Design of a GRCop-42 Regeneratively Cooled Thrust Chamber Assembly and Feed System

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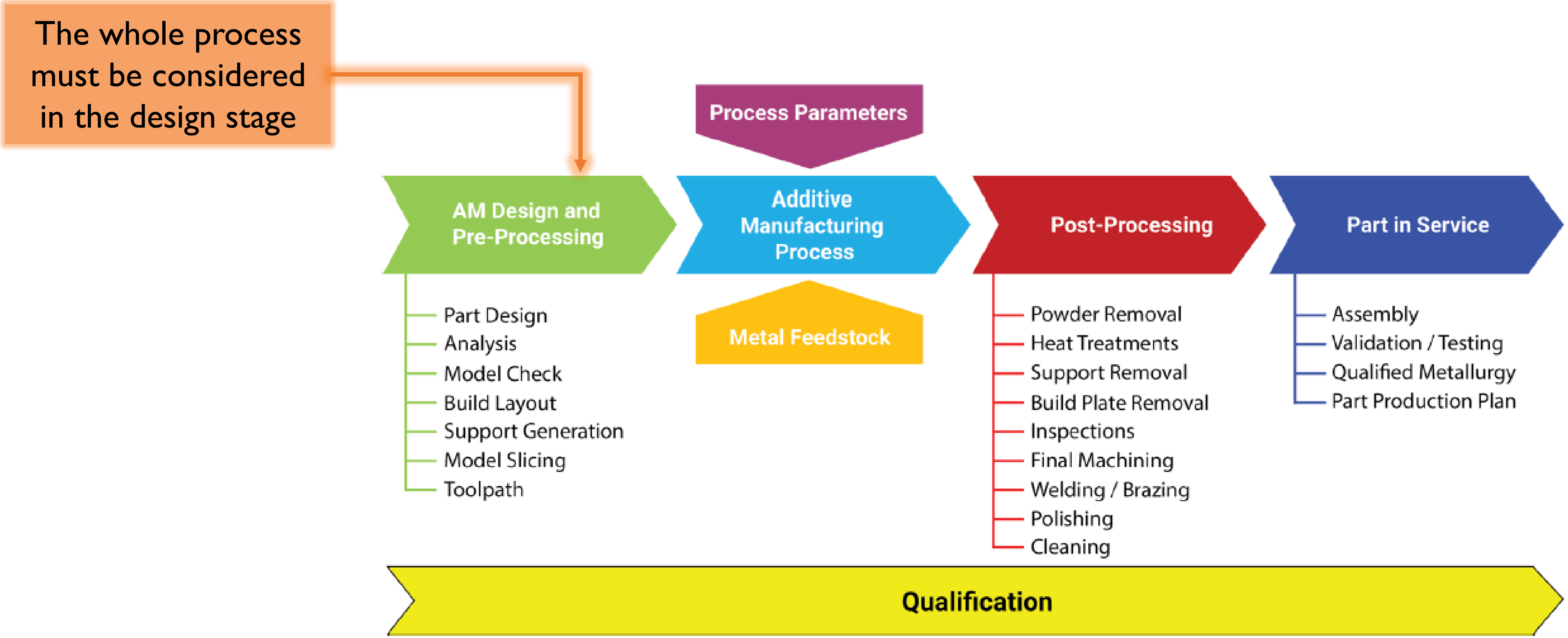
Motivation and Background

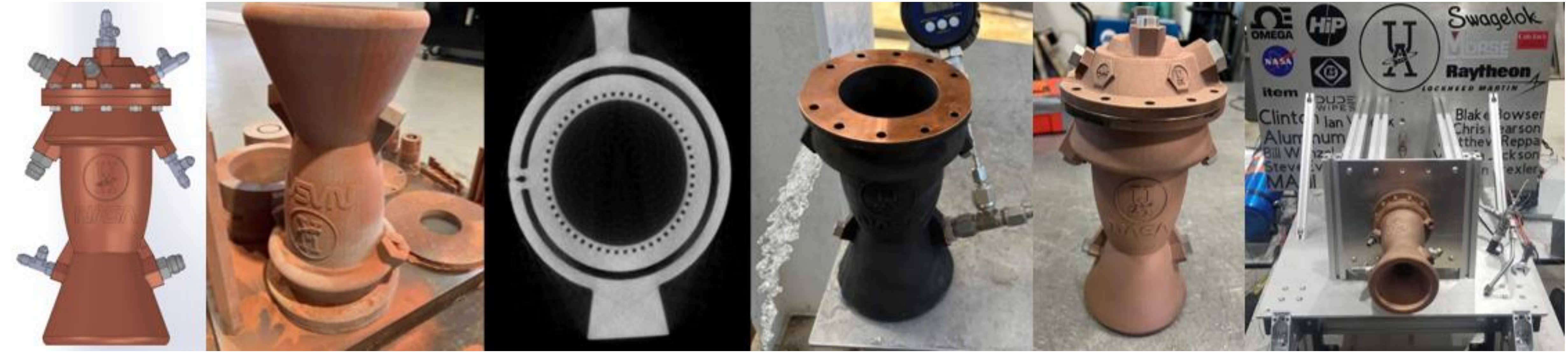
- Improve propulsion capabilities on the Akronauts Rocket Design Team
  - Hot-fire tested first liquid rocket engine Fall 2021
- Design a reusable engine with regenerative cooling
- Demonstrate a 15-s hot fire test
- Build upon existing capabilities
  - Oxidizer: nitrous oxide (N_2O)
  - Fuel: ethanol
  - Develop existing test stand

Design for Additive Manufacturing (DfAM)



Designer – vendor communication is critical: Vendors perform several of the process steps.

Design for Additive Manufacturing (DfAM)



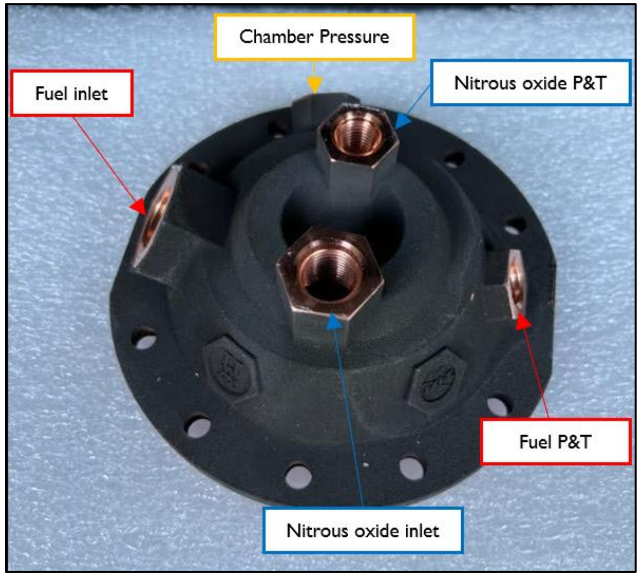
- Part design, Build direction, Supports/overhangs, Sacrificial material
- Laser powder bed fusion, GRCop-42, Powder removal, Build plate removal
- NDE Evaluation: CT Scanning, Witness samples
- Hot isostatic pressing (HIP), Final machining (datums), Water flow testing
- Polishing, Cleaning
- Assembly, Testing

Injector Design

- F-O-F triplets, influenced by previous injector design
- Ethanol orifice area designed using single phase, incompressible model

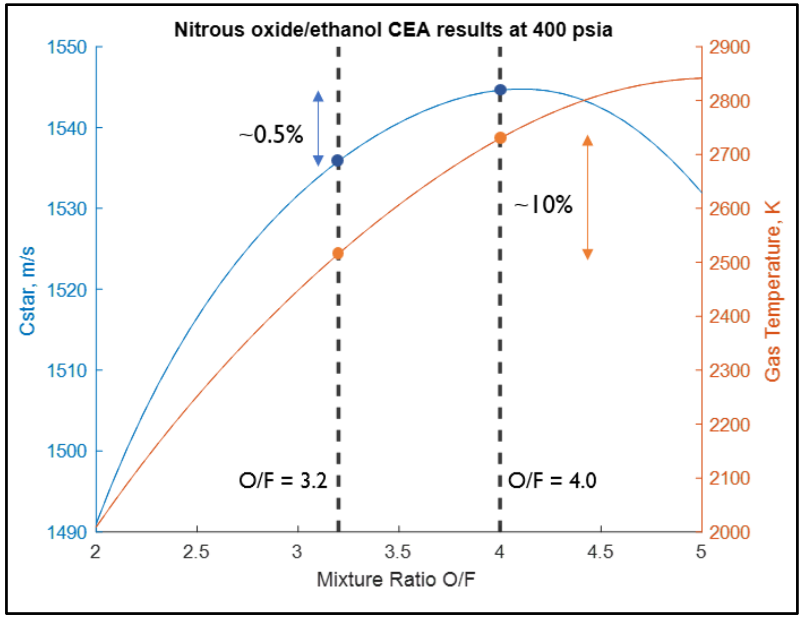
$$\dot{m}_{SPI} = A_i C_d \sqrt{2\rho_1 \Delta P}$$

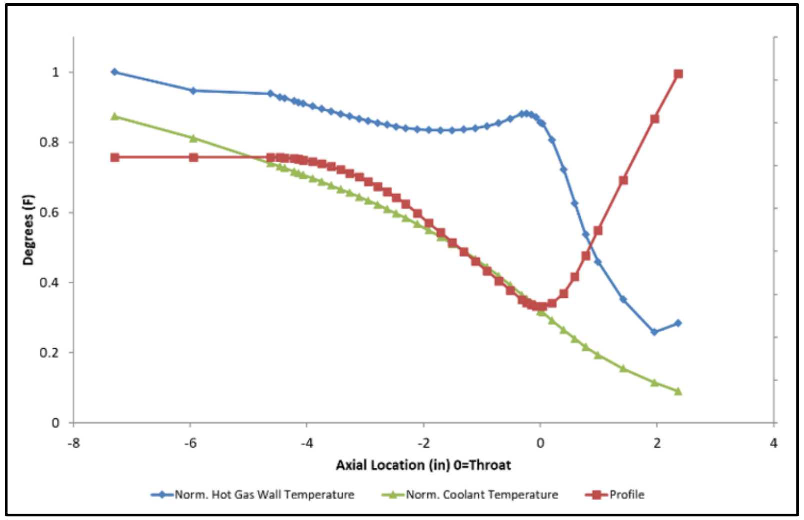
- Nitrous orifice area designed using Dyer model
  - Accounts for vapor formation from low chamber pressure
  - Nearly follows SPI model due to high manifold pressure
- DfAM allowed the manifolds to be printed onto injector face
  - One part design with no manifold seals
  - Instrumentation and chamber pressure ports



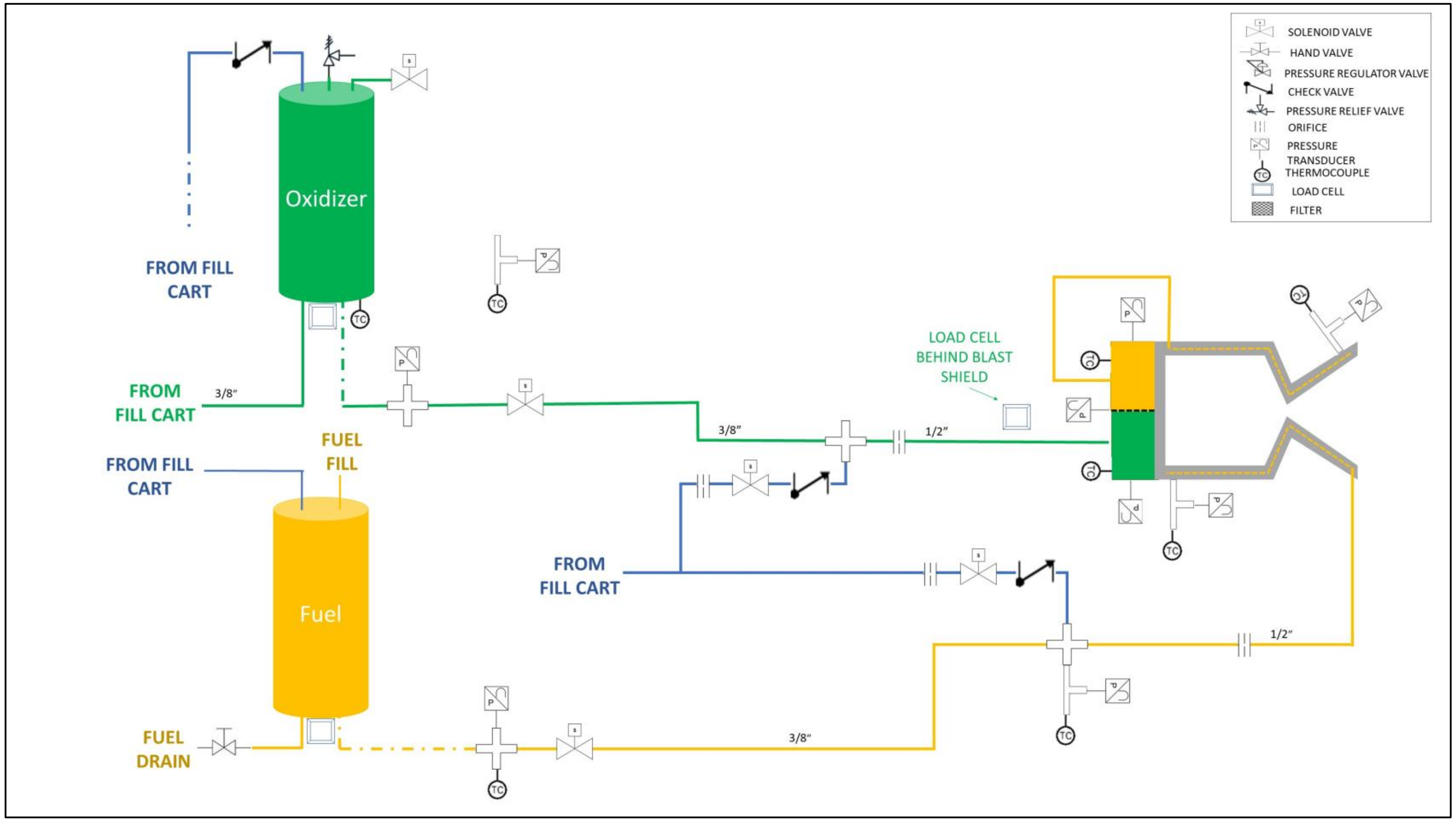
Thrust Chamber Design

- Kept same flange and injector face diameter as previous thrust chamber assembly
- NASA CEA used to find ideal operating point
  - 3.2 MR selected to lower heat loads with minimal performance loss (at 400 psi).
- Bartz heat transfer correlations used to design rectangular coolant channels
  - Near-linear coolant temperature increase
- Truncated ideal contour (TIC) nozzle design
  - Method of characteristics contour shortened for weight and length savings
- High manifold pressure to keep ethanol above critical pressure



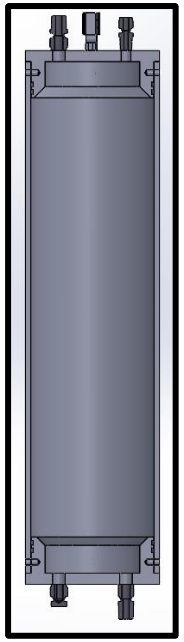


Feed System Overview



Tank Design

- Designed to hold up to 1.5x of a 1,600 psi MEOP with a factor safety of 2.
- Oxidizer and fuel tanks are pressurized with N_2.
- Oxidizer tank: 3 modules that can hold up to 5-, 10-, and 15-s worth of nitrous oxide. It includes:
  - N_2O inlet and outlet.
  - Pressure Safety Valve set to 1,800 psi.
  - Vent valve.
  - Thermocouple.
- Fuel tank: single module that holds up to 15 s of burn time.
  - Fuel drain.
  - Fuel inlet and outlet



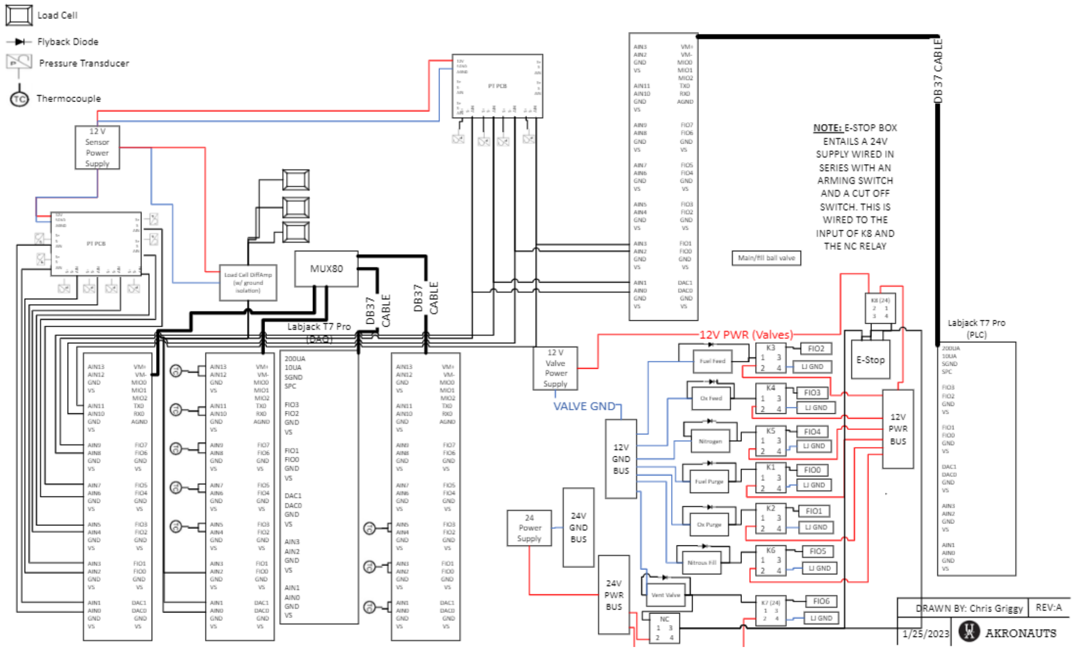
Nitrogen Gas Pressurant System

- Pressure regulator to set nitrogen pressure for system
  - For steady-state testing
  - Pressure gauge before and after regulator for operator
- Pressure relief valve set to 2,000 psi for safety of the system in case of regulator malfunction
- 3 total lines are connected to the test stand
  - Oxidizer tank
  - Fuel tank
  - Purge lines
- Another N_2 cylinder will be added to the system for increased mass flow rate and volume

Instrumentation and Controls

- Team-written software, HIVE, is the everything software for the system
  - Controls valves and DAQ
  - Controls the DAQ and control board from an external computer
  - Inputs data and directly relays it to a UI for live graph output and saving during testing

- 2 Labjack T7's used for system control and data acquisition
  - 11 pressure transducers
  - 8 thermocouples
  - 3 load cells
  - 6 solenoid valves
- Team-made op-amp is used to amplify load cells inputs and reduce noise during testing

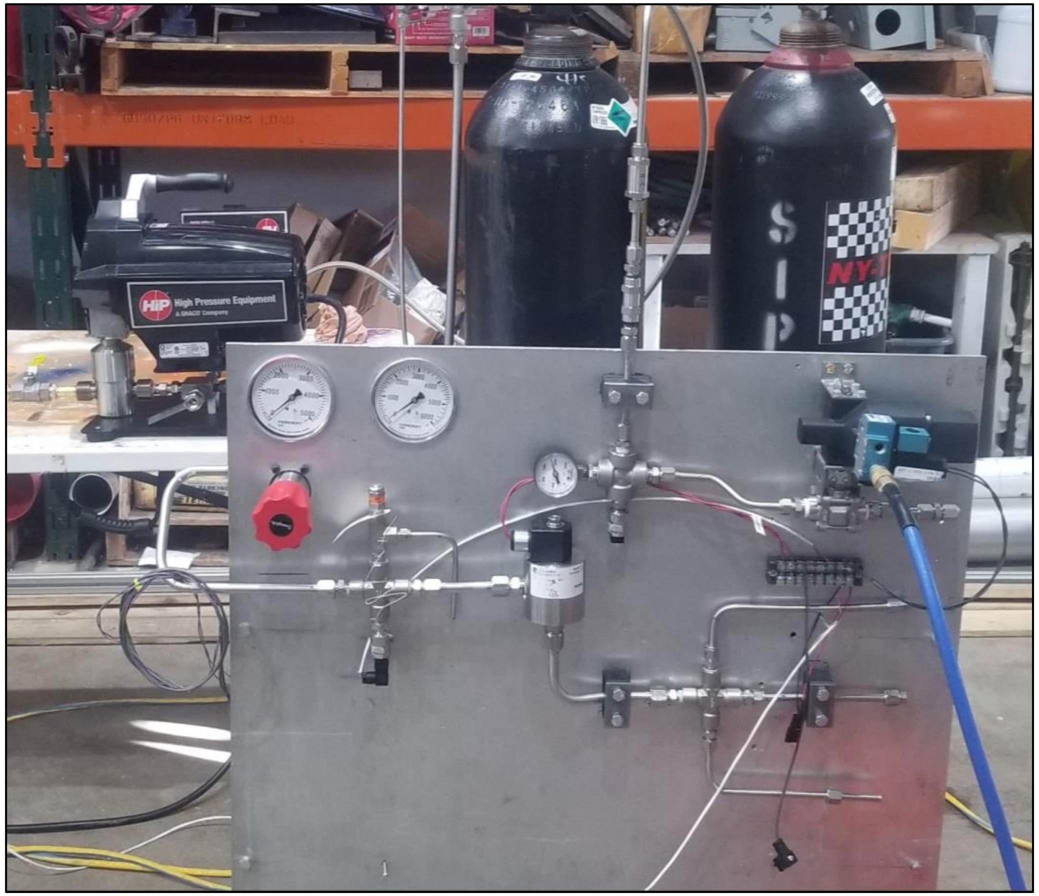


Proof Testing

- Proof tested the test stand and fill cart feed lines/tanks using hydrostatic pump

- Proved to a higher pressure than expected during testing:

Subsystem	Pressure (psi)
Test stand feed system	2,400
N_2O fill cart	1,500
EPPS fill cart before regulator	5,000
EPPS fill cart after regulator	2,400
Combustion chamber	1,200

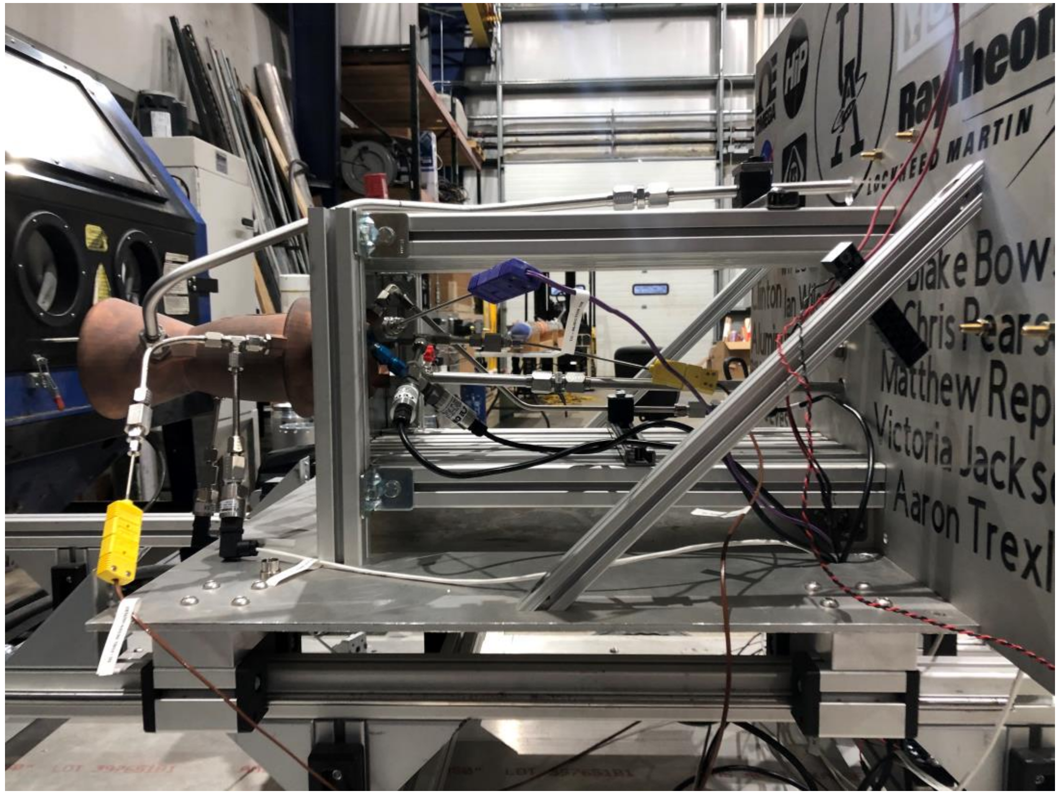


Summary and Future Work

- Designed and developed combustion hardware with regenerative cooling
  - DfAM

- Upgraded test stand with new:
  - Propellant Tank
  - Feed system
  - Control systems and instrumentation
  - Nitrogen gas pressurant system

- Future Work:



Water and nitrous oxide blowdowns pressurized with N_2 to collect test data. → **Hot fire testing** beginning in April.

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