PUmped Liquid System for Amateur Rockets

Project PikaPump

Final Design Review

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Background

- Liquid rockets are fed two propellants to provide thrust
- Key stakeholders:

- Value Added: We aim to provide the resources in one location for other people to design and build their own electric pumps

Project Requirements

Pressure	*Liquid methane pressure output of 240 psia*
Flow	*Liquid methane flow rate of 1.19 lbm/s*
Weight	*Total system weight below 12.5 lbs*
Sizing	6.6” Max diameter, 16” Maximum height
Temperature	*Can withstand temperatures of -190 °C*
Corrosion	*Resistant to corrosive cryogenic fuels*
Reusability	*Will be able to operate for at least 2 flights*
Measurement	*Able to record outputs using sensors*
Safety	*Automatic and manual emergency shutoff*
Test Ready	*System is cryogenic test ready*

Business Case

$10,000

AVERAGE BUDGET OF STUDENT ROCKET TEAMS

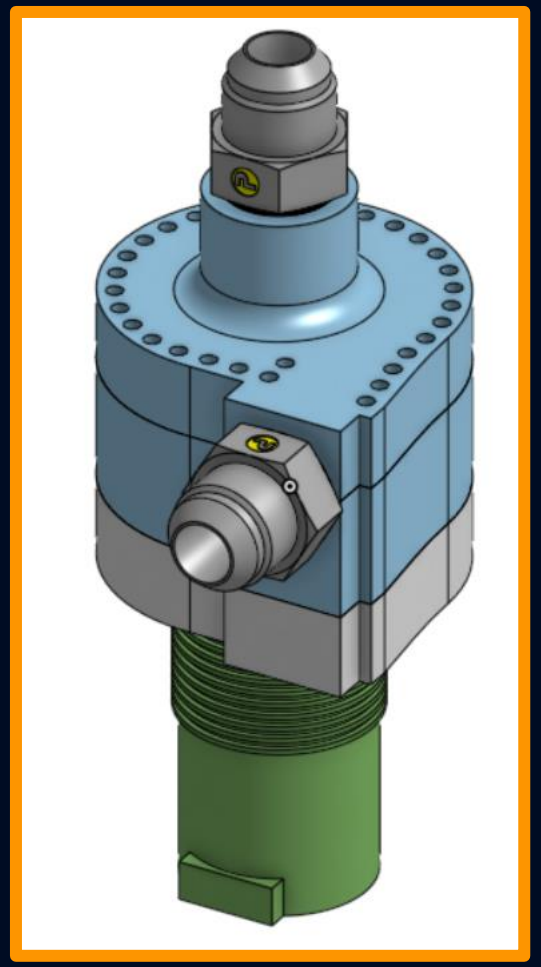
Multi-Use

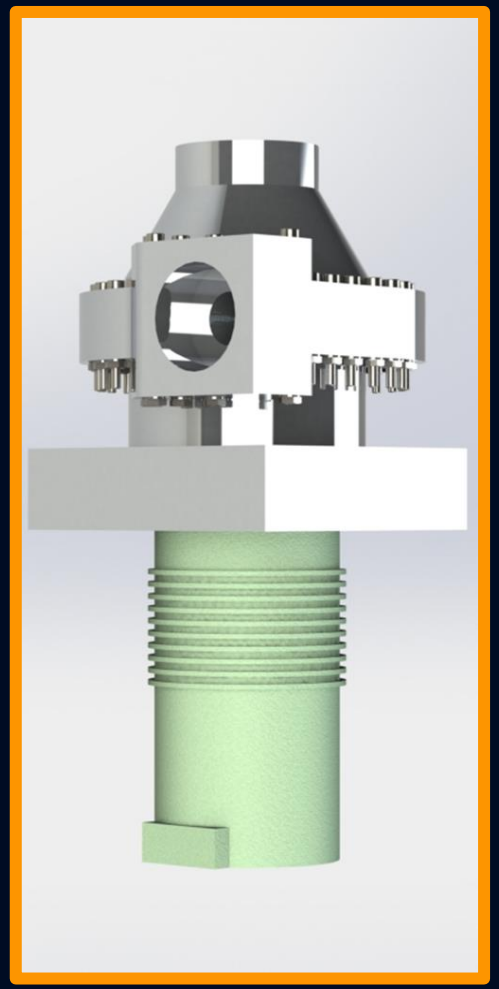
ELECTRIC PUMPED SYSTEMS HAVE GREATER REUSABILITY

Risk

LARGEST OBSTACLE IS TECHNICAL RISK

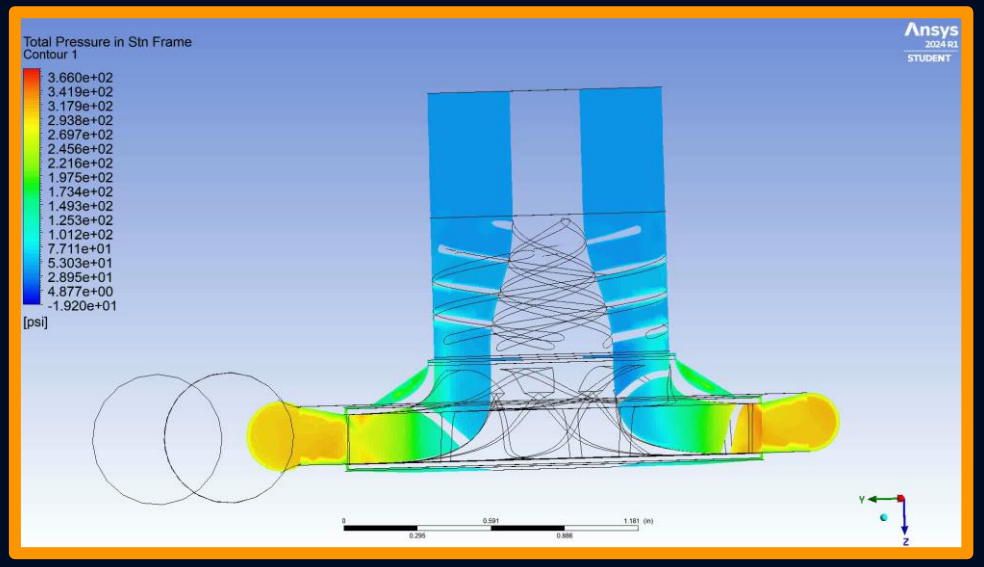
CDR to FDR Model



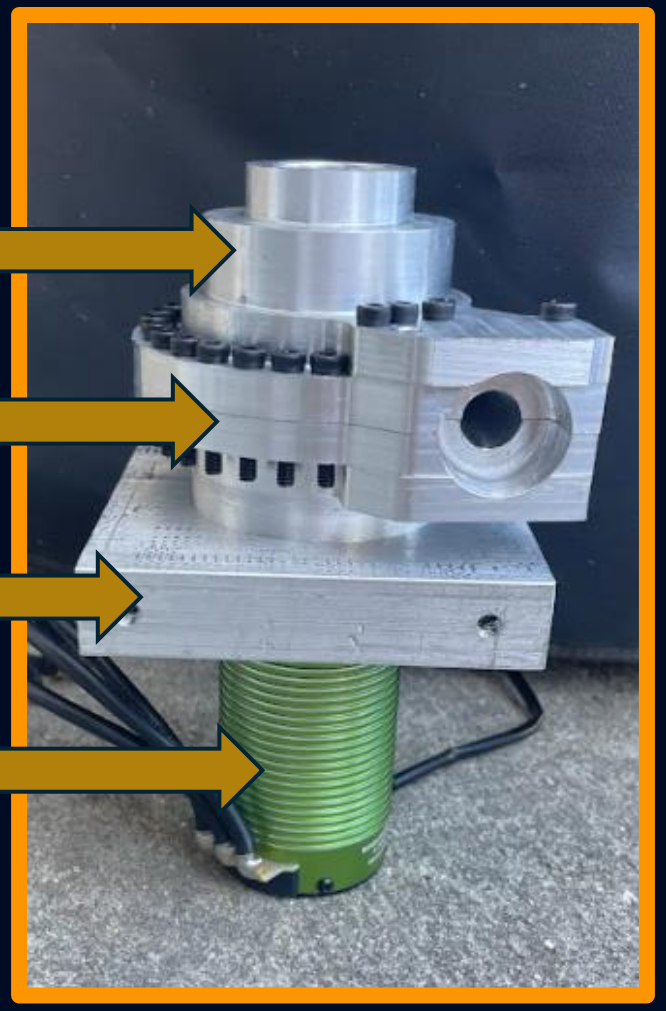


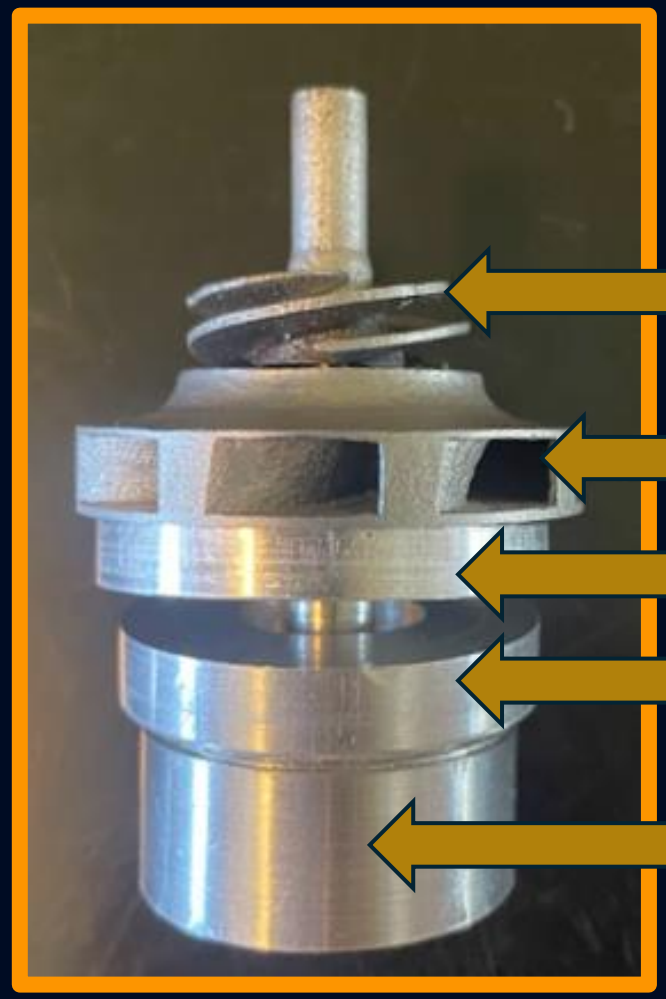
Analysis Performed

- Initial CFD sims
- Material Analysis tests
- Driveshaft design



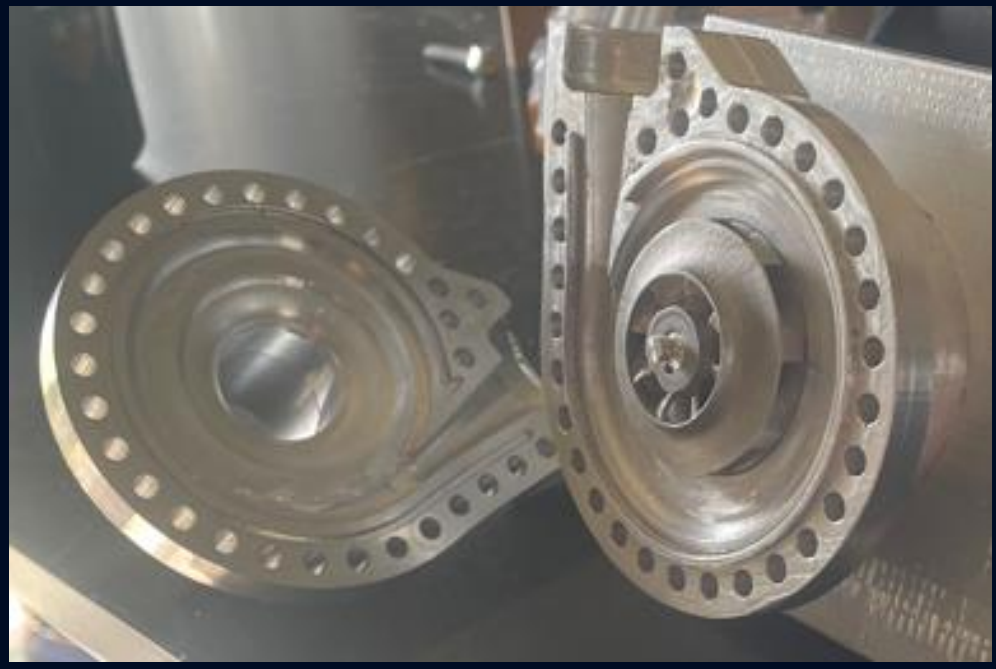
Overall Assembly





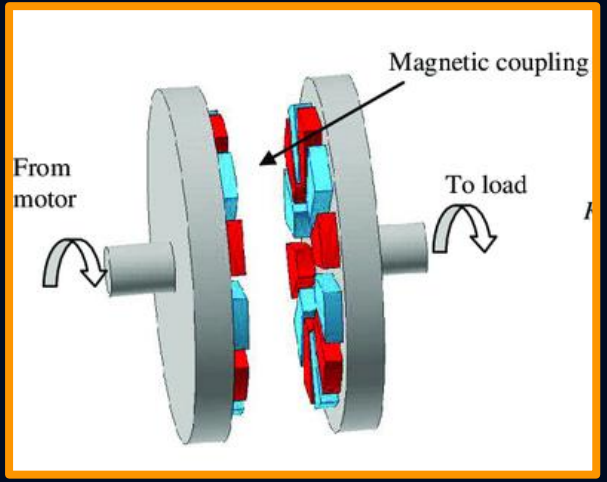
Top and Bottom Casing

- Machined on the MB-15 CNC mill
  - High precision
  - Purchased 1/16" endmill for seal
- Post processing
  - Bolted together and tapped
  - Adjusted clearances



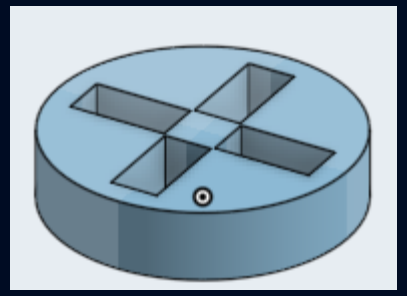
Magnetic Coupler

- Torque transmission with no leakage
- Custom-made couplers
  - Neodymium magnets packed into an aluminum case

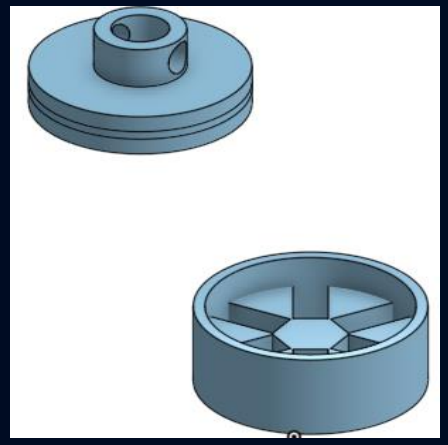


https://www.stanfordmagnets.com/magnetic-coupling.html

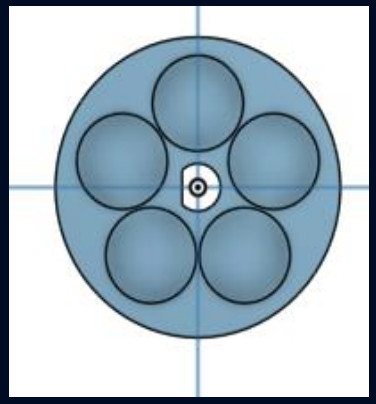
Coupler Iteration



Stage 1



Stage 2- More magnets



Final Design

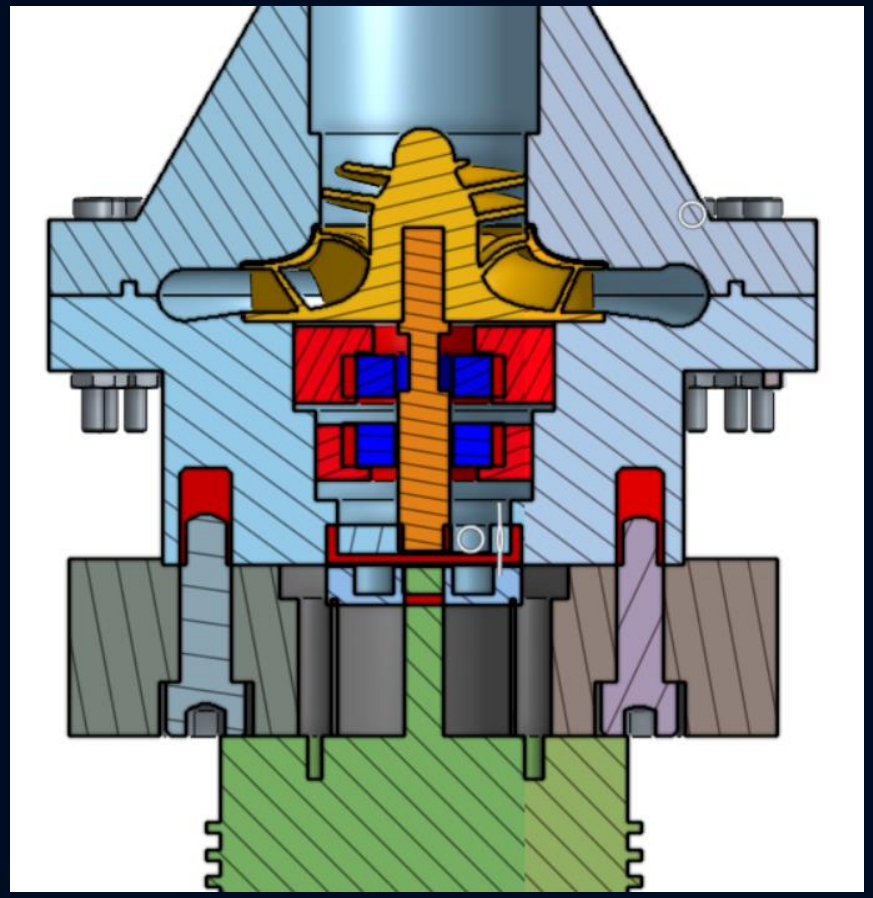
Impeller and Inducer

- Core internal pump components
- Could not be easily made in-house
  - Geometries impractical for machining
- Parts were metal 3D printed
  - Sanded down to ensure smoothness

Other Major Components

- Pump Driveshaft
  - Connects magnetic coupler to pump impeller
  - Uses left hand threading to prevent unscrewing
- Coupling Block
  - Holds magnetic coupler in place
  - Supports pump and motor
  - Bolted to test setup using a welded steel H-bracket

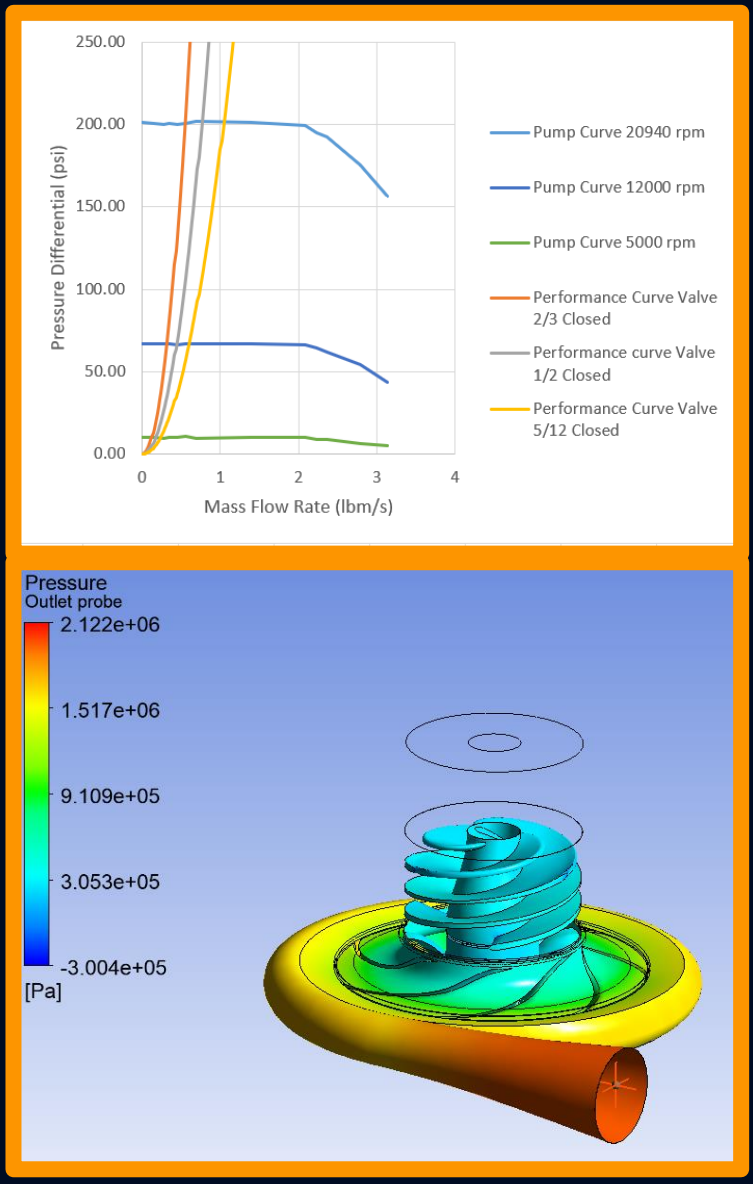
Drivetrain Iteration



Problem	Solution
Coupler must be larger	Increase bearing block size
Can't assemble driveshaft	Add "coupler adaptor" part
Threads unscrew when system spins	Use left hand threading
Bolt assembly interferes w/ motor	Decrease bolt size and move outward
Bearing blocks can't be removed after press fit	Change interference fit to transition fit
Cryogenic bearings don't spin well at low RPMs	Use cheaper bearings for testing in water
Impeller/couplers bind with the casing	Increase clearances until it runs smoothly

CFD Simulations

- Simulate a wide range of operating conditions
- Both Water and Cryogenic fluids
- Need to be validated with experiments



Validation Plan

Verifying the design to ensure it meets expected parameters

- Create test setup
- Record parameters
- Data Analysis

Data Acquisition

Gstatic

1 High pressure sensor

1 Tachometer

Tachometer

1 Flow meter

Flow meterd

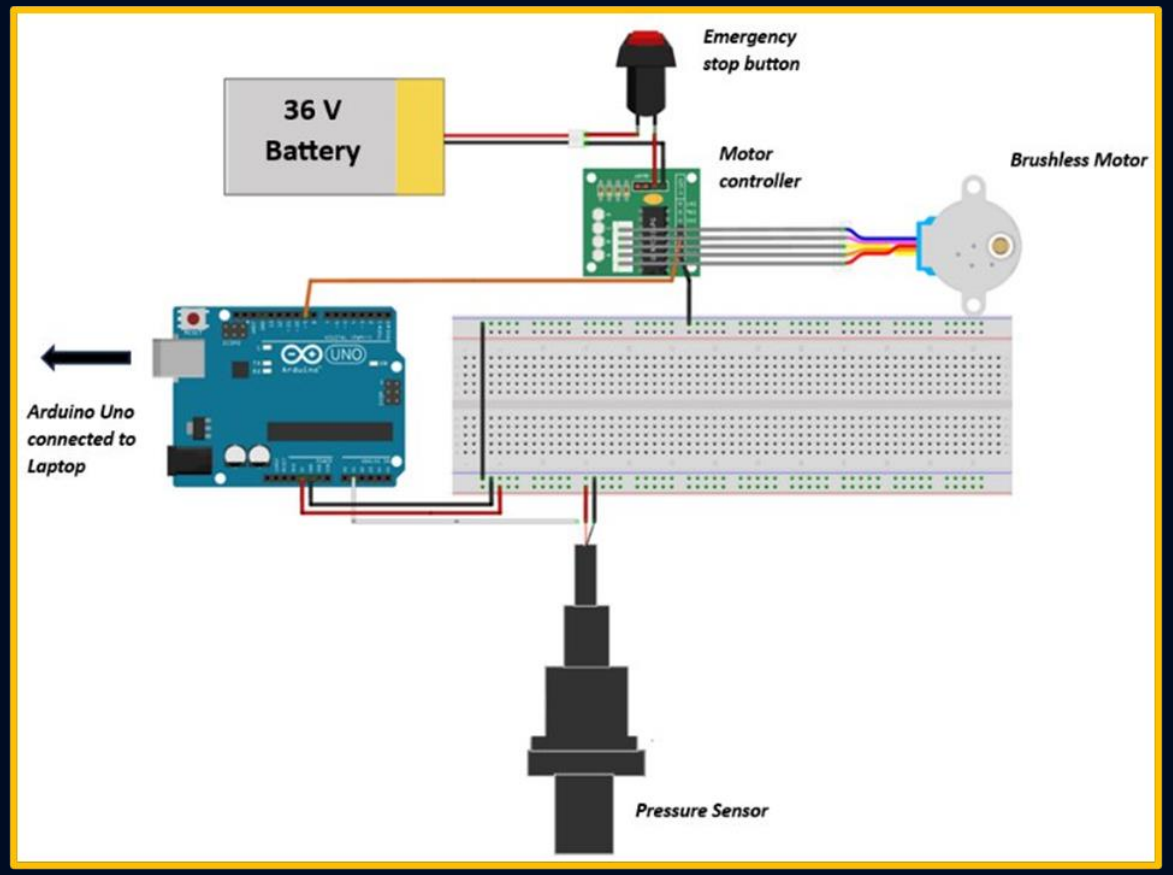
Arduino Uno

Laptop

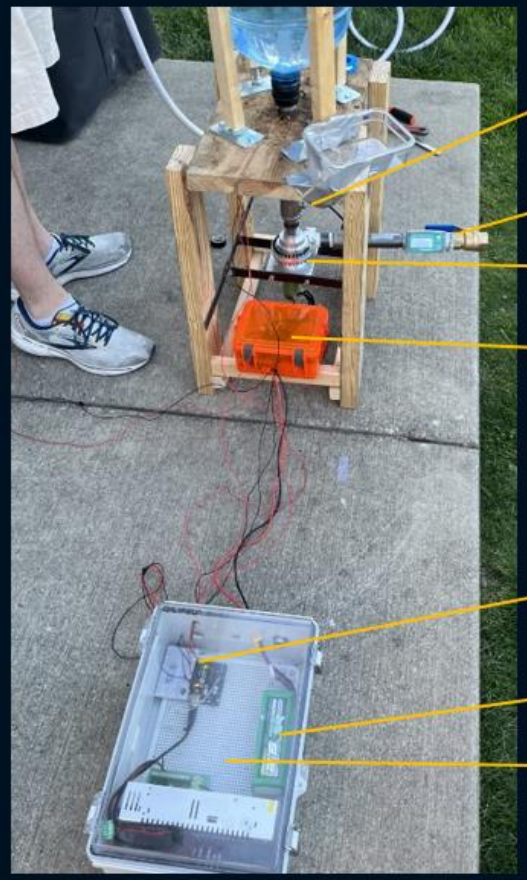
Laptop

Arduino

Electrical CAD



Test Setup

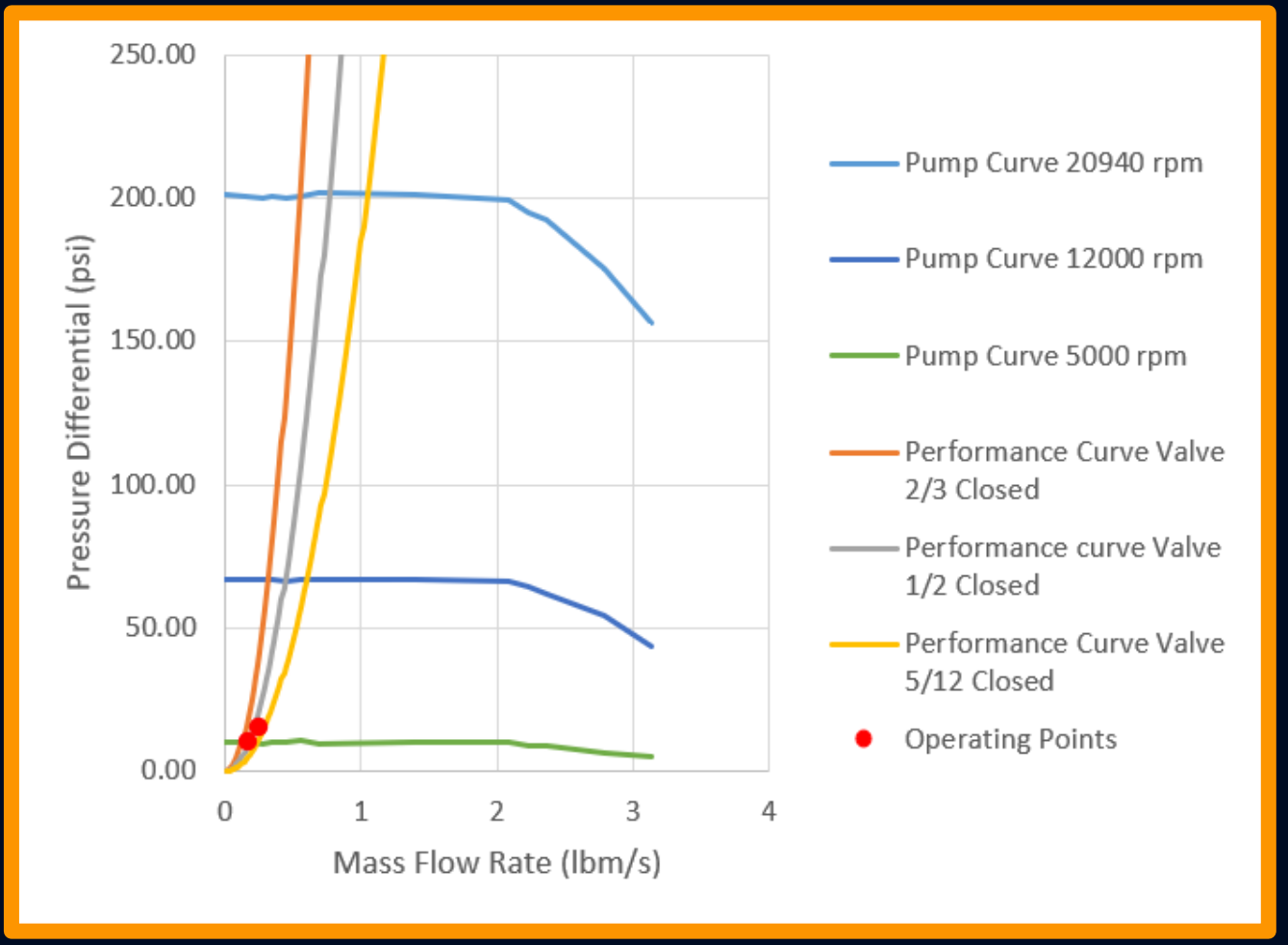

Pressure sensor
Flow meter
Pump housing
Motor controller
Arduino & Breadboard
Battery
Water proof box

Test Results

- Ran test up ~7000 rpms
- Pressure rise ~15 psi
- Flow rate of 0.55 lbm/s
- Any higher the coupler was not strong enough

Results vs. Simulation

- Point falls on the performance curves as predicted
- Validates simulation
- Would be better to test at higher rpms



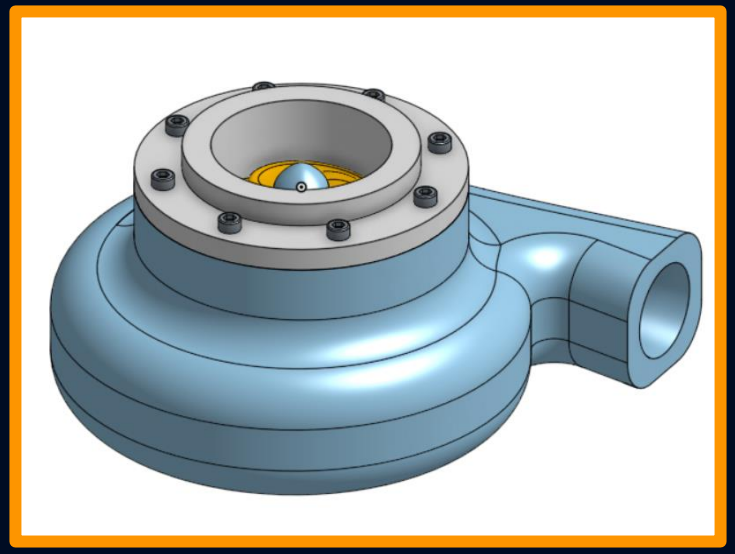
Requirements Assessment

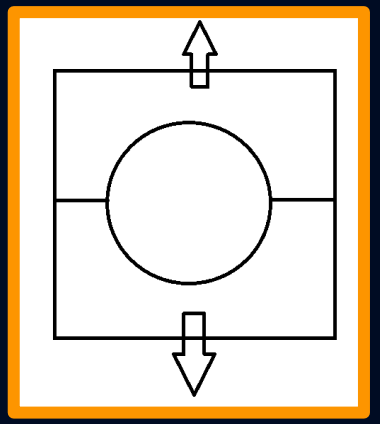
Requirement	Description	Rqmt Met?	Reasoning
Pressure	*Liquid methane pressure output of 240 psia*	*No*	*No cryo test*
Flow	*Liquid methane flow rate of 1.19 lbm/s*	*No*	*No cryo test*
Weight	*Total system weight below 12.5 lbs*	*Yes*	*~4 lbs*
Sizing	6.6” Max diameter, 16” Maximum height	Yes	4" Dia., 10" Tall
Temperature	*Can withstand temperatures of -190 °C*	*Yes**	*Full compliance*
Corrosion	*Resistant to corrosive cryogenic fuels*	*Yes**	*Full compliance*
Reusability	*Will be able to operate for at least 2 flights*	*Yes*	*Multiple tests*
Measurement	*Able to record outputs using sensors*	*Yes*	*Data acquired*
Safety	*Automatic and manual emergency shutoff*	*Yes*	*E-stop works*
Test Ready	*System is cryogenic test ready*	*Yes**	*Full compliance*

*No tests were perfomed with cryogenics, but all components are designed for cryogenic compatibility

Design Improvements

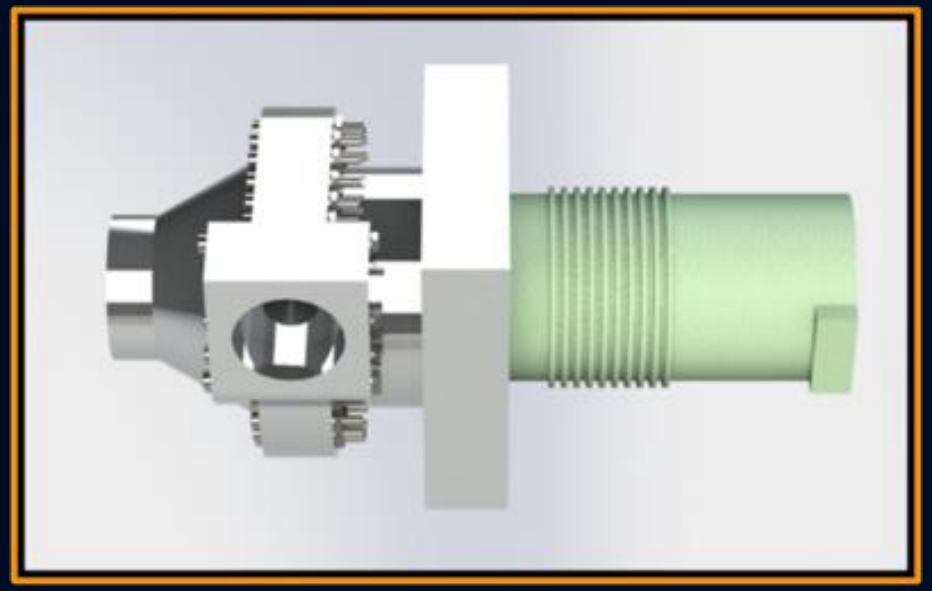
- Single piece pump casing
- Coupler magnet placement and strength
- Better machining tolerances and finish
- Sensor and data acquisition improvements





Moving Forward

- Provided roadmap, documentation, CAD, and code on GitHub so others can iterate on the design



Thank you!