Post Launch Assessment Review
2019 NASA University Student Launch Initiative
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1 PLAR Summary

The University of Alabama in Huntsville's (UAH) Charger Rocket Works (CRW) team was proud to be a part of this year's Student Launch Initiative competition. The team successfully designed, built, tested and flew a 6-inch diameter launch vehicle spanning 124 inches in length from the tip of the nose cone to the base of the tail cone. This year's payload selection was the UAV and rover combination. The team's designed a UAV to fly a beacon to a future excursion area. The launch vehicle, *ShredIt 40,00*, flew on an Aerotech L1420 motor and reached an altitude of 4,600 feet. *ShredIt 40,00* can be seen below in Figure 1 during launch.

The competition launch resulted in a recovery failure and payload mission failure. The main parachute was never successfully deployed from the body tube. This caused some damage to the payload retention system causing the payload to orient closer to the coupler than planned. When taking off the UAV was unable to correctly launch after the orientation failure and caused damage to the propellers. Once the damage to the propellers occurred the mission was stopped.

Figure 1: ShredIt 40,00 Test Flight

2 Vehicle Summary and Results

The Charger Rocket Works rocket was constructed using filament wound G12 fiberglass, G10 fiberglass sheets for the fins, 6061 Aluminum for its bulkheads, and 3D printed PLA plastic for the fin can and nose cone avionics mount. The vehicle was six inches in diameter and 124 inches in length. The rocket was launched on an AeroTech L1420R. The vehicle deployed a FruityChutes CFC-18 at apogee and a FruityChutes IFC-144 at 600 feet upon descent. The parachutes were retained with fifty feet of one-inch tubular nylon with sewn loops and 1000 lb.

quick links. The vehicle had previously flown with success during both the Vehicle Flight Demonstration and the Payload Flight Demonstration.

2.1 Flight Results and Analysis

ShredIt 40,00 was launched from Bragg Farms in Toney, Alabama on April 6th, 2019. The vehicle was launched in the second volley from pad 33 at approximately 11:45 a.m. The rocket had a loaded mass of 52.4 lbm. The center of pressure was located at 91.1 inches from the tip of the nose cone while the center of gravity was located at 75.5 inches. This resulted in a stability margin of 2.53, as shown in the OpenRocket model in Figure 2.

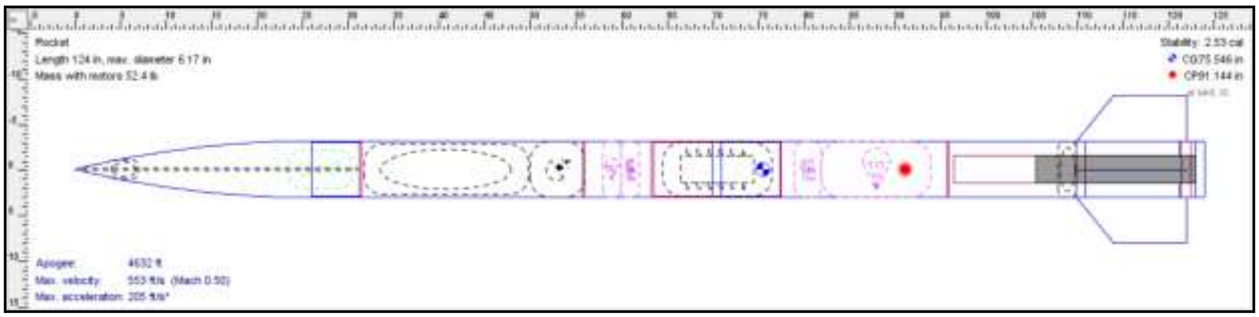

Figure 2: OpenRocket Model of *ShredIt 40,00*

The Rocksim model was adjusted with the launch day conditions. This included the reported temperature, field elevation, humidity, and wind speed. The simulation predicted an altitude of 4703 feet, 97 feet short of the target apogee of 4800 feet. This required no ballast to be flown on the rocket. The primary altimeter, a Stratologger CF, recorded an apogee of 4600 feet while the redundant altimeter recorded an apogee of 4605 feet. The Rocksim model and the primary altimeter are plotted in Figure 3.

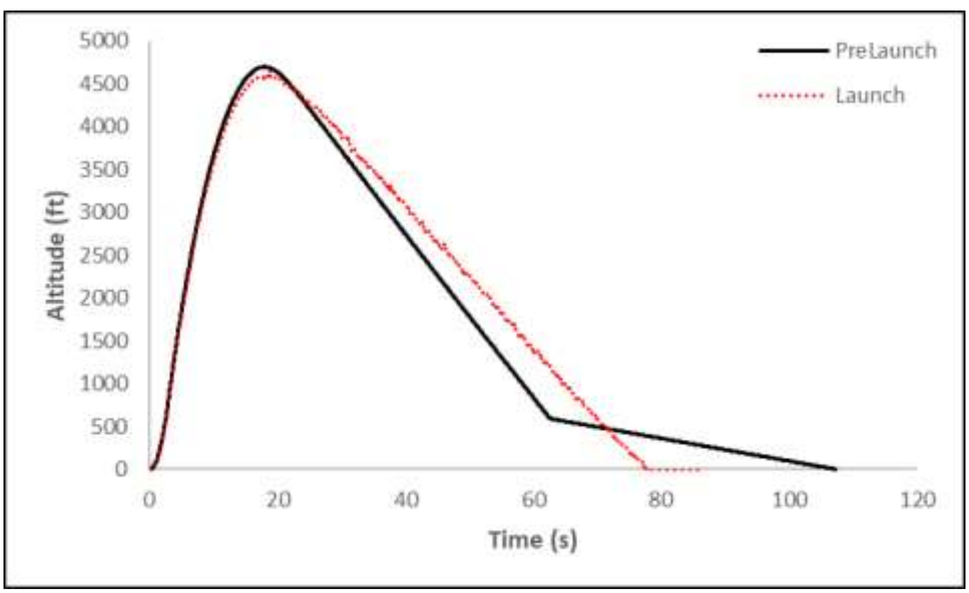

Figure 3: Pre-Launch Simulation and Actual Launch Data

The drogue parachute deployed at apogee and descended the vehicle at a rate of 82.2 feet per second. The main parachute, however, did not deploy after ejection event at 600 feet, and the vehicle fell under drogue speeds. Shown in Figure 4 is the vehicle before and after the main ejection charge had deployed. From images taken on the day of launch, it appears that a combination between inadequate separation pressure and resistance from the drogue parachute during deployment led to the main parachute being unable to fully deploy.

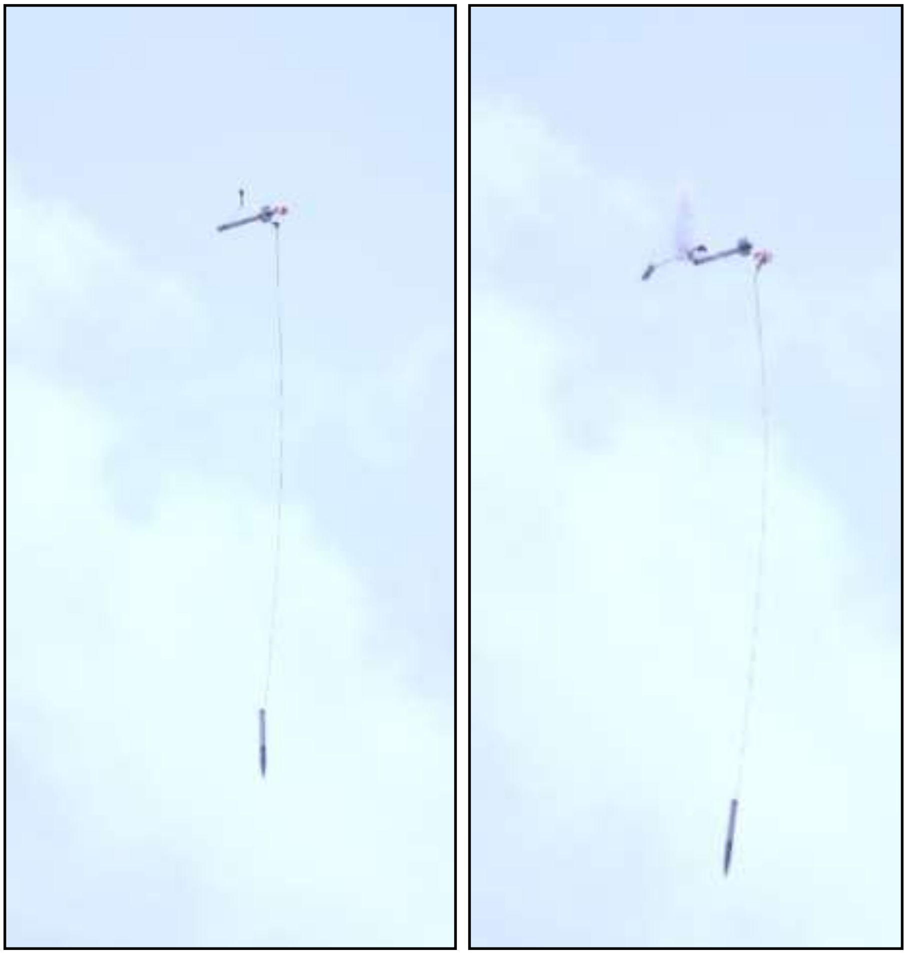

Figure 4: Airframe Before and After Main Deployment

Despite the vehicle landing at high speeds, the airframes were intact upon retrieval. The lower airframe, shown in Figure 5, landed vertically with the forward end embedded in the soil of the launch field. The vehicle was able to meet the total drift requirement as the GPS tracker recorded a total drift distance of 1105 feet from the launch pad. Likewise, the vehicle descended in 58.35 seconds and was able to meet the 90 second descent requirement. Due to the vehicle landing at drogue speeds, the vehicle landed with a kinetic energy of 1842.4 lbf-ft much larger than the kinetic energy requirement of less than 75 ft-lbf. Plots of the launch day data recorded by the Raven3 altimeter in the nose cone is shown in Appendix A.

Figure 5: Lower Airframe After Landing

2.2 Vehicle Lessons Learned

The failure of the recovery system made evident some of the alterations that needed to be made to improve the vehicle's performance. The structure of the vehicle proved to be sufficient for flight and showed that the vehicle could withstand impacts at high speeds without succumbing to irreparable damages.

The main parachute failed to clear the length of the vehicle during descent despite the coupler being successfully separated from the lower body tube. It was speculated that the ejection forces were not large enough to fully deploy the wrapped parachute and that the drogue parachute provided some resistance during the ejection. To improve upon this, there could be more packing material, or "dog barf", inserted into the airframe; this would reduce the packing volume and increase the internal pressure of the tube. Additionally, the length of shock cord spanning from the coupler to the main parachute connection could be reduced to a smaller length. The reduced length could potentially make it easier for the wrapped parachute to clear the body tube. The NAR staff have long recommended that charges be placed such that the parachutes push out against the separation point as opposed to being located on the coupler where the chutes are pulled out by the momentum of the coupler.

The nose cone avionics mount failed to withstand the force during landing. As a result, the 3D printed mount sheared near the bottom where there was a sharp angle. Despite the mount shearing, the electronics were undamaged and were able to record data throughout the entire flight. This is due to the fact that the mount is redundantly retained by the threaded rod running through the nose cone. Future designs will require more thorough loading analysis to withstand harsh landings such as this.

Figure 6: Nose cone avionics mount post-landing

The final lesson learned from the day of launch is to bring enough materials in the event that others are damaged. During assembly, the connector joint of the coupler key switch became weak and sheared. This was most likely due to a weak solder and crimp joint which sheared after extended use. A replacement was able to be made but only after borrowing a similar piece from our mentor's tool kit. In the future, it will be wise to bring replacements of all flight hardware in addition to inspecting all components more thoroughly before flight day.

3 Payload Summary and Results

The Charger Rocket Works payload team built a quadcopter UAV out of PLA, carbon fiber, and sheet metal. The UAV was capable of flight as well as FPV imaging and beacon release. The payload was properly loaded into the vehicle on competition day and retained throughout both the flight and landing. The payload mission was partially compromised due to a failure with the recovery system. The payload suffered damage when the rocket impacted the ground at an inappropriately kinetic energy. In order to deploy the payload, the deployment system had to be reset. After a second attempt, the deployment system deployed the payload but after noticing a few damaged parts on the UAV, the sheath was slightly adjusted for a UAV takeoff attempt. The UAV did not take off properly because of the damage sustained from landing.

3.1 Payload Results and Scientific Value

Major phases of the mission are listed in chronological order below, with particular attention to malfunctions and conclusions that can be drawn from each phase.

3.1.1 Condition upon Landing

The UAV remained in the body tube throughout flight, proving the functionality of the retention system. It was observed after deployment that the aft UAV retention post ripped through the UAV upon landing, as shown in Figure 7, but the UAV was still constrained by the forward retention post and body tube. This failure is believed to have been caused by the exceptionally high landing speed of 82.2 ft/s instead of the target 12.5 ft/s. Despite landing at 47 times the designed kinetic energy, the UAV sustained no other physical damage other than minor damage to the on-board camera.

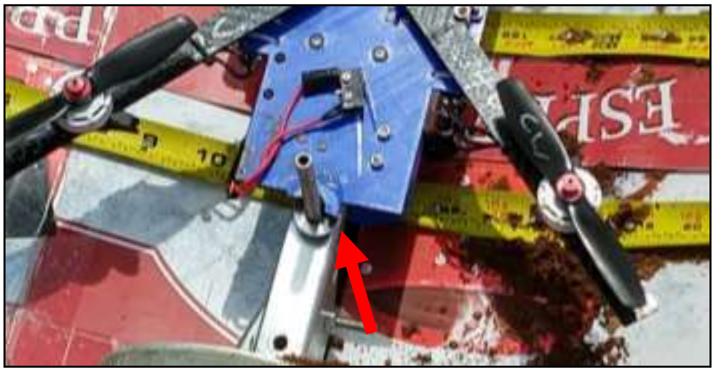

Figure 7: Damage to UAV Aft Retention Ring

A walk-around and assessment of the vehicle state was conducted. The deployment system was verified to be powered on and emitting a 1 Hz tone, indicating it was in the disarmed state. The upper airframe position upon landing is shown in Figure 8.

Figure 8: Upper Airframe Prior to Payload Deployment

3.1.2 Payload Deployment and Orientation

After clearing the area of personnel, payload deployment was conducted. Initial attempts to remotely arm the deployment controller were unsuccessful; after consultation with the RDO representative present, the test conductor approached the upper airframe power cycled the deployment controller. Upon power cycling, the deployment controller responded to arming commands as expected and ejected the payload. The payload position after ejection is shown in Figure 9; note that it stopped in furrow.

Figure 9: Payload Orientation after Ejection

After ejection, the backup charge was fired to remove all energetics from the vehicle, rendering it safe for the team to approach. The team concluded that the UAV would not be able to lift off from the as-deployed position. The arms were not fully extended or locked in place and the UAV was at a significant angle, likely preventing it from lifting off of the posts on the orientation sheath. The team elected to reorient the UAV and deployment sheath before takeoff, rather than risk damage to the UAV by attempting to take off at an angle. Figure 10 shows the UAV before takeoff; note that the UAV airframe has fractured around the aft retention post.

Figure 10: UAV Prior to Lift Off

3.1.3 Attempted Flight

The UAV connected successfully to the telemetry and control ground station, but the video stream could not be acquired. The team elected to attempt the mission without a live video stream. Upon takeoff, the UAV pitched forwards and impacted the ground, breaking both front rotors. Figure 11 shows the state of the UAV after the takeoff attempt.

Figure 11: UAV After Takeoff Attempt

The deployment system initially failed to respond to arm and deployment commands and required power cycling to regain control. This has been identified to be due to a command buffer parsing error on the deployment controller; the process for moving past an invalid command truncated the following command, rendering that command invalid in turn. This defect could have been detected with more robust testing of the command parsing function; it was verified that the controller would not activate in response to invalid commands, but it was never verified that it could respond to valid commands after having received invalid commands. This failure highlights the importance of robust, well-tested software with built-in options for handling unexpected failures. Similar issues are encountered on real-life spacecraft, but those systems include layers of backups and redundancies that allow the problem to be detected and handled.

In addition to failing to transmit, the video system also did not record video after landing. Later testing did record video as expected, leading the team to believe that the hard landing may have pushed a connector out of place or otherwise interfered with the power supply to the camera.

3.2 Post-Launch Flight Test

In order to fully assess the damage to the UAV, the UAV was taken to an RC flight range on April 10, 2019 to an open field, the t A few days after the competition. Describe the conditions and how you set this test up. Describe all results of this test. i.e. crash landings and solenoid burnouts. Your conclusions from this may be that the test showed that the payload

3.3 Payload Lessons Learned

The launch day results of the UAV and deployment system carried several important lessons for design and implementation of future missions. Future deployment systems should consider to a more in-depth extent the terrain on which the UAV will be deploying. The mechanical operation of the deployment system proved to have few points of failure; however, a more robust and versatile system should be designed to better handle rocket launch and landing forces as well as more rugged deployment terrain. Payload integration with the rocket should be considered better in the future. The payload team experienced many difficulties with loading the payload into the rocket body tube. Eventually, the load time was brought down for roughly two hours to approximately twenty minutes, but this should be design better in the future. A more aggressive schedule might produce test results and data more quickly, which could then be used to improve the payload at a good amount of time before competition day. While the payloads failure on launch day was not related to this, it would prove beneficial to stay on a tighter schedule for testing and troubleshooting.

The team developed a unique orientation system, utilizing only simple mechanical systems with few points of failure. However, systems of this type are only effective on relatively flat even surfaces, unlike those encountered at the launch field. The flight proves that this system should not be utilized in most situations, aside from applications where the landing area is well-surveyed and even.

3.4 Post-launch Payload Flight

The UAV remained intact overall after the rocket landed at a much higher velocity than originally anticipated. The only sustained damage was some broken PLA around the retention post of the deployment sheath and debris in one of the motors. It also proved to be flyable still. A few days after the competition, the payload team took the UAV to an open field, set up an FEA at the appropriate distance away according to the distance of the FEA from the landing area at the competition and carried out the UAV mission successfully. The UAV was flown to the FEA zone and the beacon was dropped. This serves to prove that in the event of a successful rocket landing and better deployment circumstances, the UAV would have been capable of completing its mission on competition day as expected. The lesson that can be learned here is to prepare for all failure modes, both payload and vehicle related. The robust structure of the UAV proved very beneficial. Wiring harnesses were well constructed. These are lessons learned with initial positive outcomes. However, the conceptual design of the deployment sheath was smart, but its actual manufacturing was sub-par. Future deployment and orientation systems should not be based solely on theory but should be designed and built to better handle real life scenarios.

4 STEM Engagement Summary

The team impacted a total of 1,031 individuals at the conclusion of the competition. CRW team members exceeded the minimum requirement set be NASA by 831 people (135%). Overall, the team not only met the requirement set by NASA but also the requirement that was set by themselves at the beginning of the competition. The team’s personal goal was to promote STEM to diverse groups which was achieved through multiple events held throughout the course of the competition. The event that the team felt really achieved this goal was Girl’s Science and Engineering Day. During this event, team members interacted with elementary and middle school girls and introduced them to two STEM topics – friction and rocketry. The girls were able to learn about these topics and why they mattered. They were also provided with hands-on activities to help the understanding of the topics – girls in the friction class created ‘CD hovercrafts’ and saw firsthand what a lack of friction would do to an object. The girls in the rocketry class were able to assemble, decorate, and launch rockets. A full list of the events held by the team can be found in Table 1.

Table 1: STEM Outreach Event Summary

Event:	Date:	Status:	Purpose:	Anticipated Number of Individuals:
St. Francis Borgia Regional High School	Oct. 12	Completed	Present Rocketry Basics	37
Girls Science and Engineering Day	Nov. 3	Completed	Present about Friction and Rocketry Basics	166
First Lego League	Nov. 10	Completed	Interaction with parents and students	72
Interactive Rocketry at Lexington High School	Nov. 28	Completed	Present Rocketry Basics	174
Interactive Rocketry at Elkhorn Crossing School	Dec. 11	Completed	Present Rocketry Basics	147
Eagle River High School	Dec. 12	Completed	Interaction with Students	26
Canyon Crest Academy	Dec. 20	Completed	Engineering Design Activity	29
Science Olympiad	Feb. 14	Completed	Interaction with students	56
UAH's Take Your Daughters to Work	Feb. 18	Completed	Rocketry Basics Activity	90
Hewitt Trussville High School	Feb. 22	Completed	Present rocketry basics & Open Rocket	212
Ramsay High School	Mar. 11	Completed	Present rocketry basics	75
			Total Impacted	1,031

5 Budget Overview

As this year's USLI competition comes to an end, only a few items needed to be added to the FRR budget tables. With the competition launch on April 8th, an additional L1420 Aerotech solid rocket motor was added to the UAH CRW budget. Other items added to this budget are the two posters displayed at the Rocket Fair at the VBC East Hall. This resulted in adding $100 to the outreach total for the total budget. The updated budget is shown in Table 2 and Figure 12.

The proposal submitted on September 19, 2018 estimated our projected expenditures to be $6,167.88. The actual expenditures value was $7,036.89. The team spent over our projected proposal monetary value in the amount of $869.01. The PRC provided reclaimed parts decreasing our expenditures a total of $1,470.24.

Table 2: Final Budget Summary

Budget Item	Totals
Sub-Scale Rocket	$388.45
Full-Scale Rocket	$3,670.49
UAV Payload	$2,220.70
STEM Outreach	$199.00
Tooling & Raw Mat.	$558.25
15% Margin	$0.00
Grand Total	**$7,036.89**

Considering the amount of hardware, rocket launches and student development that took place these past nine months, that value represents an excellent STEM investment in the lives of many students at UAH and those reached by outreach programs. The USLI program aided in the process of transitioning engineering students into professional engineers. The extensive experience gained from this project from technical, programmatic, and time management skills is invaluable.

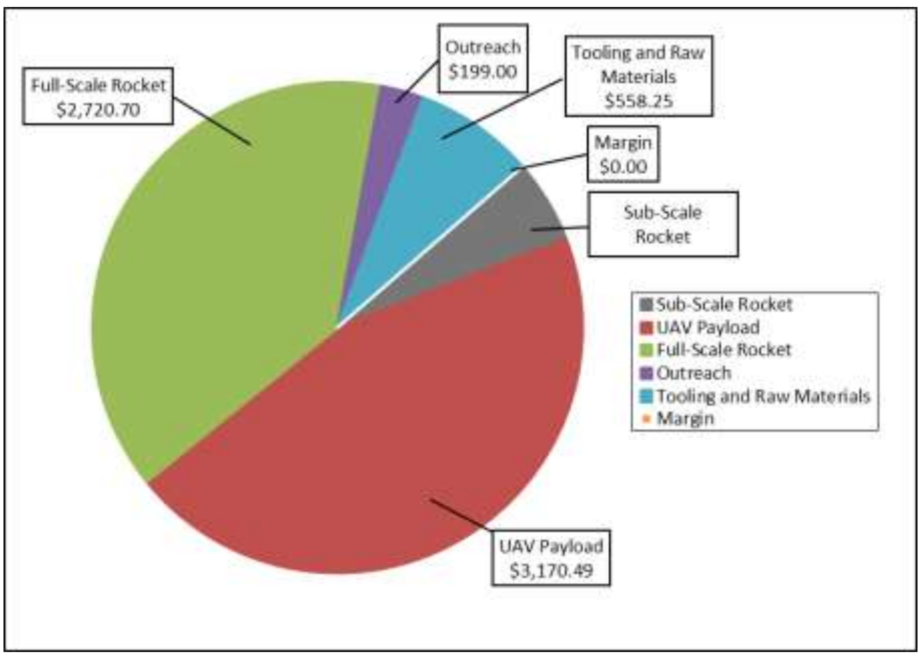

Figure 12: Total Expenditures

6 Conclusion

The road from initial vehicle concept to the competition launch was filled with many challenges and opportunities for the team, and CRW is proud of the extensive work put into designing, testing, building, and flying *ShredIt 40,00* this year. Although the final outcome of the launch was disappointing for the CRW team, there were some positives. The apogee was within the predicted apogee uncertainty band. The team was able to meet most of the competition requirements. Team prepped the rocket within the time span. The team overcame a problem on launch day (connector breaking). Post Launch test flight of the uav confirmed that it still was in working order and could be flown again with minor repairs. The payload used in *ShredIt 40,00* was tested through multiple test flights and successfully flew the mission only once before the competition. CRW is also proud to note that it was designed entirely in-house. CRW also took a massive step forward in outreach, being involved on multiple social media platforms and reaching over 1,000 individuals over the course of the year, with many more reached through conversations, website articles, and more. As this year's competition draws to a close, UAH's CRW team is proud to have been involved in Student Launch, and of all the hard work and effort poured into the project since the start of the competition in the fall 2019 semester. Every team member has gained incredibly valuable experience not just with rocketry but in a wide variety of fields – from programming to safety, software simulations, systems engineering, working in a team environment and more, every milestone achieved represented an incredible learning opportunity for everyone involved. Every team member is incredibly proud to have been part of such an amazing opportunity, and looks forward to having the opportunity to mentor upcoming CRW teams in future years.