FAMU-FSU College of Engineering

Team 501
Tribometer in Spacelike Conditions

Engineering Design Day 240404

Team Introductions

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Sponsor and Advisor

3M Science. Applied to Life.™

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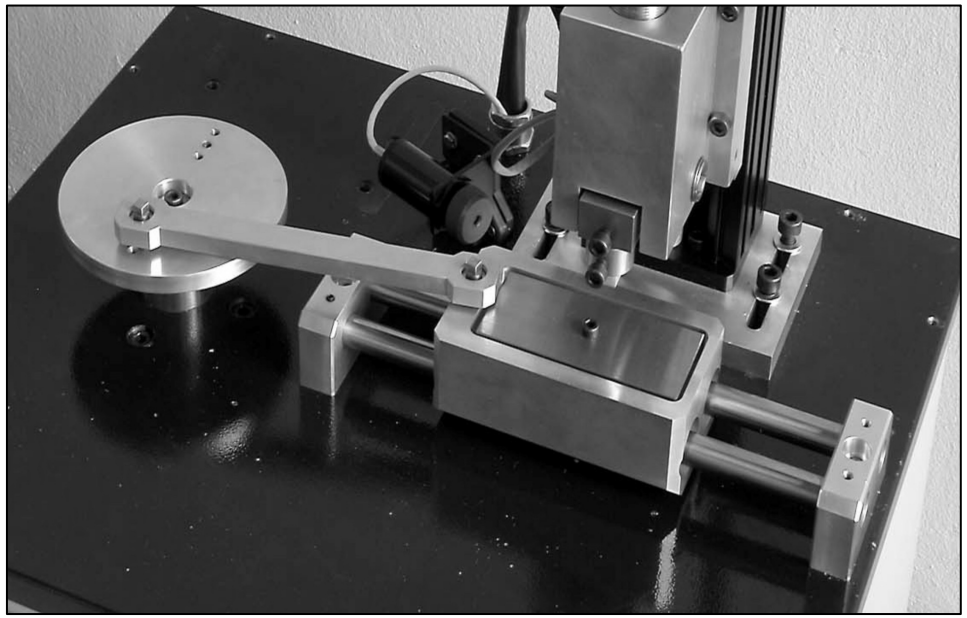
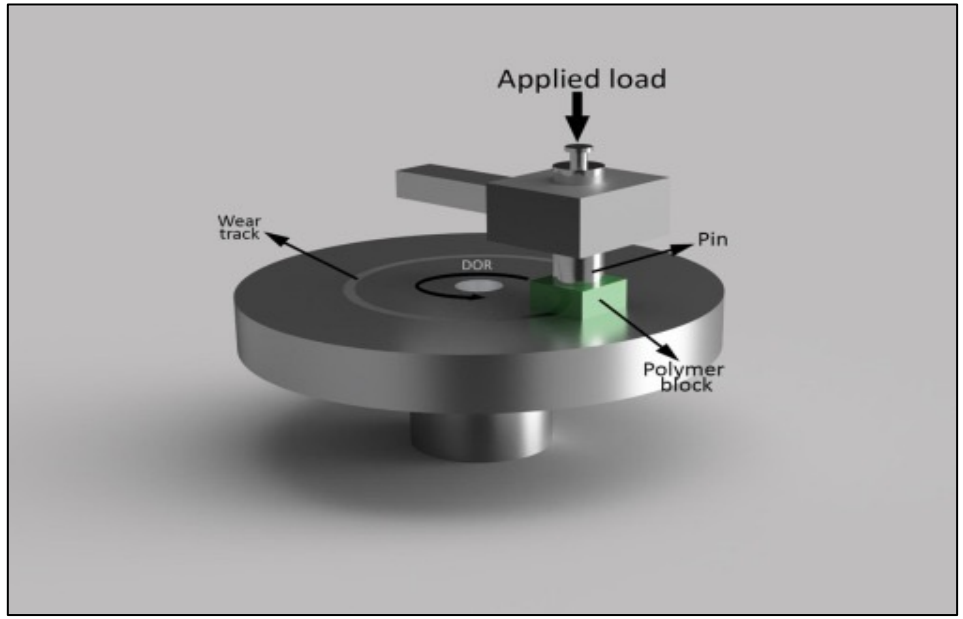
Objective

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?

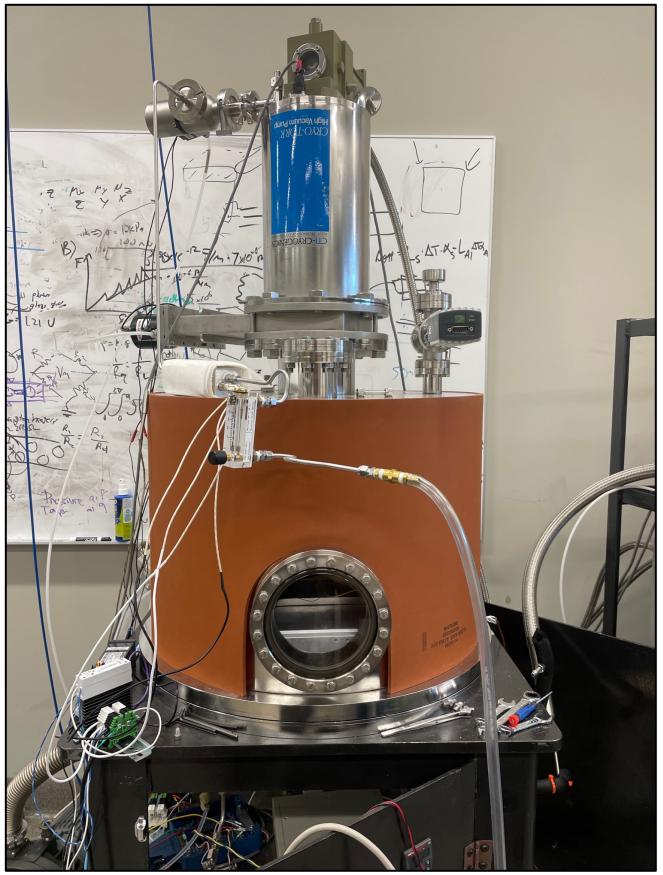
Tribometers measure quantities such as coefficient of friction, friction force, and wear volume on two surfaces in contact by simulating friction in controlled conditions.





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.

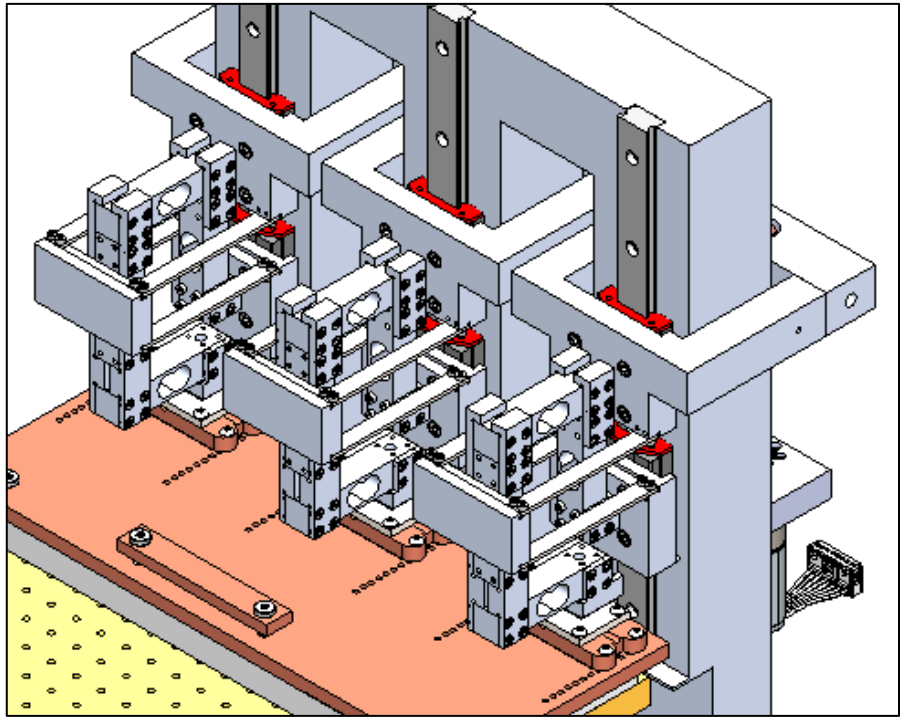


Key Goals

Test multiple samples

Control parameters

Operate in spacelike conditions

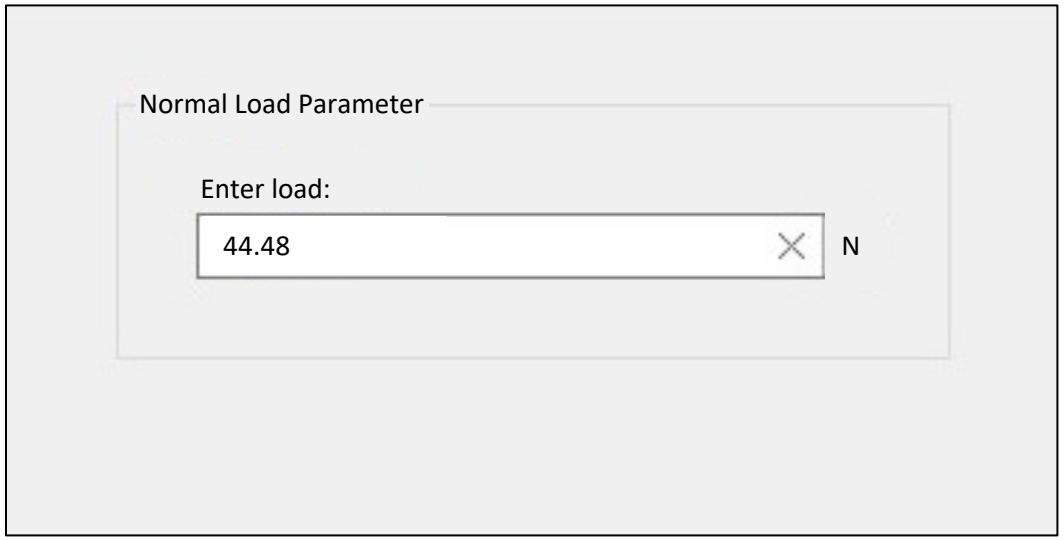


Key Goals

Test multiple samples

Control parameters:
- **-200C to 200C**
- **Max 100 N normal load**

Operate in spacelike conditions



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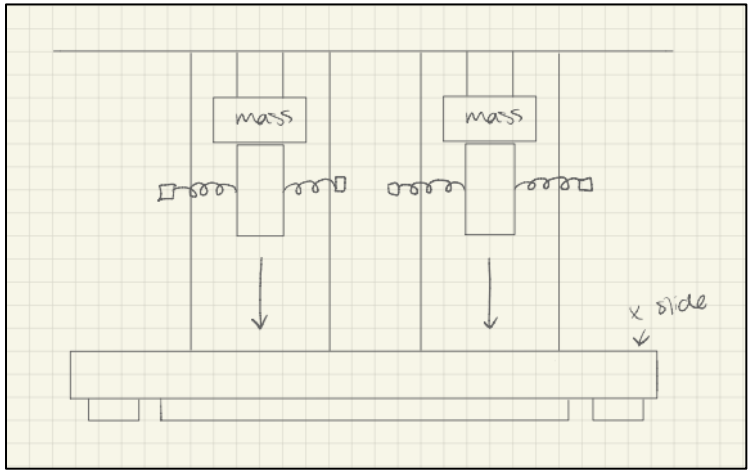
Key Goals

- Test multiple samples
- Control parameters
- **Operate in spacelike conditions**

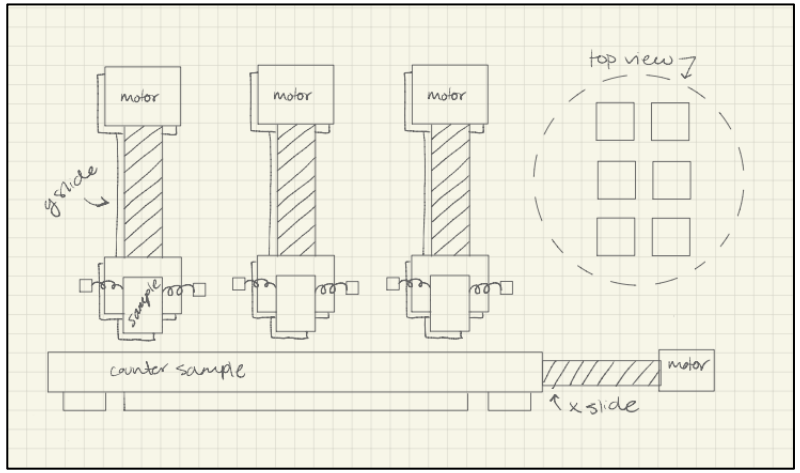
Concept Selection

Rank 1



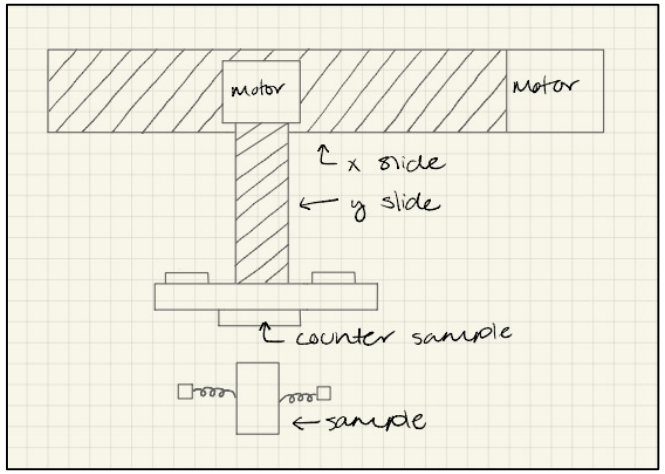
Weights to control normal load

Rank 2



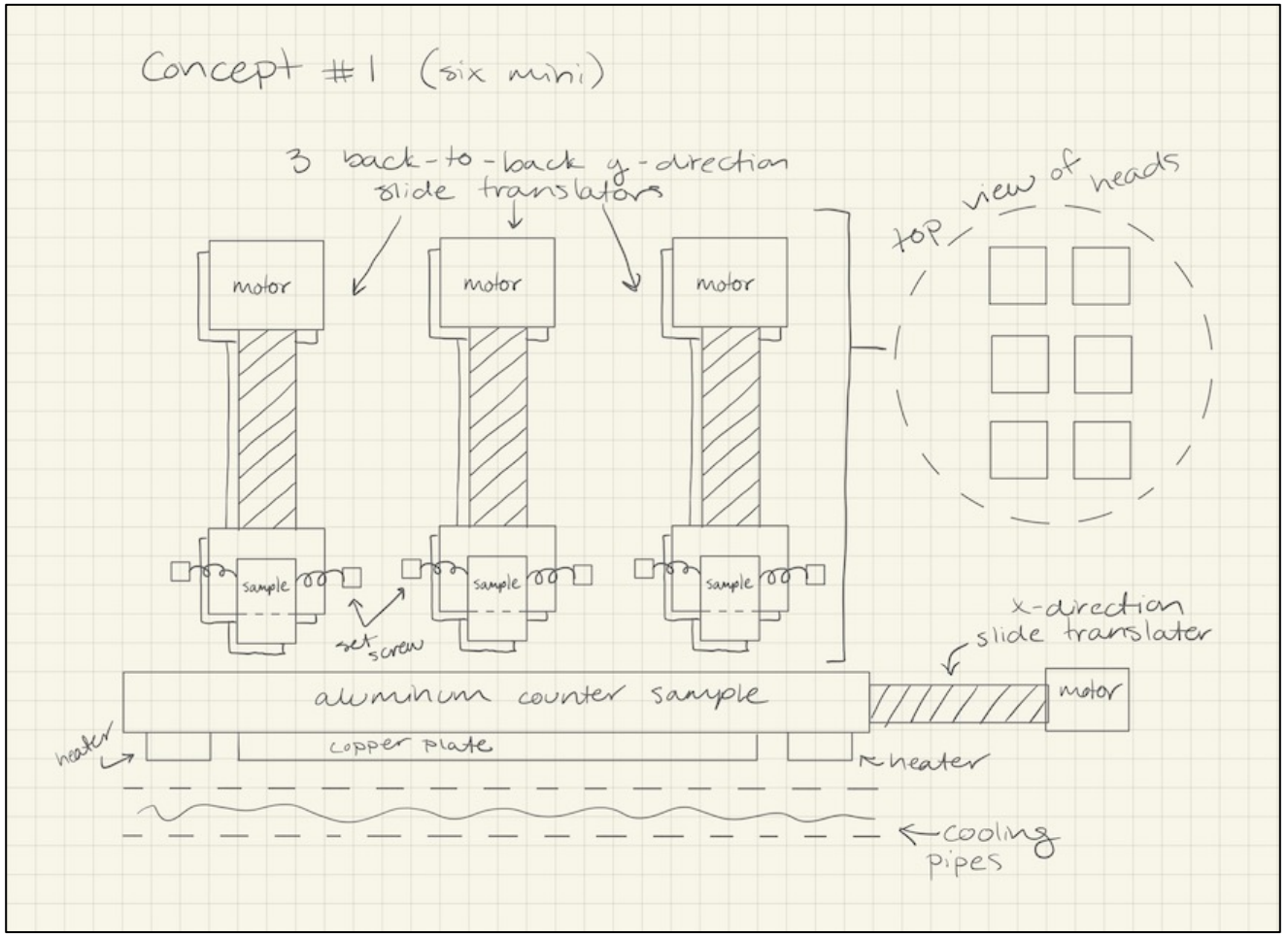
6 mini tribometers

Rank 3



Inverted tribometer

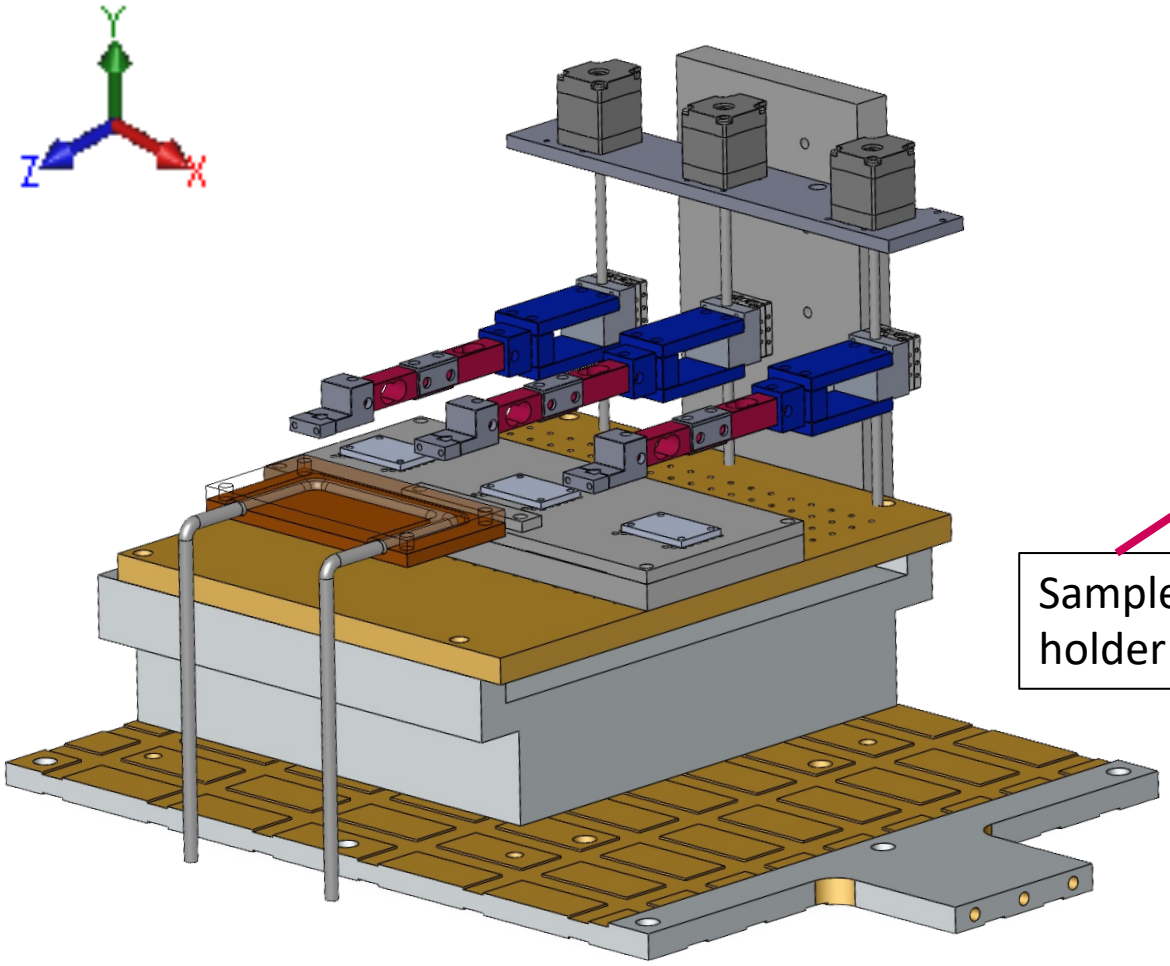
Final Concept

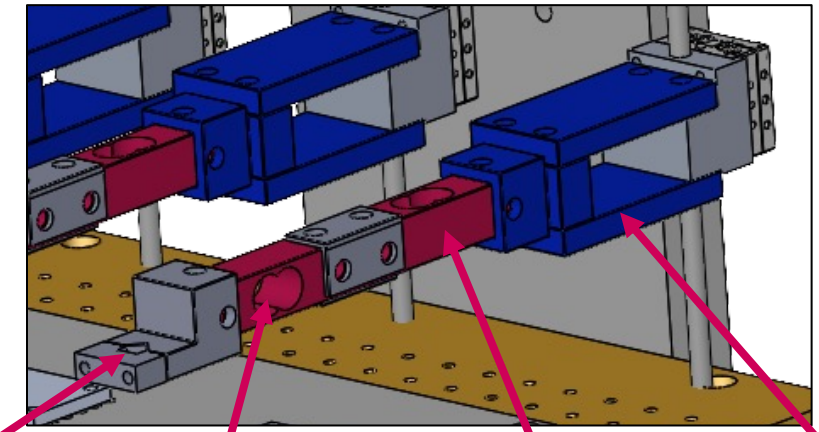


6 mini-identical tribometers.

CAD Design: Iteration 1

Large moment in the z-direction.





Sample holder

Normal force load cell

Friction force load cell

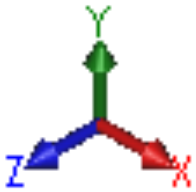
Leaf spring assembly

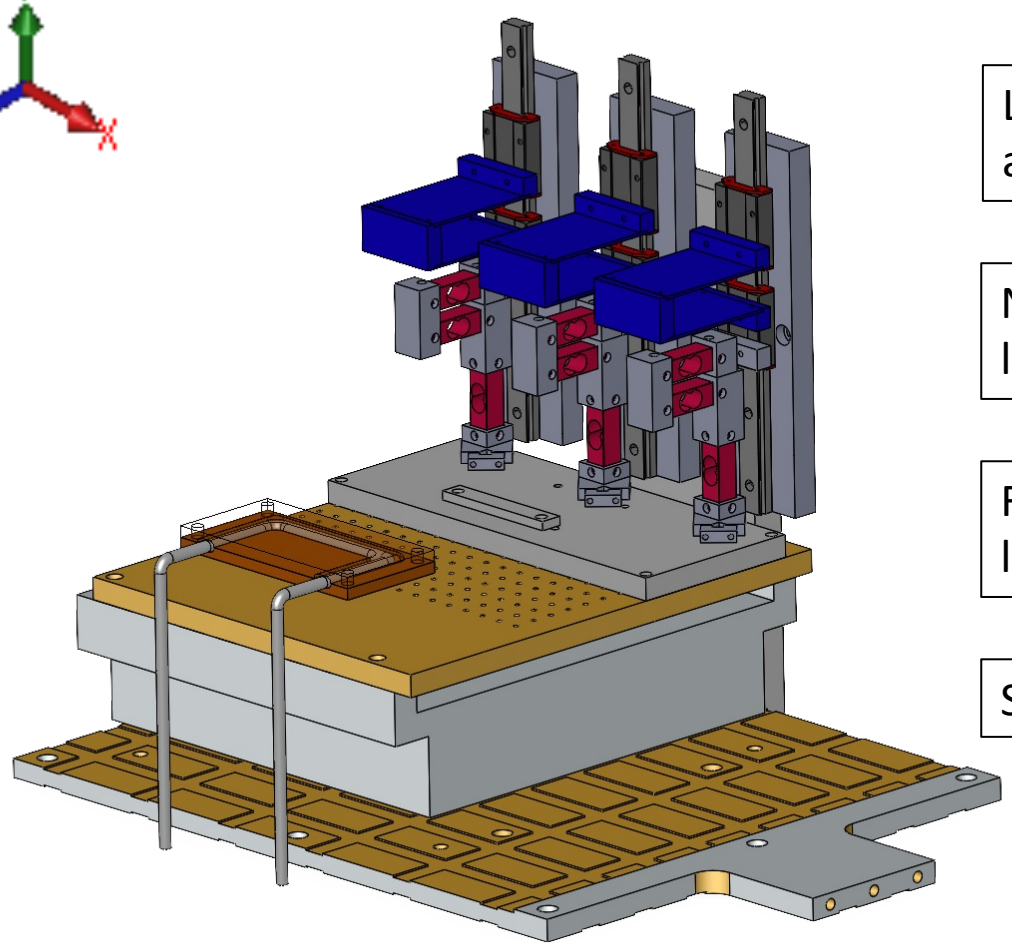
Load cell

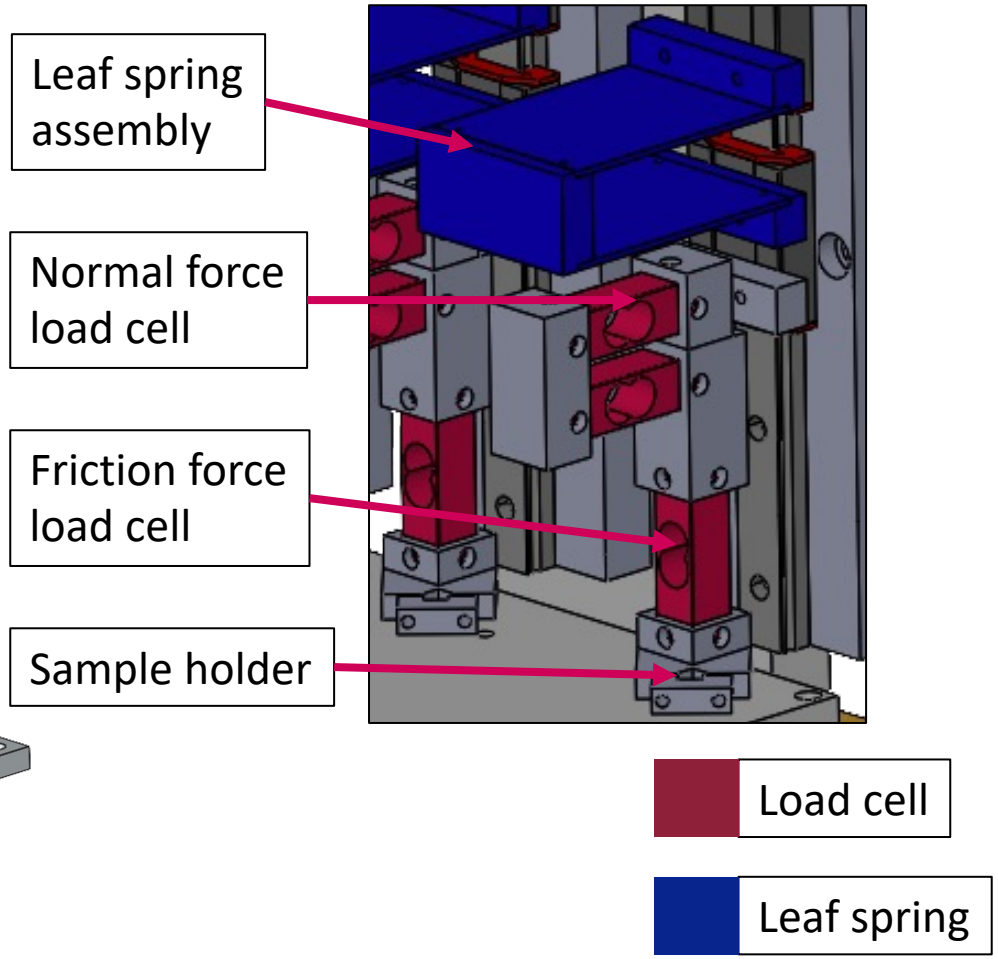
Leaf spring

CAD Design: Iteration 2

Large moment in the y-direction.

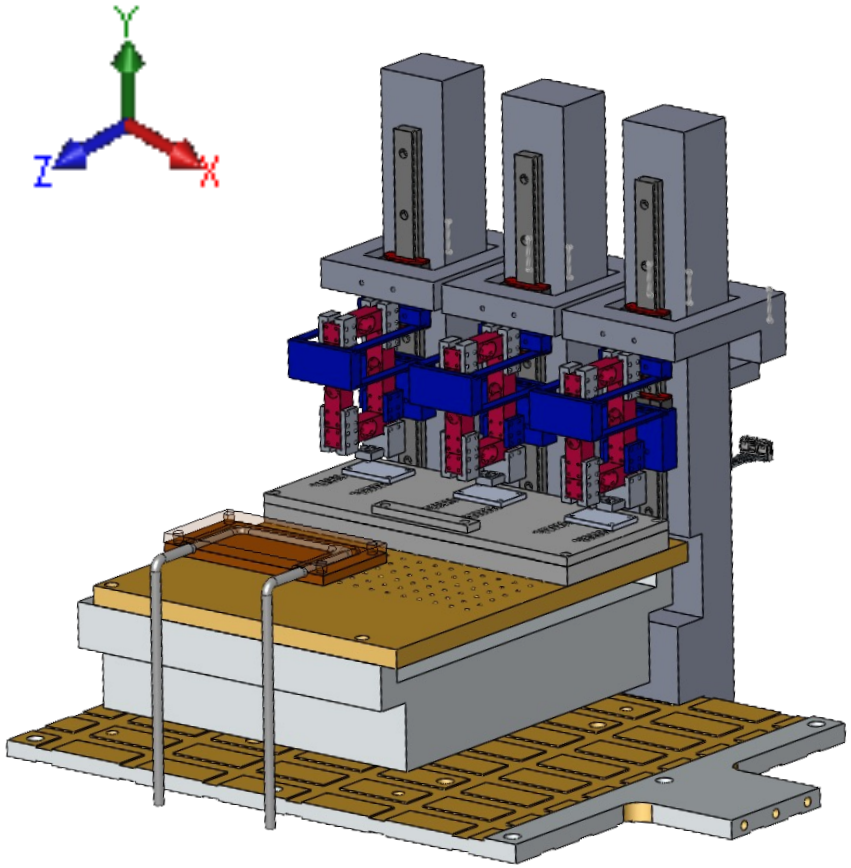


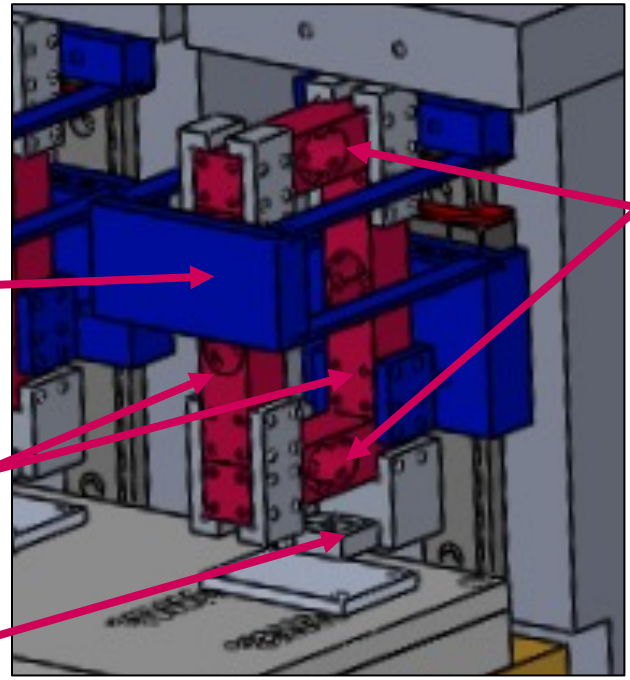




CAD Design: Iteration 3

Load head needed revision.





Leaf spring assembly

Friction force

Sample holder

Normal force

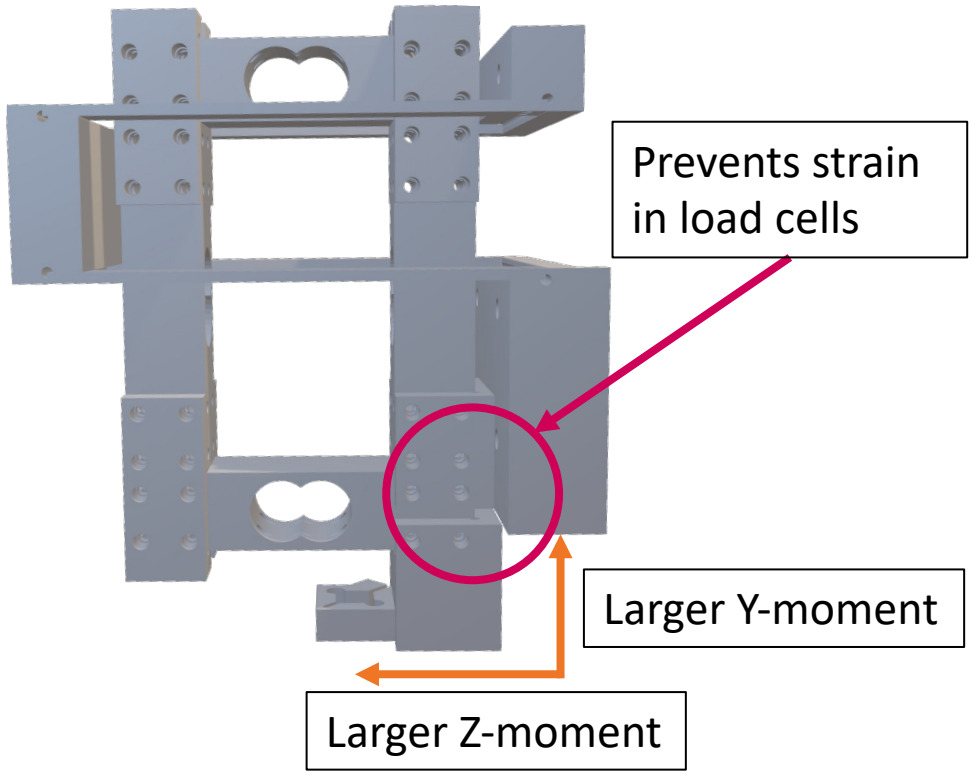
Load cell

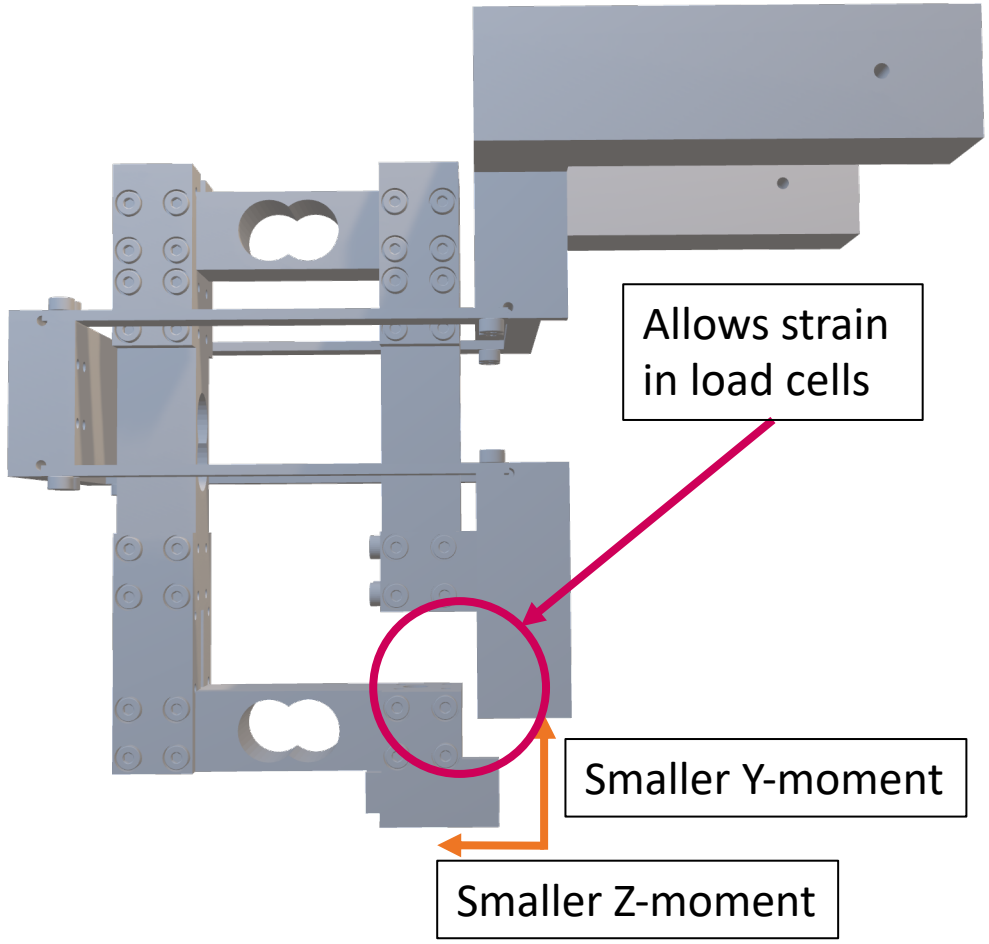
Leaf spring

Load Head Revision

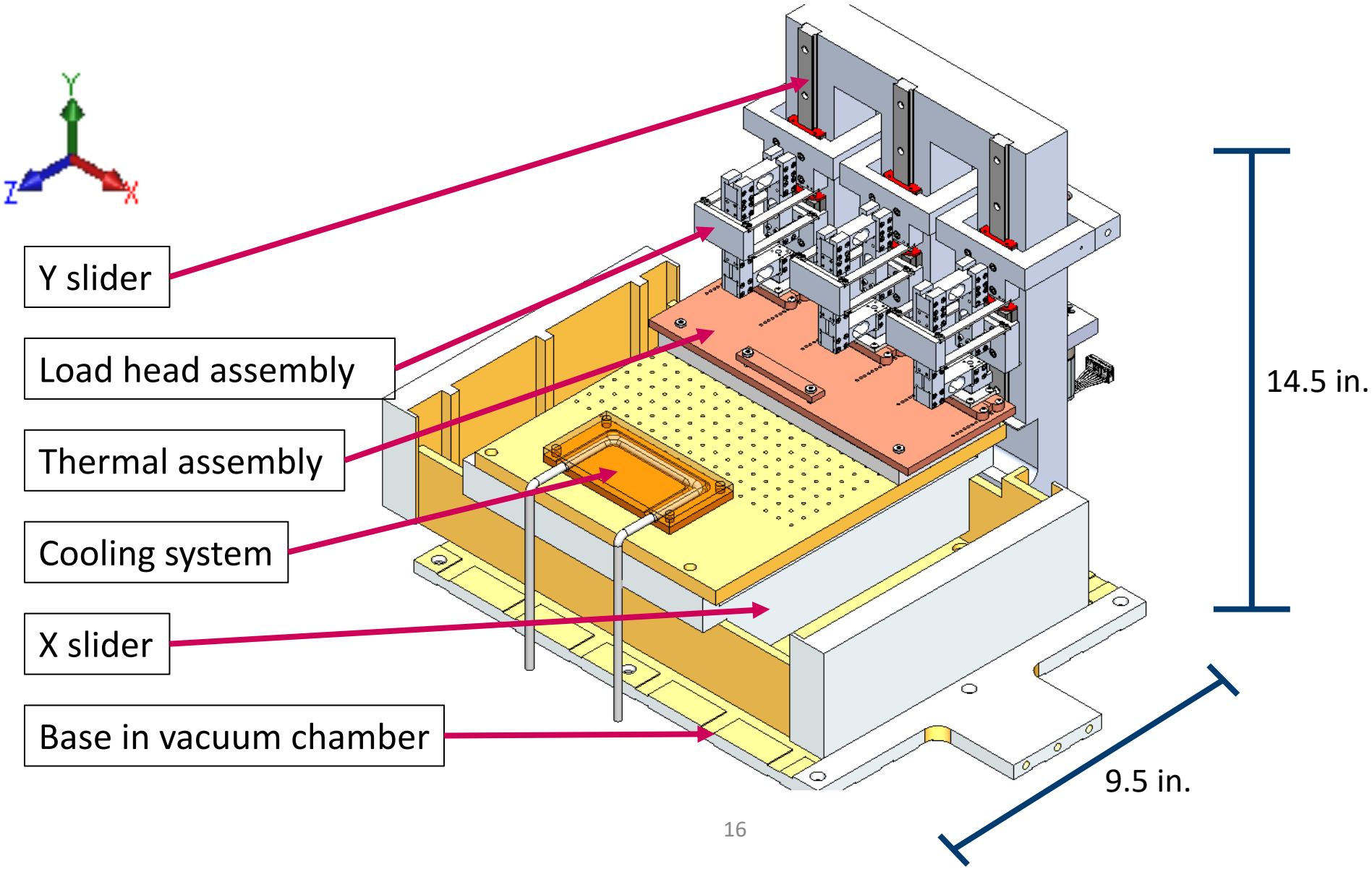
Disconnected the bottom load cell.

Inverted sample holder.

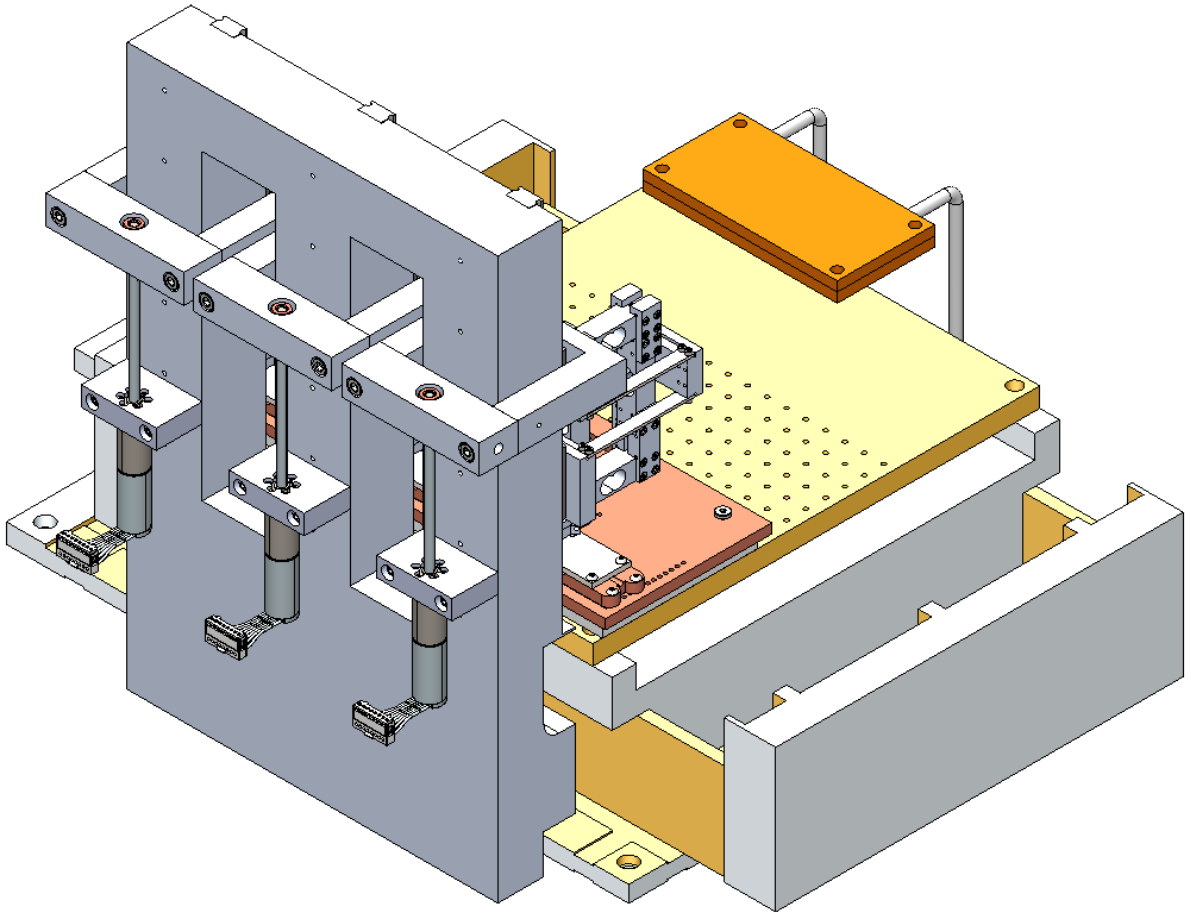


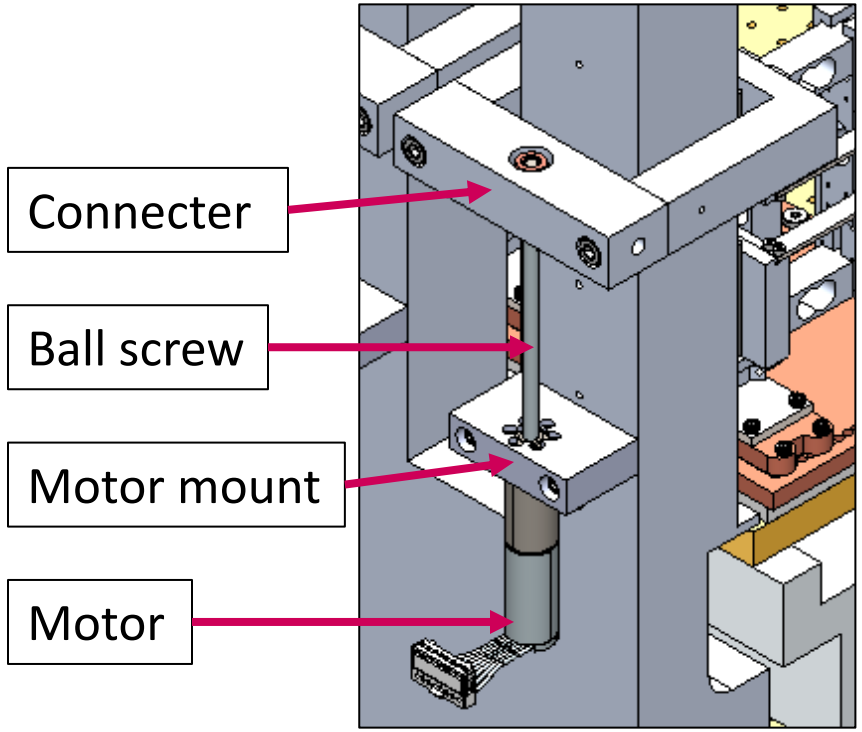


Final Design: Iteration 4

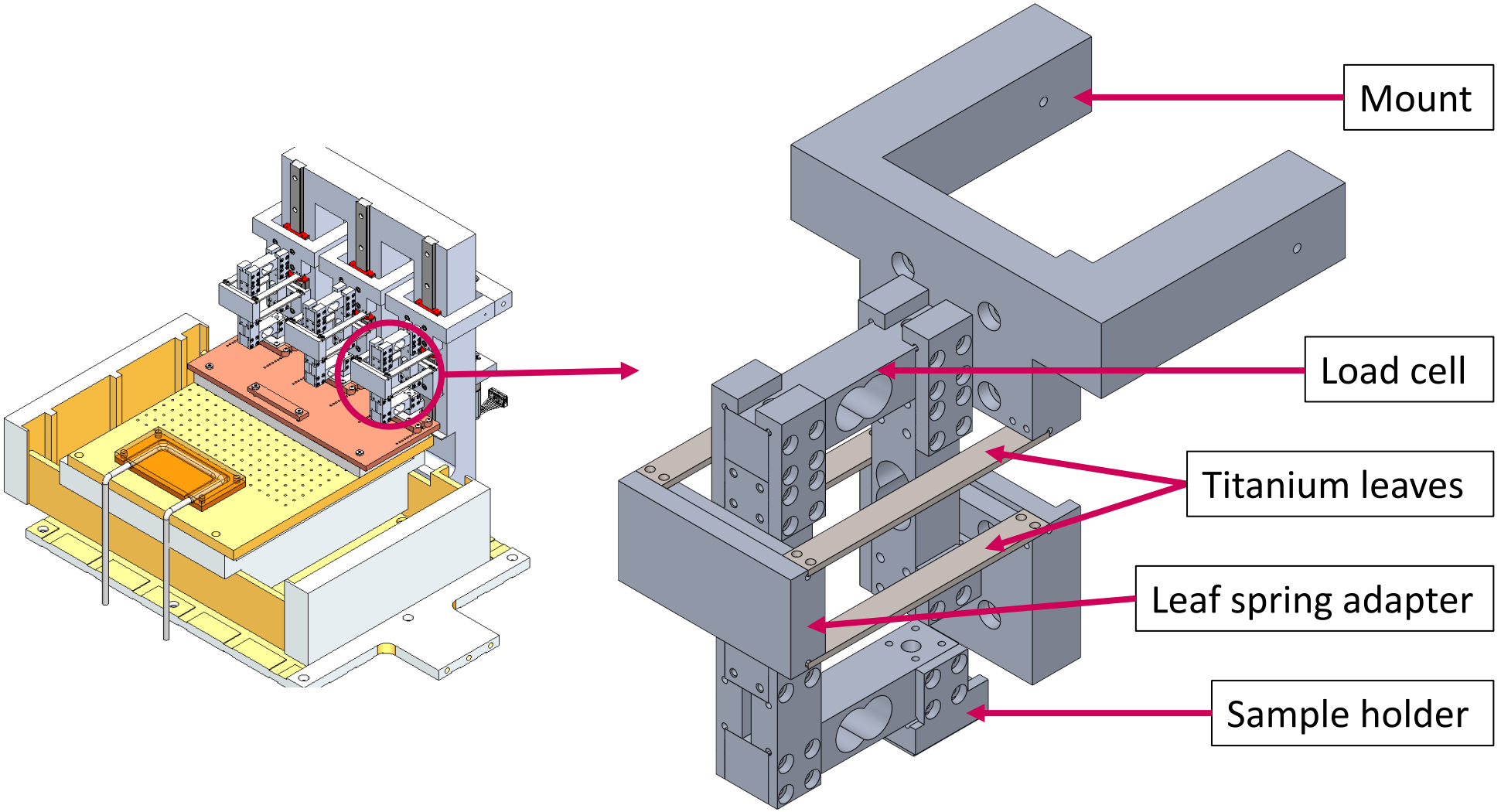


Final Design: Iteration 4



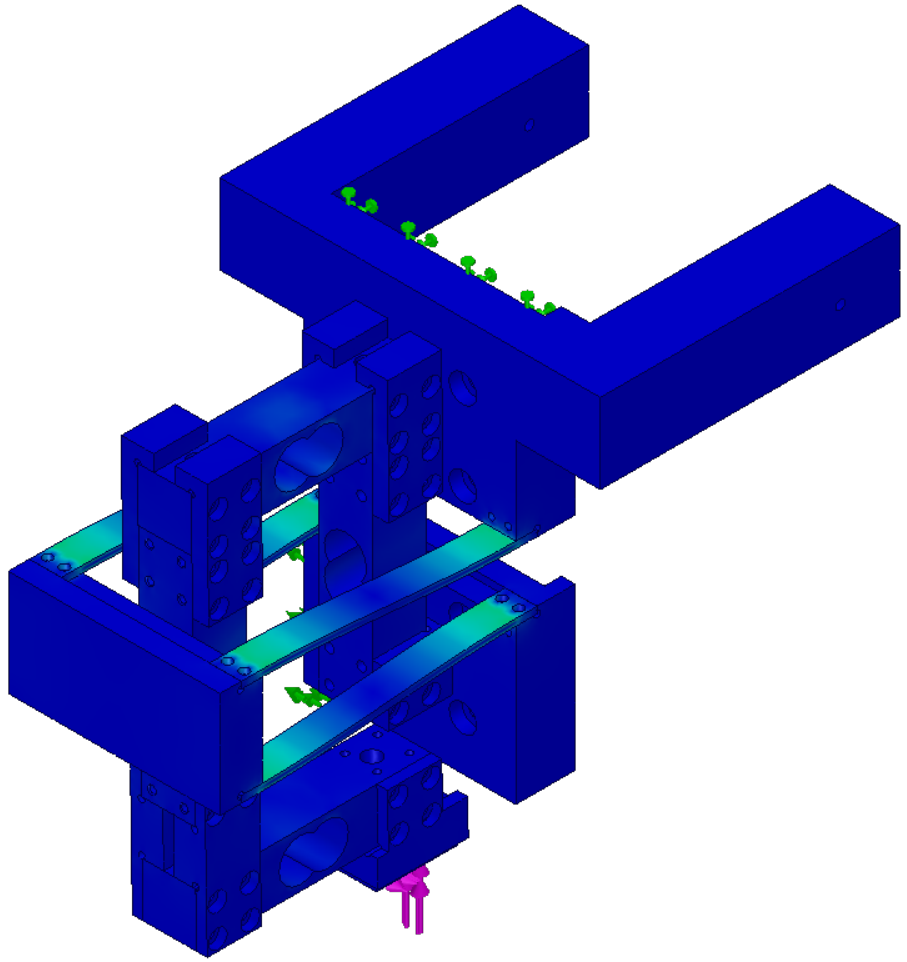


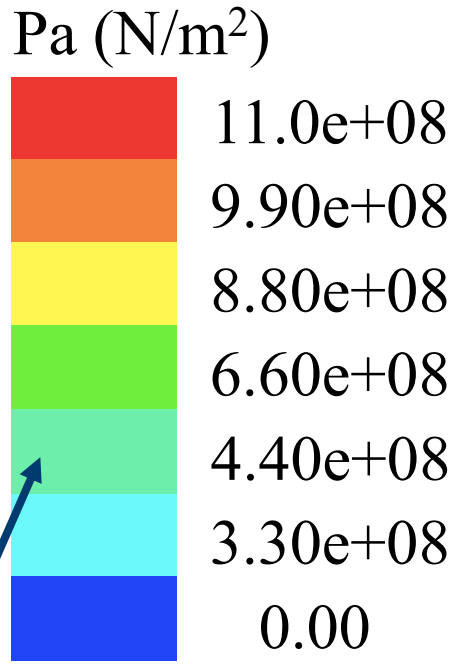
Final Design: Load Head



FEA: Stress

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

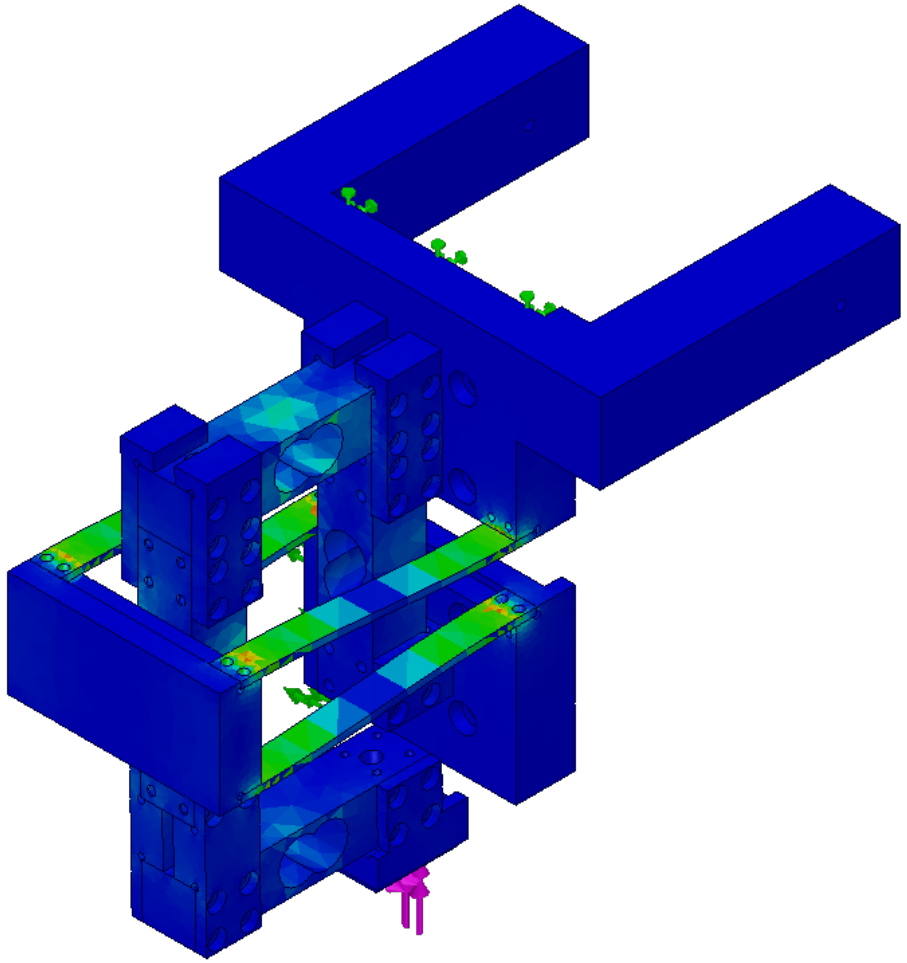


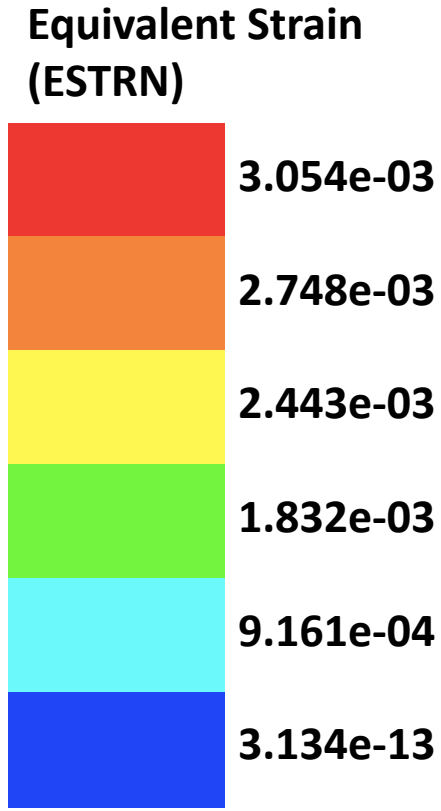


- Max stress: ~4.40e+08 Pa
- Titanium Leaves Yield Strength: ~11e+08 Pa

FEA: Strain

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





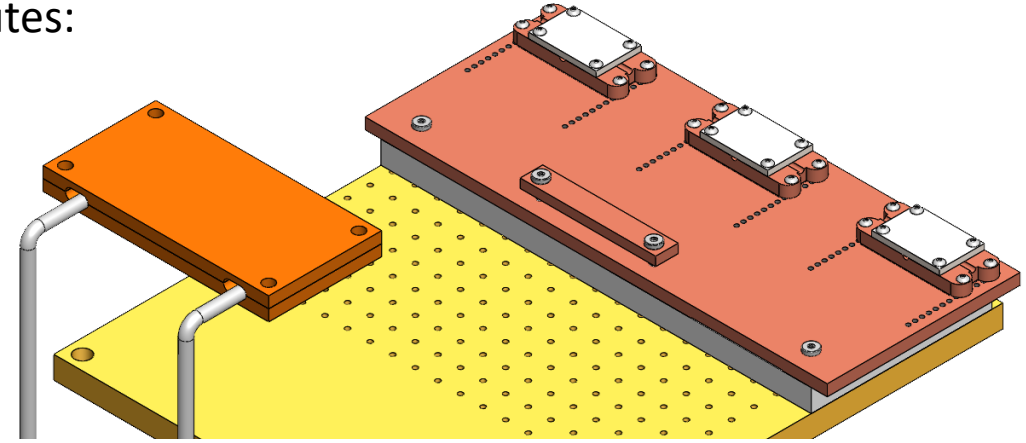
Thermal Assembly

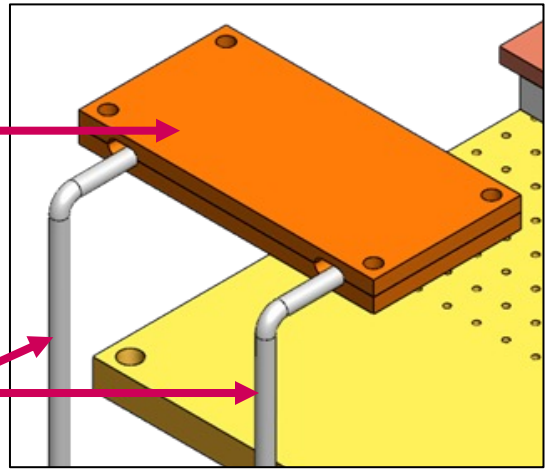
Heat to take material from -200C to 200C in 30 minutes:

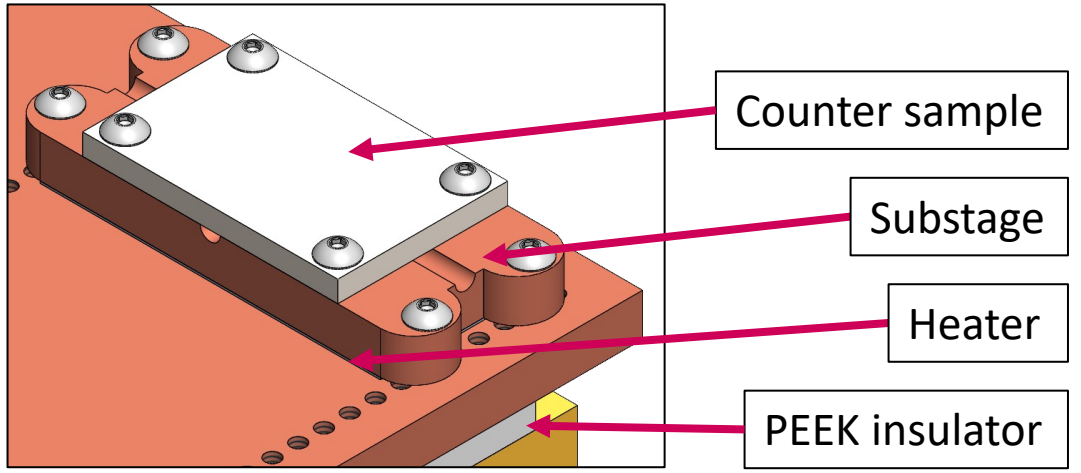
- Copper substage = 6.28 Watts
- Aluminum counter sample = 1.95 Watts

Maximum heater output is 88 Watts so,

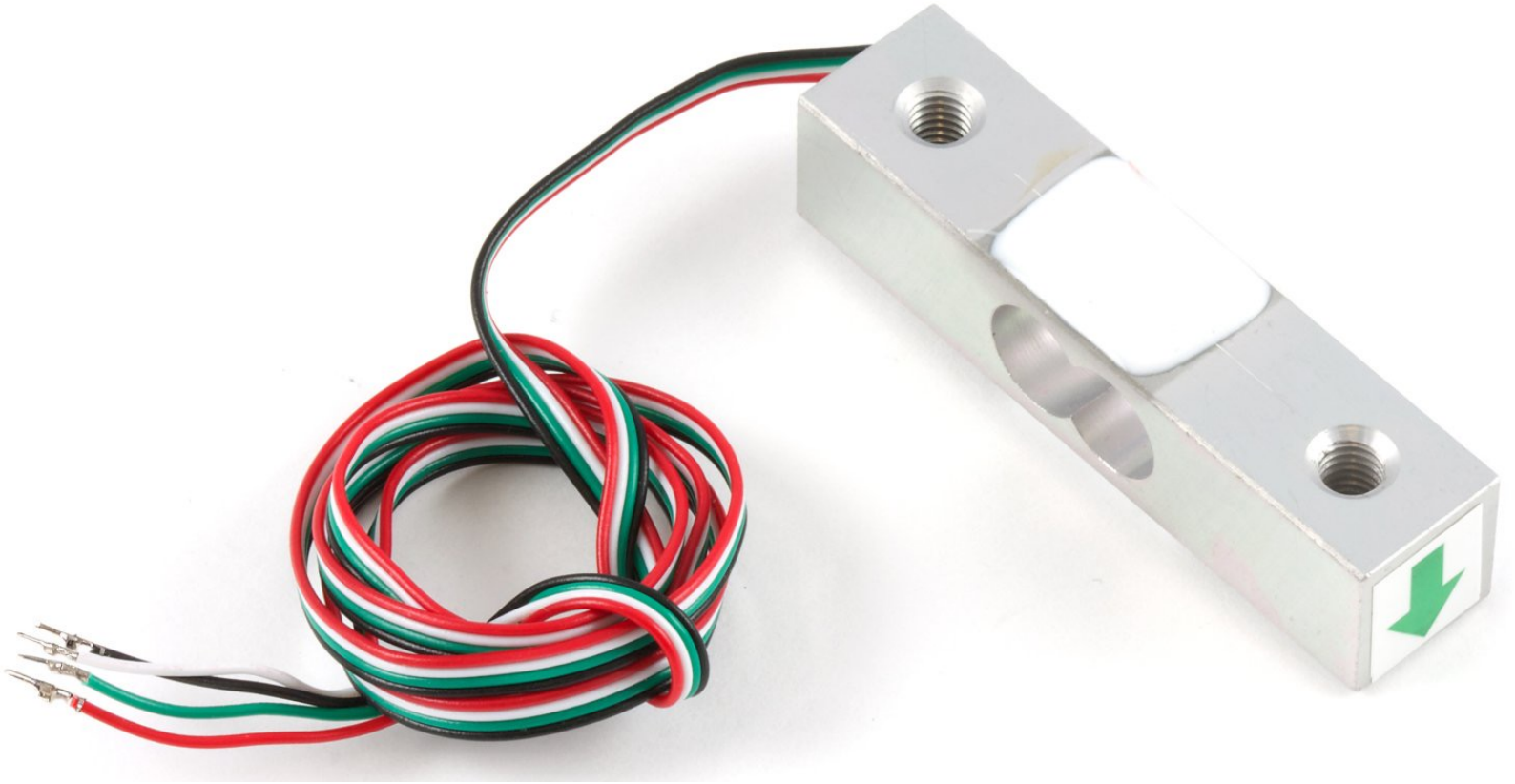
- $Q_{heater} > Q_{copper} + Q_{aluminum}$





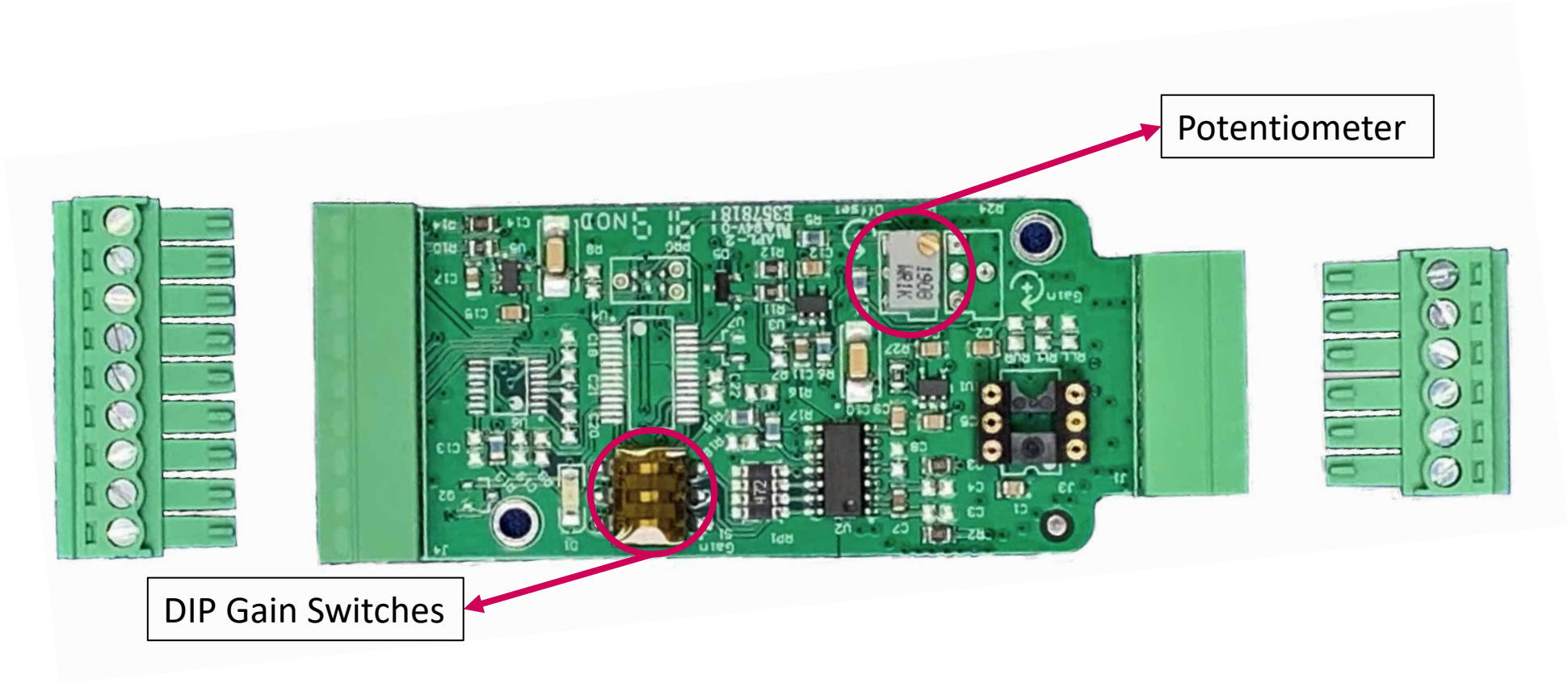


Load Cell



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

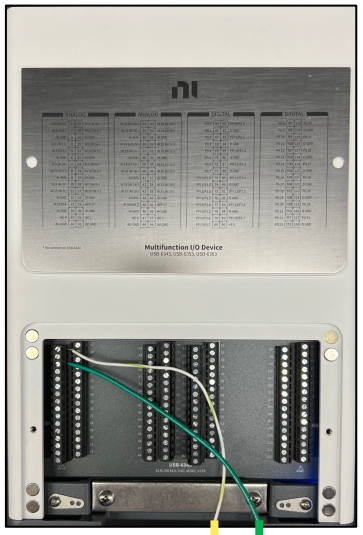
Amplifier/Signal Conditioner



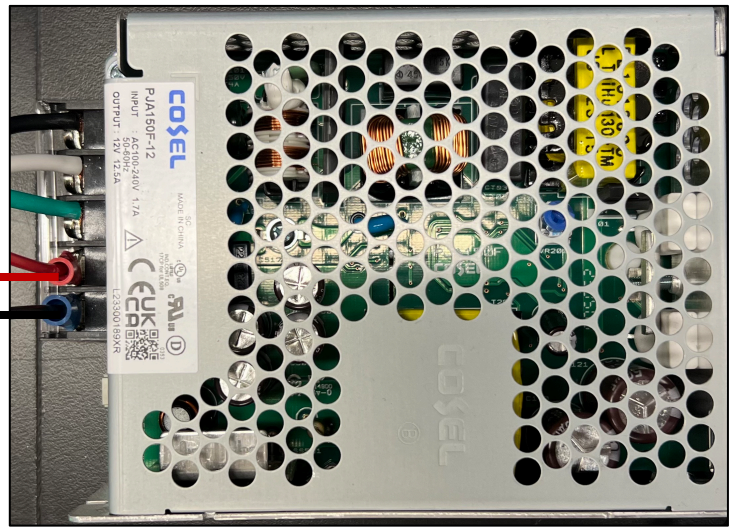
Adjusting the gain increases the signal while decreasing signal noise.

Calibrating the Load Cells

DAQ system



Power supply

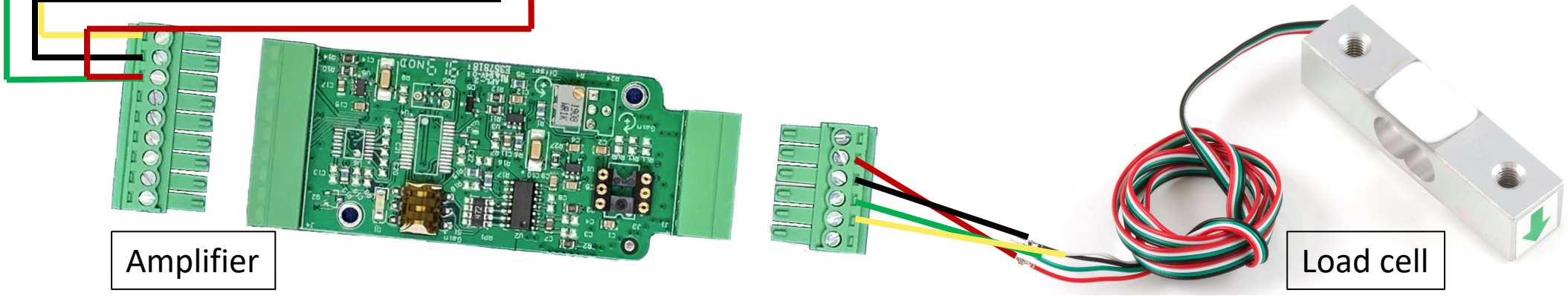


Negative Voltage

Positive Voltage

Signal

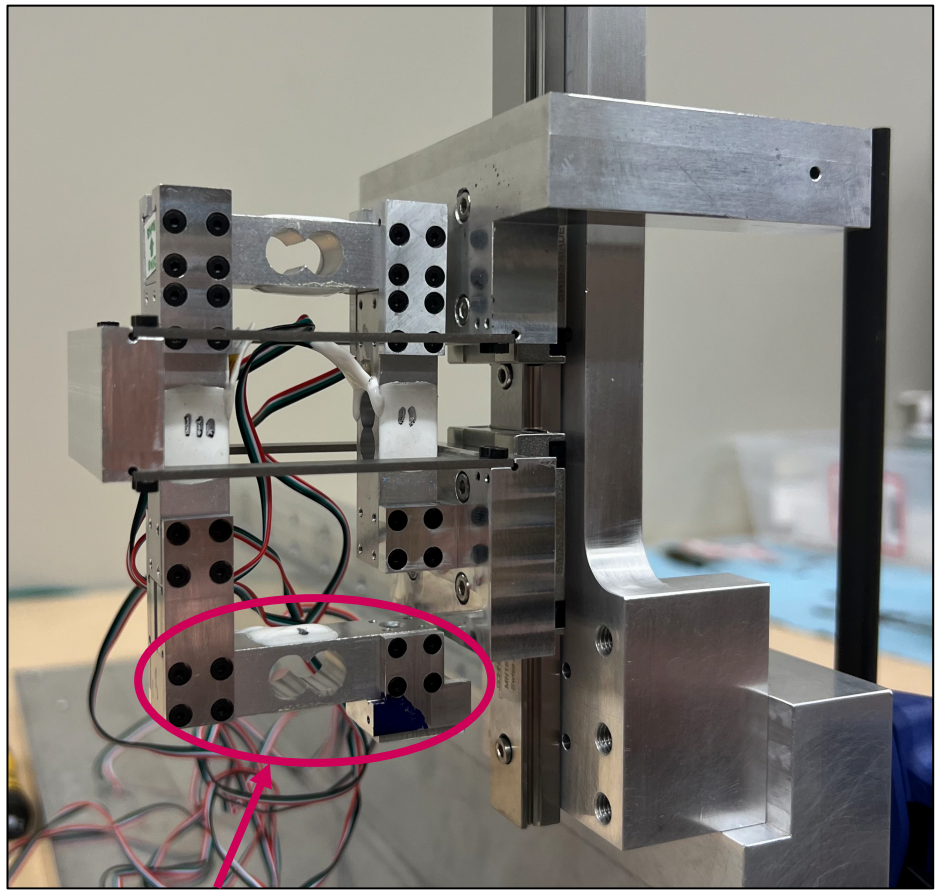
Ground



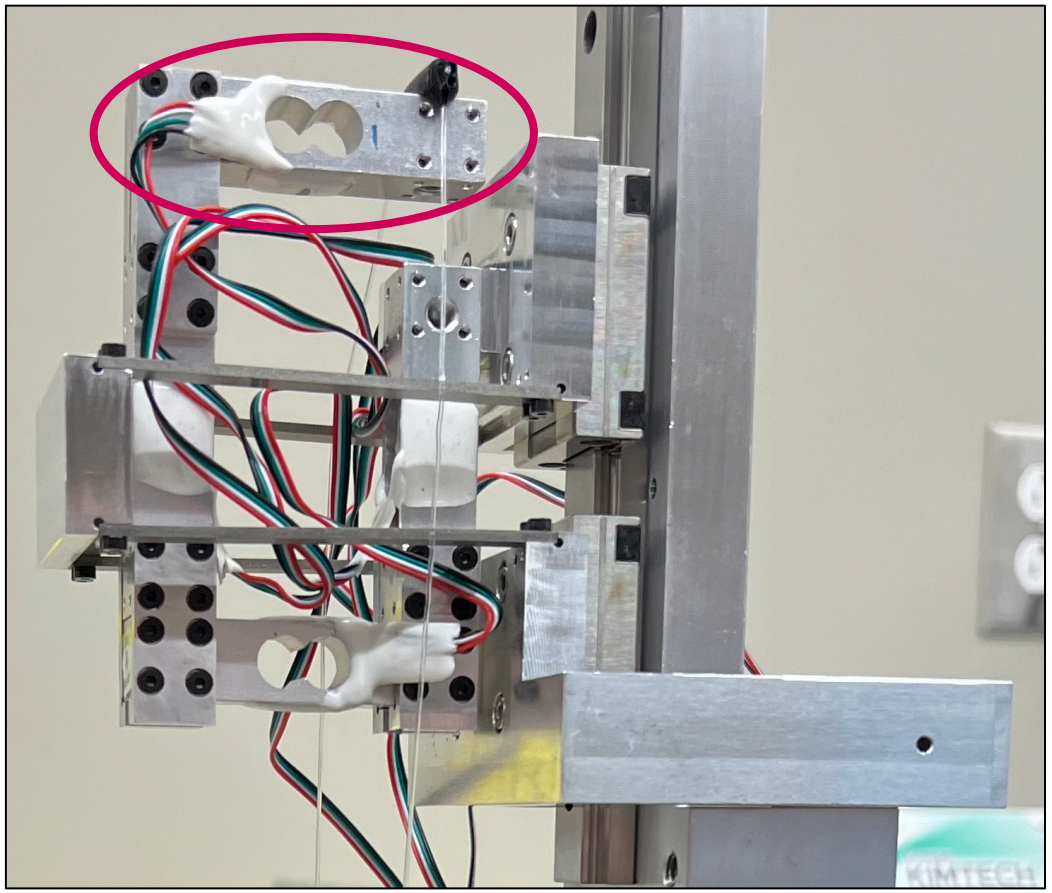
Amplifier

Load cell

Calibrating the Load Cells in the Assembly

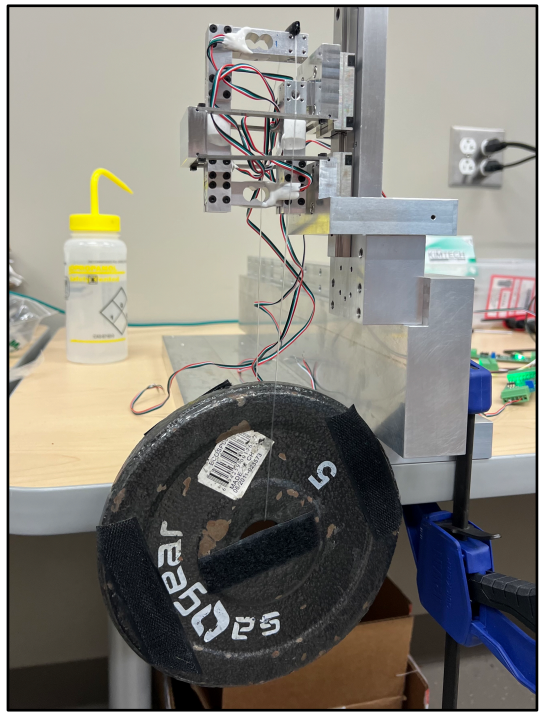


Load cell being calibrated needs to be in this position.

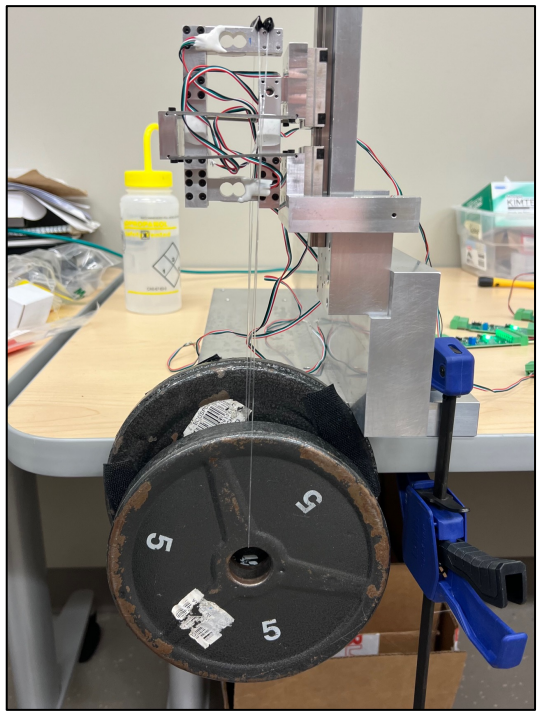


To calibrate that position with the correct force applied, the assembly had to be inverted.

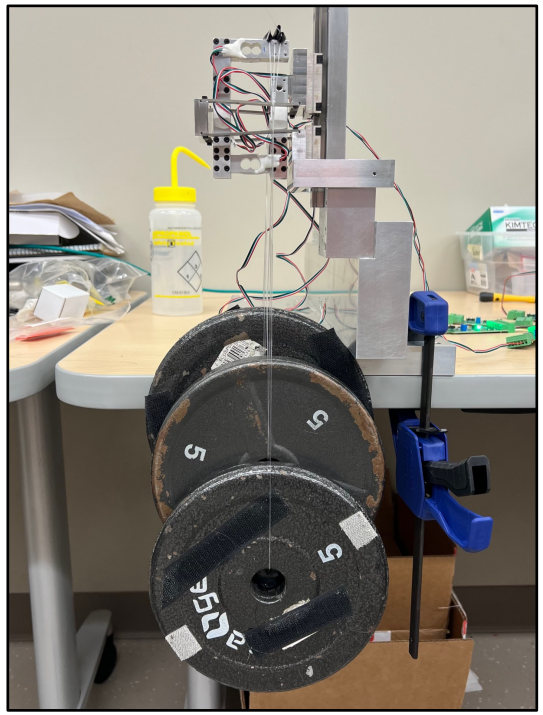
Calibrating the Load Cells in the Assembly



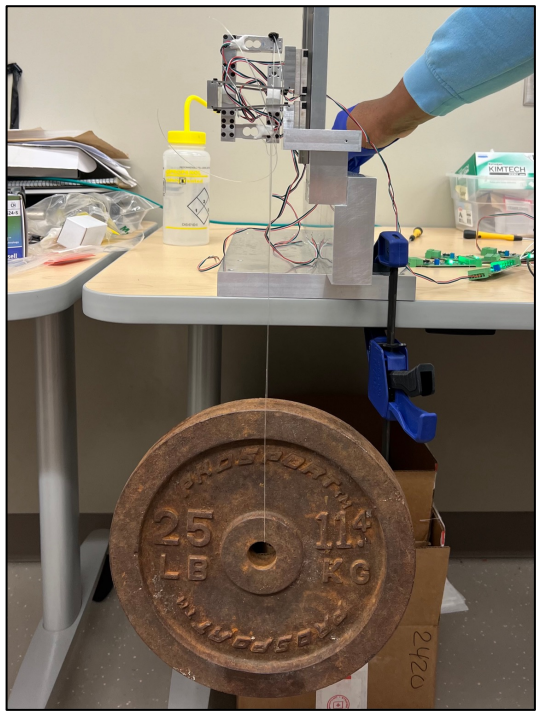
5 lbs



10 lbs

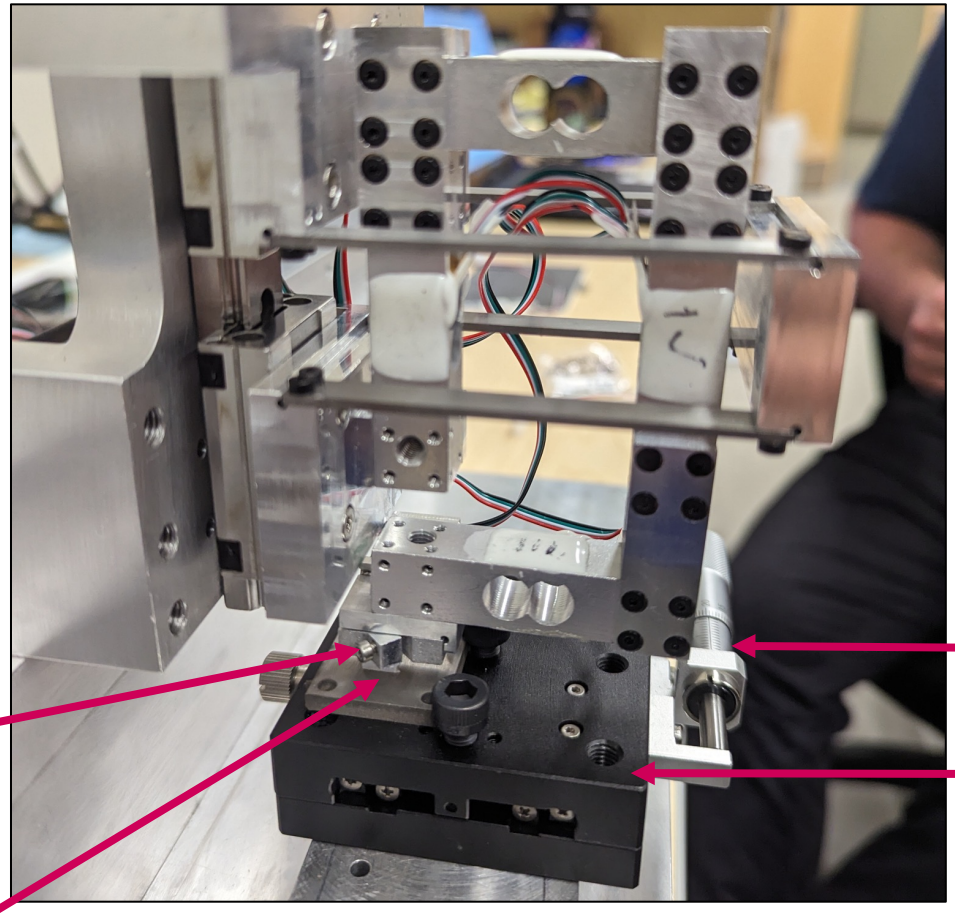


15 lbs



25 lbs

Friction Test: PTFE vs 440C Stainless Steel



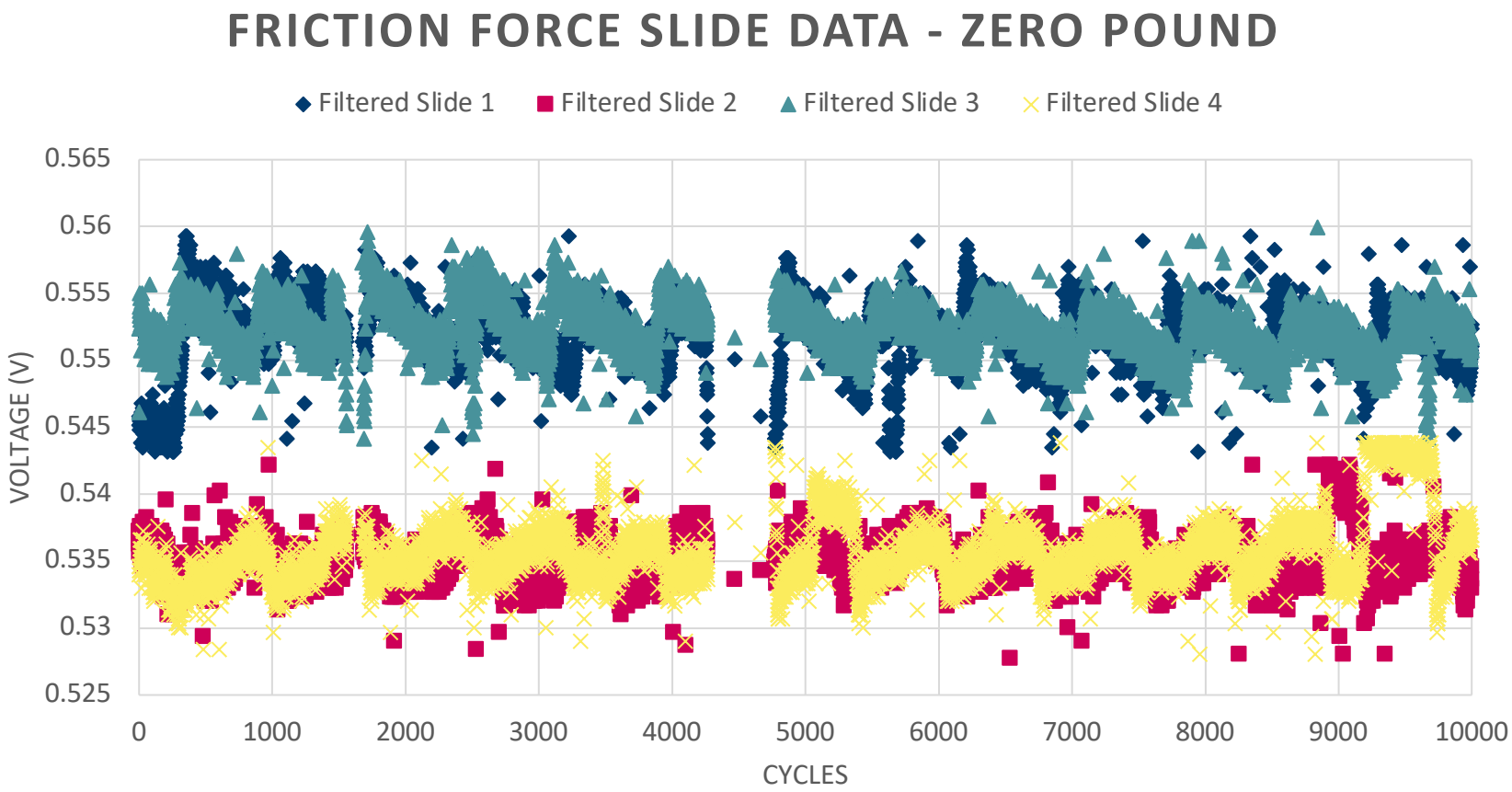
PTFE sample

440C stainless steel counter sample

Hand crank

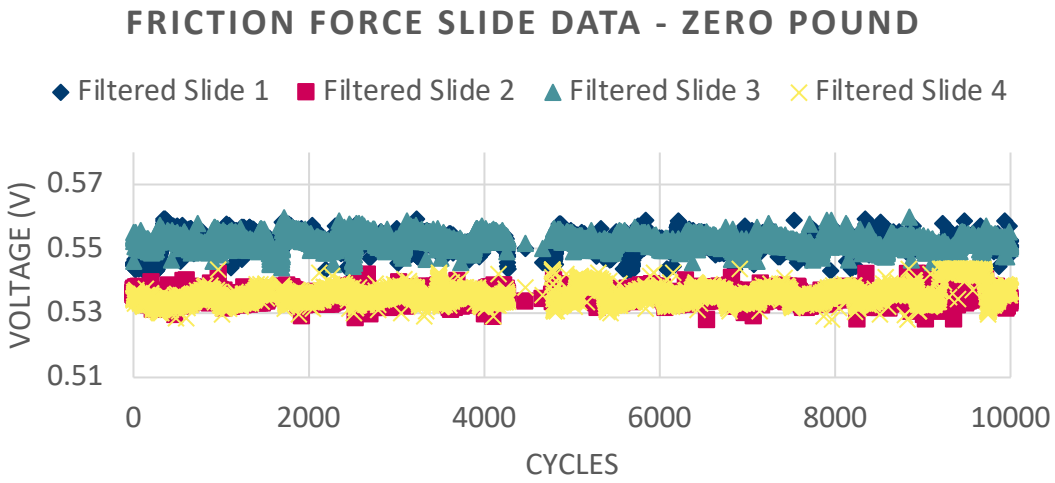
Stage

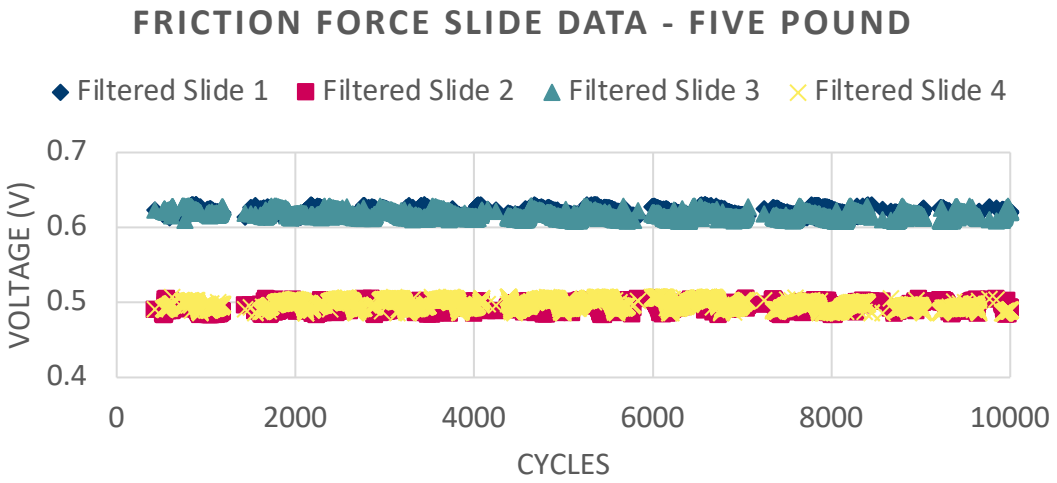
Friction Force Load Cell Data

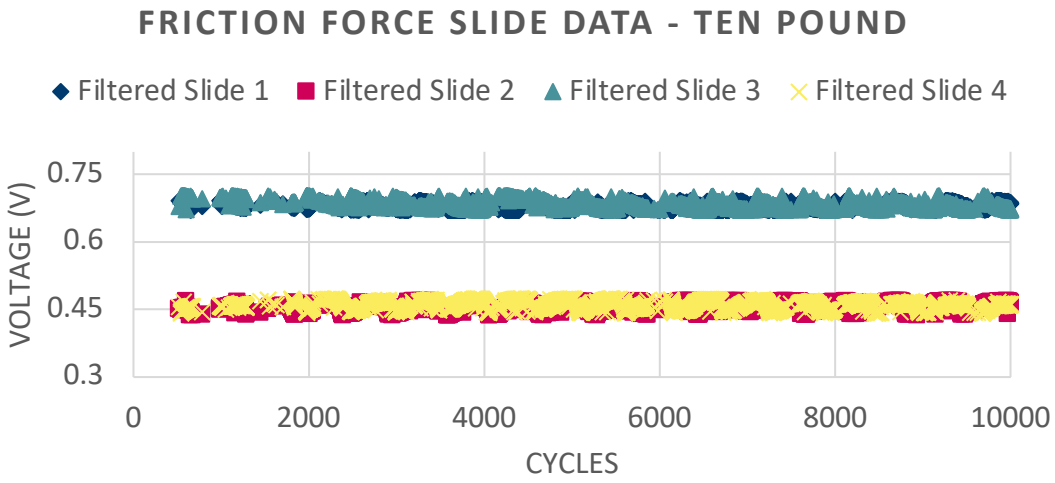


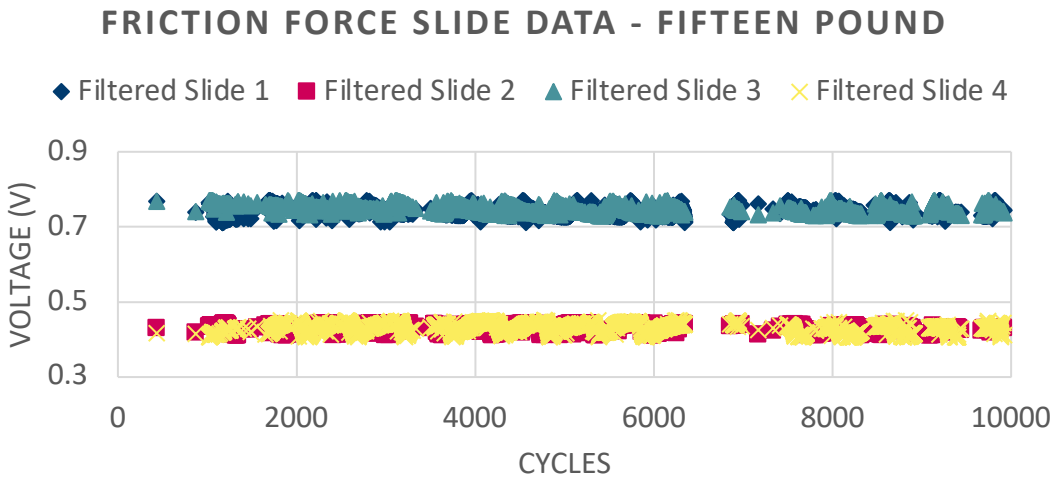
- Slides 1 and 3 are clockwise turning of the hand crank.
- Slides 2 and 4 are counterclockwise turning of the hand crank.
- The waves show a start and stop of each turn.

Friction Force Load Cell Data









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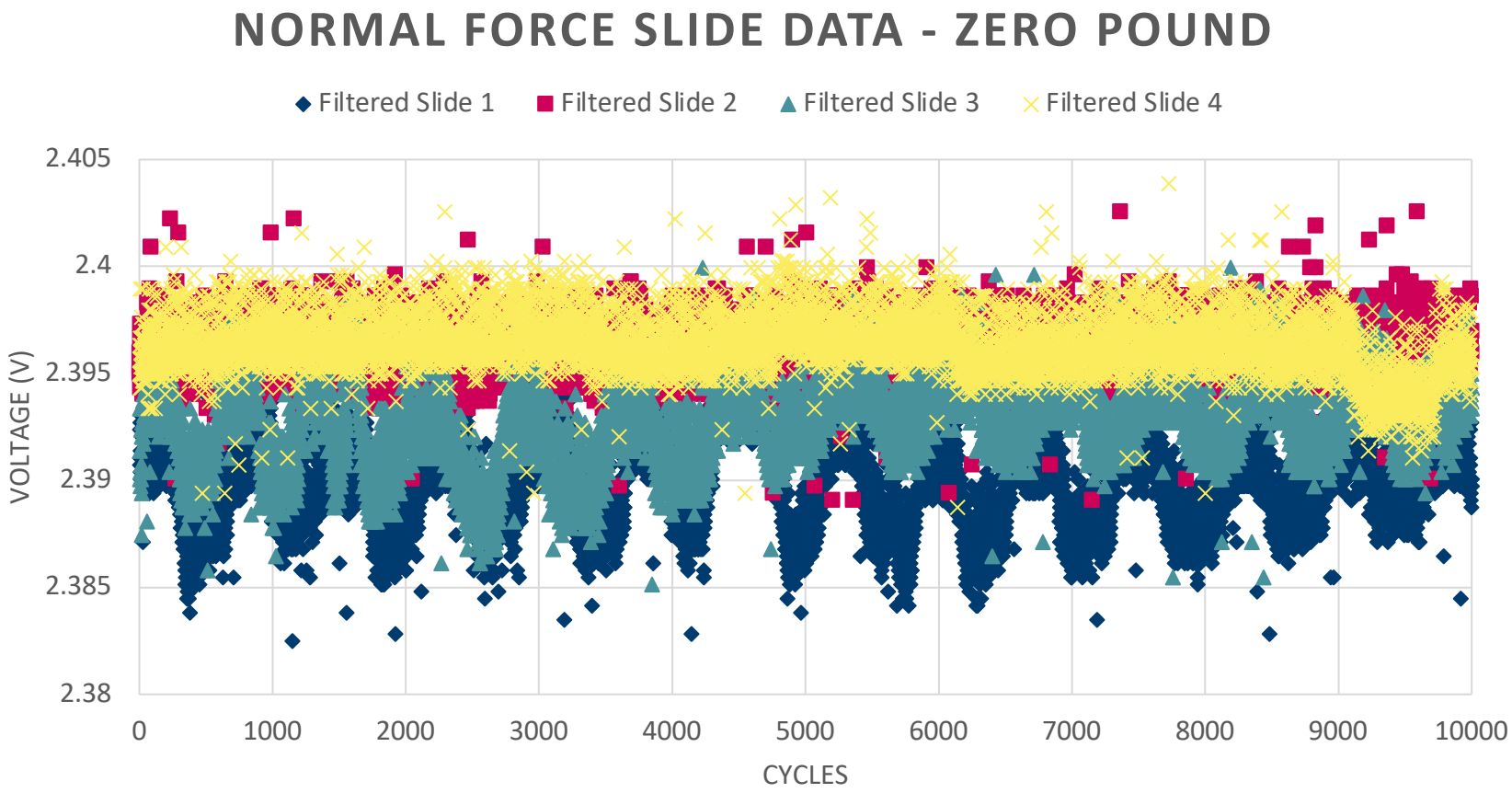
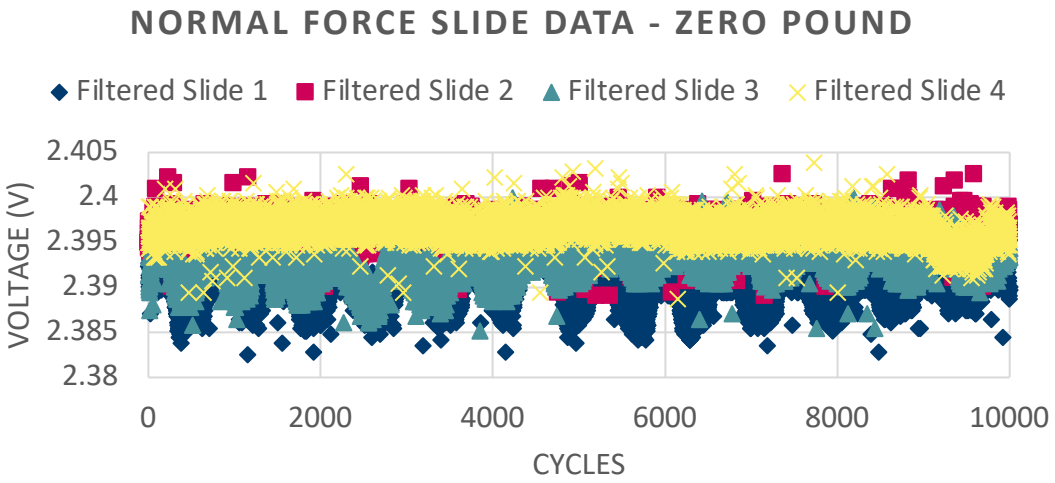
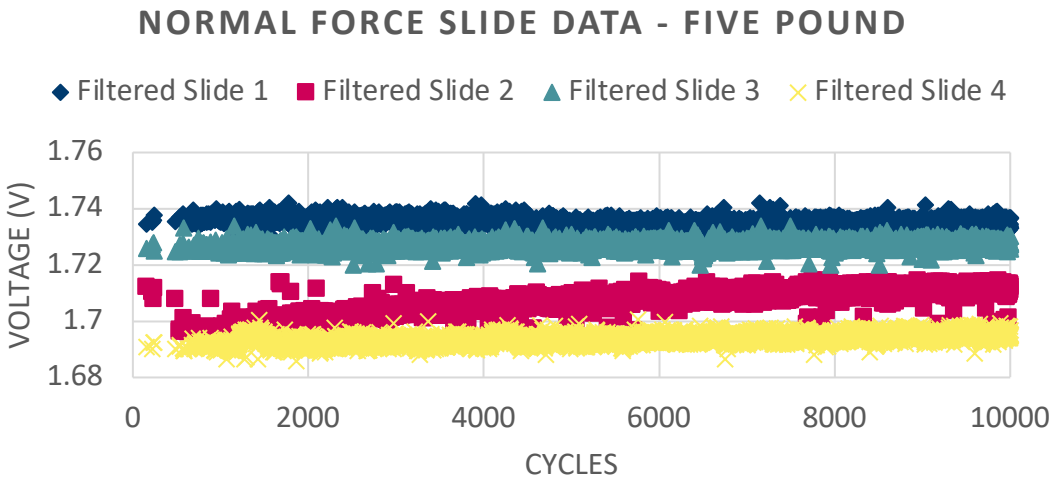
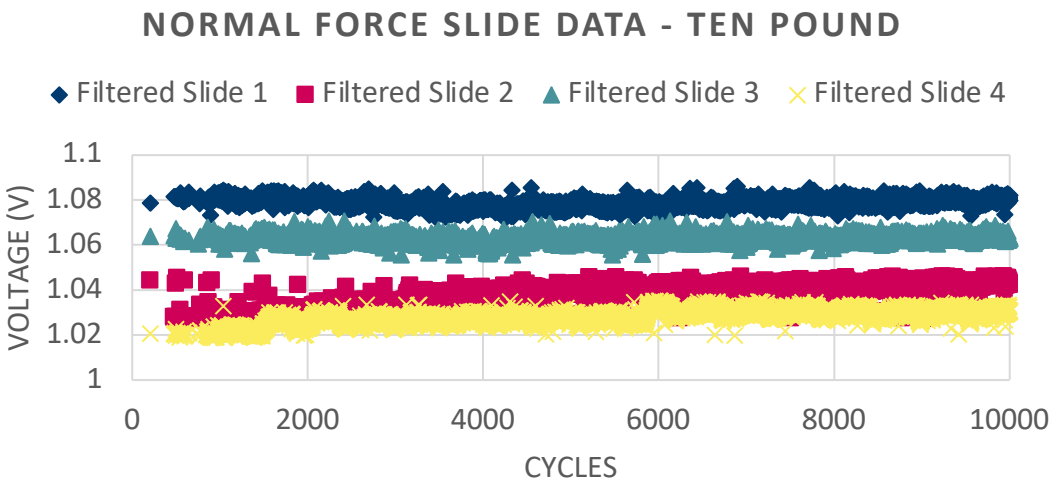
Normal Force Load Cell Data

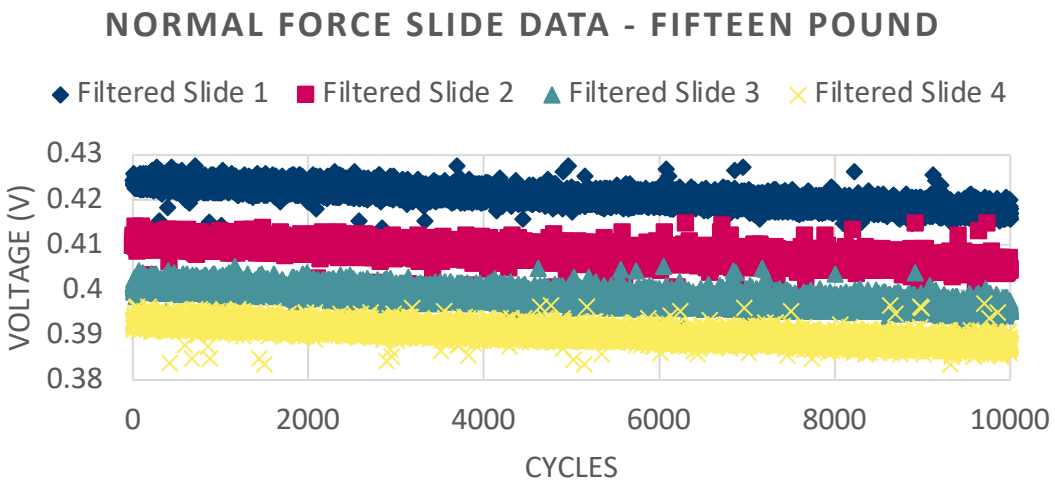


Normal Force Load Cell Data



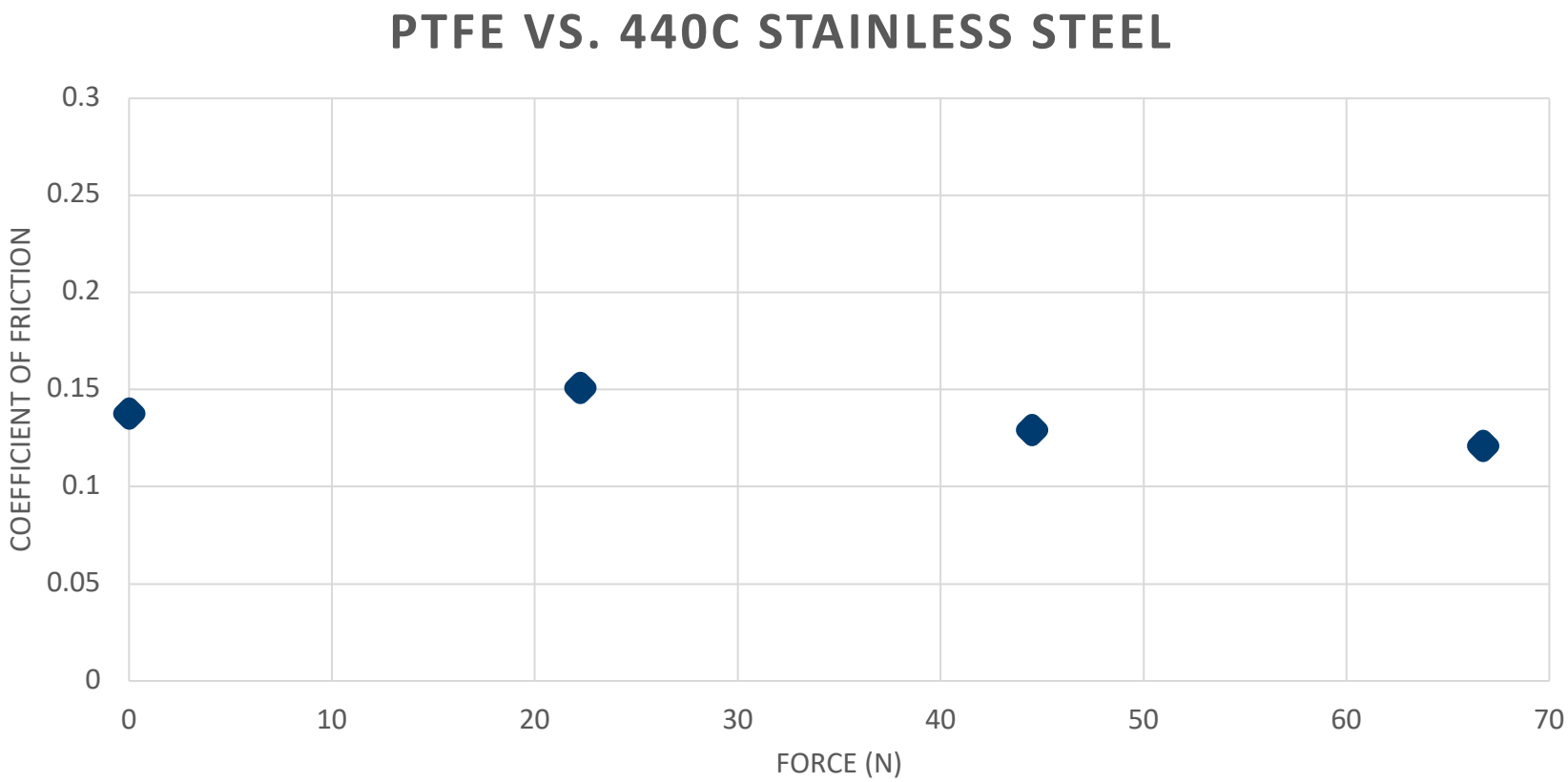






Coefficient of Friction Plot

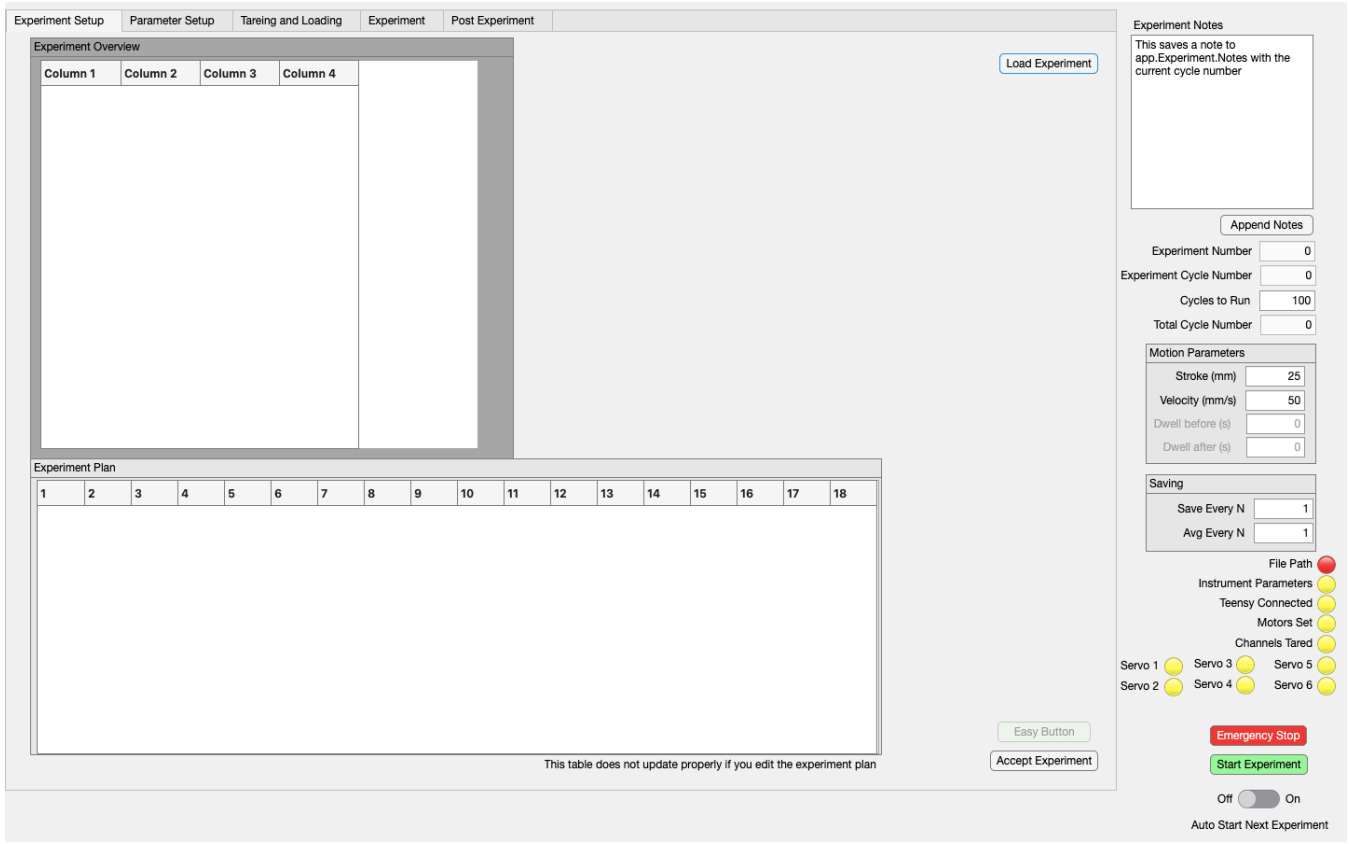
Test Results show a generally correct functionality of the load head design.

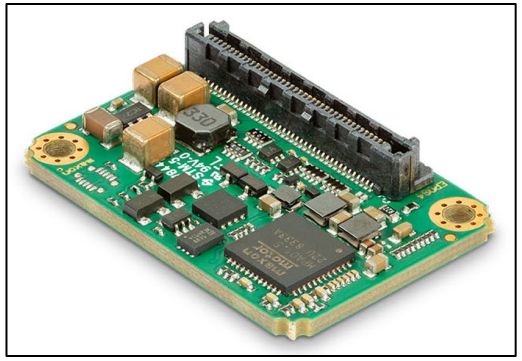


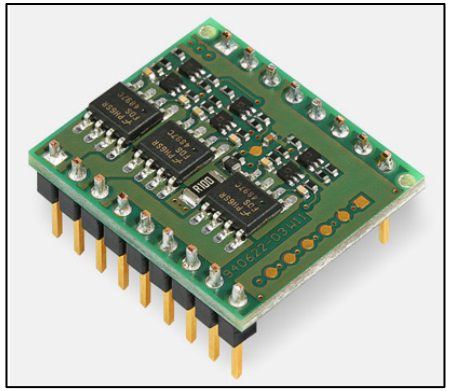
Our Average CoF: 0.13
Known PTFE CoF: 0.10 - 0.20

Madison Retherford

Using a MAXON Motor Controller with MATLAB







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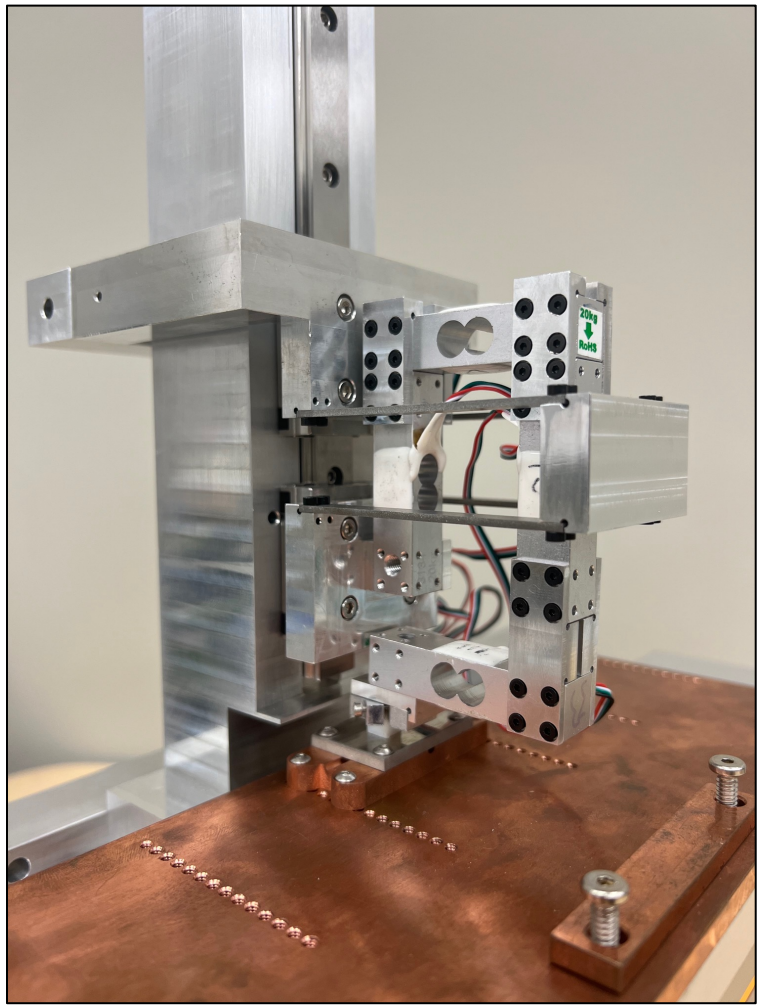
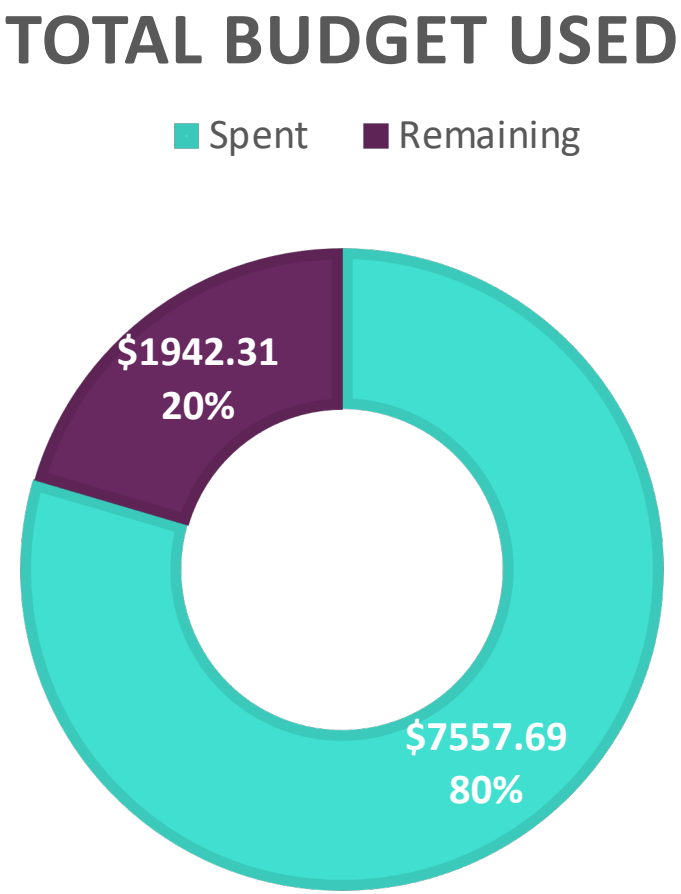
Future Work

- Adjust stage motor.
- Integrate motor control functionality with MATLAB.
- Automate test performed with the hand crank stage.
- Test critical loads with automation.

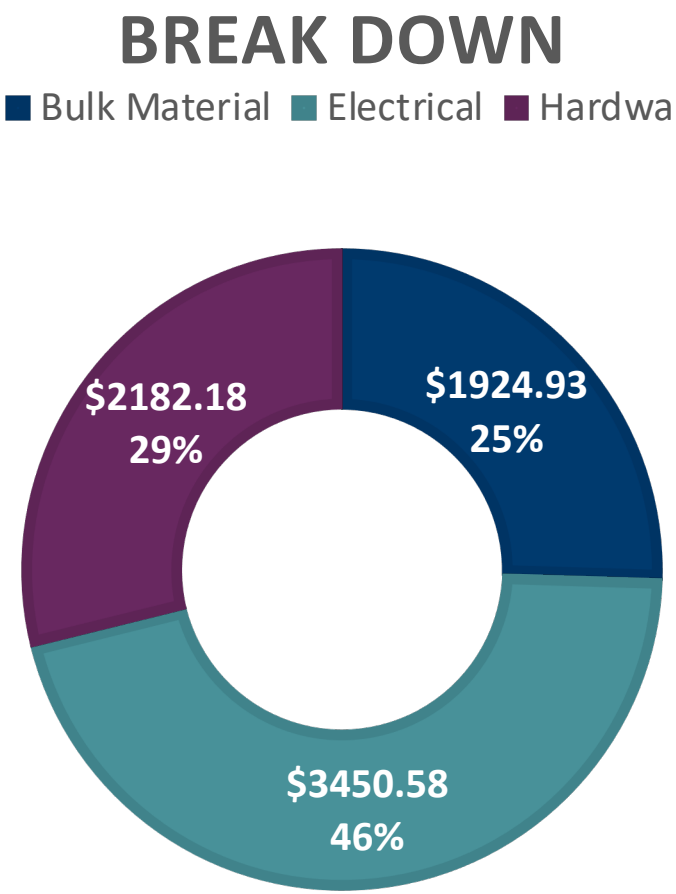


Budget

TOTAL BUDGET USED



BREAK DOWN



Lessons Learned

Communication is key.

Don’t be afraid to ask for advice.

Stay organized.

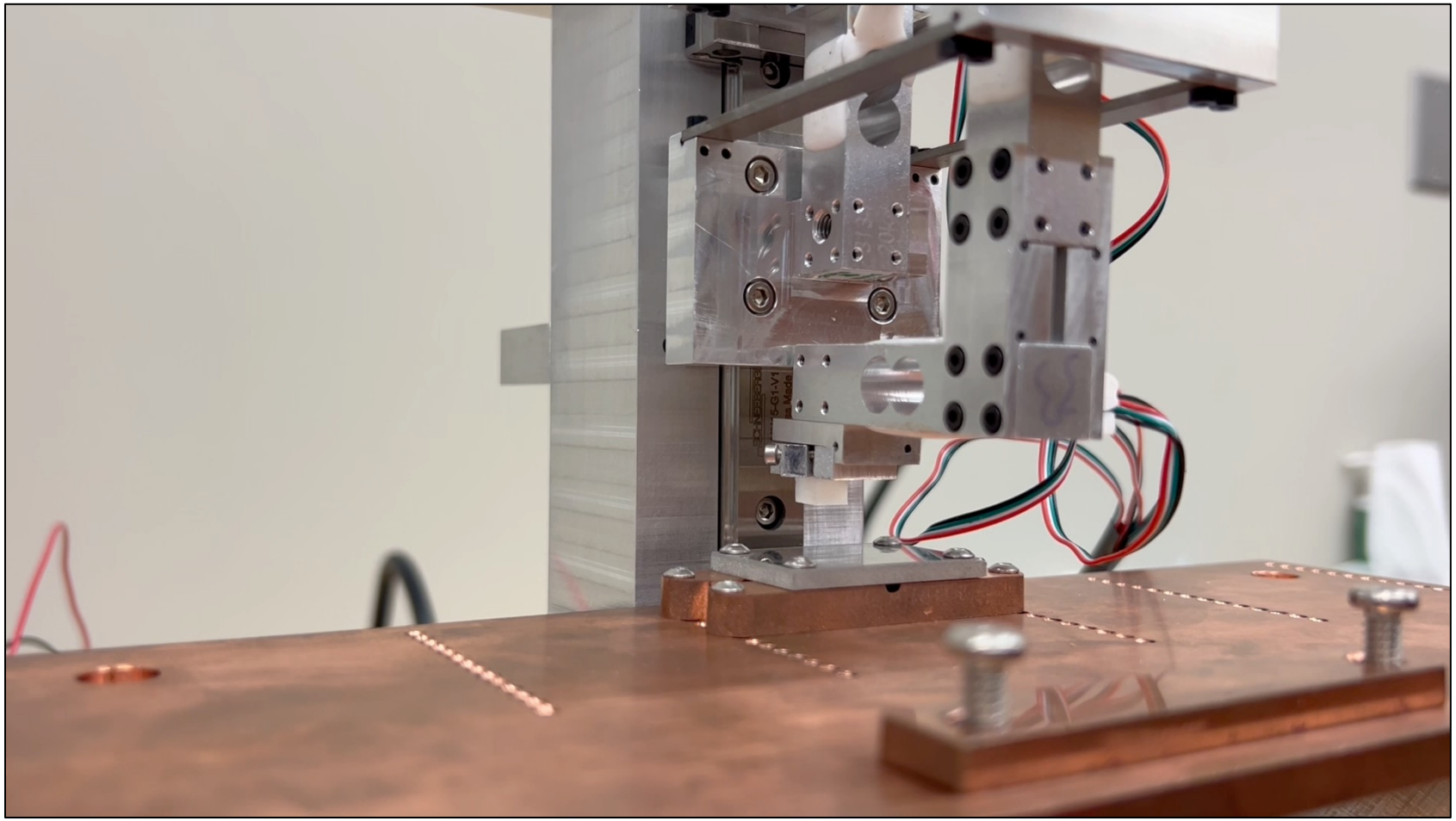
Be able to accept criticism.

Have a good file naming convention.

Everything takes longer than expected.

Make copies of everything.

Trust the process.



Questions?