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Engineering Portfolio

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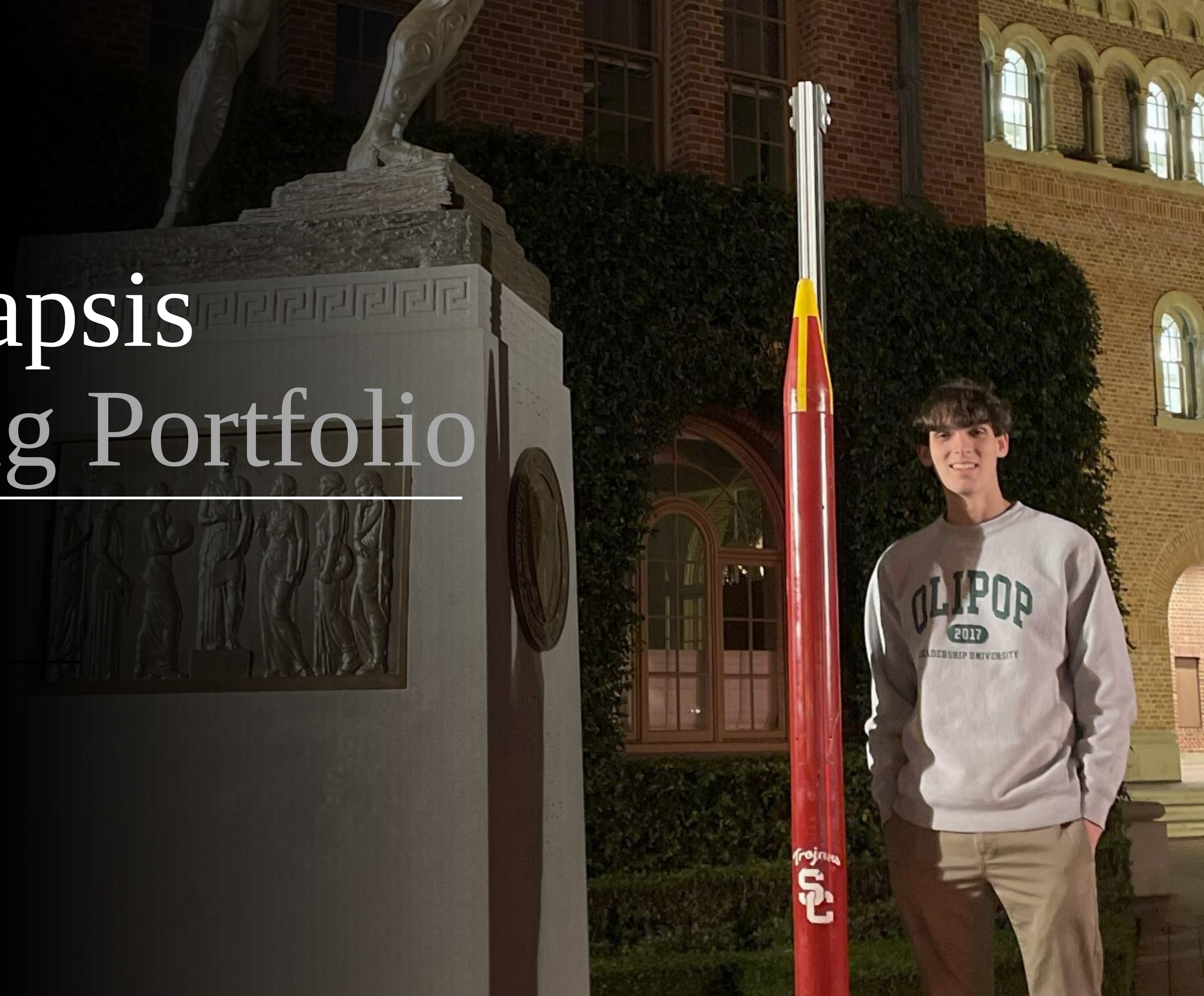
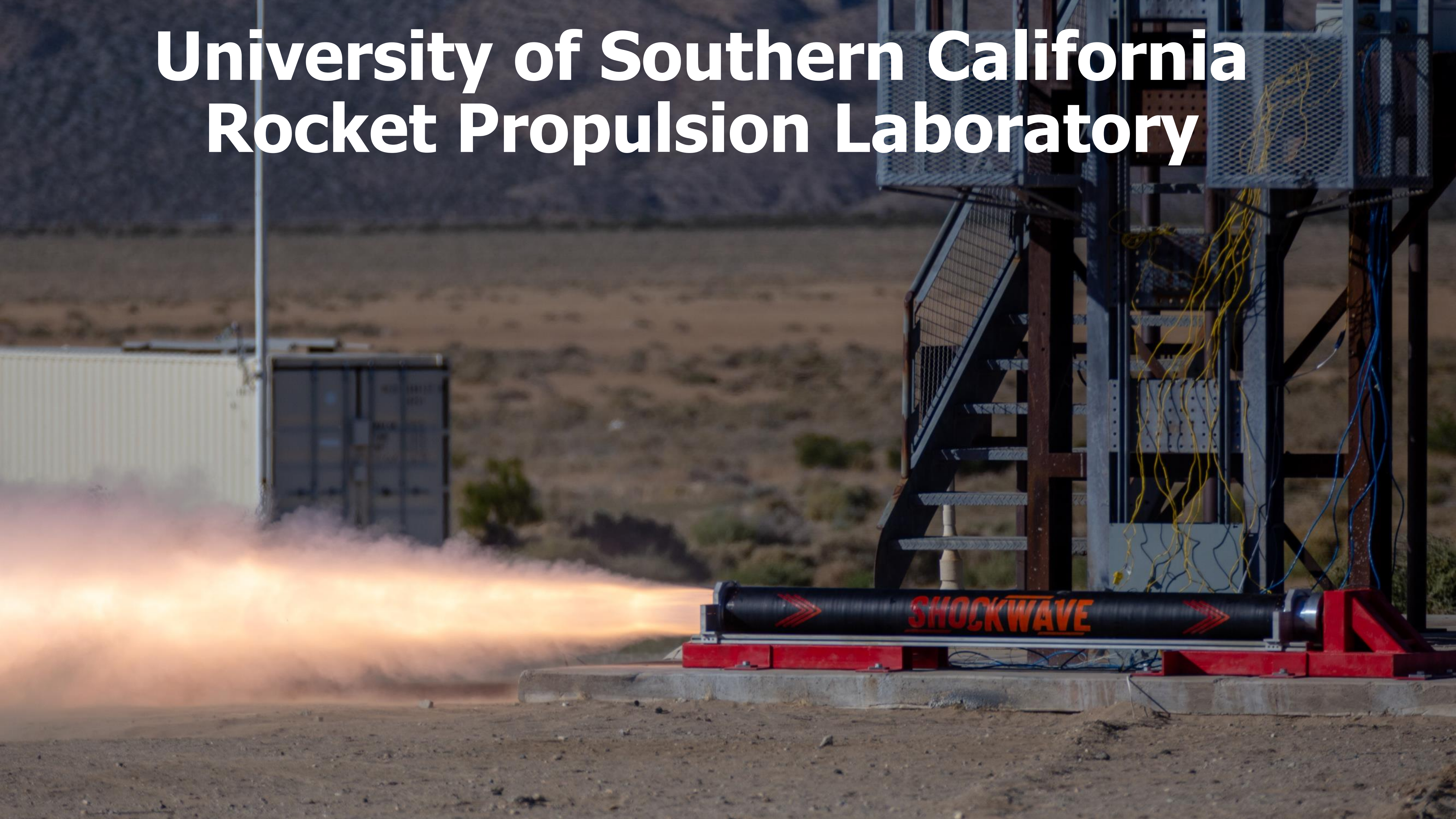


Table of Contents

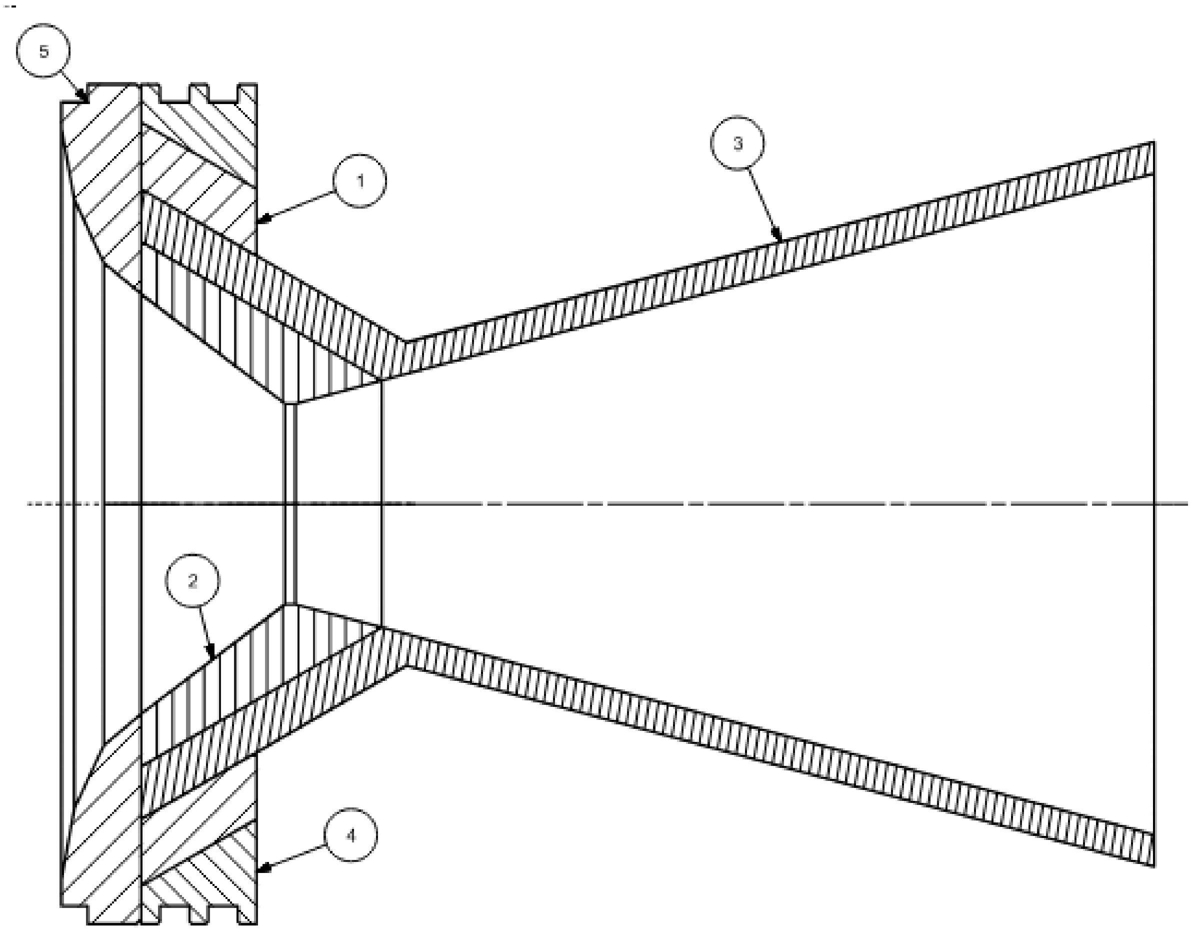
1. **USC Rocket Propulsion Lab**
    - **Nozzle Assembly** - Complex assemblies and tolerance relationships
    - **Linen Phenolic Casting Tubes** - Improving manufacturing processes to improve part quality
    - **Shoulder Ring Surgery** - Fixing mistakes and learning for future manufacturing
    - **Thrust Stand and Launch Tower** – Refurbishing and Improving legacy infrastructure
    - **Shockwave Static Fire –** Solving engineering problems under extreme time pressure
    - **Titanium Leading Edges** – Machining exotic and difficult materials to tight tolerances
2. **L2 Launch Rail**
    - **Rapid Design to Reality –** Created an amateur rocket launch rail with tight budget and timeline
3. **Baum Family Makerspace**
    - **Machining for all Undergraduate Engineering Teams –** Variety of parts, problems, and solutions

University of Southern California Rocket Propulsion Laboratory

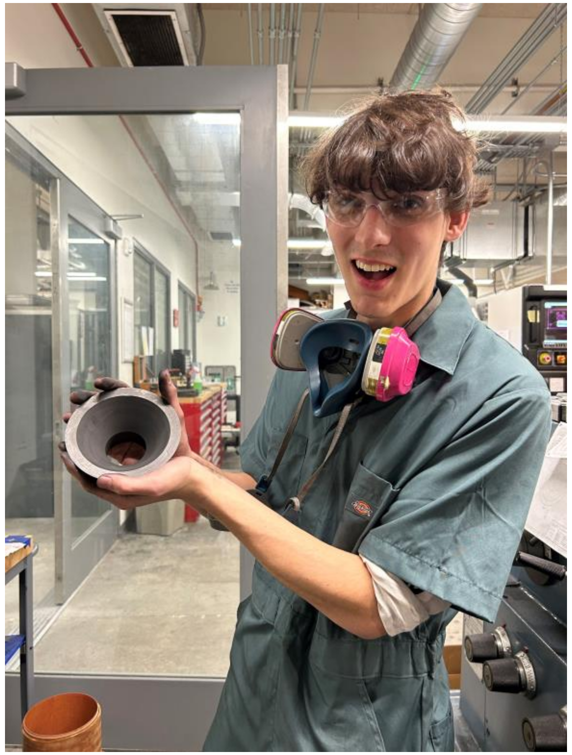


USC Rocket Propulsion Lab Machining

Nozzle Assembly Manufacturing Process
During the past school year, I helped develop the manufacturing process for our new nozzle design that saved significant mass from the previous design while increasing the factor of safety and decreasing the number of components required. The nozzle is comprised of 5 distinct parts, all needing to be perfectly bonded together with no gapping or misalignment.



SECTION A-A



Graphite Insert

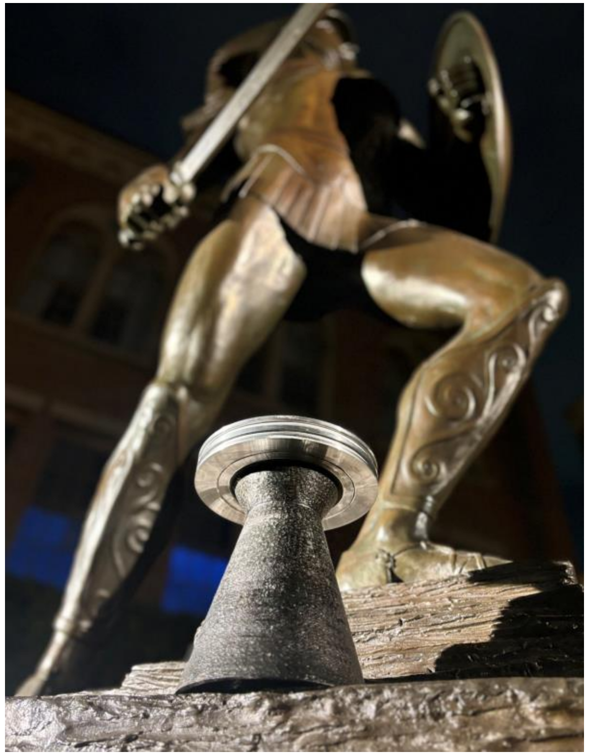
Graphite's extremely brittle nature causes it to be a challenge to machine and the throat of the insert is paramount in determining the thrust of the motor

Carrier

The carrier fit is a transition fit to accommodate O-rings into our case and thus must be precisely machined to seal

Sleeves

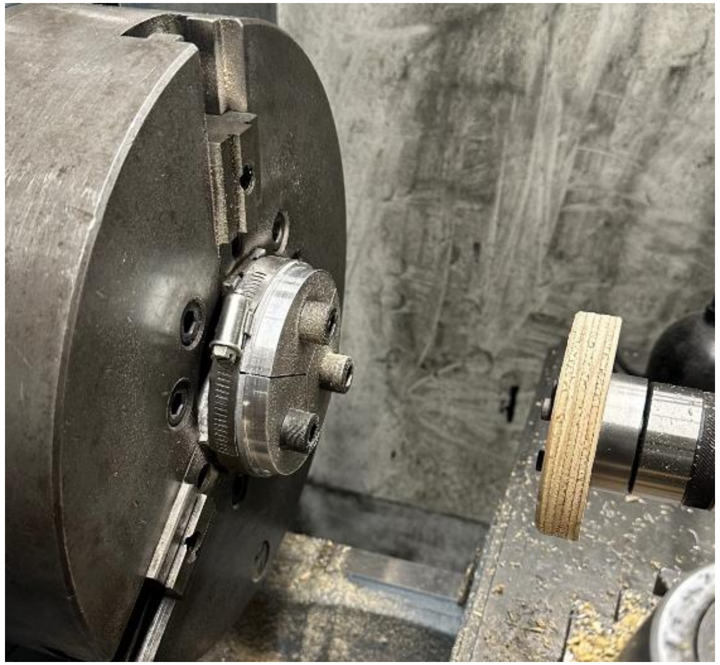
The Sleeves bridge the gap between the carrier and the carbon phenolic nozzle body. They are a perfect match fit by first being separated then machined on the lathe



Completed Assembly

The aforementioned parts are combined and bonded to complete the assembly.

Linen Phenolic Casting Tubes



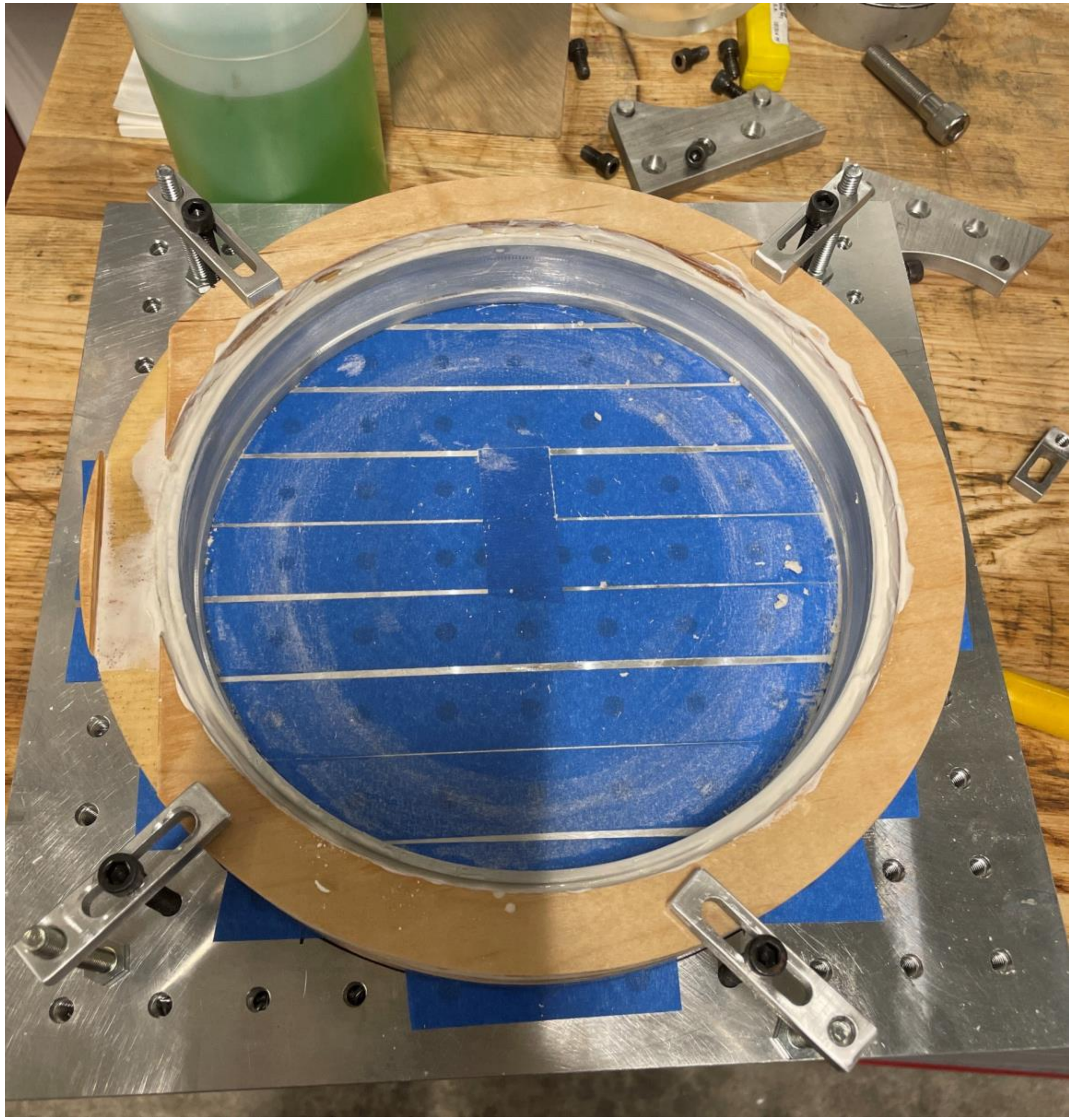
Explanation

Casting tubes are the linen phenolic liners we use to contain propellant when casting and insulate the propellent during firing. For the past decade or so the process has remained the same using a mandrel to carry the tubes and shimming the mandrel to size using painter's tape. This setup resulted in inconsistent cuts and potentially unsafe work holding.

Solution

During the summer I had machined a thin polycarbonate tube and was taught to use pi jaws to hold the material without deforming it. Since the challenges with our casting tubes were very similar to that of the polycarbonate tube, I manufactured similar pi jaws with a plywood insert as a live center, ensuring accurate and reliable cuts.

Shoulder Ring Surgery



Mistake

The shoulder ring bridges the gap between the fiberglass nosecone and carbon fiber case, allowing us to have an exact machined part to give a smooth transition. We successfully test fit the shouldering on the bottom of the nosecone, but after an additional piece of hardware was bonded to the inside of the nosecone, the diameter changed and thus the shoulder ring was no longer in tolerance.

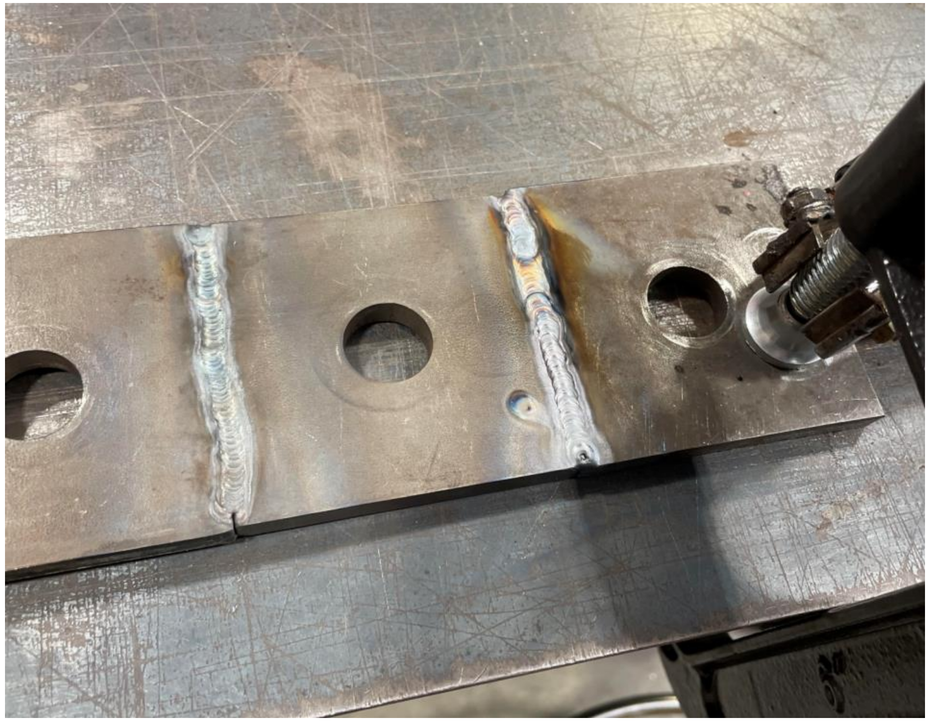
Solution

Due to the part being tapered I could not easily hold the part on the lathe again, thus I cut plywood to act as a shell around the part and poured machinist’s plaster to hold the part, minimizing chatter and giving solid work holding. I then used our CNC mill to expand the ID, successfully saving the part from being scrapped.

Thrust Stand Manufacturing

Learning to Weld

Over the summer I learned TIG welding in preparation for refurbishing our thrust stand. I first practiced flat welds, then moved up to butt welds and fillet welds, constantly learning from my mistakes.



Machining D-clamps

I used a waterjet cutter to rough the stock, then milled the D-clamps responsible for holding the rocket onto the thrust stand.

Thrust Stand Final Assembly and Integration

Welding and Test Fit
At the beginning of the semester, we installed new anchors at the MTA pad using a water-jet grid that allowed the anchors to be precisely placed while having the high pull-out strength of pour-in anchors. We then used that same grid to place the brackets in relation to each other on the stand and tacked them together. We finished welding the anchor brackets, completed the test fit and welded in the brackets to hold the 8020 extrusions perpendicular to the thrust collector.

Final Assembly
The day before the Shockwave firing, we assembled and integrated the thrust stand to the pad in less than three hours, showcasing the success of the pour in grid anchors and refurbished thrust stand.

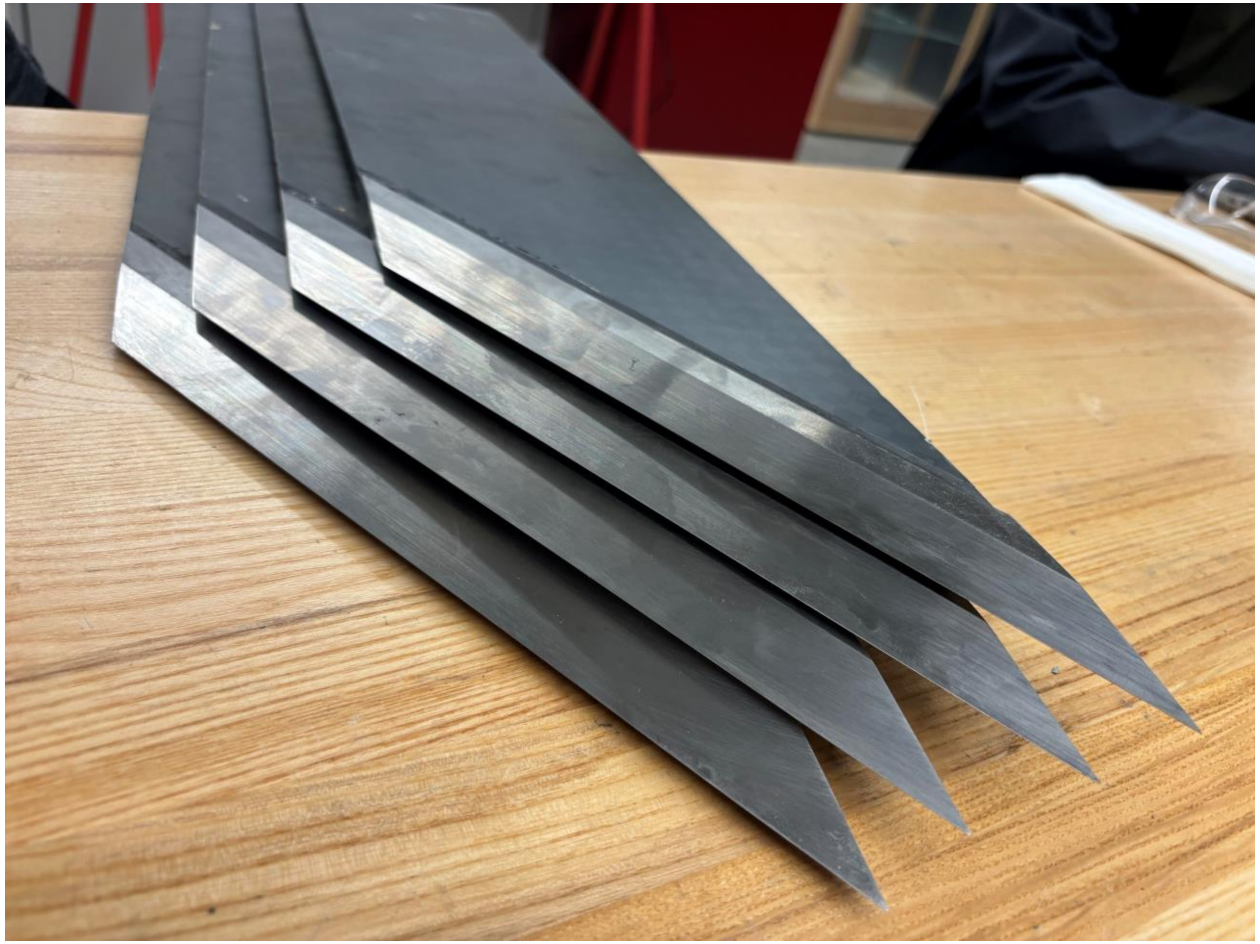
Titanium Leading Edges

Motivation

During the 2019 Launch of Traveler IV the leading edges of the carbon fiber fins saw significant delamination, increasing drag and decreasing apogee. The solution to this was metal leading edges, specifically out of Titanium due to its strength under extreme thermal conditions and density.

Machining

During the machining process we had to constantly finetune our process, varying feeds, speeds, and depth of cut to ensure the highest quality part.



Machining Continued

Inspection

While many of our parts are machined to creep up on tolerances and test fit to achieve dimensions, inspection is still critical for many components. For more complex parts like our fin leading edges, bulkheads, and many parts of our nozzle assembly inspection is key for accurate and functioning parts. I learned how to use internal, external, depth, and blade micrometers for measuring critical dimensions. Further I learned how to use fixtures on a surface table and indicators to measure angles, profiles, and give a complete picture of a part's deviation from design.

Takeaways

Beyond the technical skills learned, this experience also gave me more knowledge of the design to manufacturing to firing workflow. The earlier a mistake is made the more it compounds during the manufacturing process if not caught. Having multiple eyes going over each step in the process, planning for contingencies, and having the scrappiness to adapt when things go wrong are key to project completion.

Shockwave Static Fire

Troubleshooting

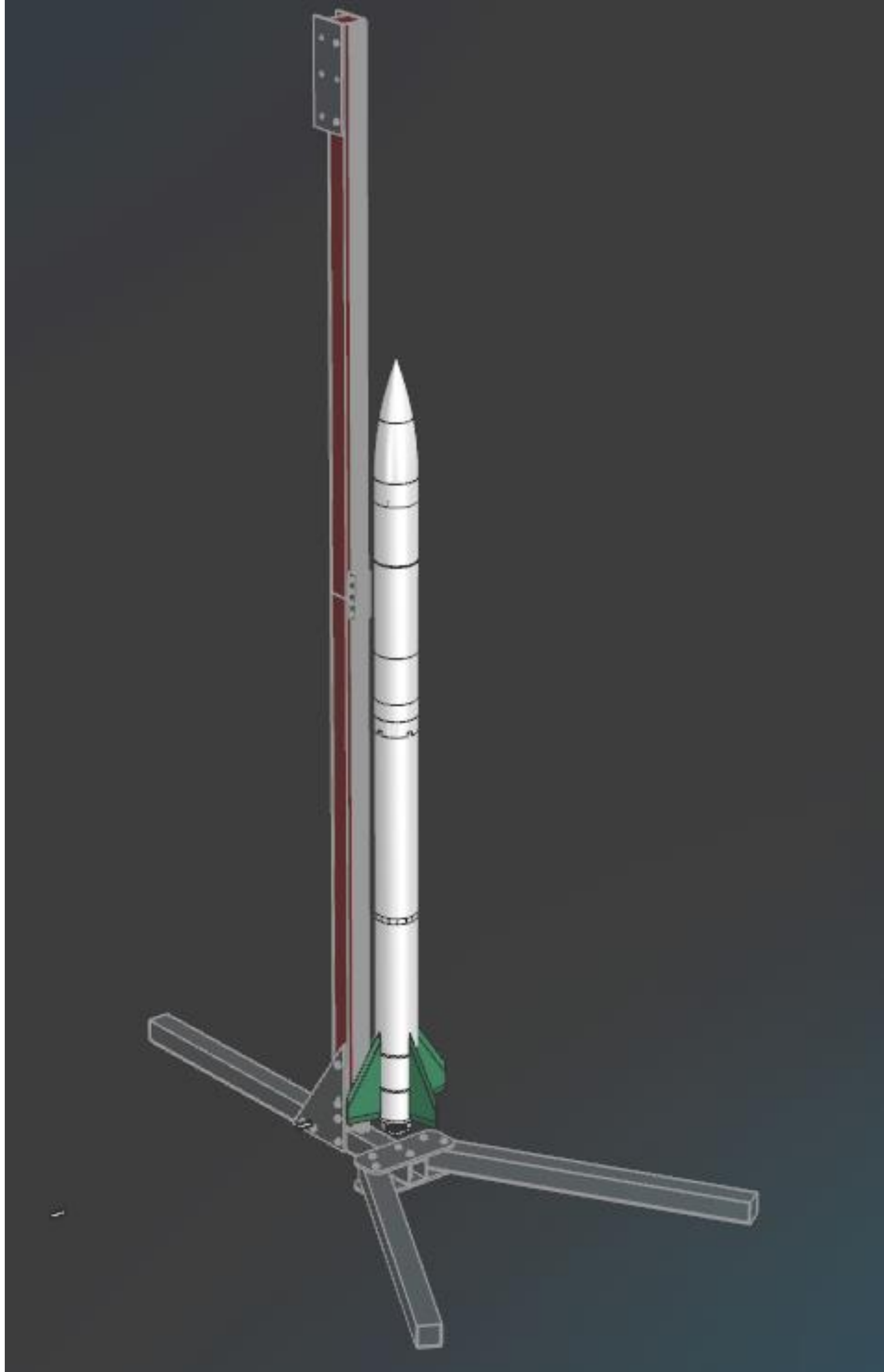
During motor integration we realized that the aft bulkhead could not seat onto the sealing surface due to a mistake during case manufacturing. To mitigate this issue, we had to create G11 spacers to move the entire stack up a quarter inch aft. After receiving rough cut stock, we had less than an hour to machine the stock down to fit the case.

Result

We created a makeshift sander capable of finishing and rounding the stock, using the case to test fit as needed. We successfully finished machining the spacer and fired the next day, resulting in a max thrust of 3,772 lbf and a total impulse of 45,698 lbf-s.

L2 Launch Rail

For this project we had three weeks to design, build, and test a rapidly deployable launch rail for an L2 rocket using a minimal budget. By using scrap stock from the university machine shop, and careful use of purchased stock we were able to complete the 8ft tall launch rail under $85. I first assisted in the design to ensure ease of manufacturability by maximizing parts done on a waterjet, using only simple bolted connections, and eliminating any welded joints due to added manufacturing complexity. I then cut and milled the rest of the tubing, completing all manufacturing a week ahead of schedule.



L2 Launch Rail Design to Manufacturing

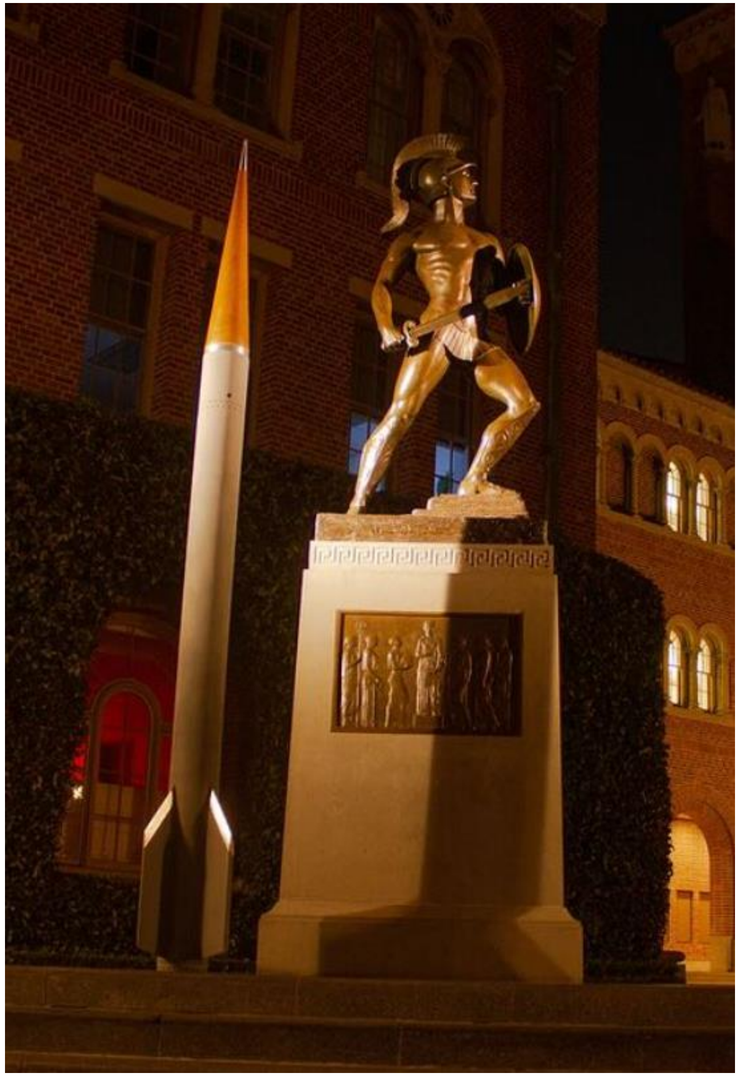
During the Launch of the amateur rocket test vehicle, we successfully assembled and secured the rail within an hour and completed our validation by showing no wind shear or deflection of the rail through slomo video. The rail is now available to use on any future ammeter rocket launches at USCRPL.

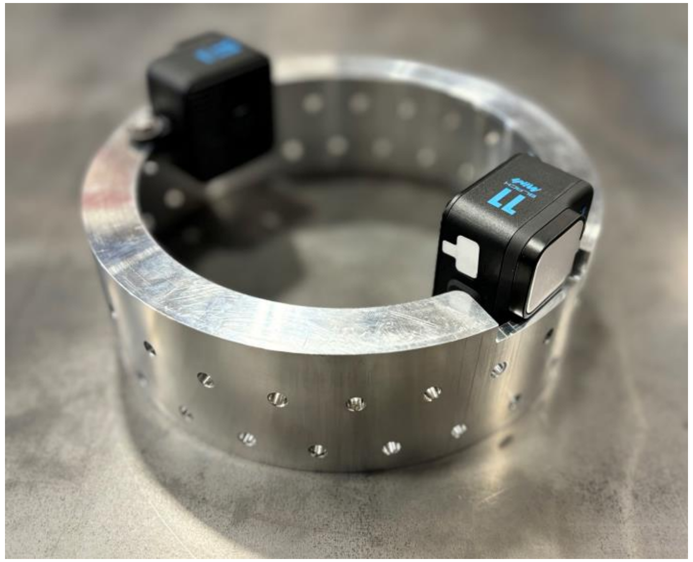
Baum Family Makerspace Machinist

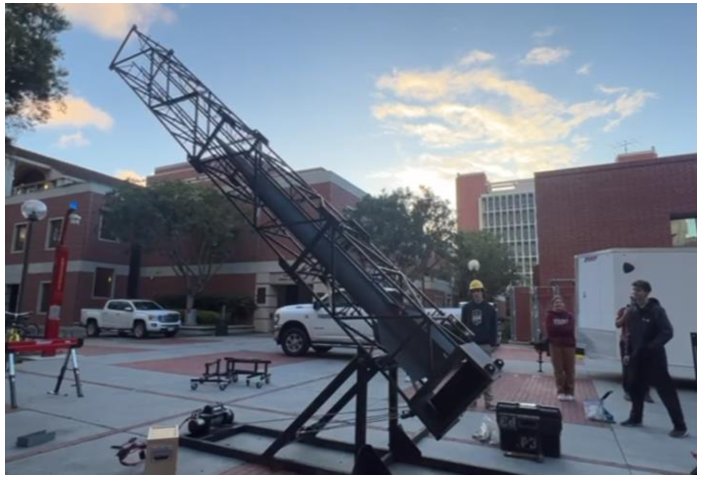
Variety of Parts, Variety of Challenges

I was responsible for making parts for a variety of USC undergraduate engineering teams including the Autonomous Underwater Vehicle team, Formula SAE, Formula SAE electric, and many other smaller projects. Each day brought new and unique challenges with their own specific requirements. Notable parts include a sonar enclosure designed to seal up to 30 meters underwater, suspension components for the formula SAE car, and hydrophone covers requiring complex fixturing and programming.

Additional Photo References







USC Viterbi
School of Engineering

Generalized Robot Learning from One Scenario

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Introduction

A major bottleneck to effective robot learning is collecting and processing enough data to solve complex tasks. The robot must interact with example scenarios many times to solve each scenario, and must be presented with a diversity of scenarios in order to generalize. We asked the following research question:

Can a robot interacting with only **one** scenario still learn to solve complex tasks?

Methods

To solve the general task, the robot must extract as much information as possible from the single scenario. We evaluate our approach on the lunar lander domain from OpenAI Gym where the objective is to land a spacecraft safely. Each scenario differs in terrain and initial conditions of the lander. In order to generalize to all scenarios, we want our robot to explore **different** solutions to landing the lander such as impacting the ground at different velocities or landing at different positions. To explore different solutions we trained our robot with the quality diversity algorithm Covariance Matrix Adaptation MAP-Elites (CMA-ME).

Research and Results

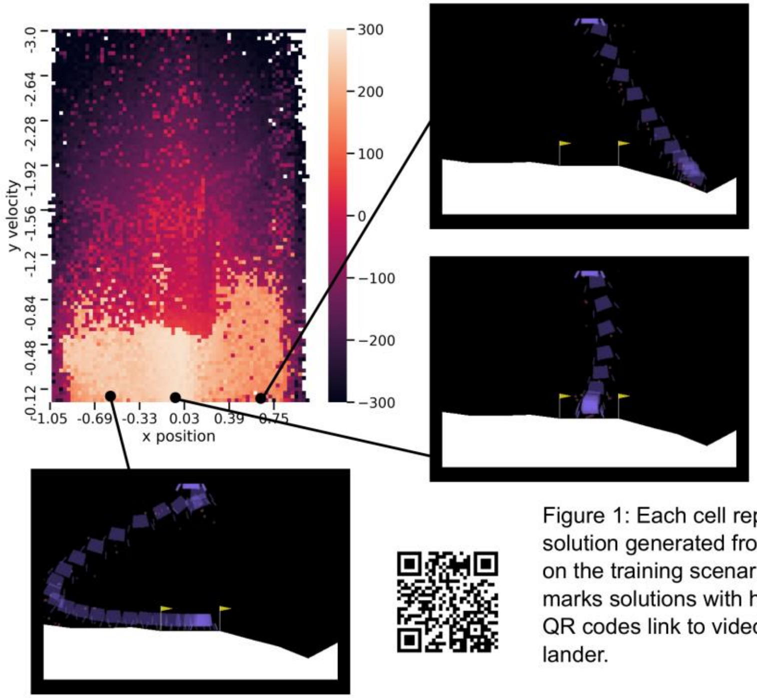
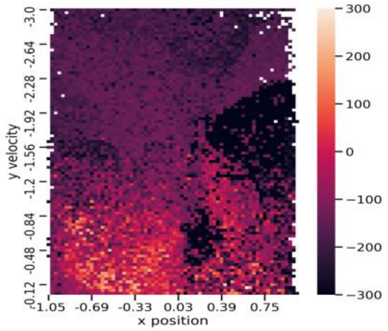


Figure 1: Each cell represents a solution generated from CMA-ME on the training scenario. Intensity marks solutions with high rewards. QR codes link to videos of the lander.

Figure 2: Each cell represents the average score from 200 different environments generated from the model made by CMA-ME for the first training environment.



Next Steps and Broader Impacts

The next steps in our project would be seeing if this method also worked in a different OpenAI Gym environment like car racing and bipedal walking. Furthermore, by implementing a neural network instead of a linear model, our method could solve more complex tasks. After demonstrating the generality of our method, we could train physical robots with fewer example scenarios.

A possible application for this method of learning is to use it where the data from an environment is extremely limited, like rovers on different planets. Diverse solutions for both design and control of rovers could lead to greater chances of mission success, and more robust exploration of planets. The applications for CMA-ME are vast and continue to grow as machine learning becomes an essential part of research and daily life.

Acknowledgements

I would like to thank Professor Nikolaidis for giving me the opportunity to work in his lab this summer. I would also like to thank my Ph.D. mentor, Matthew Fontaine, for guiding me through every step of the process of learning about machine learning and its applications with quality diversity, my lab mate Ruth Berkun, and the entire SHINE team for working through the pandemic and persevering to still educate all of us.