Project Elijah

Post-Launch Assessment Review

Cedarville Student Launch 2024-2025

Cedarville University
251 N. Main St.
Cedarville, OH 45314

April 30th, 2025

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1.1. Team Summary

Team Information	Cedarville Student Launch (CSL) custudentlaunch@cedarville.edu 251 N Main St, Cedarville, Oh 45314
Mentor Information	Dave Combs Email: davecombs@earthlink.net Phone Number: (937) 248 – 9726

1.2. Launch Vehicle Summary

Chariot Dimensions	
Target Apogee	**4100 ft**
Actual Apogee	**3719 ft**
Competition Launch Motor	**Aerotech K1000T-P**
Total Length	**108 in**
Dry Mass with / without Ballast	**23.2 lb / 22.4 lb**
Wet / Burnout / Landing Masses	**28.9 lb / 26.3 lb / 26.3 lb**
Recovery System	**15” Elliptical Drogue / 8ft Toroidal Main**
Rail Size	**1515/ 12ft Long**

Figure 1.2. *Chariot on the launch rail ready for competition launch.*

1.3. Payload Summary

The mission of the primary payload is to safely hold four STEMnauts and to transmit flight and landing information to a receiver over radio after landing. To do so successfully, the payload must first collect flight data for the entire launch duration. Then that data must be processed, formatted, and encoded for transmission via radio on the 2-meter band. The payload must also remain structurally intact to protect the four onboard STEMnauts.

The payload did stay fully intact such that the STEMnauts remained unharmed during the flight. The payload successfully collected data during the launch and captured each phase of the flight. After landing, the payload transmitted for five minutes the data shown below in Table 1.3.1, as confirmed both by the audio heard live at the launch site and the payload logs recovered after. However, no packets sent by the transmitter were decoded by the launch site receiver, meaning that portion of the mission was a failure.

Table 1.3.1 Payload Transmission Summary

Information	Transmitted	Expected	Decoded
Current Temperature	34.0 ºC	✓	–
Apogee Reached	1146.0 m	1133.5 m	–
STEMnaut Orientation	Port-Facing	Port-Facing	–
Time of Landing	0:00	20:52	–
Battery Level	89.3%	✓	–

2. Launch Data and Discussion

2.1. Data Analysis and Results

2.1.1. Vehicle Results

Chariot experienced a wobbly ascent, even during the motor burn. The rocket had been launched during a lull in the wind, so CSL attributes this behavior to the heavily repaired airframe section surrounding the airbrakes flaps. The two flights prior to the competition flight both experienced main parachute failures that damaged the thin ribs cut into the airframe around the flaps, and the epoxy repairs to this section are likely responsible for the change in performance since the previous flight showed an excellent thrust phase and no other components were altered other than the airframe repair.

Shown in Table 2.1 is a summary of the competition flight conditions and key flight performance aspects, and Table 2.2 contains a summary of the rocket's recovery performance. All recovery devices performed as intended. All primary and secondary recovery charges fired, and the rocket landed safely within the KE requirements provided by NASA. The apogee was 381 ft lower than desired due to a calibration issue with the airbrakes where they had the wrong ground pressure during the flight and therefore calculated an altitude that was ~300 ft higher than the altitude recorded by the primary RRC3 altimeter. The apogee recorded by the airbrakes was 4024 ft which is much closer to the desired apogee.

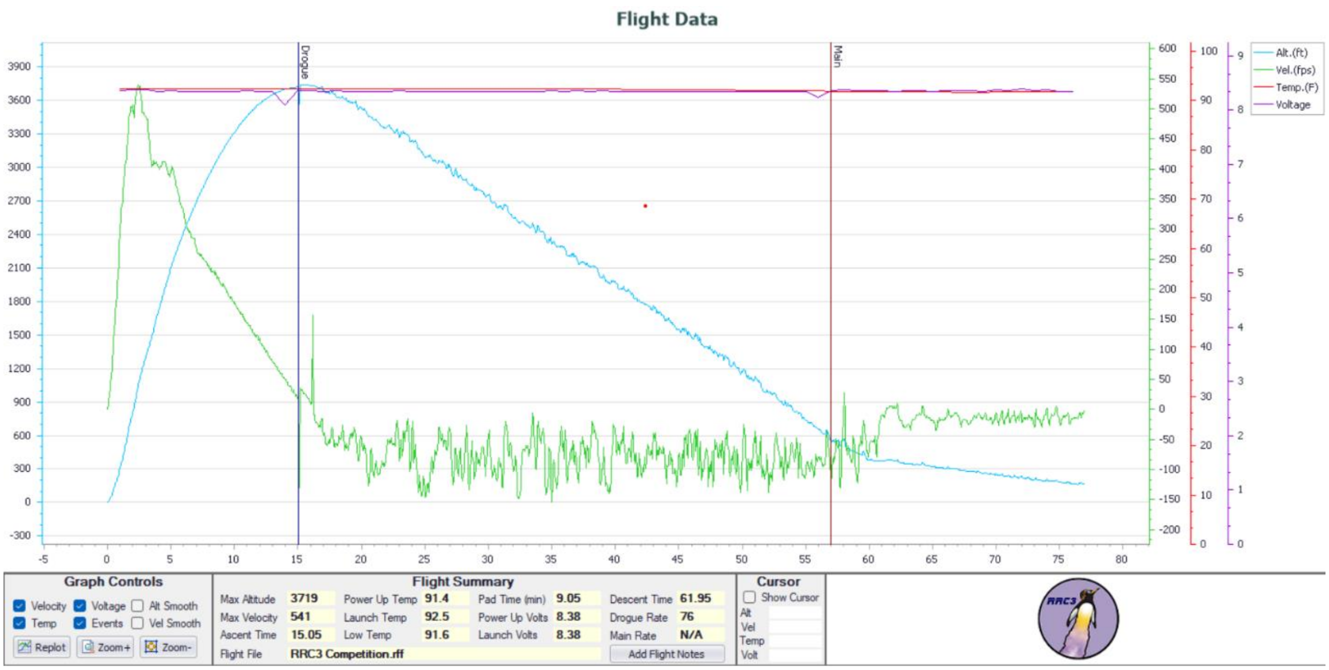
Figures 2.1-2 show Chariot's flight profile from the competition launch. The RRC3 altimeter stopped recording altitude values during the last ten seconds of descent and was not responding with flight metric tones upon recovery, though it successfully fired its charges as mentioned earlier. Figure 2.3 shows the condition in which the rocket's pieces were found, with Figure 2.4 certifying that the Eggfinder GPS onboard Chariot was indeed functional. Due to unexpectedly stiff winds at high altitudes, Chariot unfortunately drifted outside the 2500 ft minimum drift distance.

Table 2.1. Summary of competition flight conditions and performance.

Date of flight	April 28, 2025. 5:21 PM EST
Location of flight	WSR club launch site: 5995 Federal Rd, Cedarville, OH 45314
Launch conditions	Temperature: 77° F Wind: 12 mph (gusts at 17 mph) Visibility: >25 miles Cloud cover: Clear Relative humidity: 35%
Motor	Aerotech K1000T-P
Ballast flown	0.765 lb (347 g)
Payload status	Active
Air brake status	Active
Official target apogee	4100 ft
Predicted apogee	4100 ft
Measured apogee	3719 ft
Descent time	75 s
Drift distance	1317 ft
Drogue deployment	Apogee & apogee +1 s
Main deployment	600 ft & 550 ft

Table 2.2. *Competition* recovery *summary*

Section	Wet Mass (lbs)	Landing Mass (lb)	Predicted Drogue Descent Rate (ft/s)	Predicted Main Descent Rate (ft/s)	Predicted Landing Kinetic Energy (ft*lbf)	Actual Drogue Descent Rate (ft/s)	Actual Drogue Kinetic Energy (ft*lb)	Actual Main Descent Rate (ft/s)	Actual Landing Kinetic Energy (ft*lbf)
Forward	6.65	6.65	175	14.3	21.1	78.5	637.3	14.9	23.0
Avionics	3.98	3.98	175	14.3	12.6	78.5	381.0	14.9	13.7
Aft	14.76	12.43	175	14.3	39.5	78.5	1190.8	14.9	42.9



Fi**gure 2.1.** Altimeter flight profile from the RRC3 primary scoring altimeter.

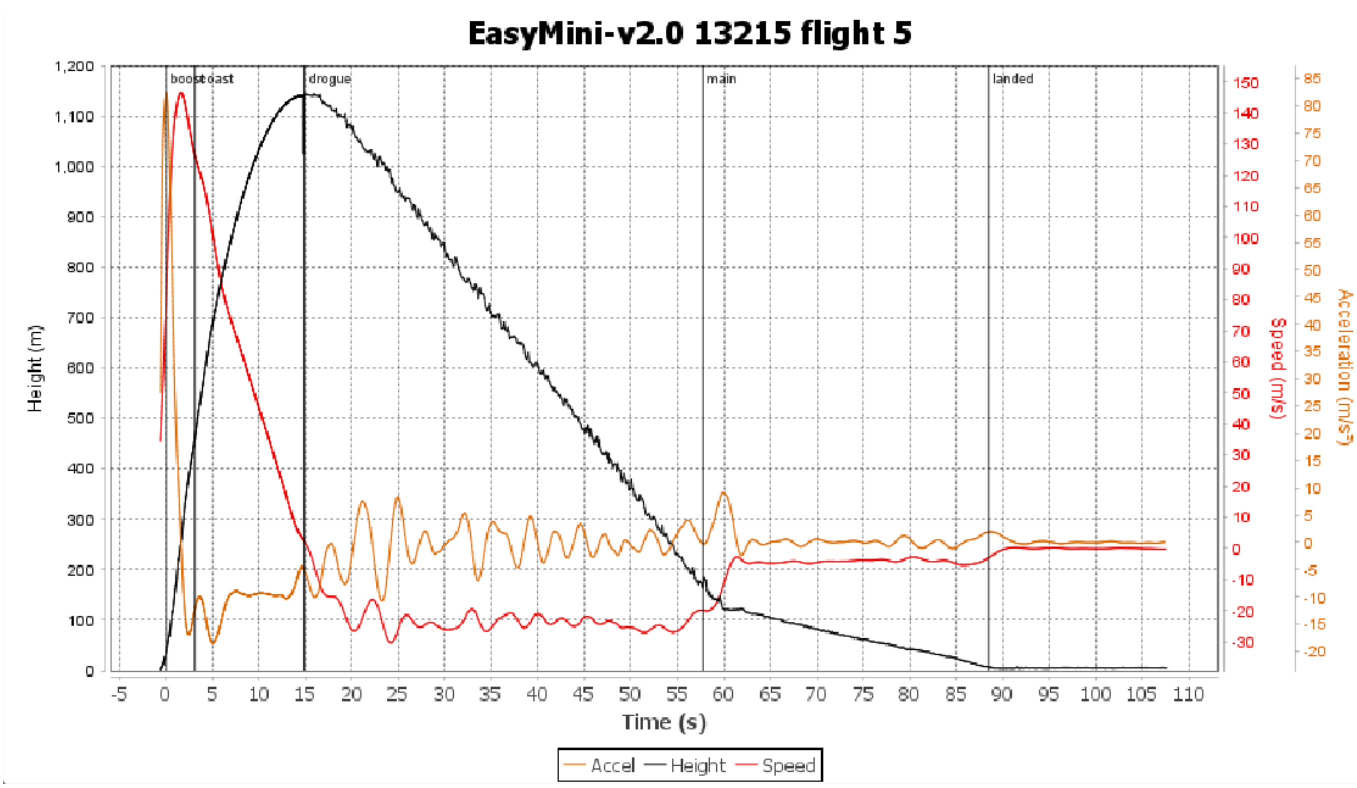


***Figure* 2.2.** Altimeter flight profile from the Altum Metrum Easy Mini

Figure 2.3. Landed condition of the independent sections of the rocket. All parts remained tethered during recovery.

Figure 2.4. **(Left)** Landing location in relation to the launch location shown in Google Earth; **(Right)** GPS coordinates of the launch and landing locations.

2.1.2. Payload Results

The rocket's primary payload, shown below in Figure 2.1.1, experienced no issues leading up to the competition launch. During the flight, both the primary and secondary circuit boards correctly detected liftoff and stepped through the launch phases, collecting data as they did so. The windy conditions carried the launch vehicle to a distance of 0.51 miles away from the launch site and radio receiver, which is outside the verified range of the payload's transmitter. The orientation of the landed payload was such that the monopole antenna pointed towards the receiver, offset only by 33 degrees, which is one of the worst cases for receiving transmissions.

Figure 2.1.1 *Front and back view of payload on competition launch day.*

At the receiver, the team observed that the radio audibly heard the transmissions sent by the payload, just as expected. However, the distance between the transmitter and receiver was great enough that the APRS packets were distorted to the point that they could not be decoded. The payload team confirmed that the packets continued to be sent for only five minutes after landing, but that zero of these packets could be successfully decoded.

The logs recovered from the payload indicate the packets which the payload attempted to transmit, and an excerpt of these logged packets is shown below in Figure 2.1.2. The current temperature and battery level both sent values which appear to be reasonable. The payload reported an apogee of 1146 meters, which is 12.5 meters higher than the value recorded by the RRC3 altimeter. The STEMnaut orientation is confirmed by the images of the landed payload, shown below in Figure 2.1.3. The only significant error with the data that was sent is the time of landing, which was likely caused by the payload restarting after landing. This error was observed during the previous full-scale launch, but was never reproduced in testing, nor was it ever observed during simulation. Steps were taken to ensure that some data could be restored after a restart. Earlier logs indicate that the payload tried to restore the landing time, and it incorrectly assumed that the restoration attempt had been successful; this led to the incorrect landing time being transmitted.

```
[After seq 8484][12:39:41][INF]: Transmit!
[After seq 8484][12:39:41][INF]:   Test transmission on 0/1/63716.
[After seq 8498][12:39:41][INF]:   Current Temperature: 34.0 degC
[After seq 8512][12:39:41][INF]:   Apogee Reached: 1146.0 meters
[After seq 8526][12:39:41][INF]:   STEMnaut Orientation: Port-Facing (7.866, -0.212, 6.429)
[After seq 8543][12:39:41][INF]:   Time of Landing: 0:0
[After seq 8556][12:39:41][INF]:   Battery Level: 89.3% (8.01 volts)
[After seq 8571][12:39:41][INF]: Transmission complete!
```

Figure 2.1.2 *Transmission logs*

Figure 2.1.3 *Landed payload, where STEMnauts inside face left*

2.2. Post-Launch Technical Reflection

2.2.1. Nosecone

CSL settled on using a PETG 3D printed design for the rocket's nosecone. This choice was made as part of a design study to determine if a 3D printed design could be reliable, modular, and have a reduced cost compared to contemporary fiberglass molded cones. Over the course of the year, the design study showed that a 3D printed cone can be designed for multiple uses in a similar fashion to conventional cones while also reducing the cost.

There were some setbacks that were encountered with using a 3D printed design. Multiple cones were broken during subscale flights and through drop tests showing inherent flaws in 3D prints due to them breaking along layer lines. Once a print was broken, it was unusable and unable to perform up to mission standards. Multiple replacement cones had to be printed throughout the semester due to broken prints. However, some goods came out of the 3D printed design, it allowed for quick iterative changes to be made. Whenever a fault was found in the existing cone design, the design was reevaluated, and a new iteration was made to improve the design's performance. By the end of the year, the design had been improved to the point that the finalized nosecone design has withstood four rocket launches and landings in a completely reusable and undamaged state.

The PETG 3D printed nosecone design proved to be a successful endeavor. The finalized design proved to be reliable over the course of four full scale launches and was successfully able to be integrated into the rest of the rocket in such a way that the payload was housed and protected.

The overall costs of manufacturing and designing the nosecones used throughout the semester still ended up being cheaper than purchasing a contemporary fiberglass cone. The only thing that was sacrificed during this design study was the time spent on printing and iterating the design.

2.2.2. Airframe, Couplers, & Bulkheads

CSL conducted a trade study to determine the best material for the rocket's airframe. In light of this trade study, combined with the fact that G12 fiberglass tubing is ubiquitous in high-powered model rocketry, CSL chose to use a fiberglass airframe for the student launch. Over time, using fiberglass proved to be the right choice as CSL saved money and time, as fiberglass is affordable and withstands heavy use without showing signs of damage. The launch vehicle's airframe is divided into three main sections: the aft section, the avionics section, and the forward section. The aft section houses the thrust structure, the motor retention system, and the airbrake system. Since CSL was greatly concerned about the structural integrity of the airbrake slots in the aft section, a coupler was added for reinforcement. This proved to be the right choice as CSL learned that if a recovery failure occurred, the airbrake slots would buckle.

As CSL recovered the launch vehicle, there was no damage to the airframe, as the launch vehicle had a successful recovery sequence. The airframe worked as intended, as the fiberglass withstood a gust of wind as CSL ignited the rocket. The coupler in the airbrake slots proved to be the right design choice, as a recovery failure would have likely caused these slots in the airframe to buckle. An image of the aft section of the airframe during recovery is shown in Figure 2.2.1.

Figure 2.2.1. *Image of the airbrake airframe slots after recovery of launch vehicle.*

2.2.3. Avionics

The avionics subsystem performed nominally on all full-scale flights with the exception of the competition flight and the first flight. On the first flight, the EasyMini altimeter stopped recording data at apogee and during the competition flight the RRC3 stopped recording data ~150 AGL. All four black powder charges were successfully ignited at the proper time during every full-scale flight. The avionics provided valuable data to CSL which was used for post flight analysis especially when data was not collected by either the main or secondary payloads. Among other things, this data was used to estimate the drag coefficient of the rocket for each flight as well as to tune the controller for the airbrakes.

The experience gained by CSL from manufacturing and flying the subscale avionics proved to be extremely valuable for the full-scale. The lessons learned were applied to the design, manufacturing, and launch day assembly of the full-scale vehicle. This experience is what allowed CSL to experience zero recovery failures related to the avionics system.

2.2.4. Camera Shroud

Early in the competition, CSL aimed to mount a camera on the rocket to record in-flight footage for data analysis, airbrake deployment verification, and outreach through social media. The initial plan placed the camera in the nosecone, but this idea was abandoned due to the added complexity it introduced to the nosecone’s design and structure. Instead, CSL decided to mount the camera directly onto the airframe with a clear view of the airbrakes.

At first, the camera was to be mounted onto the airframe using a 3D printed mounting shroud that would be held to the airframe via an epoxy adhesive. However, during the first full scale launch, both the camera shroud and the camera itself detached during landing. This failure, combined with the unreliability of the Estes Astrocam in cold conditions, pushed the team to search for a new solution. CSL turned to a more robust setup by mounting a RunCam and its included mounting point directly to the airframe via a 10-32 screw. This added reliability and modularity to the design and allowed CSL to successfully capture flight footage during four of our full-scale rocket launches including the competition launch.

2.2.5. Recovery & Shock Cord Mount

There were many different requirements and design restraints that needed to be fulfilled in choosing the two parachutes. To find a pair that worked the best codes and simulations were used and many different iterations completed to validate the final decision. These codes and simulations were able to be confirmed through subscale launches and some of the first full-scale launches completed by comparing in-flight data with the predictions found. This gave CSL promising results as the two agreed fairly well with one another. It did show need for a safety factor for the kinetic energy at landing, however, since the actual velocity at landing tended to be higher than the simulated one and the actual weight of the rocket and the different sections could be different that what was originally placed into the code. This showed up mostly with the first few full-scale launches which had a main parachute that was only slightly below a kinetic energy of 75 [ft-lbf] at landing but exceeding it in flight which caused damage to the rocket body and electronic systems at times. This increase was also caused by the use of a Parabolic parachute instead of an Elliptical or Toroidal which has a much better coefficient of drag and therefore works better to slow down the rocket.

During CSL's competition launch both parachutes were able to deploy successfully and almost fulfilled all of NASA requirements by slowing the rocket down to a landing velocity of 13.9 [ft/s] meaning the max kinetic energy was 36.57 [ft-lbf] and the descent rate was 75 [sec]. However, due to large wind gust the launch vehicle drifted over 2500 [ft] away from the launch pad, landing 2692 [ft] away instead.

Analyzing, testing, and verifying the shock chord mount provided instrumental value in terms of engineering lessons learned. The analysis was complex and required multiple facets of engineering such as statics and dynamics to determine the failure mechanisms. It also required experimental testing with an Instron tension test machine to help verify some assumptions and provide crucial data to continue the analysis. Thankfully, since the shock chord mount was designed to have a high safety factor, it never failed during any of the flights.

2.2.6. Centering Rings, Thrust Structure, & Fins

CSL's launch vehicle uses custom-designed centering rings to secure the motor tube and fins within the rocket's airframe. They ensure proper alignment inside the aft section, which is essential for stable flight. The ring is cut out in the center to fit around the motor tube and keep it secure. Slots were constructed on the face for the fins to be inserted and screwed in tightly. CSL secures the motor tube primarily by using a 3D-printed flange designed to keep the motor centered within the vehicle's aft section. CSL had trouble with tolerances when it came to the construction of the subsystem. A lesson learned from this year would be to focus more on the tolerances of pieces so that they fit as a whole within the rocket's airframe.

Upon recovery of the launch vehicle, the centering rings and thrust structure were inspected, and it received no damage. The centering rings and the motor retention flanges worked as intended, as the thrust of the motor was transferred to the centering rings. This reflected the results of the FEA analysis that was completed for the CDR. As intended, this subsystem would be ready to launch again the same day without repairs.

Regarding the fins, they provided significant insight with analysis which involved engineering topics like statics and fluid mechanics. Analysis was done to determine if there was enough fin area for the fins to withstand the force of the wind and it was determined to be multiple orders of magnitude safe. After the final design for the fins were finished, they suffered virtually no damage throughout the test flights.

2.2.7. Tailcone Motor Retention

The 2024-2025 CSL launch vehicle is unique in that it is the first CSL system to employ custom motor retention. Demonstration flights submitted to NASA proved that a PETG 3D-printed tail cone (boattail) can serve as an effective, heat and impact resistant motor retainer, while also being easily iterable. This design opens the door for CSL to pursue customizable, economical, and aerodynamically beneficial motor retention options. Basic CFD analysis showed that modifying the boattail's geometry and increasing the vehicle diameter from four inches to five,

five-and-a-half, or six inches could slightly reduce drag, though other system improvements might yield greater performance gains.

The iterative nature of this year's retention system was particularly valuable, as it had to be redesigned several times to accommodate changes to the thrust structure during development. Through all testing and demonstrations, the tailcone never experienced destructive failure or detached from the launch vehicle. This system does not impact the payload, as the systems are located on opposite sides of the launch vehicle.

3. Final Discussion

3.1. Overall Project Experience

In the 2024–2025 season, CSL set out to make significant advancements in design, testing, and information retention. To achieve this, the team focused on several core objectives: (1) refining the launch vehicle design and system integration, (2) constructing a subscale vehicle to train members in rocket building, (3) establishing a comprehensive testing and requirement verification system, (4) developing a functional airbrakes secondary payload, and (5) delivering a successful mission payload.

To enhance the launch vehicle design, CSL adopted a modular architecture. Each subsystem was connected using non-permanent attachment methods, allowing for independent development, easy modifications, and streamlined integration. This approach ensured that changes to one subsystem did not impact the entire vehicle and enabled staggered progress across components. CSL also implemented a Mass Growth Allowance strategy, assigning specific mass budgets to each subsystem. Managed by the Chief Engineer, this system maintained rocket stability and flight viability throughout development. These measures provided CSL with strong control over the design process and informed decision-making at every stage. Due to their success, both the modular design and the mass growth allowance plan are expected to be standard practice in future CSL teams. Looking ahead, CSL may also designate broader subsystem leads to facilitate more granular tracking and management.

In designing the subscale proof-of-concept, CSL intentionally built the rocket near the ¾ scale limit to closely simulate full-scale construction. This decision gave team members hands-on experience with high-power rocketry techniques such as bulkhead fabrication, airframe construction, epoxy bonding, and recovery system design using black powder. This approach proved invaluable: every team member gained practical experience, and lessons learned from the subscale build (especially from manufacturing errors) helped avoid mistakes in the full-scale project. Though it took three attempts to verify the subscale *Chariot*, each failure contributed to a smoother full-scale development process.

To meet all project requirements, CSL introduced a new requirement verification system. This system tracked each requirement, compliance methods, and verification plans using standardized templates. The result was precise monitoring of requirement fulfillment throughout the project lifecycle. The verification system also supported testing documentation, providing clarity and consistency across test procedures. By formalizing this process, CSL improved its ability to communicate vehicle capabilities to NASA personnel and gained a deeper understanding of system performance. Future teams are expected to further refine this system.

CSL strove to improve apogee prediction and control through the development of a secondary airbrakes payload. Drawing on data from multiple test flights, the team created a control system that monitored altitude and velocity, adjusting four deployable flaps to generate drag and reduce apogee. While the system did not meet its target precision, it successfully sensed vehicle conditions, deployed correctly, and demonstrated the ability to reduce altitude. This represents a significant step forward and lays a solid foundation for future improvements to CSL's apogee control systems.

The mission payload addressed CSL's primary objective for the season. It utilized sensors and onboard electronics to collect and transmit data to a ground-based antenna. Rigorous testing confirmed the payload's durability during recovery and its transmission capability over expected drift distances. During full-scale test flights, the payload performed reliably; however, issues arose during the final competition flight. The rocket landed 2,694 feet away behind dense foliage, causing interference that prevented successful data decoding despite partial signal reception. This worst-case landing scenario was difficult to predict or mitigate beyond the measures CSL had already implemented. Although the payload's competition performance was hindered by environmental factors, it functioned as designed, and CSL remains confident in its capabilities under more favorable conditions.

3.2. STEM Engagement Summary

The CSL visited eight schools in four different cities. These schools represented a large variety of students from all ages, abilities, ethnicities, and socioeconomic backgrounds. The CSL STEM Engagement Officer chose the Ohio School of the Deaf (OSD) to serve students with special needs; Horizon STEM academy because it was a Title 1 school, which means that they serve severely underprivileged students; and Dayton Early College Academy (DECA) because it focused on majority minority students of inner-city Dayton. Among these, the CSL visited many other schools which are outlined in Table 3.2.1.

Table 3.2.1. *STEM Engagement School Involvement Outline.*

Date	Location	City	Actual Attendance	Grade	Activity
5-Oct	DECA	Dayton	25	5-8	Bottle Rockets
9-Nov	Horizon	Columbus	30	9-12	Bottle Rockets
16-Nov	Horizon	Columbus	30	9-12	Bottle Rockets
19-Nov	Cedar cliff	Cedarville	30	Kindergarten	Paper Airplanes
23-Jan	OSD	Columbus	10	6-8	Bottle Rockets
27-Jan	Cedar cliff	Cedarville	33	3	Straw Rockets
30-Jan	Xenia Elementary	Xenia	60	3	Straw Rockets
22-Feb	DECA	Dayton	10	5-8	Bottle Rockets
13-Mar	Horizon Elementary	Columbus	130	3	Straw Rockets

The bottle rockets activity had the most fleshed out curriculum and plan, thus it was used quite often. It included an hour of lectures on rocketry concepts in four different 15-minute stations. This then transitioned to bottle rocket design, analysis, building, and flight. It modeled the entire NASA rocketry process in the span of five packed hours. The straw rockets activity was fun and easily scalable. It hosted anywhere from 15 students to 70 students at a time. It consisted of cutting out the straw rocket, assembling it, and flying them in a competition to determine who could use the scientific method to guess the most precise distance on the ground. Lastly, the paper plane activity was used for the youngest students. They folded paper airplanes and tested to see how far they could throw them.

A pre and post assessment was given to the students for the bottle rocket activity and their scores improved from the pre to the post test. This can be seen in Figure 3.2.1. In addition to this analysis, a student handbook was written from STEM Engagement for future teams to use.

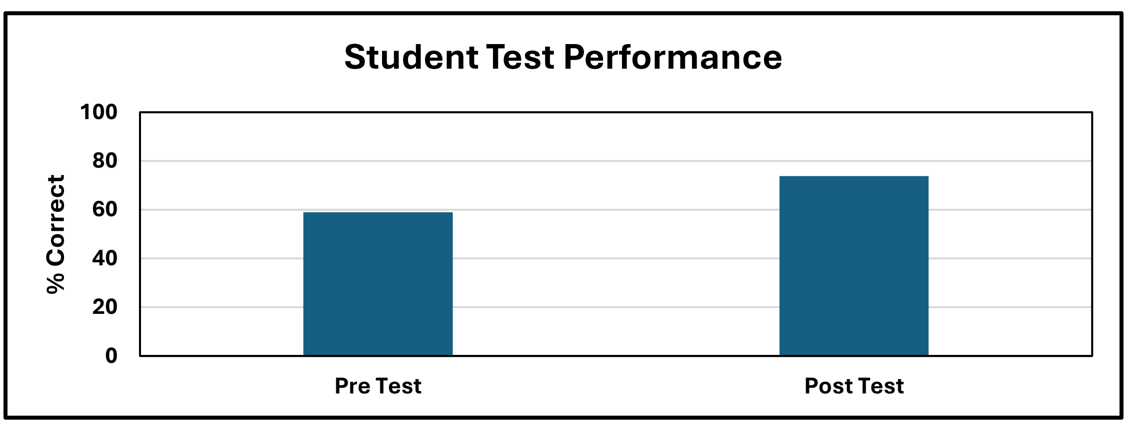


Figure 3.2.1. *Student Pre and Post Assessment Performance.*

3.3. Hours Report

Throughout the nine months CSL has worked on the NSL competition to complete deadlines and showcase all that we have learned in our education at Cedarville University. CSL has completed over 5,900 hours altogether, with approximately 5,400 hours being spent on the NASA SLI mission. An outline of these work hours can be seen in Table 3.3.1.

Table 3.3.1. *Total amount of hours spent completing NSL mission requirements for the 2024-25 competition.*

Category	Hours
Proposal	271
PDR	532
CDR	623
FRR	601.5
FRR Addendum	85
PLAR	107.5
STEM Engagement	~750
Social Media	64
Launch Activities	~2,400
Total Hours	**~5,400**

3.4. Final Budget Summary

At the beginning of the year, the CSL team proposed a budget of $6500 for the whole year. After keeping track of every single purchase, the CSL team spent $6373.33, which is $126.66 under budget. The whole budget sheet can be seen in Table 3.4.1. The allocated total was assigned at the beginning because the team did not know the cost of everything when the need arose.

Table 3.4.1. *CSL final team budget.*

Overall Budget for NASA Project									
System	**Qty**	**Item Name**	**Item Description**	**Actual Price**	**Allocated Price**	**Total**	**Allocated Total**	**Source**	**Purchased?**
Airframe	2	G12 Fiberglass Tubes	4 ft length, 4 in diameter	$ 80.00	$ 80.00	$ 160.00	$ 160.00	Link	X
	2	Body Coupler	9 in length, 4 in diameter	$ 24.00	$ 24.00	$ 48.00	$ 48.00	Link	X
	1	G12 Body Goupler	8 in length, 4 in diameter	$ 33.00	$ 33.00	$ 33.00	$ 33.00		X
	1	G12 Fiberglass Motor Tube	22 in length, 75 mm diameter	$ 55.00	$ 55.00	$ 55.00	$ 55.00	Link	X
	2	G12 Fiberglass Motor Tube	18 in length, 54 mm diameter	$ 41.00	$ 41.00	$ 82.00	$ 82.00	Link	X
	1	G12 Fiberglass Tube (Madcow Rocketry)	4ft length, 4 in diameter	$ 182.00	$ 182.00	$ 182.00	$ 182.00	Link	X
	1	G12 Coupler (madcow rocketry)	9 in length, 4 in diameter	$ 37.00	$ 37.00	$ 37.00	$ 37.00	Link	X
	1	G12 Fiberglass Tubes	24 in length, 4 in diameter	$ 71.39	$ 71.39	$ 71.39	$ 71.39	Link	X
	Total					**$ 668.39**	**$ 668.39**		
Recovery/Avionics	1	Black Powder Charges	1 lb (already owned)	$ -	$ 50.00	$ -	$ 50.00	Link	X
	1	Main Parachute - Full-scale	Flat Nylon, 7 ft diameter	$ 260.00	$ 225.00	$ 260.00	$ 225.00	Link	X
	100	1yd of Shock Cord	9/16 in Tubular White	$ 1.50	$ 150.00	$ 150.00	$ 150.00	Link	X
	2	Stainless Steel Tapered Heat-Set Insert	18-8, 4-40, 0.135' installed length, pack of 10	$ 6.01	$ 6.01	$ 12.02	$ 12.02	Link	X
	1	Black -Oxide Alloy Steel Socket Head Screw	4-40 Thread Size, 5/8" long, pack of 100	$ 11.65	$ 11.65	$ 11.65	$ 11.65	Link	X
	1	Atlus Metrum Easymini Altimeter	dual deploy altimeter with Logging	$ 80.00	$ 80.00	$ 80.00	$ 80.00	Link	X
	1	Drogue Parachute	Flat Nylon, 1 ft diameter	$ -	$ 28.50	$ -	$ 28.50	Link	
	3	Cable Straps and Ties	8"-12"-18", adjustable, 20 pack	$ 8.45	$ 8.45	$ 25.35	$ 25.35	Link	X
	Total					**$ 539.02**	**$ 582.52**		
Electronics/Payload	2	FCC Ham Radio License	radio license	$ 35.00	$ 35.00	$ 70.00	$ 70.00	Link	X
	1	BTECH APRS-K1 PRO	APRS encoder/decoder	$ 34.49	$ 34.49	$ 34.49	$ 34.49	Link	X
	1	BTECH APRS-K2	APRS encoder/decoder	$ 22.49	$ -	$ 22.49	$ -	Link	X
	2	UV-5R Ham Radio Transceiver	radio transmitter	$ 31.69	$ 31.69	$ 63.38	$ 63.38	Link	X
	3	RH707 Diamond Dual-Band Antenna	dual-band antenna	$ -	$ 29.99	$ -	$ 89.97	Link	
	1	BMP280 Barometer & Thermometer (10-pack)	barometer/thermometer	$ 7.99	$ 7.99	$ 7.99	$ 7.99	Link	X
	1	1000mAh 2S Li-Po Battery (2-pack)	Li-Po battery	$ -	$ 14.99	$ -	$ 14.99	Link	
	1	W25Q64 Flash Memory Module (5-pack)	flash memory	$ 7.99	$ 7.99	$ 7.99	$ 7.99	Link	X
	1	Micro SD-Card Reader (10-pack)	removable memory	$ 8.89	$ 8.89	$ 8.89	$ 8.89	Link	X
	1	Micro SD-Card 32GB (5-pack)	removable memory	$ 19.20	$ 29.94	$ 19.20	$ 29.94		X
	2	PCB Manufacturing per Version	printed circuit board	$ 21.50	$ 40.00	$ 43.00	$ 80.00	Link	X
	4	LEGO STEMnauts	minifigure	$ 5.00	$ 5.00	$ 20.00	$ 20.00	Link	X
	1	Mini Transmitter	Eggfinder	$ 75.00	$ 75.00	$ 75.00	$ 75.00	Link	X
	1	LCD Handheld Receiver	Eggfinder	$ 55.00	$ 55.00	$ 55.00	$ 55.00	Link	X
	1	Rotary Encoder	Taiss 5 pack	$ 9.99	$ 9.99	$ 9.99	$ 9.99	Link	X
	Total					**$ 437.42**	**$ 427.64**		

Subscale	1	G12 Fiberglass	5 ft length, 3 in diameter, for Airframe	$ 98.00	$ 98.00	$ 98.00	$ 98.00	Link	X
	4	PETG plastic	1.75 mm, black filiment, for 3D printing	$ 20.00	$ 20.00	$ 80.00	$ 80.00	Link	X
	2	Coupler Tubes	9 in length, 3 in diameter G12 Fiberglass	$ 22.00	$ 22.00	$ 44.00	$ 44.00	Link	X
	1	Main Parachute - Subscale	Flat Nylon, 4 ft diameter	$ 115.00	$ 115.00	$ 115.00	$ 115.00	Link	X
	1	U-Bolts	8880T957	$ 1.98	$ 1.98	$ 1.98	$ 1.98	Link	X
	6	G10 Fiberglass	1/8 thickness, 1 ft x 1 ft, for fins	$ 31.38	$ 31.38	$ 188.28	$ 188.28	Link	X
	2	J540R-L Motors	54 mm	$ 135.99	$ 135.99	$ 271.98	$ 271.98	Link	X
	6	Stainless Steel Powder	for mass control	$ 16.98	$ 16.98	$ 101.88	$ 101.88	Link	X
	2	Checkered Contact Paper	17.7 x 118 in, for velocity blanket	$ 6.99	$ 6.99	$ 13.98	$ 13.98	Link	X
	Total					**$ 915.10**	**$ 915.10**		
General Construction	2	Epoxy	Quart of epoxy for parts that need it	$ -	$ 80.00	$ -	$ 160.00		
	1	Alumninum Roundstock	4 inch diameter, 6 inch length	$ 82.73	$ 82.73	$ 82.73	$ 82.73	Link	X
	10	Threaded eye bolts	1/4" X 20" 1"	$ 7.00	$ 7.00	$ 70.00	$ 70.00	Link	X
	2	Rail Buttons	10/10 ERX 9075C	$ 3.00	$ 3.00	$ 6.00	$ 6.00	Link	X
	200	Shock Cords	9/16 in width, 1500 lbs tensile strength	$ 1.50	$ 1.50	$ 300.00	$ 300.00	Link	X
	2	Fasteners	(50 ct) 18-8 Stainless Steel Button Head	$ 7.56	$ 7.56	$ 15.12	$ 15.12	Link	X
	9	PETG plastic	Plastic for 3D printing, 1 kg spool	$ 15.99	$ 20.00	$ 143.91	$ 180.00	Link	X
	3	Smooth T-Slotted Almuminum Extrusion	36 in length	$ 8.42	$ 8.42	$ 25.26	$ 25.26	Link	X
	6	Smooth T-Slotted Almuminum Extrusion	9.5 in length	$ 2.48	$ 2.48	$ 14.88	$ 14.88	Link	X
	2	Threaded Rods	1/4-20, for the avionics bay	$ 12.34	$ 12.34	$ 24.68	$ 24.68	Link	X
	1	Carbon Fiber Square Rods	6mm x 6mm	$ 50.99	$ 50.99	$ 50.99	$ 50.99	Link	X
	2	15 Min Epoxy	212 epoxy, 13 combined oz	$ 24.99	$ 29.99	$ 49.98	$ 59.98	Link	X
	10	Male-Female Threaded Hex Standoff	for secondary payload	$ 2.38	$ 2.38	$ 23.80	$ 23.80	Link	X
	Total					**$ 807.35**	**$ 989.64**		
Flight Consumables	7	Motor reload kit	Motors for full scale launches	$ 202.99	$ 250.00	$ 1,420.93	$ 1,750.00	Link	X
	1	Shear Pins (100 ct)	for the mainframe recovery system	$ 5.50	$ 5.50	$ 5.50	$ 5.50	Link	X
	Total					**$ 1,426.43**	**$ 1,755.50**		
Other	1	Team Shirts	16 shirts total	$ 396.25	$ 396.25	$ 396.25	$ 396.25	Link	X
	1	Motor Case	75mm 2560 CASING Reloads	$ 258.99	$ 258.99	$ 258.99	$ 258.99	Link	X
	1	Ogive Nosecone	FNC4.0-FW-MT 3:1	$ 85.99	$ 85.99	$ 85.99	$ 85.99	Link	X
	Total					**$741.23**	**$741.23**		

Stem Engagement (One Time Purchases)	4	Model rockets	Demonstration Materials	$ 7.00	$ 7.00	$ 28.00	$ 28.00	Link	X
	1	Table Cloth	construction materials	$ 9.99	$ 9.99	$ 9.99	$ 9.99	Link	X
	1	Dish Set	construction materials	$ 13.49	$ 13.49	$ 13.49	$ 13.49	Link	X
	1	Toy Cars	Demonstration Materials	$ 7.60	$ 7.60	$ 7.60	$ 7.60	Link	X
	1	Wood	construction materials	$ 4.42	$ 4.42	$ 4.42	$ 4.42	Link	X
	1	Tennis Balls	Demonstration Materials	$ 3.94	$ 3.94	$ 3.94	$ 3.94	Link	X
	1	Stuffed Toy	Demonstration Materials	$ 9.99	$ 9.99	$ 9.99	$ 9.99	Link	X
	1	Balloons	Demonstration Materials	$ 5.99	$ 5.99	$ 5.99	$ 5.99	Link	X
	1	Compressed Air	Demonstration Materials	$ 12.00	$ 12.00	$ 12.00	$ 12.00	Link	X
	1	Glasses	Demonstration Materials	$ 3.99	$ 3.99	$ 3.99	$ 3.99	Link	X
	1	Forks	Demonstration Materials	$ 5.99	$ 5.99	$ 5.99	$ 5.99	Link	X
	1	Baseball Bat	Demonstration Materials	$ 10.99	$ 10.99	$ 10.99	$ 10.99	Link	X
	1	Fan	Demonstration Materials	$ 30.99	$ 30.99	$ 30.99	$ 30.99	Link	X
	1	Ruler	construction materials	$ 6.99	$ 6.99	$ 6.99	$ 6.99	Link	X
	1	Markers	construction materials	$ 13.75	$ 13.75	$ 13.75	$ 13.75	Link	X
	1	Hot Glue Gun	construction materials	$ 9.99	$ 9.99	$ 9.99	$ 9.99	Link	X
	2	Scissors	construction materials	$ 13.99	$ 13.99	$ 27.98	$ 27.98	Link	X
	1	Scale	construction materials	$ 9.98	$ 9.98	$ 9.98	$ 9.98	Link	X
	1	Measuring Cups	construction materials	$ 7.99	$ 7.99	$ 7.99	$ 7.99	Link	X
	1	Launching Material	(already owned)	$ -	$ 100.00	$ -	$ 100.00	N/A	X
Stem Engagement (Consumables)	5	Chloroplast corrugated cardboard	construction materials	$ 26.74	$ 26.74	$ 133.70	$ 133.70	Link	X
	4	Foam Footballs	construction materials	$ 19.99	$ 19.99	$ 79.96	$ 79.96	Link	X
	1	Toothpicks	Demonstration Materials	$ 3.99	$ 3.99	$ 3.99	$ 3.99	Link	X
	1	Corugated Card Board	construction materials	$ 26.74	$ 26.74	$ 26.74	$ 26.74	Link	X
	3	Pencil	construction materials	$ 16.99	$ 16.99	$ 50.97	$ 50.97	Link	X
	80	2 Liter Bottles	construction materials	$ 1.00	$ 1.00	$ 80.00	$ 80.00	Link	X
	1	Corrugated cardboard	construction materials	$ 9.88	$ 9.88	$ 9.88	$ 9.88	Link	X
	1	Gravel	construction materials	$ 5.59	$ 5.59	$ 5.59	$ 5.59	Link	X
	2	Plastic Cups	construction materials	$ 5.06	$ 5.06	$ 10.12	$ 10.12	Link	X
	1	Straws	construction materials	$ 5.98	$ 5.98	$ 5.98	$ 5.98	Link	X
	1	Straws (380 pack)	construction materials	$ 18.99	$ 18.99	$ 18.99	$ 18.99	Link	X
	1	Rubber Bands	construction materials	$ 6.80	$ 6.80	$ 6.80	$ 6.80	Link	X
	1	Tissue Paper	construction materials	$ 5.99	$ 5.99	$ 5.99	$ 5.99	Link	X
	1	String	construction materials	$ 4.99	$ 4.99	$ 4.99	$ 4.99	Link	X
	2	Popsicle Sticks	construction materials	$ 4.99	$ 4.99	$ 9.98	$ 9.98	Link	X
	1	Construction Paper	construction materials	$ 5.99	$ 5.99	$ 5.99	$ 5.99	Link	X
	1	Tape	construction materials	$ 23.39	$ 23.39	$ 23.39	$ 23.39	Link	X
	2	Scotch Tape	construction materials	$ 9.99	$ 9.99	$ 19.98	$ 19.98	Link	X
	1	Name Tags	Identification	$ 5.53	$ 7.99	$ 5.53	$ 7.99	Link	X
	1	Stickers	construction materials	$ 5.99	$ 5.99	$ 5.99	$ 5.99	Link	X
	1	Bracelets	construction materials	$ 9.99	$ 9.99	$ 9.99	$ 9.99	Link	X
	2	Tape	construction materials	$ 23.39	$ 27.95	$ 46.78	$ 55.90	Link	X
	1	Boxes	construction materials	$ 25.02	$ 25.02	$ 25.02	$ 25.02	Link	X
	2	Metal bb and Pebbles	construction materials	$ 8.99	$ 8.99	$ 17.98	$ 17.98	Link	X
	Total					$ 838.39	$ 949.97		
Grand Total						$6,373.33	$7,029.99		
Surplus/Deficit							$656.66		