TREL

TEXAS ROCKET ENGINEERING LAB

The University of Texas at Austin
Cockrell School of Engineering

THE ROCKET REPORT
OCTOBER 2024

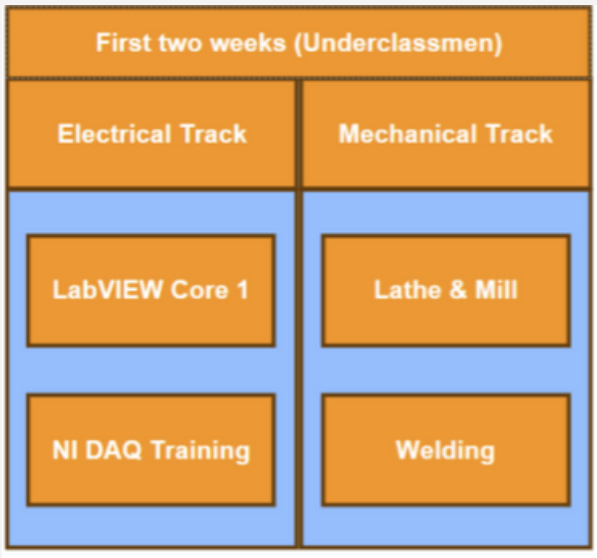
The Texas Rocket Engineering Lab is excited to share some incredible updates regarding the future of the lab, recruitment, and launch date.

SKUNKWORKS

TREL's mission is to prepare students for the aerospace industry by providing hands-on rocketry experience. In aims to stay true to this and launch Halcyon, our liquid bi-propellant rocket, TREL's leaders approached recruitment a little differently, onboarding a select few. The Texas Rocket Engineering Lab would like to introduce a brand-new program: TREL Skunkworks. This division of TREL uses research and development-based projects to train new TREL members. So far, new members have spent their time working through one of two skill tracks, mechanical or electrical, while upperclassmen team leads have been hard at work preparing a design review to answer the program's primary problem statements.

Section by Zachary Muckler, Chief Engineer

The Program



The program's problem statements were determined with future Halcyon upgrades in mind and include the following:

- "Nemo," an Electric pump-fed engine
- Steel Tank Research
- RCS Test Bed
- Antenna Ground Station
- Propellant Measurement
- Custom Liquid Oxygen Valve

Each of these teams are working to support future upgraded versions of Halcyon.

***Image**: Skunkworks member learning to solder*

Section by Zachary Muckler, Chief Engineer

“The Nemo, ” an Electric pump-fed engine

The Nemo rocket engine is a 700 lbf electric pump-fed rocket engine. It’s a fifth of the size of Halcyon’s current rocket engine, “Havoc (TXE-2),” but still packs a punch, requiring several kilowatts of power. The team has reached several major milestones since the start of the semester:

- Conducted a water submerged electric motor test
- Hydro-proofed a hermetic seal prototype
- Conducted engine system design review with Tom Mueller, covering pump design, sealing, combustion chamber cooling and geometry, and injector design
- Performed cryogenic valve dunk testing at Pickle Research Campus
- Completed Quantity Distance calculations for test stand building

The team is hard at work this week preparing to machine a sealing test rig. This assembly will be used to characterize leakage mass flow rates of water, kerosene and eventually liquid nitrogen and liquid oxygen. The testbed matches our current pump design and, upon successful test, can be modified to match our final pump housing geometry. The team also looks forward to printing its first impeller and injector test pieces this week and aims to complete a fuel pump test by mid-October.

Image above: *Ben Juenger pouring liquid nitrogen*

Image to the left: *Valve immediately following a cryogenic beath*

Section by Zachary Muckler, Chief Engineer

Steel Tank Research

The steel tank research team is investigating the manufacturing processes required for a welded stainless steel pressure vessel. This team has been hard at work over the past week brainstorming various weld geometries and steel rolling methods. Their next upcoming milestone is welding their first tensile coupon in which they will subject a 316 and 304 stainless steel weld to uniaxial tension under normal temperature and then cryogenic temperatures.
By the end of the Fall semester, the steel tanks research team will publish a paper of their findings to present at an AIAA conference in March. Their research will highlight the advantages of steel as a pressure vessel and compare various weld geometries under extreme environmental conditions. This research will help derive empirical relationships that Halcyon will use in the future for propellant tank design.

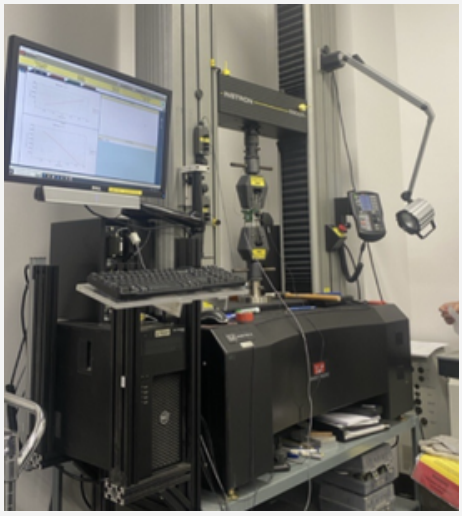


Image above: *A steel test piece under uniaxial in an Instron 500*

RCS Test Bed

The RCS test bed team is working on a novel controls test bed in which a 3D inverted pendulum is controlled by cold gas thrusters. This mechanism will allow students to design and test controls algorithms in an environment just like that of Halcyon, while also using a similar control mechanism. Interestingly, the team has come up with a unique approach to reducing fluid line stiffness by creating a custom joint that allows the thruster gas to flow through it while also retaining the ability to lock each degree of freedom for development testing. Furthermore, the team's pendulum will offer the advantage of a customizable mass in which students can change its location or swap it out altogether for something heavier or lighter. The team will also build the reaction control system for Mark 1 Halcyon. By the end of the semester, this team will have built flight hardware and created TREL's first ever controls test bed.

Antenna Ground Station

The antenna ground station team is building an automated altitude/azimuth radio antenna mount that can be transported to any Halcyon launch location. Using its own GPS and receiving data from the rocket, this ground station will automatically track with the rocket's trajectory, retaining a pointing accuracy of around 1 degree. This ground station will be robust, built to last in the desert conditions of Halcyon's launch site and the 40 mph wind gusts seen during a typical desert day. By the end of the semester, the ground station team will deliver a finished product for Halcyon's Mark 1 flight.

Section by Zachary Muckler, Chief Engineer

Propellant Measurement

The propellant measurement team is building a device that will be able to measure the liquid level in Halcyon's propellant tanks. This team is adopting a differential pressure method of propellant sensing and has jumped right into preliminary testing, first using water to determine sensor error. This team hopes to increase testing scope to cryogenic liquids and quickly converge on a design in time for Halcyon's Mark 1 launch this fall.

Image on left: *Nicolas Giglio demonstrates how to wire a pressure transducer*

Image on right: *Skunkworks members inspect transducer tubing and harnessing*

Custom Liquid Oxygen Valve

The skunkworks valve team is responsible for designing and building a custom cryogenic valve for use on Halcyon's liquid oxygen circuit. This valve presents a very difficult challenge in that it must withstand temperatures around -297 F and seal under a 1000 psi differential pressure. On top of that, it must have a small form factor and be relatively lightweight so that it can fit in Halcyon's engine bay. By the end of this semester, the valve team will have machined and tested its very first prototypes.

Looking Ahead

The skunkworks teams covered a lot of ground in their first week and TREL has much more planned for them. Over the semester, students will provide maker portfolios and final presentations which Halcyon leadership can use to pick exceptional candidates to join their teams. As this continues, TREL will develop a strong pipeline of exceptional engineers for its flagship program.

Section by Zachary Muckler, Chief Engineer

HALCYON UPDATES

We kicked off this school year with a full mission review to assess Halcyon's performance and baseline a flight that provided the quickest path to breaking the collegiate altitude record, while minimizing remaining development time and risk.

What we unsurprisingly concluded is that, while Halcyon is not capable of reaching 100+ km in its current iteration, Halcyon's size allows it to far exceed the current collegiate liquid rocket record (70+ km vs ~14 km). This provides an opportunity to not just break the record, but truly set the bar way higher. However, given our complex architecture with immense system interdependencies and closed-loop active control, the likelihood of succeeding in a way that fully takes advantage of Halcyon's potential in TREL's first rocket flight is admittedly low.

We were left with a fundamental challenge: How do we take an iterative learning approach that enables calculated risk-taking when we only have one (incredibly unforgiving) vehicle?

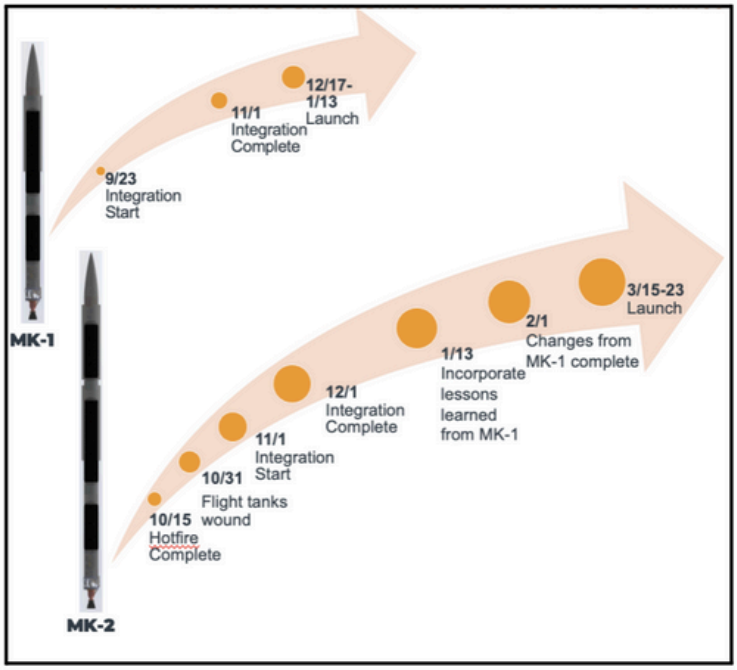
"Well, what if we built an intermediate vehicle with the hardware we have on hand?"

Enter Halcyon Mk1. Simplified hardware configuration with blowdown pressurization system. Use the 2x LOx/RP-1 COPVs we have on hand that we previously used for pressure cycle testing. Start integration immediately and fly over winter break to double the collegiate altitude record. The higher-performing variant of Halcyon that we have been designing for years will be called Halcyon Mk2. We will fly this vehicle in March over spring break, aiming to at least double the record we will set with Mk1. We'll sprint to a first flight, learn all the lessons associated with integrating and launching our first rocket, and make any necessary adjustments to Mk2 in the beginning of 2025 ahead of launch in March. This will allow us to really push Mk2 to its limits with increased confidence - all while leaning into our iterative development ideology.

Section by Buckner Newberry, Halcyon Chief Engineer

Image: Graphic of what Mk1 and Mk2 will look like respectively

Image on right: *Timeline for Halcyon Mk1 and Halcyon Mk2*



High-level academic year timeline. Graphic credit: Prof. Jamie Huffman

September Progress

We've hit the ground running since we've been back from summer break and have made significant progress over the last month. Here are the highlights:

Propulsion

-(Mk2) Almost every valve needed for integration has been physically kitted
-(Mk2) Remaining hardware needed for integration has been specced and purchased
-(Mk1, Mk2) Vehicle propulsion flight model has been built from ground up, enabling higher accuracy GNC simulation results and mission design/trajectory trades
-(Mk1, Mk2) Significant progress in TVC assembly analysis with integrated FEA revealing new areas for improvement, design modifications in progress
-(Mk1, Mk2) TVC actuators tested with flight computer
-(Mk1, Mk2) Havoc SN2 hotfire preparation with sequence modifications, new stand CdA calculations from recent cold flow, and igniter assembly procedure updates
-(Mk2) Nozzle extension V2 (ablative) design near completion (CDR this week)

Section by Buckner Newberry, Halcyon Chief Engineer

Structures
-(Mk1, Mk2) Significant progress on intertank avionics mounts designs
-(Mk1, Mk2) Skirt coupler metal redesign kicked off (improved manufacturability/flexibility)
-(Mk1, Mk2) Skirt alignment stand completed
-(Mk2) 5 of 6 skirts manufactured
-(Mk1, Mk2) LOx COPV pseudo-qualification test data review presented
-(Mk1, Mk2) Determined max LOx COPV strain/strain rate for operational limits
-(Mk1, Mk2) Nosecone separation system design maturing
-(Mk1, Mk2) Recovery deployment test setup

Flight Control
-(Mk1, Mk2) Rebuilt 1DOF from ground-up, using for heavy iteration in mission design and trajectory
-(Mk1, Mk2) Baseline 3DOF and 6DOF models written and running
-(Mk1, Mk2) Ran flight software state machine and tested ability to control hardware
-(Mk2) Significant progress on avionics integration layout and hardware purchasing
-(Mk1, Mk2) Completed design on vehicle converter PCBs
-(Mk1, Mk2) Ran Vehicle Test Stand VI on DAQ system, validated input/output architecture

Integration
-(Mk2) Delivered coarse dry mass estimate to GNC
-(Mk2) Completed integrated vehicle CAD
-(Mk2) Finalized Nosecone-Pressurant intertank configuration

Test & Launch
-(Mk1, Mk2) Post-summer test stand maintenance and reactivation work completed
-(Mk2) Significant progress on hydrostatic test cart pressure up-rating to support increased in-house capability
-(Mk1, Mk2) Built new, permanent and dedicated, LOx/RP-1/Water supply on Engine Test Stand
-(Mk1, Mk2) Engine Test Stand ox cold flow performed to determine new runline CdA
-(Mk2) Significant progress on Engine Test Stand upgrades design (DCR this week)
-(Mk1, Mk2) Significant progress on Vehicle Test Stand fluids and electrical system build
-(Mk1, Mk2) Launch mount painted

Section by Buckner Newberry, Halcyon Chief Engineer

The entire (~100 person) Halcyon team has been full throttle since we've been back to school. I wish you could all first-hand see the new buzz that exists in the program. I don't think I have ever seen more activity in the TREL room, PRC, Teams chats, etc. in my almost 4 years in TREL. It is truly a sight to behold, I know many of our alumni would be (and should be) proud to see the organization we are developing into.

Despite our significant progress in the last month, in order to meet our launch timelines for both Mk1 and Mk2, we have even more work to do in the next month. Here are the high-level milestones we need to hit:

October Goals		
Team	Mark 1	Mark 2
Propulsion	*Acceptance test Havoc SN1 *Integrate fluid system *Assemble TVC system	*Acceptance test Havoc SN2 with ablative nozzle *Map all intertank assemblies
Structures	*Proof GHe test tank and use in VTS tanking test *Install intertanks, couplers, raceways, and brackets *Manufacture nosecone *Test bonded joint *Purchase all recovery hardware	*Wind 3x COPVs *Build out inventory of unpressurized structures
Flight Control	*Fabricate all harnesses and integrate avionics system *Complete FSW stack *Complete 3DOF *Complete 6DOF + TVC/RCS controllers	*Map all intertank assemblies *Purchase all avionics hardware
Test and Launch	*Proof GHe test tank proof *Conduct VTS tanking test *Water flow Havoc SN1 *Acceptance test Havoc SN1 *Submit FAA launch license	*Water flow Havoc SN2 *Acceptance test Havoc SN2

Section by Buckner Newberry, Halcyon Chief Engineer

Image: *Halcyon MK1 in early stages of integration*

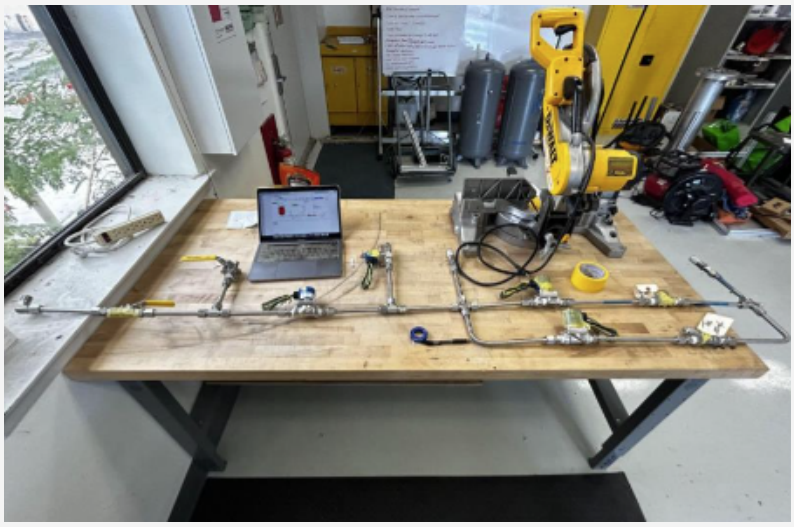


Image: *Vehicle Test Stand RP-1 system build*

Image: *Vehicle Test Stand “launch mount” painted*

Section by Buckner Newberry, Halcyon Chief Engineer

Image: *Engine Test Stand LOx cold flow at Firefly Briggs test site*

Image: *Heating up fitting post-cold-flow to disassemble*

Image: *Carson David Dutton, Vehicle Test Stand member, holding GHe isolation valve*

Section by Buckner Newberry, Halcyon Chief Engineer

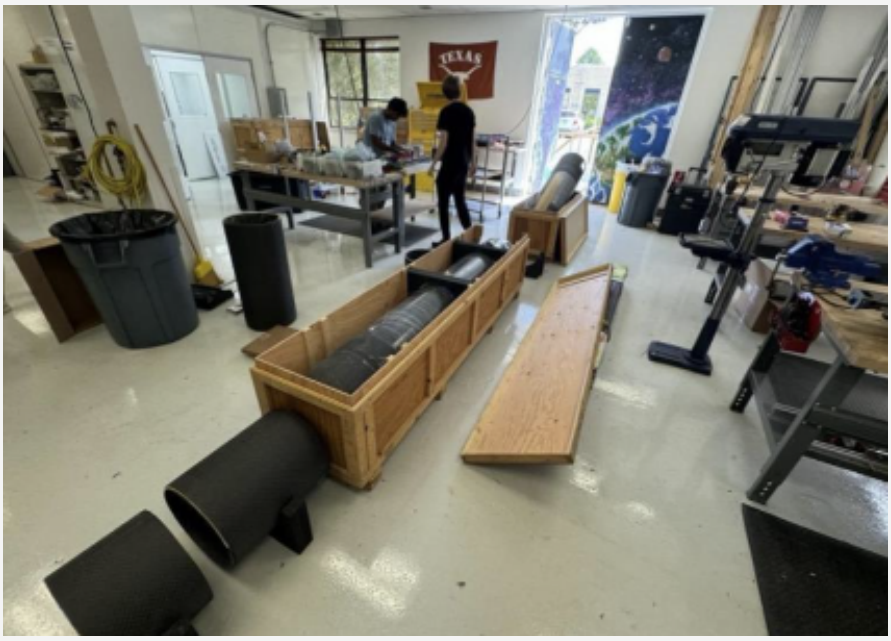


Image: *Mk1 COPVs and intertanks lined up pre-integration*

Image: *Bao Nguyen, Engine Test Stand Lead, posed in front of the stand*

Image: *Structural Test Stand for COPVs, cut and welded in-house*

Section by Buckner Newberry, Halcyon Chief Engineer

Image: *Cutting sheets of pre-preg carbon fiber for Halcyon Mk1*

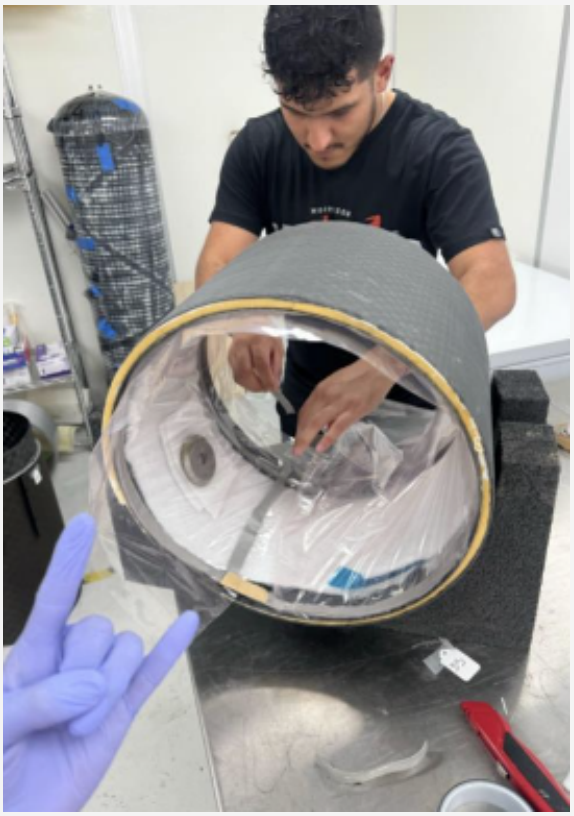


Image: *Last composite coupler layup, complexity of this part justified pivoting to metal*

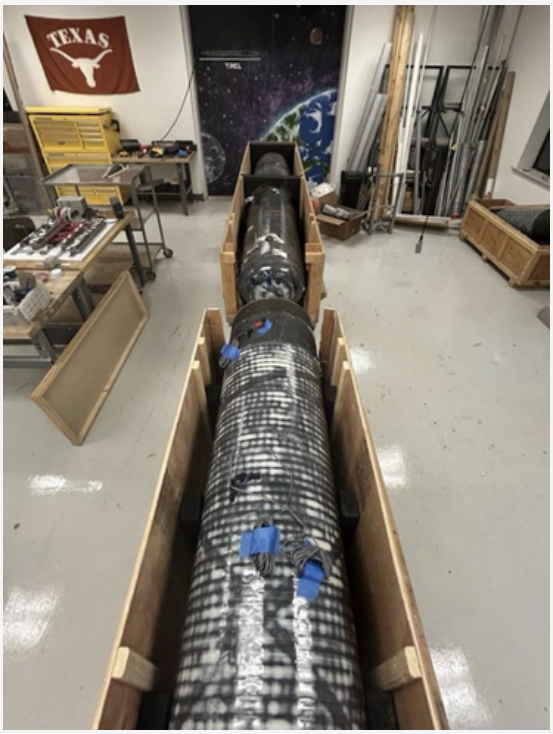


Image: *Another angle of Halcyon Mk1*

Section by Buckner Newberry, Halcyon Chief Engineer

SHOUTOUTS

During our bi-weekly all hands meetings we started giving out an “Ingenuity Award” for a member who goes above and beyond what is expected of them - we want to shout them out here as well:

Dylan Roberts, GNC Lead Engineer:
“Under a lot of pressure (from many different parties) to deliver 1DOF simulation results to unblock vehicle MR trades. Exhibited immense persistence and commitment, working through challenges and putting in many hours. Presented simulation progress to Director of GNC at Relativity and ran an effective meeting despite admittedly nascent development. Immediately picked it back up and pressed on the gas pedal to continue working towards an accurate simulation..”

Ian Cochran, TVC Lead Engineer:
“I have not seen someone physically in the lab more than Ian, constantly grinding away at his tasks. He meets every ask and challenge with incredible drive to push TVC forward. He is an excellent communicator and team lead - making sure they are contributing to tasks and divvying up work. As one of Halcyon's most complicated systems - he is driving to completion on schedule and doing so as a team player.”

Section by Buckner Newberry, Halcyon Chief Engineer