

Liquid Bi-Propellant Feed System

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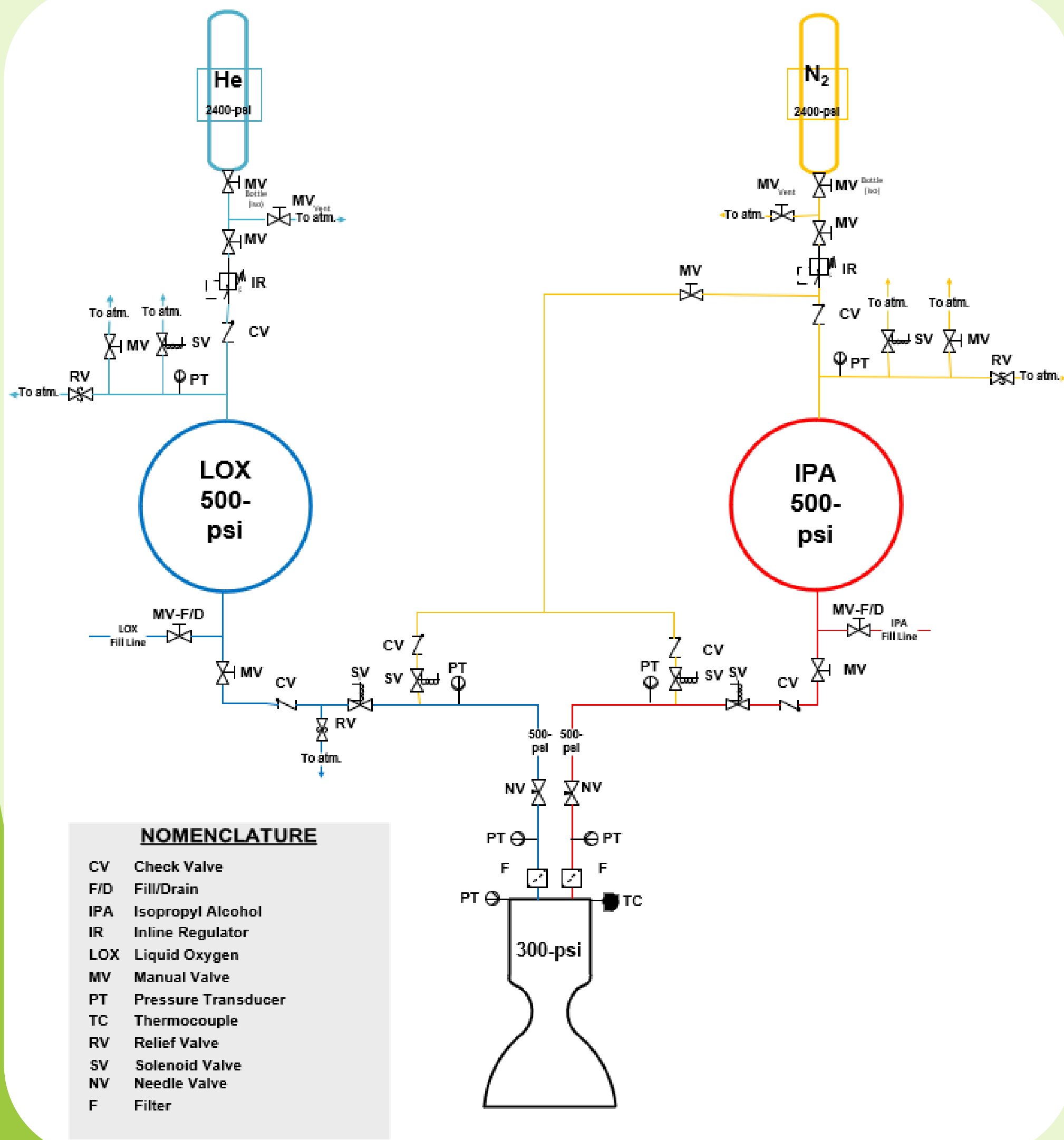
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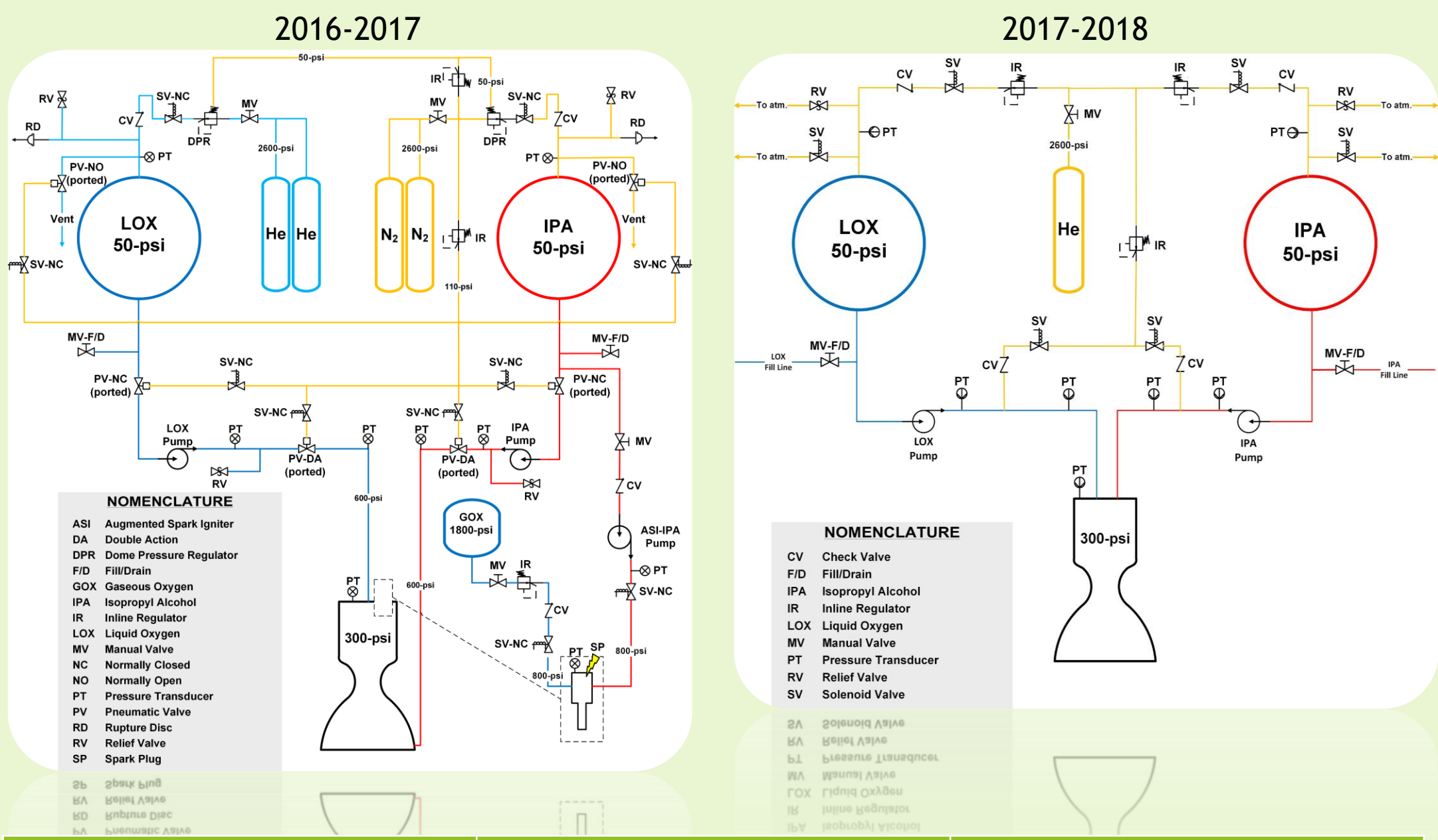
Abstract:

The goal of this project is to provide a propellant feed system that will deliver isopropyl alcohol (IPA) and liquid oxygen (LOX) to the combustion chamber of a liquid bi-propellant rocket engine. In rocket engines, popular focus is directed towards the combustion chamber and the engine nozzle. However, the more significant half of the engine is the propellant feed system. A proper feed system is crucial to bring the propellants up to necessary operating pressure for ideal combustion between the oxidizer and the fuel. Without a secure feed system, there is no way to ensure that design of the combustion chamber and nozzle are acceptable. Inert gases such as helium and nitrogen will pressurize the liquid oxygen and isopropyl alcohol, respectively. The use of inert gases ensures that the pressurant are less likely to dissolve with the propellants. By using a purely pressure fed system, the cost and trouble of maintenance of cryogenic and non-cryogenic turbo-pumps are mitigated. The system will consist of a base of Swagelok tubing and valves to simplify the system. Cryogenic rated check valves and solenoid valves are to be substituted to ensure successful safeties and operability of the LOX side. The IPA side of the system will use existing tubing and fittings and adapt the necessary Swagelok components. Before implementation, proper flow rates and pressure losses of the components must be measured to ensure successful operation of the feed system during a test fire.

Piping & Instrumentation Diagram



Previous P&ID



Item	Liquid Oxygen	Isopropyl Alcohol
Manual Valve	Habonim - Cryogenic Ball Valve*	Swagelok - SS-AFSF12 Ball Valve
Solenoid Valve	Habonim - Electrically Actuated Cryogenic Ball Valve*	Valworks - Electrically Actuated Ball Valve
Inline Regulator	Swagelok - RSH8	Swagelok - RSH8
Check Valve	RegO - CG750SSL*	RegO - CG750SSL*
Relief Valve	RegO - PRV29434TP550*	RegO - PRV29434TP550*
Pressure Transducer	LORD Sensing - ST3550*	Omega - PX309 Series
Needle Valve	Ratermann - 3000-11SS*	Ratermann - 3000-11SS*

* Cryogenic rated: -320°C to +140 °C

The propellant feed system has been redesign to fit the needs of the Rocketry Club as well as be cost efficient. Working with Ben Kellie of The Launch Company and K2 Dronotics, a purely pressure fed system was designed to mitigate the costs of turbopumps to pressurize the propellants. The previous designs from 2016-2017 and 2017-2018 were overly complicated and overly simplistic, respectively. Both designs incorporated turbopumps to increase the propellant pressures before entering the combustion chamber. However, a turbopump can range from \$20,000 to \$50,000, considering that one would need to be cryogenically rated.

Each part of the system was design to suit a range of flow rates so that iterative engine designs could be tested. The system was also designed with redundant safeties so it would be safe for students to handle. Starting at the pressurant gasses, the inert gasses are stored in k-bottles that are initially 2400 psi. After multiple tests, the k-bottles will lose pressure and must either replaced to continue testing. In order to safely remove a k-bottle, the manual valve on the k-bottle, and the system must be closed. However, pressurized gasses remain between the valves, so a third manual valve facing away from the system and handler must be opened to relieve the remaining pressure before the k-bottle is detached.

Cryogenic liquids are self-pressurizing at room temperature, and must be allowed to vent into the atmosphere to maintain safe pressure levels. At the propellant tanks there are three methods to relieve pressure if the tanks were to get over pressurized. During operation, the first safety method is the relief valve set to 550 psi. If the relief valve cannot relief pressure at a fast enough rate, then an electrically actuated ball valve will open if the pressure remains at or above 550 psi for greater than 3 seconds to relieve any extra pressure. There is also a manual valve if the tank needs to be open to the atmosphere. The tank safeties are identical on either side incase the club decided to use two cryogenic propellants in the future as well as prevent over pressurization of the tanks. Any tubing that can trap LOX must be able to vent to the atmosphere. Before a test fire, the last solenoid valve can trap fluid between itself and the check valve, therefore a relief valve is required to vent pressure if the trapped LOX self-pressurized beyond the desired value.

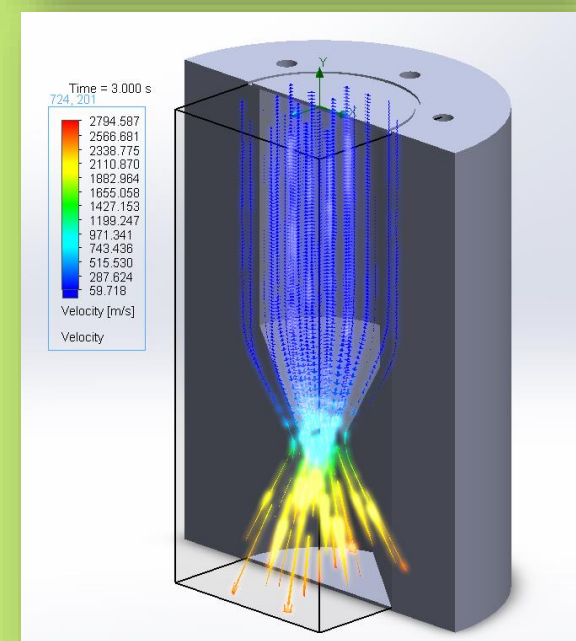
Test Trailer

The horizontal test trailer is intended to test the engine thrust and aid in perfecting the timing sequences for propellant flow throughout the piping and instrumentation that will be mounted to the trailer. To prevent the trailer from moving during a test fire, 3,000lb blocks of concrete are going to set on each foot allowing for the trailer to push back against the thrust generated by the engine. Much of the support structure has been completed through the help of the Ironworkers local #751 team. Currently, the team has completed mounting the floor and blast shield to the structure. The tank mounts are ready to be installed and the legs are being manufactured. All that remains is to design the mounting systems for the engine and the propellant feed system to make it operational.



Baseline Engine

The Baseline Engine was designed to be a test engine in order to practice testing procedures and test trailer/instrumentation. The engine is uncooled, therefore test runs will last for about 2-3 seconds so that the throat of the engine does not melt before more tests can be conducted. Setting the chamber diameter to 4 in., the length to 12 in., and the area ratios of 3.00 for Chamber to throat and 3.65 for exit to throat, the following engine was produced. To lessen the friction and vorticity at the throat, a fillet of 1.5 in. was used to smoothen the transition of the hot gases from the chamber to the nozzle. The engine weighs about 62.6 lbs and is made out of 6061 aluminum.



Team & Contributors

Current team:

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Faculty Advisor:

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Sponsors:

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