Journey to Spaceport

Charlie Nitschelm

Prospective SpaceX Employee, Build Engineer

My Background

- Senior mechanical engineering major and physics minor at the University of New Hampshire
- Founded UNH SEDS and the current President and Lead Engineer
- Member at Large at SEDS USA

Job Experiences

Summer 2018
Inconel Behavior at NIST

2018-2019 School Year
Effect of tool coatings at TURBOCAM International

Summer 2019
Rutherford engine production at Rocket Lab USA

Just visiting!

The 3-Year Plan

Year One
2017-2018

Rocket Building
Simulating
Launching
Optimizing

Year Two
2018-2019

Hybrid Engine
Engine Design
Manufacture
Test

Year Three
2019-2020

Hybrid Rocket
Spaceport America Cup
Rocket Vehicle
Engine Optimization

Year 1 – Sophomore Year

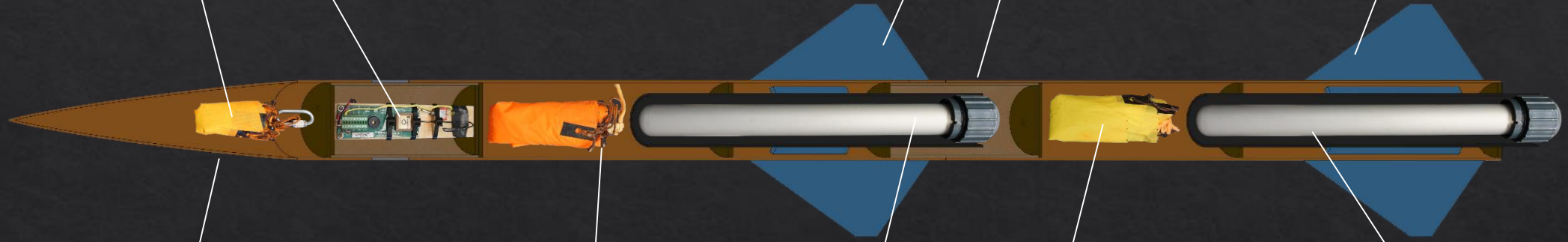
Organization Statistics

Committed Members: 11
Majors: 3
Senior Projects: 4
Funding: $2,250

My Role
President, Lead engineer

SEDS Rocketry Competition, May 2018, Maine

Year 1 – Rocket Building



Electronics Bay
Houses the TeleMega GPS and controls flight events

Staging Coupler
Supports stage separation at sustainer ignition

Drogue Parachute
A small parachute deployed at apogee

Forward Fins
Provides stability to the sustainer

Aft Fins
Provides stability to the rocket

Custom Nose Cone
A 3D printed nose cone that houses the drogue parachute

Sustainer Engine
Propels the rocket to flight apogee

Booster Engine
Initiates flight

Sustainer Parachute
The main parachute that slows the sustainer to landing speed

Booster Parachute
A large parachute for booster landing

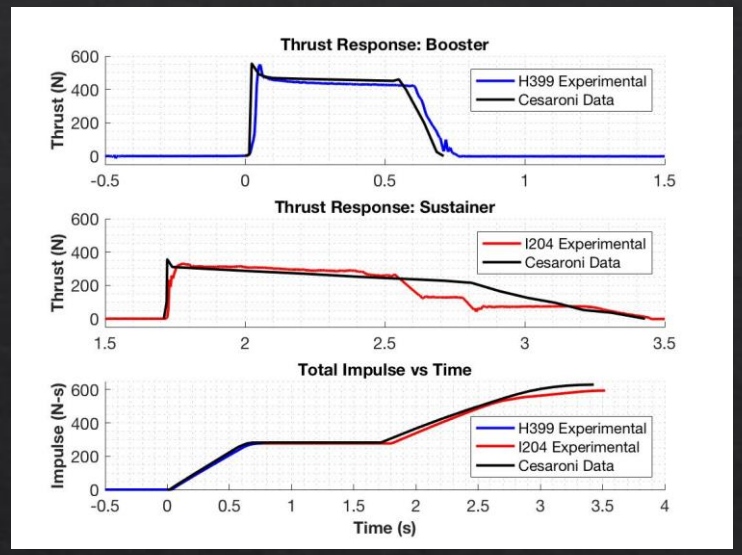
Year 1 – Simulating

$$\sum_{n=1}^{\infty} F = \frac{d\vec{p}}{dt} = \text{Mass} * \vec{a}(t, v, h)$$

$$\vec{a}(t, v, h) = \frac{Thrust(t) - Weight(t) - Drag(t, v, h)}{Mass(t)}$$

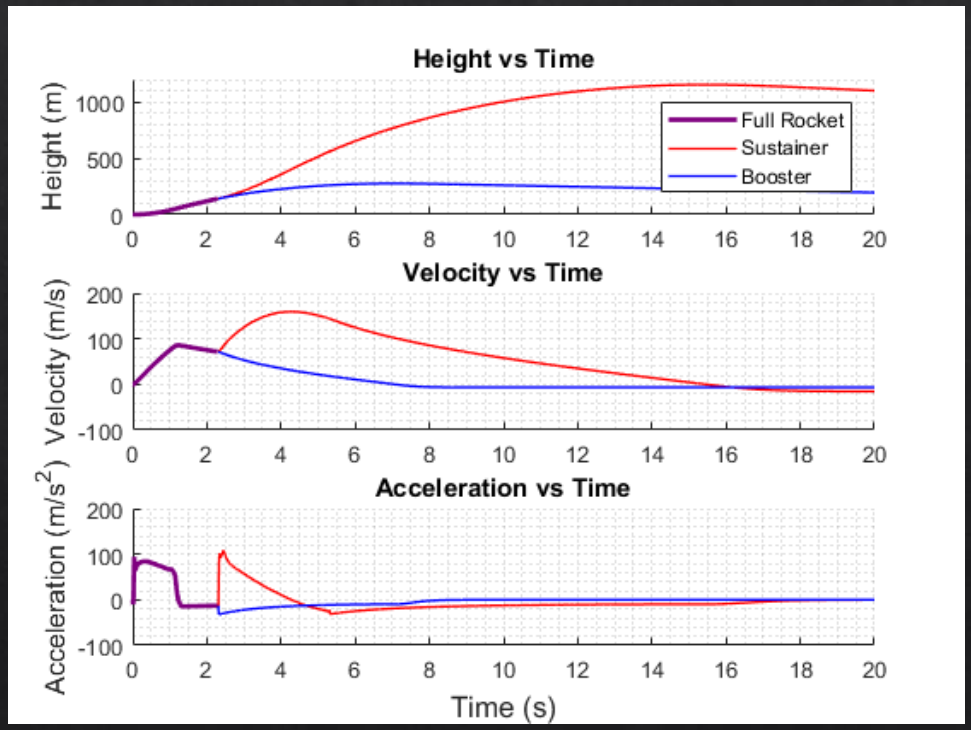
$$Where\ Drag(t, v, h) = Drag_{SF} + Drag_{PD} + Drag_{BD}$$

Hot Fires of COTS engines to obtain thrust data



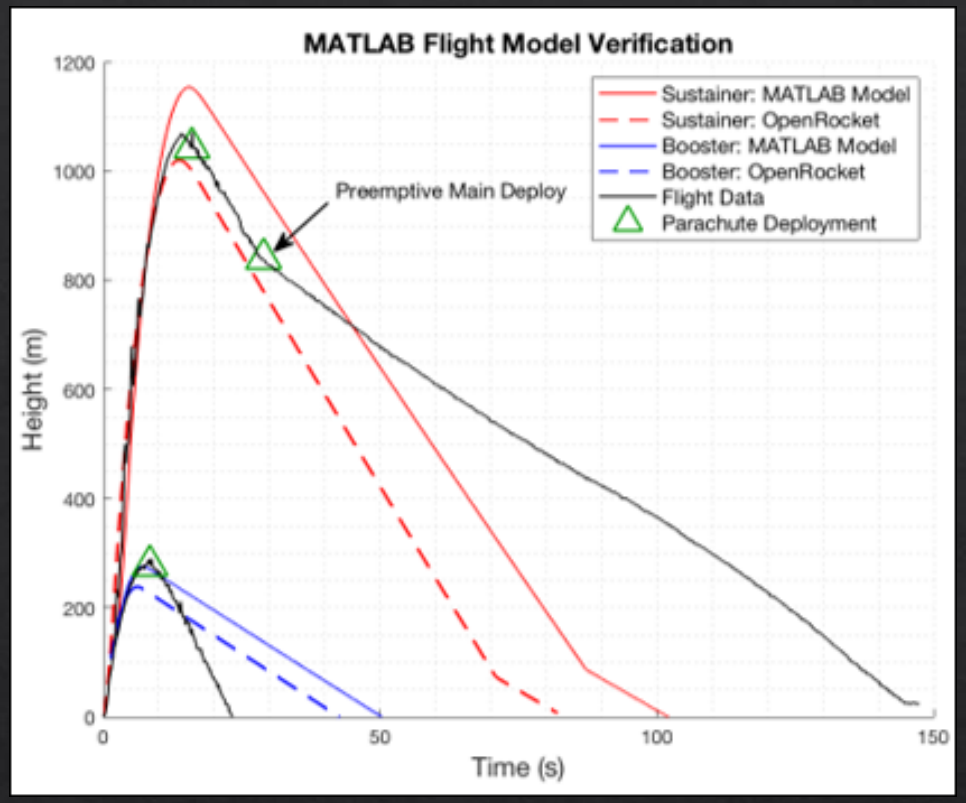
	Reported Max Thrust	Measured Max Thrust	Reported Total Impulse	Measured Total Impulse
Booster Engine: H399	545.8 N	549.6 N	282.2 N-s	277.1 N-s
Sustainer Engine: I204	356.8 N	329.7 N	347.7 N-s	322.7 N-s

Discrete-Event Simulation



Year 1 – Launching

- Built nine experimental rockets with six being multi-stage
- Reduced flight failures from 4 out of the first 5 to 1 out of the last 4.

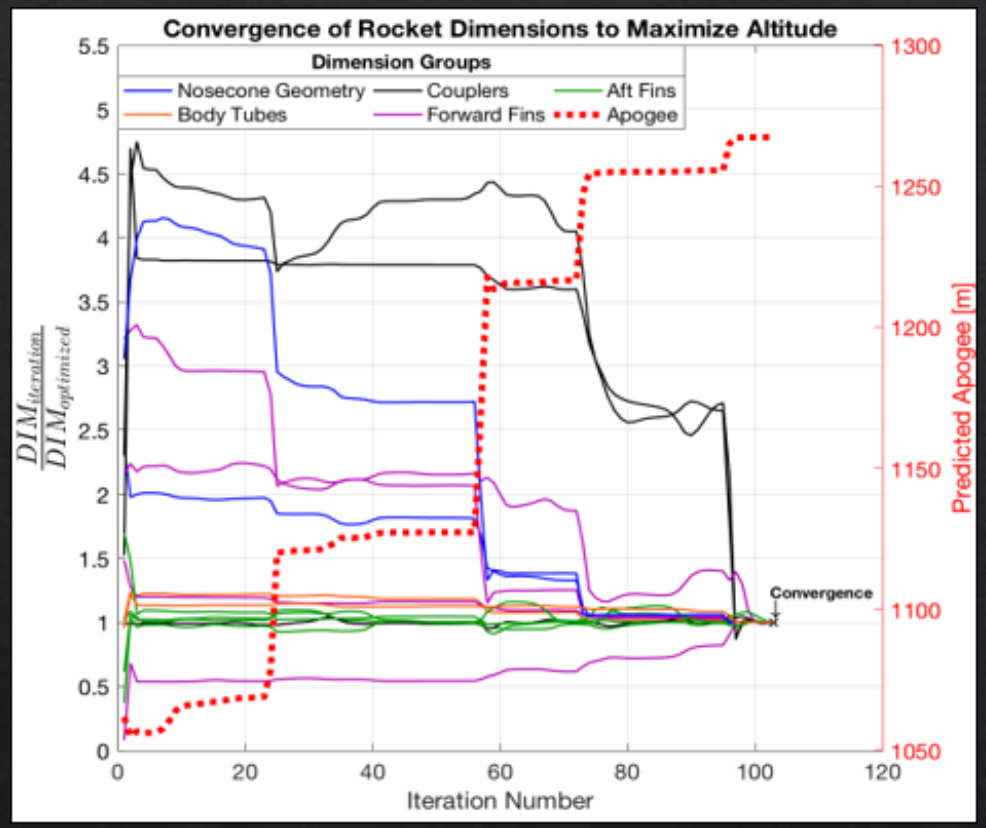


Rocket 6/9
7% Error

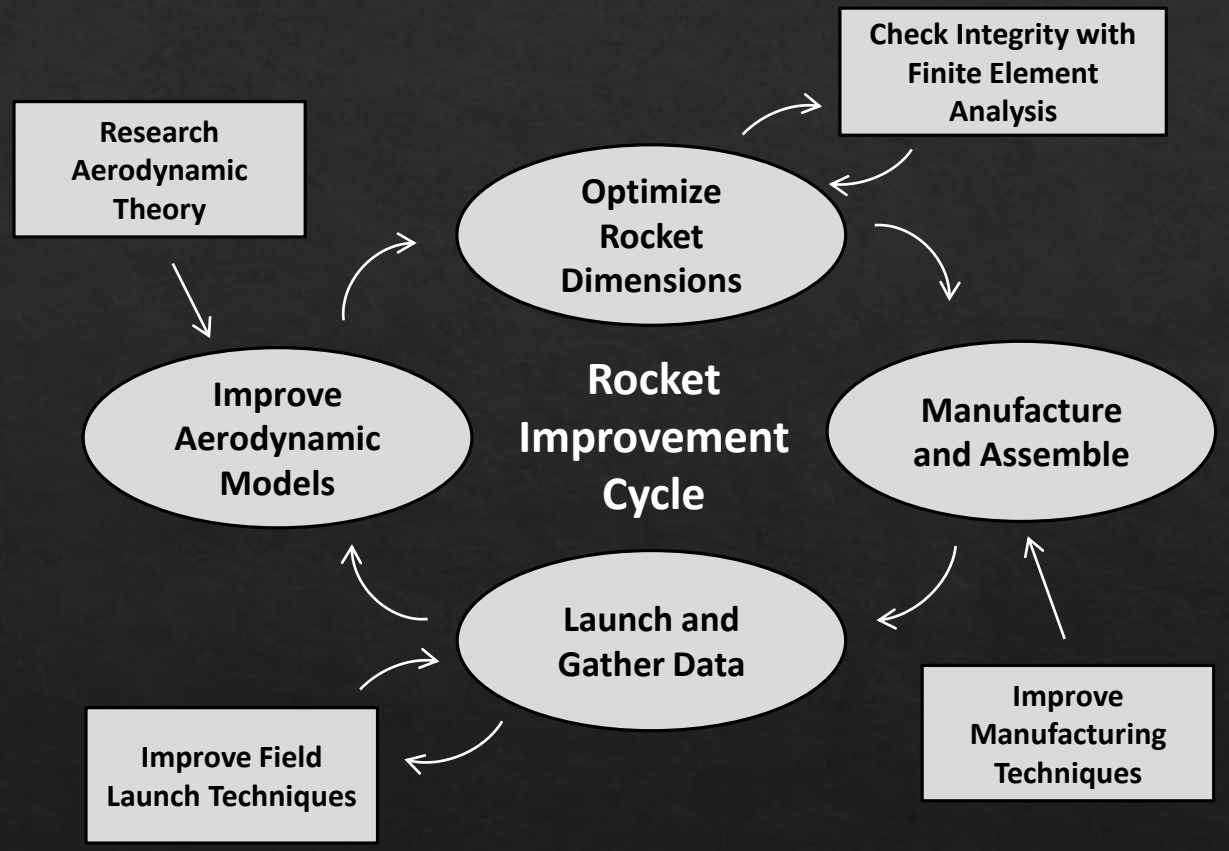
	Flight Data	OpenRocket Model	MATLAB Model
Sustainer Apogee	1071.1 m	1020.6 m	1154.1 m
Booster Apogee	290.0 m	238.6 m	276.3 m

Year 1 – Optimizing and Repeat

- Uses our in-house simulations in a nonlinear solver to converge on a set of rocket dimensions



- Refined simulations to match experimental data from ± 35% on 1st rocket to ± 5 % on the last



Year 2 – Junior Year

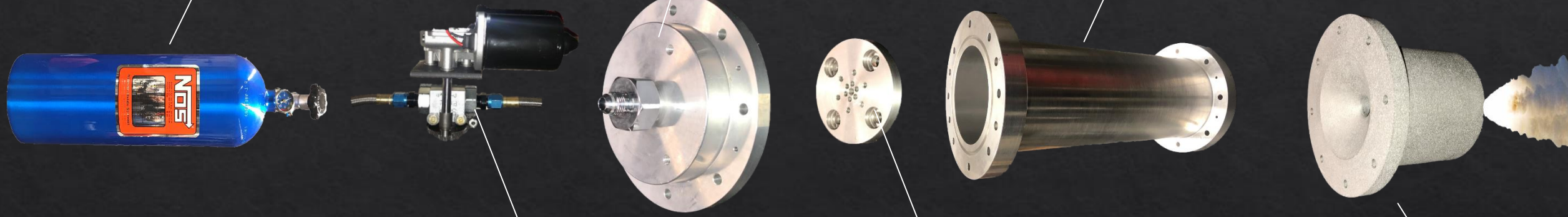
Organization Statistics

Committed Members: 20 (+9)
Majors: 5 **(+2)**
Senior Projects: 9 (+5)
Funding: $5,500 (+$3,250)

My Role
President, Lead Engineer

Spacevision 2018, November 2018, San Diego

Year 2 – Hybrid Engine



Oxidizer Tank
A highly pressurized vessel that contains liquid Nitrous Oxide

Injection Plate
Responsible for providing desired oxidizer flow into the combustion chamber

Combustion Chamber
An enclosed volume that produces heated, highly pressurized gas

Flow Regulator
A motorized valve that monitors flow regulation of the liquid oxidizer

Impinging Plate
An interchangeable plate responsible for the flow streams of the oxidizer

Nozzle
Machined into a de Laval curve responsible for directing the flow of hot, pressurized gases

Year 2 – Engine Design

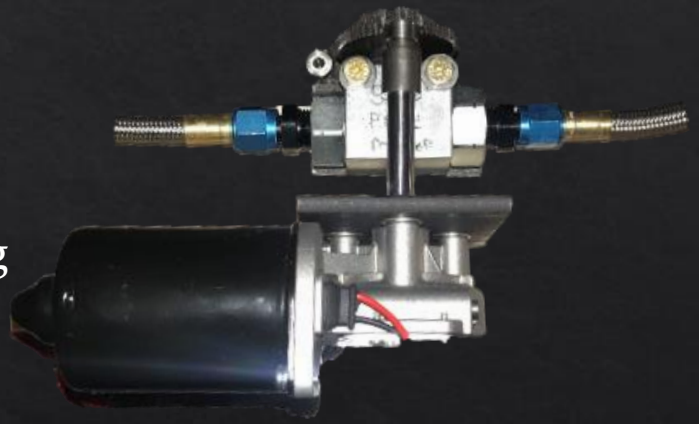
From past hybrid papers: ~400 psi and 700 K

Oxidizer Selection and Flow Regulation

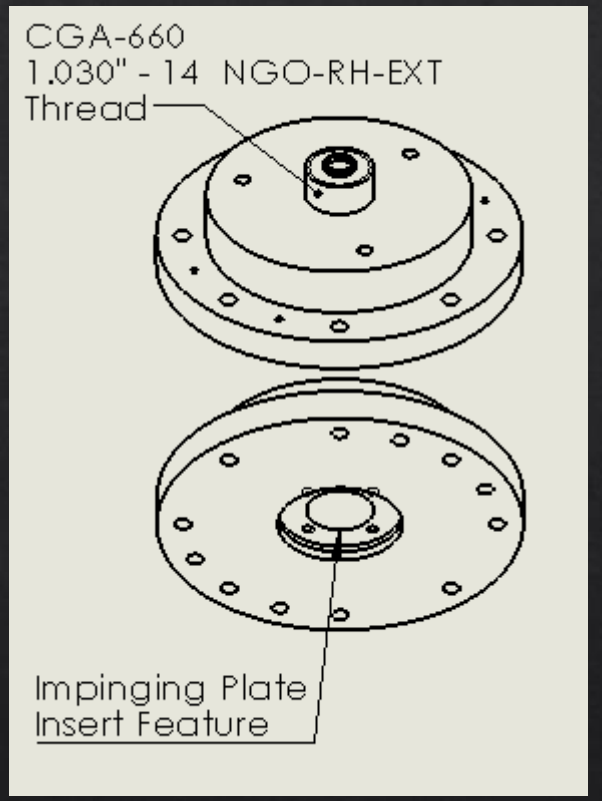
- Needs to be self pressurizing
- Needs to be safe to handle
- Can be refilled within a day

- Nitrous Oxide meets these requirements

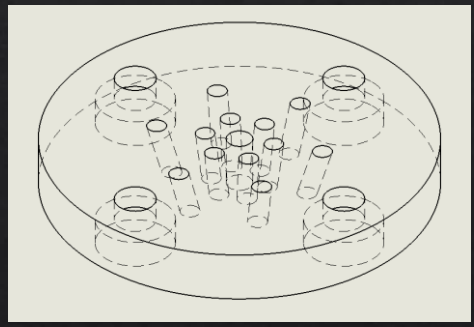
- Suitable for ground testing
- Ability to throttle
- 1000 psi rated valve/tubing
- Cheap – 150 dollars



Injector and Impinging Plate



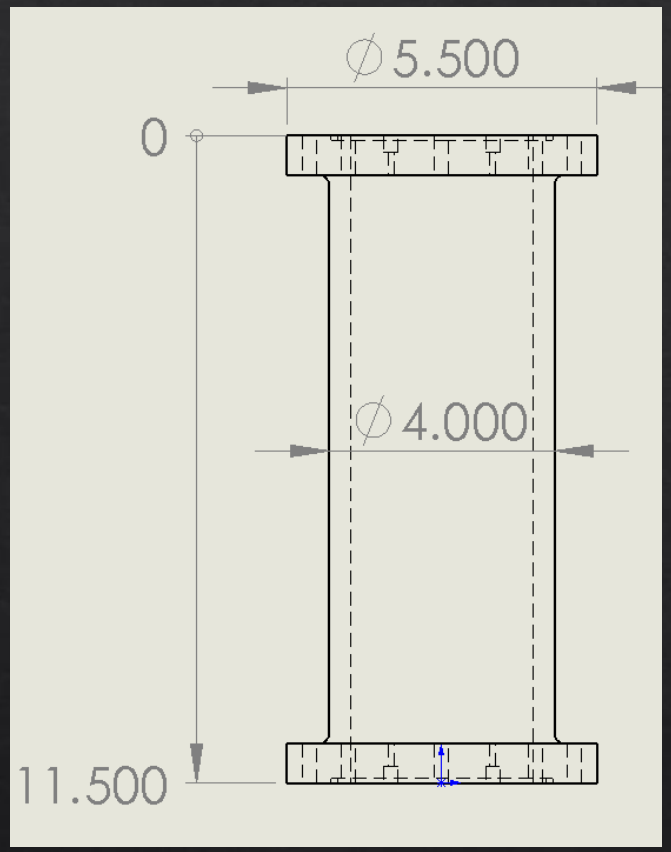
- Interface with COTS piping from flow regulator
- Quick testing of different impinging geometries
- Transitions the liquid oxidizer to a gas

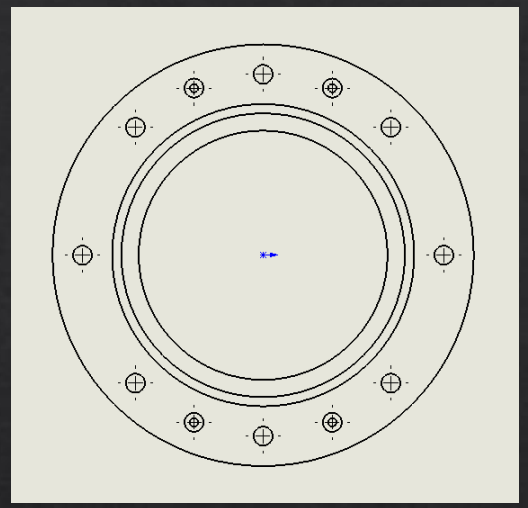


Year 2 – Engine Design

From past hybrid papers: ~400 psi and 700 K

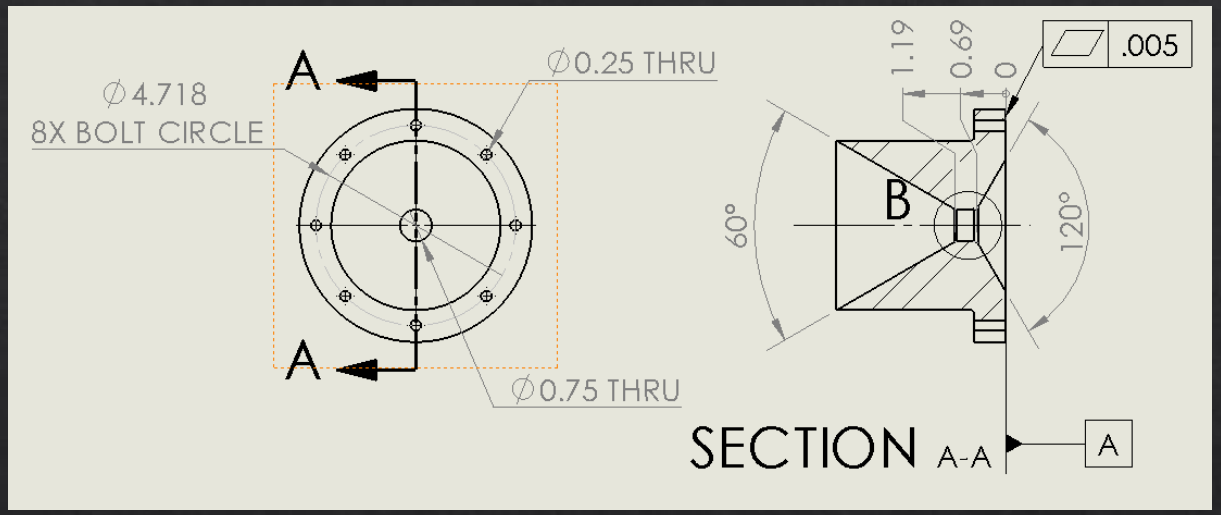
Combustion Chamber





- Withstand internal operating conditions
- Hold a volume of fuel (HTPB) to support the defined mixture ratio (~6)
- Seals with the nozzle and injector flanges

Nozzle

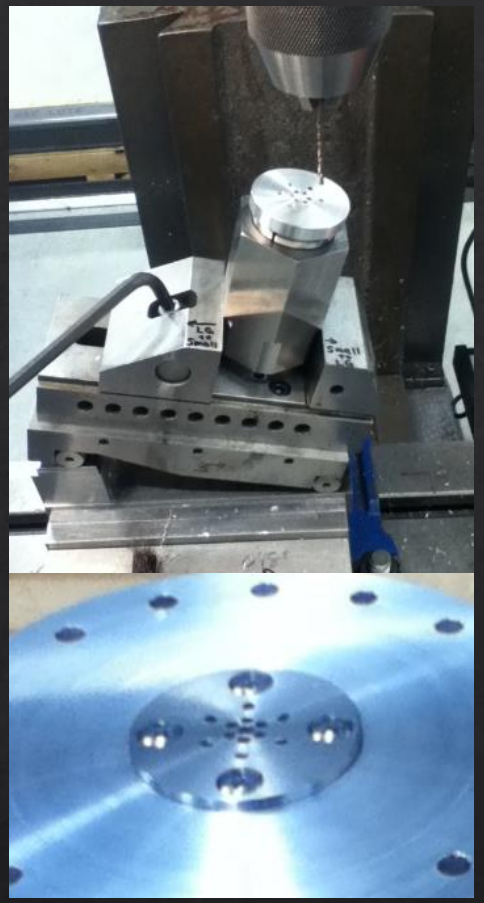


- Accelerate the hot gases within the combustion chamber using converging/diverging design
- Withstand a corrosive, high temperature environment

Designed these components in Solidworks, no experience with NX but understand differences (tree, solid bodies, no convert entities)

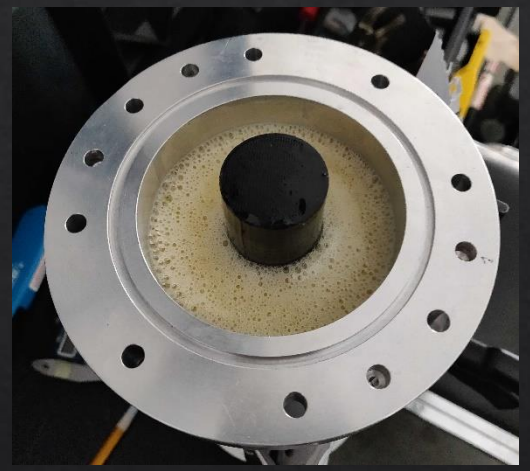
Year 2 – Manufacture

Combustion chamber chucked on the lathe machined by a machinist at TURBOCAM and myself



Machining and assembly of impinging plate

Assembly of the flow regulator

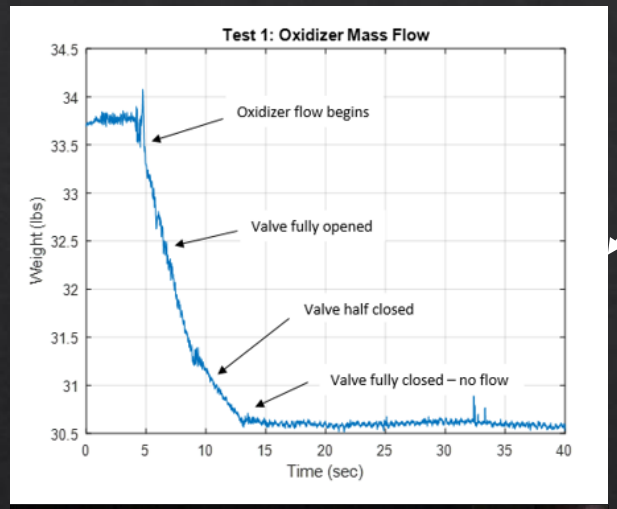


Molding the rubber into the combustion chamber

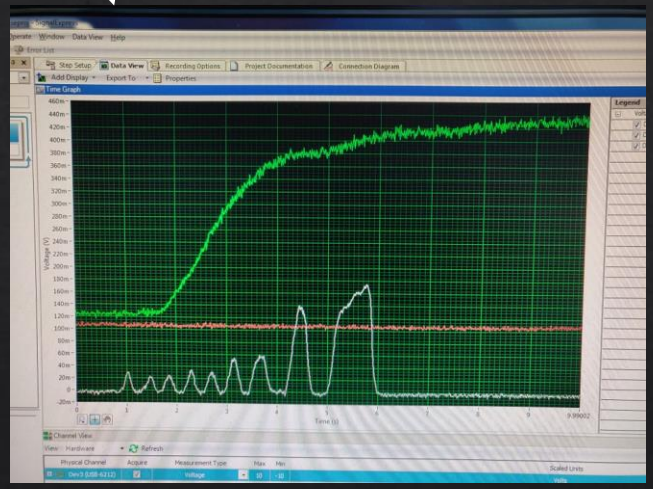
Runaway fully assembled with the aluminum chamber, injector and graphite nozzle

Year 2 – Test

Rapid impinging plate designs tested for impingement and desired flow rate



Obtain thrust and temperature data during the hot-fire test



Electric spark and igniter assembly

Control bunker for hot-fire tests

Hot-fire test 1 – Ignition

Year 3 – Senior Year

SPACEPORT AMERICA® CUP

- Rocket competition hosted in New Mexico from June 16th to June 20th
- UNH SEDS will be competing in the 10,000-foot experimental hybrid engine category

Organization Statistics

Committed Members: 42 (+31)
Majors: 7 (+4)
Senior Projects: 14 (+10)
Funding: $9,000 and counting (+$6,750 so far)

My Role
President, Lead Engineer, Propulsion Lead

Year 3 – Rocket Vehicle

Avionics
An electronics module responsible for GPS tracking, engine ignition and flow control

Research Payload
A payload built in-house to collect data

Throttle Control
A flow regulation system to insert oxidizer flow into the chamber

Recovery System
A recovery module that is deployed at apogee

Oxidizer Storage
A pressurized vessel holding the liquid oxidizer

Runaway
New Hampshire's first hybrid rocket engine that utilizes a liquid oxidizer and solid fuel

Year 3 – Engine Optimization

Hot-Fire Test 2 – August 2019

- .15 seconds in, nozzle brittle failure from tension
- Simulations underestimated pressure and designed to FOS 1.25 → bad decision

Stainless 304 selected for new nozzle

- Provides a FOS of 3
- Common material for temperature and corrosive resistance
- Machined by a new sponsor

Hot-Fire Test 3 scheduled for October 10th by 5:00 pm EST

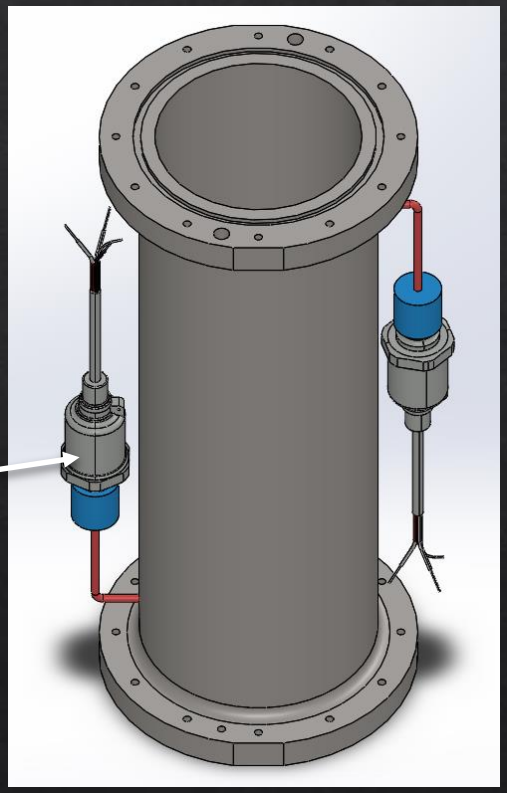
- Cleaner electronic start sequence
- Stainless nozzle

Future Engine Development

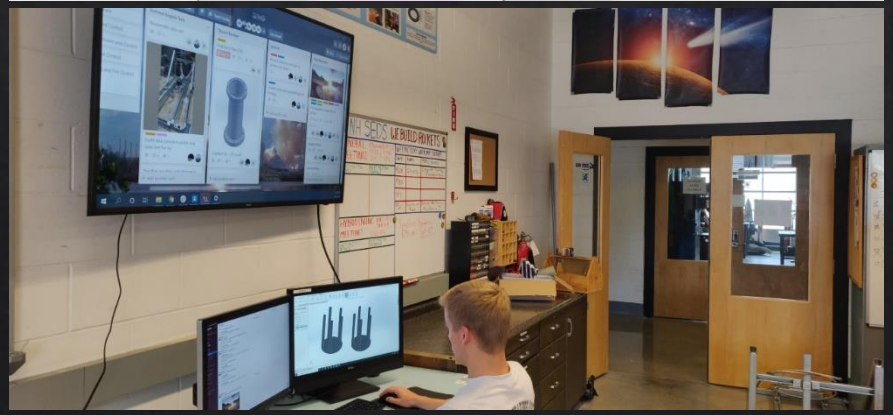
- Obtain pressure data from hot fires
- Pressure testing via hydrostat
- Flow simulations to optimize nozzle and impinging plates
- Reduce mass with dynamic sims

SPT25-20-1000A

- 0-1000 psi
- 12V DC operating voltage
- Corrosion and heat resistant (SS sensor)



Year 3 – Project Management



Companies	Responsible	Status	Notes
Advanced Machine Technology	Thomas Pham	Contacted	
Apex Plastics	Thomas Pham	Contacted	
Aviation Technology Inc	Lucas Simmonds	Contacted	contacted kboyer@aviationtec.com
Boston Welding & Design, INC.	Thomas Pham	Contacted	
Cannon Mountain	Silas Johnson	Needs Action	
Choice Metals	Lucas Simmonds	Needs Action	
Cirtronics	Grace Johnston	Needs Action	
Cohen Steel	Thomas Pham	Contacted	
ControlAir, inc.	Thomas Pham	Contacted	
Dynomite Dynamometer	Grace Johnston	Needs Action	
Fibre Glast Developments Corporation	Thomas Collins	Rejected	No direct sponsorship, advice and some discount
G&A Machine	Thomas Pham	Contacted	
General Dynamics Electric Boat	Lucas Simmonds	Talking	Contact for EB in CT
Geokon	Grace Johnston	Needs Action	
GT Advanced Technologies	Carly Benik	Contacted	
Hitchiner	Silas Johnson	Accepted!	
Incite Innovation	Lucas Simmonds	Contacted	Contacted through LinkedIn
Kimball Physics	Megan Johnson	Contacted	
KMC Systems, inc.	Ben Letourneau	Contacted	
L3 Warrior Systems	Zach Raboin	Talking	Doesn't look good for sponsorship :/
Lewis and Saunders	Megan Johnson	Contacted	

$5,000 – BBQ for all
$9,000 - Chicken Suit day of conference
$15,000 - Dye Hair any color (2 weeks)
$25,000 - Tattoo on the behind
$30,000 - Dye and Tattoo

Takeaways and Moving Forward

SPACEPORT AMERICA® CUP

Engineering

- Building techniques, flight simulations → use for throttle control
- Lead the development of New Hampshire's first hybrid engine
- Directing the entire hybrid rocket project for Spaceport
- Didn't push the importance of FEA/CFD

Organization and Project Management

- Built a family of future aerospace engineers
- Grew as a leader, understanding people have different imperatives to life
- The importance of transparency to leadership
- Now the most interdisciplinary engineering organization
- Didn't realize the importance of showing the success of the organization to the school/community

Moving Forward

- Continue to iterate Runaway to be the propulsion module in the hybrid rocket
- Manage all engineering leads
  - Frame, Avionics, Operations
- Compete in Spaceport America Cup
- Ensure successful knowledge transfer to underclassmen with defined future leaders

Presenting at a national space conference