Harvey Mudd College

University Student Launch Initiative

Post Launch Assessment Review 2011-2012

Table of Contents

I. Introduction

A. Team Name

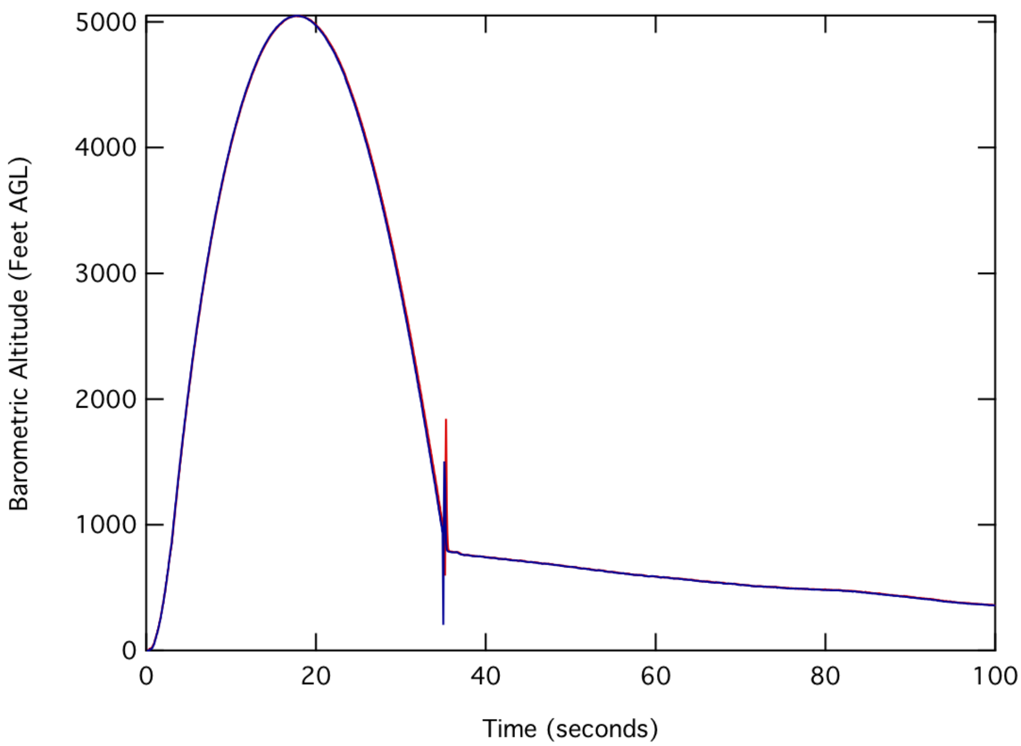
Harvey Mudd College University Student Launch Initiative (HMC-USLI)

B. Motor Used

For our final flight in Huntsville we used a Aerotech J540R.

C. Altitude Reached

Our rocket, the Sub-Sonic Screwdriver, reached an altitude of 5051 feet according to the beeped-out value at landing. The two altimeters recorded values of 5045.8' and 5048.8' feet AGL.



Barometric altitude as recorded by the onboard Raven2 flight computers.
Front Raven
Rear Raven

II. Vehicle Description

A. Rocket Height

The rocket stands at 89.4 inches in height.

B. Rocket Diameter

The rocket has a standard 3 inch diameter with an outer diameter of 3.13 inches.

C. Rocket Mass

The unloaded rocket mass was approximately 8.48 lbs.

D. Vehicle Summary

i. Vehicle Size

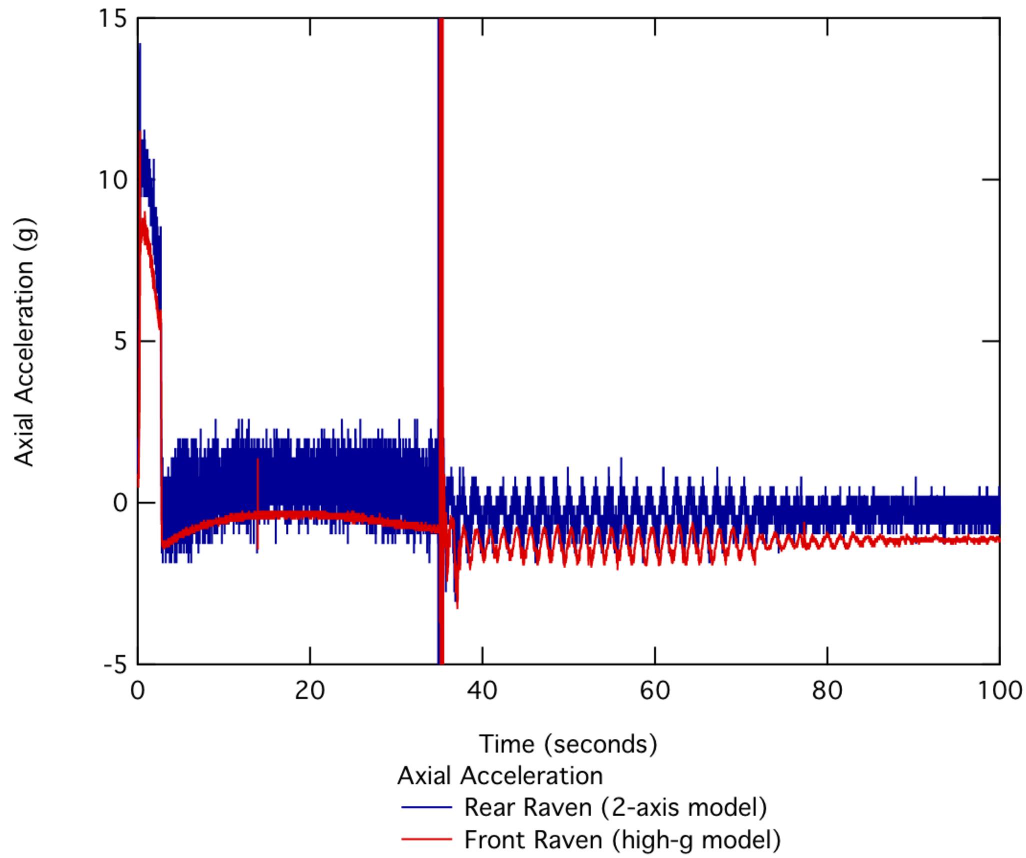
- Total length: 89.4”
- Nose cone length: 15.75”
- Tube diameter: 3” standard tubing (3.13” OD)
- Fin semi-span: 4”
- Fin root chord: 7.5”
- Fin tip chord: 2.5”
- CG: 53 inches from nose, loaded
- CP: 72 inches from nose
- Loaded stability: 6.33 caliber
- Estimated unloaded mass: 8.48 lbs
- Payload bay length: 12”
- Payload bay diameter: 3”
- Rail Size: ¼” wide, 6 ft long, 1” x 1” 80/20

ii. Recovery System

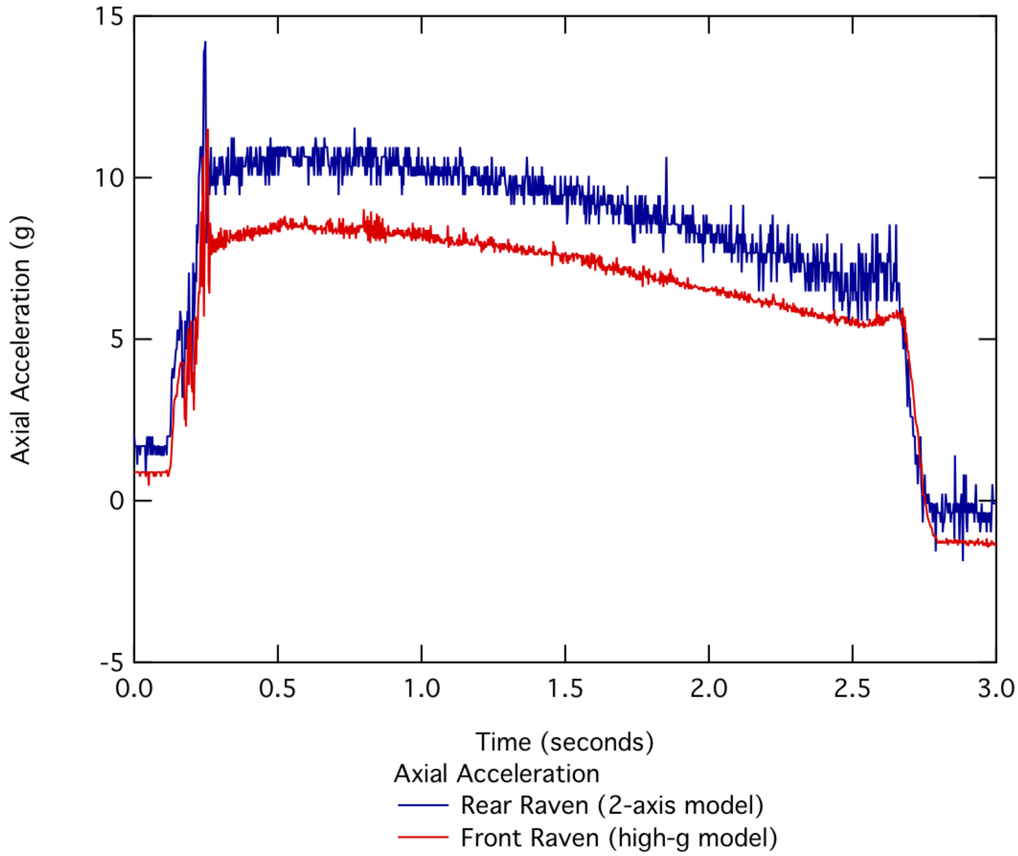
The rocket will rely on a pair of Featherweight Electronics Raven2 altimeters for actuation of dual-deployment. The Raven2’s will be configured for accelerometer-based apogee deployment, and barometric-based main deployment at the specified altitude (1000’). They will draw from separate high-current lithium-ion aerospace-grade 9V batteries, and be wired to separate black powder charges. Both the drogue and main deployment bays will use pistons and tubular kevlar near the black powder charges. The drogue is a 24” Rocketman box parachute, while the main is a 60” Fruity Chutes elliptical parachute.

E. Data Analysis and Results

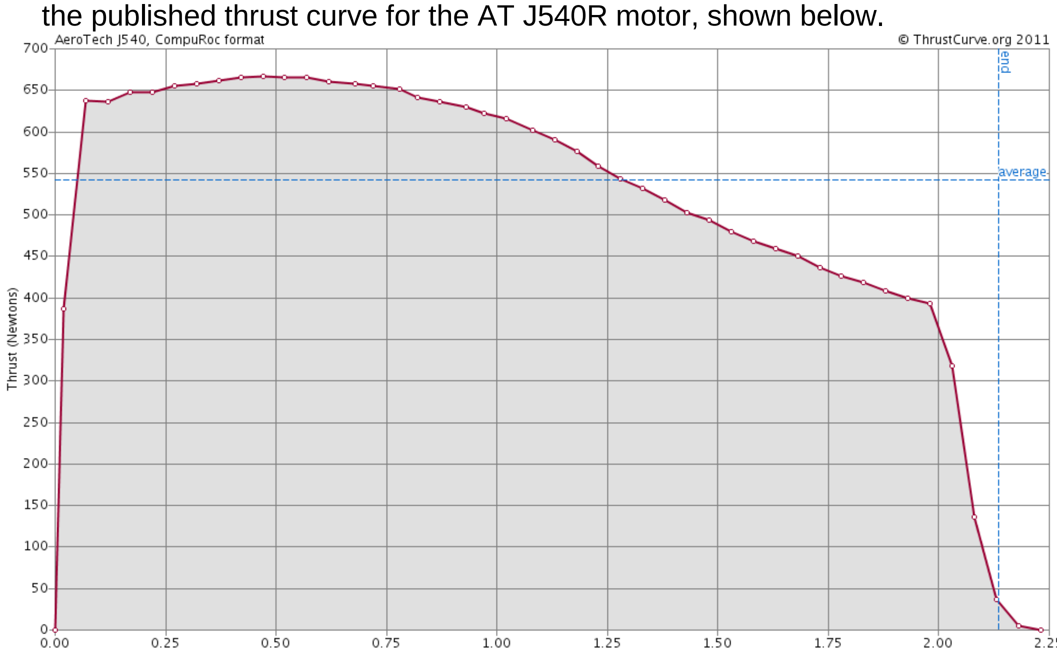
The flight was not successful. Despite the last-minute switch to a higher-impulse motor, severe weathercocking from a stiff wind brought the apogee down to a mere 5051 feet (official scored altitude). Furthermore, the two charges which did go off at apogee failed to separate the rocket, and so the rocket was largely destroyed when the main impacted the ground. The following plots are taken from the onboard Raven2 flight computers.



This plot shows the majority of the flight data from the onboard axial accelerometers on the ravens. We notice several things. First and most strikingly is the spike in acceleration at ~35 seconds; this was the main parachute deployment. The recorded accelerations actually clipped both the 70g-range accelerometer on the rear raven, and the 250g-range accelerometer on the front raven. It's also interesting to compare the ravens directly; the 70g-range raven clearly has more noise and a DC offset compared to the 250g raven. This will be taken into consideration on future raven flights where data is a concern. Finally, note the spike at ~18s on the Front raven trace; this is the apogee event, which fired (as determined by this spike, the current output data, and the burned charges). The oscillatory behavior shown after the destructive main event is due to the nosecone swinging back and forth under the main chute.



This plot is enlarged to show the thrust curves recorded; they are in agreement with the published thrust curve for the AT J540R motor, shown below.



F. Experience Summary

The process of constructing the launch vehicle was rewarding and yielded a significantly greater understanding for the complexity of fully redundant systems. The fabrication of various parts of the rocket provided useful experience in vehicle construction which will help improve future exploration into the realm of high power rocketry. In attempting to reach our goal to create the smallest, most efficient launch vehicle we gained a greater appreciation for the difficulties in creating such a design.

In the future, though we would still be interested in creating efficient vehicle we would like to potentially create a wiring system which would be more easily constructed and altered during the process. The wiring through the shock cord, though effective in testing, may not have been the simplest or best method which we could have used. Additionally, in creating an efficient vehicle we also made the choice to use the minimum amount of black powder necessary. In the future we would instead use the largest amount of black powder which would safely separate the rocket without causing any damage.

Overall, the construction of the rocket provided the team with a greater understanding of the fabrication process as well as a greater appreciation for design efficiency. Although the launch was not entirely effective, we learned a significant amount about rocketry in general.

III. Payload Description

A. Brief Description

The payload flown in the vehicle was designed according to the NASA SMD specification to record climate data as well as solar intensity data. It was located above the booster of the rocket, away from the recovery electronics. In addition to the sensors and electronics installed to meet the NASA SMD specification, a 6-axis accelerometer was included to analyze flight characteristics in the event of rocket failure.

The payload operated as expected during flight with the exception of the cameras. Following impact, the payload electronics continued to operate normally. GPS position data transmitted wirelessly was used successfully to locate the rocket.

B. Expanded Description

The payload flown consisted of the following primary components:

Primary Electronics

- ArduPilot Mega with ATMega 2560
- ArduPilot Mega IMU Shield/OilPan Rev-H V1.0
- Maxim MAX127 12-bit, 8-channel, 8ksps A/D Converter

- XBee Pro 900 Wireless Data Transmission System
- MediaTek MT3329 10Hz GPS
- 3x OmniVision OV9712 720p Cameras

Sensor Package

- Honeywell HEL-705-T Platinum RTD Thermometer
- Freescale MPXAZ6115A Absolute Pressure Sensor
- Thorlabs FGAP71 GaP Photodiode
    - 150nm-550nm effective wavelength
    - A 400nm shortpass filter will be installed to cut the effective wavelength to 150-400nm
- Thorlabs FDS100 Si Photodiode
    - 350nm-1100nm effective wavelength
    - A 400nm longpass filter will be installed to cut the effective wavelength to 400nm-1100nm
- Thorlabs FGA21 InGaAs Photodiode.
    - 800nm-1800nm effective wavelength
    - A 1100nm longpass filter will be installed to cut the effective wavelength to 1100nm-1800nm
- Honeywell HIH-5030 Relative Humidity Sensor
- Microchip MCP6004 Quad Operational Amplifier
- Microchip Analog Devices AD623 Instrumentation Amplifier

Power Subsystem

- 2x 7805 5V Voltage Regulators
- MCP1702-3302E 3.3V Voltage Regulator
- 7.4 V 2600mah Lithium Polymer Battery

All components operated normally before and after flight with the exception of the cameras. It is suspected that the camera start packet sent to the XBee Pro 900 was dropped, and that recording never began prior to flight. However, video following impact was present on one camera. This suggests that the cameras were on but not recording, and that the impact of the landing had triggered the mechanical relay controlling that camera.

The scientific experiment performed by the electronic payload involved quantifying the absorption of 3 separate wavelength bands of light by the atmosphere as a function of altitude. The wavelength bands measured were 150nm-400nm (UV), 400-1100nm (visible-NIR), and 1100nm-1800nm (NIR). This was achieved using three separate photodiode elements located in close proximity. To ensure that the data from each separate photodiode contained the wavelengths of interest, the following filters were installed on each sensor in order to isolate each wavelength band to their respective photodiode.

- A 400nm shortpass filter was installed onto the Thorlabs FGAP71 GaP Photodiode to cut the effective wavelength to 150-400nm
- A 400nm longpass filter was installed onto the Thorlabs FDS100 Si Photodiode to cut the effective wavelength to 400nm-1100nm

- A 1100nm longpass filter was installed onto the Thorlabs FGA21 InGaAs Photodiode to cut the effective wavelength to 1100nm-1800nm

A Honeywell HEL-5030 Humidity sensor was used to measure relative humidity. Since water vapor displays many photoabsorption properties over a large range of wavelengths, humidity is a relevant variable to include in the analysis of photointensity as a function of altitude.

Altitude data was recorded using a Freescale MPXAZ6115A absolute pressure sensor and temperature data was recorded using a Honeywell HEL-705-T Resistance Temperature Detector.

The experiment complied with the guidelines set by the NASA Science Mission Directorate for a sponsored payload.

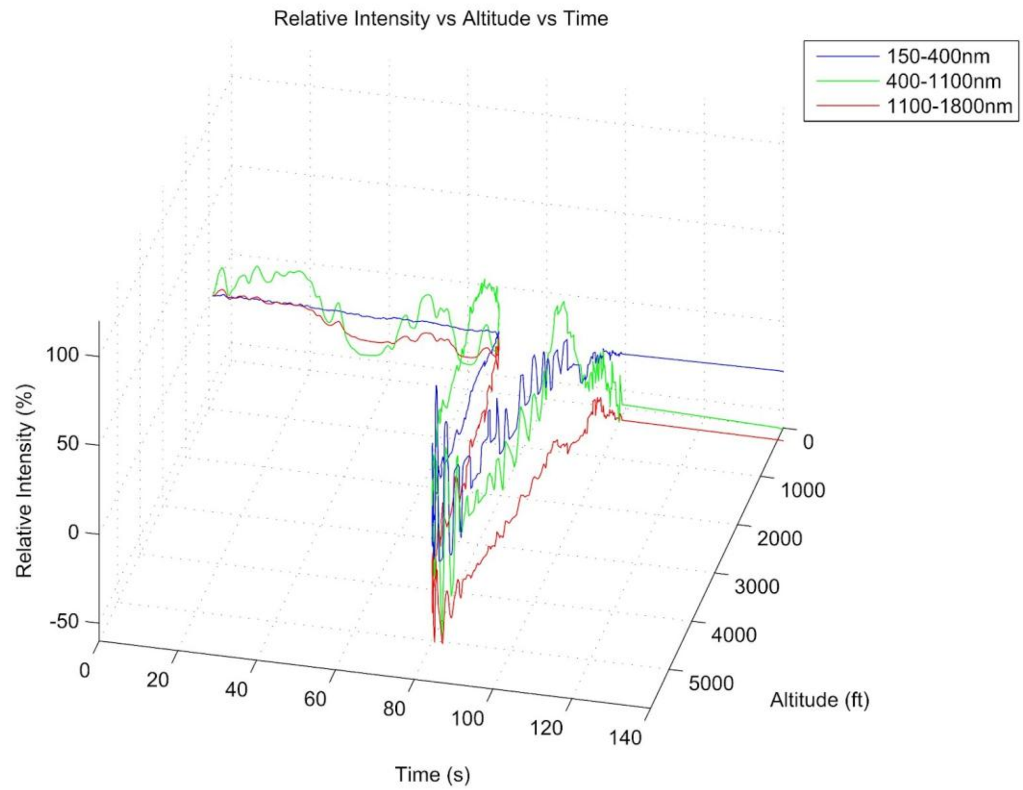
C. Data Analysis and Results

As outlined in the FRR, the experimental goal of the payload is to generate the following plots:

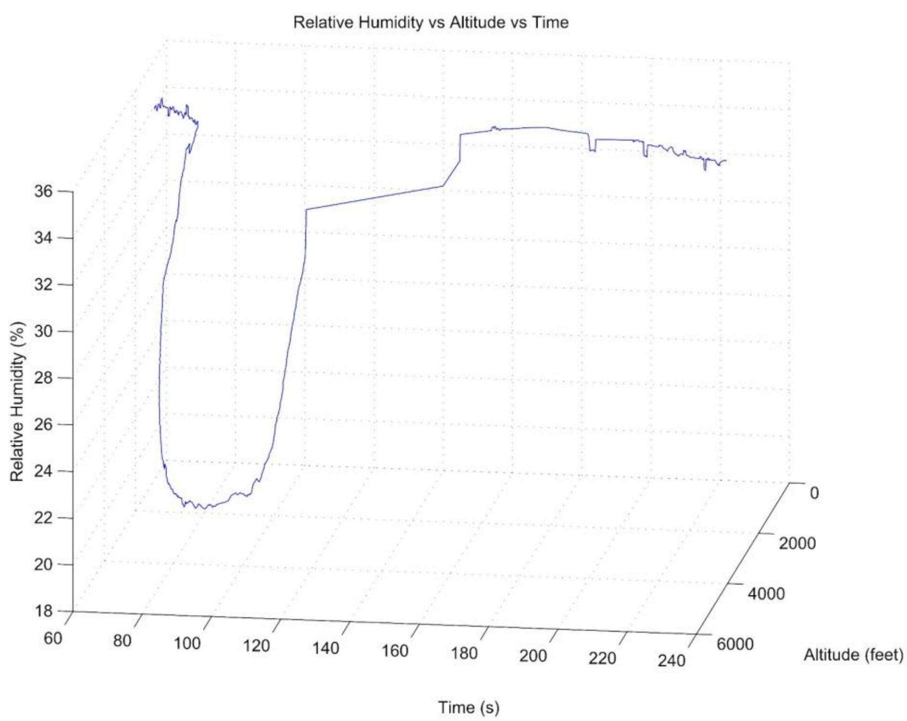
1. Photointensity with respect to Altitude
2. Humidity with respect to Altitude
3. Photointensity with respect to Humidity
4. Altitude with respect to Time
5. Humidity with respect to Time
6. Photointensity with respect to Time

The data is presented below.

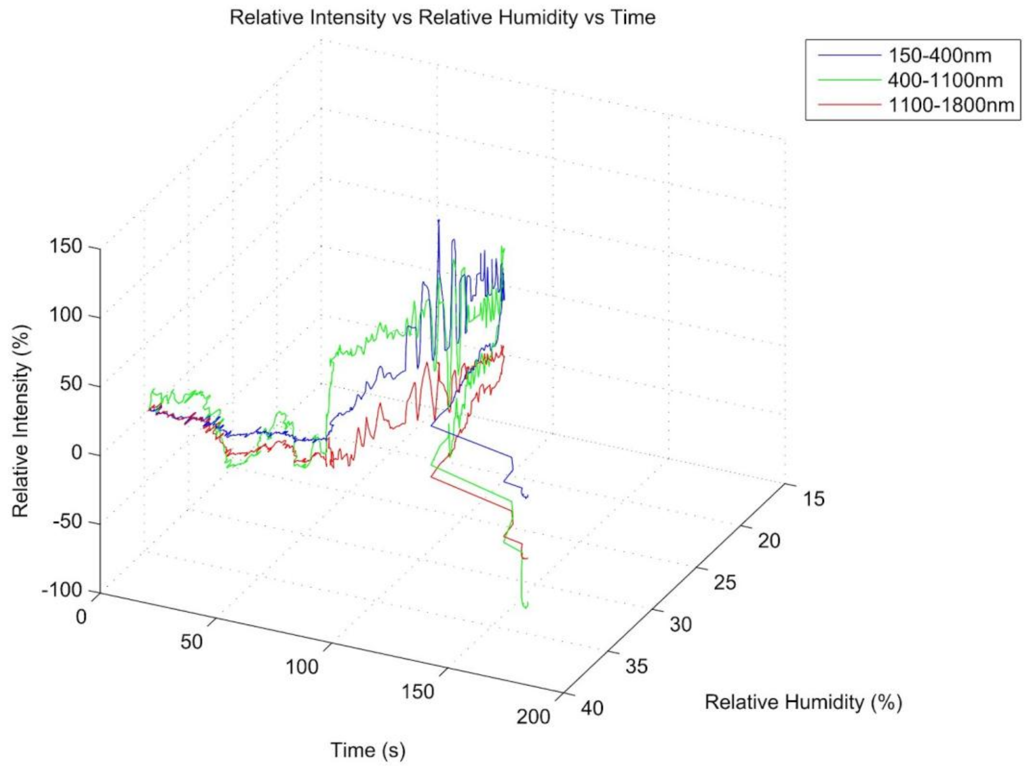
1. Photointensity with respect to Altitude



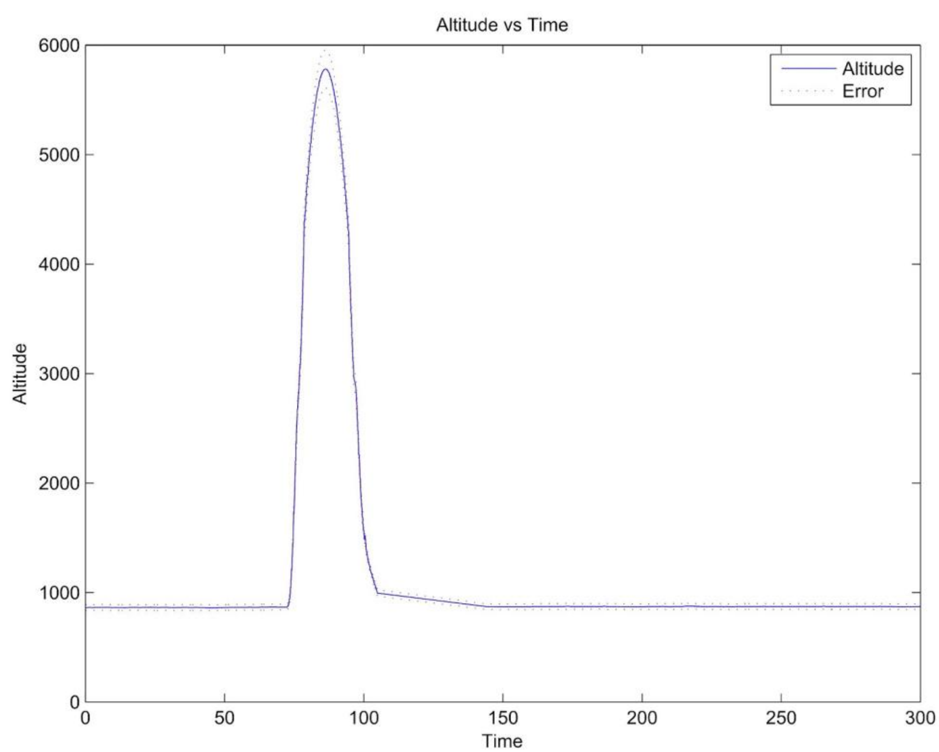
2. Humidity with respect to Altitude



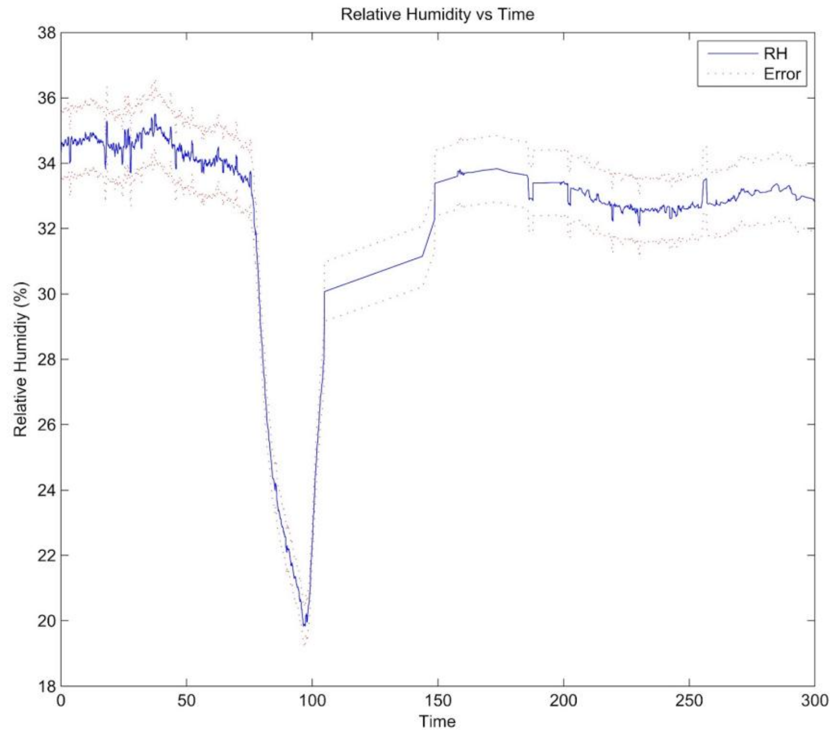
3. Photointensity with respect to Humidity



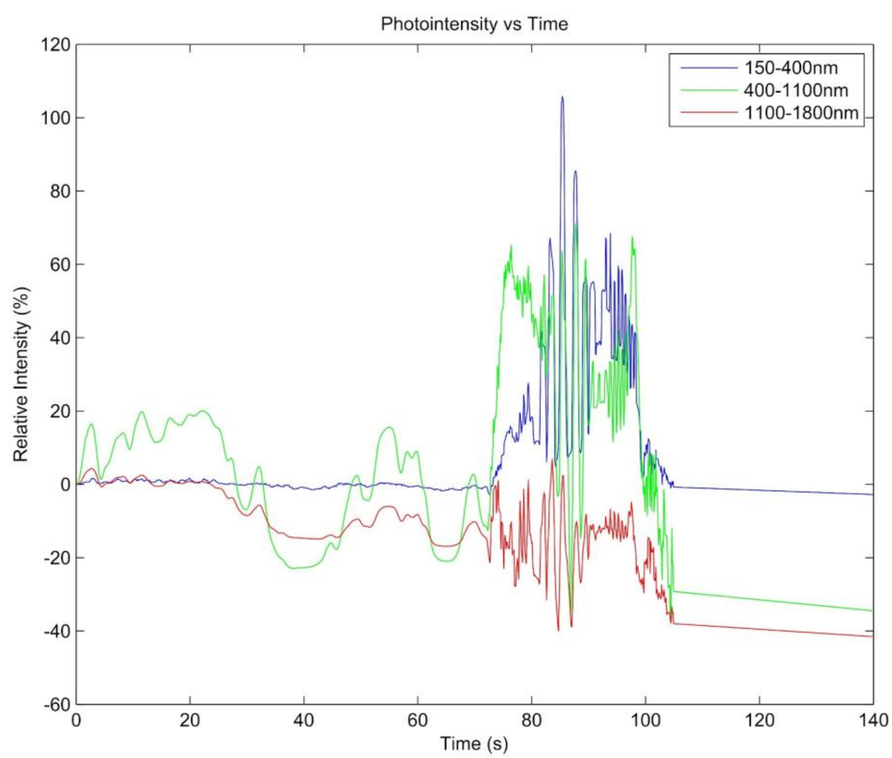
4. Altitude with respect to Time



5. Humidity with respect to Time



6. Photointensity with respect to Time



Photointensity is measured relative to levels recorded on the ground prior to flight. Relative humidity is temperature compensated using readings from the RTD temperature sensor. Altitude is calculated using the BMP05 barometric pressure sensor due to bit overflow in the data recorded by the MPXZA6115A. Calculated apogee was approximately 5022 feet, slightly lower than that measured by the Ravens located in the recovery electronics compartment (5051 feet). Rise to apogee can be observed to occur around 90 seconds from data initialization.

As expected, humidity at apogee is lower than at ground. Plots 2 , 4, and 5 confirm this trend. The vehicle did not fly through a cloud, as confirmed by review of launch day video and the data revealing no significant rise in humidity while the vehicle is on its way to apogee. As seen in Plots 1, 3, and 6, the average photointensity of 150-400nm and 400-1100nm light increases with altitude. Light in the IR spectrum (1100-1800nm) remains of approximately the same intensity. Photodiode readings following apogee are not taken into account due to the improper deployment of the drogue to orient the payload bay in a vertical position required for the photodiodes to receive solar radiation.

The simple conclusions that can be drawn from this data are that water vapor affects the transmission of light in the 150-1100nm spectrum but does not affect the transmission of light in the 1100-1800nm spectrum. However, to verify and elaborate on these conclusions, further testing must be performed. The flight trajectory of the payload was unexpected and did not produce a full set of data required for full analysis. Calibration to relate photodiode readings with absolute light intensity would be required to distinguish direct solar intensity data from reflected solar intensity data. In addition, a camera mounted in the direction of the photodiodes would be useful in determining if the photodiode port was facing the Sun at a given point in time.

D. Scientific Value

The scientific value of the data acquired from the flight is inconclusive. Given the ballistic trajectory of the payload, data acquired on descent was discarded given the tumbling of the vehicle under no parachute. Given a longer window in which to acquire a steady flow of data during flight, more definitive conclusions could be made about the relationship between the photoabsorption of light by the atmosphere and altitude. Unfortunately, the same experiment cannot be performed without reconstruction of the launch vehicle.

E. Visual Data Observed

Malfunction of the camera control system prior to launch resulted in no video recorded. Video of launch day from NASA revealed severe weathercocking of the vehicle off the pad. This explained the discrepancy in apogee altitude from simulations in RASAero and RockSim.

F. Experience Summary

Building, testing, and following the continued operation of the payload following a ballistic landing was extremely rewarding. Although further testing of the camera control system would have been beneficial towards the final launch, the success of the majority of the systems onboard the payload confirmed it to be a well-thought-out and robust piece of engineering. The team learned a lot about the prototyping process of board-mount electronics as well as the importance of performing functionality testing following the development of each component. The design process of the payload was very insightful; in the future, the team will consider including more redundancy in systems to prevent mission-critical components from failing.

IV. Activity Plan

A. Educational Engagement Summary

Through four educational engagement workshops, we reached a total of 73 students and educators. The workshops were highly successful and had no safety issues. Each workshop consisted of a short physics discussion followed by the construction and launch of small Payloader One kit rockets using A6-4 motors. In student feedback, almost 70% of participants expressed an increase in their desire to study science or engineering as a result of the workshop.

Despite the success of the workshops, we were not able to reach the goal of 100 students. Although the team had scheduled time for more workshops, supplier delays prevented us from holding the last workshop to complete our goal. Another major limiting factor was our small team, which limited the number of students per workshop to approximately 30. A future team would certainly be able to reach the 100-student goal by having more team members, using established contacts, and ordering supplies further in advance.

B. Budget Summary

The final expenses for the project were $9435.13, slightly lower than projected. The remaining amount in the budget was $3814.87, which we plan to use for future teams or other rocketry-related expenses. This will allow us to be more financially confident in future years, which will permit more ambitious vehicle or payload designs.

V. Conclusion

A. Lessons Learned

Through the course of this project, we have learned a lot about the design, construction, and bureaucratic process involved in NASA engineering. Some of the major lessons learned from this process are summarized here:

1. Double check everything, twice.

   Though we had prepared a flight checklist for the day of the launch, we did encounter some problems which could have been avoided with a more thorough rechecking of every aspect of the rocket. This includes double checking the programming of all electronics and testing the data collection system before launch.

2. Be better prepared.

   This competition was difficult in part because we were unable to transport all our usual materials since we had to fly to the competition. This meant that we were not fully prepared with all the materials needed to set up the rocket and thus had to borrow materials from other teams or make the best with what little we had available. This proved problematic when picking up our black powder and may have been partially responsible for the failed recovery.

3. Minimization is not always best.

   Part of our design goal focused on creating the smallest, most efficient design possible. This translated in part to our selection for the size of each black powder charge in the rocket. However, this minimization proved potentially problematic during our launch in Huntsville since our separation failed. In the future, it seems that instead of trying to minimize everything it would be best to select the maximum amount of black powder which would provide separation without causing any damage to the rocket.

4. Start early and plan ahead.

   There were a couple times during this project when we were faced with a time crunch in completing various tasks. This is in part due to organizational problems and in part due to the difficult schedule and workload from our university. To counteract the problems provided by the university, we would attempt to develop a stricter schedule to help complete all tasks earlier. This would help to limit the stress towards the end of the project (which falls the week before our finals) and would hopefully lead to a better quality of work and workmanship.

5. Contact reliable vendors

During this project we had multiple problems with the reliability of our vendors. In two cases, the unreliability caused us to be unable to complete the tasks at hand and made the overall process much more difficult. As such, in the future we would attempt to develop relationships with more reliable vendors which would facilitate the ease of which various projects could be completed.

Overall, we learned many lessons from this competition all of which will be useful for any future team which decides to participate in the competition.

B. Experience Summary

The experience of constructing the vehicle and payload provided the team as a whole with a lot of useful insight into the design and fabrication process. This insight will prove particularly useful for any future teams participating in the University Student Launch Initiative and in any other endeavours into high power rocketry.

The team participation in the educational engagement process was also very rewarding. Because of the quantity requirement for educational engagement, the HMC USLI team focused on existing connections to conduct educational outreach. Though it was wonderful working with all of the children that we did, some team members expressed interest in trying to work with underprivileged children in the future. For this project we worked with children from wealthy neighborhoods, so we believe that it would be beneficial to work with underprivileged children in the future since it holds the potential to make more of a difference.

The rest of the competition was an interesting and beneficial experience. The team agreed that our participation within this competition was a worthwhile experience which provided the team with useful insight into the NASA engineering and design process. Despite the failed launch, we enjoyed our time in Huntsville and the opportunity to see the projects from other teams. We enjoyed participating and would like to encourage and assist a larger team to participate in the future.