University of Central Florida – 2023 – PLAR – Report

4000 Central Florida Blvd, Orlando, FL 32816

Knights of Experimental Rocketry

04/19/2023

1 Summary

1.1 Team Name

Team name: Knights Experimental Rocketry

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Orlando, FL 32765

Mentor Name: Gary Dahlke

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Email Address: rocket1@palmnet.net

NAR Number: #21735

Certification Level: 3

Hours Spend: 48 hours

Social Media:

Instagram @ucf_rocketry

Twitter: @KnightsRocketry

YouTube: Knights Experimental Rocketry

1.2 Motor Used

The motor that was used was an Aerotech RMS K1000T.

1.3 Brief payload description

The primary experiment functions to simulate a lunar lander. The experiment will be ejected out of the upper body tube upon main deployment where it will then land and orient itself parallel to the horizon. The experiment will then accept a series of RAFCO commands and execute them within a time frame specified by NASA. The experiment consists of two rotating sections allowing for orientation across the xy-plane. A lead elevator mechanism will then lift the camera and rotate it about the z-axis.

A SRAD Flight Computer will also be flown on the rocket. The flight computer will is used solely for data acquisition and is located in the nose cone.

1.4 Vehicle dimensions

The rocket is a custom laid composite dual deploy rocket. It has an outer diameter of 5.2 inches, with a booster section of 30 inches long, a 12 inch coupler with a two inch switch band, a 34 inch upper body tube, and a 17 inch von karman nosecone. We incorporated four trapezoidal fiberglass fins that have a root cord of 7 inches, a height of 5.5 inches, a tip cord of 3 inches, and a sweep length of 5 inches.

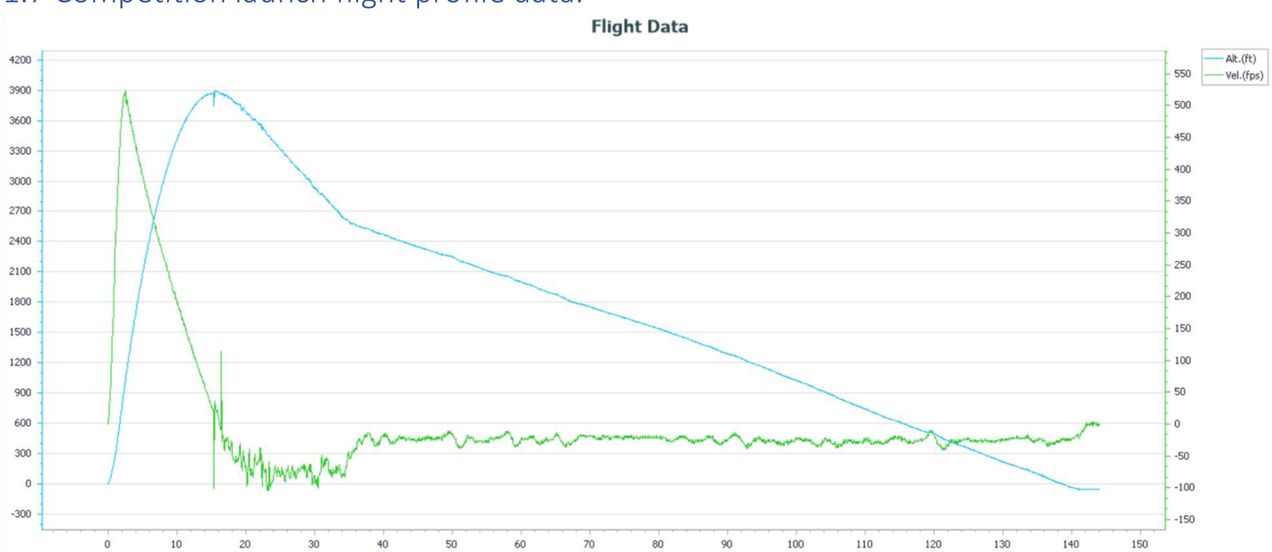
1.5 Altitude reached (ft.)

The rocket reached a confirmed altitude of 3917 ft AGL.

1.6 Official target altitude (ft.)

The official target altitude set from Preliminary Design Review (PDR) is 5507 ft AGL.

1.7 Competition launch flight profile data.



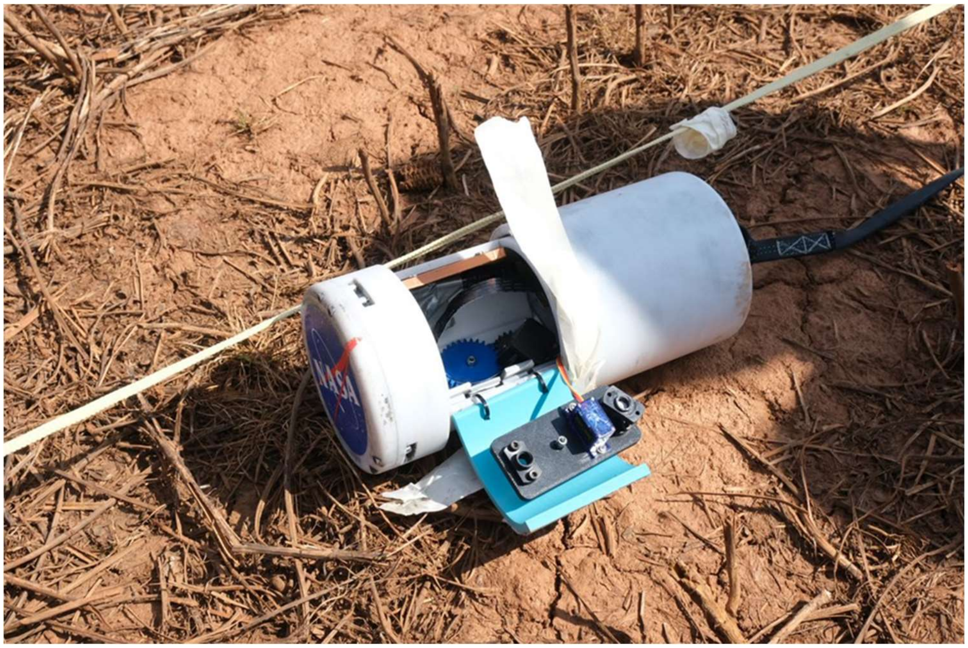
2 Vehicle summary

2.1 Data analysis & results of the vehicle

Looking at our data, we can see that there was an event at apogee which is when our drogue and our main parachute deployed simultaneously. We believe the cause of this to be the packing volume limit had been reached with our switch in parachutes leading to extra force on the shear pins. When the drogue charges went off in flight, we believe that the force from the charges sheared both the drogue shear pins as well as the main shear pins. After flight, our rocket recovered safely with minor scuffs on the outside of the airframe. Both parachutes were checked for holes, and none were found. On the recovery coupler, one of the main charges didn't go off. We replaced the recovery pin and removed the charge safely. Our payload had successfully deployed; however, the inner camera mount of the payload had broken upon impact.


Go KXR to Space + Beyond!


Rick Chappell



2.2 Describe separation events and state altitude of events

After liftoff, the primary altimeter set off the drogue charges approximately 15.4 seconds after launch at an apogee of 3917 ft AGL. However, at this point the nosecone was displaced from its launch position at apogee due to the sheer bolts being sheered from the compression of the main parachute and the shock wavs of the drogue charges.

Despite that, the redundant charge went off approximately 1 second after the drogue charge as programmed. The main parachute deployed 20 seconds later at an altitude of 2577 ft AGL. Both main primary and main redundant were set off at 600 ft AGL as programmed.

2.3 Ascent and descent analysis and metrics of the launch vehicle

From liftoff, the rocket ascended to an apogee of 3917 ft AGL in 16.35 seconds with a coasting phase of about 13.88 seconds. The maximum velocity achieved was 523 ft/s.

The maximum descent rate under drogue was 103 ft/s with an average descent rate of about 80 ft/s. Approximately 20 seconds later after the drogue deployed, the main parachute deployed early and descended at a rate of 25 ft/s. From main deployment to ground hit it took roughly 108 seconds and it landed with a KE value of roughly 60 ft-lbf.

3 Payload summary

3.1 Data analysis & results of the payload.

The payload (PILL) was able to accurately detect the launch of the rocket using its onboard accelerometer. While in flight, the PILL deployed successfully from the rocket behind the main parachute, exiting the upper body tube and remaining attached by its nylon shock cord. The PILL descended with the rest of the rocket. Upon landing, the PILL oriented itself correctly, such that the exit hatch was level with the horizon. Landing conditions were successfully detected, but the camera was unable to deploy through the hatch due to damage sustained to the linear elevator mechanism, most likely during landing. No RAFCO commands were received by the payload, so instead the pre-programmed sequence was executed. Four images were captured by the camera as dictated by the command sequence, with the correct visual filters applied. Timestamps were present in each image, with a 1-hour error due to a time-zone issue. Overall, the operation of our payload was a success, with multiple key goals met.

3.2 Scientific value achieved

The primary scientific value of this payload is as a proof-of-concept. This mission confirmed that distributing the internal weight of the PILL to the bottom served as an effective orientation mechanism. It also proved the viability of a simple accelerometer as a method of launch and landing detection. Finally, while the images captured by the camera do not show the surrounding environment as intended, they do verify that the PILL landed successfully with its electronics intact.

3.3 Visual data observed

Due to the failure of our camera deployment mechanism, our images are of the inside of our payload. Each image has a timestamp which is off by one hour but is otherwise accurate. The filters used are as follows: (1.) no filter, (2.) grayscale, (3.) our special filter, which overlays an image of a dancing skeleton on top of the original image, (4.) flip.

4 Lessons learned

4.1 Lessons learned for vehicle, payload, and overall project

4.1.1 Aerostructures

4.1.1.1 Manufacturing

Throughout this project, we learned a great deal about how to lay custom composites. Most of our team was new to this process and had to quickly learn the process. We were able to learn the importance of measuring twice and cutting once, as making mistakes in cutting could and have set us back with our efficiency of producing our airframe. We also practiced skills in dedication to gradual work, as it took hours of sanding to make minimal progress to make our airframe fit together.

4.1.1.2 Design and Analysis

For a majority of our members, this was their first experience working with ANSYS to simulate various composite layups in order to maximize the strength of our body tubes, while also keeping them as light as possible. This also helped to strengthen our teamworking abilities as we collaborated with the other sub-teams, such as interfacing with the integration team to ensure all our parts will fit together, and the manufacturing team to communicate the final design which is to be built. Our team was responsible for ensuring that our designs were feasible to create, which we were able to successfully demonstrate throughout the course of this project.

4.1.1.3 Recovery

During the course of this project, we learned numerous things related to the function of the recovery system from learning the importance of reliability not just from our own work but from manufacturers as well to learning how to make our assembly process more efficient. There were many trials and errors throughout the project, but something each and every member had was perseverance to keep going even when it felt like we were moving backward. In the beginning, a lot of us were new and most of us were not aware of how critical it is to be perfect for the recovery system. Recovery is not only bringing the rocket down safely but also ensuring that the rocket does not become a hazardous object to the public below.

4.1.2 Payloads

4.1.2.1 Experiments

We learned many important lessons during the development of the Payload. Integrated. Launch. Log. (PILL). When we began this project, we had nothing but the NASA mission requirements to work with. Through many hours of meetings, whiteboard drawings, and a test fixture made from plastic bottles, we learned how to create a design the same way professional engineers do. Teamwork and collaboration were essential. A majority of the students on this project were freshmen, yet everyone contributed to the design in some way. Once we had our design, creating the preliminary design report provided many lessons in rigorous documentation and team coordination. Then we started manufacturing, where we encountered no shortage of problems, as parts shipments were delayed and design elements didn't function as intended. Our team worked many late nights getting everything ready, even performing code edits and testing the night before our payload demonstration flight. This process highlighted the importance of keeping to a strict schedule and leaving enough time for failures and testing. The lead-up to our payload demonstration flight taught us how to operate under pressure, following pre-flight procedures and getting the PILL launch ready. Unfortunately, after launching, our rocket landed in the only nearby canal, destroying most of our electronics and rendering the PILL useless. However, we did not give up, instead rebuilding our entire payload in the three weeks before the competition. On launch day in Huntsville, we followed our preparation procedures and worked through numerous issues as our launch time got closer. Thankfully, we were able to get our payload into a functional state and load it into the rocket. Seeing our two semesters worth of work launch into the air and land successfully was a great experience for all our team members.

4.1.2.2 Telemetry

Through our work on this project, we gained extensive experience in troubleshooting and problem-solving as a team, particularly in the development of the telemetry system and flight computer. We encountered several technical challenges, including PCBs and SD card modules failing to work as expected. However, we persevered through countless hours of troubleshooting, which included soldering and debugging PCB designs, as well as writing and testing hundreds of lines of code. As a team, we honed our skills in brainstorming and finding creative solutions to technical problems. We also learned the importance of thorough testing and maintenance, both to identify and resolve issues proactively and to ensure optimal system performance. To minimize the impact of any setbacks, we ordered numerous extra parts and implemented redundancy in our designs, so that a single failure would not bring down the entire system. Overall, this project taught us the importance of technical competence and resilience, as well as the value of teamwork in achieving a complex goal.

4.1.3 Overall

Over the course of nearly a year, our USLI team has faced various challenges that we did not believe we would overcome. However, through the perseverance of our team, we were able to travel to Alabama, ready for the flight. One of the essential skills we learned was wet-laying the body tubes by hand. It required precision and patience, and we had to perfect our technique through trial and error. However, our team eventually succeeded in creating high-quality body tubes that met the project's specifications. Unfortunately, we realized that we had not chosen a big enough parachute for the descent, which caused our rocket to go ballistic at approximately 100 mph. As a result, our team had to switch from a 12" drogue to a 30" parachute. Another critical skill we learned was following proper checklist procedures. Our team learned to adhere to these checklists and procedures to guarantee that our rocket would meet the standards set forth by NASA. Moreover, our team tackled the challenge of creating a self-originating payload body with a linear actuator. This required a comprehensive understanding of the mechanisms involved, as well as coding and computational skills. Through collaborative efforts and perseverance, our team was able to successfully create this innovative and complex system. Despite facing a setback when our payload landed in a river, we were able to acquire the necessary funds and rebuild the payload system.

4.2 Discussion of successes and failures of individual subsystems

4.2.1 Aerostructures

4.2.1.1 Manufacturing

Major successes we've had were being able to make custom composite airframes with minimal experience in a very short amount of time. However, we did not check over every system as optimally as we could have. Part of the reason why our nosedive on the vehicle demonstration flight happened was due to not sanding bulkheads enough. This oversight caused a crash landing and required us to quickly manufacture a new nosecone and cut off a small section of our upper body tube. This new nosecone did not fit our first nosecone tip, and required us to use excess stock to machine a new one. This oversight set us back not only in terms of prep for our payload demonstration flight, but for other subsystems to be able to finish their work to integrate the entire design together.

4.2.1.2 Design and Analysis

Our team was successful in analyzing the expected strength of our composite parts and confirming that our rocket was structurally sound, which was proven by our multiple launches, ballistic landing, and canal landing. Although it was not entirely necessary, we had initially planned to manufacture carbon composite samples for materials testing, though due to time issues and budget constraints, we were unable to perform this testing. Even without this extra testing, our team was able to successfully confirm that our rocket would be able to withstand the harsh conditions of a launch.

4.2.1.3 Recovery

When we were selecting our parachutes, we spent a month going over the creditability of the Rocketman parachute data. This research led us to learn many things from how to ensure one is using the right size to learning how the shape of your parachute affects your descent rate. While we proved the numbers to be acceptable, in reality, they were far from acceptable. Our rocket's drogue parachute was too small and didn't perform as simulated. Furthermore, the main failed to deploy and resulted in our rocket plunging to the earth at 150 ft/s upon impact. On top of that, our assembly efficiency prevented us from launching one time because of the way it was constructed. It was very time-consuming, and the wires kept getting caught in places that prevented the coupler from sliding down. In some cases, the bulkhead was put on wrong and therefore we had to remove it and correct its orientation to fit. The wiring space was an oversight. We thought the space left open on the sides was enough to run the wires from one side to the other. However, it proves to be very difficult to work with and get right and, thus, required us to drill holes into the plates for better wire management.

Our major success was our Payload demonstration flight. It was the first time both parachutes deployed and brought the rocket down safely. It was a major success because of all our past failures and the trials we had to endure to get to that point, it felt like we finally reached a major milestone in a journey that felt like we made no progress. Although, it was short-lived. It so happens to be that the rocket landed in a 20 feet wide canal, but not all was lost. One of the altimeters was still working after we pulled it from the water to give us our apogee before we disarmed it and possibly shorted it.

4.2.2 Payloads

4.2.2.1 Experiments

Key Goals	Result
Launch and Landing Detection	Success
Self-Orientation	Success
Receive RAFCO Commands	Fail
Camera Deployment	Fail
Record Images with Filters	Success

The core design of our payload proved to be fully functional in testing, able to orient itself, deploy the camera, receive radio commands, rotate 360-degrees, and record images. However, the PILL was only able to demonstrate some of these capabilities during launch.

- **Launch and Landing Detection:** The BNO055 on the PILL detected the acceleration of launch, and subsequent drop in acceleration upon landing, causing it to attempt camera deployment at the correct time.
- **Self-Orientation:** The PILL was perfectly upright upon landing, with the hatch level to the horizon.
- **Receive RAFCO Commands:** Although we were able to receive the radio commands being broadcast for testing at the Von Braun center, on launch day an unknown issue prevented us from receiving commands. We spent multiple hours troubleshooting this issue, which included replacing our RTL-SDR, but only managed to receive commands intermittently with no reliability. When analyzing our data post launch, we saw no logged RAFCO commands, and the sequence of recorded images matches the pre-programmed sequence.

- **Camera Deployment:** While troubleshooting the issues with our radio, one of the two lead screws used in our deployment mechanism broke off. We attempted to repair it, but reinstalling it was causing further problems and we were very close to our designated launch time. The decision was made to launch with only a single lead screw, which was still capable of pushing open the hatch. However, upon landing the lack of both lead screws caused the entire linear elevator mechanism to fall apart, as seen in the above photo.
- **Record Images with Filters:** Following the pre-programmed command sequence, our camera was able to capture four images, each with a timestamp. The recorded times were off by one hour due to issues with setting the correct time-zone on our raspberry pi but were otherwise accurate. The first image used no filters, followed by grayscale, our special filter (which overlays a secondary image) and finally a flip of the image.

We have learned much from both the successes and failures of our payload, which we will apply in our future projects.

4.2.2.2 Telemetry

During our project, we encountered both successes and failures in our individual subsystems. Unfortunately, our main failure was a critical one: nothing worked as expected due to our PCB failing, and without any backups, we were unable to recover the system. This was a difficult setback, but it also taught us an important lesson about the need for redundancy and contingency planning. Going forward, we will ensure that we have backups for critical components, to minimize the risk of a complete system failure.

On the positive side, one of our successes was the development of a modular and working master code for the flight computers. This was a significant achievement that required the coordination of multiple subsystems and the integration of complex hardware and software components. We learned a great deal about the importance of testing, debugging, and iterative development, as well as the value of collaboration and communication among team members. The master code provides a solid foundation for future flight computer development and will allow us to build on our successes while avoiding the mistakes of the past. Overall, while we faced significant challenges during this project, we emerged with valuable insights and a stronger foundation for future work.

4.2.3 Safety

The USLI safety officer established a safety hazard analysis method by assigning a letter and number to each event, based on their respective likelihood and severity. This allowed for a more efficient description of each event and ensured that they were treated accordingly to minimize potential accidents. To further mitigate safety risks, extensive research was conducted on products, tools, and methods to produce Manufacturing Process Procedures. These documents instructed students on the process description of each tool, how to use them in a numerical step-by-step format, and established specifications on the condition and corrective action of each step. Additionally, each subsystem was given and required to utilize a pre-flight checklist. These checklists highlighted the materials required on-site for each system and provided step-by-step instructions on how to assemble and check each component for readiness. Moreover, test procedures were enacted to further validate the successful functionality of our systems during the launch. While the utilization of these documents was a success, the USLI team faced challenges when working on-site during launches. Although there were no major safety failures, instances occurred where students did not comply with the safety officer, resulting in disruptions during assembly and poor communication overall. These moments served as valuable lessons that were addressed and not repeated during later launches.

4.3 Summary of overall experience

Participating in the NASA Student Launch was a new and valuable experience for the University of Central Florida's USLI team. Our team consisted of seasoned upperclassmen and enthusiastic freshmen who were eager to learn and contribute to the project. With varying technical skills and communication abilities, we faced several learning curves throughout the project. Overall, participating in the NASA Student Launch provided our team with an above-amateur-level understanding of how rockets are manufactured, assembled, and launched. Our team members left the project with new technical skills, enhanced communication abilities, and a deeper appreciation for the importance of teamwork and collaboration in achieving a common goal.

4.4 Total Hours

Student Launch Activities	Hours Spent
Proposal	336.00
PDR	184.00
CDR	260.00
FRR	220.00
FRR addendum	33.00
PLAR	48.00
STEM Engagement	24.00
Social Media	2.00
Launch Activities	60.00
Total Hours	1167.00

4.5 STEM Engagement summary

Through our parent club, Knights Experimental Rocketry, the USLI team of the University of Central Florida reached approximately 2,000 individuals through ten STEM engagement activities. Six of our engagement activities were categorized as workshops, wherein students had the opportunity to acquire complex skills applicable to the industry environment, such as hardware and manufacturing, Arduino, and Open Motor. Our most significant engagement activity was when our team presented both our rocket and payload to four introductions to engineering classes, effectively reaching over 1,000 students. Moreover, we were privileged to be invited by the University of Central Florida to present during a STEM Seminar, where we showcased our project to over 400 individuals. While the USLI team felt accomplished by the students we reached, there were events that we, unfortunately, did not have the chance to host, such as collaborating with the National Society of Black Engineers to teach 3rd to 5th graders about rocketry.

4.6 Final Budget summary

The University of Central Florida's student government granted our team a $3,000 bill, exclusively allocated for the USLI project. All purchases were filed through the ASF office's accountant and covered all fees associated with vehicle design, as well as a significant portion of the payload's budget. However, due to unforeseen circumstances, the Florida Space Grant Consortium was unable to provide the $3,000 matching contribution. Nevertheless, our parent club, Knights Experimental Rocketry, continued to acquire funds. Furthermore, the parent club secured sponsorships from Blue Origin and Lockheed Martin, which enabled us to meet our matching grant requirements and allowed us to pay additional expenses for the project. Regarding travel expenses, approximately $2,300 was reimbursed to students who drove to and from Alabama. In terms of lodging, the Student Government agreed to cover half of the lodging costs with a similar matching contribution. Rough estimates suggest the lodging costs amounted to approximately $3,000, including taxes, which were accrued via member funds. The aerostructures budget was approximately $2,300, the payloads budget was $1,800, and the propulsion budget was $1,200, resulting in a total of approximately $5,500 for our rocket.