# Renewable Rocket Engineering

Liquid-fueled Rocket Motor


# Overview

- Team Introduction
- About The Project
- Design Overview
- Current Project Status
- Conclusion

# Project Team

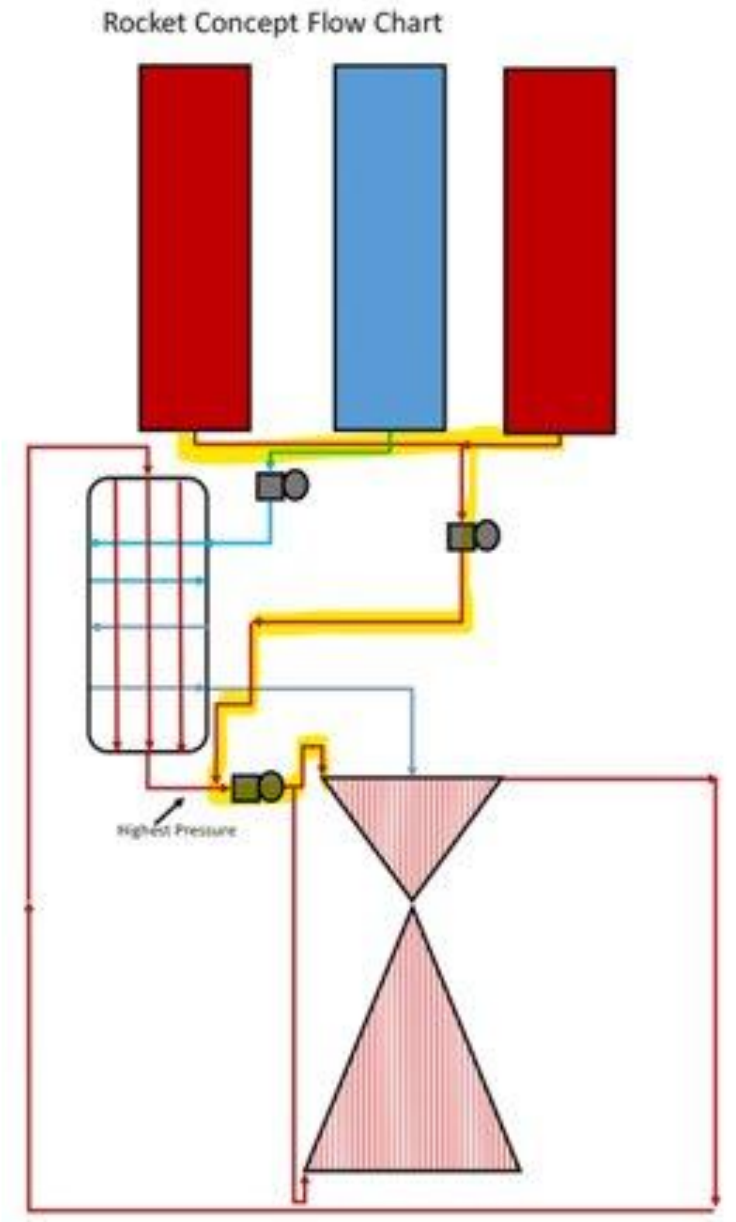
- Team members:
  - Benoit Saulnier – Project manager
    - Interested in space exploration and propulsion systems
    - Sub-system responsibility: Pumping systems
  - Nathan Juven
    - Interested in the aerospace field and space exploration
    - Sub-system responsibility: Heat exchanger and swirler
  - Raymond Daly
    - Interested in aerospace engineering and sustainability
    - Sub-system responsibility: Combustion chamber and nozzle
  - Deane Casey
    - Interested in aerospace engineering and renewable energy
    - Sub-system responsibility: Fuel storage and assembly
- Faculty advisor: Dr. Forrest Ames

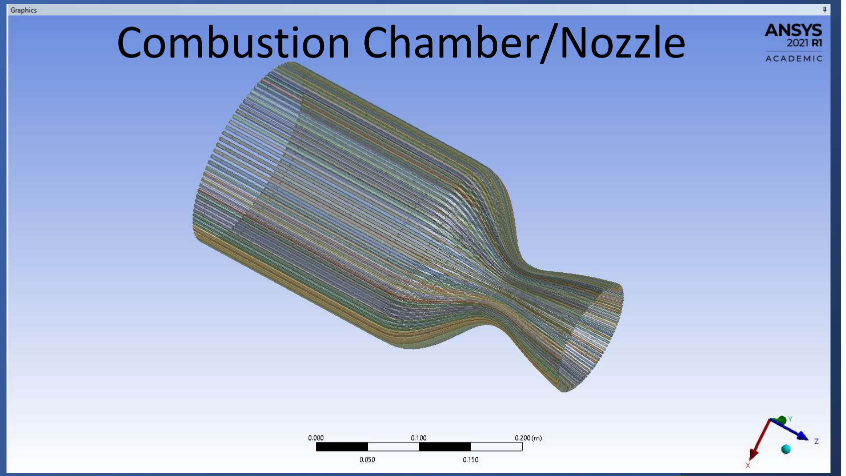
# Project Background

- Overall goal is to design a liquid-fueled rocket capable of reaching the Karman Line (internationally recognized boundary of space – 100 km)
- Initially started as part of the BASE-11 launch competition
- Continued as a mechanical engineering senior design project for ME 487/488, this is the third year
- Ethanol/LOX fueled rocket, 2250 lbf thrust
- We have formed a student organization called Renewable Rocket Engineering
- Base 11 was cancelled until further notice

# Design Concept

- 3 tanks – 2 Ethanol + 1 Liquid O2
- Pumps for Ethanol and LOX
- Combustion chamber and nozzle regeneratively cooled with the help of a recirculation system
- LOX gasified through a heat exchanger and fed to the combustion chamber via swirlers – for optimized mixing
- Electrical system will be powered by LiPo batteries – will power the pumping systems and the ignition system



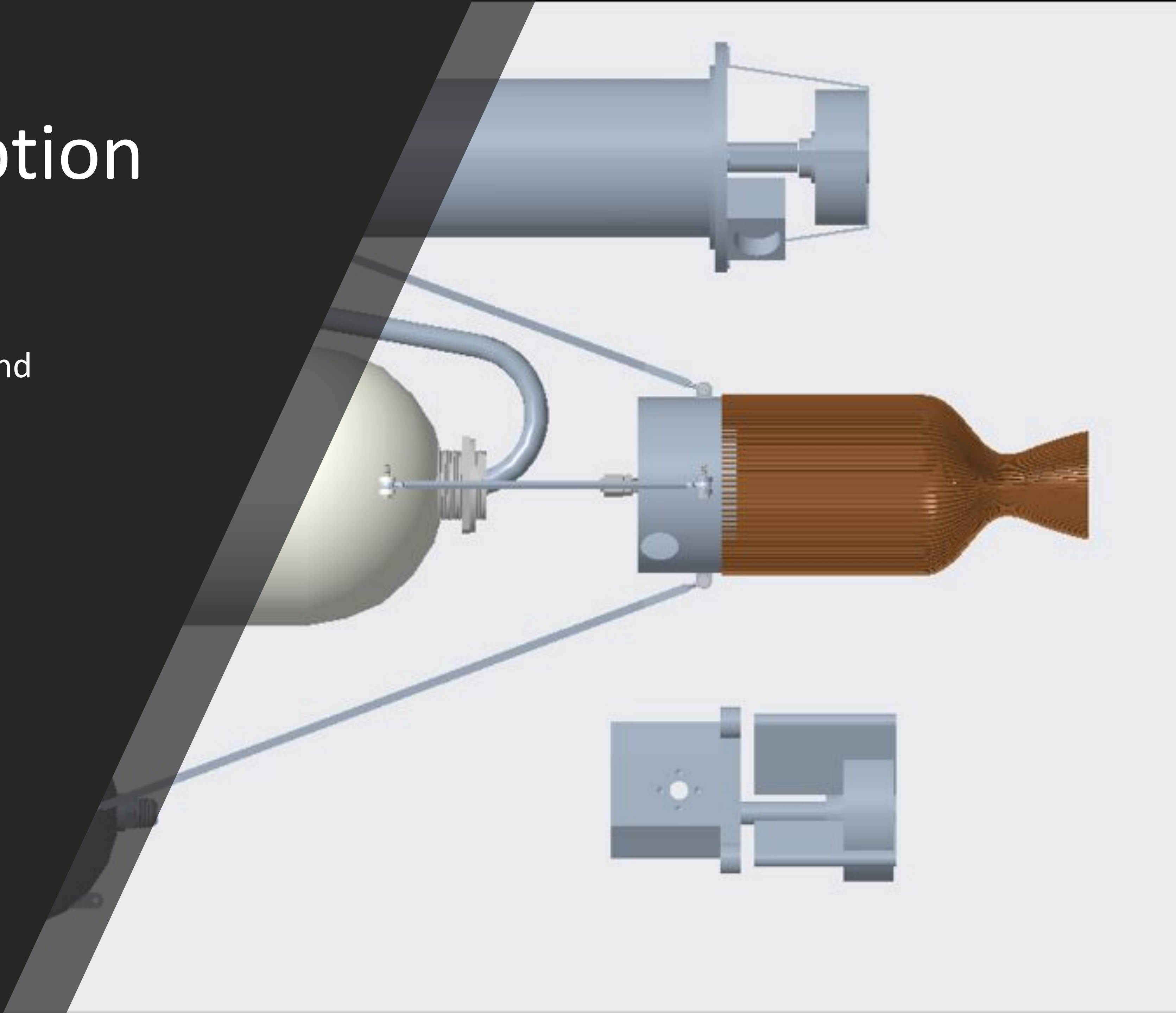



# Rocket Specifications

- Design thrust: 2250 lbf
- Planned weight: 1500 lb w/ 1000 lb being fuel and oxidizer
- Thrust to weight ratio: 1.5
- Fuel flow rate: 1.7 kg/s
- Oxidizer flow rate: 2.1 kg/s
- Chamber pressure: 24 bar
- Electrical power required: 25 kW for approximately 2 minutes

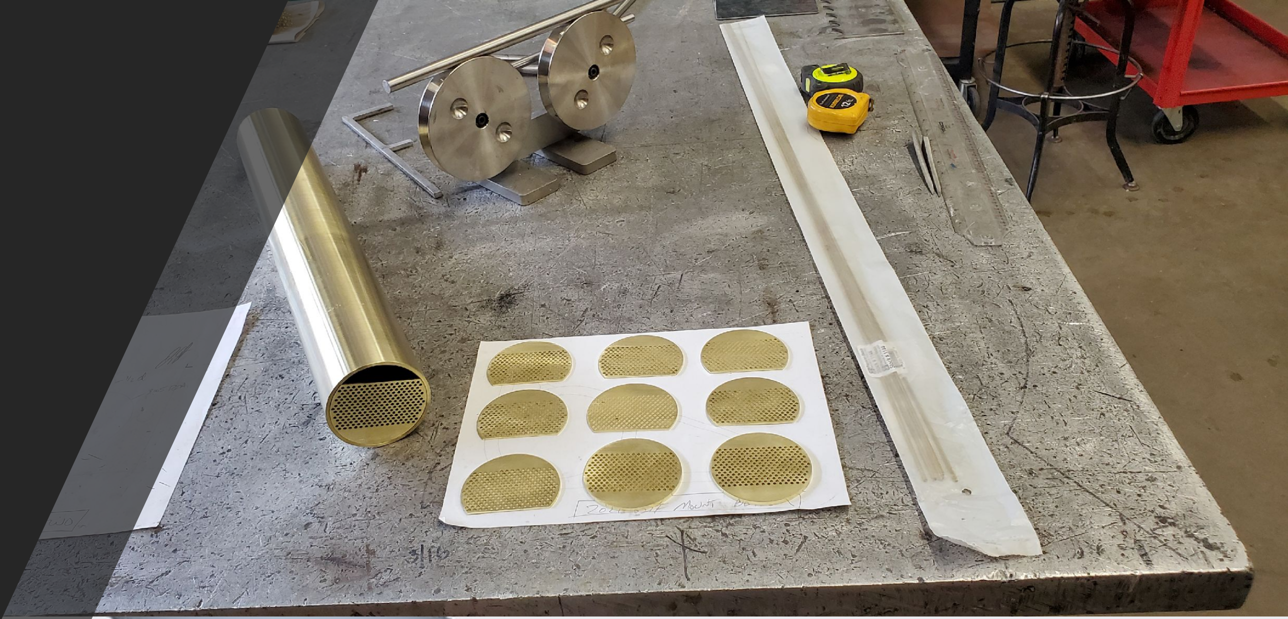
# Project Description

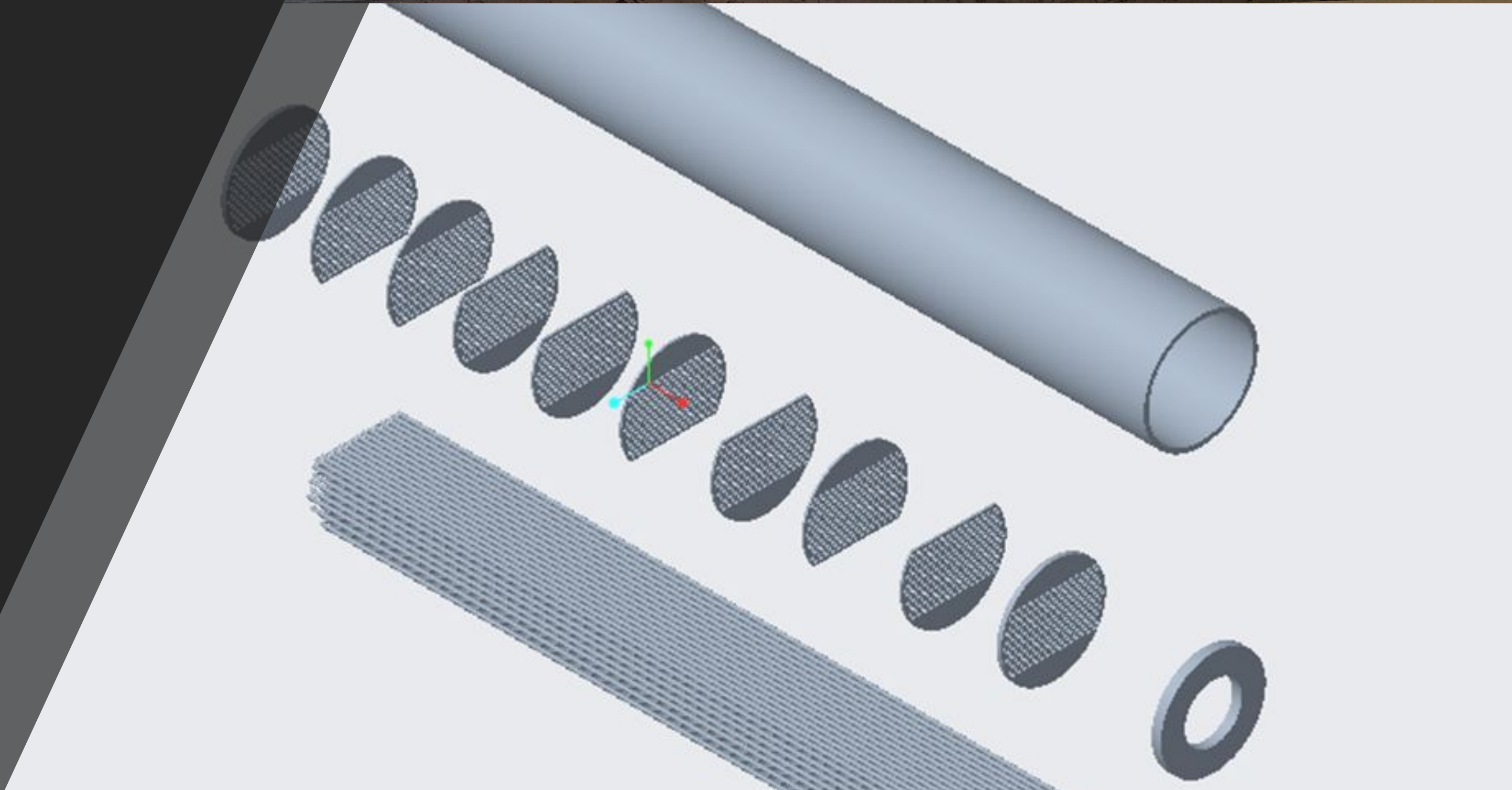
- This year's team will conduct analysis, design, fabrication, and testing of the following subsystems:
  - Heat exchanger
  - Nozzle
  - Pumping systems
  - Combustion chamber
  - Fuel and oxidizer storage
  - Fuel and oxidizer tank insulation

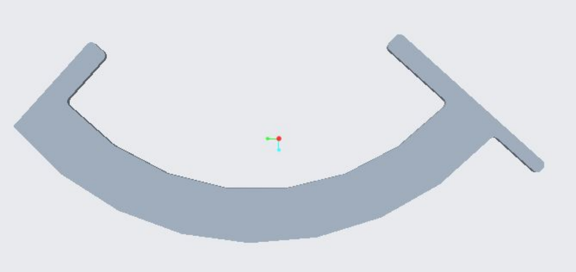


# Current Design: Heat Exchanger

- Current Status
  - Flow analysis on heat exchanger completed
    - Assessed flow rate, design parameters and pressure loss in the heat exchanger.
  - Multi-pass parallel flow shell and tube heat exchanger
    - 242 tubes for ethanol
    - 8 baffles for oxygen to direct flow over the tubes
  - Materials have been received and fabrication started.
    - In large part thanks to the grant received from NDSGC

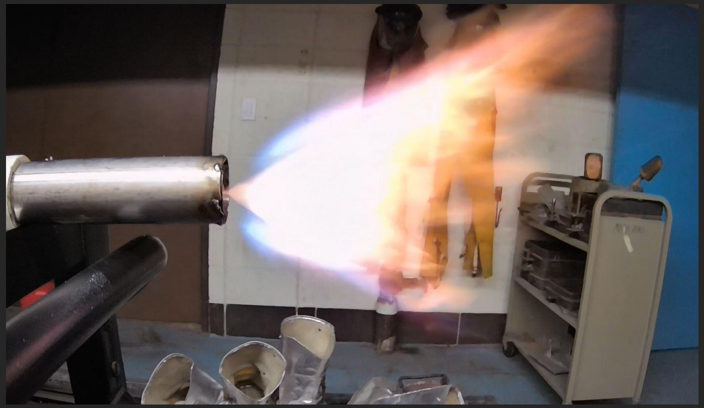






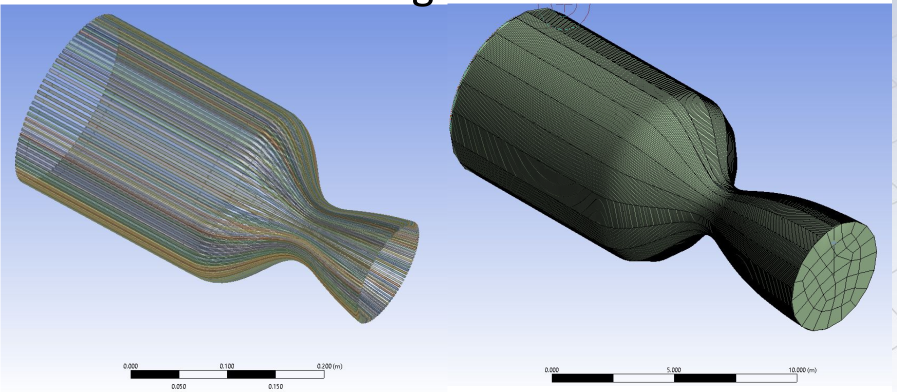
# Current Design: Swirlers

- Current Status
  - Swirler design amended
    - Swirler vane angle changed from 50 to 60 degrees for better mixing
    - 8 vanes instead of 6
  - Repositioning of the holes on the inner tube and redesign of the swirler vane
  - Inner and outer tubes have been purchased
- What’s Next
  - Looking to get final approval of design to begin fabrication and testing



# Current Design: Combustion chamber/Nozzle

Fig. 1



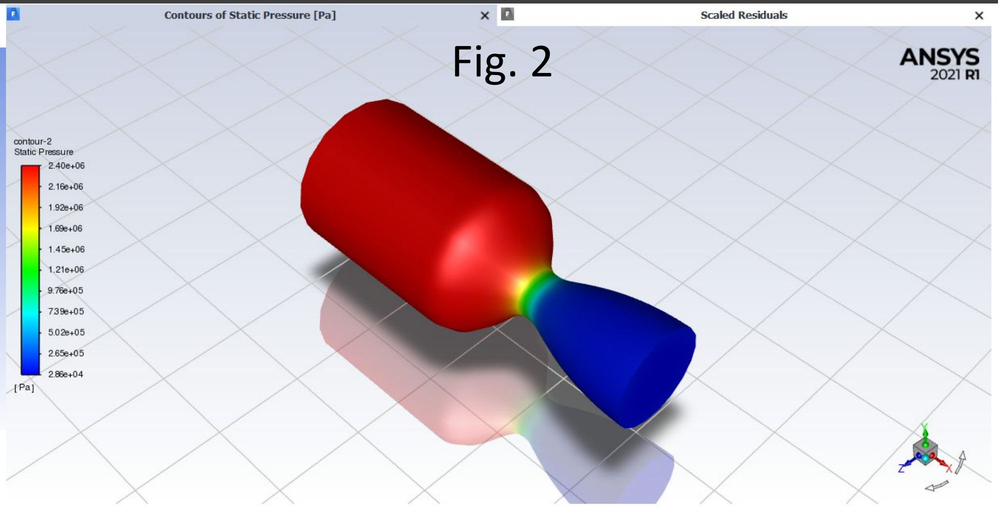



Fig. 2

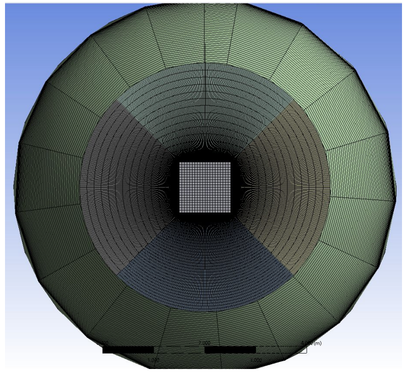


Fig. 3

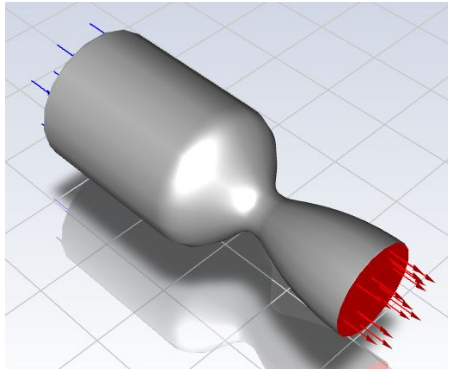


Fig. 4

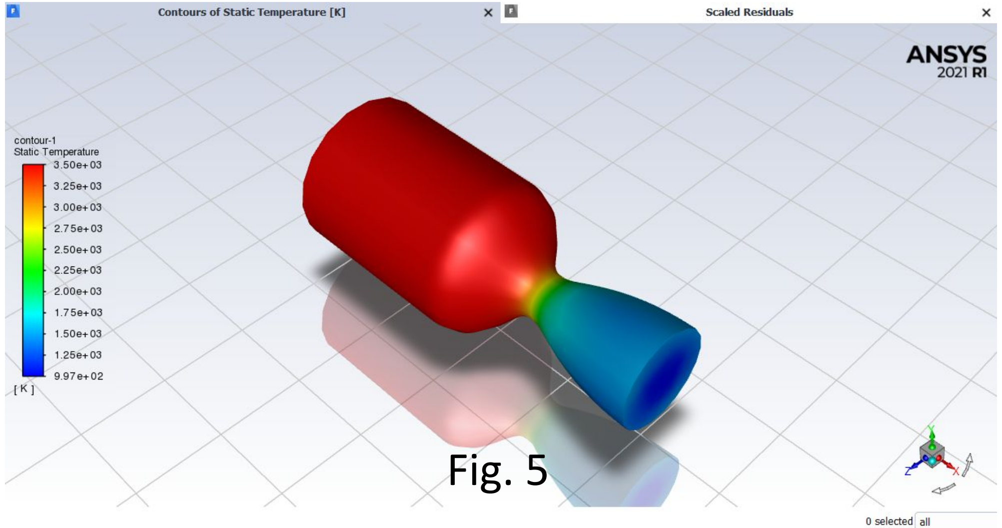



Fig. 5

Parameters:

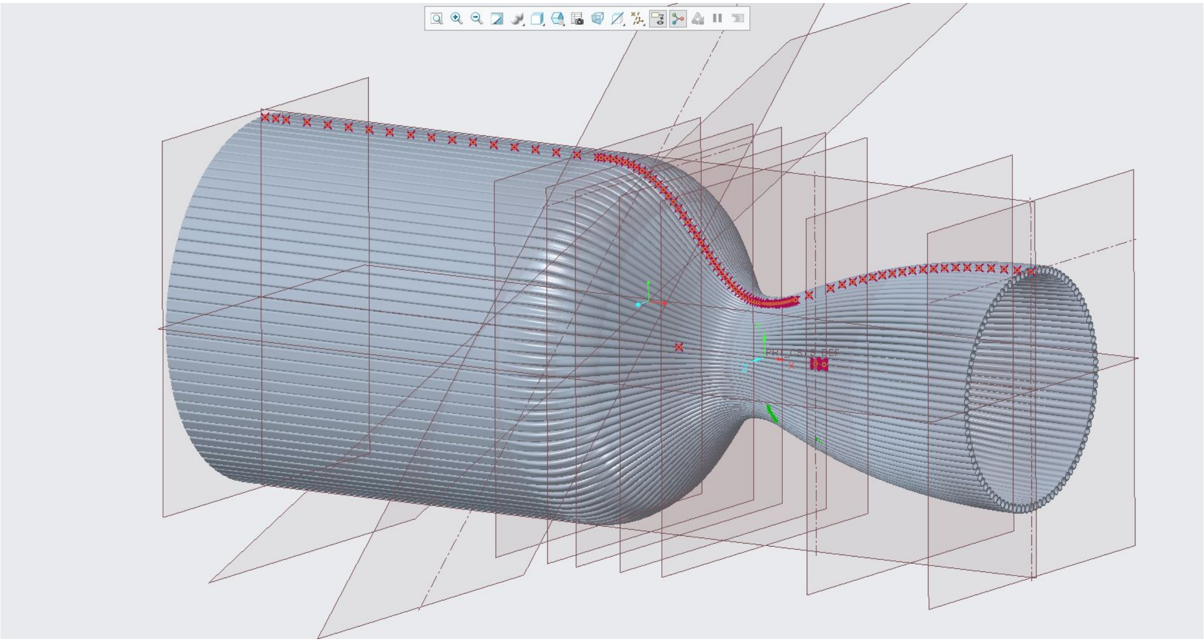
- Energy Eq. On
- Viscous Model: k-epsilon
- Fluid: Air (Ideal Gas)
- Fluid Viscosity: Sutherland
- Inlet: 24 bar
- Outlet: 1 bar
- Hybrid Initialization
- 200 Iterations for Calculation

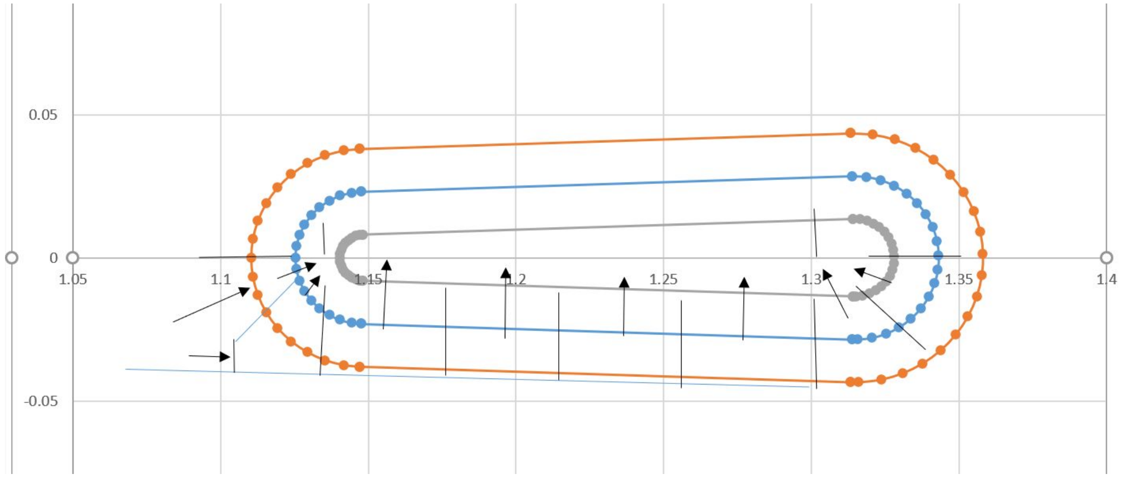
- Meshing Combines
  - Sweep Method
  - Multizone Method

- Analysis in-progress

# Current Design: Combustion chamber/Nozzle

CAD





# Current Design: Combustion chamber/Nozzle

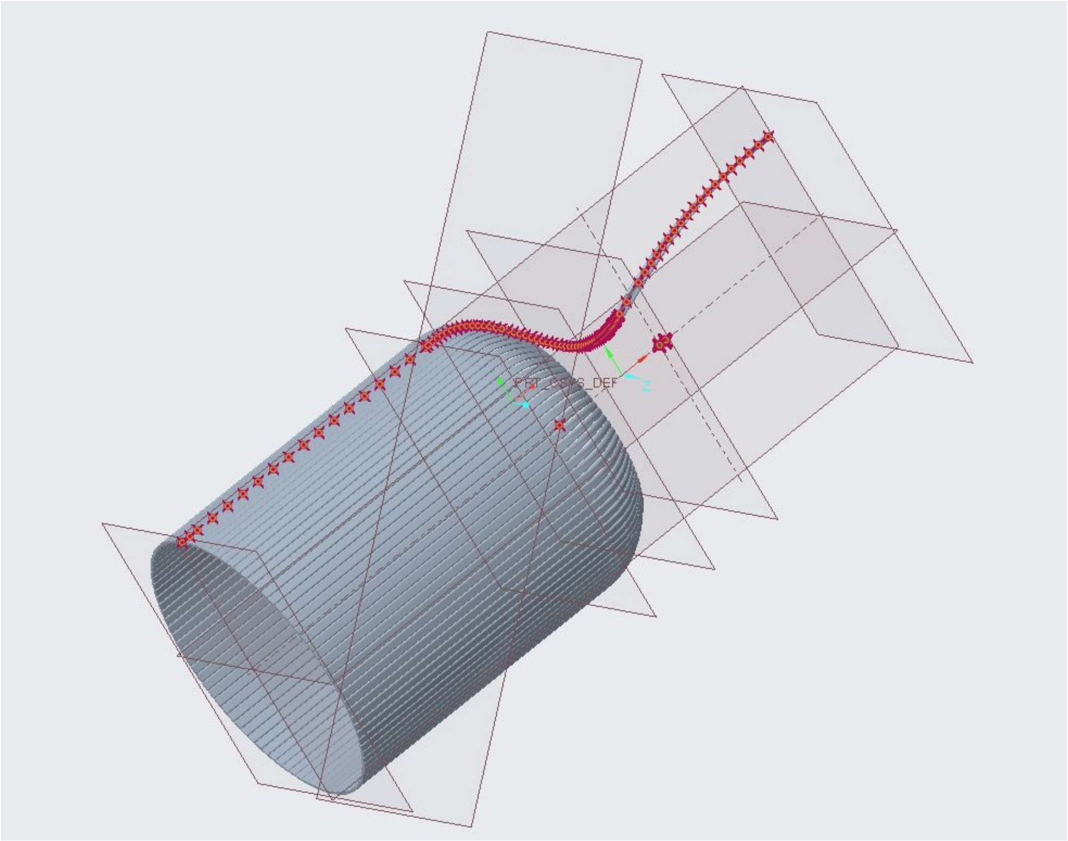
CAD

**Recently accomplished:**
-Variable Cross-Section

**Next Steps:**
-Shell on the outside

-Recapture Ports

-Recapture System



# Current Design: Combustion chamber/Nozzle

**Fabrication:**

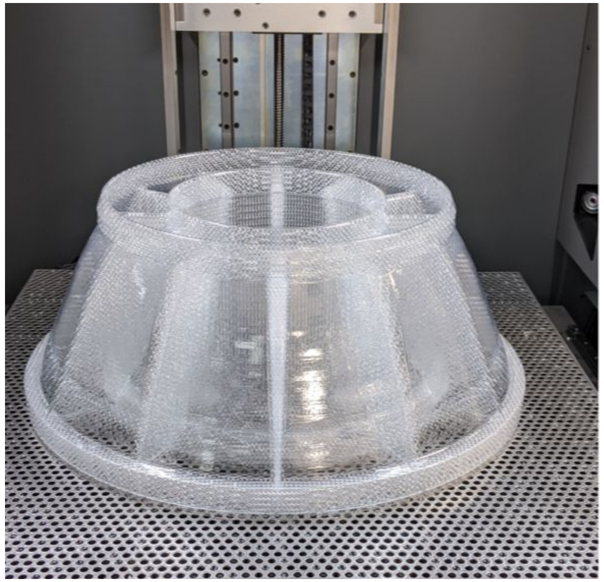
3 methods of fabrication explored:

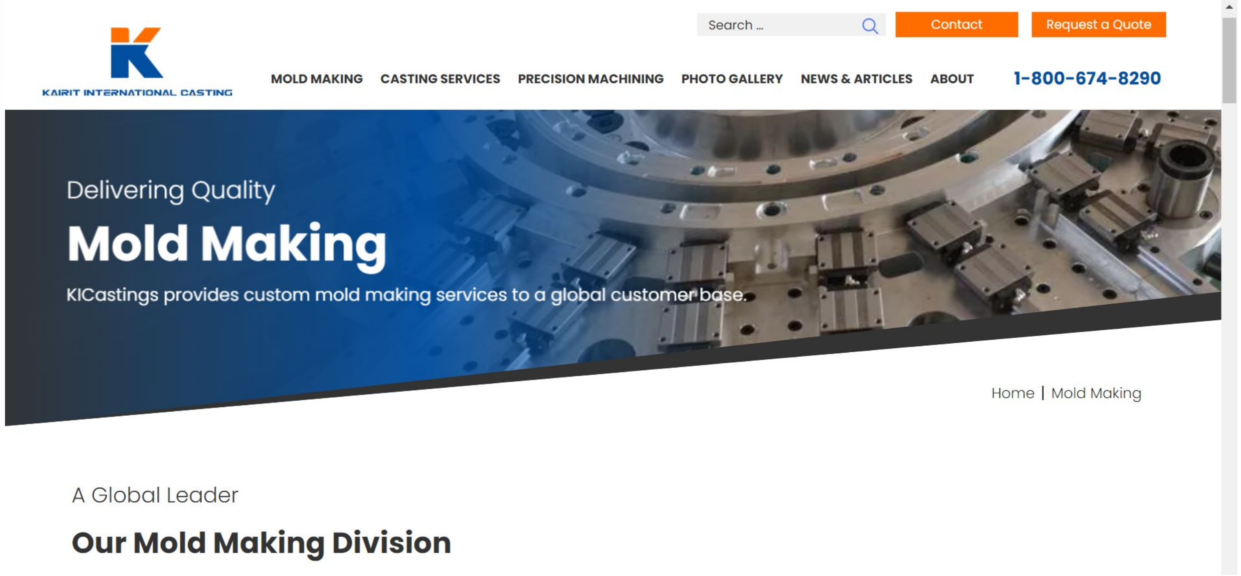
- Tube bending
- 3D printing
- Investment casting

Investment Casting

Low-Ash Stereolithography

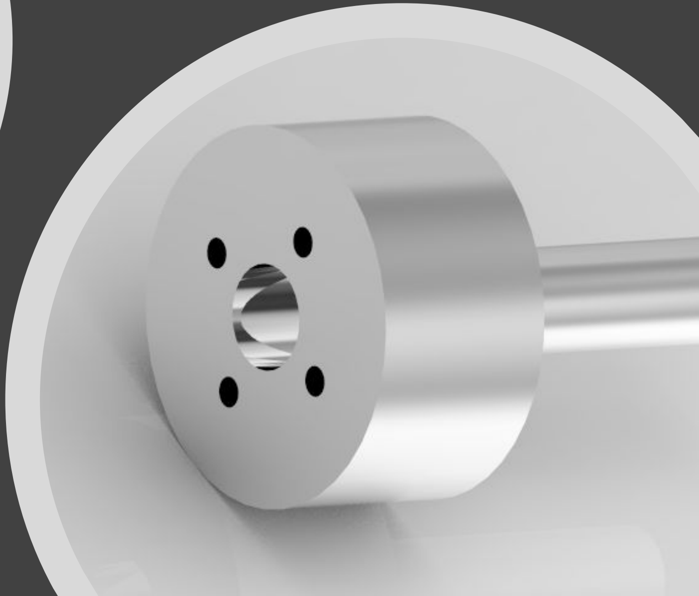
Selection of Firm





# Current Design: Pumping systems

- Current Status:
  - Stainless steel centrifugal pump (LOX)
    - Flow and power calculations confirmed
    - RAE pumps GMVCP 8 centrifugal pump
  - Aluminum gear pumps (ethanol)
    - Danfoss SNP3NN 033/075 gear pump selected
- What’s next?
- Obtain drawings and pricing for centrifugal pump
- Complete the motor coupling design
- A 075  Ordered

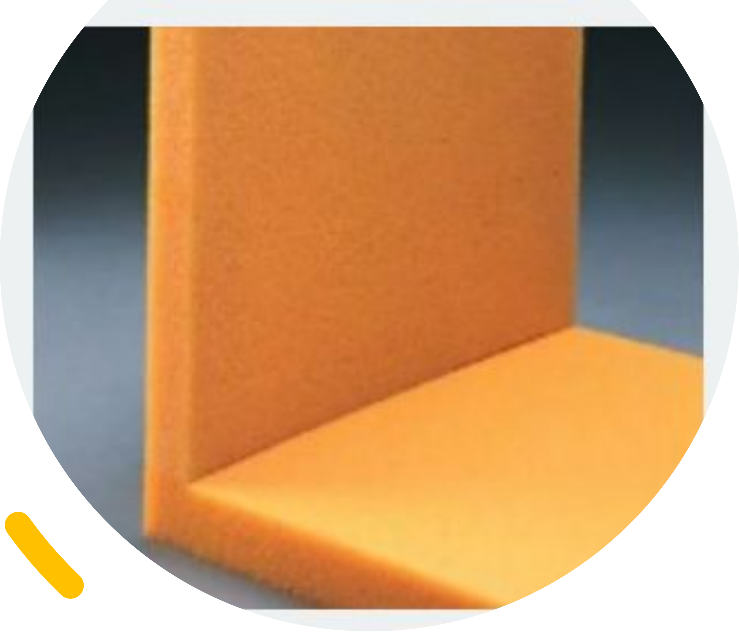
# Current Design: Storage and Mounting System

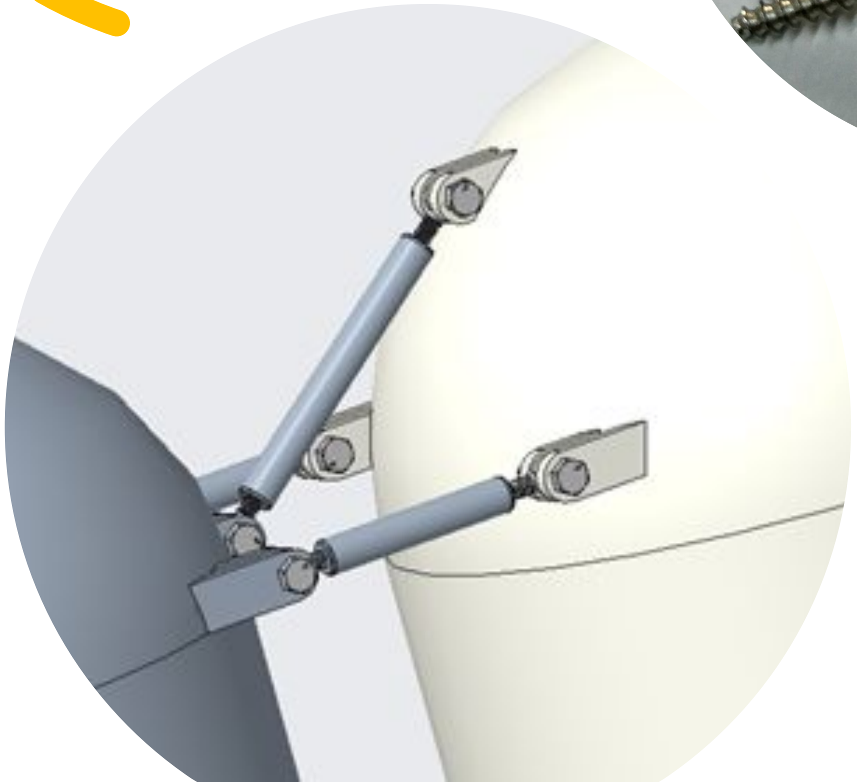
Current Status

- Tanks
    - Triangular support design
    - Composite struts
- Insulation & Mounting
- Solomide/Microlite Blanket
- Plastic composite nails

Next Steps

- Determine design constraints for reducing vibrations
- Heat loss and stress analysis
- Select adhesive and determine curing methods
- Select mounting nails/brads





# Conclusion

- Our team has met several of its objectives for this year, including:
  - Approved analysis of heat exchanger subsystem
  - Design and drawings for the heat exchanger
  - Materials ordered for the heat exchanger, tanks and pumping
- Fabrication and testing is currently taking place.
- Full system testing will probably be a goal for next year’s team, in continuation towards the objective of building a flight-ready rocket.

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