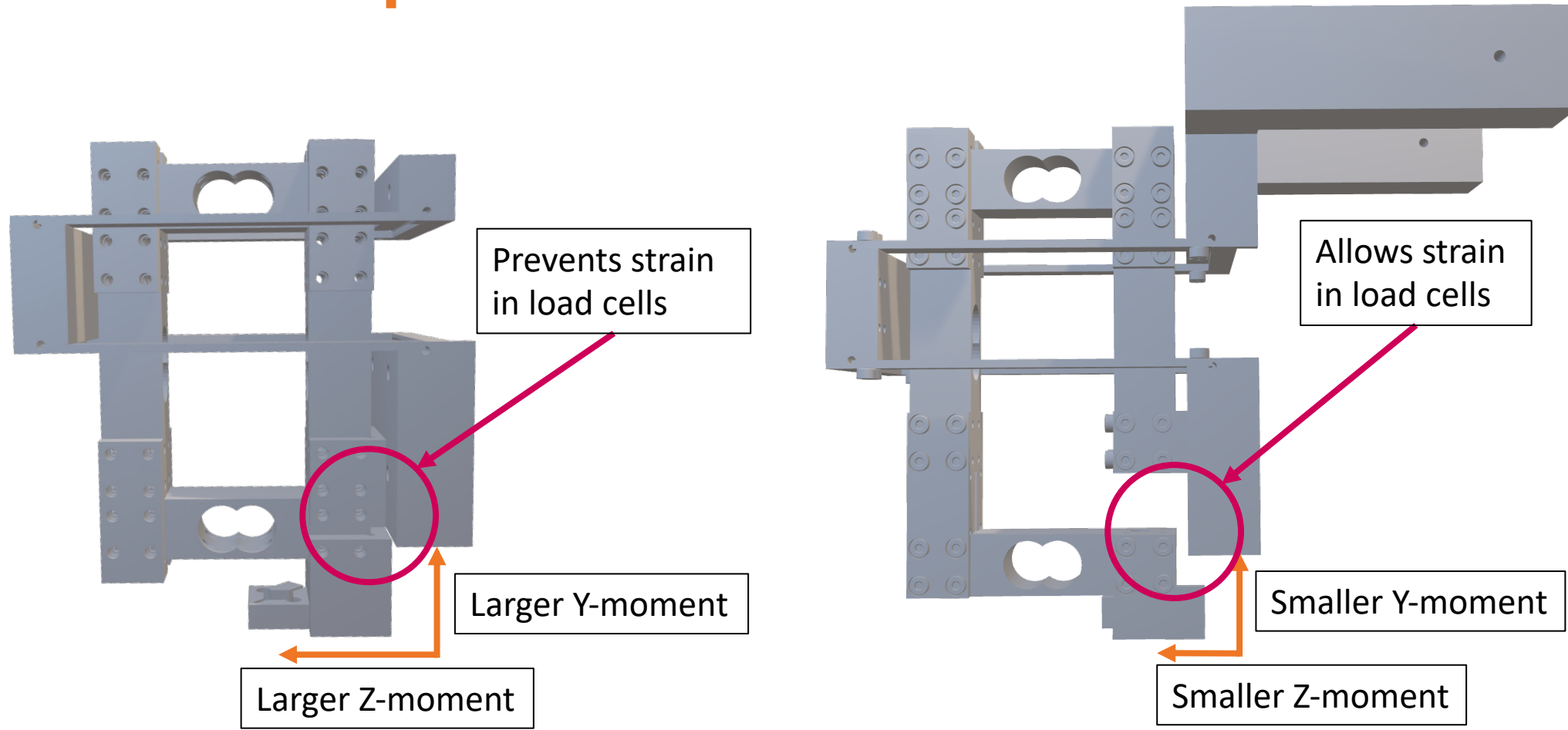
Leaf spring



Load Head Revision

Disconnected the bottom load cell.

Inverted sample holder.



Final Design: Iteration 4



Y slider

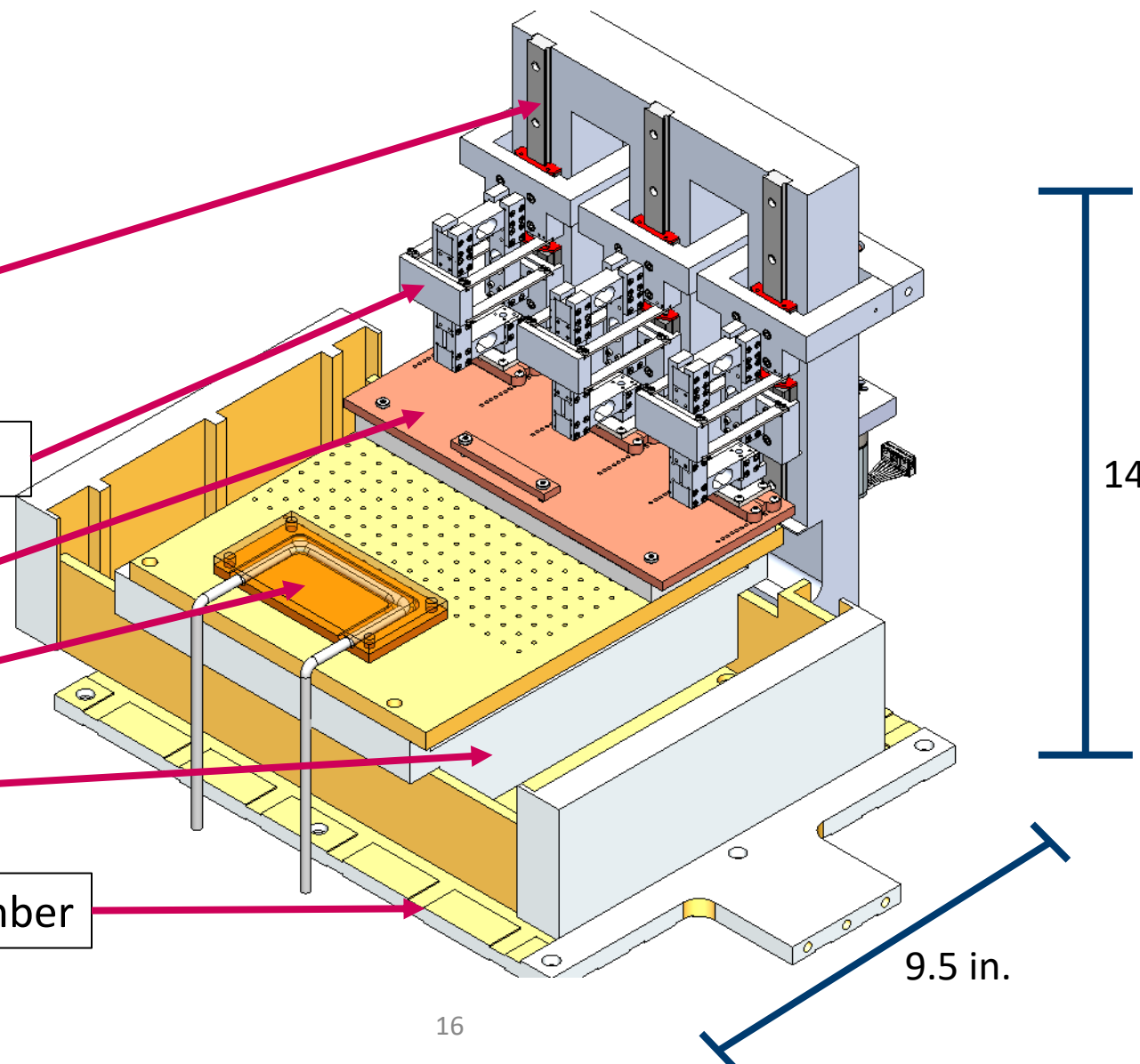
Load head assembly

Thermal assembly

Cooling system

X slider

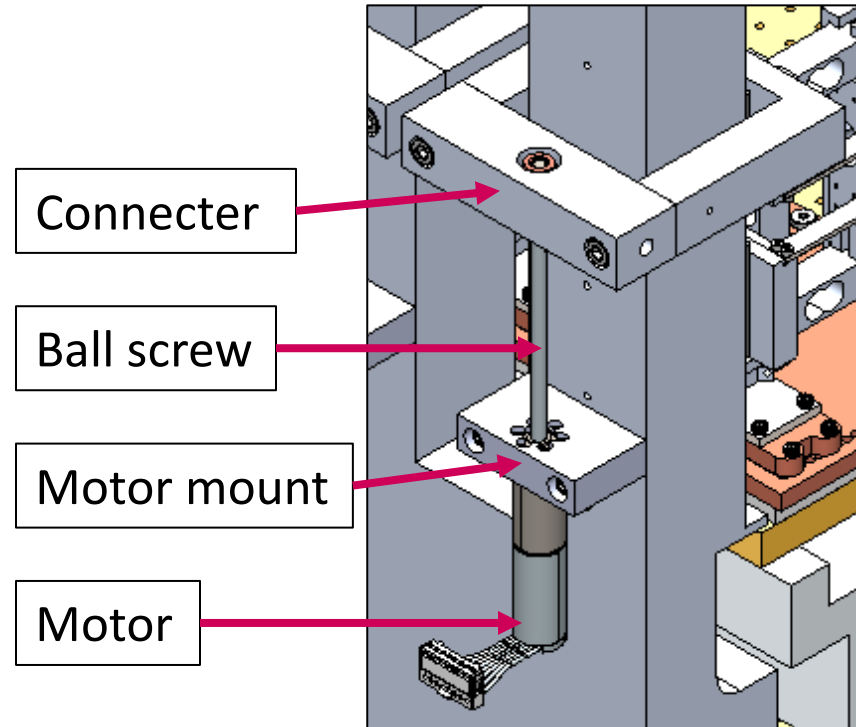
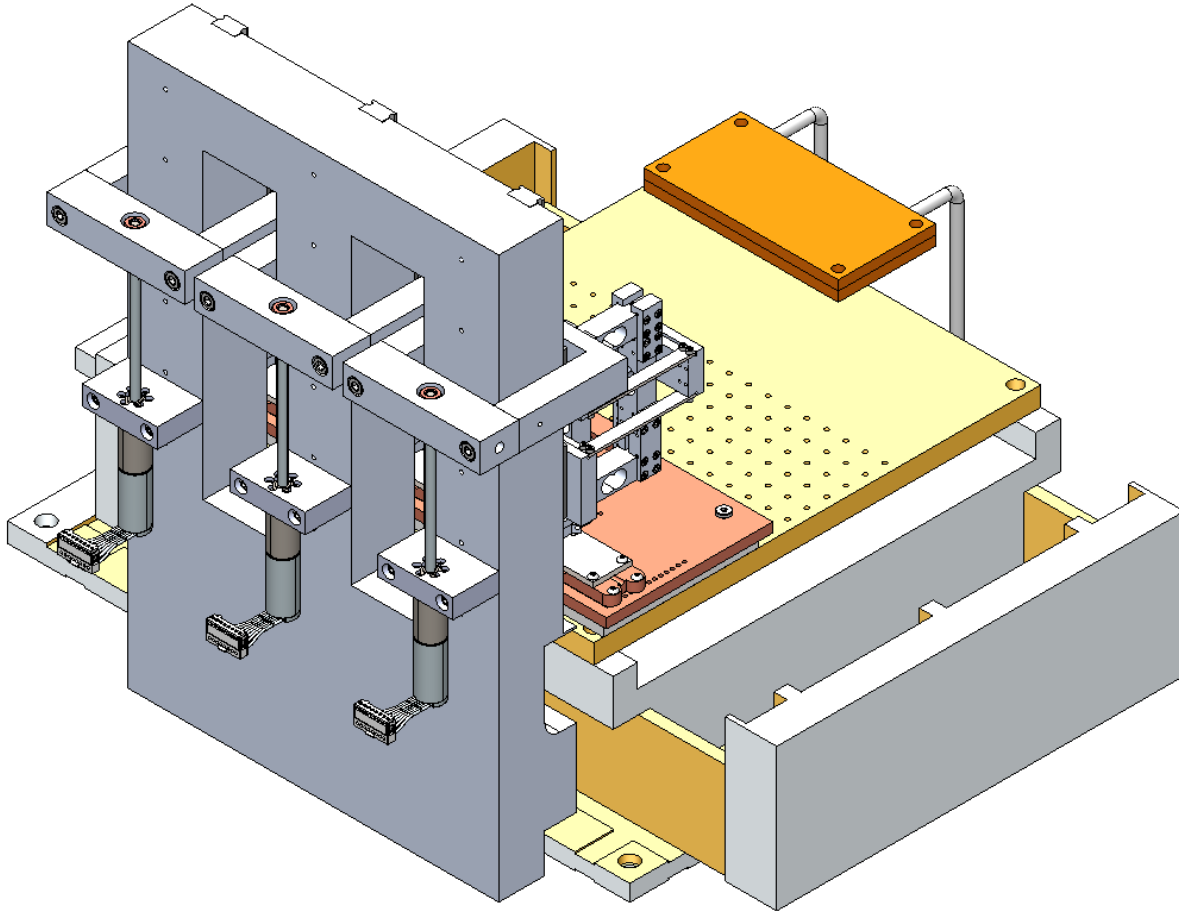
Base in vacuum chamber



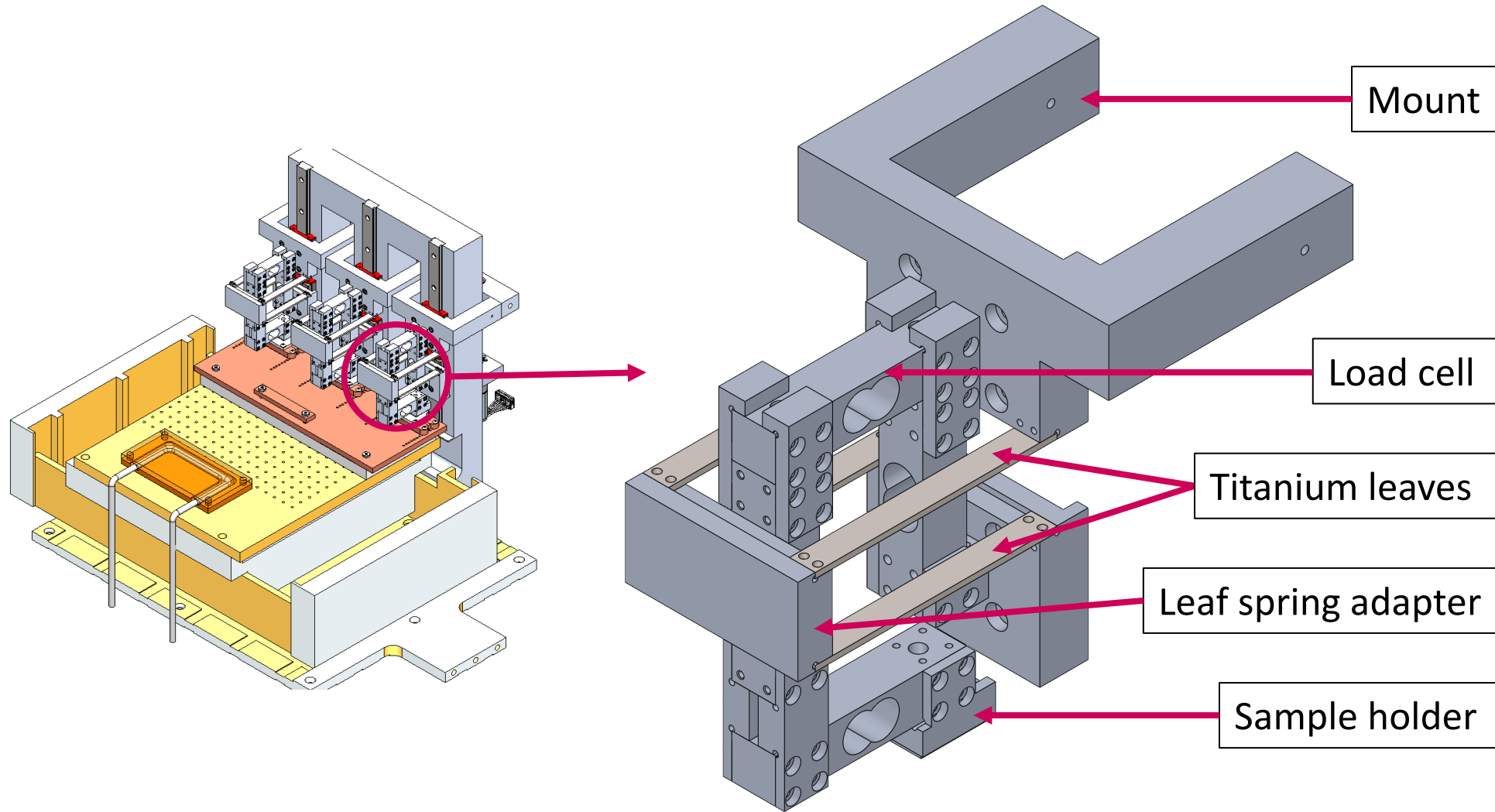
14.5 in.

9.5 in.

Final Design: Iteration 4

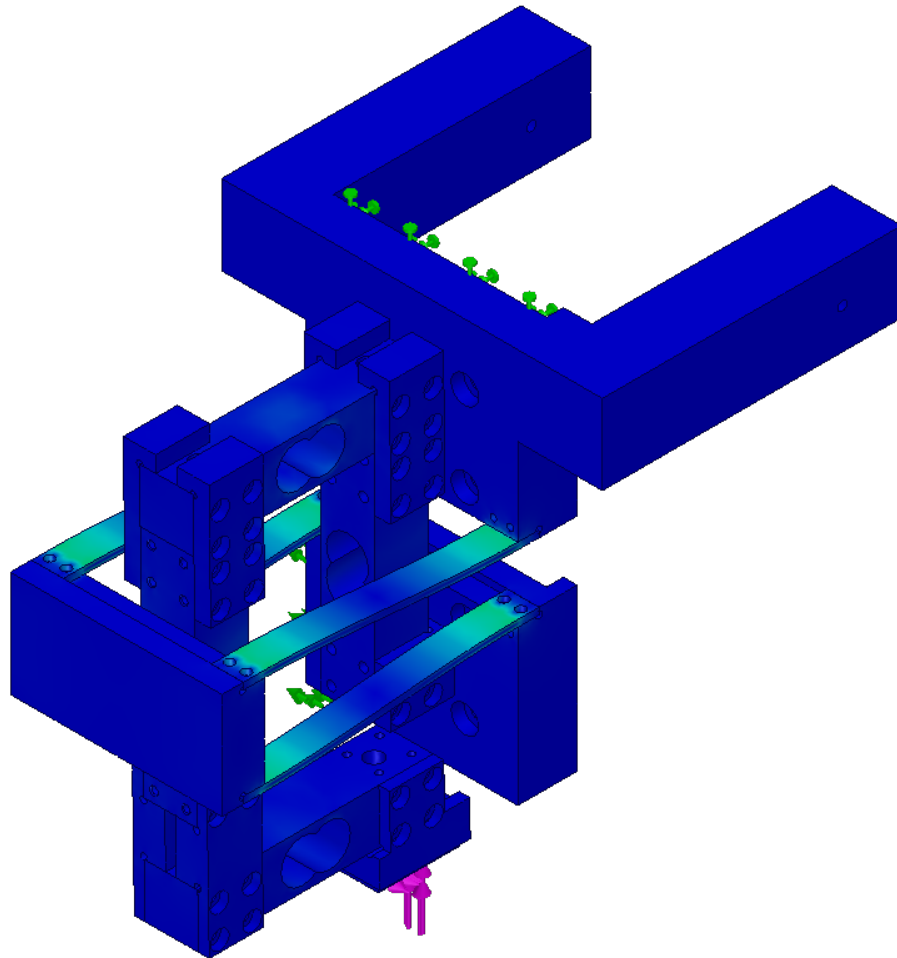


Final Design: Load Head

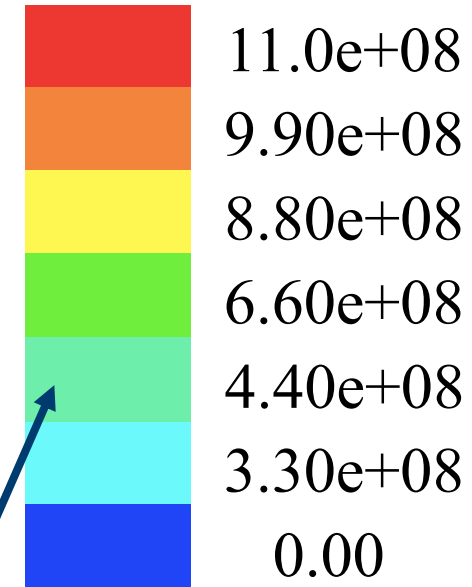


FEA: Stress

Leaf spring ensures constant and even contact of sample to counter sample.



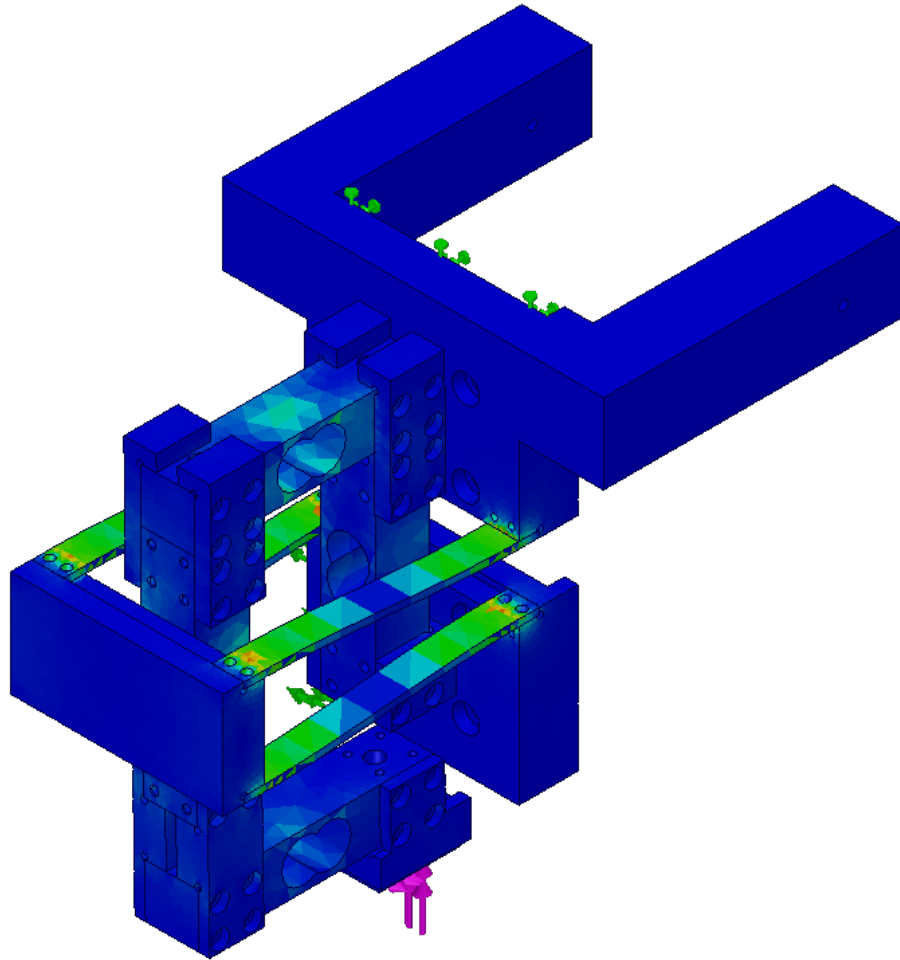
Pa (N/m²)



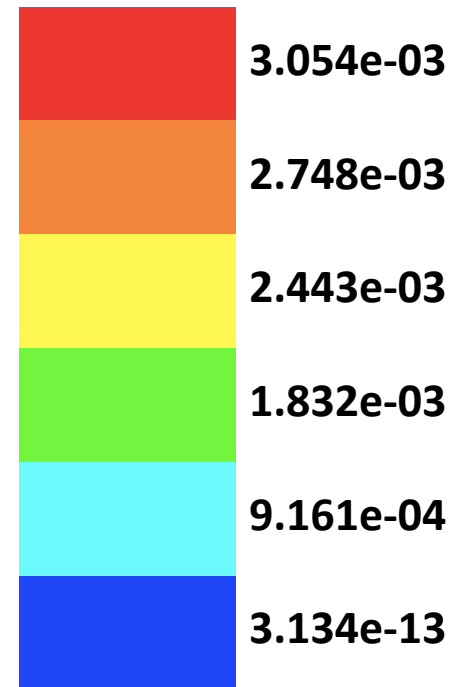
- Max stress: $\sim 4.40e+08$ Pa
- Titanium Leaves Yield Strength: $\sim 11e+08$ Pa

FEA: Strain

All strain is in the load cells and the leaf spring assembly.



Equivalent Strain
(ESTRN)



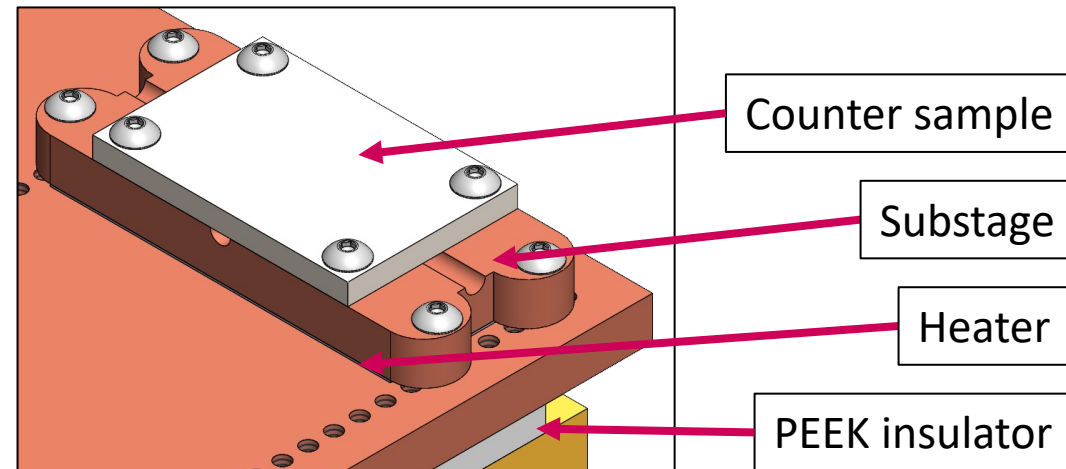
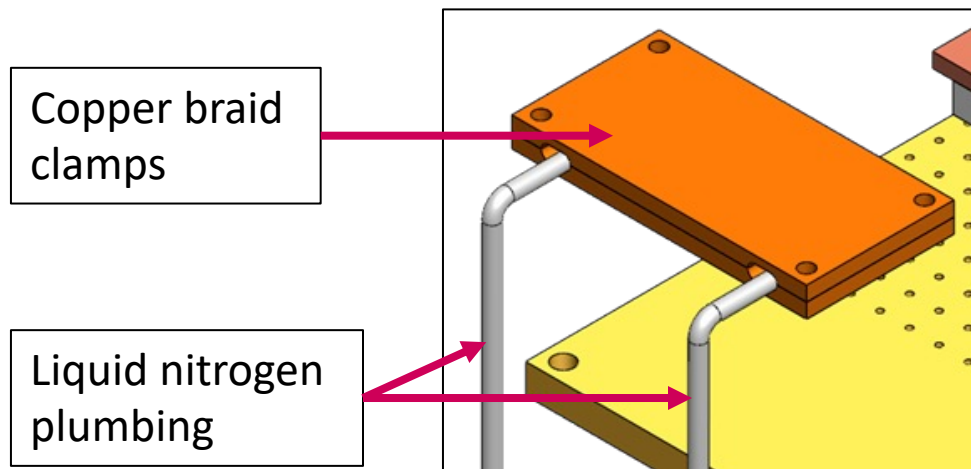
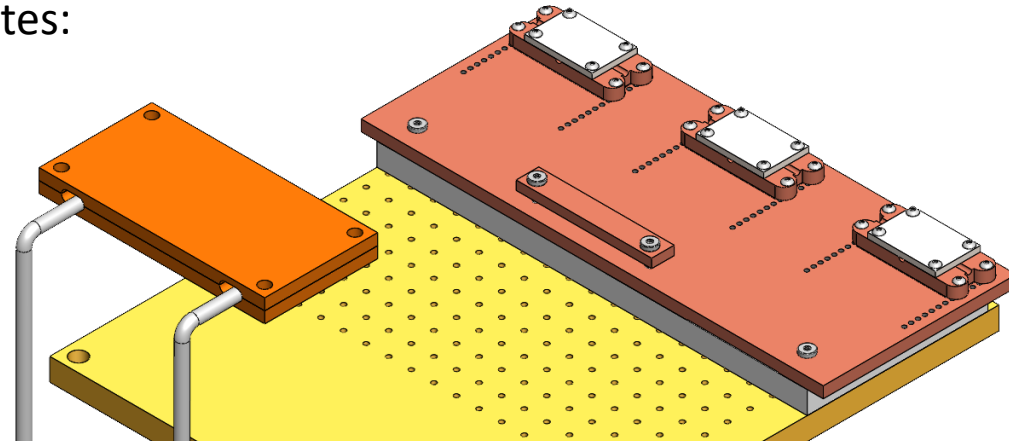
Thermal Assembly

Heat to take material from -200C to 200C in 30 minutes:

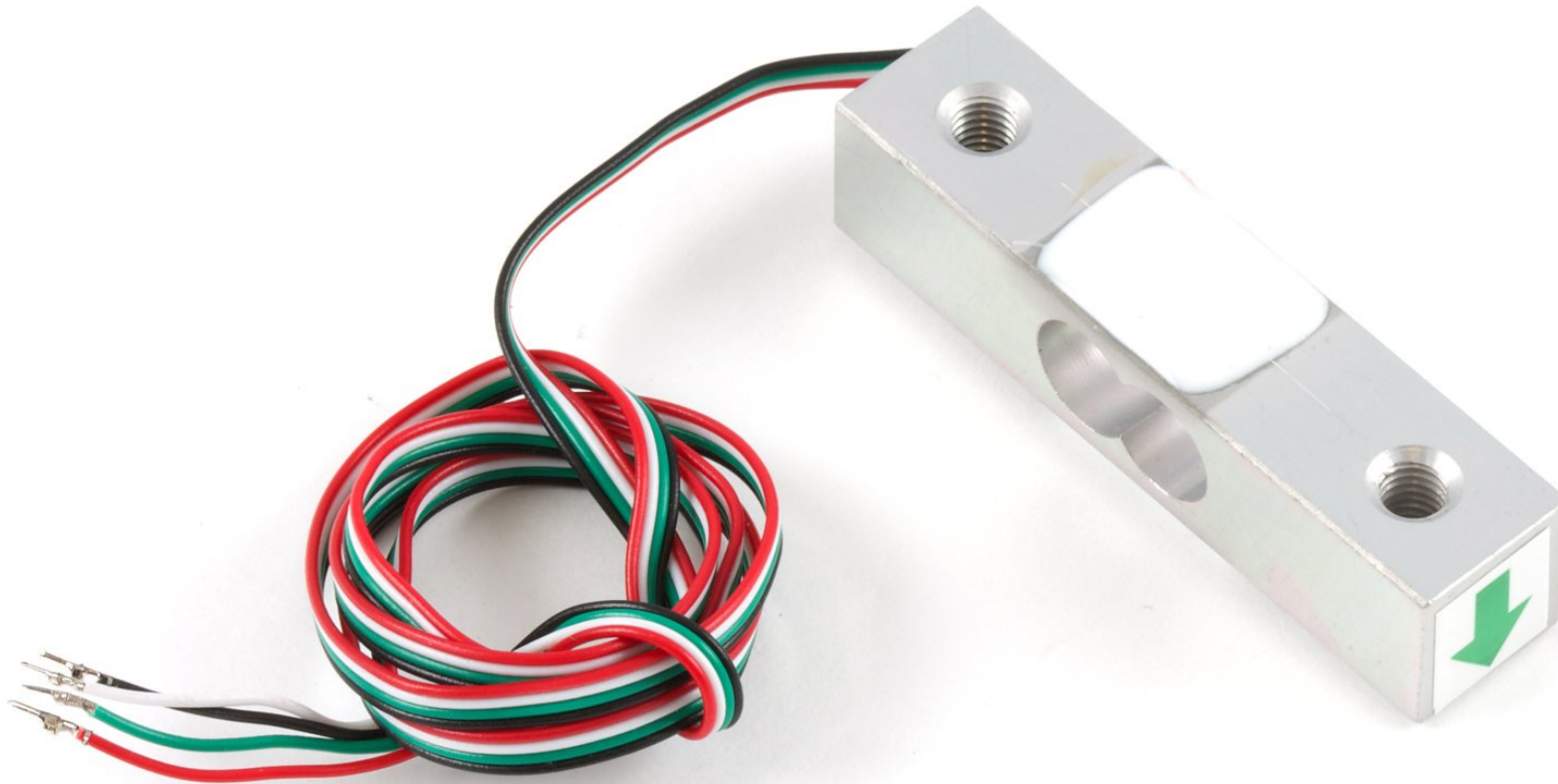
- Copper substage = 6.28 Watts
- Aluminum counter sample = 1.95 Watts

Maximum heater output is 88 Watts so,

- $Q_{heater} > Q_{copper} + Q_{aluminum}$

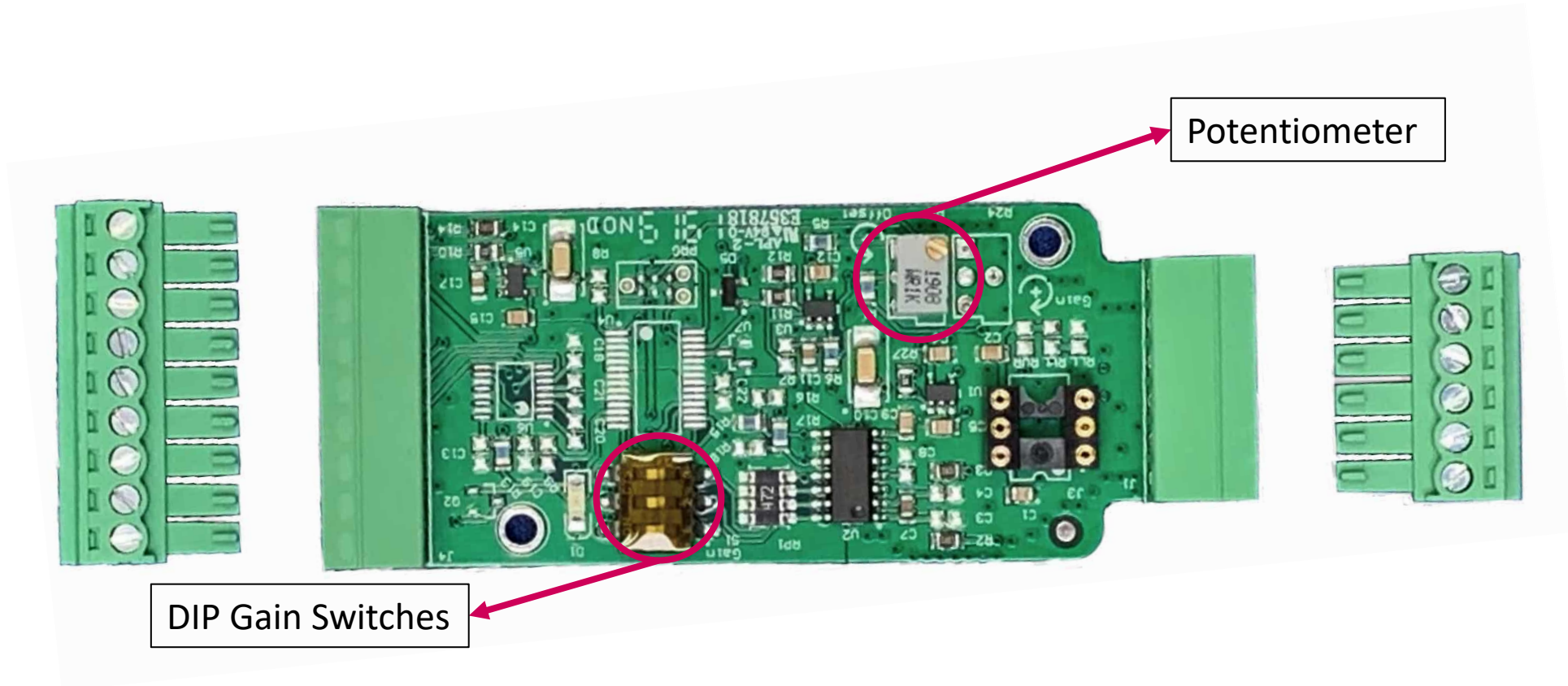


Load Cell



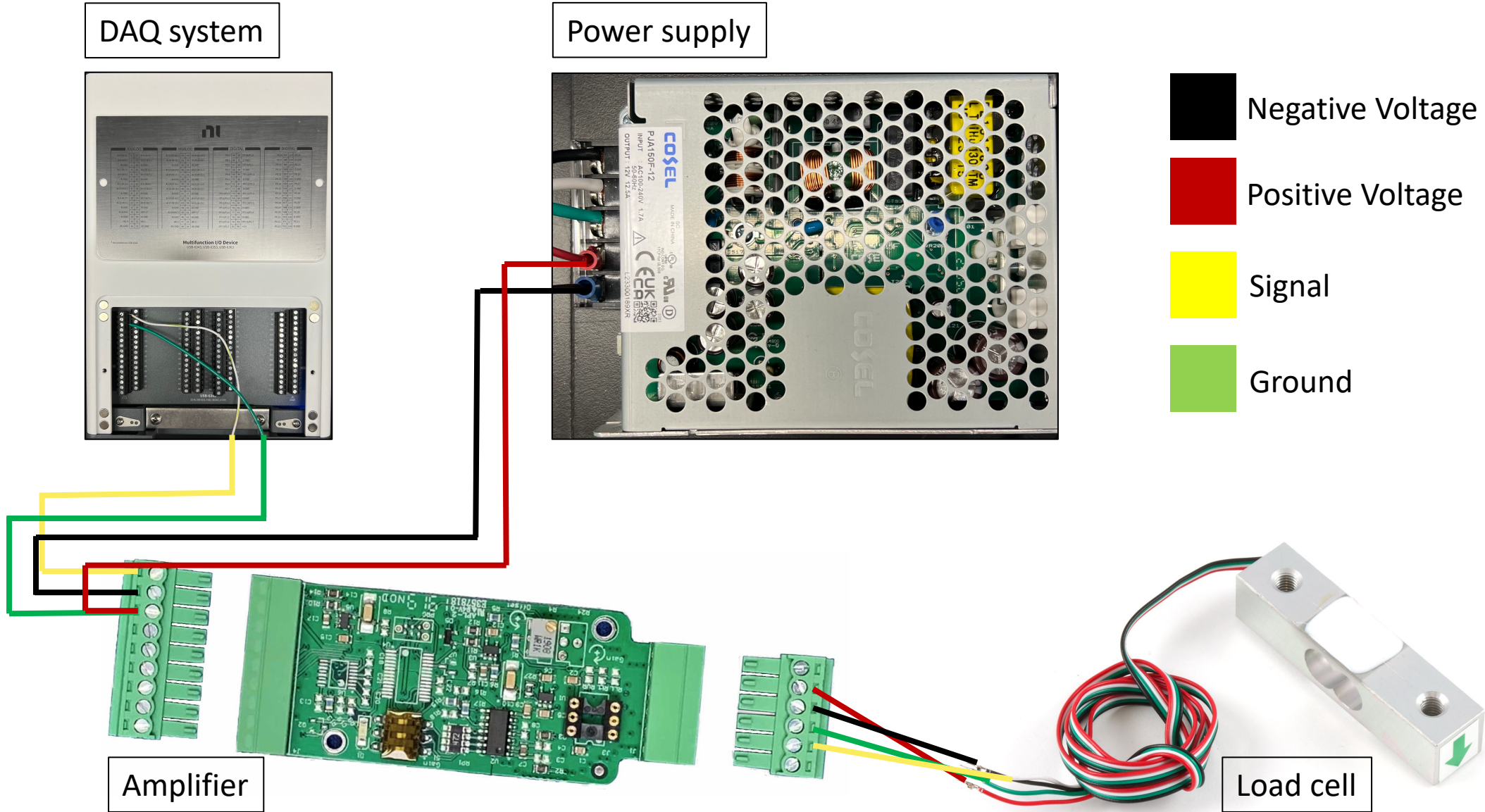
- Measures force by converting mechanical strain into electrical signals.
- Output, mV/V , is converted to other units of measurement through calibration.

Amplifier/Signal Conditioner

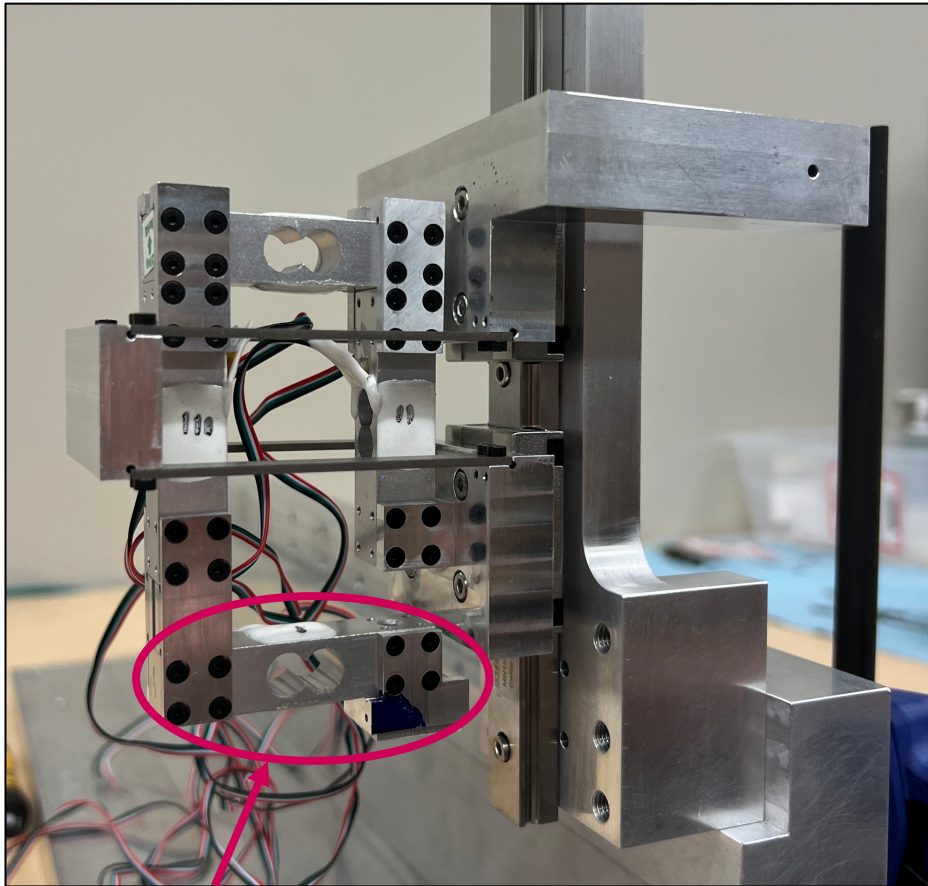


Adjusting the gain increases the signal while decreasing signal noise.

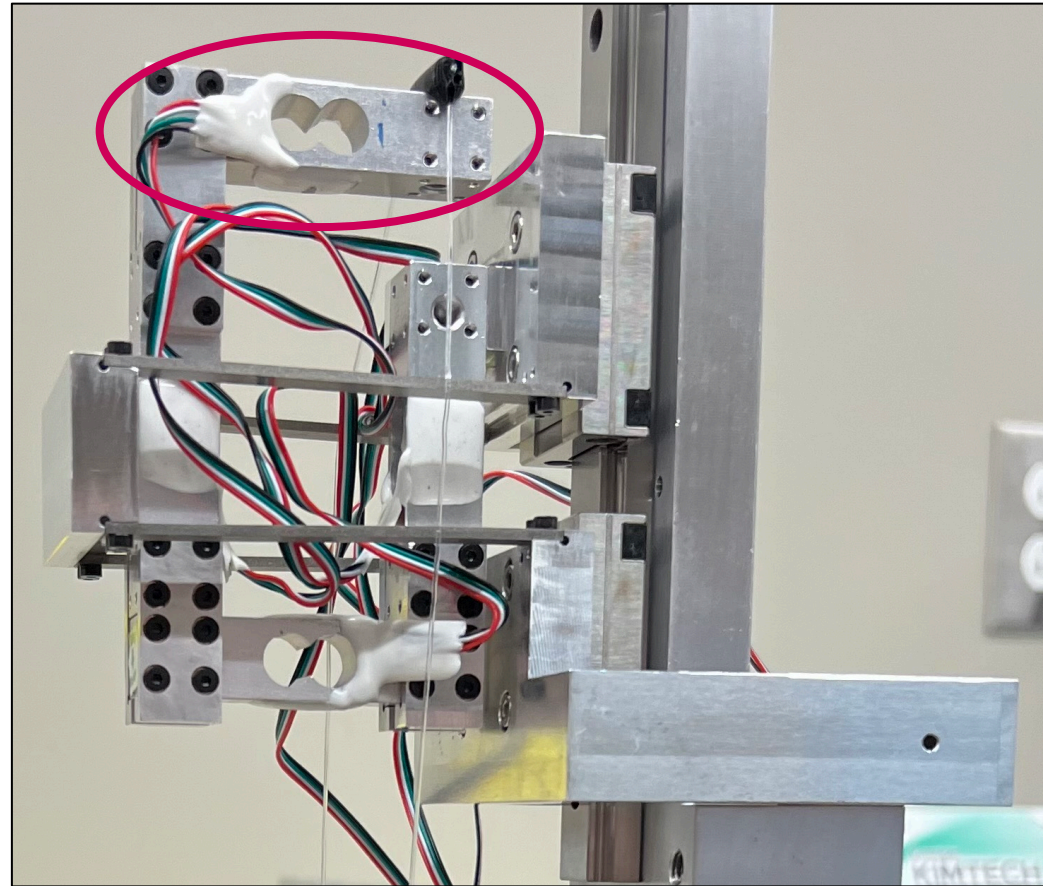
Calibrating the Load Cells



Calibrating the Load Cells in the Assembly

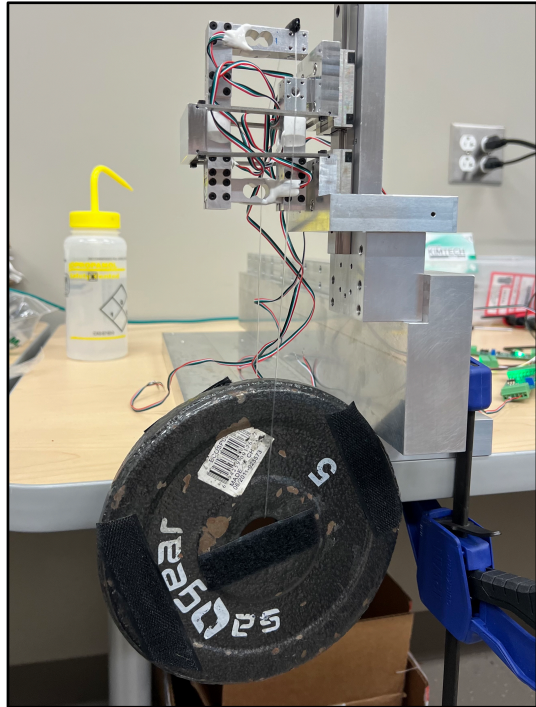


Load cell being calibrated needs to be in this position.

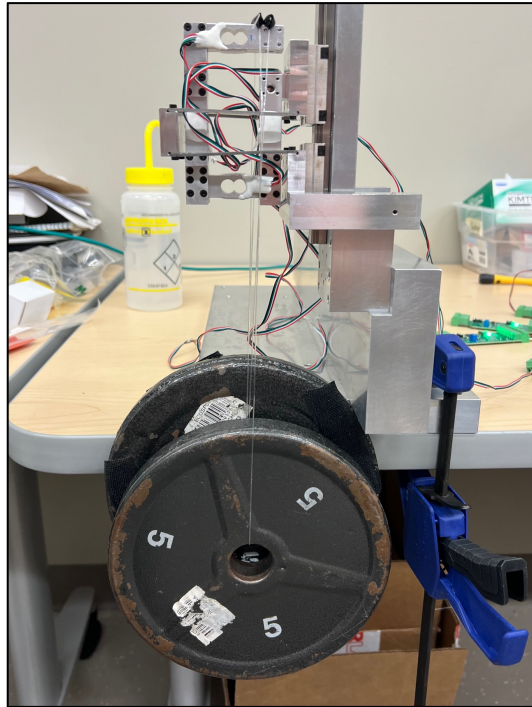


To calibrate that position with the correct force applied, the assembly had to be inverted.

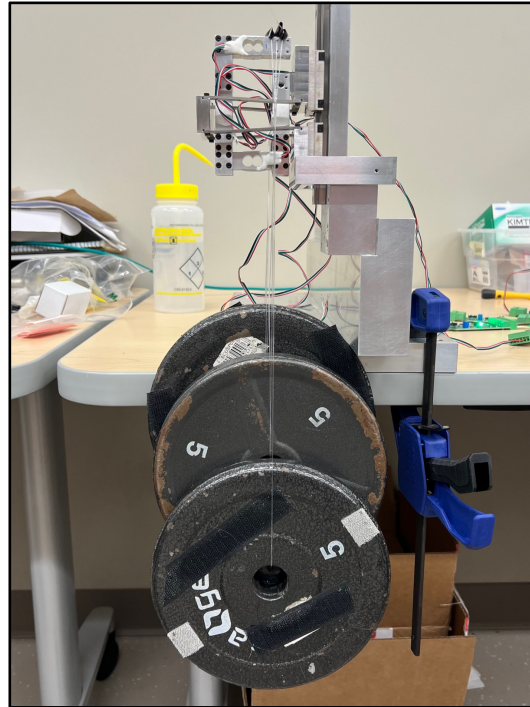
Calibrating the Load Cells in the Assembly



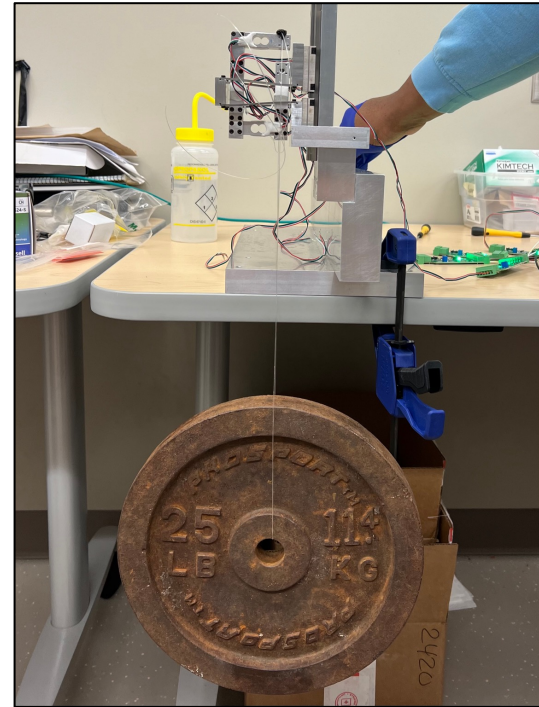
5 lbs



10 lbs

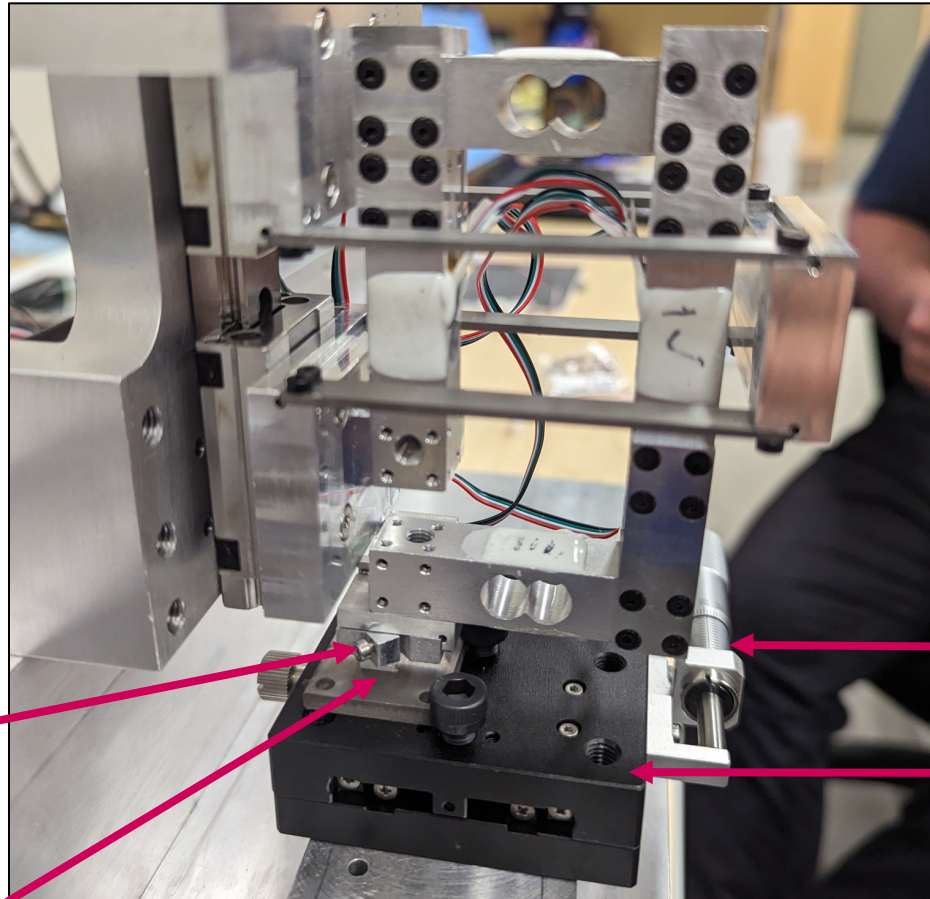


15 lbs



25 lbs

Friction Test: PTFE vs 440C Stainless Steel



Hand crank

Stage

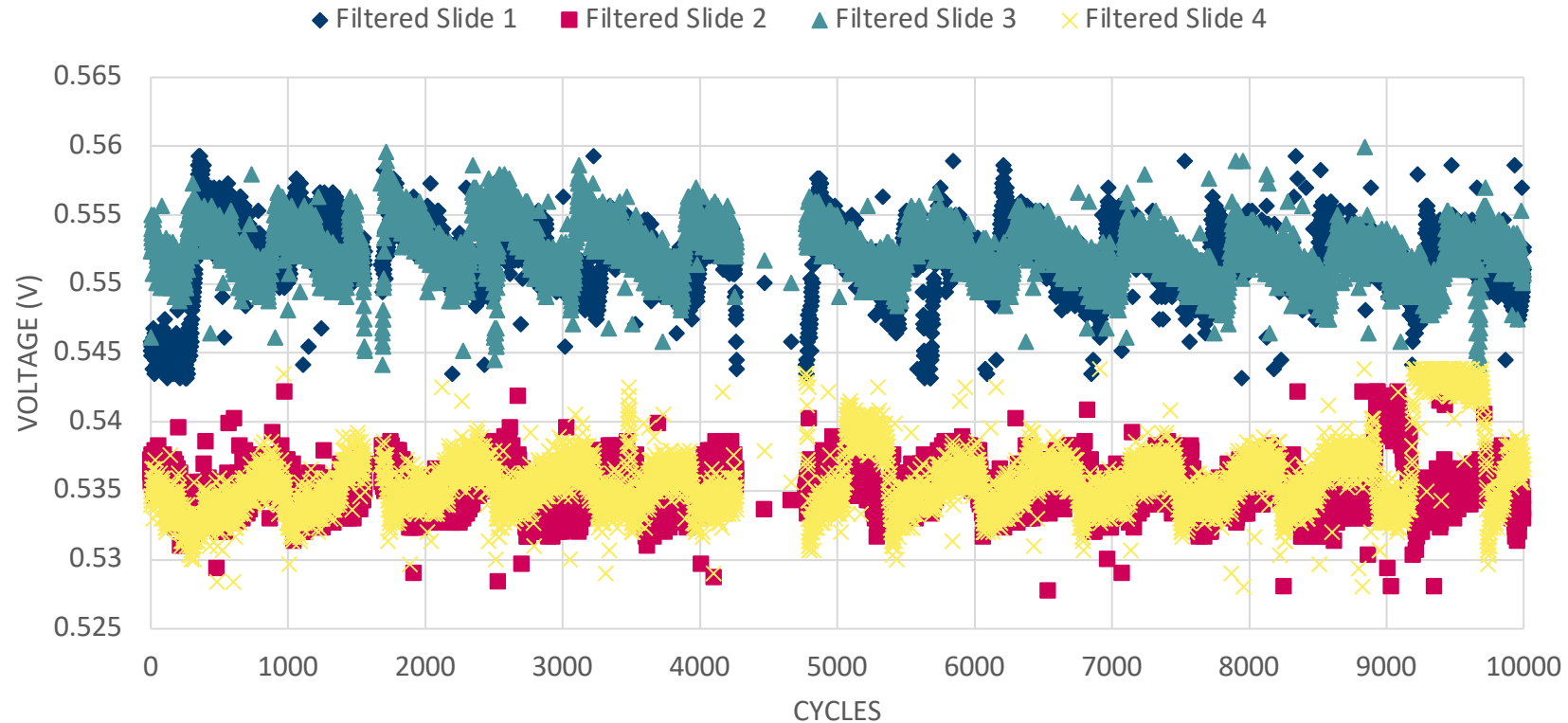
PTFE sample

440C stainless steel counter sample



Friction Force Load Cell Data

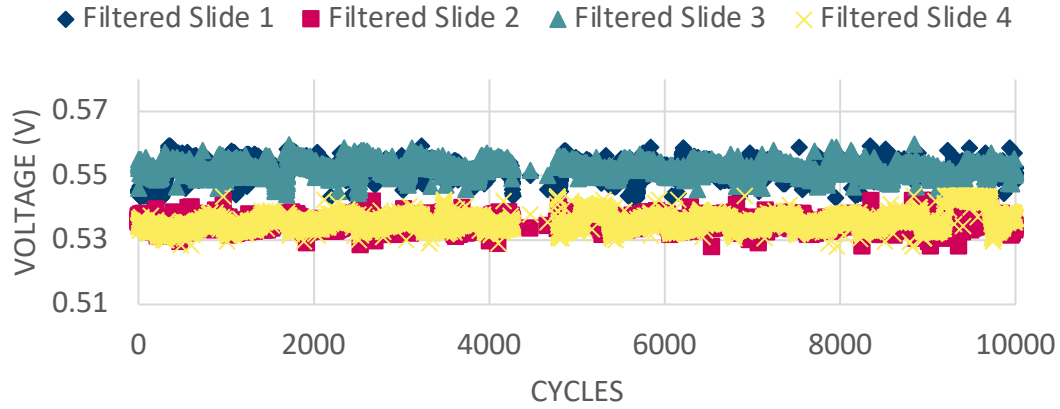
FRICITION FORCE SLIDE DATA - ZERO POUND



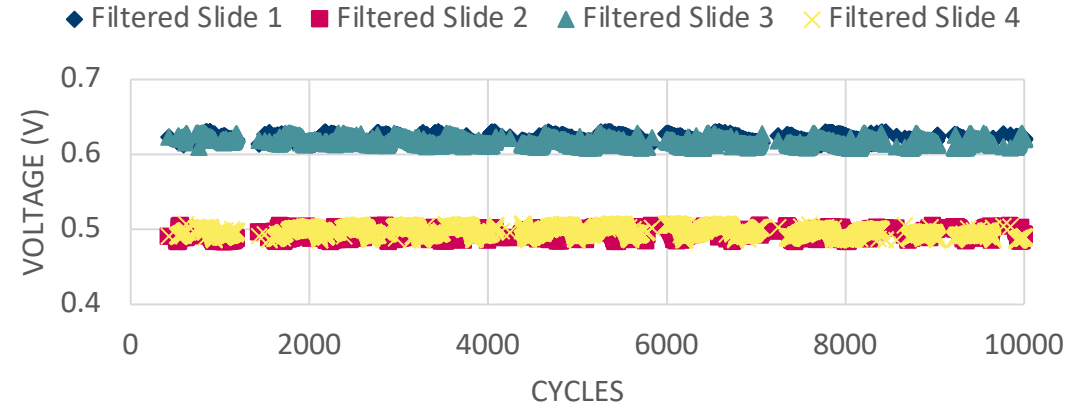
- Slides 1 and 3 are clockwise turning of the hand crank.
- Slides 2 and 4 are counterclockwise turning of the hand crank.
- The waves show a start and stop of each turn.

Friction Force Load Cell Data

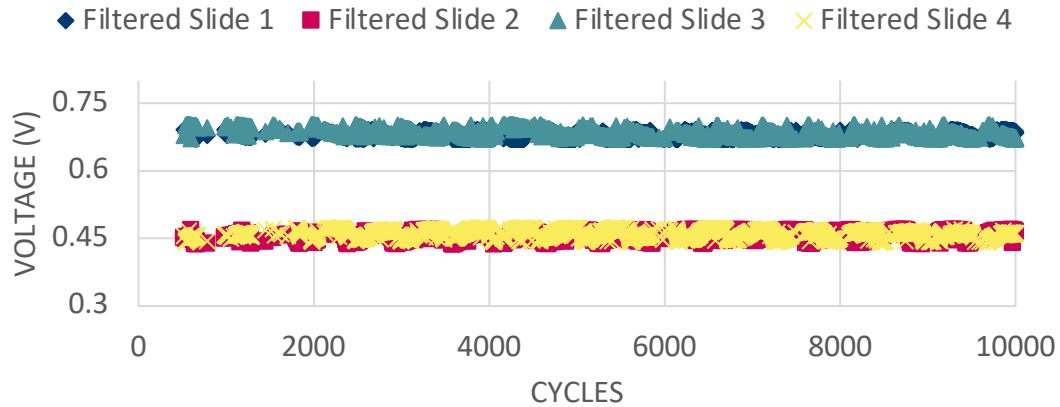
FRICITION FORCE SLIDE DATA - ZERO POUND



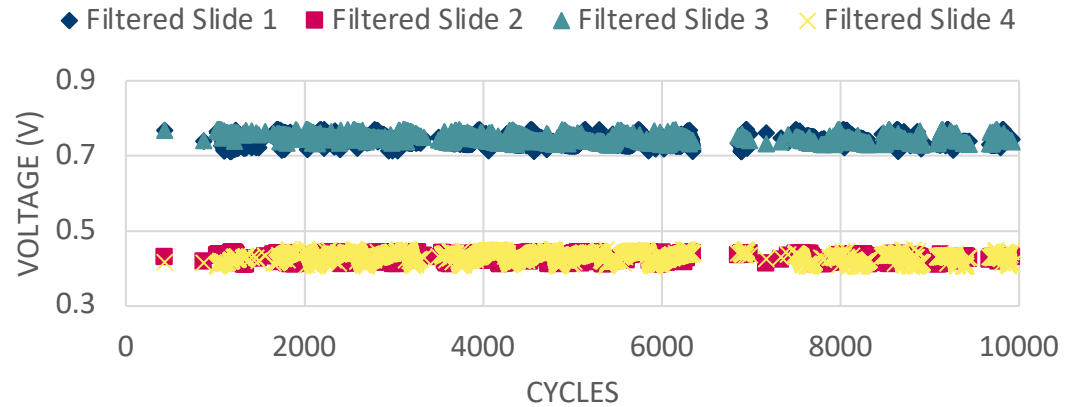
FRICITION FORCE SLIDE DATA - FIVE POUND



FRICITION FORCE SLIDE DATA - TEN POUND

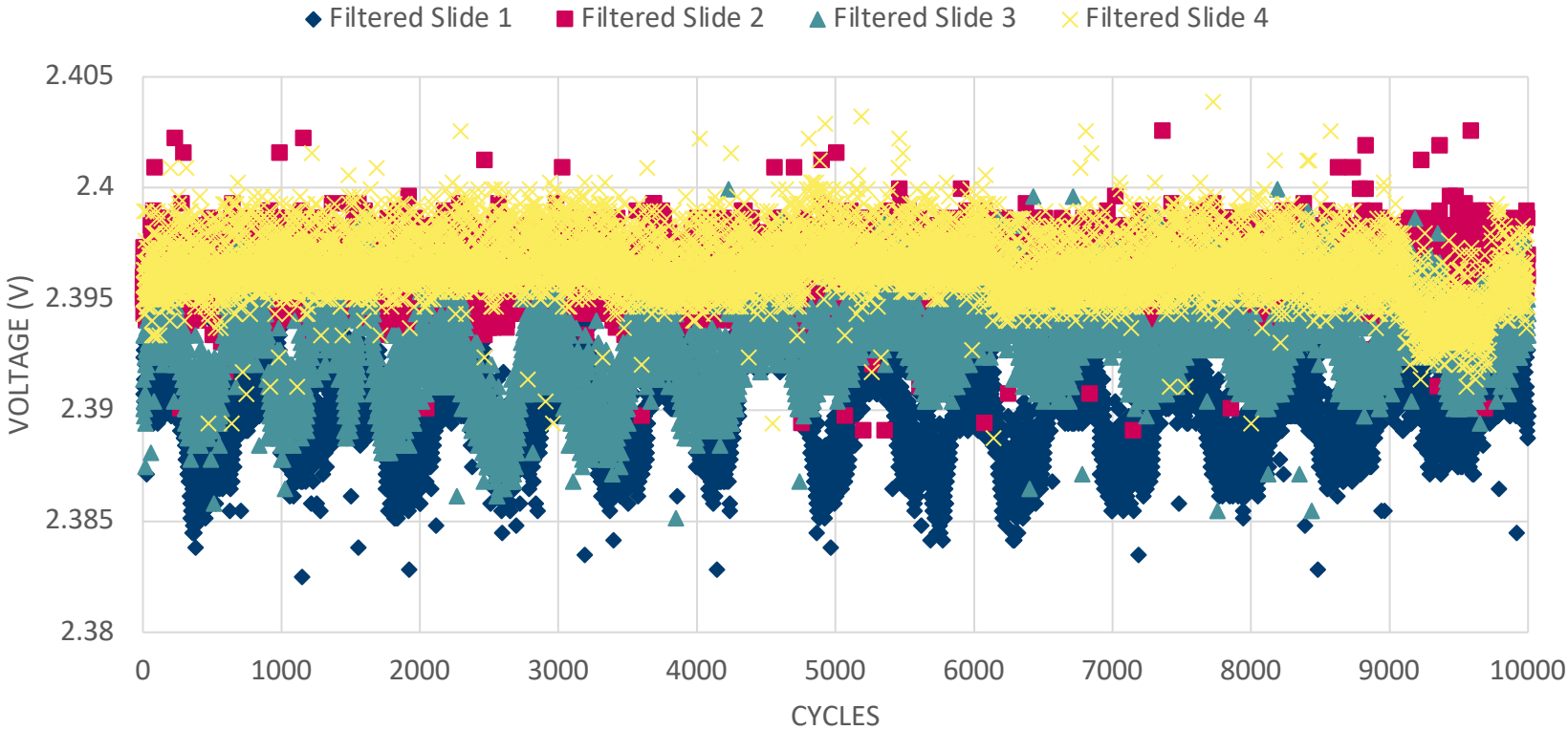


FRICITION FORCE SLIDE DATA - FIFTEEN POUND



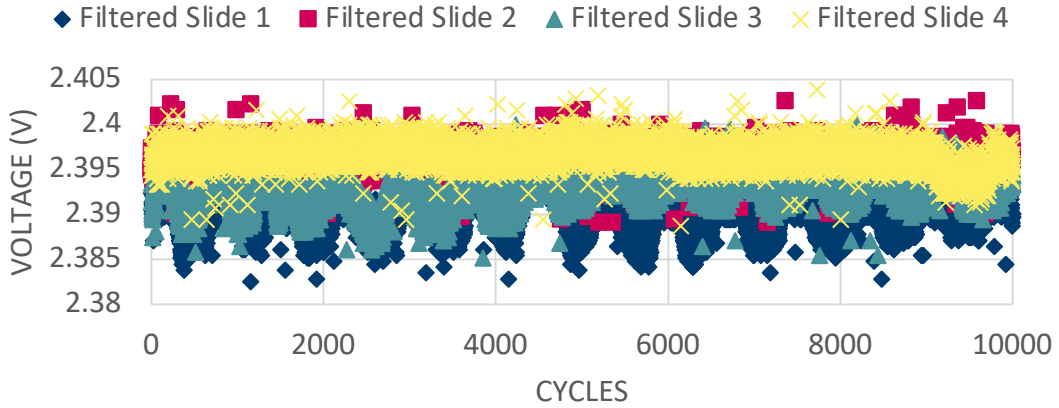
Normal Force Load Cell Data

NORMAL FORCE SLIDE DATA - ZERO POUND

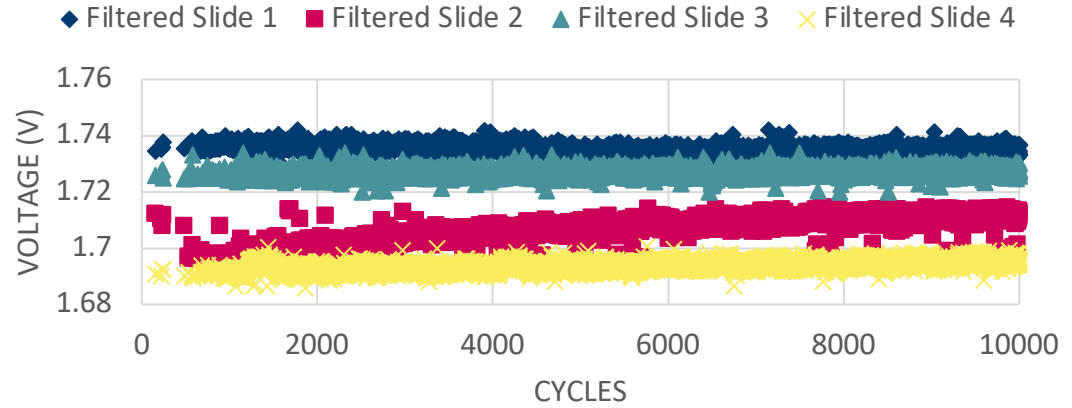


Normal Force Load Cell Data

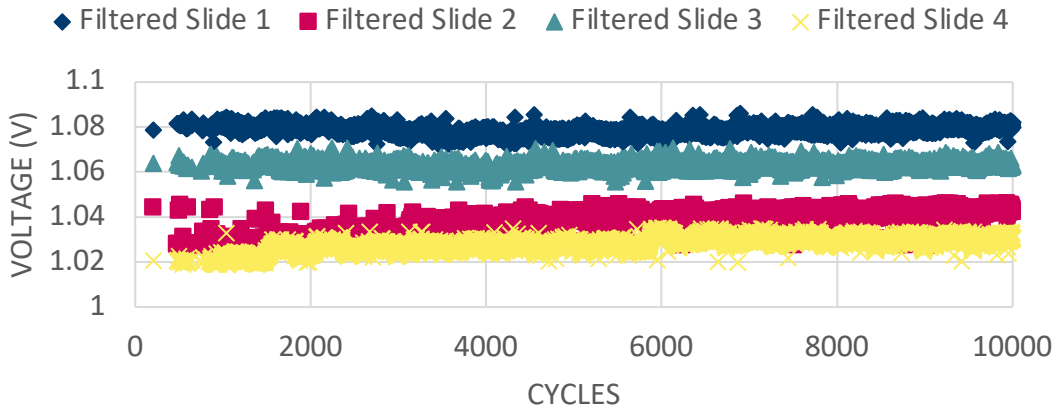
NORMAL FORCE SLIDE DATA - ZERO POUND



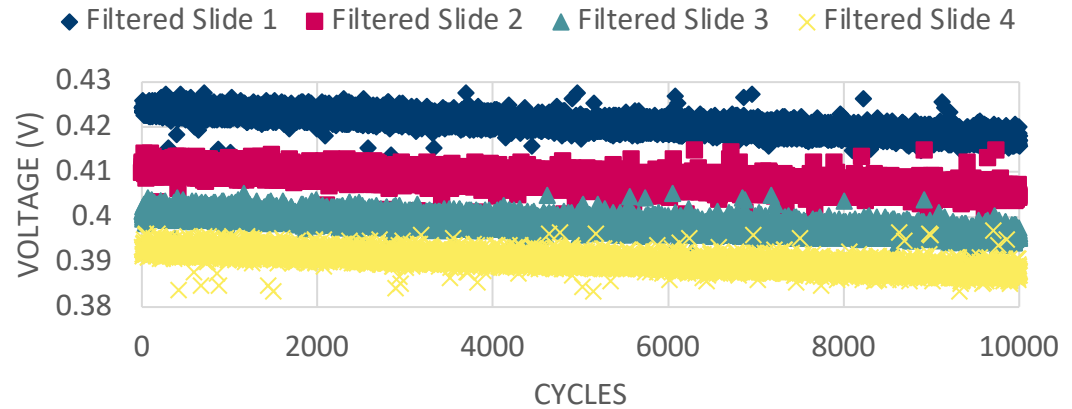
NORMAL FORCE SLIDE DATA - FIVE POUND



NORMAL FORCE SLIDE DATA - TEN POUND



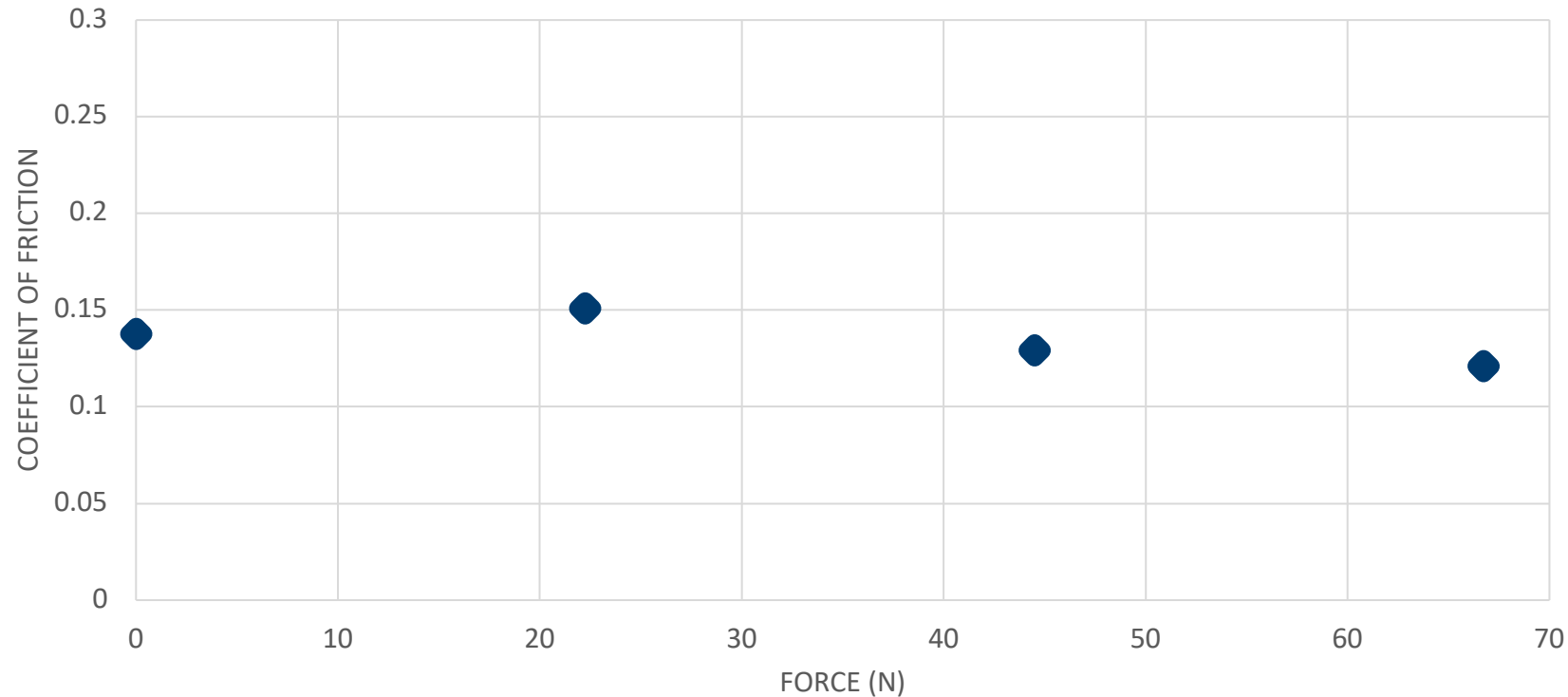
NORMAL FORCE SLIDE DATA - FIFTEEN POUND



Coefficient of Friction Plot

Test Results show a generally correct functionality of the load head design.

PTFE VS. 440C STAINLESS STEEL



Our Average CoF: 0.13
Known PTFE CoF: 0.10 - 0.20

Using a MAXON Motor Controller with MATLAB

Experiment Setup Parameter Setup Taring and Loading Experiment Post Experiment

Experiment Overview

Column 1	Column 2	Column 3	Column 4

[Load Experiment](#)

Experiment Plan

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18

This table does not update properly if you edit the experiment plan

Experiment Notes
This saves a note to app.Experiment.Notes with the current cycle number

[Append Notes](#)

Experiment Number
 Experiment Cycle Number
 Cycles to Run
 Total Cycle Number

Motion Parameters

Stroke (mm)
 Velocity (mm/s)
 Dwell before (s)
 Dwell after (s)

Saving

Save Every N
 Avg Every N

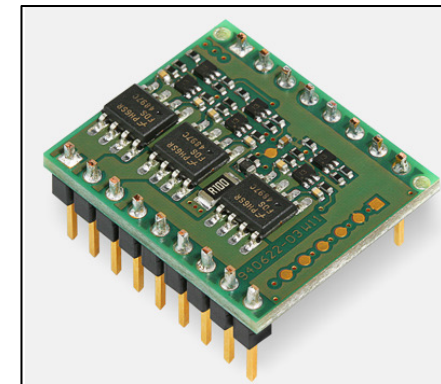
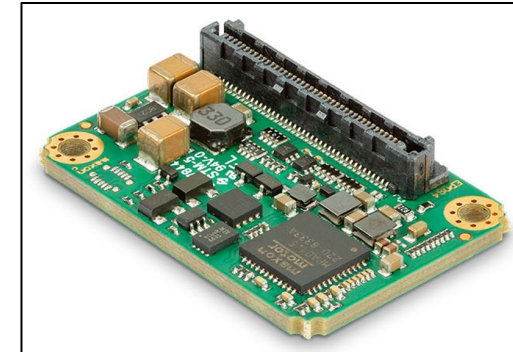
File Path ●
 Instrument Parameters ●
 Teensy Connected ●
 Motors Set ●
 Channels Tared ●

Servo 1 ● Servo 3 ● Servo 5 ●
 Servo 2 ● Servo 4 ● Servo 6 ●

Emergency Stop
Start Experiment

Off On
 Auto Start Next Experiment

[Easy Button](#)
[Accept Experiment](#)



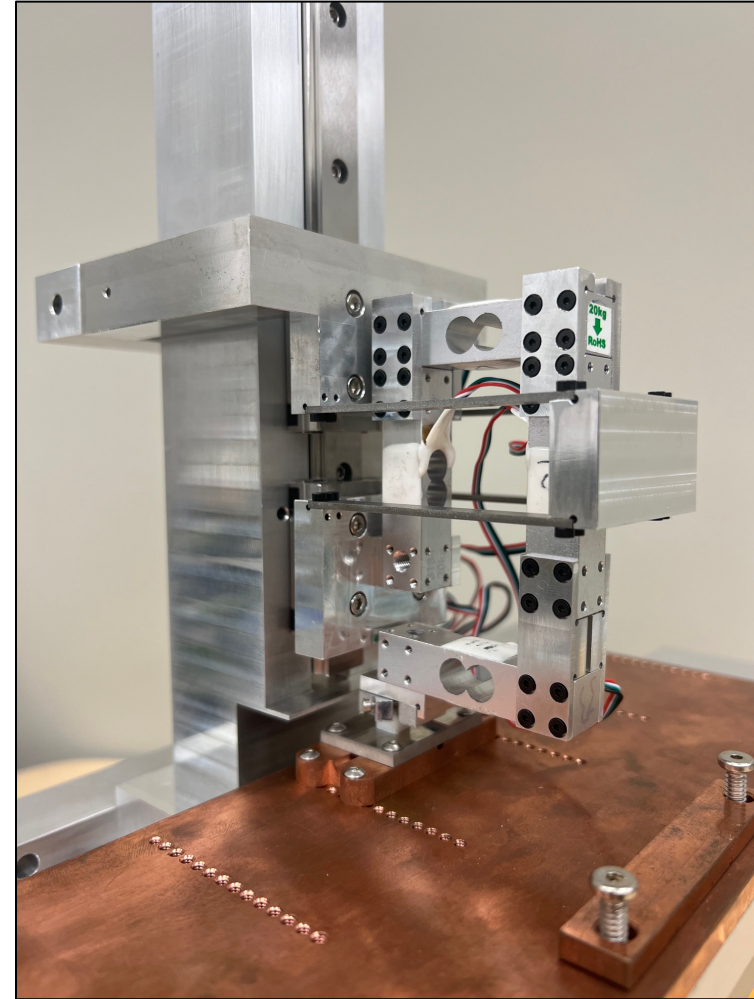
Future Work

Adjust stage motor.

Integrate motor control functionality with MATLAB.

Automate test performed with the hand crank stage.

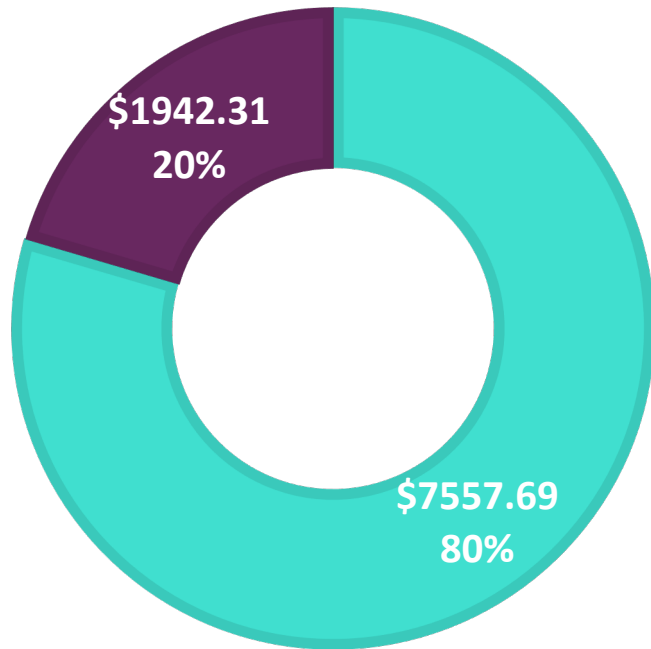
Test critical loads with automation.



Budget

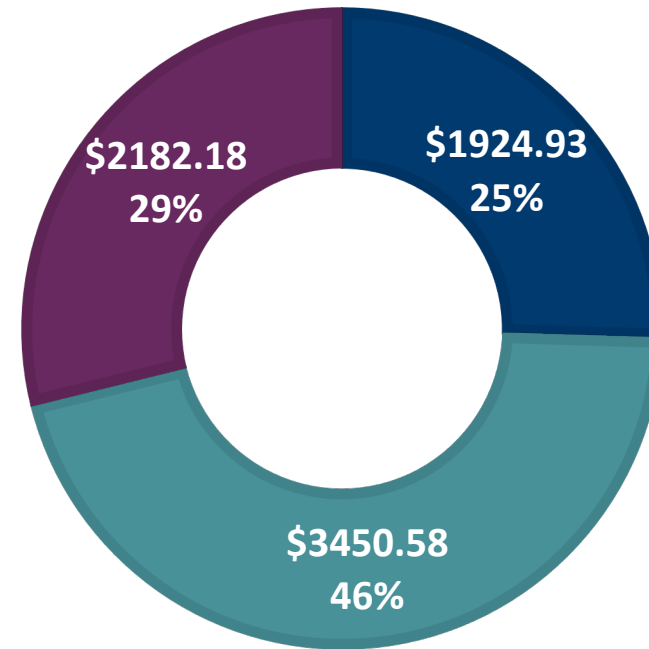
TOTAL BUDGET USED

■ Spent ■ Remaining



BREAK DOWN

■ Bulk Material ■ Electrical ■ Hardware



Lessons Learned

Communication is key.

Don't be afraid to ask for advice.

Stay organized.

Be able to accept criticism.

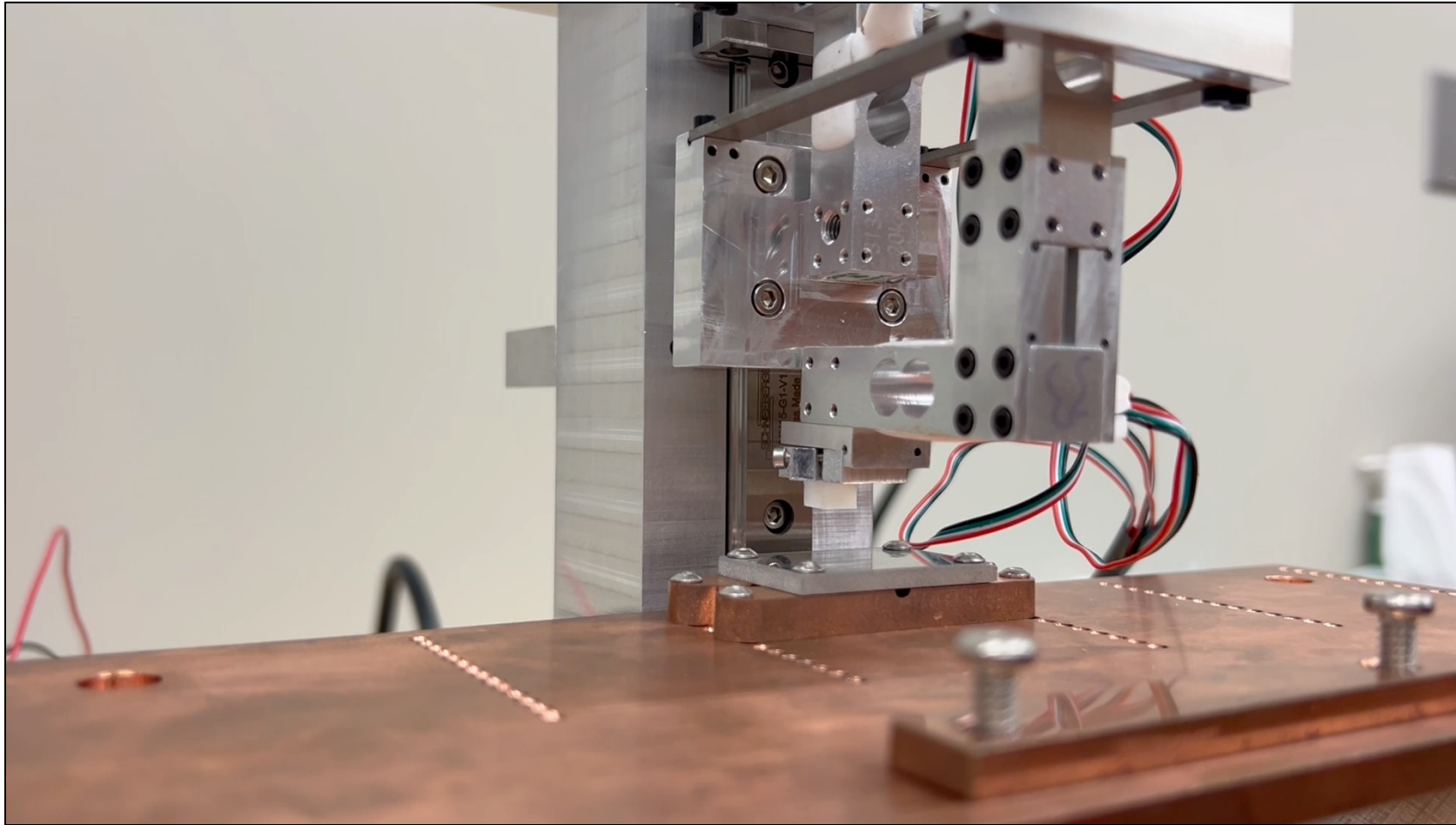
Have a good file naming convention.

Everything takes longer than expected.

Make copies of everything.

Trust the process.





Questions?

