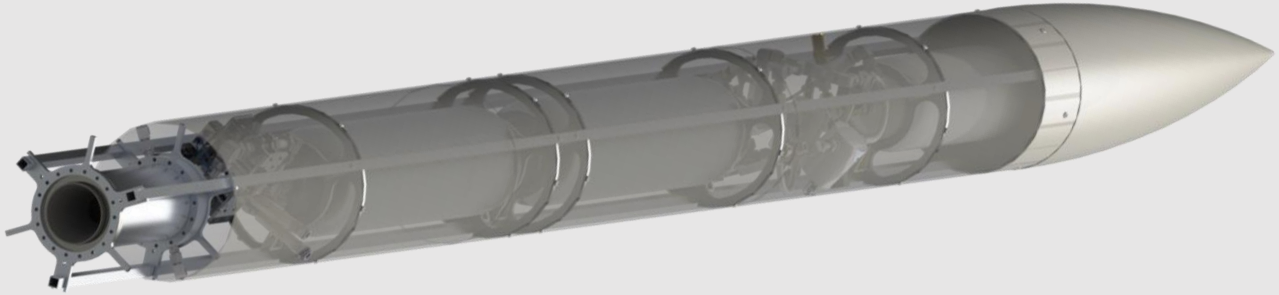
Trevor Tuck

Hi, I'm a Mechanical Engineer graduate from UC Irvine with interest in manufacturing and structural design.

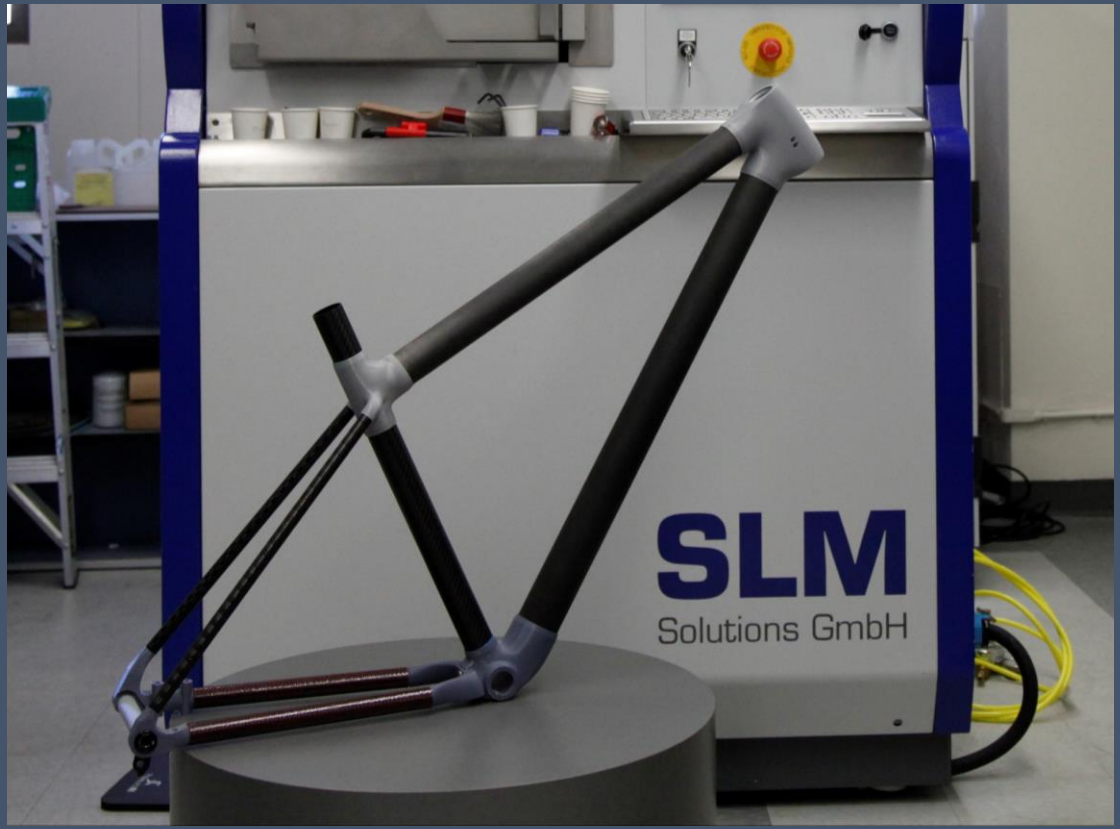
Thanks to Adrienne Zuniga for revising the portfolio and converting pictures to .png. My references include past chief engineers of UCIRP including Owen Osborne and Tony Drabeck; my advisors for Gluebi include Dr. Valdevit, Ben Dolan, and Tyler Schuldt.

Gluebi: Weldless Bike Frame

UCI Rocket Project



Gluebi



140 mm
fork travel

3.73 lb.*
frame weight

29 x 2.6 Geo
Unlimited adjustment

About

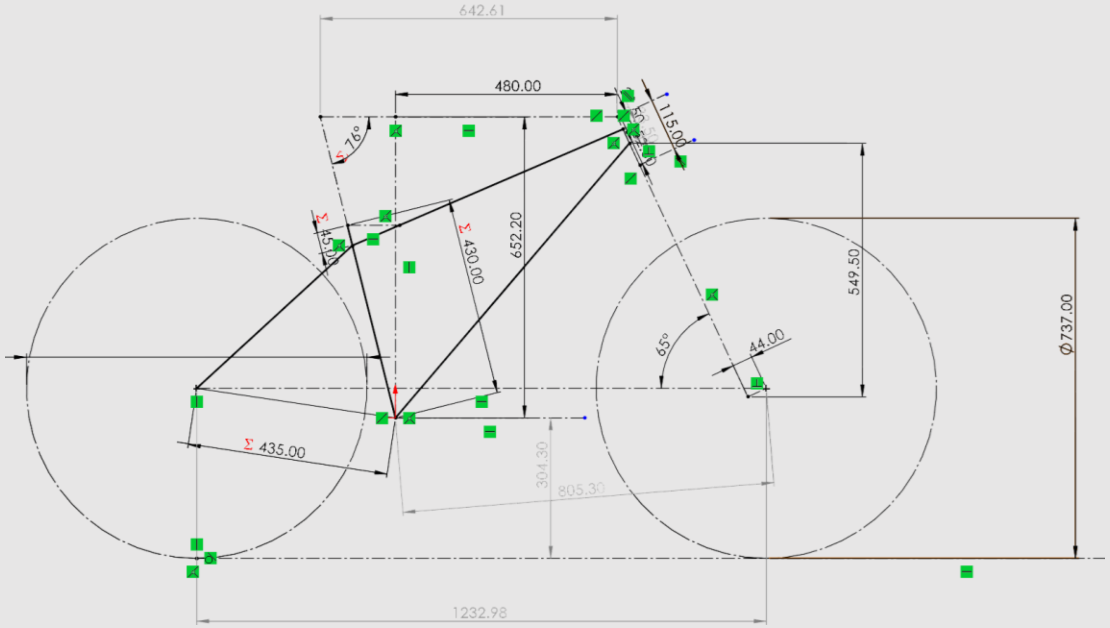
“Gluebi” is an experimental project started in Spring 2021 by the UCI Bike Builders club. My teammates included Felix Slothower and Tony Drabeck. Our final research report details our goal to create an improved, additively manufactured mountain bike controlled by CAD to produce custom geometry.

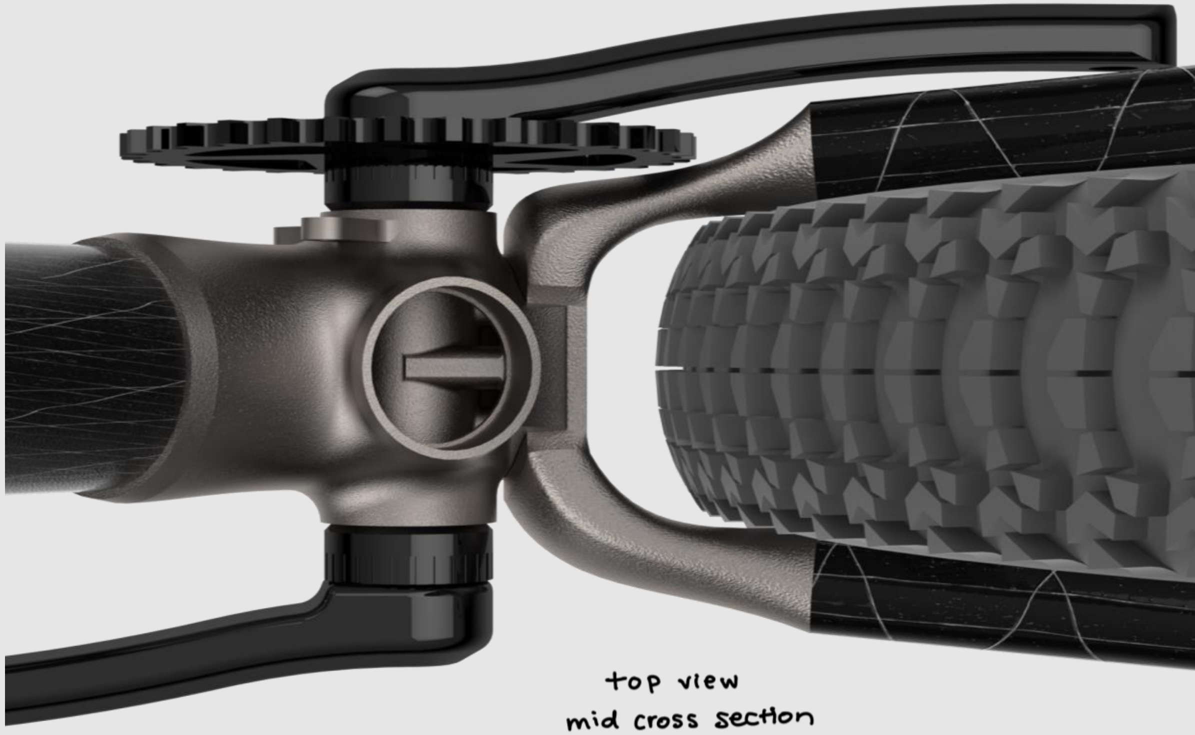
In Spring 2021, the team achieved a preliminary design of the bike’s front triangle and printed one lug on the SLM 3D printer as a prototype for our final report. After Spring 2021, members Felix Slothower and Tony Drabeck moved on from the project.

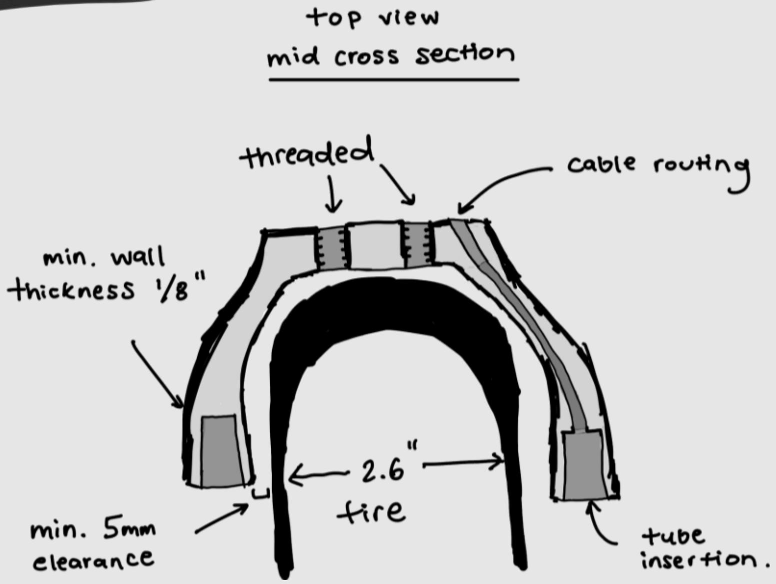
After returning, my goal in Fall 2021 was to complete a full bike frame without welding to complete the rear triangle, despite the size limitations of UCI’s SLM. I completed the entire design, analysis, and manufacturing plans for Gluebi in Spring 2022.

Parametric CAD & Yoke Design

Developed by Felix Slothower in Spring 2021, the master sketch enables the adjustment of bike geometry with a set of equations in SolidWorks. After converting parts into an assembly, I split the files into three configurations for the final DMLS print, soft jaws for post-processing, and post-processed results. The SLM-125hl build volume limits the design, so I developed the yoke to achieve a weldless design. The yoke relies on bolts and adhesives to provide the strength and stiffness that a typical welded connection might.

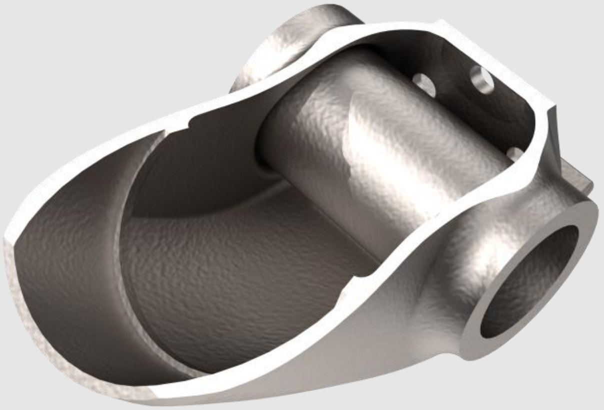


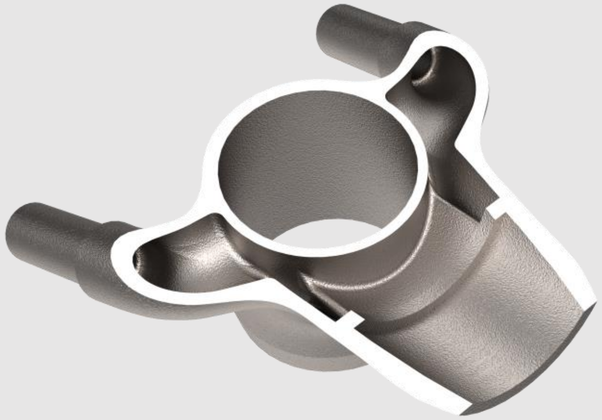




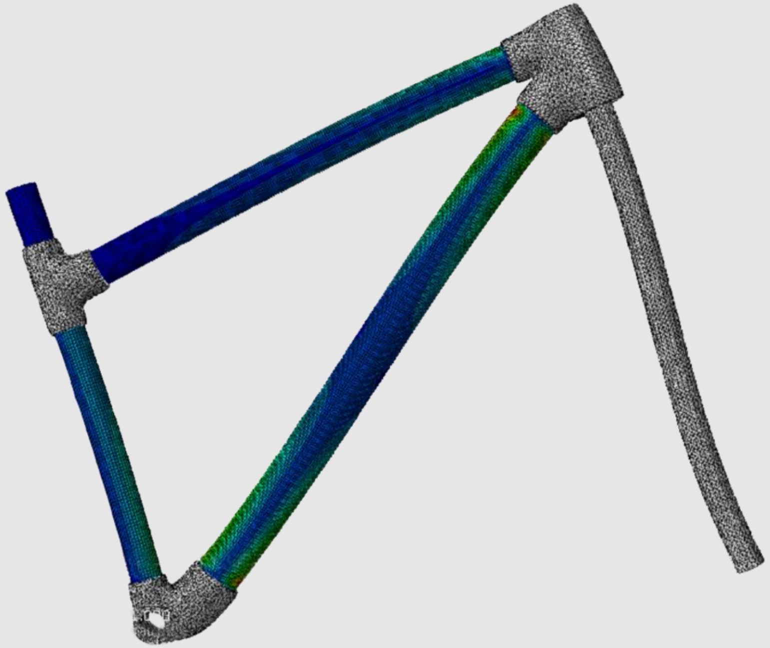
Lug Surface Modeling

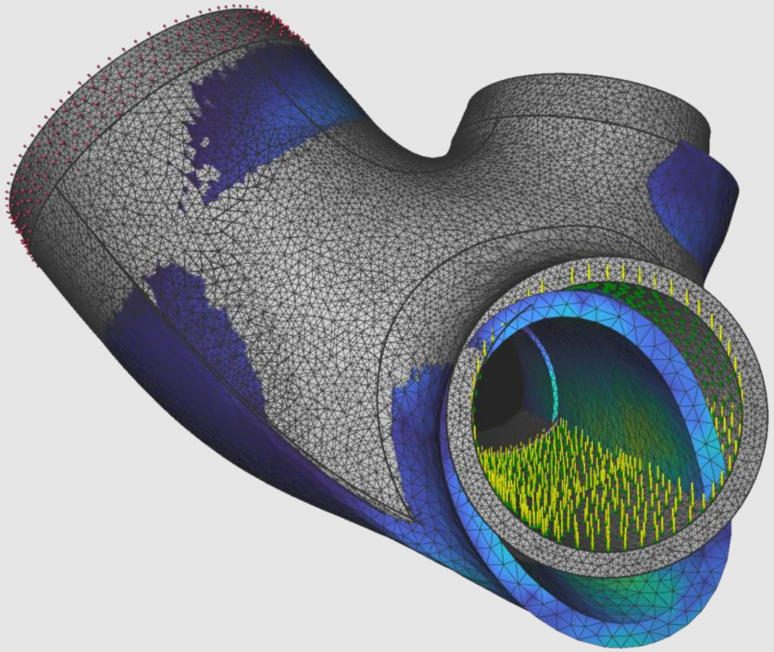
One design decision in CAD was using complex surface modeling to maximize the benefits of 3D printing. Keeping the geometry in sketches and surfaces reduced assembly complexity and allowed our simulations to run on laptops. Parts such as the seat tube lug contained complex lofts and sweeps, which were not ideal in SolidWorks, but still were optimized for stress. While the seat tube lug did not have continuous geometry, the deviation was small enough to be post-processed.





Abaqus & nTopology FEA



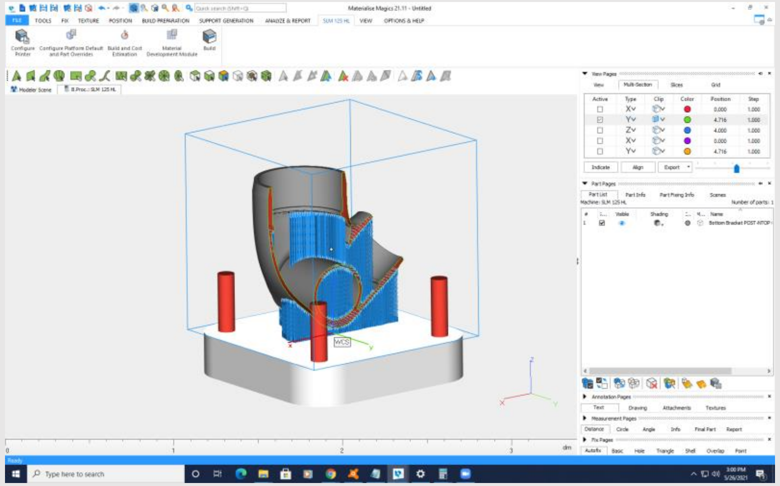


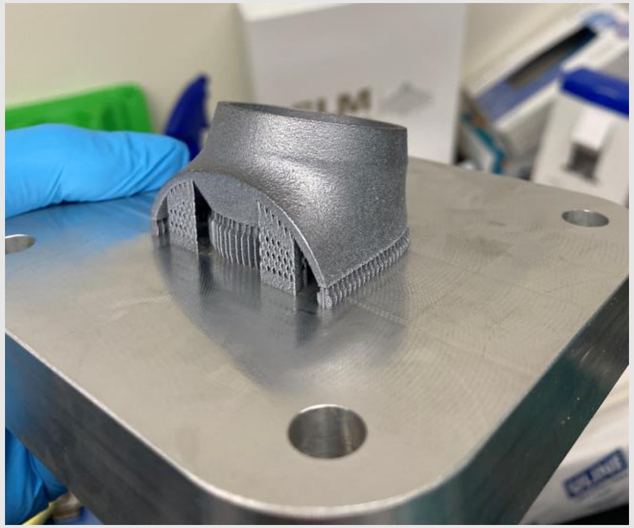
Methodology:
The Abaqus simulation shows the bike frame undergoing a dynamic loading on the fork with a fixed bottom bracket. I chose Abaqus over SolidWorks because of its ability to run on lab computers with more memory, highly controllable mesh properties, and superior layup analysis. This simulation illustrates the concentration of forces on the downtube and its torsional strength requirements.

Methodology:
Setup by Felix, the nTopology simulation of the completed shelled bottom bracket lug demonstrates von mises stress given a typical pedaling force of an average rider. The sim aided in surface optimization and conducting shell operations for printing. Stress concentrations guided my decision on bolt hole placement..

Results:
The lug under peak stress (bottom bracket simulated on the right side) has an FoS of 13 with 300 lb. loading and a 3900 lb. UTS. Peak stress occurs at tube interfaces (expected). The frame can withstand a large fork deflection of .15" and has room for light-weighting.

Prototyping & Manufacturing





Prototyping of lugs was done by creating supports in Netfabb and using Magics predictive print time to estimate layer build time. On the top row was the process for the bottom bracket lug, which I programmed a mill to bore out the supports. On the bottom row are the first tests completed: machining an Al lug and CF tube which I epoxied together successfully at a 10 thou bond gap (± 1 thou), as well as a cross section of the bottom bracket lug which I selected by making a cut and surface offset for the soft jaws.

UC Irvine Rocket Project

Weldless design

950 lbf methalox engine

14ft. 162 lb. structure dry weight

About

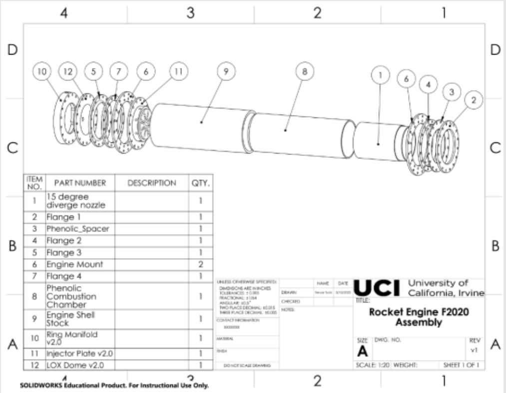
I joined the UCI Rocket Project in Fall 2022, knowing nothing about the team and its structure.

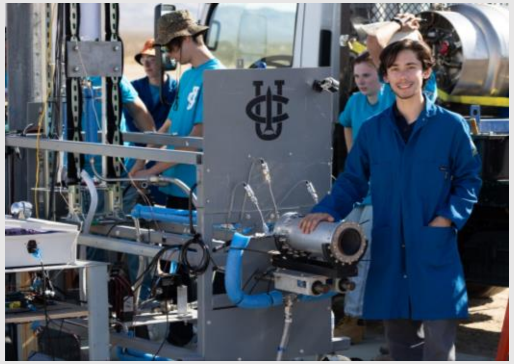
Initially, I began studying the CAD and significant structural design choices, quickly realizing the team had not simulated any structural members of the rocket. This was a priority, considering the team planned to launch within a year.

The first task I accepted was organizing the rocket assembly CAD and simulating the rocket's internal structure using past static test fire data. Next, I developed the "Rocket Erector," where the team could assemble the rocket structure.

Finally, I manufactured the new engines for the first vertical test fire and subsequent launch. UCI did not have the machining capability, so I used connections with Orange Coast College to machine the engine parts there. OCC posted a video in Summer 2022 about my process.

Methalox Rocket Engine Manufacturing





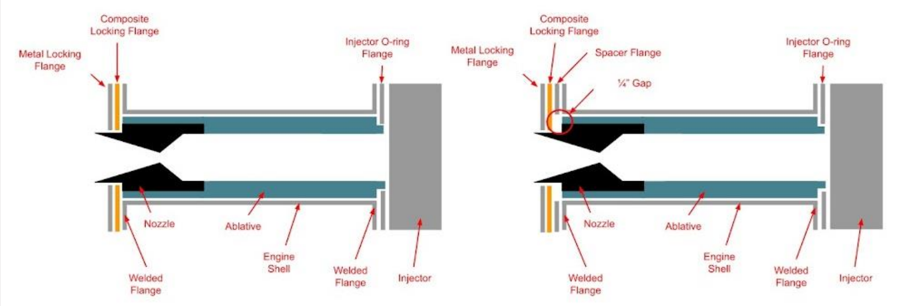


Figure 3. Correct Engine Assembly (left) vs. Incorrect VTF2 Engine Assembly (right)

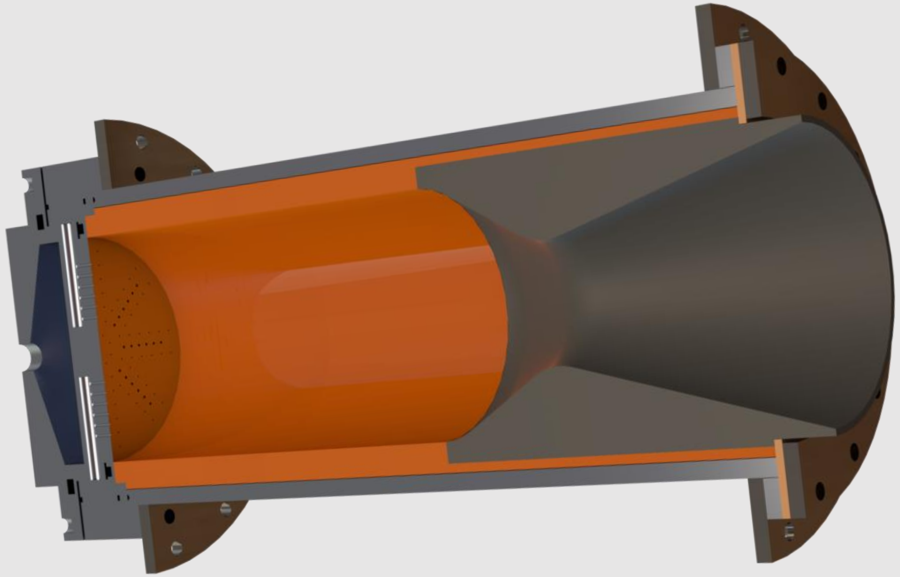
I considered material properties and manufacturability to redraw an engine with updated propulsion characteristics. I updated the old engine drawings with the measurements I took. Then I created five engineering drawings for the flanges and combustion chamber and manufactured with precision ranging from 1 to 15 thou. After Tyler Schuldt MIG welded the flanges, I post-processed the welded surface to reach a perfect surface finish for the injector mating.

“Engine IPA” was successfully test-fired. The engine was assembled by wiping surfaces with isopropyl alcohol, applying silicone RTV to the tolerance gaps, adding the high-temperature O-rings, and tightening the fasteners in a calculated star fashion. However, the engine sustained minor damage during the test fire due to the “propulsion leads” failing to assemble the spacers in the correct order. Failure analysis shows tight tolerances prevented an explosion and enabled the reuse of the engine.

Skins Jig

My task was to attach the skins to the rocket's internal structure. I designed and 3D printed a skins jig with holes to drill/tap into 3⁄8" 6061-T6 bulkheads. This design creates an easy method to slide the jig along the rocket, maintaining a constant orientation for the three bolts. Each hole contains a slot with a corresponding drill and tap bushing. I completed this print on the BigRep with ProHT filament for $16.

UCIRP CAD Drive



I developed the UCI Rocket Project Google CAD drive and organized the rocket assembly. Google Drive replaced the messy GrabCAD system, and I provided an introductory video explaining how to use the drive. I required members to participate in a CAD quiz to gain access to the drive. The first folder was my updated CAD of the engine, which included a set of drawings, photos, renders, and notes for new members to gain familiarity more quickly.

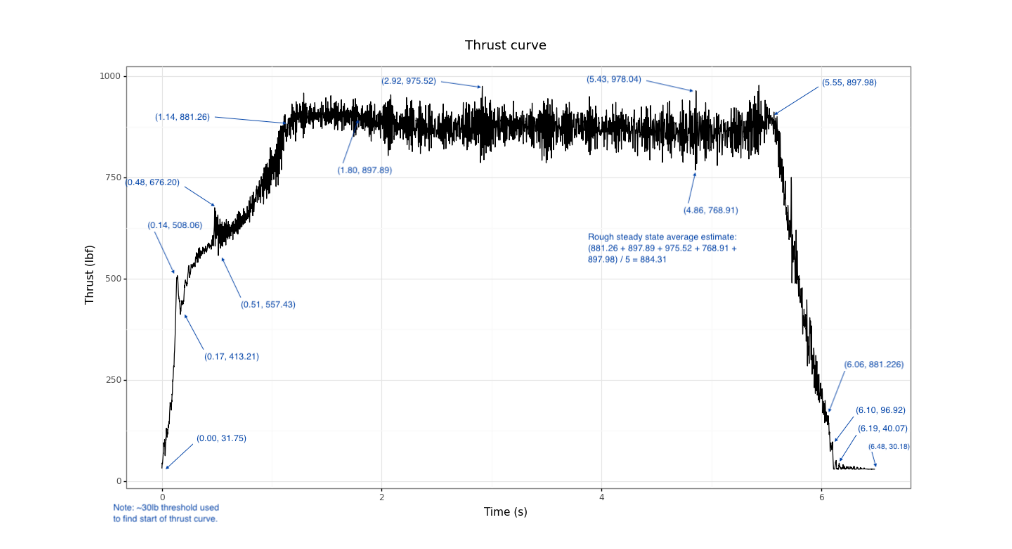
Bulkhead Isogrid

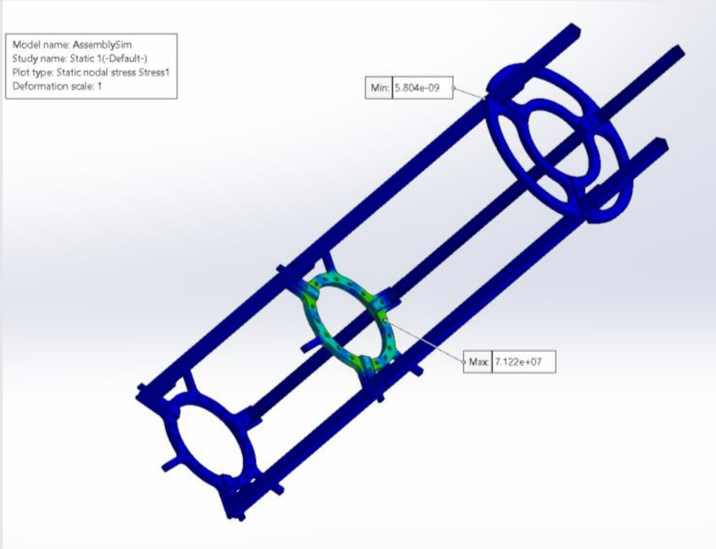
After creating a simulation with SolidWorks generative design, I light-weighted the part to an FoS of 1.5. Then, I made the CAM for the school HAAS CNC to mill the part with three operations: 3/8" endmill along the OD for assembly tolerancing, 3/8" endmill removal of isogrid material, and chamfer mill to smooth the sharp edges. The three ½" bolts on the bulkhead provided fixturing in the CNC and will be used to mount recovery parachute equipment.

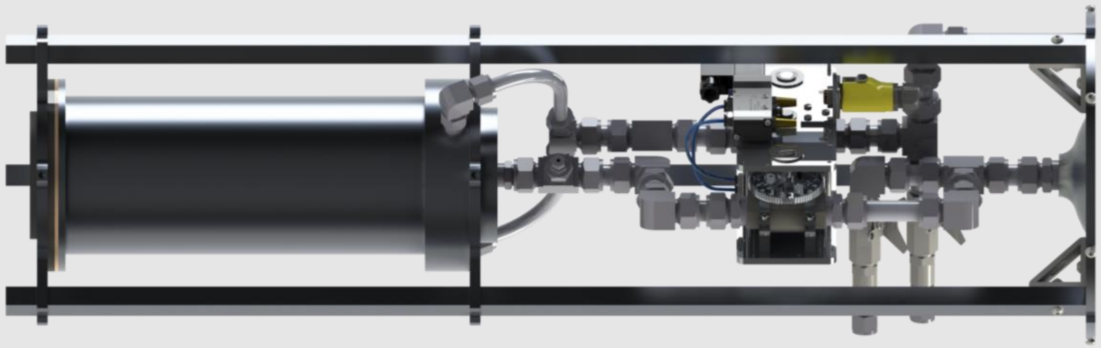
Rocket Erector

My testing task was to develop a system to hoist our rocket assembly to allow for realistic vertical test fires. The requirements included determining how to store the rocket inside our lab and frequently transport it to our testing location. Using the team's old steel cart, I designed a modular Unistrut, pulley, and winch system to bolt to our steel cart. The system relies on our team-owned drill and socket to turn the winch and hoists the 300lb system in under a minute. I completed the manufacturing of the system with teammate Collin Kramer who assisted in machining steel parts and adding fasteners.

Structural Sim







Using the raw .tdms data from UCI's most recent static test fire, I modified an engine performance analysis script (from past test fires) in Python to smooth values for SolidWorks to accept a dynamic thrust curve. The peak stress values on the rocket section containing the engine mount are shown above. The model found an FoS of ~3, which was proven during the launch. After a recovery failure, the rocket remained intact despite falling 9500ft.

Links and References

Links:
Rocket Engine Machining – Video from OCC on my manufacturing process
5 Redesigned Rocket Engine Drawings – Google Drive link to manufacturing drawing PDF's
Instructional CAD Video – Video of me instructing Rocket Project members how to use the CAD Drive
CAD Quiz – Quiz I wrote to grant access to the Rocket CAD drive
UCI Bike Builders Final Report – Report on Gluebi progress

References:
Dr. Valdevit – Joint MSE & MAE Professor, Director of IDMI
Ben Dolan – Director of Engineering Research Projects
Tyler Schuldt – Machine Shop Director
Tony Drabeck – UCI MAE Colleague
Owen Osborne – UCI MAE Colleague
Collin Kramer – UCI MAE Colleague
Felix Slothower – UCI MAE Colleague