Engineering Portfolio

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https://mahoep.github.io/

Overview

- Current Research at Purdue
- Senior Capstone Project at Oregon State
- Undergraduate Research at Oregon State

Current Research

- Dr. Meyer's research involves investigating thermal-fluid behavior under extreme environments. (Propulsion and combustion)
- Almost all work revolves around the use of ultra-fast lasers to study the regions of interest at extremely high repetition rates.

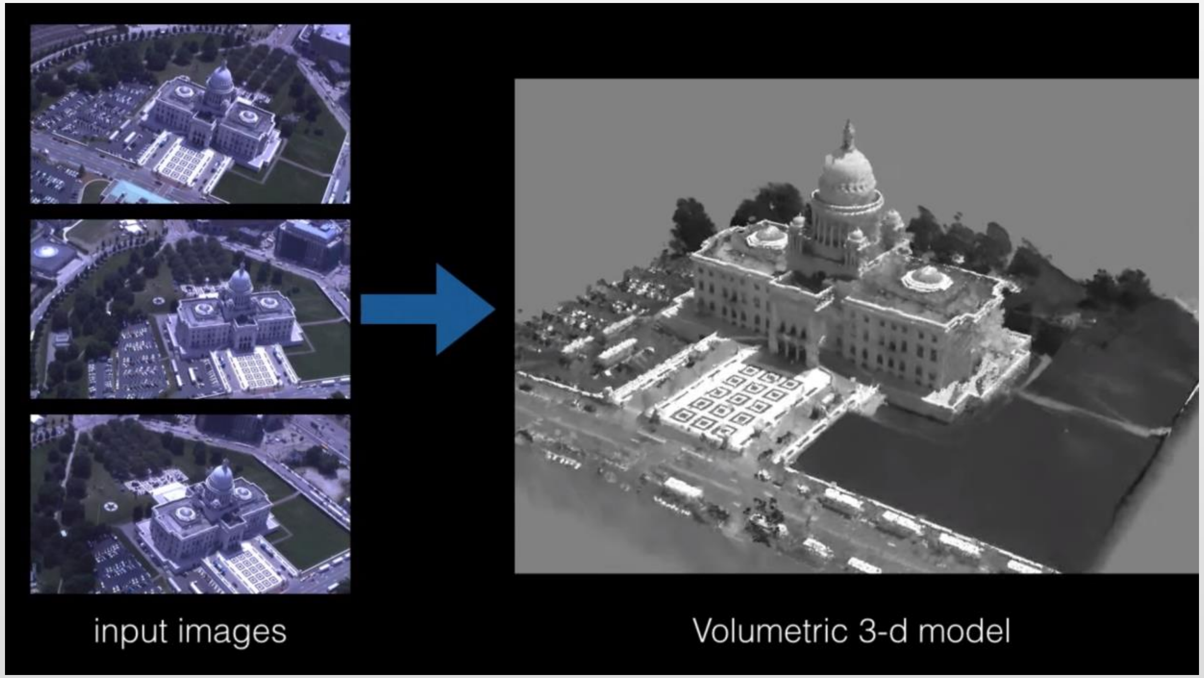
Can't go into too much detail here.

Current Research

- For example, I work on a project to study the evolution of explosive blasts.
- Time scales are very short so we need to image quickly.
- We used a camera that can capture up to 5 million frames per second
- However, at this rate, the shutter is only open for ~80 nanoseconds and almost no light will be captured.
- So we use a laser that produces an incredible amount of energy to illuminate the blast enough so it can be captured by the camera.

Current Research

- As extension of the blasts project, I'm currently working on creating software that can do volumetric reconstruction of flow fields from only a few images.



Ulusoy, Geiger, Black (2015), Max Planck Inst.

*Not exactly the same, but good illustration.

Current Research

- I also work on a project that studies fuel sprays and atomization.
- Understanding how liquid/vapor distributions in fuel sprays evolve is essential for increasing combustion efficiency and/or lowering emissions, for example.
- We use a laser for laser induced fluorescence (LIF), which excites the fuels and causes them to emit light, which we image. (Similar to how glow in the dark stickers work but on a higher energy and faster scale.)

Senior Capstone

- Sounding rocket project for the Spaceport America Cup (formerly ESRA/IREC)
- 18 person team composed of ME, EE, and CS majors
- 3 people per sub team
- Aerodynamics and Recovery, Propulsion, Structures, Payload, Avionics, and Computer Science
- Propulsion was my focus

Senior Capstone

- A technical report of the entire rocket can be found here:
  https://mahoep.github.io/resume/21_project_report.pdf
- A presentation given at the SA Cup Conference can be found here:
  https://mahoep.github.io/resume/21_Presentation%20Slides.pdf
- And corresponding abstract, here:
  https://mahoep.github.io/resume/21_Extended%20Abstract.pdf

Senior Capstone

- In charge of designing, manufacturing, and testing the propulsion system
- Solid propulsion was chosen early on
- OSU is not ready for hybrid/liquid in this competition and solids were used for the past 4 years
- Design phase starts in September, build phase begins in January

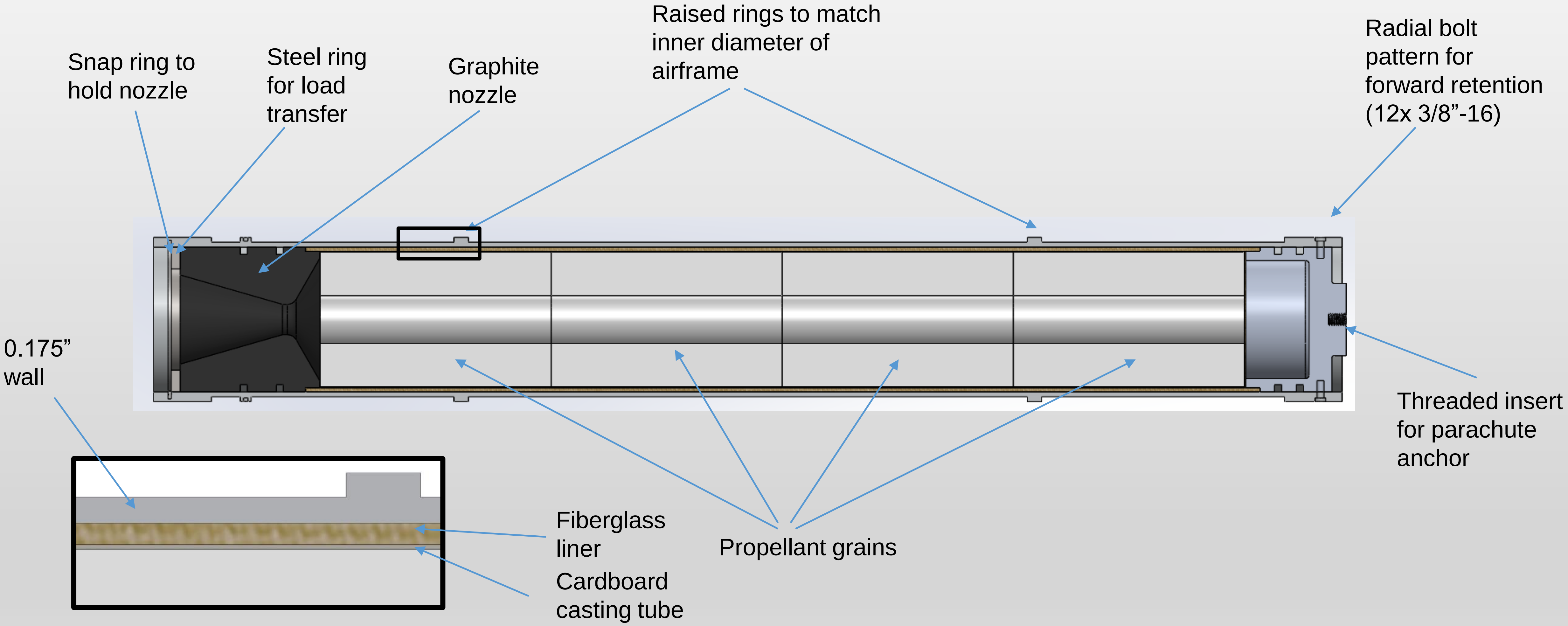
Senior Capstone

v1.0

- Version 1.0 was the selected design at the end of Fall term.
- 5.0" ID, 6061-T6 aluminum casing, 40" long
- Graphite Nozzle
- 4x 8" BATES grains made of APCP
- Exact propellant formulation was still TBD, testing required

Senior Capstone

v1.0



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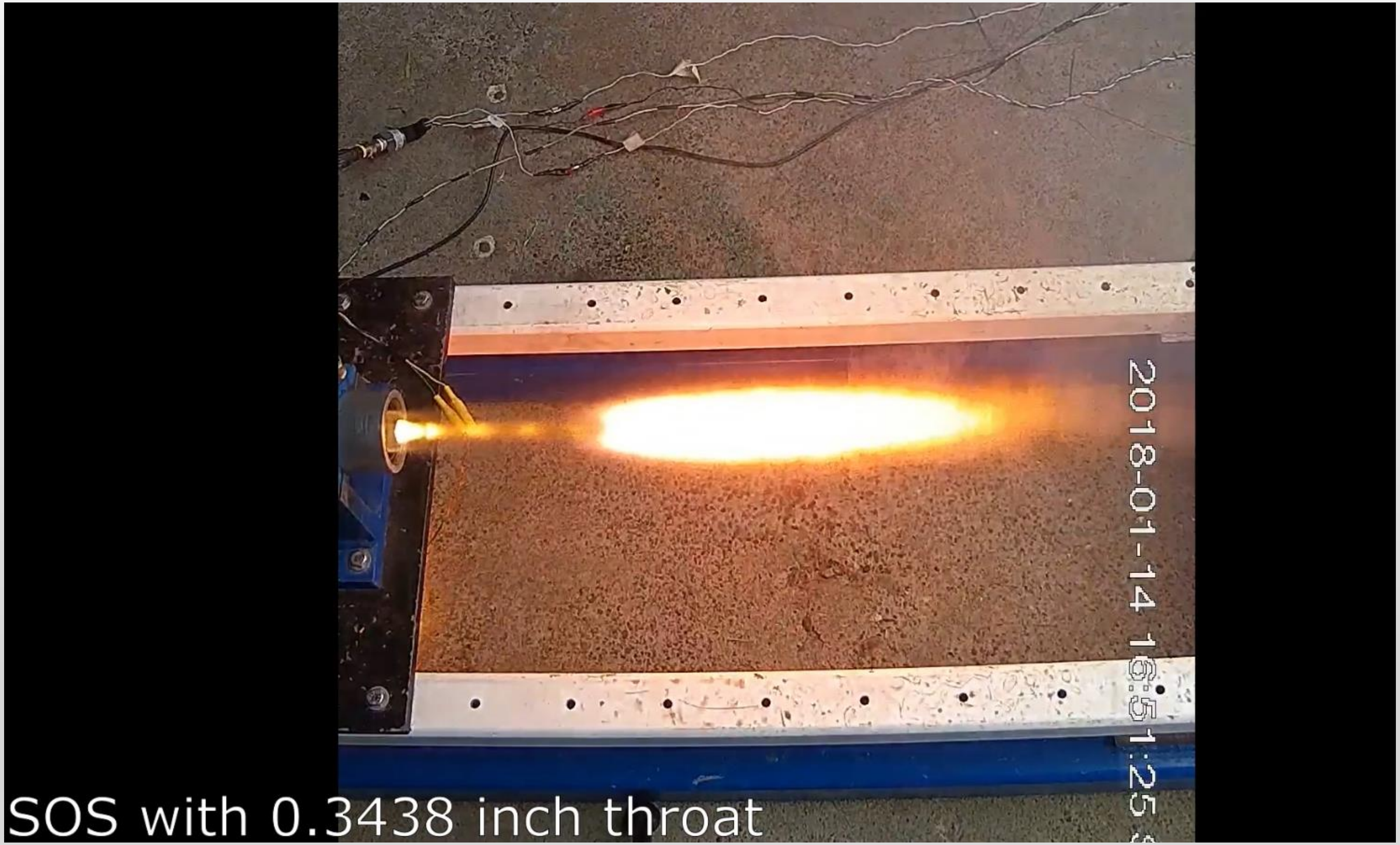
Senior Capstone

- Performed many sub scale tests to identify and characterize propellants
- First round of testing had "SOS", a slow burning propellant and "RIO" a high metals, fast propellant

- Performed many sub scale tests to identify and characterize propellants

Senior Capstone

Sub Scale Testing



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Sub Scale Testing

- SOS was too slow, RIO was too fast
- Removed burn rate enhancer from RIO, called it Bare Bones

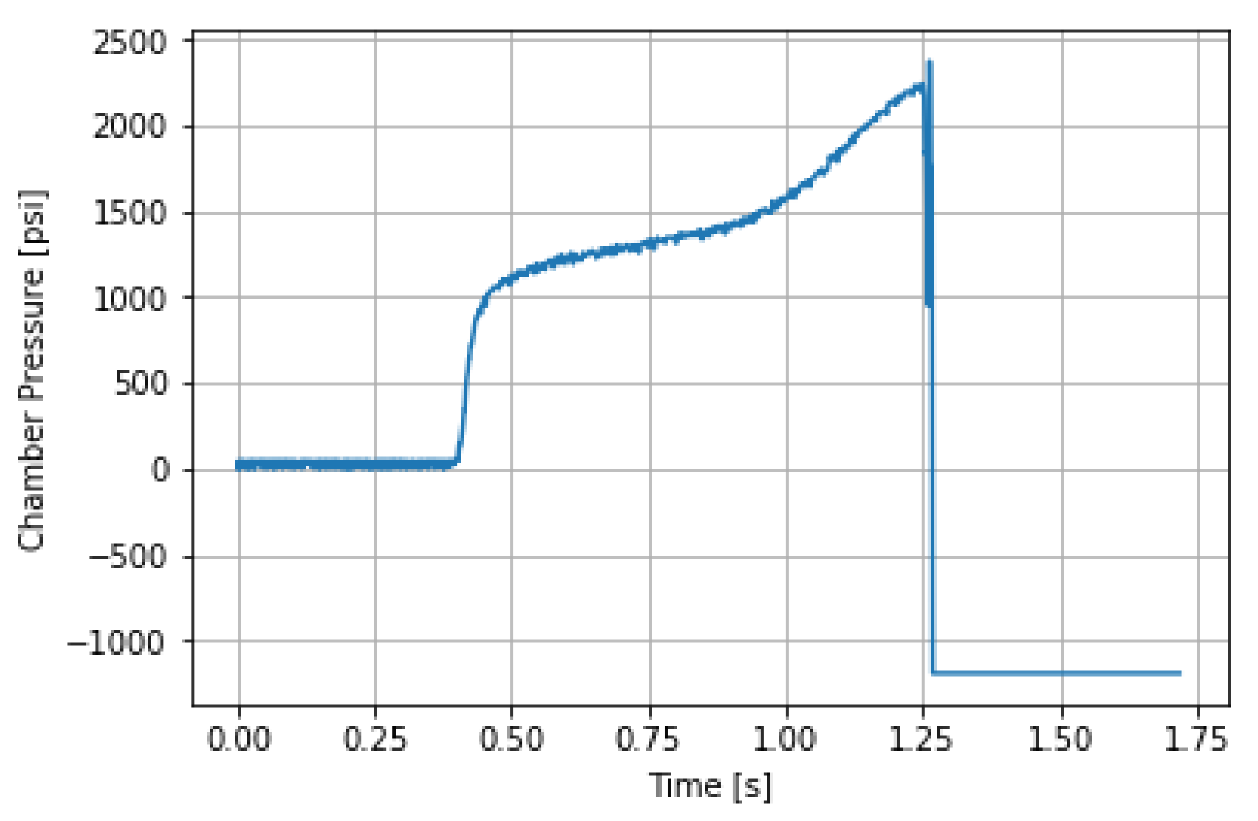
Senior Capstone

- First full scale static fire on March 3rd, 2018
- Plume is grossly under expanded

…. did not end well

Senior Capstone

- Burn lasted for about ¾ of a second.
- Expected pressure: 800 psi
- Failure attributed to improper preparation of the grains during casting and assembly.
- No injures or damage to property (except for small patch of grass that was burned)



Senior Capstone

V1.0 Testing

- The casing was designed to have the snap ring groove fail first so that the nozzle would eject
- We figured the wall got much hotter than the groove so that it became the weakest point.

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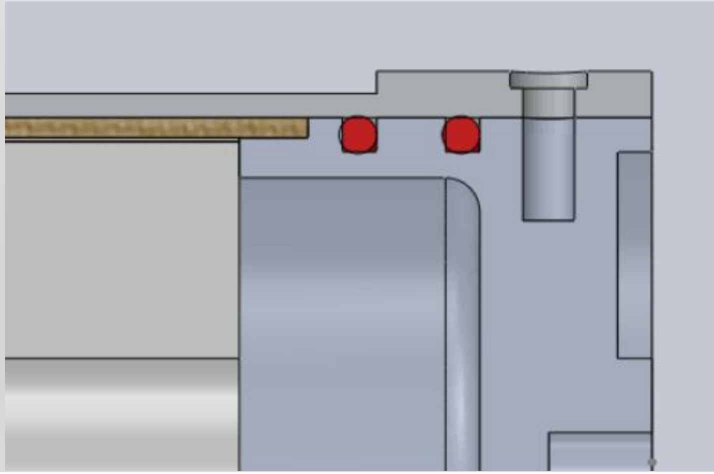
Senior Capstone

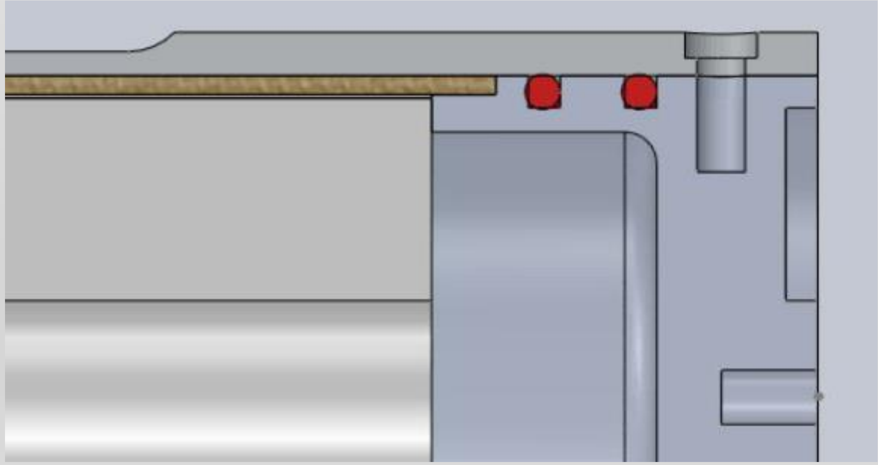
- Notice how the casting tube burned away.
- The extra surface area that was burning contributed to the over pressure. (more mass combusting = higher pressure)

Senior Capstone

- Needed to add more propellant to achieve necessary altitude. Added a 5" grain to increase impulse. (Weight of other systems increased)
- Added filets to reduce stress risers and increased wall thickness by 0.015"
- Increased edge length:



vs



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- Second full scale static test fire on March 23rd, 2018

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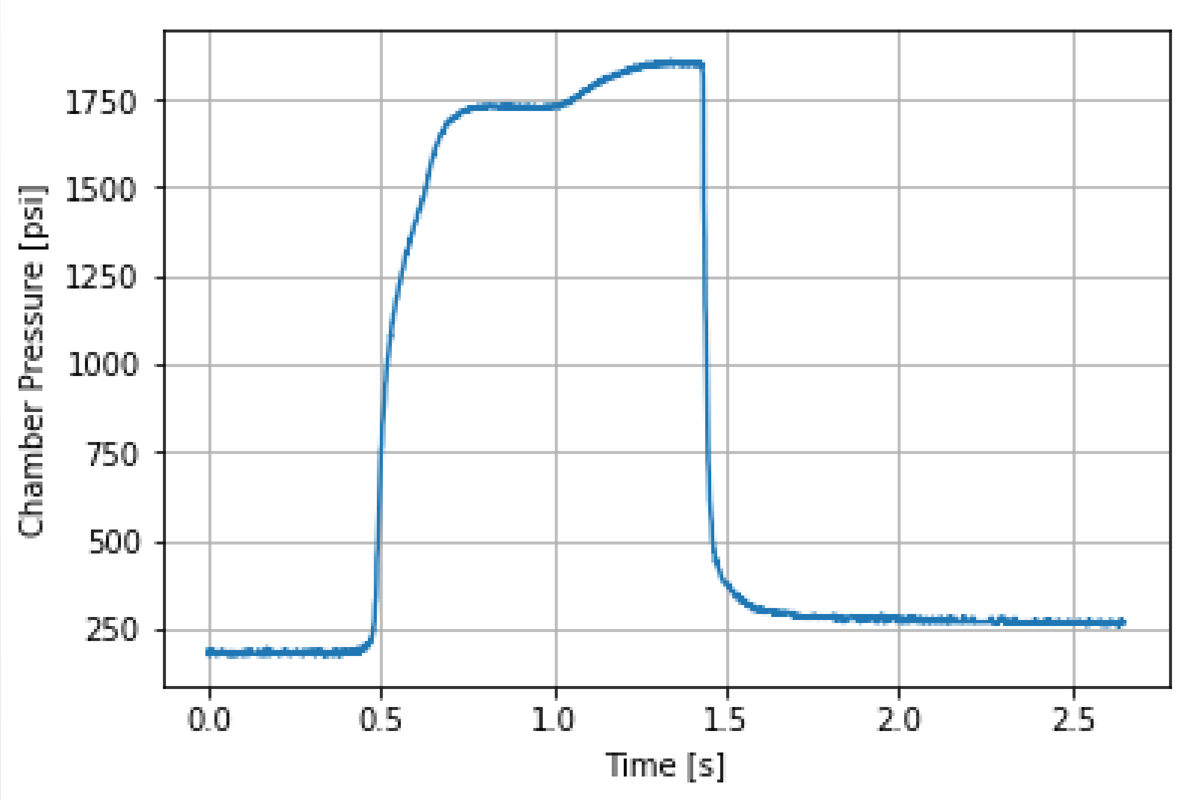
- Burn lasted for about 1 second.
- Expected pressure: 600 psi
- Failure attributed to a bonding agent that was added to the formulation based on a recommendation.
- We were told, "No increase in burn rate"
- The team had doubts about that and went back to subscale testing...



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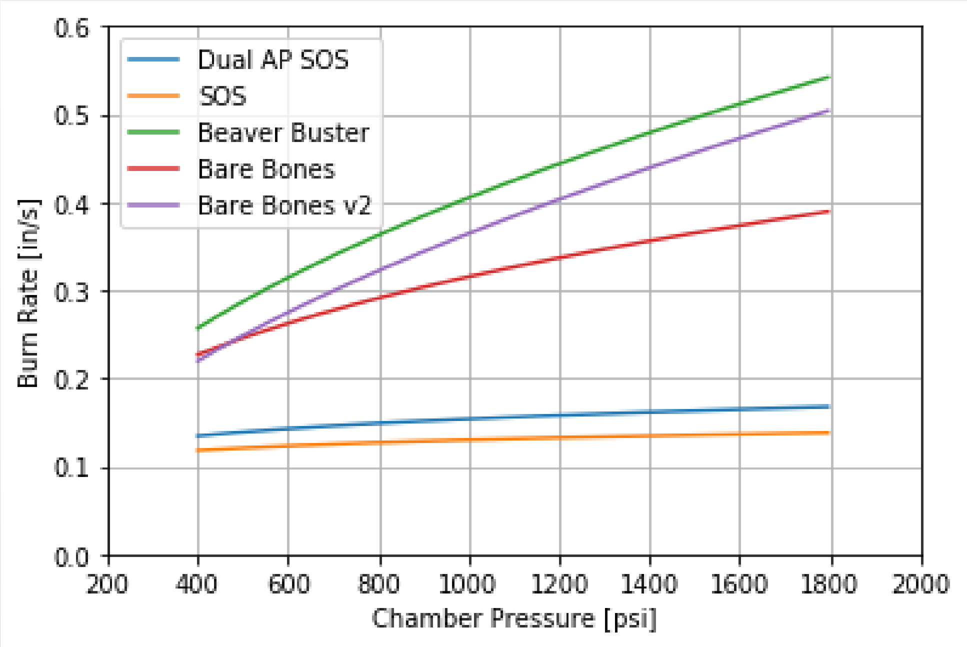
- Bare Bones v2 is the exact same as Bare Bones except it has a tetra functional polyol bonding agent that makes up less than 1 percent of the total mass.
- BB2 was used in the 2nd static fire, while BB1 was used in the 1st and previous subscale.
- Beaver Buster is a derivation of RIO that has the bonding agent as well as a catalyst.



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Redesign Phase

- Team decided to move away from Bare Bones and use a propellant that has been well characterized by Oregon State in the past called Orange Koolaid.
- Performed a "Mid Scale" test that used the diameter from the full scale but only half the length.
- Test was on April 15^{th}.

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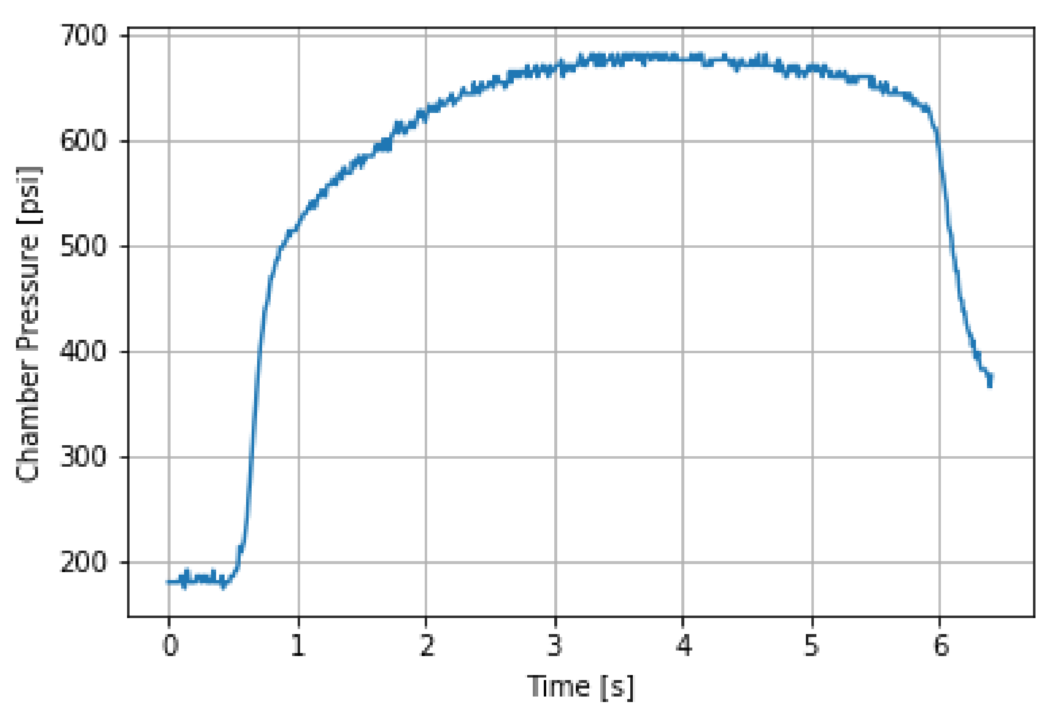
- And it worked beautifully!

Senior Capstone

- Expected max pressure was within 10 psi of the actual.
- We were all very happy, to say the least.
- Transitioned back to full scale.



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V1.2

- The next iteration of the design was largely the same as the 2nd.
- Wall thickness was 0.20” and edge length was increased by another ½”
- Testing commenced on May 10th

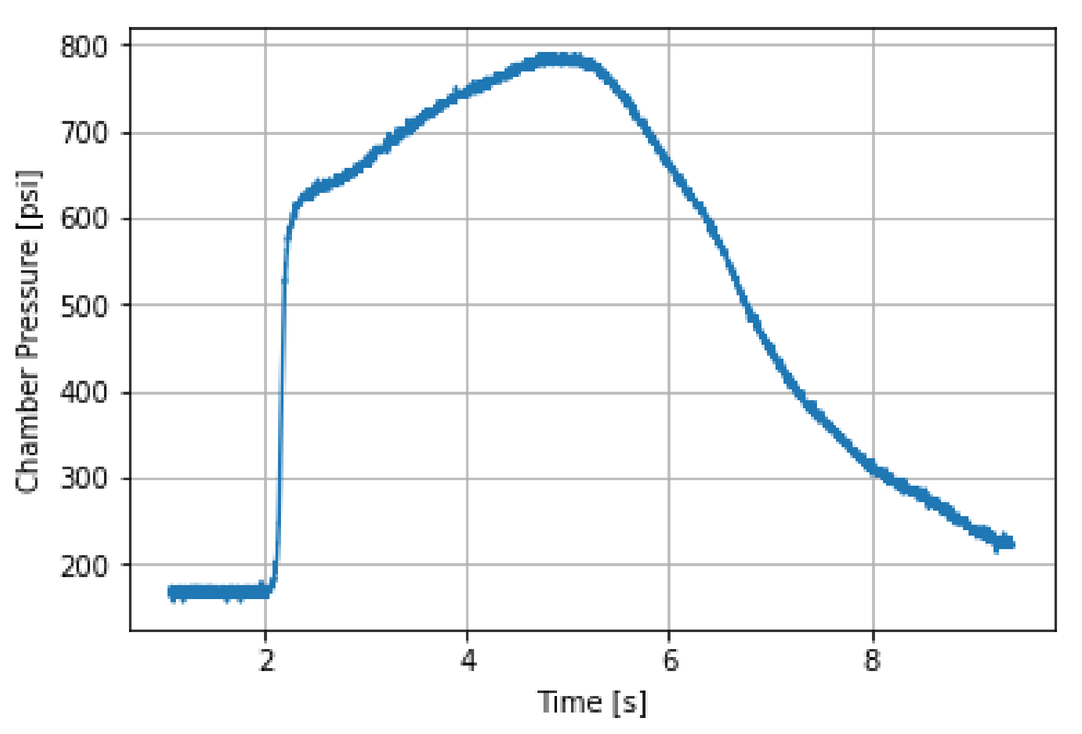
Senior Capstone

- Again, it worked great!

Senior Capstone

- A few mentors said, “That was the best test I have ever seen”
- We were very pleased with the test
- Solid Rocket Motor Specs:

30 lb propellant
28,500 Ns
787 psi peak pressure
1570 lbf peak thrust
6 sec burn time



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- With the support of our advisors, the team gambled on the test succeeding so we already had another motor worth of propellant ready to go.

- On May 13th we had our first test launch at Brothers, OR

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- The rocket performed well and was recovered with only cosmetic damage.

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Test Launch

- Chuff off the rail at test launch (combustion instability) which caused the rocket to cock off of vertical
- Suspected cause: hardness of cured propellant
    - Several points lower compared to static test
    - Possibly shearing propellant and clogging the nozzle
- To mitigate, we changed how much curative we added to the propellant mixture for the competition mix.
- 32 seconds to reach 25,000ft, reached ~Mach 1.6

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- Come time to launch, the team had high hopes that we would place well considering we received a 100% on the report score.
- All we had to do was to assemble and launch the rocket. (Something we had dry ran a dozen times)
- Rocket Specs:

27,000 ft AGL
101 lbs at liftoff
12.5ft tall

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- Against everyone's hopes and dreams the motor suffered a chuff (combustion instability) at about t+1s. The nozzle was ejected along with all of the propellant.
- The upper section of the airframe was shredded. Miraculously, the motor was still fixed to the lower airframe, but only just. The nose cone and payload were recovered with minimal damage.

- Video here: https://youtu.be/Vxc1HLs-mfQ?t=372

Senior Capstone

- What was left…
- The motor was still in one piece with little signs of yield

Senior Capstone

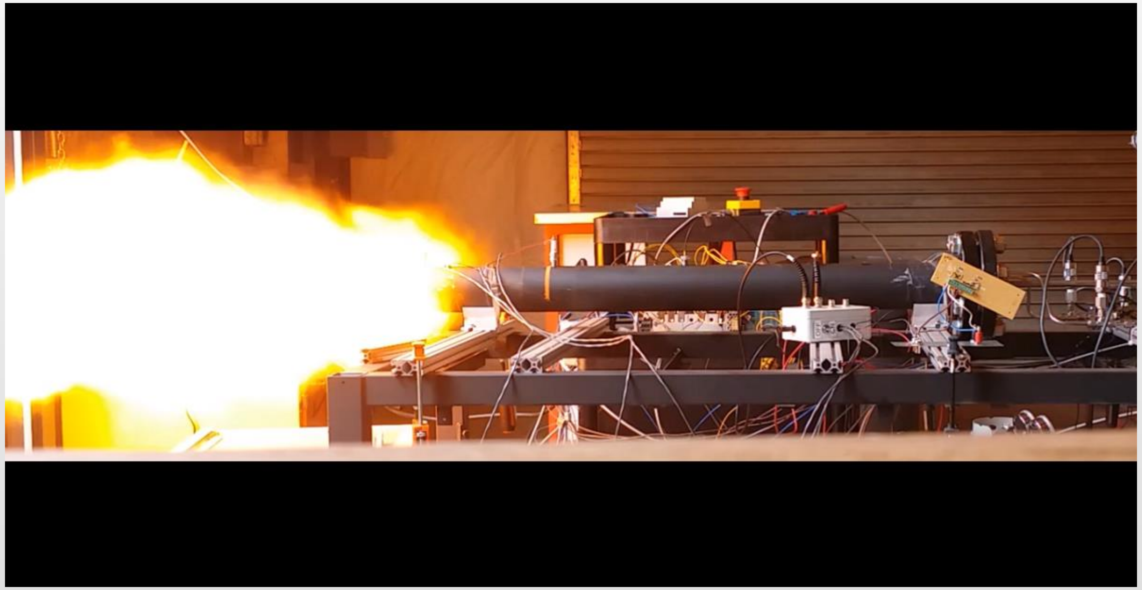
- The chuffing problem that the motor experienced in both launches was not unique to our team.
- Another rocketry team at OSU was experiencing similar problems
- After Spaceport America, our advisor had asked us to investigate.
- Decided that the reason for chuffing was the ammonium perchlorate quality. (Our source was bad)
- I left for graduate school three weeks before the test, but it was successful: no chuff.

Senior Capstone

This project was the most difficult, time consuming, saddening, and rewarding project I have ever been apart of. I would do it again in a heartbeat.

Research at OSU

- Worked for Dr. David Blunck at the Oregon State Propulsion Lab
- For most of my time there I worked to support a pulse detonation engine project.
- The focus was to investigate how the influence of inert gases (N_2, CO_2) effect detonation velocities.
- Used propane and nitrous oxide, later methane and oxygen to achieve detonation speeds of ~3000 m/s
- Again, detail will be scarce unfortunately.



Research at OSU

- The other project that I worked on involved solid propellant combustion.
- We wanted to investigate the combustion behavior of the propellant under various *conditions*.
- The details of the conditions can’t be disclosed here but they have not been studied thoroughly and by very few groups.