# University of Iowa AIAA Post-Launch Assessment Review

4/29/2016


**Team Members:**
Austin Brenner
Andrew Opyd
Ryan Bellamy
Alec Archer
Frank Schmitz
Victoria Trojanowski
Matthew Driggers

**Honorable mention:**
George Grigalashvili

**Table of Contents**

**Project Overview**

This year, the University of Iowa AIAA team participated in the MAV Centennial Challenge. For this challenge, both a high-power rocket and autonomous ground system were designed and constructed. This system was designed to autonomously pick up a payload and insert it into a bay on the rocket. The bay would then close and the ground system would erect the rocket to launch position. Finally, the ground system would insert the igniters into the rocket motor and launch the rocket. The payload inside the rocket was a simple PVC tube, 3 in long and ¾ in diameter weighing about 4 oz. Since our team participated in the MAY challenge, there was no scientific payload to be launched.

On launch day, the rocket was flown on a Cesaroni K630 motor. The ejection charge in the motor was removed, and the rocket's recovery was done using a dual-deployment system. This system is further described in the *Launch Vehicle Overview* section.

**Launch Vehicle Overview**

The launch vehicle weighed approximately 13.6 lbs (6156 g) and was 7.8 ft in length (238 cm) from tip to tail. The main body of the vehicle was made of G10 fiberglass, 4 inches in diameter. The fins were also G10 fiberglass with a simple trapezoidal shape, a thickness of 3/16 in., and a bevel on the three exposed edges. The nosecone was reused from a previous year and was also made of fiberglass.

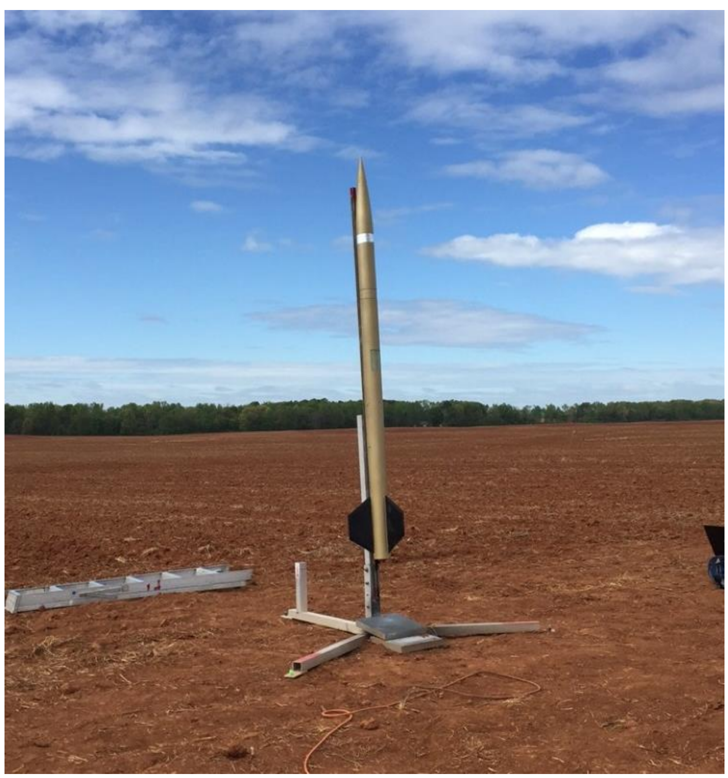


*Figure 1: Launch Vehicle on Launchpad*

On the interior there were 6 bulkheads in total, 4 made of fiberglass and 2 made of plywood. Two of the bulkheads were used to secure the electronics for the recovery system. The system included a Telemetrum altimeter and a Perfectflight Stratologger. These devices controlled the black powder ejection charges that were set to deploy the drogue parachute and main parachute at apogee and 1000 ft, respectively. The Perfectflight served as a redundancy measure deploying black powder charges shortly after apogee and at 700ft. These electronics were mounted with machine screws onto a balsa wood board and slid on threaded rod tracks into the fiberglass body tube.

*Figure 2: Recovery Electronics Sled being Prepared on Launch Day*

The payload bay was made of an inner tube also made of fiberglass and had a fiberglass bulkhead on each end for containment. This tube would rotate and thus seal the bay. The rotation was done using a small servo motor that was mounted on a separate balsa wood board that also held the Arduino that controlled the servo motor, also mounted using machine screws. The Arduino was connected to a light dependent resistor inside the rotating bay that varied the voltage output based on the ambient light present. When the voltage dropped below the set threshold the payload bay rotates and seals the payload inside. For flight, the payload bay had two threaded rods along the length of the bay as extra stabilization. These rods helped to disperse the forces from launch and ejection charges.

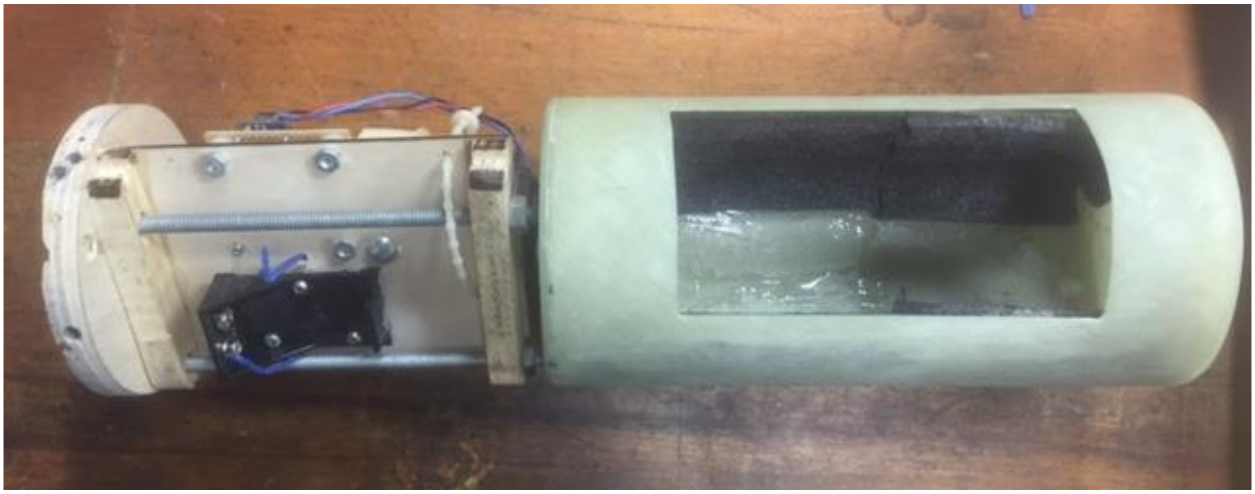


*Figure 3: Rotating Payload Bay*

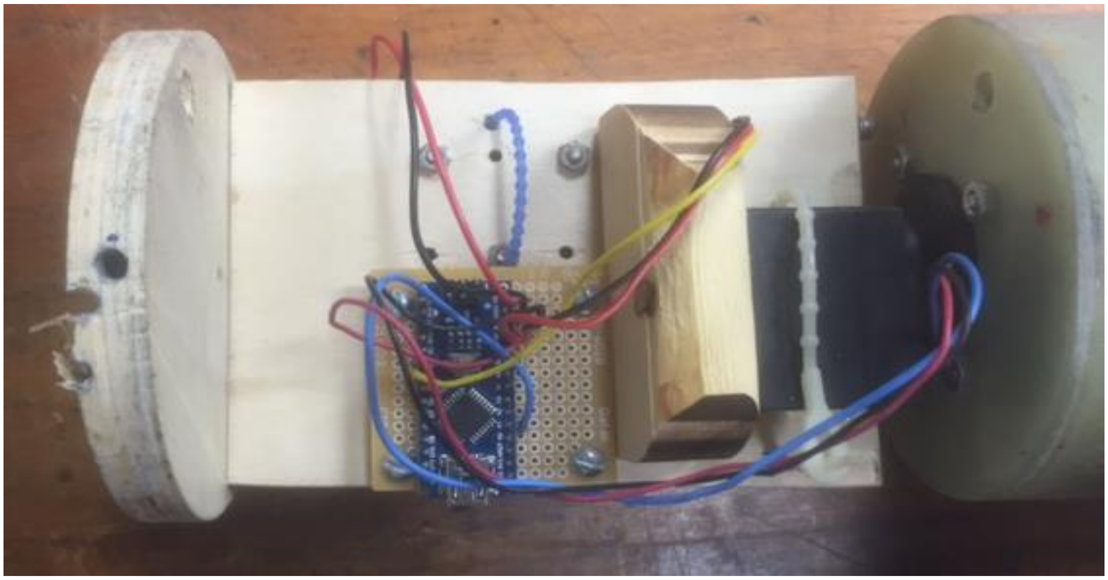


*Figure 4: Electronics for Payload Bay*

The main parachute used was a 52 in diameter LOC Angel chute and the drogue parachute used was a 24 in diameter Fruity chute. The first plywood bulkhead was mounted below the drogue chute and the second was mounted below the electronics that controlled the servo. These bulkheads were secured to the outer airframe with wood screws. The motor was secured with a casing that was fitted into an interior tube made of blue tube. This tube was secured to the inside of the fiberglass body tube with the use of plywood centering rings. These rings also served to secure the fins to the airframe.

**AGSE Overview**

The dimensions of the AGSE were 5.5ft  by 3ft by 8ft. It included a steel frame, a launch rail with a steel platform, a robotic arm, servo linear screw for igniters and a spring and winch system. The system demonstrated at the event did not have the full spring load. More tests was required for a complete use of the spring and winch system. The system was ideally operated by laptop computer using one click to start, stop, or pause the system. The first step was placing the sample payload in the pick up location where the system began with the robotic arm picking up the payload placing it into the rotating payload bay closing the the sample off then releasing slack on the winch where the springs would generate enough force to rotate the launch platform to a full vertical. The robotic arm was a LynxMotion servo package bought from a vendor and was controlled by their third party software on a laptop. The control board that came with the robotic arm was used to control the servos for the winch and igniters as well. The AGSE frame and robotic arm are shown below. Total costs were under $1,500 making the system compact and inexpensive.

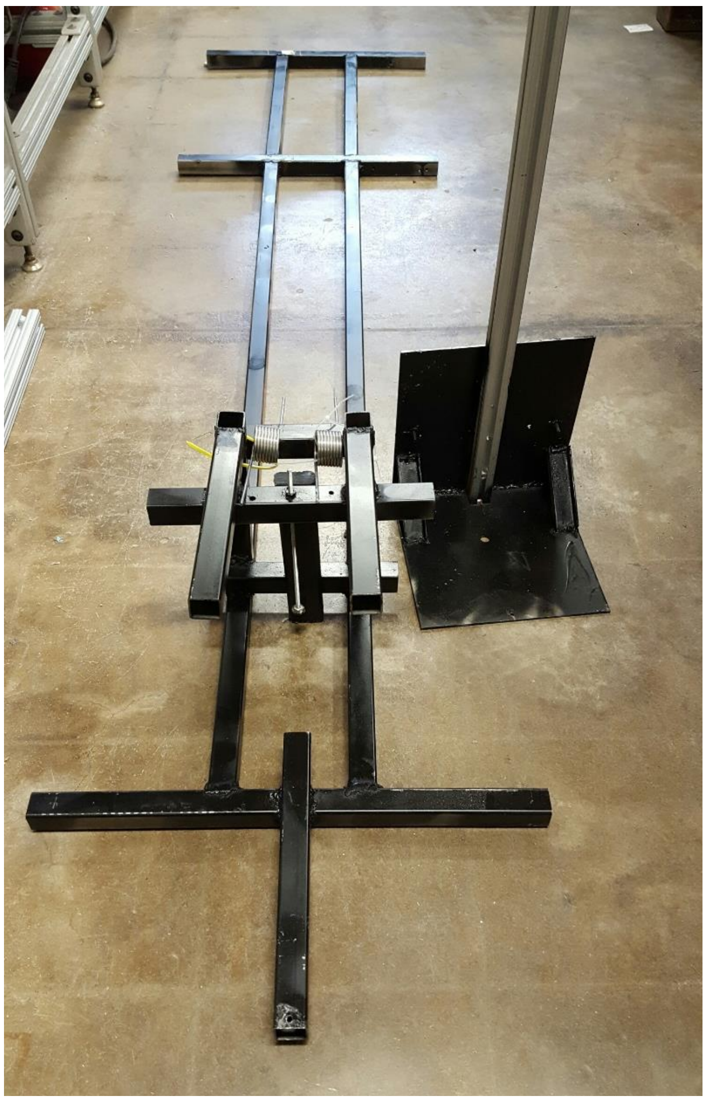


*Figure 5: AGSE Frame*

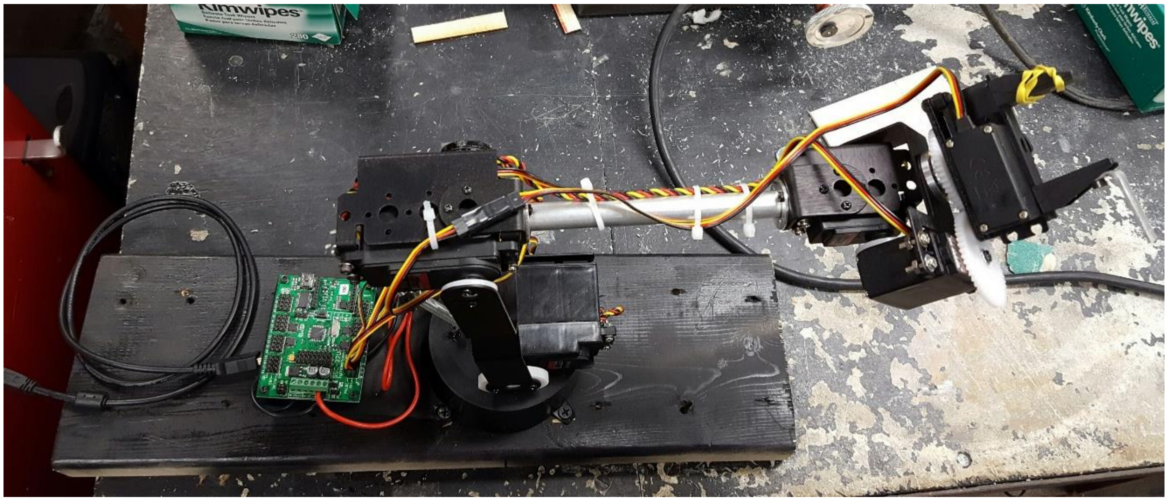


*Figure 6: Robotic Arm*

## Actual vs. Predicted Data

The predicted maximum altitude for the launch vehicle was 5262 ft (1604 m). The figures below show the simulations for the altitude vs time for the actual and predicted case. The actual flight data recorded from the Telemetrum appears to have lost connection sometime before apogee. The position curve appears to change to a linear interpolation. The maximum altitude may have been above the value listed by the Telemetrum. The maximum acceleration was predicted at 387 ft/s^2 (118 m/s^2) and the velocity at impact was predicted at 19.26 ft/s (5.87 m/s). Table 1 summarized the actual vs predicted data for this launch. The maximum acceleration was close to that predicted by the simulations but the velocity at impact was higher. As discussed later this was due to the main chute not deploying and the launch vehicle landing under drogue.

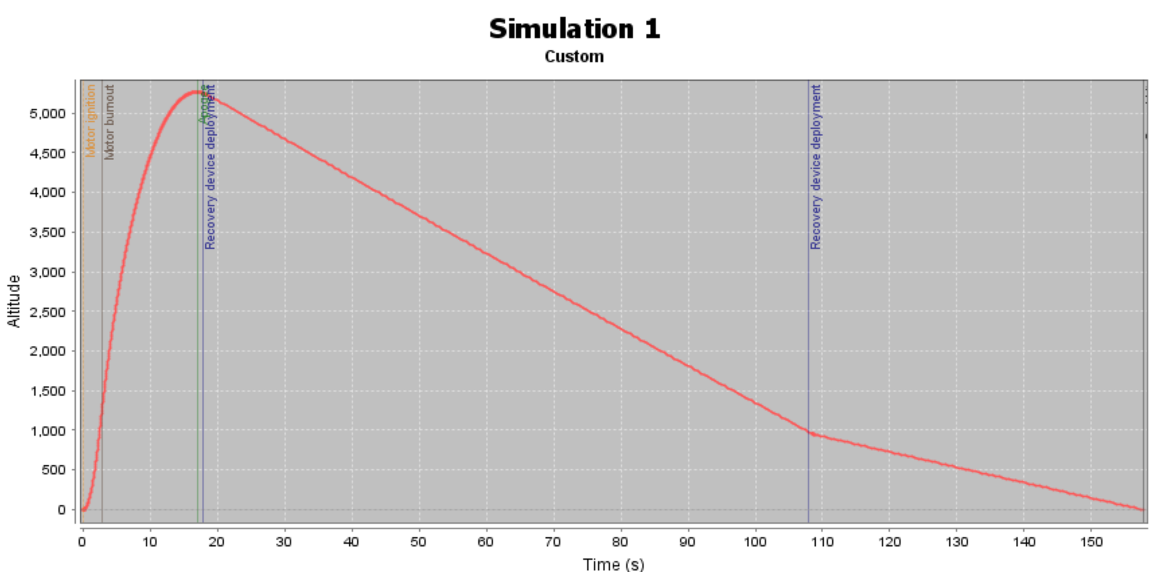
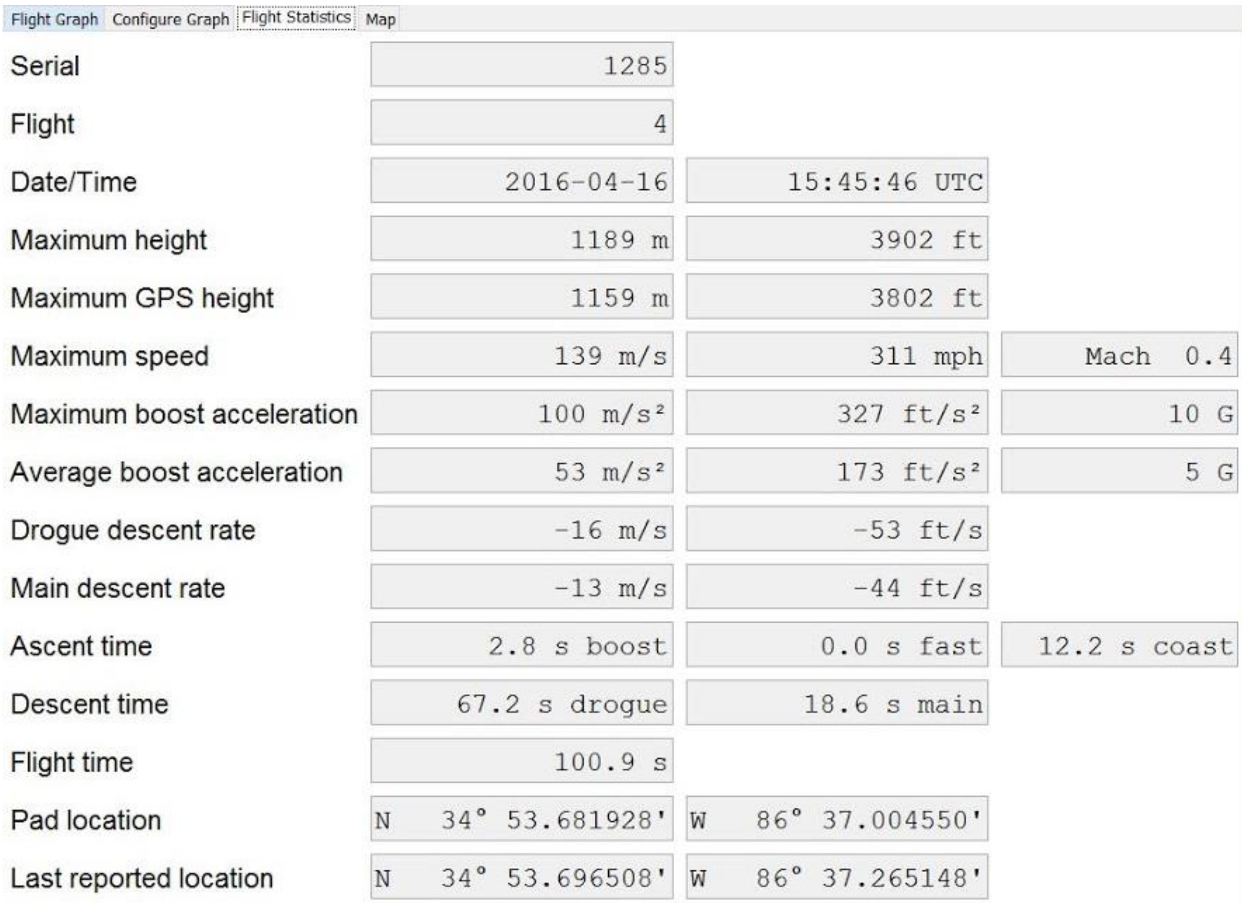



*Figure 7: Predicted Flight*

Table 1: Actual vs Predicted Flight Statistics

| | Apogee (ft) | Max Velocity (ft/s) | Max Accel. (ft/s$^2$) | Impact Velocity (ft/s) |
|---|---|---|---|---|
| **Predicted** | 5262 | 771 | 387 | 19.26 |
| **Actual** | 3902 | 456.133 | 327 | 44 |



Flight Graph | Configure Graph | Flight Statistics | Map

| | | | |
|---|---|---|---|
| Serial | 1285 | | |
| Flight | 4 | | |
| Date/Time | 2016-04-16 | 15:45:46 UTC | |
| Maximum height | 1189 m | 3902 ft | |
| Maximum GPS height | 1159 m | 3802 ft | |
| Maximum speed | 139 m/s | 311 mph | Mach 0.4 |
| Maximum boost acceleration | 100 m/s² | 327 ft/s² | 10 G |
| Average boost acceleration | 53 m/s² | 173 ft/s² | 5 G |
| Drogue descent rate | -16 m/s | -53 ft/s | |
| Main descent rate | -13 m/s | -44 ft/s | |
| Ascent time | 2.8 s boost | 0.0 s fast | 12.2 s coast |
| Descent time | 67.2 s drogue | 18.6 s main | |
| Flight time | 100.9 s | | |
| Pad location | N 34° 53.681928' | W 86° 37.004550' | |
| Last reported location | N 34° 53.696508' | W 86° 37.265148' | |

*Figure 8: Full Flight Data from TeleMetrum*

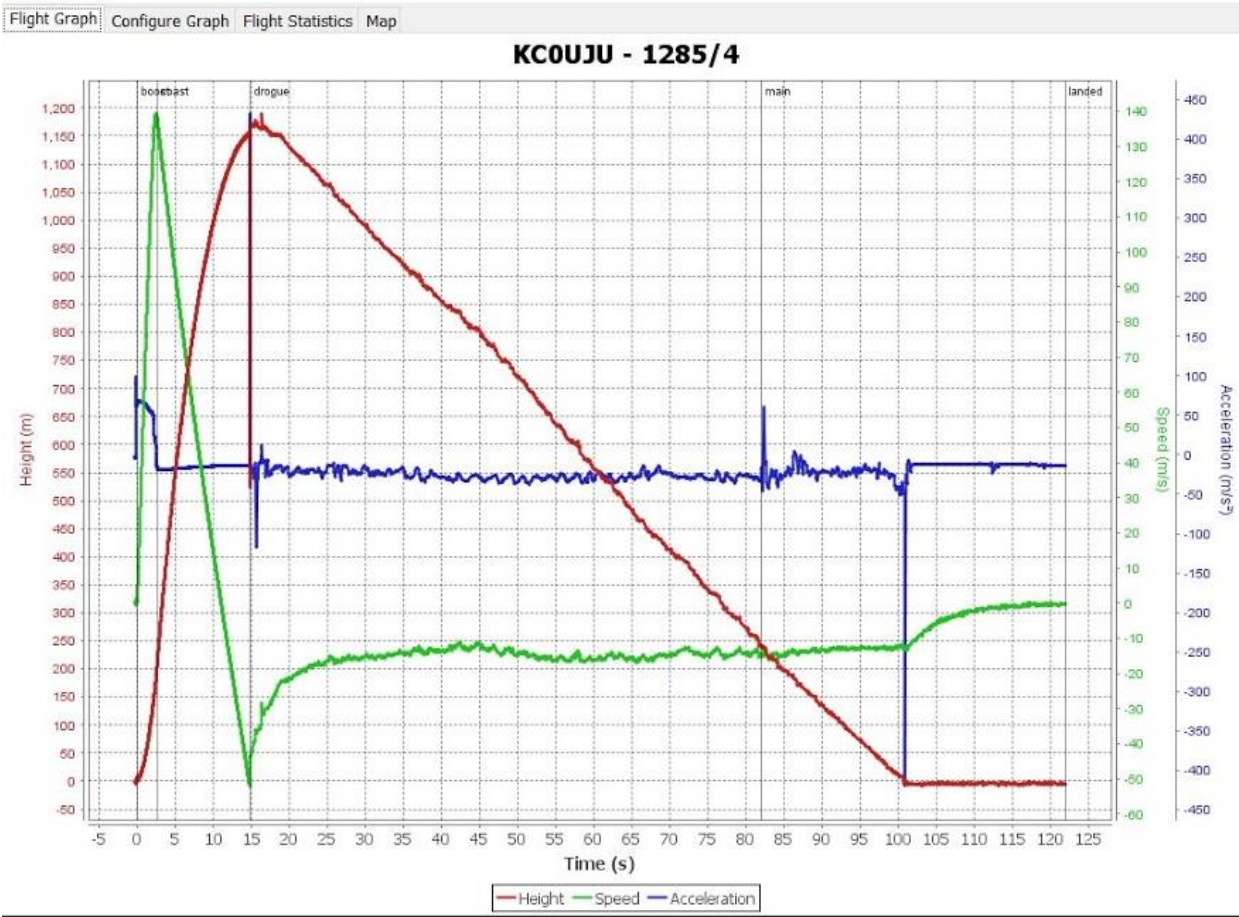



*Figure 9: Flight Graph from TeleMetrum*

## Visual Data Observed

Visually, it was observed that the vehicle had a successful liftoff. The rocket left the rail with no issues and traveled upward to its maximum altitude. In flight, it was observed that the drogue parachute successfully deployed, although it is difficult to say from sight what that deployment altitude was. The ejection charges for the main parachute were also successfully ignited, however the parachute did not deploy. This led to the vehicle landing on the ground with a much higher velocity than anticipated. After landing, the rocket was recovered and inspected. After it was inspected, the vehicle appeared to have taken minimal to no damage. This inspection included the electronics, fins and main body. It was also determined that the ejection charge for the main parachute only served to push the chute further into the nose cone, thus not allowing the two to separate successfully.

*Figure 10: Rocket as Found Post-Launch*

## Lessons Learned

Some of the biggest lessons learned with this project involved time management and communication. From the beginning, our team was struggling to meet the deadlines for all of the reports. This mostly occurred due to poor communication throughout the team and trying to coordinate everyone's schedules at the last minute, which added to the stress we were all already experiencing from school work and everyday life in general. This also led to poor time management and not being able to dedicate as much time as necessary to write good reports and also be prepared to give the presentations. The team also learned exactly what the difficulty of participating in the MAV challenge was. Being a much smaller team in comparison to the other participants, our ground system was not able to perform nearly as well as others, because we did not have the manpower, resources or funding that other teams had. A definite change for next year will be to either assemble a bigger team, or only participate in the launch with a scientific payload. We mostly learned the importance of setting deadlines and working to meet them. This would have allowed our team to have an easier time on launch week, instead of scrambling to finish everything at the last minute.

## Educational Engagement Summary

Educational outreach was done with students in the 2nd-4th grades that are tutored on weeknights at the University of Iowa College of Engineering. Two outreach events were held. Team members constructed PVC stands to launch paper rockets from. Construction paper was used for both the body and fins of the rockets. The students were able to pick the paper colors they wanted to use, and got to assemble the rockets themselves using masking tape. Paper clips were used to close off the top of the rockets and to add weight to better balance the rocket. The students were able to launch the rockets by jumping on empty 2-liter pop bottles. SLI team members oversaw the activity along with other members of AIAA. The distance each rocket flew was marked on the ground with a piece of tape with the child's name on it. One of the most most rewarding parts of the outreach was hearing the students talking to each other about ways to get their rockets to fly farther. Many of them had intelligent ideas that are commonly employed in high-power rocketry, meaning that the students were learning and applying important principles. It was apparent throughout the event that the kids were enjoying themselves and learning important rocketry principles in a fun and engaging way.

**Budget:**

| Item | Cost |
|---|---|
| Reimbursements | $154.48 |
| Fiberglass Bulkheads (2) | $18.73 |
| Fiberglass Coupler (2) | $63.99 |
| K630 Motor | $112.95 |
| Miscellaneous Construction Supplies | |
| Servo Motor (1) | $18.69 |
| Telemetrum | $321.00 |
| Fiberglass Bulkheads (6) | $36.90 |
| Strattologger | $56.00 |
| Educational Outreach | $ 20.00 |
| Model Rocket Nose Cones | $ 55.94 |
| Kite Line | $ 11.98 |
| Estes Igniters | $ 42.55 |

## Summary of Overall Experience

Overall, the experience was one-of-a-kind. It was amazing just to get the chance to talk with the other teams and get insight for how they approached the problems of designing a rocket with the given design constraints. It was incredible what simple (and sometimes not-so-simple) methods they were able to come up with that our team had overlooked. Coupling with that, it was an honor to be able to not only take a tour of the Marshall Space Flight Center, but also to hear talks from Kjell Lindgren about his trips into Earth's orbit and also from Kathryn Crowe talking about the Space Launch System project currently underway.