NPOI Vacuum Manifold

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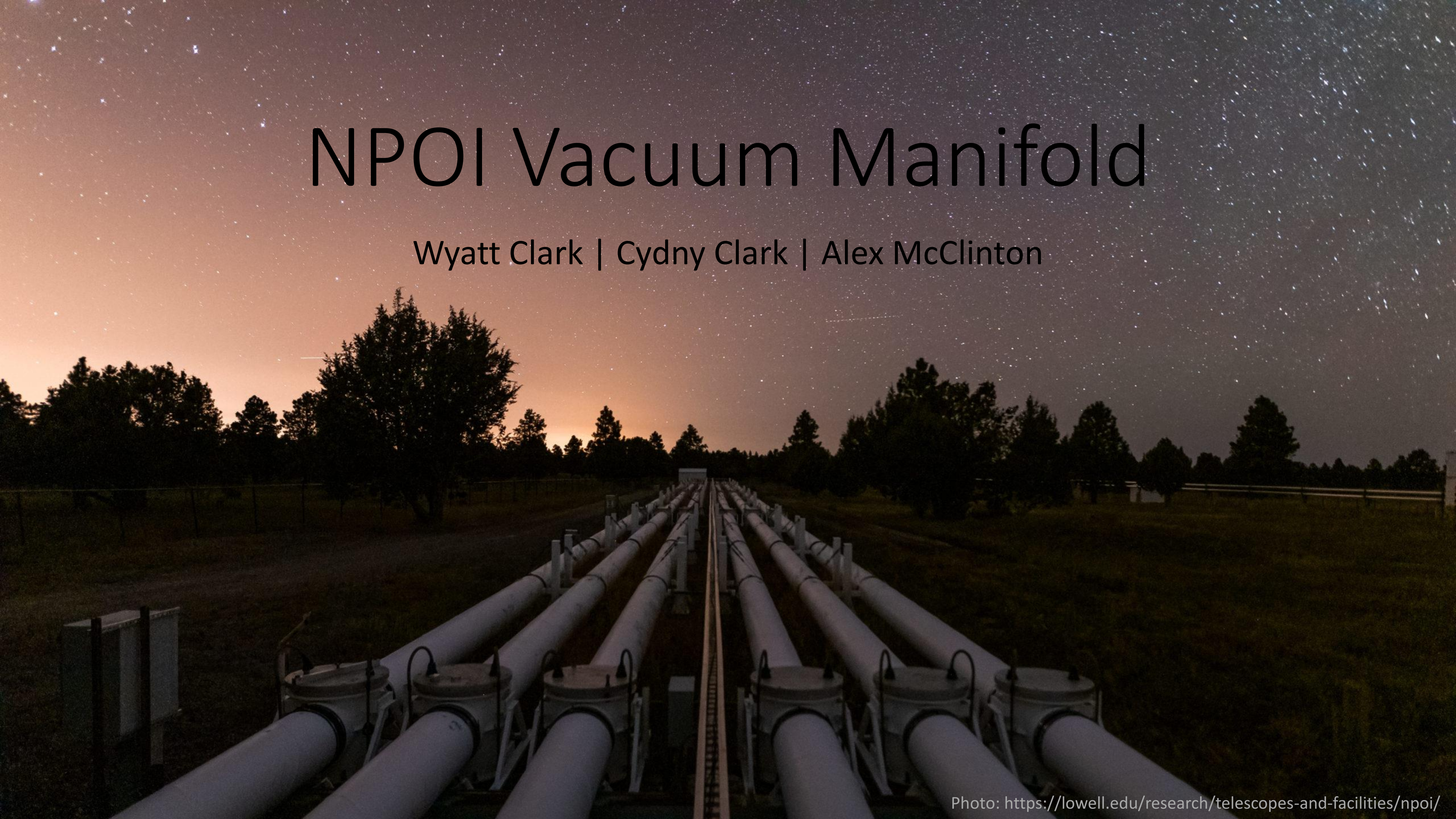


Photo: https://lowell.edu/research/telescopes-and-facilities/npoi/

Presentation Outline

- Project Description
  - Who is the client
  - Background information
- Benchmarking
  - Previous system
  - How we fit in
- New Design
  - CAD overview
  - Design iterations
- Manufacturing
  - Student work
- Implementation
  - Build and assembly
- Results
  - System performance
  - Comparison to benchmarks

Our Clients

The Navy Precision Optical interferometer (NPOI) is a Navy instrument in collaboration with long term contractor Lowell Observatory. Jim Clark is the primary client representing all three organizations. He is also the current director of NPOI.

Background Information

- NPOI is the world's largest optical interferometer with a 430-meter footprint
- It is a system of up to 6 small telescopes that work together to synthesize a much larger telescope
- Star light collected by the telescopes travels through a large vacuum array to a detector
- Parts of the vacuum system require redesign to increase safety and relatability

https://www.google.com/maps/@35.0965761,-111.5337258,600m/data=!3m1!1e3

Previous system

The six fast delay line vacuum tubes

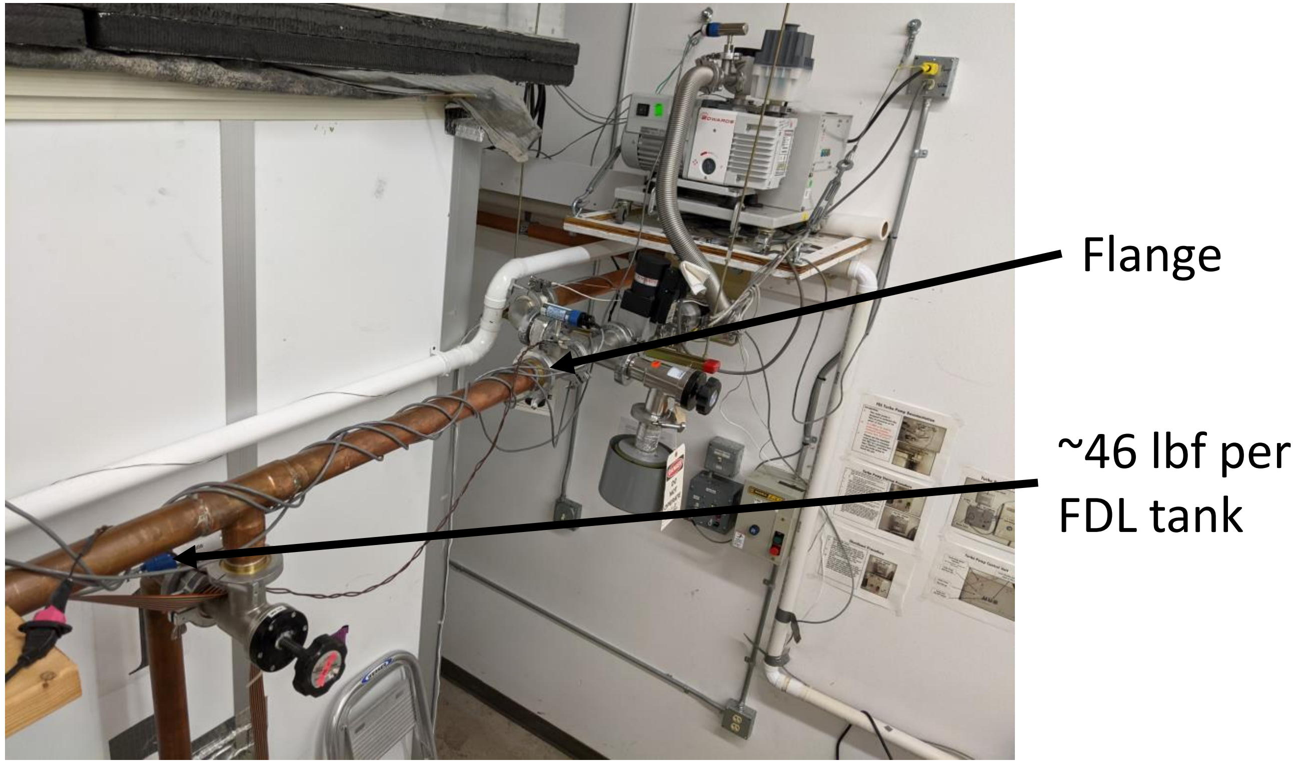
- NPOI utilizes two types of light path delay lines. The left image features the “Fast Delay Lines” (FDLs) which are held under vacuum
- The Capstone Team was tasked with mechanically interfacing with all six FDLs
- The interface must bridge the vacuum pump system with the delay lines and isolate each delay line from each other.

Previous system

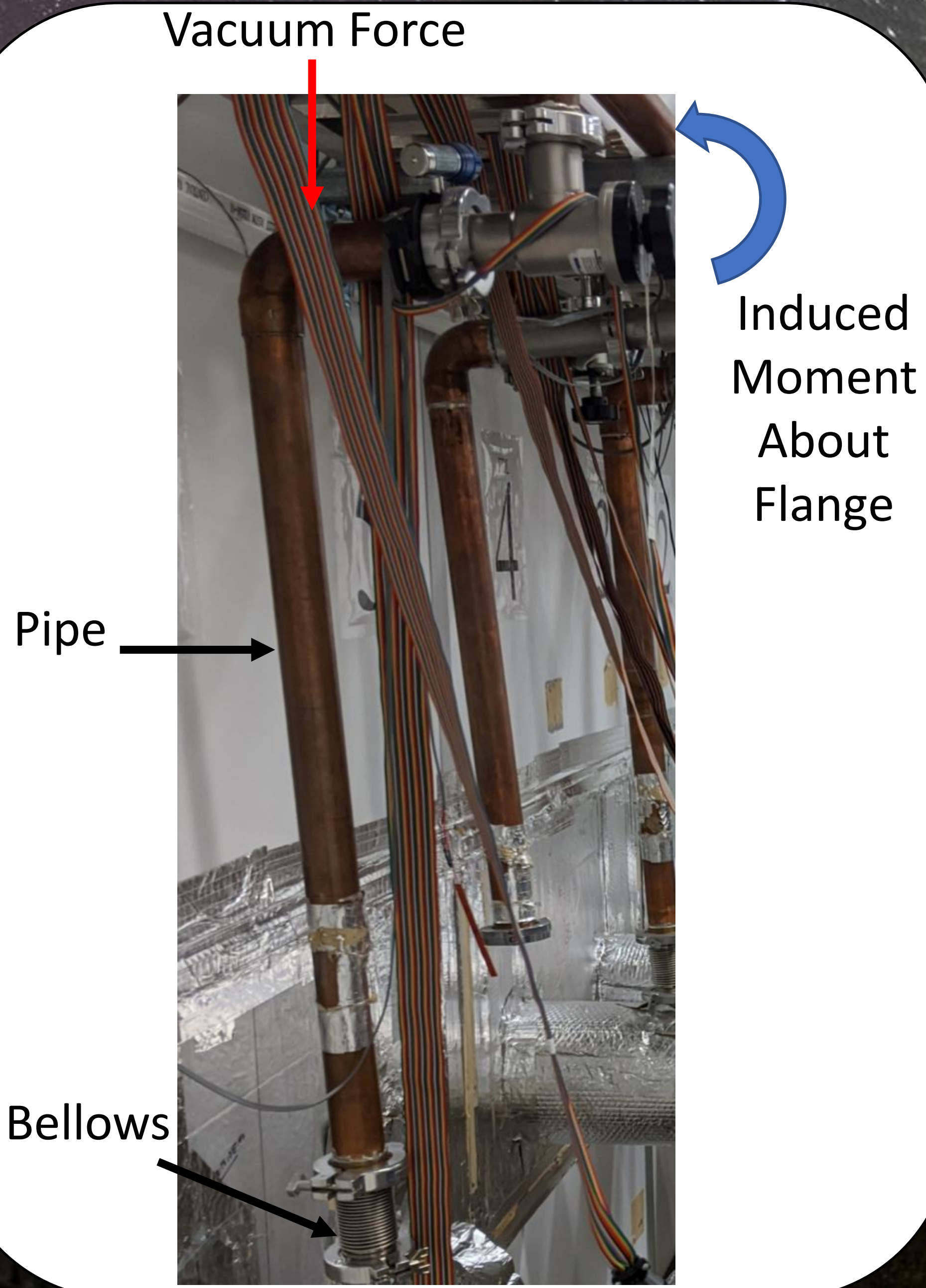
- A rotary-vain vacuum pump is mounted to the wall (out of frame toward right)
- Braised copper pipe was used to connect the vacuum pump to each of the delay lines
- Each delay line was isolated by a vacuum valve
- The old manifold attached to the delay line via the optical “snoots”

Connection of FDL to previous vacuum manifold

Previous system



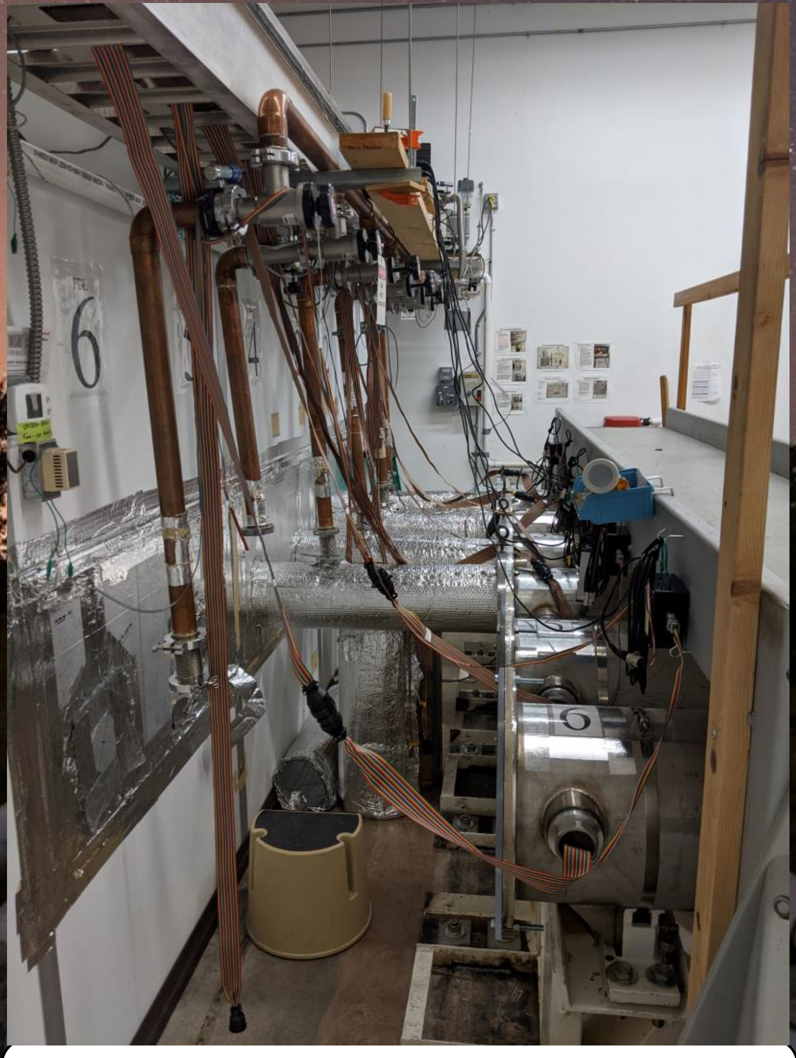
Pump and previous vacuum manifold



How We Fit In

Why it's Important

Previous system was failing, hard to use, and becoming dangerous

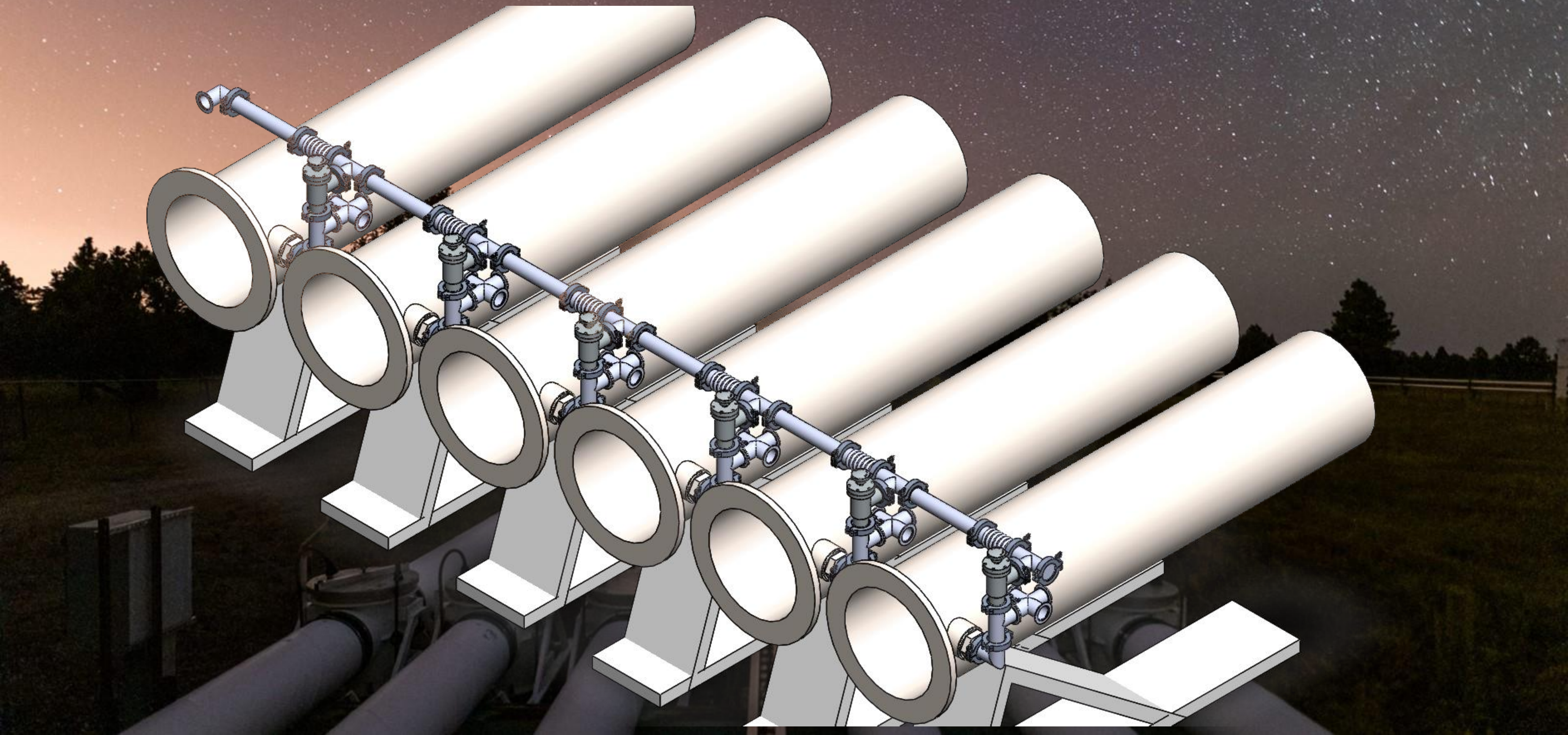


Different angle of connection of previous manifold

What we did

The Capstone Team was tasked to design, manufacture, install, and validate a new FDL vacuum manifold

Initial New Design (CAD Overview)

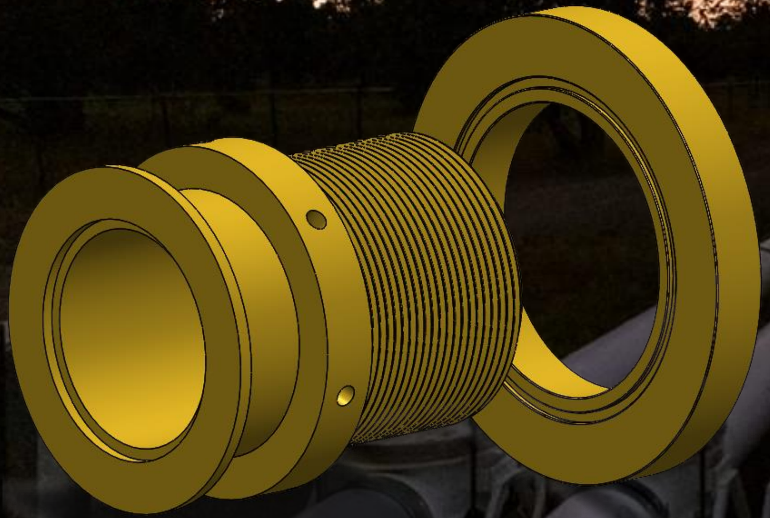


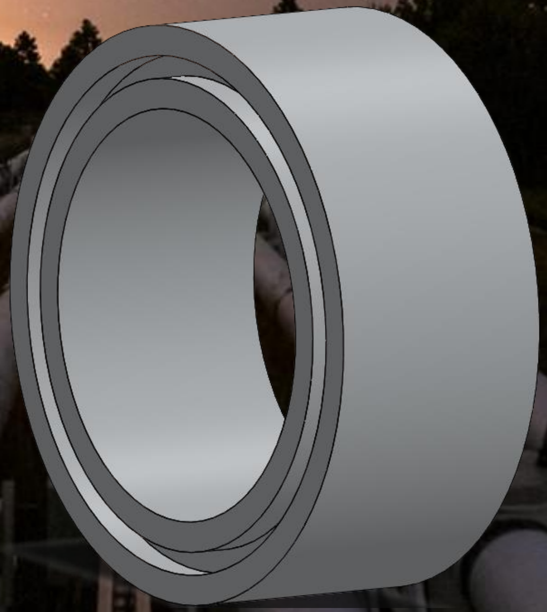
Design Iterations

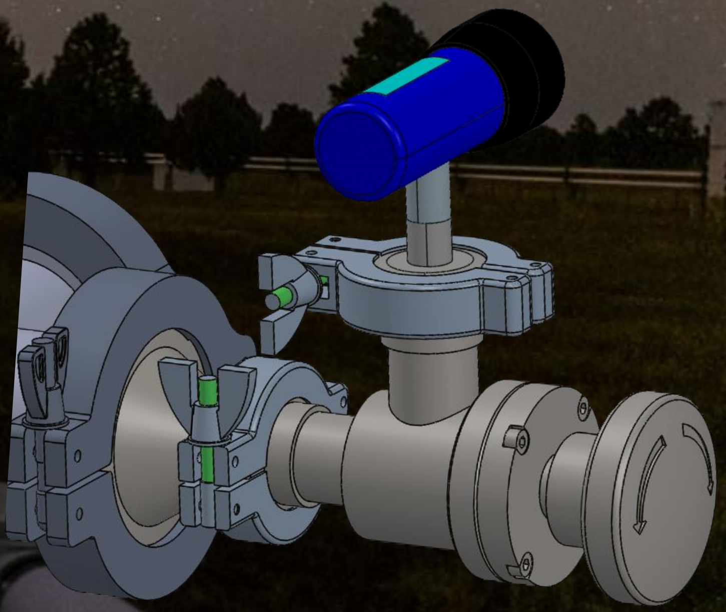
Changed interface to match available brass stock and added adaptor ring to compensate for size difference

Added electrical extension to allow both ends to fit within the manifold cross pipe

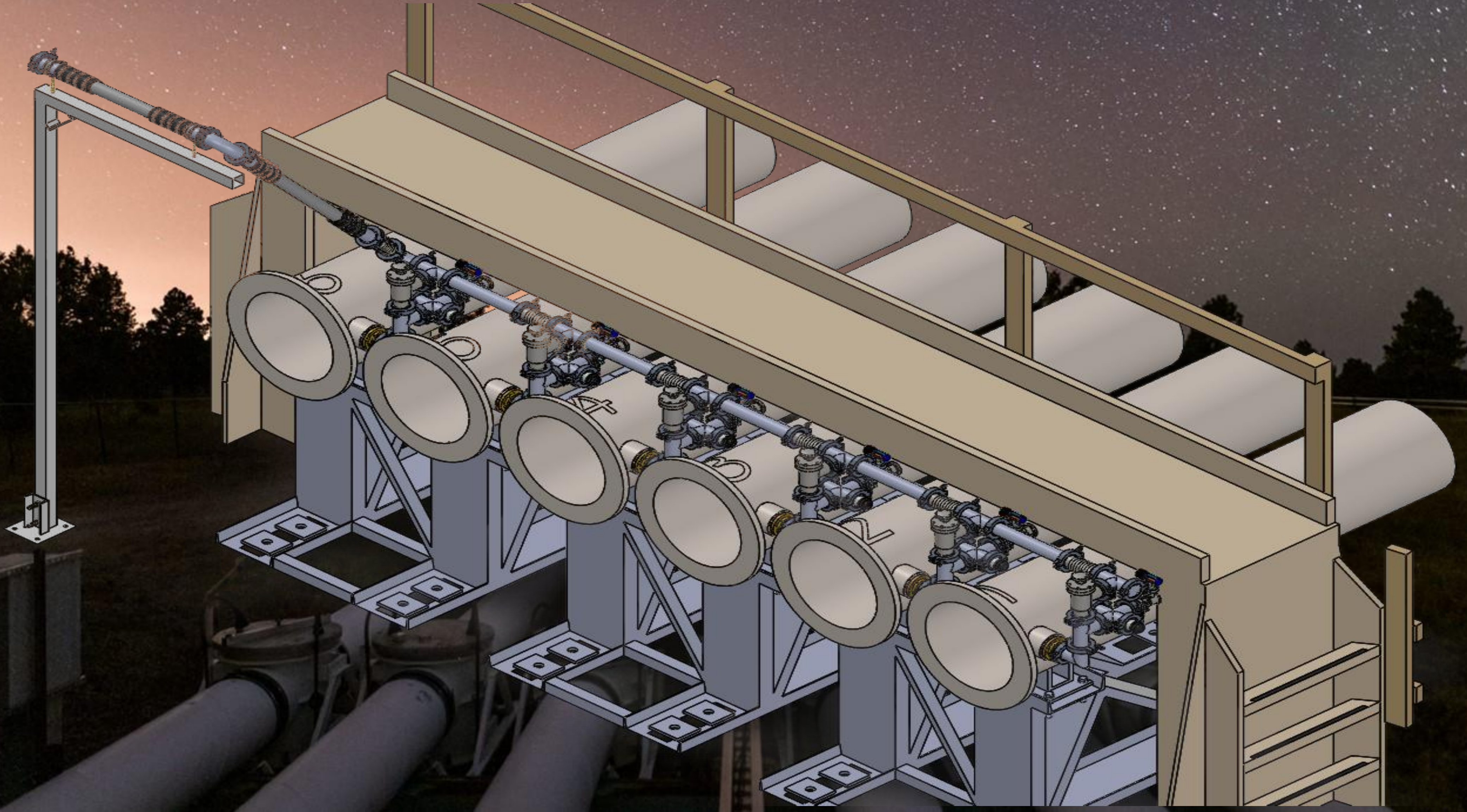
Added extra valve for pressure gage at request of client

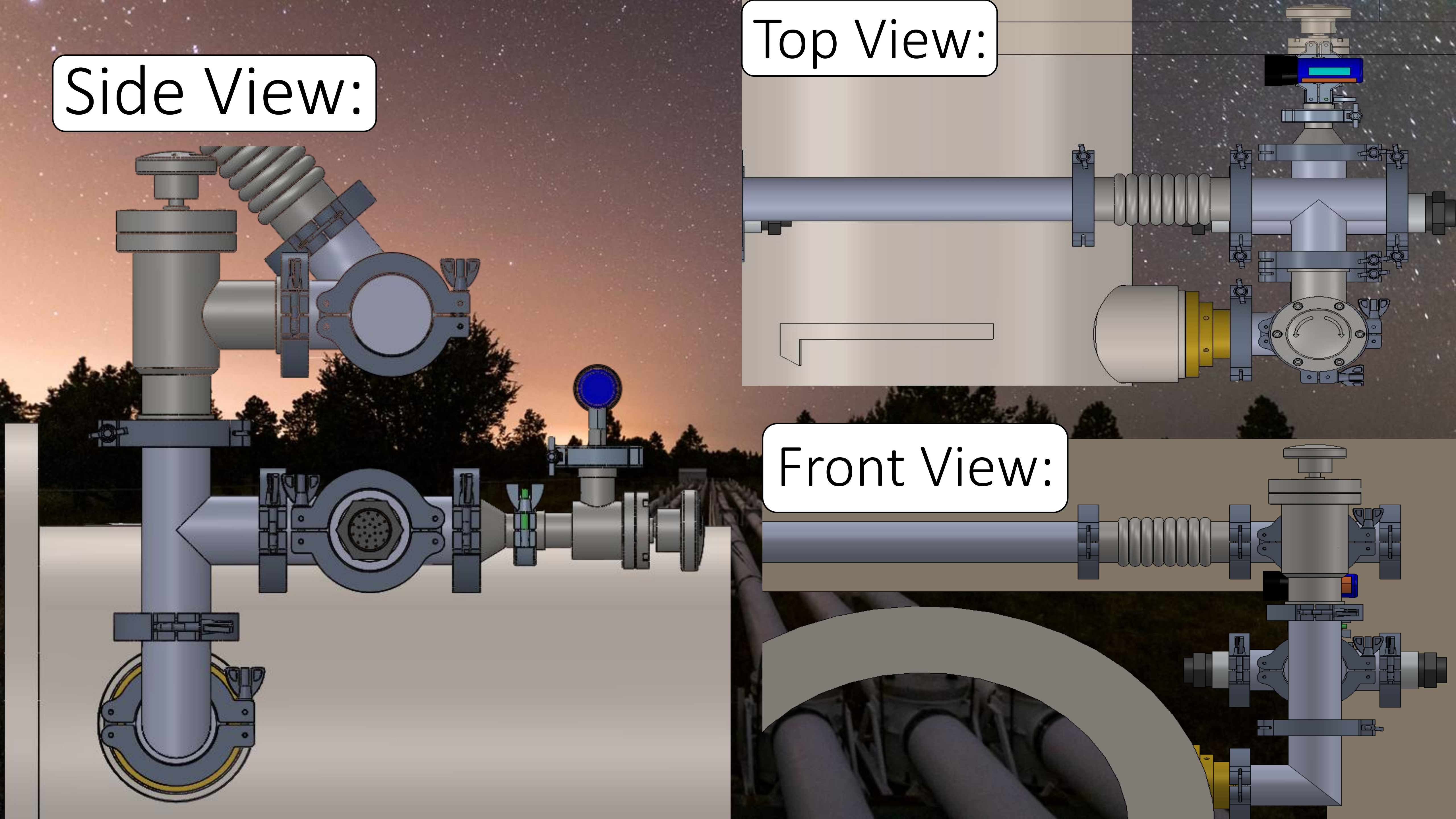




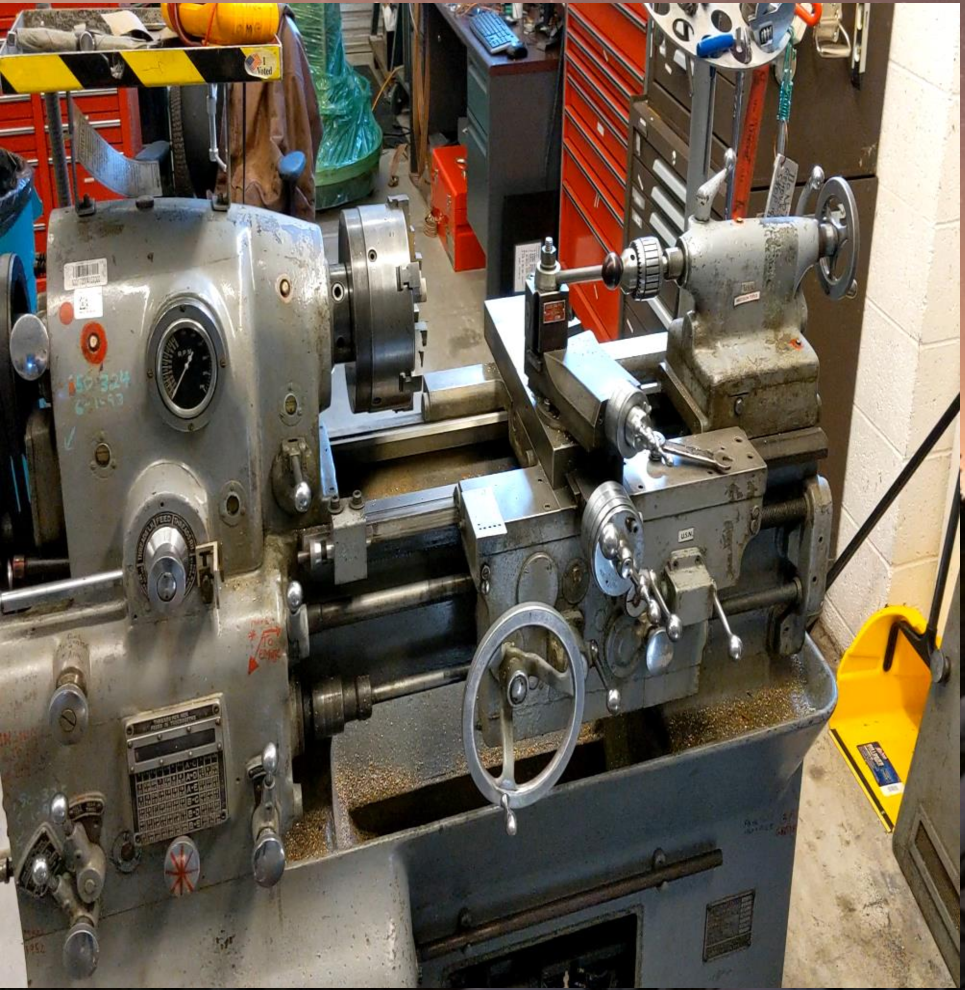


Final Design



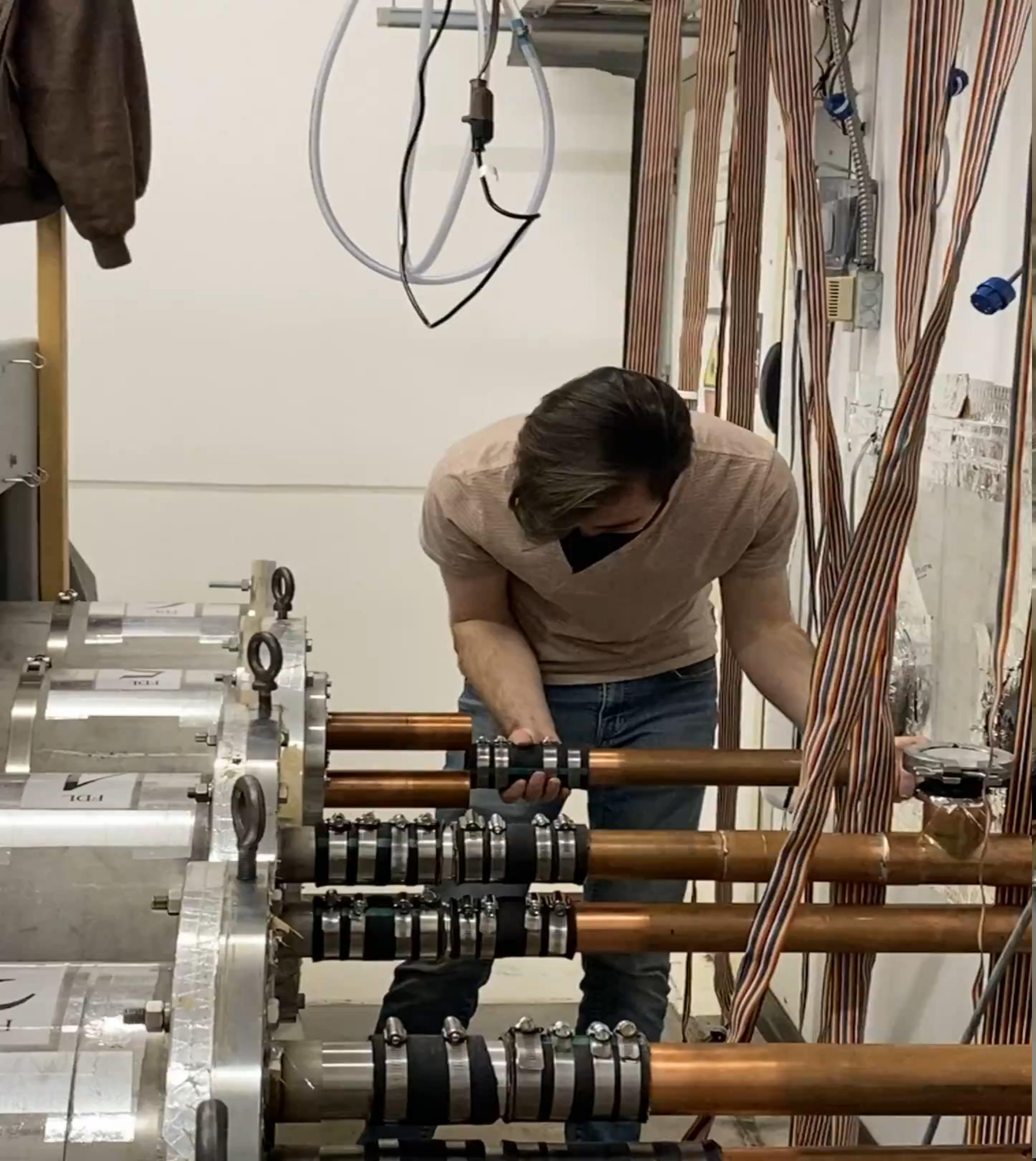

Side View:
Top View:
Front View:

Manufacturing



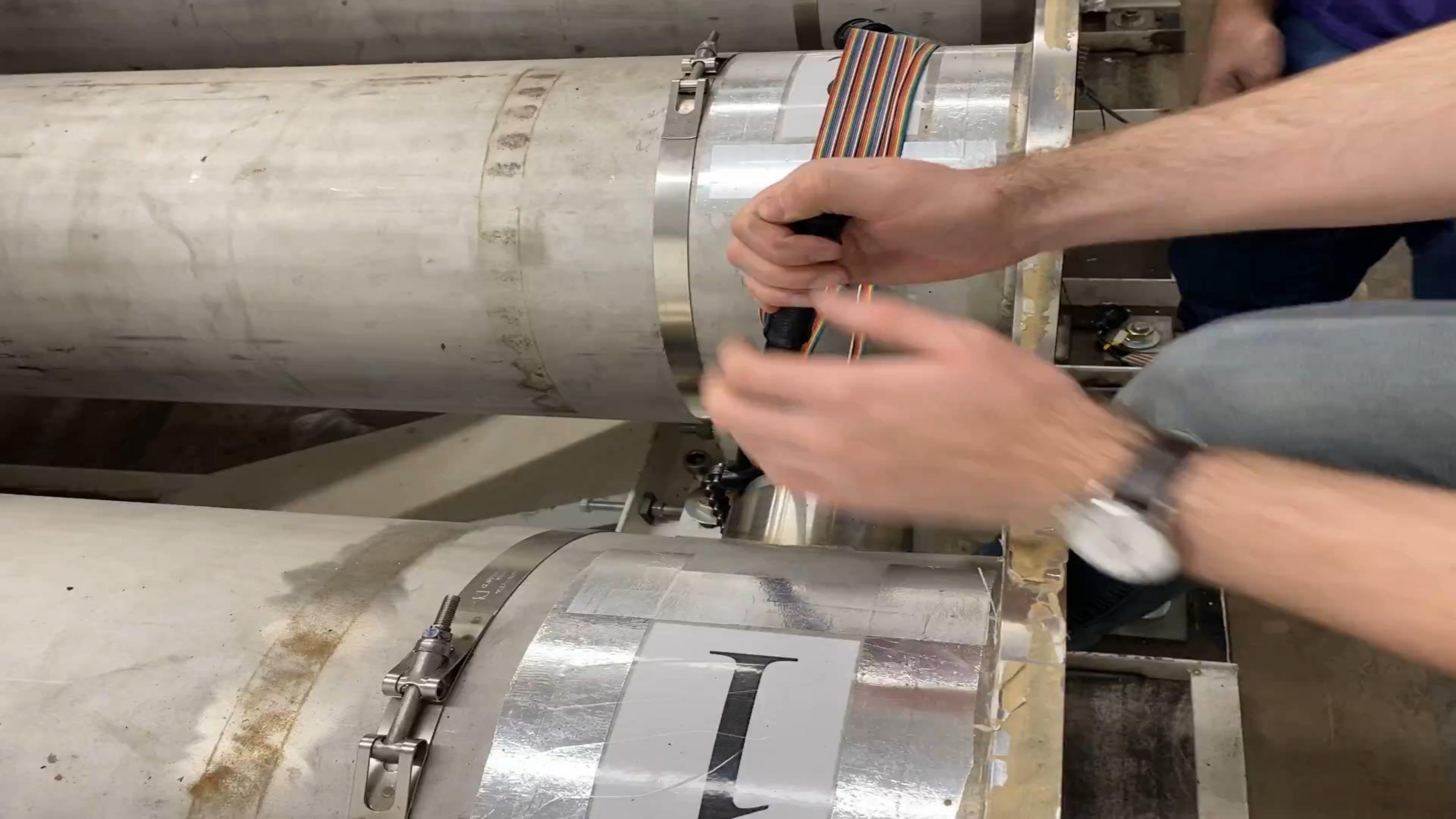
Manufacturing

Disassembly of Old System

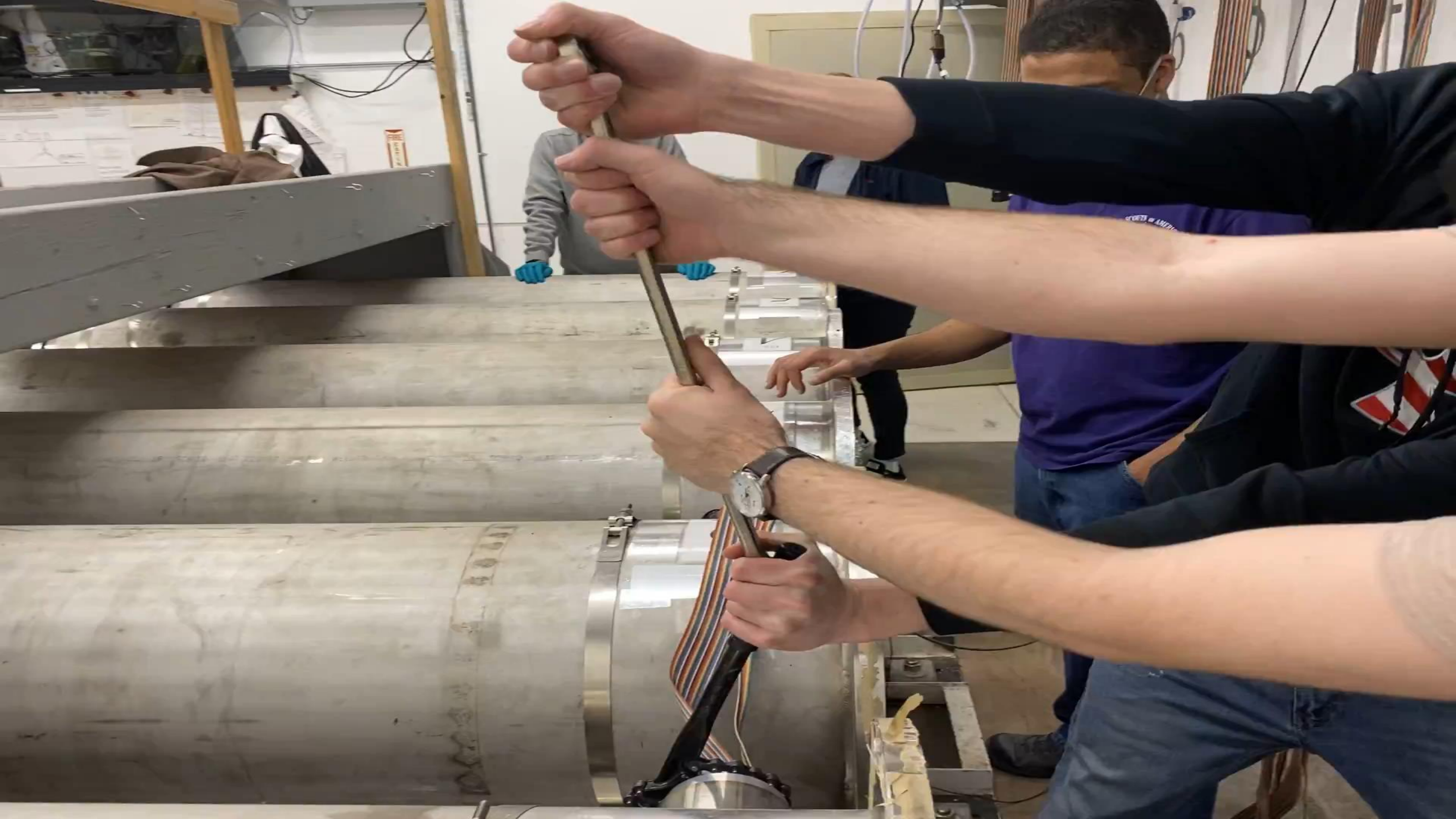



SEE OTHER SIDE
"THRIFTY"
1 TON
WALLACE GANTRY
COFFING
EXIT
LUNA

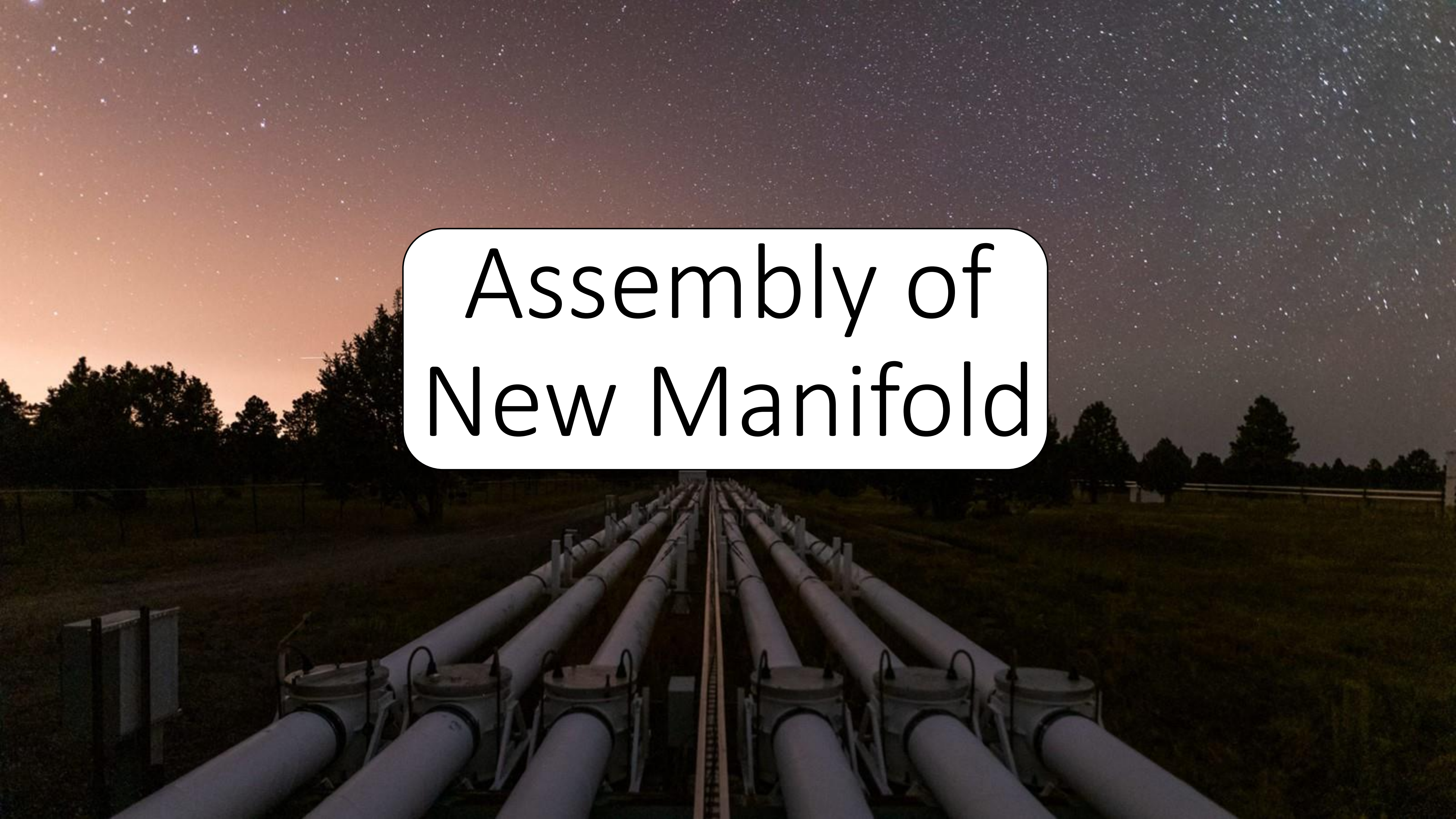
LUNA
DEFYING IMPOSSIBLE.



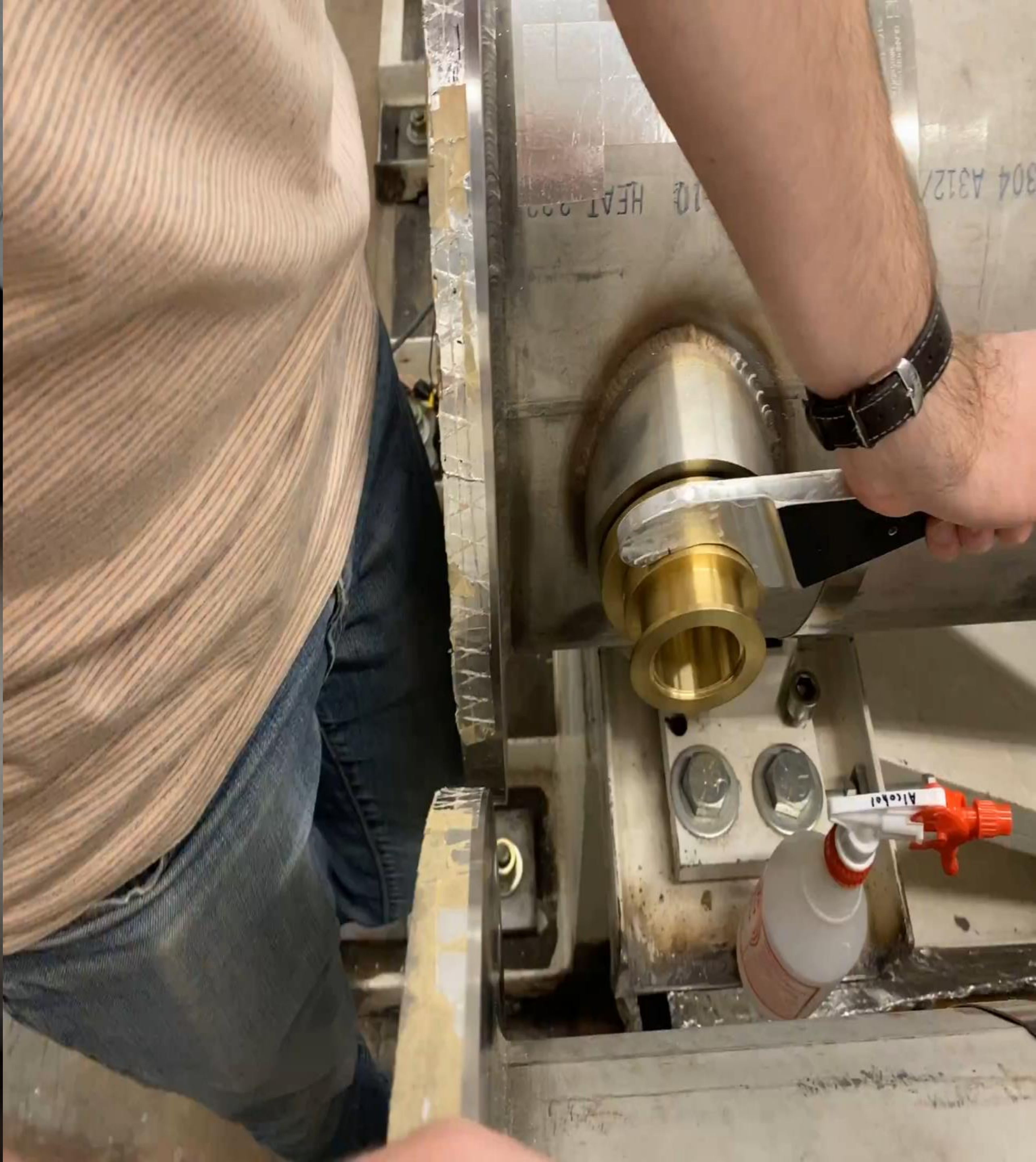

EXIT
1
FDL



Assembly of New Manifold

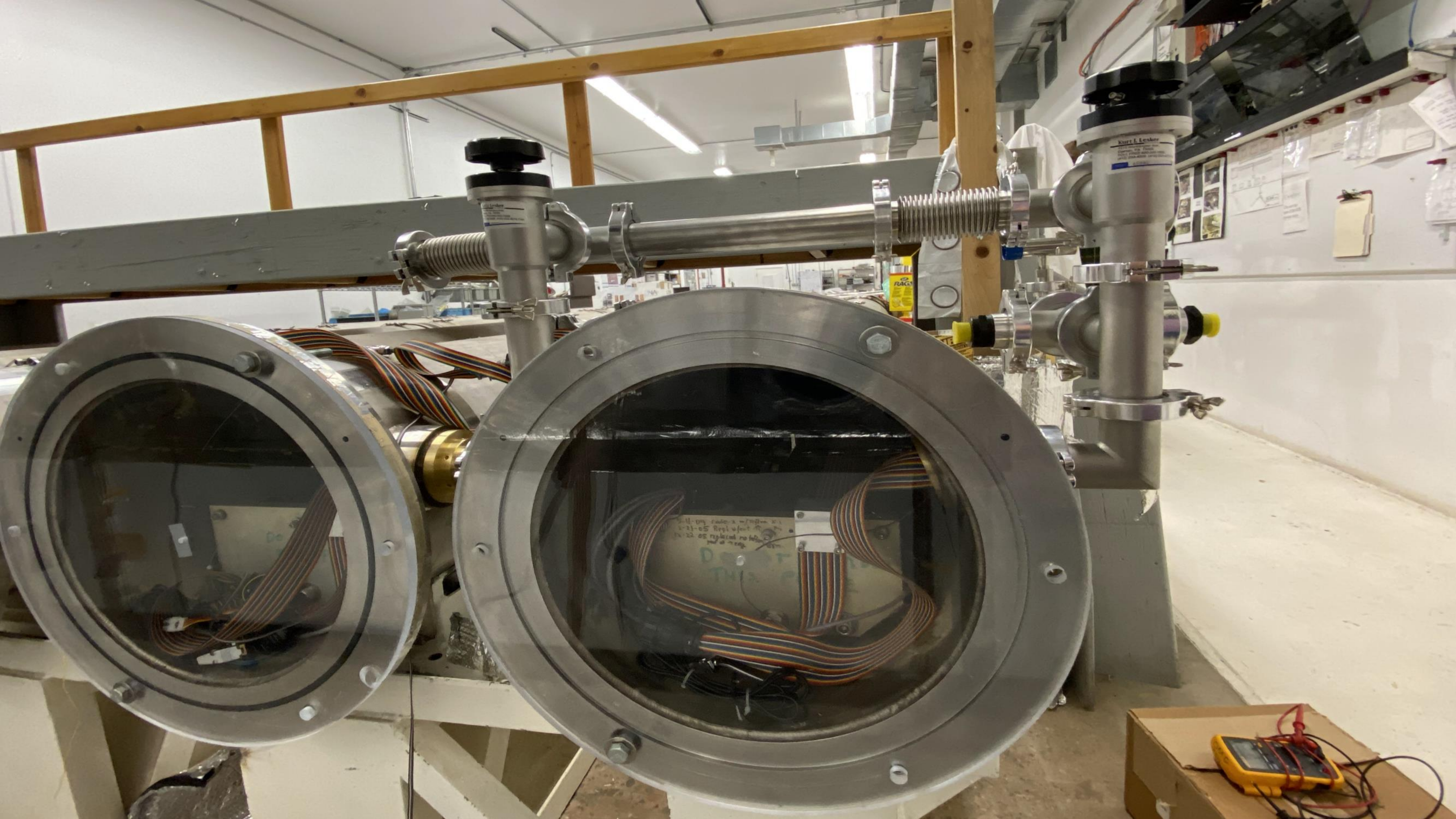



NuTone


Alcohol


FDL
6
FDL
5


5
FDL
6


Kurt J. Lesker


FDL
5
FDL
4


FDL
5
4
3
2
1
WARNING!
DANGER
DO
NOT
OPERATE
6
5
4
3
2
DANGER
DO
NOT
OPERATE


DANGER
DO NOT OPERATE
FDL 1
FDL 2
FDL 3
4
5
6

Testing Results

Design Requirements

Customer Requirements (CR)

1. Safety
2. Reliability
3. Maintenance accessibility
4. Within budget
5. Easy to use
6. Future project integration

Engineering Requirements (ER)

1. Factor of safety
2. Project Cost
3. Minimize Downtime
4. Leak Rate

Top Level Testing Summary

Experiment / Test	Relevant Design Requirement
1. Front Plate Disassembly Time	CR3, CR5, ER3
2. Leak Rate Test	CR2, ER4
3. Cable Passthrough Setup	CR3, CR5, ER3
4. Cable Continuity Test	CR1, CR2, ER3
5. Pressure Gauge Calibration	CR2,CR3, ER3

Front Plate Disassembly Time

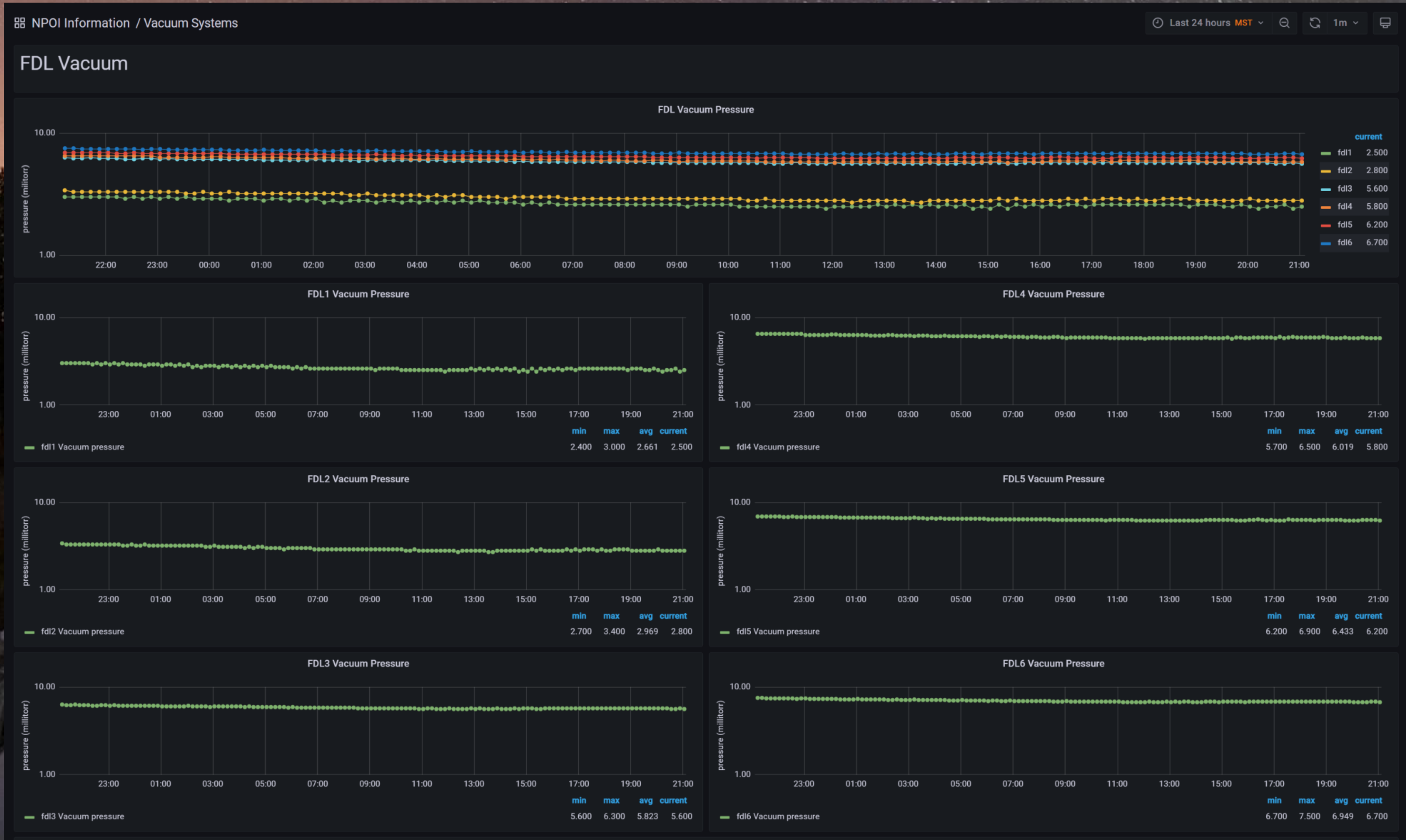
- Purpose
  - Determine time needed to remove front plates for regular maintenance of FDLs
- Procedure
  - Follow the previously established procedure for removing “snoots” from FDL tanks. Proceed to use crane to move front plate from tank. Time process.
- Result
  - Total time was ~10 minutes. This is ~20 minute improvement from previous system

Front Plate Disassembly Time

Leak Rate Test

- Purpose
  - Evaluate ability of manifold to maintain vacuum when pump system fails
- Procedure
  - Pump FDL tanks to standard operating pressure. Isolate tank from vacuum pump. Record time taken to reach 30mTorr from isolation.
- Results
  - Manifold maintained vacuum pressure below 30 mTorr for seven days (April 01-07, 2022)

Leak Rate Test



Cable Passthrough Setup

- Purpose
  - Understand time needed to disassemble and remove the cables for regular maintenance of FDLs.
- Procedure
  - Once the snoots and front plates have been removed, the process of disassembling the cable connection and removing the cable that resides in the manifold will be timed.
- Results
  - The time it took to disassemble and reconnect the cable connection was 10 minutes for one manifold.

Cable Passthrough Setup

Cable Continuity Test

- Purpose
  - Ensure cables are built correctly and will be able to function with the FDL carts
- Procedure
  - 2-person job. Requires testing at one end of outer cable and testing at the other end of inner cable. Using a digital multimeter each person will touch lead to one of 36 pins at the same time, starting at pin 1 and moving in ascending order.
- Results
  - Each cable was built correctly and where able to move operate FDL carts

Cable Continuity Test

Pressure Gage Calibration

- Purpose
  - Ensure accurate data is being recorded.
- Procedure
  - Gauge is placed on mass-spectrometer that produces 10^{-5} torr vacuum. Reading on display box is adjusted until it reads zero. Gage is then brought back to atmospheric where its display is adjusted until it reads 585 torr. This process is repeated to ensure values displayed are still correct.
- Results
  - Each gage was successfully calibrated and was able to have data collected properly.

Pressure Gage Calibration

Final Results

Customer Requirement	CR Met (✓ or X)	Client Acceptable (✓ or X)
CR1 - Safety	✓	✓
CR2 - Reliability	✓	✓
CR3 - Maintenance	✓	✓
CR4 - Cost	✓	✓
CR5 - Ease Of Use	✓	✓
CR6 - Future Integration	✓	✓

Engineering Requirement	Target	Tolerance	Measured /Calculated Value	ER Met (✓ or X)	Client Acceptable (✓ or X)
ER1 - Factor Of Safety	2	±0.5	>10	✓	✓
ER2 - Cost	10000$	±4000$	11678.04 $	✓	✓
ER3 – Minimize Downtime	2 hr	±1 hr	30 min	✓	✓
ER4 – Leak Rate	5 days	±1 day	7 days	✓	✓

Photo: https://lowell.edu/research/telescopes-and-facilities/npoi/