Spring 2022 Technical Report

Cornell Rocketry Team
Payload Systems and Integration
Recovery and Payload
Gabe Mitchell [gfm48]

Cornell University
Sibley School of Mechanical and Aerospace Engineering
124 Hoy Road
Ithaca, NY 14853

Summary

1 Technical Report

1.1 Semester Overview

My semester started with refining the payload CAD in preparation for manufacturing. I then spent the next month manufacturing payload and payload housing parts. After manufacturing, both the payload and housing were assembled. I then oversaw electronics, servo, and payload deployment testing. As the Recovery and Payload moved toward electronics integration, we had servo control issues, and I took the lead on debugging the problem. After all electronics issues had been solved, I also took the lead on integrating all electronics into the Payload. Electronics integration was done in parallel with two dress rehearsals, whereby the Recovery and Payload subteam worked through many LV integration issues. After electronics and LV integration, CRT completed its test launch. The last subteam project for the year was payload flight testing using our new heavy lift drone, which is still an on-going project.

1.2 Updating Payload Design

Changes to the payload CAD included feature addition and part refinement for the sake of mass reduction and ease of assembly. The original CAD is pictured in the image immediately below, and the updated CAD is shown in the subsequent picture.

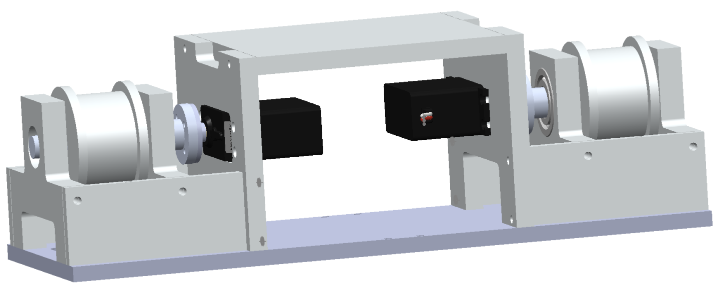

Figure 1: **Original Payload**

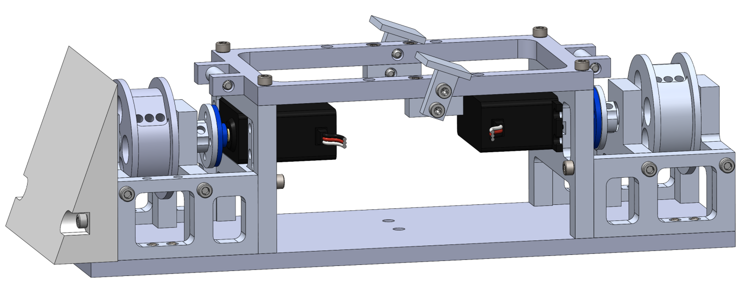

Figure 2: **Payload Post-JanFab Changes**

I made mass reductions, added modules to interface with springs in the payload housing system, added a ramp to interface with the ramp on the payload housing system, refined the shaft to servo horn adapter, changed the suspension line mount (previously an eyebolt), and refined the wheel drums such that they could interface correctly with both the shaft and steering lines.

1.3 Housing and Payload Machining

After payload changes had been finalized, manufacturing began. Most metal parts on both the payload and payload housing were made in house by machining aluminum 6061-T6 using manual lathes and mills. Exceptions include the payload door, payload shaft mounts, payload side mounts, and payload top support, all of which were made on the CNC. The only major mistake made during this process was making the payload shafts out of aluminum. Both the wheel drums and shaft adaptors are mounted to the shaft via set screw: a technique which has damaged the shafts. Now the connections between the shafts and shaft components are slightly weaker. No such issues would have occurred had the shafts been made of steel. Almost all of the machined housing and payload parts, sans the payload door, are included in the picture below. Engineering drawings can be found in tech reports written by Matt Bryan and Alex Allen

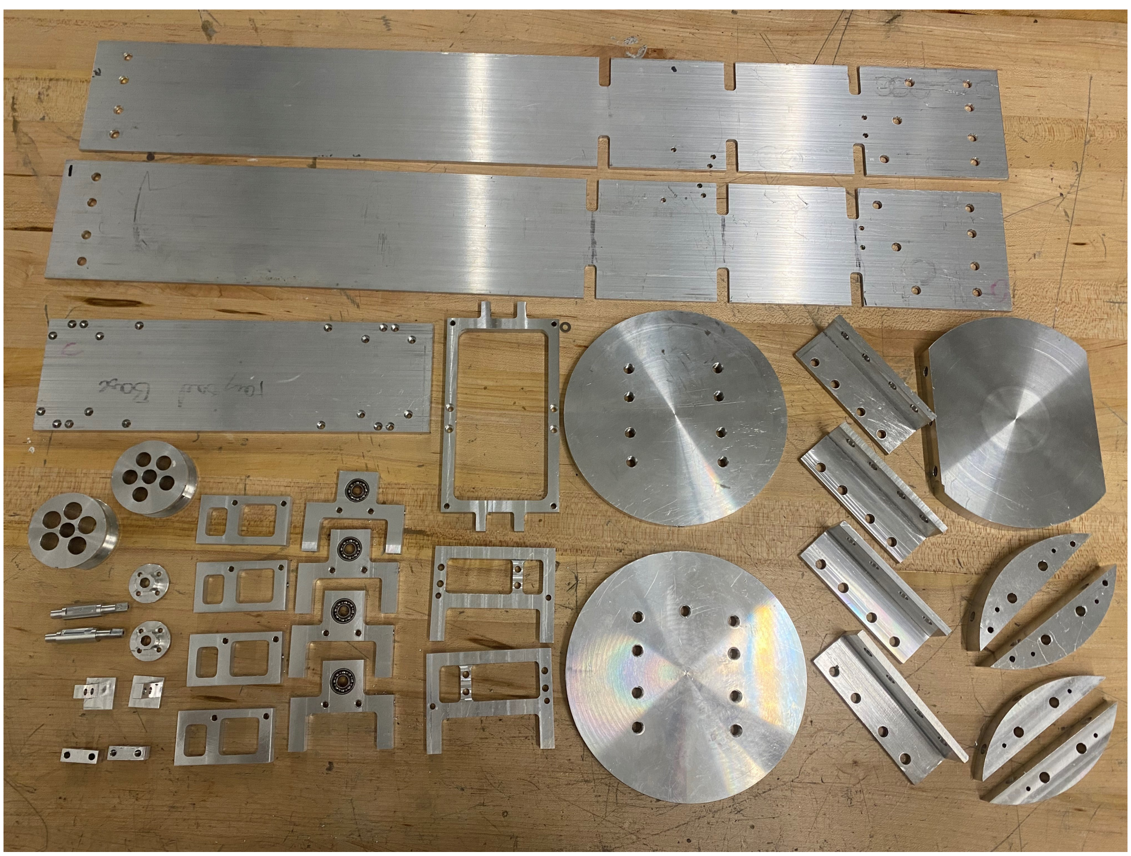

Figure 3: **Housing and Payload Parts**

1.4 Housing and Payload Assembly

After machining, the Recovery and Payload subteam assembled the housing and payload. The assembled systems are pictured below.

Figure 4: **Payload Housing Assembled**

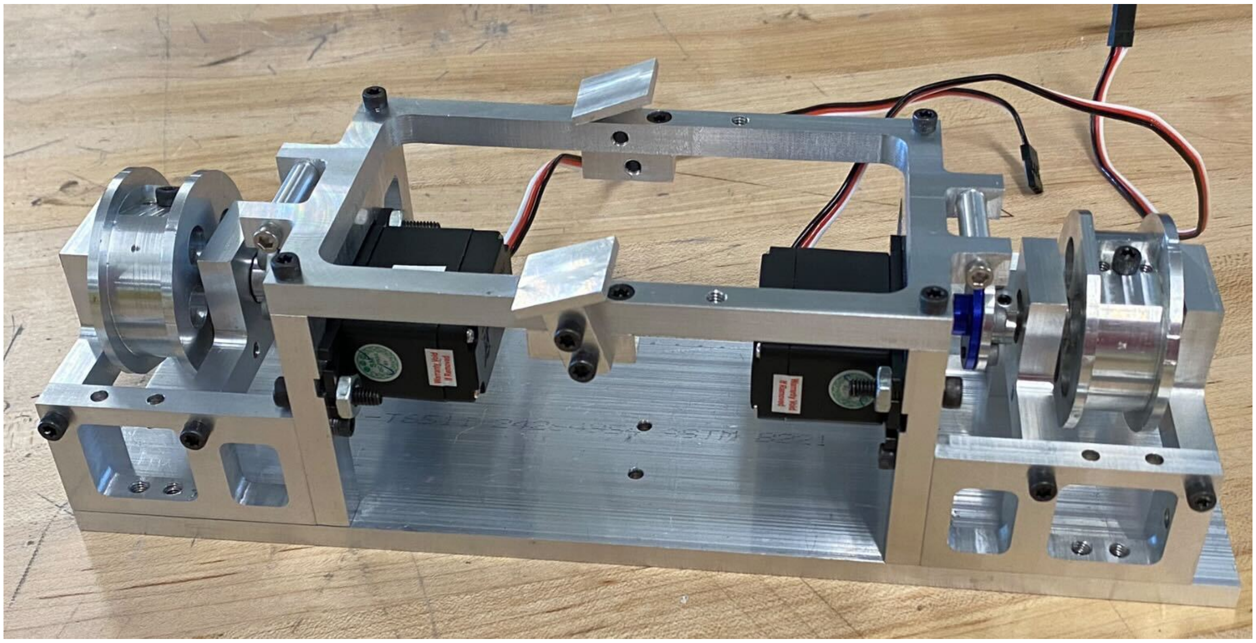

Figure 5: **Payload Assembled**

Housing and payload assembly went mostly as planned. However, the housing and especially the payload had issues with fastener alignment. I encouraged the Recovery and Payload subteam to design these systems with an excess of structural components and fasteners. I envisioned that without these features, parts on the housing and payload would have play with respect to each other. My expectation was based upon past experience with bolt-nut-through hole connections that did have too much play. However, almost every connection on both the payload and housing was between a bolt and a steel threaded insert. I learned that these connections are much more constraining than those with through holes, so excess structural components and bolt connections were not only unnecessary, but problematic. Because Recovery and Payload included excess threaded connections and structural components, there was more opportunity for bolt holes to be misaligned due to machining errors. That exact issue occurred, and now many bolt holes on the payload are not in use due to misalignment. There is no engineering issue (the threaded connections that are in use suffice), but the payload now looks less professional. If the payload were remade, it should include less threaded connections and structure, as these features only add mass and complexity without providing structural benefit.

1.5 Helping with electronics, servo, and deployment testing

After the housing and payload had been manufactured and assembled, testing began. The subteam began by testing its sensors, servos, and deployment system. I did not lead any of these tests, but I did help out when needed. For more detail on electronics, servo, and deployment testing, please see tech reports written by Nick Johnson, Aidan Herz, and Matt Bryan.

1.6 Payload Housing Changes

Payload deployment tests revealed issues with the housing spring mounts. The original mounts successfully ejected the payload from the rocket, but not without catching on parafoil lines. The original mounts are pictured below.

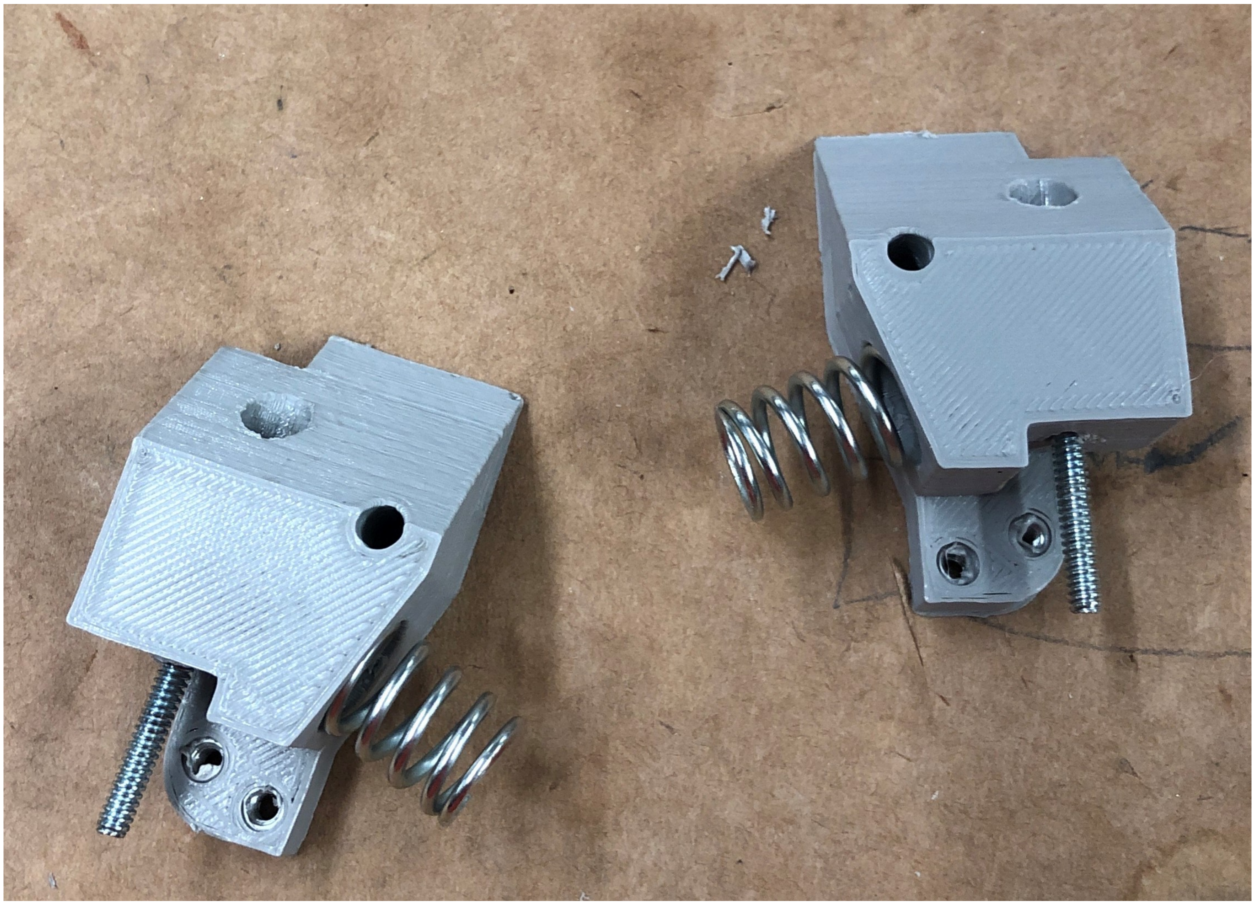

Figure 6: **Original Spring Mounts**

New Spring Mounts were designed such that the sharp edges and extrusions were replaced with smooth contours. Additionally, a cap covers the springs in the new iteration. Unlike the old spring mounts, the spring, cap, and mount were fastened together by melting the spring into the resin that composes the cap and mount. The new spring mount is pictured below.

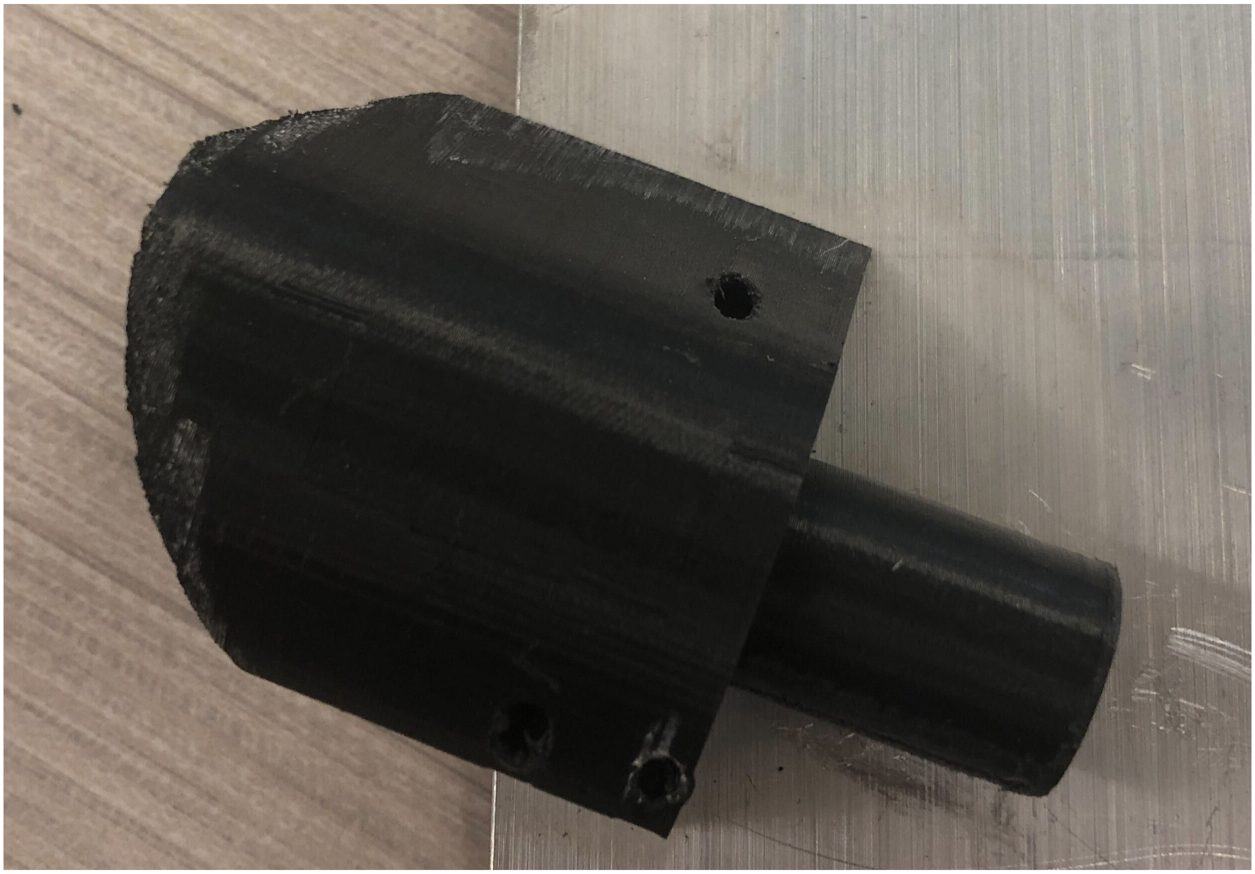

Figure 7: **New Spring Mount**

1.7 Electronics Changes

Electronics testing revealed many issues. There was interfacing problems between the payload arduino and PCB breakout board sensors. The Recovery and Payload subteam subsequently moved away from its existing PCB and quickly brought up a protoboard with new sensors soldered on. The accelerometer and altimeter on the PCB were replaced with the Adafruit 10-DOF IMU Breakout, which includes both an accelerometer and altimeter. The GPS on the board was replaced by the Adafruit Ultimate GPS Breakout. The protoboard communicates with the Arduino via I2C and serial communication protocols. Physical electrical connections are made via wires that are soldered to the protoboard and to a motorshield. Male motor shield pins press fit securely into the female arduino pins. The protoboard, along with all other electrical updates, is pictured in the figure on the next page.

The next electrical issue was extremely erratic servo behavior. Identical electrical setups displayed different servo behaviors from one test to another, and servos often did not adhere to code. The first issue was how the motor shield regulated power supply voltage that was then sent to the servos. The Recovery and Payload subteam had the impression that there was a regulator onboard the motorshield. However, there was no such regulator, and the motorshield instead made use of the regulator on the arduino.

This meant the servos were pulling too much current through the arduino, resulting in unpredictable behavior. To resolve this issue, a 5V regulator separate from the arduino was added to the protoboard. The Recovery and Payload subteam also switched from continuous rotation servos to positional rotation servos.

The third electrical change was made to track the payload after landing. To do so, a egg timer GPS transmitter was added to the payload, and it is powered by a 9V battery separate from the battery that gives power to the arduino, sensors, and servos. The protoboard, regulator, and egg timer are all pictured in the figure below, which also showcases the new electronics mounts.

1.8 Electronics Integration

Following the electrical changes, new mounts needed to be printed such that electrical hardware could be fastened to the payload. All mounts were 3D printed, and they are pictured below.

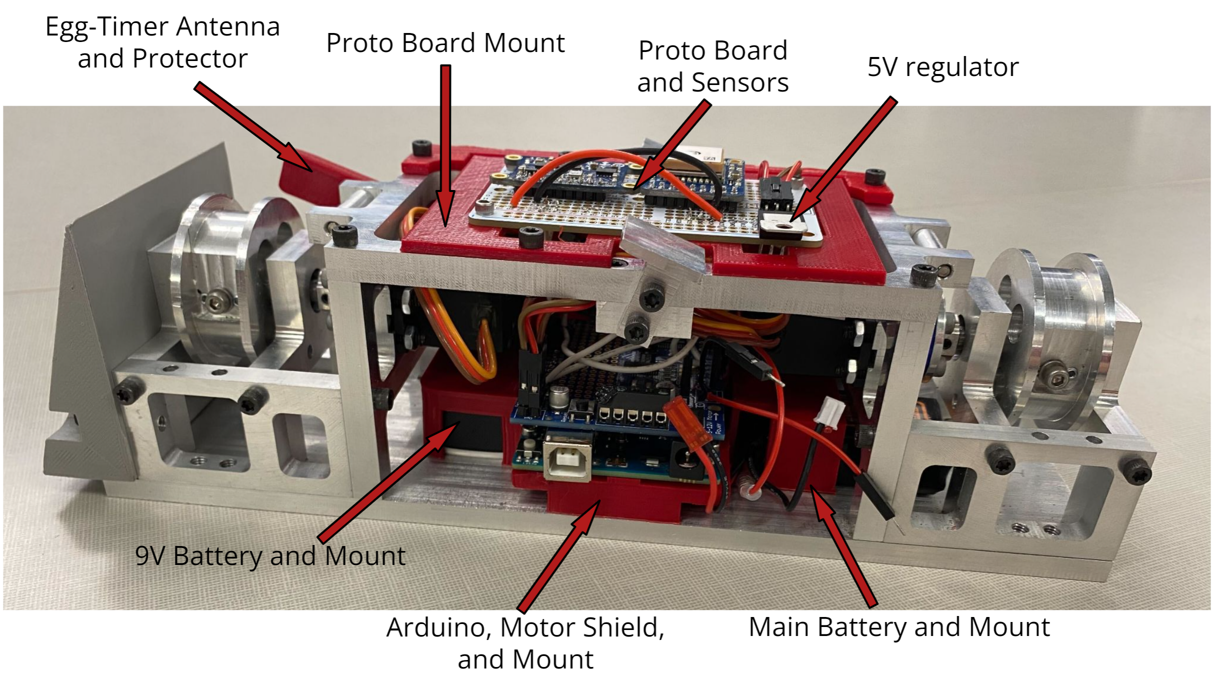

Figure 8: **Payload Electronics**

1.9 LV Integration

Integrating the housing, payload, and parafoil into the LV was at first a lengthy process. However, the Recovery and Payload subteam modified processes, and integration became reliable and quick. The only design change that full rocket integration brought about was remaking the payload housing door. The original 3D printed door bent substantially due to spring force. However, when the door was remade out of metal by Sam Noles, there was no such bending. The door installed in the rocket is pictured below.

Figure 9: **Metal Payload Door**

1.10 Test Launch

During the Spring 2022 test launch, the payload failed to deploy. Upon landing, the payload door was still fasten to the airframe exactly as it was prelaunch. After all hardware was returned to the ELL, CRT determined that the issue was unfastened electrical connectors in the AV bay. During flight, no electrical signal was sent from the CFC to the payload deployment board to initiate the burn that would melt 3D printed columns and release the door.

1.11 Flight Testing

The last task of the semester was drop testing. For drop testing, the Recovery and Payload subteam ordered the Yuneec Tornado H920, a drone capable of lifting 5 pounds. The drone was then outfitted with hooks on both of its foldable legs. The hooks can hoist either a testing bed or the payload itself (outfitted with a special module that interfaces with the hooks). When the legs fold up (as instructed by the drone pilot using the drone controller) the hooks are removed from object being hoisted, and the object is dropped. The leg hooks and payload hoisting module were designed by Alex Allen.

The Recovery and Payload subteam first used the drone to lift the testing bed pictured below. This testing bed was used during parafoil testing last semester. The bed was equipped with mass such that it weighed in total 2.5 lbf: the same weight as the payload.

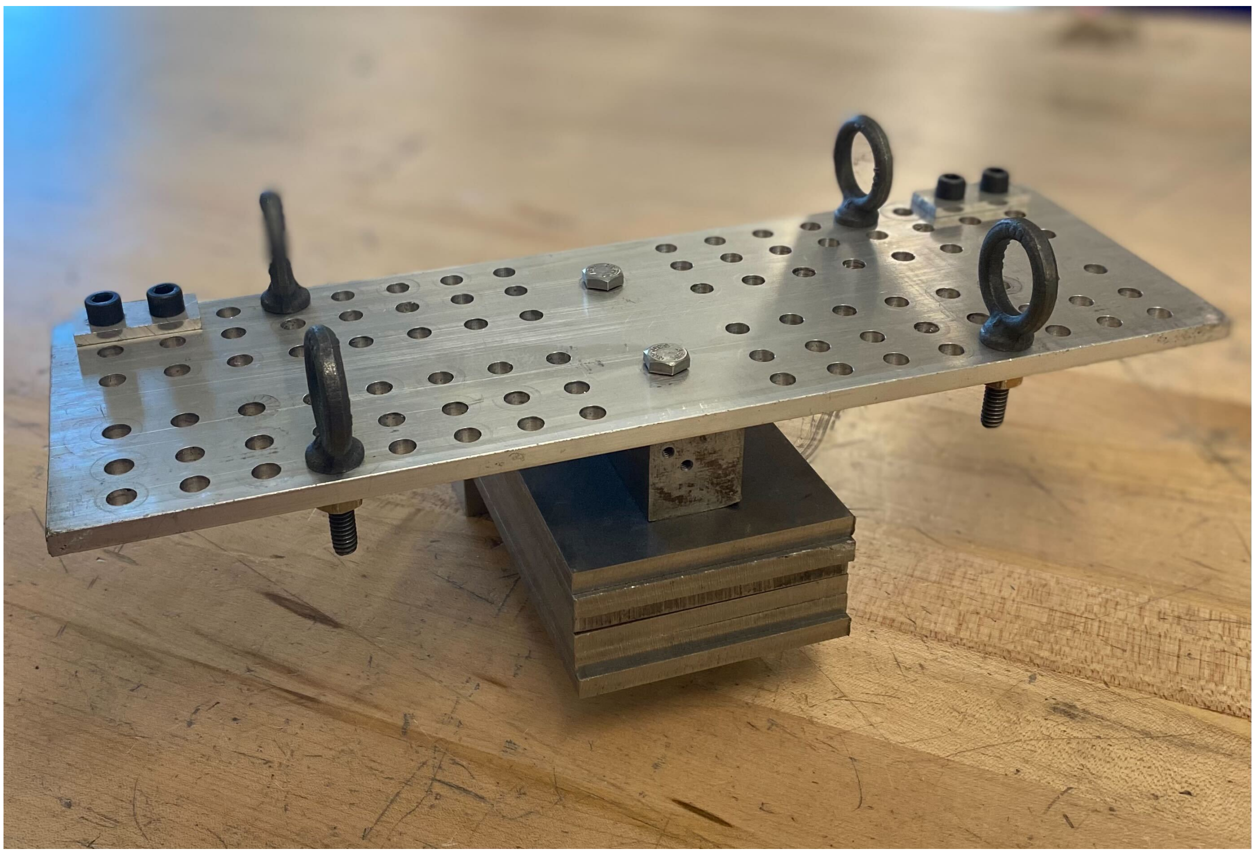

Figure 10: **Testing Bed**

The drop testing process began with rigging testing, as the Recovery and Payload subteam needed to find a configuration that the parafoil would inflate reliably after drone deployment. An image of the drone hoisting the testing bed and folded parafoil is pictured below.

Figure 11: **Heavy Lift Drone and Testing Bed**

The rigging process is still on going, and the payload itself has yet to be lifted by the drone. The Recovery and Payload subteam has tested many different configurations, but not one has yet resulted in a consistent deployment. Rigging configurations include using a slider, adding weight to the slider, using multiple sliders, using sliders with grommets, using different packing configurations, loosely wrapping lines with rubber bands, taping lines together, and others. Some of these solutions have encountered success, but nothing consistent enough to permit the payload being hoisted. The principle failure mode is the payload tumbling in the air immediately after deployment. This tangles lines and prevents the parafoil from inflating fully.

1.12 Current State

The number one priority of the Recovery and Payload subteam over the Summer of 2022 is finding a parafoil rigging method that deploys reliably. This will ensure success at competition and a productive start to the Fall 2022 semester where guided parafoil flight software can begin development immediately.

2 Reflection

The Spring 2022 semester was easily my toughest and most educational semester on rocketry. I, like every member on CRT, took away so many technical and leadership lessons. I could not be more excited to bring them into next year. Before the semester, I had minimal experience with electronics. However, working through the payload electrical issues gave me many relevant skills. I am excited to use these skills in all my future engineering projects. I am also happy that I came away with the little mechanical lessons mentioned previously in the tech report. Little things such as making shafts out of steel and using fasteners only as needed are what take a design to the next level.

Out of all the things I learned this year, I think my most important take away isn't highly technical, but rather a high level approach to design and design management. When solving a problem with an unproven design, one must assume that the design doesn't work. Such an approach gives the designer a needed sense of urgency. This expedites both design and testing, allowing the designer to continuously iterate until a working design is finalized. If a designer approaches a design challenge assuming his solution will work, he risks a relaxed timeline where he only realizes design flaws too late.

An assume-it-does-not-work approach either worked or would have worked for all things Recovery and Payload. This approach was used well during the payload housing design and test process. The system went through substantial yet gradual design changes throughout the fall and spring semester, as informed by design review feedback and then testing results. Payload subsystems that needed this approach earlier include electronics and electronics mounts, and I should have encouraged my teammates to take such an approach sooner. Had we assumed electronics didn't work and tested accordingly, the issues that we found half way through second semester would have been discovered half way through first semester. Additionally, electronics mount integration problems would have been found immediately after manufacturing by my teammates instead of the day of a dress rehearsal by me. This would have more evenly distributed work amongst Recovery and Payload members.

Overall, I think I did a poor job encouraging accountability amongst my subteam members. My approach for the semester was simply assuming my subteam members would do what I needed them to do. While that was most often the case, there were still instances where I needed to do a better job clearly telling my teammates what was required of them - and then holding them accountable if expectations weren't met. One approach I could have taken is holding my meetings like ES, whereby all members fill out a slide describing their progress that week.

Overall, it was a great semester, and I loved learning along side my teammates while CRT took on full scale integration for the first time in 3 years. Approaching previous rocketry semesters, I was primarily nervous. Following the hard-learned lessons of the spring semester, I am finally excited for rocketry this upcoming year, as I have never been more confident in my own and my team's abilities to succeed on technical projects.