



Project Avigator

NASA University Student Launch Initiative 2024 Post-Launch Assessment Review

University of Florida

Swamp Launch Rocket Team
571 Gale Lemerand Drive MAE-C Room 134
Gainesville, FL 32611
April 20th, 2024



Table of Contents

1. Summary	2
1.1 Launch Vehicle Summary	2
1.2 Payload Summary	2
2. Data and Results.....	3
2.1 Launch Vehicle Results.....	3
2.2 Payload Results	3
2.3 Flight Profile Data	3
2.3.1 Separation Events	4
2.4 Landed Configuration of Launch Vehicle.....	4
2.5 Flight Analysis.....	6
2.5.1 Ascent Analysis	6
2.5.2 Descent Analysis.....	7
3. Discussion	8
3.1 Scientific Value	8
3.2 Visual Data	8
3.3 Lessons Learned.....	8
3.3.1 Launch Vehicle Lessons.....	8
3.3.2 Payload Lessons	8
3.3.3 Overall Project Lessons	9
3.4 Subsystem Functionality	9
4. Competition Summary.....	9
4.1 Summary of Experience.....	9
4.2 Hours.....	10
4.3 STEM Engagement Summary	10
4.4 Budget Summary	11
6. Conclusion	12



1. Summary

Team Summary	
Team Name	Swamp Launch Rocket Team
Motor Used	AeroTech L1150
Altitude Reached (ft)	4606
Official Target Altitude (ft)	5000

Table 1: Team Summary

1.1 Launch Vehicle Summary

The team performed their final launch at Huntsville during Launch Week on April 13th, 2024. A summary of the launch vehicle is shown in Table 2.

Launch Vehicle Title: Fasten Your Seatbelts (Gator Air)

Launch Vehicle Summary				
Official Target Altitude	5000 ft			
Final Motor Choice	AeroTech L1150			
Rail Size	1515, 144 in			
Dry Mass (without Ballast)	558.5 oz			
Dry Mass (with Ballast)	579.5 oz			
Wet Mass	625.6 oz			
Burnout Mass	552.7 oz			
Landing Mass	471.9 oz			
GPS	Eggfinder Mini			
Main Altimeter	Stratologger CF			
Backup Altimeter	MissileWorks RRC3			
Drogue Parachute	SkyAngle CERT-3 Drogue			
Main Parachute	Fruity Chutes 96 in Iris Ultra			
Section	Payload	Central	Aft	Total
Length	55.0 in	54.0 in	24.5 in	133.5 in
Mass	254.7 oz	143.2 oz	227.7 oz	625.6 oz

Table 2: Launch Vehicle Summary

1.2 Payload Summary

The payload is a remote-controlled aircraft with thin, bendable wings that fold up inside the launch vehicle and unfurl when released from the payload retention system at 400 ft. It safely transports four STEMnauts to the ground. The wings, made of thin carbon fiber, can roll in one direction for stowing aboard the vehicle, but load stiffen in the other direction during flight. A ground control station receives a live video feed with telemetry overlaid from the payload. The ground station, in turn, controls payload separation and flight via a radio transmitter. Acceleration data is recorded and used to calculate the g-forces the STEMnauts experience, determining whether the landing satisfied the defined criteria for human survivability.



2. Data and Results

2.1 Launch Vehicle Results

The launch vehicle met the mission success criteria; all components were recovered successfully and the system performed nominally with the exception of a non-critical entanglement of the drogue parachute in its recovery harness (2.5.2 Descent Analysis). Flight information for the launch vehicle was recorded (Table 3).

Flight Overview	
Date of Flight	April 13 th , 2024
Flight Location	Huntsville, AL
Motor Flown	AeroTech L1150R
Ballast Flown	N/A
Final Payload Flown?	No
Official Target Altitude	5000 ft
Predicted Altitude from Simulations	4625 ft
Measured Altitude	4606 ft

Table 3: Launch Day Flight Overview

2.2 Payload Results

The payload was not flown because it was not approved to do so. As such, data was not collected and there are no results to report.

2.3 Flight Profile Data

Experimental flight data was recorded by the main altimeter, the Stratologger CF, and the secondary altimeter, the MissileWorks RRC3 (Table 4).

Parameter	Stratologger CF	MissileWorks RRC3
Apogee Altitude	4606 ft	4539 ft
Drogue Descent Rate	98.0 ft/s	98.8 ft/s
Main Descent Rate	16.2 ft/s	16.3 ft/s

Table 4: Altimeter Flight Data Comparison

The altitude and velocity profiles for both altimeters are shown in Figure 1 and Figure 2 respectively. During descent under drogue, some noise is visible due to fluctuations in air conditions and slight entanglement of the recovery harness in the shroud lines.

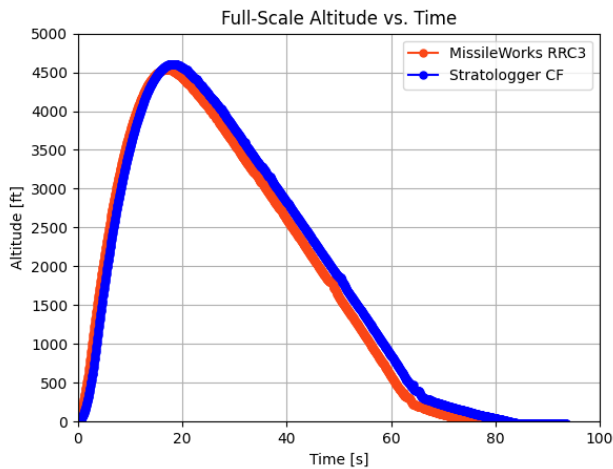


Figure 1: Altitude vs. Time

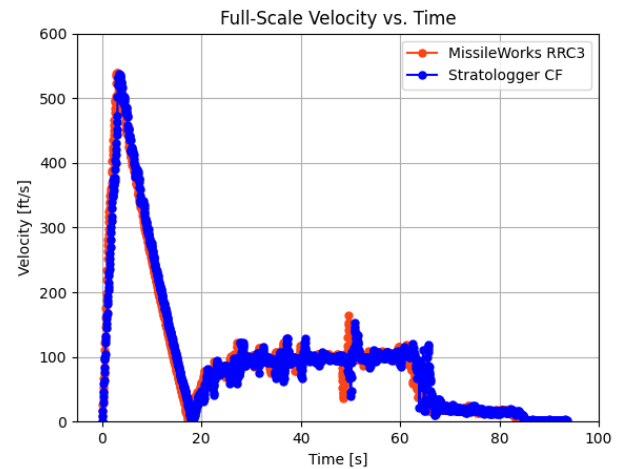


Figure 2: Velocity vs. Time

2.3.1 Separation Events

The first separation event, where drogue deployed, occurred at apogee with a backup charge firing one second after apogee. Both ejection charges detonated as intended and altimeters indicate that separation events occurred at the desired times. The second separation event for main deployment occurred at an altitude of 550 ft, with a backup charge firing at an altitude of 500 ft. Similar to the first separation event, both ejection charges detonated as intended and altimeter data indicates separation at the desired altitude.

2.4 Landed Configuration of Launch Vehicle

The launch vehicle was undamaged from the flight. Some of the paint was removed after landing because high winds caused the launch vehicle to move on the ground, but ultimately the launch vehicle was recoverable and reusable. The following figures show the landed configuration of the launch vehicle as found during recovery.



Figure 3: Payload Section



Figure 4: Central Section



Figure 5: Main Parachute



Figure 6: Drogue Parachute



Figure 7: Aft Section



Figure 8: Full Launch Vehicle



2.5 Flight Analysis

The launch vehicle met the mission success criteria. At the launch site, the as-built mass and center of gravity position from the nosecone tip of the launch vehicle were recorded (Table 5) and overridden in OpenRocket using the launch day conditions (Table 6) to simulate its performance. The simulated altitude and velocity profiles were plotted against the altimeter data (Figure 9, Figure 10).

As-Built Parameter	Value
Mass	625.3 oz
Center of Gravity	79.8 in

Table 5: As-Built Inputs for Launch Day Simulation

Launch Day Conditions	
Wind Speed	6 mph
Launch Angle	7°
Launch Rod Length	144 in
Latitude	34.6 °N
Longitude	86.7 °W
Elevation	800 ft
Temperature	70°F
Pressure	1 atm

Table 6: Launch Day Conditions at Braggs Farm

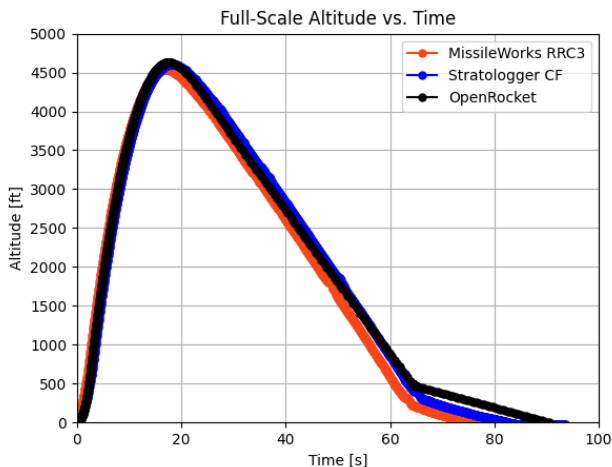


Figure 9: Actual vs. Predicted Altitude Profiles

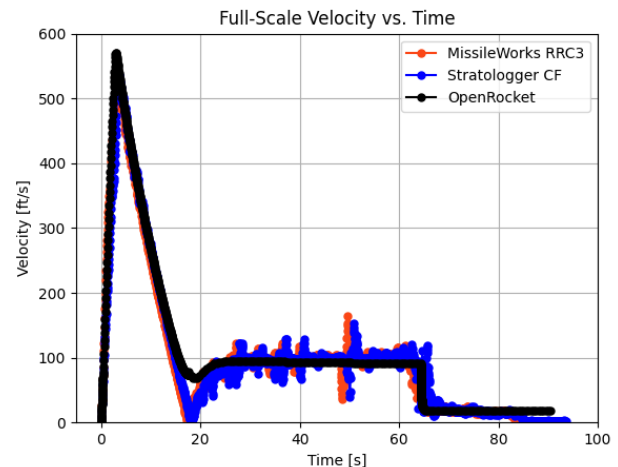


Figure 10: Actual vs. Predicted Velocity Profiles

2.5.1 Ascent Analysis

Comparisons of the predicted and actual ascent results were tabulated (Table 7).

Parameter	Stratologger CF	MissileWorks RRC3	OpenRocket	Error (Stratologger)
Apogee Altitude	4606 ft	4539 ft	4625 ft	0.4%
Maximum Velocity	538 ft/s	540 ft/s	565 ft/s	4.8%

Table 7: Ascent Value Comparison Between the Main Altimeter and Simulation

The altitude and velocity profile data from the main altimeter, the Stratologger CF, and the secondary altimeter, the MissileWorks RRC3, were used to obtain the apogee and maximum velocity. The apogee, according to the main altimeter, deviated from the projections by 19 ft, or 0.4%. Due to a suspected miscalibration in the backup altimeter, indicated by the final altitude being around 86 ft lower than the final altitude for the main altimeter, the apogee according to the MissileWorks RRC3 was off by 91 ft.



The apogee altitude of the launch vehicle was accurate with the launch day simulation, within a 0.4% error. However, the apogee altitude was significantly lower than target apogee altitude of 5000 ft. This disparity is due to an increase in the total mass of the launch vehicle since submission of the target apogee altitude.

The launch day simulation maximum velocity is accurate within a 4.8% error to the actual maximum velocity. This error may be attributed to changes in wind speed during the ascent of the launch vehicle.

2.5.1.1 Drag Coefficient Estimation

The launch day OpenRocket simulation was performed and the coefficient of drag for the entire launch vehicle was overridden and manipulated until the apogee altitude from the simulation equaled the apogee altitude from the Stratologger CF altimeter. The drag coefficient from this method is equal to 0.43, which agrees with past drag coefficient calculations reported from this method (Table 8).

Launch	C _d
Vehicle Demonstration Flight – Attempt 1	0.46
Vehicle Demonstration Flight – Attempt 2	0.44
Launch Week	0.43

Table 8: Drag Coefficient Comparisons from Past Launches

2.5.2 Descent Analysis

GPS data from the Eggfinder Mini GPS, located in the nosecone of the launch vehicle, was recorded prior to launch and upon landing of the launch vehicle (Table 9). The drift of the launch vehicle was computed using these coordinates, yielding a drift of 2229 ft, which is below the 2500 ft maximum.

Location	GPS Location
Launch Pad	34.89428° N, 86.61722° W
Landing Site	34.89134° N, 86.61069° W
Total drift = 2229 ft	

Table 9: Telemetry Locations at Launch and Landing of the Launch Vehicle with Drift

Using the altitude and velocity profile data from the main altimeter, the Stratologger CF, and the secondary altimeter, the MissileWorks RRC3, the apogee of the flight was recorded along with the average drogue descent rate and main descent rate. The drogue and main descent rates deviated from the predicted simulation by 8.2% and 0.6% respectively (Table 10). This increase in descent rate for the drogue parachute was caused by an entanglement in the drogue recovery harness, which in turn led to a decrease in the descent time from the predicted time by 7.6 s, or 10.1% (Table 10).

Parameter	Stratologger CF	MissileWorks RRC3	OpenRocket	Error (Stratologger)
Apogee Altitude	4606 ft	4539 ft	4625 ft	0.4%
Drogue Descent Rate	98.0 ft/s	98.8 ft/s	90.6 ft/s	8.2%
Main Descent Rate	16.2 ft/s	16.3 ft/s	16.1 ft/s	0.6%
Descent Time	67.7 s	66.7 s	75.3 s	10.1%

Table 10: Descent Value Comparison Between the Main Altimeter and Simulation

With the descent rates and the mass of each launch vehicle section, the kinetic energy at landing for each section was calculated, with maximum kinetic energy occurring for the payload section with a value of 64.93 ft-lbf, which is under the 75 ft-lbf requirement (Table 11).



Section	Mass at landing (lbs)	Drogue Descent rate (mph)	Main descent rate (mph)	Kinetic Energy (ft-lbf)
Payload	15.92	66.8	11.1	64.93
Central	6.13	66.8	11.1	24.99
Aft	11.35	66.8	11.1	46.30

Table 11: Kinetic Energy Results

3. Discussion

3.1 Scientific Value

The project pursued this year had several components that hold some scientific value. On the launch vehicle, research was conducted into vehicle construction with the implementation of a transition into the vehicle. This research revealed a method to increase usable payload bay volume without a significant increase in vehicle size and cost.

On the payload side, the rolling carbon fiber wing poses substantial scientific value. This method for constructing wings and aircraft control surfaces holds great value for integration of an airplane payload into a rocket. The rolling wing can be very compactly packed for the wing area attained.

3.2 Visual Data

The launch vehicle performed as designed. The drogue and main parachutes appeared to deploy at the intended altitudes with the primary ejection charges. After landing on the ground, the vehicle appeared to be dragged some distance by the main parachute catching wind.

Though the payload was not flown on launch day, all of its systems were functional, as seen from ground tests done for the team's 2023-2024 Flight Readiness Review.

3.3 Lessons Learned

3.3.1 Launch Vehicle Lessons

The masses of the transition assembly, recovery components, epoxy, and foam were underestimated in the mass estimations reported in PDR. Therefore, predictions for the apogee altitude at this stage were overestimated. Moving forward, more accurate mass estimates of these components will be incorporated in the simulations run in the PDR stage of the report, so that the launch day apogee altitude is more accurate to the declared target apogee altitude.

Space for the payload within the launch vehicle was a tight fit. Increasing the tolerance between the components housed within the payload section or enlarging the diameter of the airframe would create additional room for accommodating the payload and its retention components.

3.3.2 Payload Lessons

The payload was not flown for this launch. As such, there are no payload lessons learned within the context of this launch. However, overall, the lessons learned would be to be earlier with deadlines to allow increased time for improved integration testing. This increased testing could have improved the likelihood of payload demonstration flight succeeding and being approved to be deployed at this launch.

Assembly of the payload proved to be challenging and time consuming. The lesson learned is that it is important to design for assembly when you are iterating through the design process. Minor changes to the design could have allowed for a much faster assembly time.



Another lesson learned is to integrate an external switch to turn payload systems on and off. Arming the payload required complete assembly and disassembly, which could have been prevented with an external switch.

Attaching the 3D printed parts to the rest of the payload assembly also proved to be challenging. This was due to the heat-set inserts implemented in the 3D printed parts. When inserted, the inserts tended to lean to one side, and not melt into the part completely straight. This problem could have been remedied with looser tolerances on the hole locations that lined up with the heat-set inserts. The general lesson learned is to allow for looser tolerances with 3D printed parts.

3.3.3 Overall Project Lessons

During the project, the team faced some difficulties staying on schedule, particularly during the manufacturing phase, which limited the time available for testing. Some possible mitigations could be to hold more frequent team meetings to check the progress of each subsystem's development and to order duplicates of smaller, system-critical parts to avoid delays if a part needs to be replaced during manufacturing.

A significant factor that contributed to the team going over budget was the cost of obtaining prepreg carbon fiber for the payload wings, which was significantly more than initially expected. To minimize this risk in future projects, more thorough research should be done on the costs to obtain materials considered for use in the launch vehicle and payload early on in the design process. Additionally, future budgets should include a margin to account for unexpected costs such as damage repairs after flights.

3.4 Subsystem Functionality

The recovery subsystem functioned as intended, with successful recovery of the launch vehicle being achieved. The descent rate of the drogue parachute was off from projections by 8.2% due to entanglement in the recovery harness, which prevented full deployment. This led to a difference in descent time of 10.1% from the OpenRocket projections. Despite these slight deviations, kinetic energy, descent time, and drift radius requirements were all still met. Values of 64.93 ft-lbf for the maximum kinetic energy upon landing, a 67.7 s descent time, and a 2229 ft drift, were below the requirements of 75 ft-lbf, 90 s, and 2500 ft respectively.

The payload retention system functioned as intended, staying closed (locked) throughout the duration of the vehicle's flight.

As the payload was not flown, its subsystems were not used. Thus, no statements can be made about subsystem functionality within the context of this launch. However, the payload mechanical, electrical, and software subsystems had been previously tested and were functional, as shown in the team's Flight Readiness Review.

4. Competition Summary

4.1 Summary of Experience

During Launch Week, our goal was to successfully fly the launch vehicle. To that end, the project was a success. The launch vehicle performed successfully, with only a single non-flight critical off-nominal event. The drogue got slightly tangled, but this did not cause the vehicle to fail. The payload was not flown, nor was there any intent to fly it at competition after it failed to deploy during the team's payload demonstration flight.

The designed payload was a remote controllable plane with rollable carbon fiber wings. The payload has a controllable rudder and elevator, as well as diagonal stabilizers. The initial goal for the payload was to eject from the launch vehicle at 400 ft and pilot it down via a ground station. After a failed payload demonstration



flight, the payload was not approved to fly at competition. Despite the failure to launch, the project was a valuable experience with many lessons learned. This includes educational lessons such as how to do carbon fiber layups, design a wing, and ensure stability of an aircraft. Manufacturing methods such as CNC machining, 3D printing, and manual machining were also learned through this process. Additionally, lessons were learned in project structuring. Prioritizing testing and sticking to tight deadlines could have resulted in a successful payload.

4.2 Hours

Table 12 shows the total hours spent on the project for the 2023-2024 year.

2023-2024 Hours Summary	
Proposal	561
PDR	834
CDR	712
FRR	986
FRR Addendum	109
PLAR	35
STEM Engagement	39
Social Media	16
Launch Activities	61
Total	3353

Table 12: 2023-2024 Hours Summary

4.3 STEM Engagement Summary

Table 13 shows a summary of the STEM engagement events that were held by the team for the duration of the project. The team was able to provide lessons at varying levels of complexity to different age groups of students with the goal of engaging the students in STEM topics that were interesting to them. Overall, the students appeared to enjoy participating in the activities, and the team plans to maintain and expand its connections with schools and educational groups in the future.

STEM Engagement Summary				
Event	Students	Student Level	Event Type	Event Description
Level 1 NAR Certifications	4	Undergraduate	Education/ Direct	The participants were taught the basics of high power rocketry, including the structure of rockets, flight dynamics and how to use the OpenRocket software, and recovery. The participants iterated and edited their designs until they had a stability margin between 1.5 and 2.5 and until the OpenRocket simulation showed safe a safe velocity off the rod, at deployment, and upon ground hit. The participants manufactured their own rockets under supervision of L2 members. On the day of launch, each participant individually set up their own rocket and prepared their motors by setting the delay grain to the delay used in their OpenRocket simulations. Each participant successfully launched and recovered their rockets, earning their NAR Level 1 certifications.
Introduction to OpenRocket	60	Undergraduate	Education/ Direct	The participants were taught the basics of rocketry design with a short PowerPoint presentation that covered the components of a rocket, the concept of stability, and motor selection. The participants were then instructed to use OpenRocket to design a rocket that could be used for a NAR level 1 certification. Experienced team members helped the participants design stable rockets by providing instruction on typical components used for NAR level 1 rockets. Once each participant designed their rocket, they were shown how to conduct a simulation on their rocket.



Paper Helicopters at Passage Christian Academy	30	Preschool-Grade 4	Education/Direct	The students were first asked to predict if a crumpled piece of paper or a flat sheet would fall faster. A demonstration was then conducted so the students could observe the results themselves. The students were then split into groups of 4-5 people, with one team member assisting each group. Each group was led through the activity by the team member. Each student was given one of four paper helicopter templates and paper clip to assemble their helicopters. Each template had a different rotor length or width. Once every student in a group assembled their paper helicopters, the team member helped them run an experiment. In this experiment, each student would raise their helicopter to the same height, then drop the helicopters at the same time. They would then observe which helicopter fell to the ground the slowest. The students were then asked why they thought one helicopter was faster than the other. The objective was for the students to understand that the helicopter rotors with the largest surface area would fall the slowest, since the area results in greater air resistance.
Paper Helicopters at Kanapaha Middle School	150	Grades 5-9	Education/Direct	The paper helicopter activity described above was done with students at Kanapaha middle school.
Paper Helicopters at Caring and Sharing	20	Preschool – Grade 4	Education/Direct	The paper helicopter activity described above was done with students at Caring and Sharing.
Path-Following Robots at Passage Christian Academy	30	Preschool – Grade 4	Education/Direct	The students were split into two groups and each student was given an identical set of cards that had a variety of different arrows printed on them, and a robot that used a camera to track and follow paths. Each student individually made their own path using the set of cards. They each took turns using the robot and allowing it to follow their path. The students were able to see that the paths were all different even though they each used identical sets of cards.

Table 13: STEM Engagement Summary

4.4 Budget Summary

The final project cost was \$11,496.57 (Table 14). Total non-travel spending for the project was \$5,554.17. This was significantly higher than the initial budget of \$4,100, which was most likely due to the unexpected complexity of the project, as well as repairs and motor replacements after the unsuccessful vehicle demonstration flight and payload tests (Table 15). Despite this, the team was able to draw upon donations from sponsors and team savings to complete the project. Travel costs were not included in the budget because they were entirely covered by the University of Florida’s Mechanical and Aerospace Engineering department.

2023-2024 Total Spending	
Subscale	\$ 1,345.16
Full-Scale Vehicle	\$ 2,913.03
Payload	\$ 1,295.98
Total (Non-Travel)	\$ 5,554.17
Hotels	\$ 5,360.00
Gas	\$ 582.40
Total (Travel Only)	\$ 5,942.40
Total	\$ 11,496.57

Table 14: 2023-2024 Total Spending

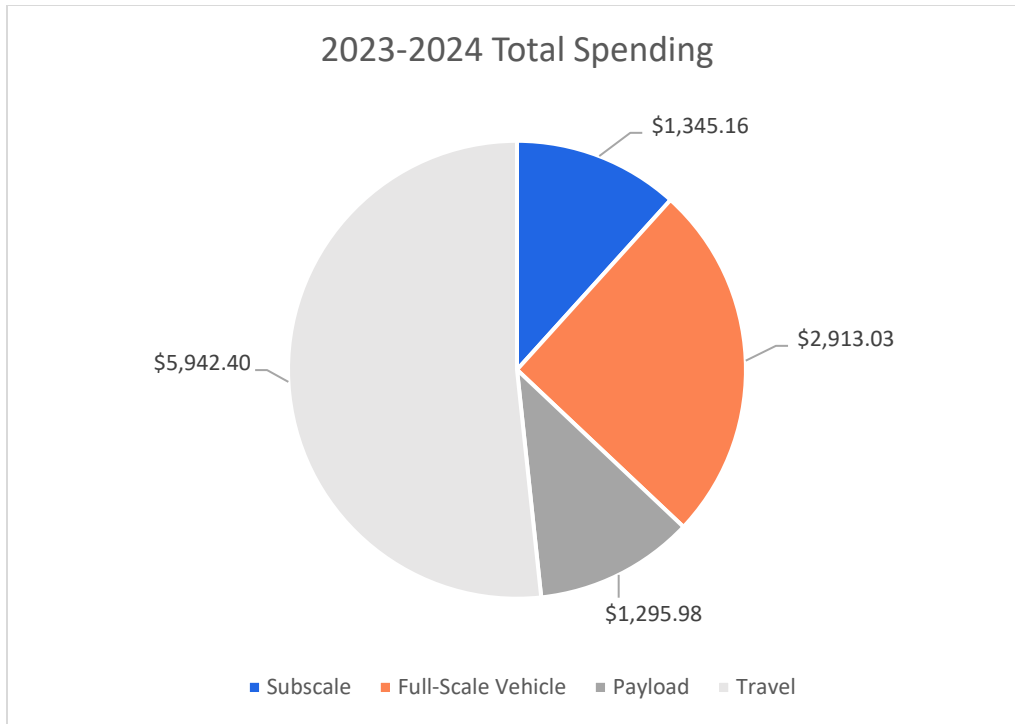


Figure 11: 2023-2024 Total Spending

Itemized Budget (Non-Travel)			
Total Allocated Budget:			\$ 4,100.00
Item	Budget	Actual Cost	Margin
Subscale	\$ 1,000.00	\$ 1,345.16	134.5%
Full-Scale Launch Vehicle	\$ 3,040.00	\$ 2,913.03	95.8%
Payload (without prepeg)		\$ 878.08	28.9%
Fullscale (total, without prepeg)		\$ 3,791.10	124.7%
Prepeg	\$ 60.00	\$ 417.91	696.5%
Total	\$ 4,100.00	\$ 5,554.17	135.5%

Table 15: 2023-2024 Non-Travel Budget

6. Conclusion

On behalf of the University of Florida, the team would like to thank the NASA Student Launch staff for a great competition year.