Eclipse-I Post Launch Assessment Review

NASA University Student Launch Initiative Proposal

(2012 – 2013)

Submitted to

NASA Marshall Space Flight Center

University of California, Davis—SpaceED_Rockets Team

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Rocket Summary

Institution Name	University of California, Davis

Vehicle Properties	
Diameter (in)	4"
Length (in)	71.5"
Gross Liftoff Weight (oz)	251.59
Launch Lug/button Size	1"/1.5"
Motor Retention	Slimline ogive boat-tail retainer

Motor Properties	
Motor Manufacturer	Aerotech
Motor Designation	K550W
Max/Average Thrust (N/lb)	655.3/396.8
Total Impulse (N-sec/lb-sec)	1539.1 Ns
Mass pre/post Burn (lb)	3.65/2.087

Stability Analysis	
Center of Pressure (in from nose)	56.2187
Center of Gravity (in from nose)	46.9731
Static Stability Margin	2.31
Thrust-to-Weight Ratio	8.19
Rail Size (in) / Length (in)	1"/96"

Ascent Analysis	
Rail Exit Velocity (ft/s)	78
Max Velocity (ft/s)	538.63
Max Mach Number	0.47
Max Acceleration (ft/s^2)	249.3
Peak Altitude (ft)	4,225

Rocket Performance	
Apogee Altitude	5670 ft
Drift Distance	3115 ft
Max Velocity	725 ft/s

Vehicle Design Summary

The final weight of the launch vehicle, excluding the weight of the motor, prior to lift-off was 251.59 oz. This final weight includes a total motor weight of 52.45oz and 12oz ballast, which was to compensate for the effect of the wind on the launch day. There were no changes made to the dimensions launch vehicle between FFR and lift-off. Hence, final length and diameter of the launch vehicle remained at 71.5 inches and 4 inches respectively. The launch vehicle was recovered after flight with no damage and this validated the structural integrity of the vehicle.

Data Analysis

After the launch of the rocket, the two altimeters, the Raven3 and Stratalogger altimeters, both recorded an altitude of 5670 feet, which does not match the 5280 feet altitude from the simulations performed prior to launch. The drift distance of the rocket measured by the payload GPS was 3115 ft. The discrepancy in altitude is attributed to insufficient ballast weight, which was needed to counteract the effects of the wind on the rocket. However more investigation is needed to determine the exact reason for the mismatch between simulated and actual results. Figures 1 and 2 below show the altitude of the rocket as recorded by the Raven 3 and Stratalogger altimeters.

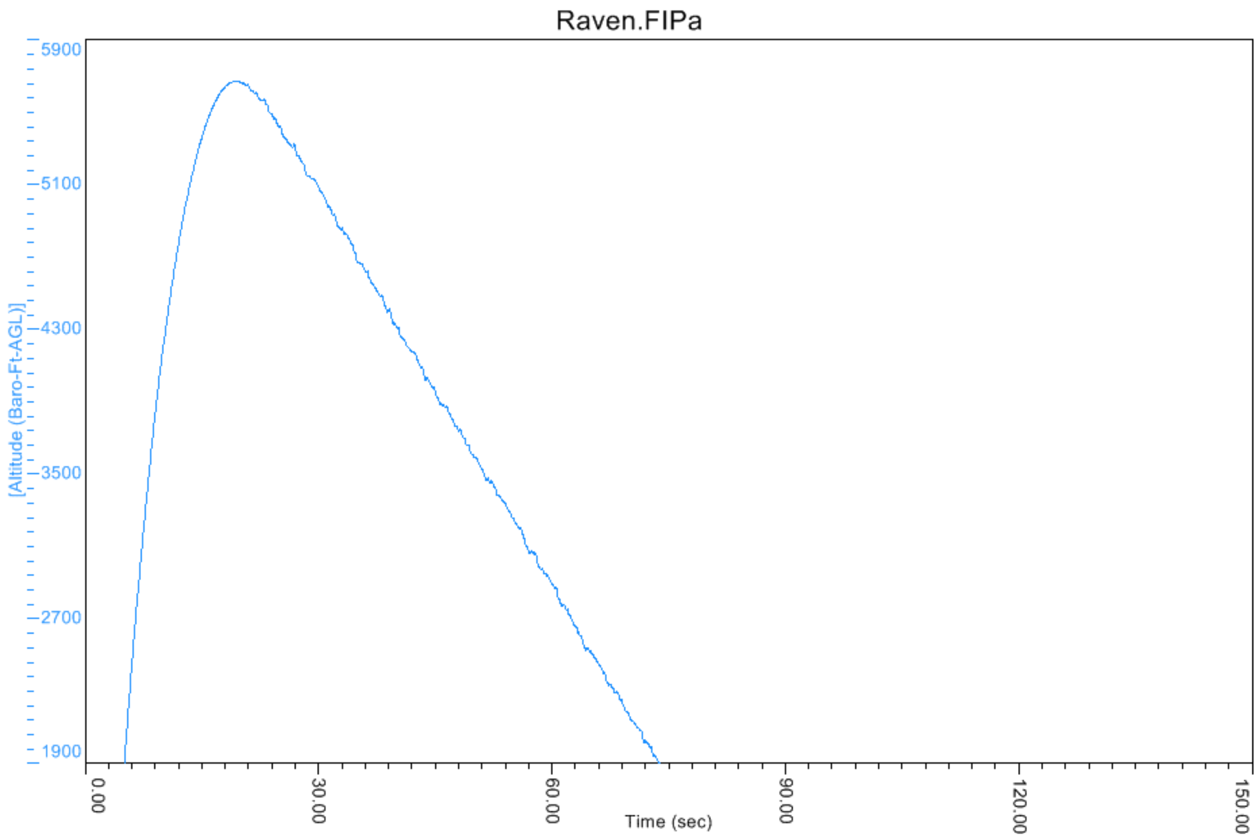

Figure 1 - Altitude of the rocket as recorded by the Raven 3 barometric altimeter

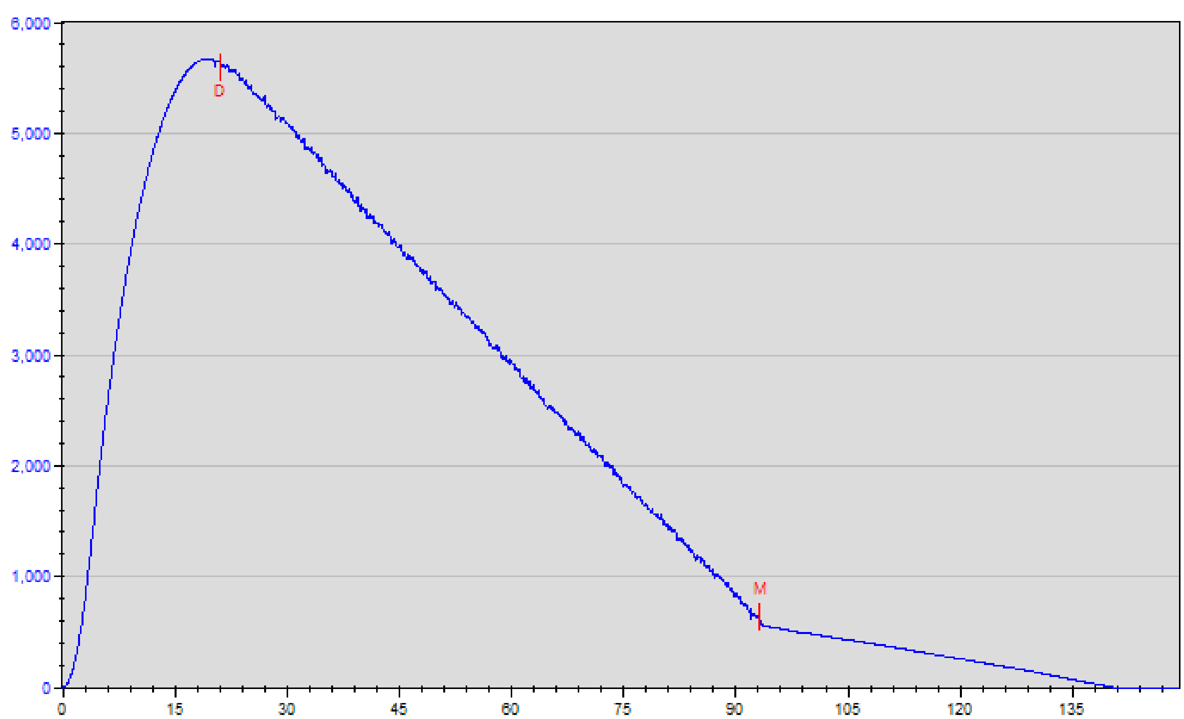

Figure 2 - Altitude of the rocket as recorded by the Stratologger altimeter

Payload Summary

The SpaceEd Rocket Team submitted a Rocket Performance and Atmospheric Evaluation Module (RPAEM) payload containing the ArduPilot Mega 2.0 (APM 2.0) as the data acquisition system with the ATMega 2560 as the core processor. The payload was designed purely as a self-contained performance data acquisition system to collect both atmospheric and dynamic performance data during rocket accent and descent. The data is then analyzed to compare simulation models to actual rocket performance data. The analysis not only helps to understand inconsistences between theoretical and experimental data, but allows for design modification to improve the rockets performance and stability in various atmospheric conditions.

Overall, the payload system includes external and internal sensors measuring solar irradiance, temperature, humidity, triaxial acceleration, altitude, barometric pressure, GPS data, and triaxial angular rotation. The electronics are mounted in an elevated position using silicon vibration dampening mounts on a G-10 fiberglass board. In addition, the payload is powered by a 2600 mAh lithium polymer battery, and maintains a total weight of 13 ounces (including the bay and bulkheads). Custom firmware was developed by the SpaceEd Rocket Team that assembles the measurements from all of the sensors into discrete packets on the APM 2.0. The packets are wirelessly sent to a ground station, via 915MHz transmitter, and logged in onboard non-volatile memory.

The ground station itself is a modification of open source software (QGroundControl) to receive and parse the wireless data transmitted from the rocket. The communication protocol implemented between the ground station and the rocket is a redundant algorithm that allows for the extraction of all measured data from the rockets onboard memory. This protocol was developed in the event a packet is dropped or communication is temporarily interrupted.

Payload Data Analysis and Results

The final flight of the rocket went to an altitude of 5670 feet, which is 390 feet above the target altitude. Data was collected during the entire flight of the rocket; however, significant errors and mismatching of theoretical values occurred within the received data. For instance, the altitude reached is within troposphere which allows for simple theoretical correlations. Temperature should decrease linearly within the troposphere at a rate of -9.8ºC/km, but the data collected shows a semi-constant temperature for the entire rocket flight. In addition, many of the other sensors, such as humidity, gave incorrect correlations as well.

The main reason for the errors is for exceeding the design capability of the data acquisition system. The system is rated to a maximum of 4g’s of acceleration, which is typical for consumer available electronics and electronic systems. However, as the design was changed for an overall lighter weight, a smoother surface finish, and the more powerful Aerotech K-550 motor the acceleration at liftoff was too much for the board the function properly.

The test launch that was done of the full-scale rocket on March 2, 2013 (with the Aerotech K-550) showed the board functioned properly during the entire flight to an altitude of over 4700ft in a 13 knot wind. However, the USLI competition flight went nearly 1000’ higher meaning a higher acceleration was reached. As stated, the high acceleration led to errors within the data. On the other hand, during post processing, some of the data was extrapolated for the flight of the rocket to yield more reasonable values. For instance, the altitude, which was measured by a correlation of the barometric pressure, shows a flight to 6422ft referenced from sea level (or 5614ft from ground level). This correlates well with the altitude recorded from the separate redundant altimeters of 5670 ft.

All the data is given below in graphical form in Figure 3-8. The errors are obvious in Figure 5 and 6 for temperature and humidity, but are more subtle in the other data.

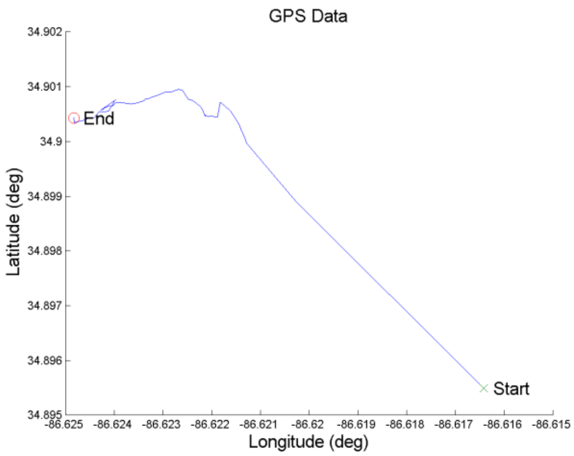

Figure 3 - GPS Data

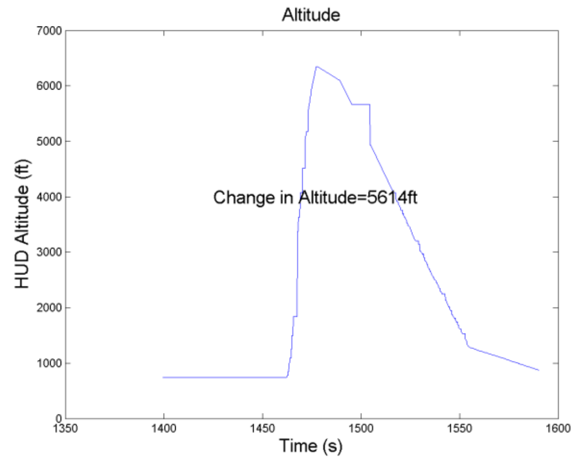

Figure 4 - Altitude Data

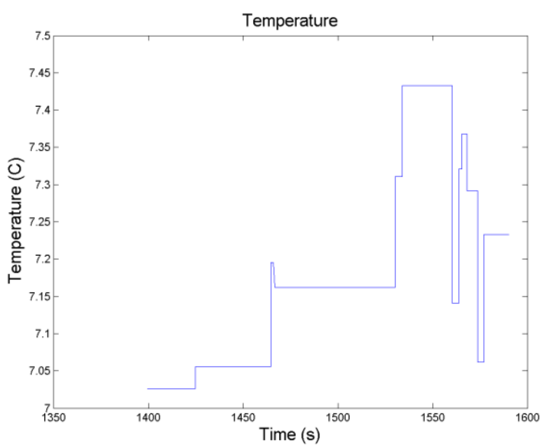

Figure 5 - Temperature

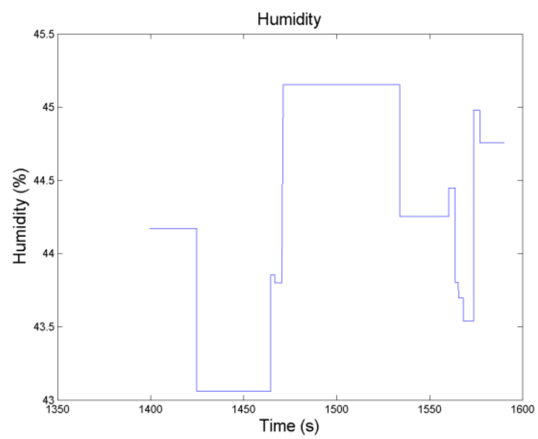

Figure 6 - Humidty

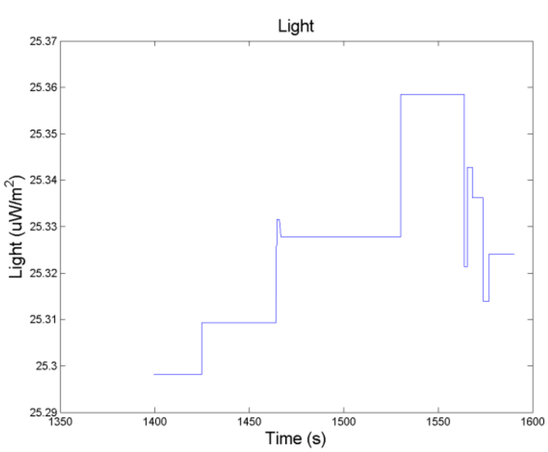

Figure 7 - Solar Irradiance

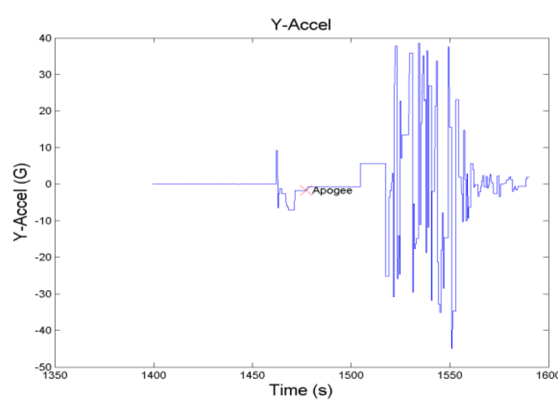

Figure 8 - Axial Acceleration

Science Value:

The objective of the payload is to collect atmospheric data and model the rockets dynamic behavior during flight. Constantly monitoring atmospheric conditions helps create flight performance profiles that help predict the effects on the rockets flight during various weather patterns. Thus, the ability to accurately measure atmospheric data is essential. In addition, measuring a rocket's dynamic behavior, such as triaxial rotation, combined with the atmospheric data leads to improved rocket designs and performance characteristics. The data obtained was used in comparison to scientific models on weather pattern effect to draw correlations between the predicted flight path and performance and the experimental.

Visual Data Observed

The most significant visual data gained from the rocket's flight occurred within seconds of ignition. Immediately off the launch pad, the UC Davis rocket was displaced from vertical, presumably by a gust of wind or possibly a thrust anomaly. As the rocket picked up speed, the stabilizing force driven by drag grew and the rocket quickly corrected itself, flying vertically for the remainder of the flight. On prior tests, the rocket flew very straight from start to finish. The disturbance in the competition flight may have been caused by a redistribution of weight in the rocket due to a modified ballast system. The static margin of the rocket suffered a small amount from this redistribution.

Lessons Learned

This was UC Davis' first year competing in NASA USLI. The entire experience was enlightening for all team members in many ways. While the teams flight was considered a success, the flight well exceeded the goal (and predicted value) that the team was aiming for. An improved testing procedure would have made it considerably easier to achieve the desired apogee of 1 mile. Increasing the number of full scale tests from 2 to 3 would provide a boost in real world data and confidence in the team's final weight and aerodynamic decisions. Perhaps more important than the number of flights, however, is the quality of each test conducted. The team would have benefited from a test flight with the rocket in its absolute final configuration. While the team aimed to achieve this, it turned out that many small things were still changed leading up to the competition. Painting the rocket, with the extremely smooth surface that resulted, seems to have affected flight more than expected. The data the team gained from 2 test flights before competition indicated an apogee of about 2.5% BELOW that predicted by rocksim; the competition flight ended up about 7.5% ABOVE the simulation, effectively disqualifying the team. A test flight with the rocket in absolute final weight and surface finish would have allowed the team to nail down the value of simulated data.

The team learned a lot about what it takes to deliver an effective review and accompanying report. The disjointed and inconsistent sections individuals submitted to the captain for final organization proved to be almost incompatible, and each report was rushed through in the end. Better organization and a clear set of guidelines for each individual’s writing and formatting would be helpful.

Finally, organization of a small team (<15 people, perhaps) such should be as simple as possible. The UC Davis team tried to impose a corporate-styled structure, with many sub teams and captains of each. This created conflict in the selection of captains, confusion in the assignment of duties, and potentially stemmed initiative of members who have cross-discipline knowledge. The function of a small team’s leadership should be final decision making and organization; a capable captain should be able to handle these responsibilities. Any excess authority is pointless and stratifies the team.

The aerodynamics and propulsion group learned a lot regarding team work and how every component of the rocket affects the overall performance of the flight vehicle. Not knowing what to expect for a first-year team, the students hoped to gain as much experience in working in a team environment while doing what they love. As report deadlines were near, team members met to discuss and assigned sections to each individual. Conflicts arose when some members of the team were busier than others in terms of school and work. This, of course, was expected and the students managed to improvise and organized a schedule that suites best for the team. While having a busy school life, the team still manages to dedicate enough time to write the best possible reports they could.

In terms of motor selection, the team spent several meetings discussing if a more powerful motor was necessary. The team was initially skeptical of both the simulation and actual flight data since they did not agree. Students quickly realized that the configuration and weight in the simulation file did not match the actual rocket’s specifications. As a result, these mistakes were quickly corrected and the team decided that a motor change will benefit the success of the mission. However, during competition day, the rocket flew over 5600 feet. This was unexpected because the simulations were thought to give decent accuracy. In the end, the team learned that simulations can be useful, but it is difficult to judge just how accurate they are compared to actual results. In order to obtain adequate results from simulations, more trial runs have to be performed.

Educational Engagement

SpaceED Rockets has had an overall success in terms of not only teaching elementary and middle school students about rocketry, but also learning how to teach and reach out to the community. SpaceED Rockets hosted 35 middle school students, giving them a brief presentation on rocketry basics and the team's progress in the USLI competition. About fifteen model rockets were passed around during the presentation for students to take apart and observe a rocket's basic components. Following the presentation, students were given a hands-on project in which they build paper rockets either individually or in small groups. Each paper rocket was then launched off of a PVC pipe rocket launcher SpaceED Rockets had made specifically for their educational engagement programs.

With this presentation, SpaceED Rockets has successfully exceeded the Educational Engagement requirements of the USLI competition, with a total of 367 students engaged. Still, the team has continued to contact elementary, middle, and high schools throughout northern California, and hopefully will proceed with as many presentations as possible in the near future. Furthermore, as it starts to get warmer outside, the team is looking into the possibility of having a "field day" on UC Davis campus to which multiple schools would be invited for a large presentation, provide students with different projects, and host small competitions.

Lastly, the team has sought out a way to become more involved with the local community, so SpaceED Rockets has started to plan monthly model rocket launches at parks in Davis. Thus far, these monthly launches have not been formally planned, but every time team members do their personal launches curious children in the area come look at the rockets. In the coming months, the team is hopeful to have a more formal way of advertising launch days so that the entire community can be involved.

SpaceED Funds

The team has been fortunate enough to have support from our university. Through the College of Engineering and the Mechanical and Aerospace Engineering (MAE) Department, the team acquired a total $2000. The team has spent approximately $2500 in materials alone. The team was also approved for funding support from the Club Finance Council for $1725.56. However, this money can only be used for the purchasing of specific materials and gas costs. In addition, The American Society of Mechanical Engineers has agreed to co-sponsor some of our outreach events. With the help of Dr. Susan Ustin and the California Space Grant Consortium the team's travel expenses were fully covered.

Material Costs

Type	Cost	Quantity	Total
Recovery System	$664.68	1	$664.68
Structure	$761.28	1	$761.28
Air brakes	$21.56	1	$21.56
Propulsion	$467.33	1	$467.33
Payload	$480.51	1	$480.51
Miscellaneous	$47.97	1	$47.97
		Total Costs	*$2443.33*

Funding

Program	Quantity	Restricted	Type
MAE Department	$1,000	No	Materials
College of Engineering	$1,000	No	Materials
Club Finance Council	$322.43	Yes- CFC	Gas
	$1,403.13	Yes- CFC	Rocket Kits
Total Funding for Materials	*$3,403.13*		
Total Funding	*$3,726*		

Conclusion

Participation in the NASA University Student Launch Initiative was a great and essential learning opportunity for all students involved. Although the final altitude of the rocket exceeded limits, the experience gained and lessons learned by going through the design and competition process is invaluable. Being a first year team, having successfully made it to competition and through the entire USLI process has helped to secure the future of the team and encourage support for future years. The team is greatful for