Bi-Propellant Rocket Engine

Team:

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Background

Michigan Launch Alliance is a new initiative dedicated to bringing students within the Mid-Western United States together to learn, adapt and refine rockets and other aerospace related projects. The goal of MLA is to give opportunities to students no matter the current University/College attended. The projects developed by MLA, are developed to connect academia and industry by giving students applicable experience to use in their careers.

MLA is developing a bi-propellent rocket capable of competing in either the IREC (Intercollegiate Rocket Engineering Competition), or the FAR DPF (Friends of Amatuer Rocketry, Dollar Per Foot) competition. To complete this goal, the team needs to develop a bi-propellent engine that is capable of taking a launch vehicle on a sub-orbital trajectory.

Specifications

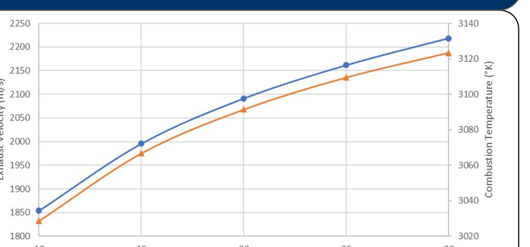
The intent for this project was to develop a demonstrator liquid bi-propellant rocket engine capable of delivering 100 lbf of thrust for at least 8-10 seconds. A variety of specifications were chosen due to safety, viability, and to be able to learn as much about the propulsive technology as possible. These specifications can be seen below.

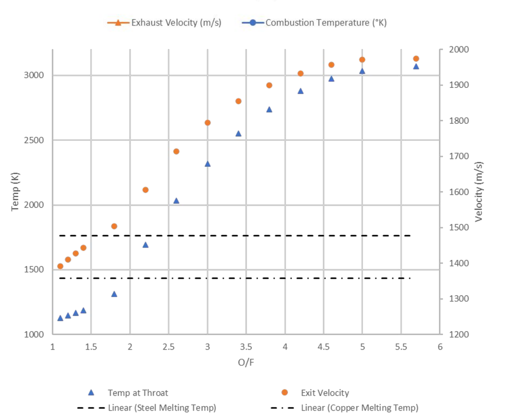
Parameter	Spec	Verification Method	Test Parameters	Applicable Regulation(s)
Burn Time Withstood (min, target)	8 s, 10 s	Analysis (simulation/ modeling) proceed to Testing	Four static fires. Incrementally step up time of tests based on amount of propellant in tanks. (2 s burn, 5 s burn, 10 s burn, etc). Examine engine for burning and warped material.	• 14 CFR § 101.29 (2009) • IREC § 5.8 • IREC § 5.14 • DPF § 17
Thrust Goal (min,nominal)	75 lbf, 100 lbf	Load Cell	Thrust vs time curve will be generated from the WMU DAQ system. Four static fires.	• IREC 5.22 • DPF § 3
Chamber pressure	10-30 bar	Analysis from testing data	Calculate from specific impulse (must integrate the thrust v time curve). Verify within 10-30 bar of pressure.	• IREC § 5.20
Propellant choice	safe, non-cryogenic, storable	Inspection	Limit risk/toxicity with decision	• IREC §5.5
Max total impulse	9,208 lb-s	Inspection/Analysis	FAA Class 2 Rocketry	• FAA 14 CFR § 101.25 (2009)
Weight	Less than 100 lbf	Scale	Weigh engine	• 14 CFR § 101.29 (2009)
Size	Less than 4 ft by 4 ft by 4 ft	Measure	Measure engine with tape measure	• 14 CFR § 101.29 (2009)

Chemical Equilibrium with Applications

The team started by working with industry CEA (Chemical Equilibrium with Applications) software. Both NASA CEA, and RPA softwares were utilized. These softwares generated necessary fuel and oxidizer parameters to help us categorize optimal theoretical properties. Useful properties included:

- O/F ratio (Oxidizer/Fuel)
- Specific Impulse
- Chamber pressure
- Combustion temperature
- Combustion gas velocity

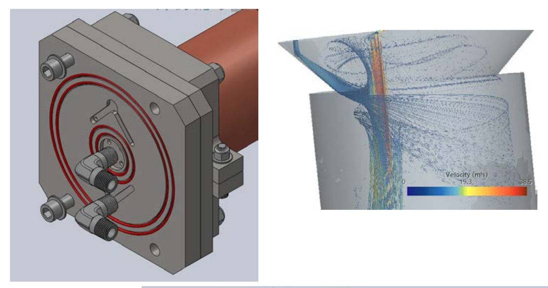


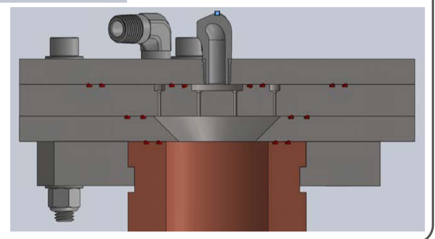


Injector

The injector must mix and atomize the liquid propellants in preparation for combustion.
Important design criteria:

- Mass flow rate
- Pressure drop across injector
- Length to Diameter ratio of each orifice
- Fuel and Oxidizer impingement with splash plate
- Pintle like device for increased propellant stay time and slower speed

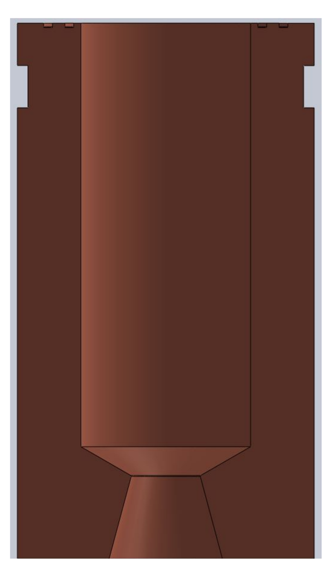


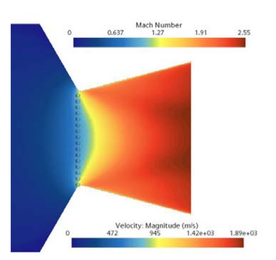


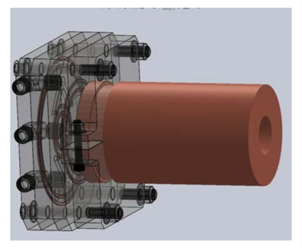
Nozzle & Combustion Chamber

Nozzle and combustion chamber were necessary to take advantage of the burning propellants efficiently.

- Withstand combustion temperatures of over 2000K
- Accelerate the combustion gasses to over Mach 1
  - Exit speed ~Mach 2.4
- Machined out of copper for high thermal conductivity
- Sized based to combustion gas characteristics and project specifications



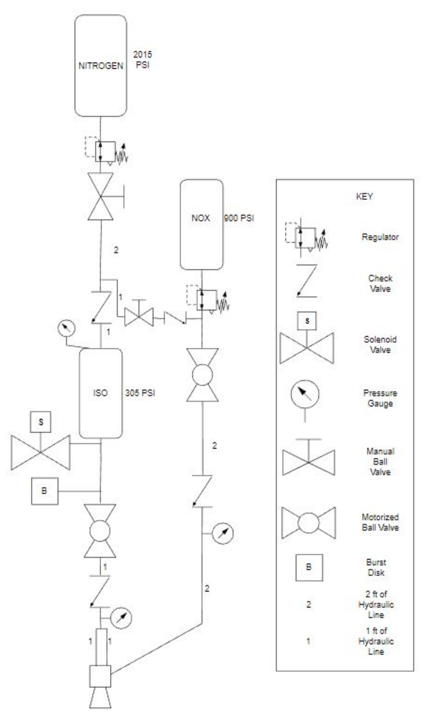




Plumbing

Plumbing was necessary to transport both the isopropanol and Nitrous Oxide to the engine.

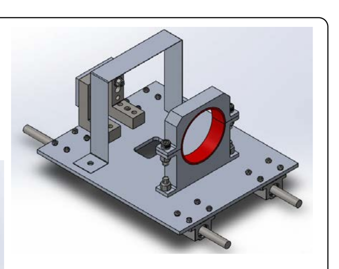
- Inert gas tank was used to pressurize isopropanol
- Motorized ball valves for remote operation
- Check valves to prevent back flow of propellants
- Modulating ball valves for throttling engine
- Custom fuel tank designed and welded

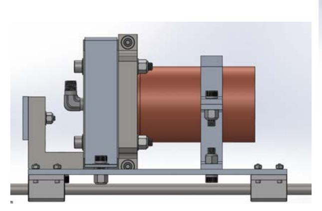


Static Test Stand

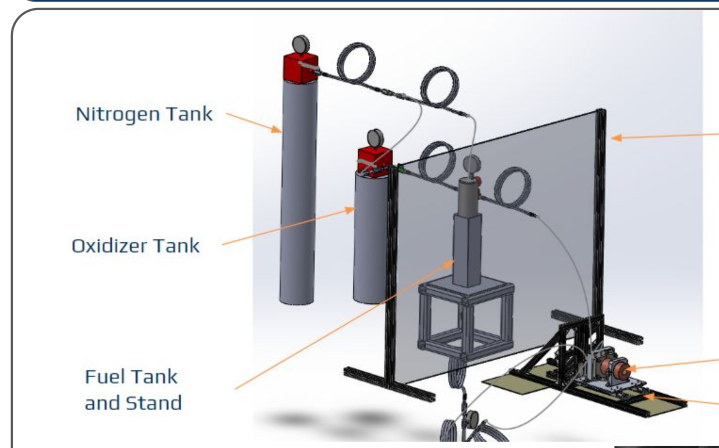
A linear rail system was used to ensure as much thrust was read through a load cell as possible.

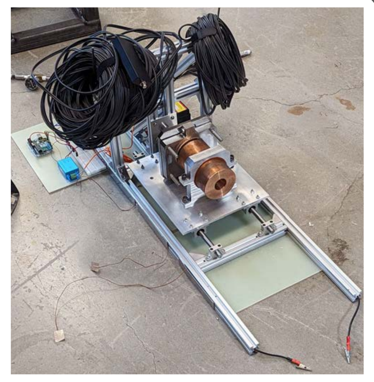
The system was designed to hold 300 lbf of load.

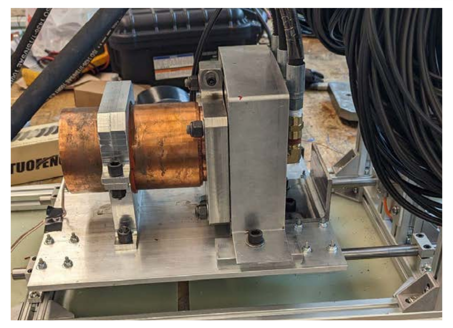


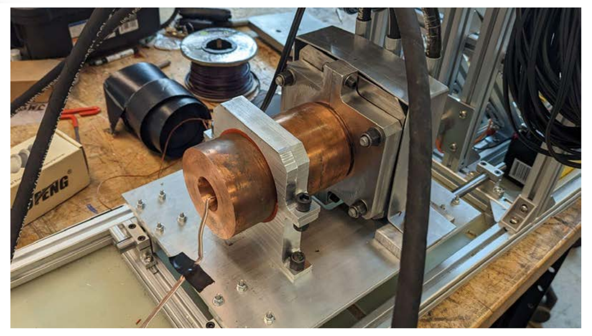


Final Design









Thank You Sponsors!

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SolidWorks

MLA

Testing Campaign

V1.0

Three injector prototypes were designed:

- Shower head
- Two different splash plate shower head hybrid designs
- Ideal injector atomizes and mixes the propellants
- The yellow splash plate shower head hybrid was selected

V2.0

The second revision saw a complete build and test of the engine.

- Cold flow testing
- Multiple Static Fires
- O/F ratio was lower than expected
- Combustion instability problems

V3.0

Results of V3.0:

- Thrust ramped up from 60 lbf to 95 lbf
- Total burn time of 12 seconds

The third revision saw the addition of:

- Throttleable propellants
  - Ramp ignition cycle (0-60%)
- Permanent ignition system with miniature solid rocket motor
- Blow-out plumbing system
- Pintle addition to injector to slow oxidizer flow