Centennial Challenge

Mars Ascent Vehicle Challenge

Post-Launch Assessment Review

Madison West High School—Martians, Madison, WI

Student Launch 2016: Martians

Vehicle

Vehicle Design

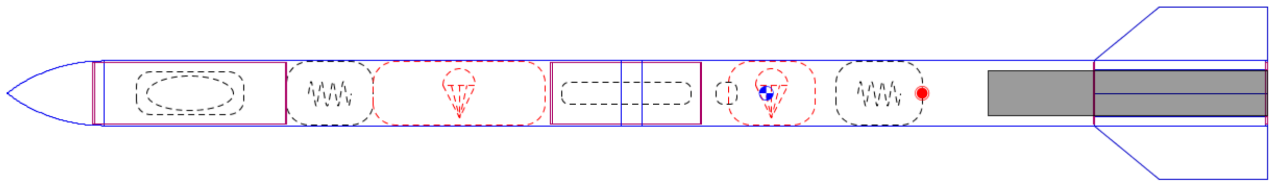


Figure 1: OpenRocket drawing of our rocket, showing center of gravity and center of pressure. The stability margin of our rocket is 4.4 calibers.

Our vehicle, the Bananabee, flew on a CTI J760WT to an apogee of 5,056*ft* AGL. We flew the standard MAV payload, a 4”x.75” piece of PVC tube with domed endcaps, filled with sand and weighing 4 ounces.

The total length of the vehicle was 58” and it was 3” in diameter, 11.1lbs liftoff weight. The center of pressure is 42.5 inches from the tip of the nosecone, and the center of gravity is 35.3 inches from the tip of the nosecone. The rocket has a stability margin of 4.4 calibers at liftoff. The rocket stability and robustness was verified both by a scale model flight and a full scale vehicle flight.

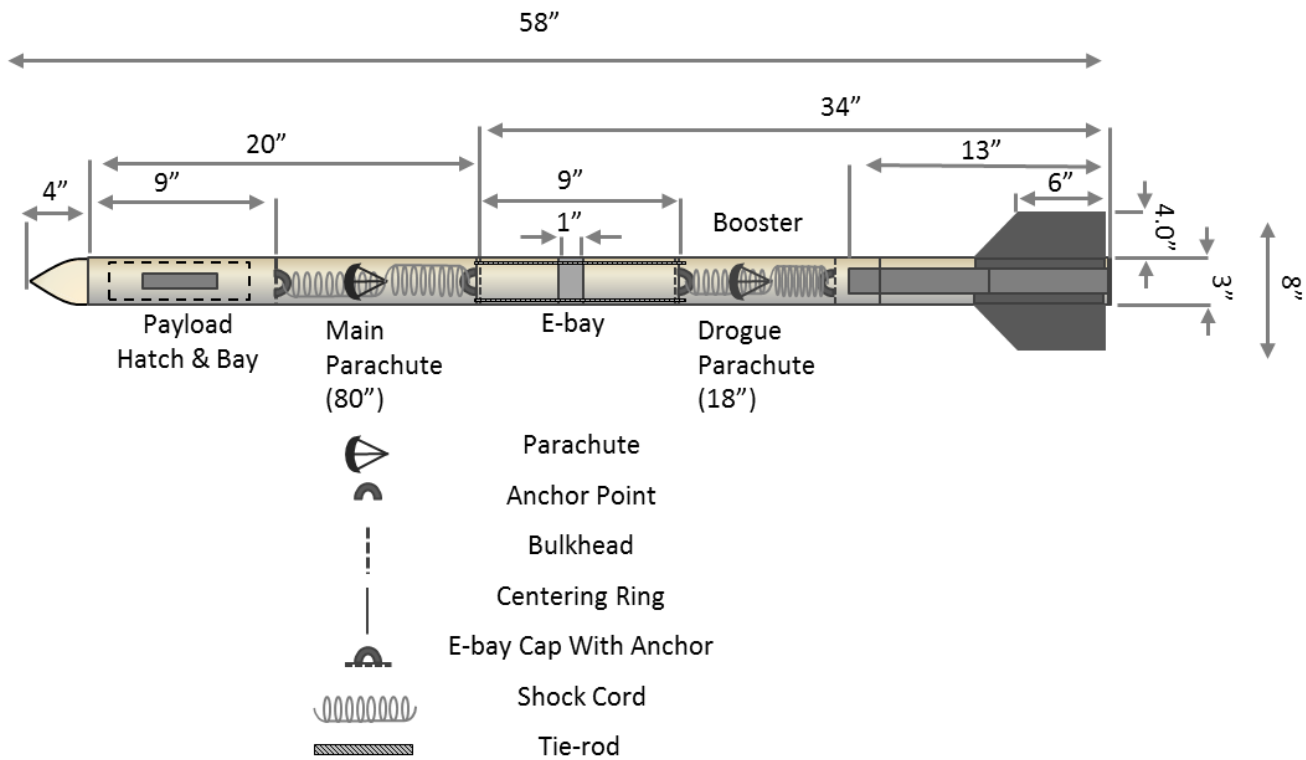


Figure 2: Dimensioned drawing of our vehicle. The length of each part is listed.

Flight Data

According to the data from the two on-board altimeters, the vehicle reached an altitude of 5,056*ft* AGL at 17.55 seconds after liftoff. The drogue parachute deployed at 17.35 seconds after liftoff, slightly before apogee. At this time, the main parachute also deployed. Flight data from the altimeters shows that the main parachute ejection charges did not activate until 700*ft* AGL. Based on this, we have concluded that the main parachute was deployed due to the forces of the drogue charges, and not due to user error while connecting the ejection charges to the deployment electronics. We believe that this was caused by the strong winds on launch day in Alabama. The wind caused the rocket to turn horizontally much faster than in previous launches. Because of this, the shear pins at the main parachute separation point broke during drogue deployment. We had not experienced this during any of our test launches prior to launch day in Huntsville.

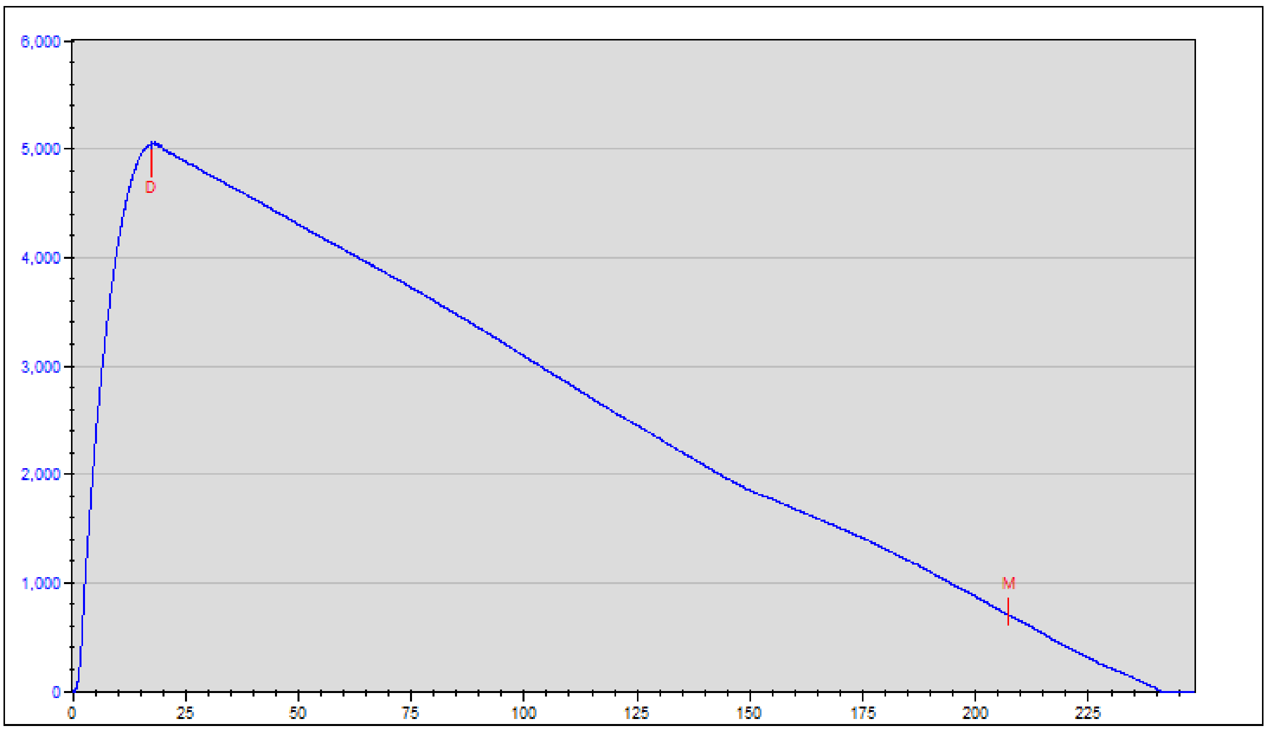
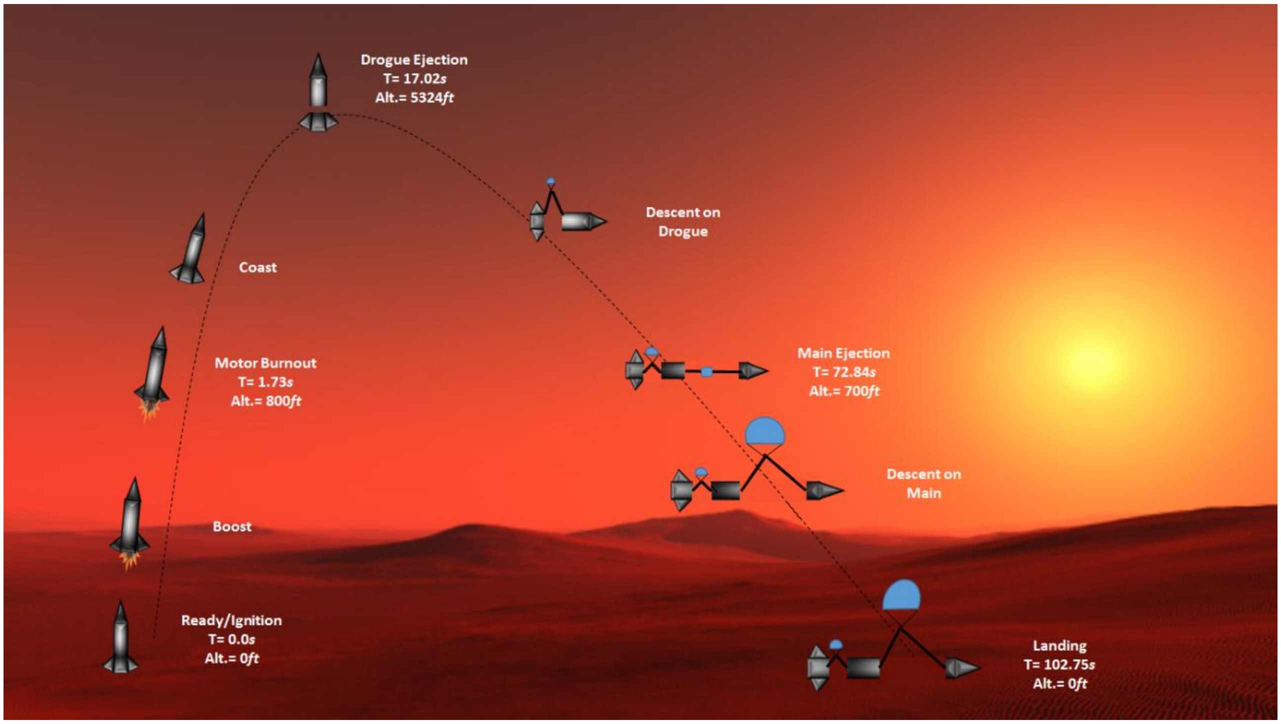


Figure 4: Altitude profile for our vehicle, as reported by on-board altimeters.

Flight Description

Our vehicle weathercocked, due to the high winds, but still flew to an apogee of 5,056 feet AGL, only about 224 feet away from the target apogee. Both parachutes deployed at apogee (the main was supposed to deploy at 700 AGL upon descent). We believe that the wind caused our rocket to turn horizontally at apogee, which broke the shear pins and caused the premature deployment of our main parachute. Our mission profile chart shows the intended order of flight events.



Flight Sequence

Figure 5: This figure shows our desired flight sequence, including the deployment scheme.

1. Rocket is ready on the pad, all electronics on,
2. Motor is ignited and rocket is launched,
3. Motor burns out,
4. Rocket coasts,
5. Apogee at 5324*ft* AGL, and drogue deploys,
6. Vehicle descends on drogue,
7. Main parachute deploys at 700*ft* AGL,
8. Vehicle descends on main,
9. Vehicle lands.

Our simulations and test flights predicted an apogee of 5,324, just over a mile; however, the wind in Huntsville meant our flight went to 5,056*ft*, just under a mile.

Payload Retention System

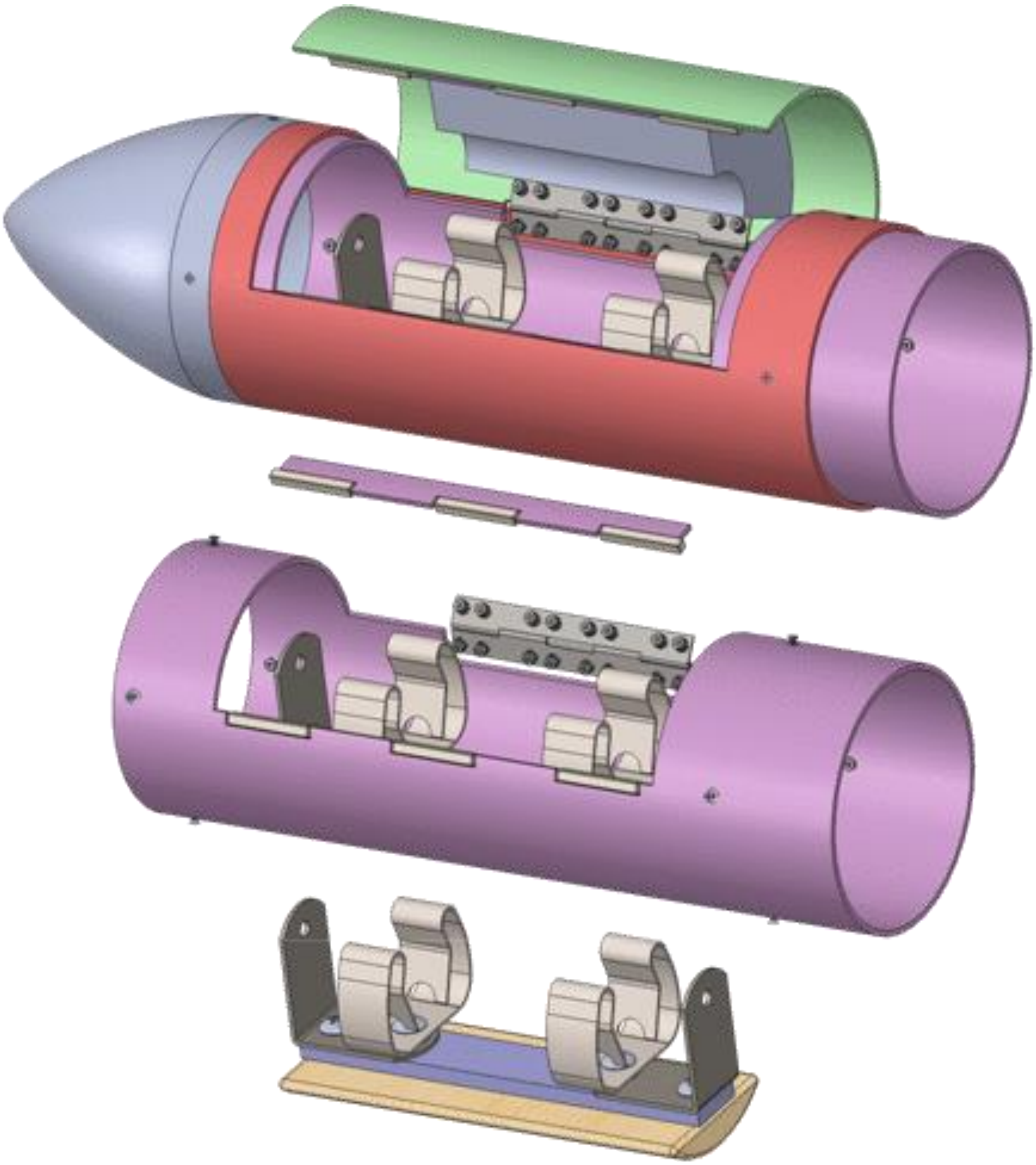


Figure 6: The payload attachment scheme is shown above.

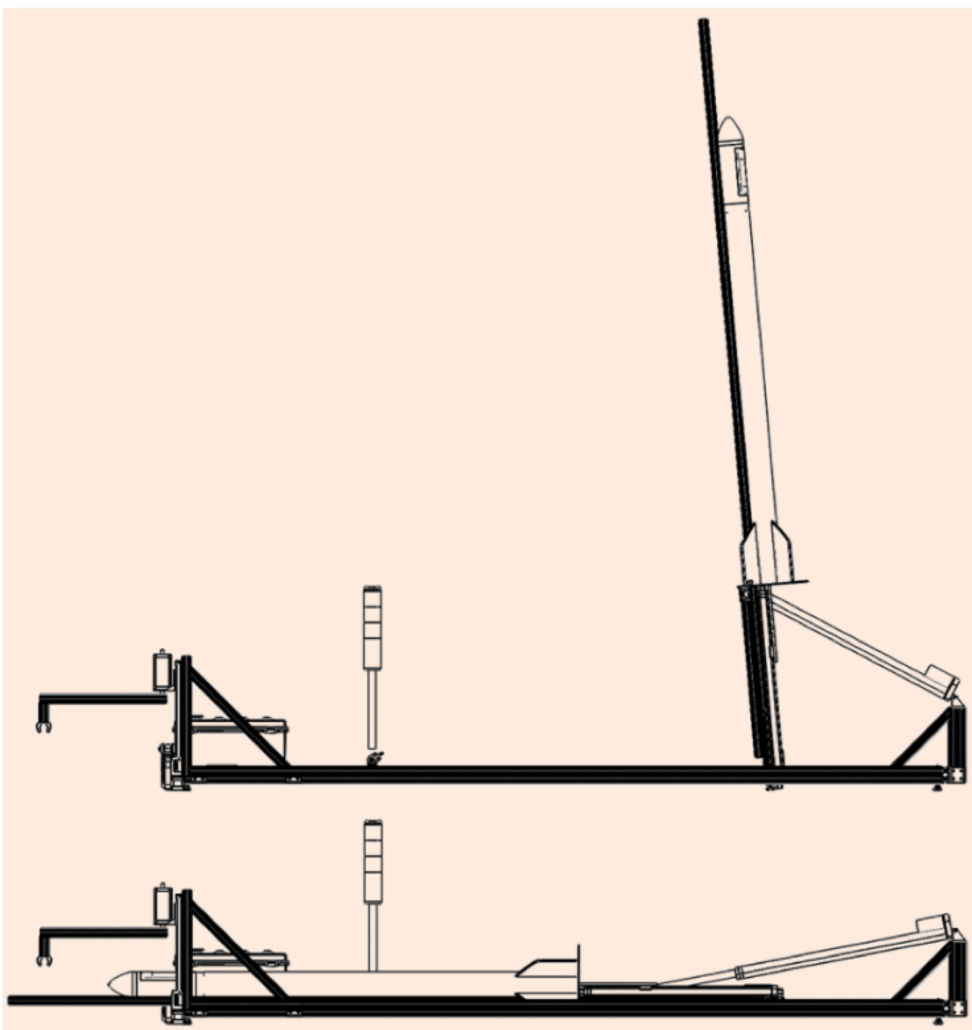
Our payload was secured to the rocket using two metal clips commonly used to hold gardening tools to a wall. On either end of the payload are L brackets. The clips and brackets are screwed onto a piece of aluminum that is in turn screwed onto a balsa wood sled. The full sled assembly is secured through screws onto both the outer body tube and the inner coupler tube. The door to the payload bay is attached to the body of the rocker by bistable hinge found in glasses cases. A piece of memory foam is glued to the door and further serves to secure the payload. The door is held closed with six neodymium magnets that possess a pull force of 50 lbs total.

During our flight in Huntsville the payload remained completely secured during flight. The door remained closed during the entire flight. The clips secured the payload through the flight and only a minor shift towards the rear of the rocket by the payload occurred. This took place during previous launches and leads us to believe the g-forces experienced by the rocket during launch causes this shift. However, the L brackets on the front and rear of the payload section along with the memory foam on the door prevented the payload from shifting out of the grasp of the retaining clips. With these results we believe that our payload retention system performed exactly as expected.

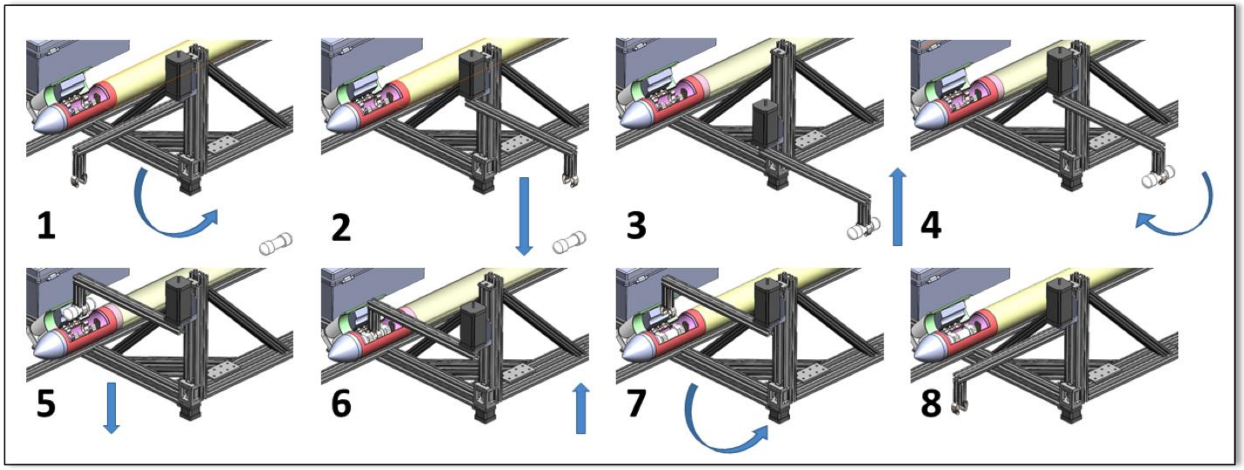
Autonomous Ground Support Equipment

Mechanical Design

The Autonomous Ground Support Equipment (AGSE) was designed to fulfill NASA requirements of acquiring a payload and inserting the payload into the rocket before elevating the rocket from horizontal to five degrees from vertical then inserting an ignitor into the rocket. In order to occupy a small volume of space and decrease weight, the AGSE was built out of commercially available lightweight 8020 aluminum. To achieve high efficiency and minimize mechanical failures, commercially sold stepper motors and linear actuators were incorporated into the separate stages. Stepper motors operated the payload retrieval arm's linear and rotational motion. Linear actuators closed the payload door, elevated the rocket, and inserted the ignitor into the motor. The payload retrieval and insertion processes included two passive aspects; the acquirement and transfer of the payload is executed by the physical tension of retention clips similar to that of household rake clips, the closing and securing of the payload compartment door is done by a bi-stable hinge and high strength magnets.



AGSE in Starting Position (Lower) and Launch Ready Position (Upper)



Payload Retrieval and Insertion Sequence

Program Integration

The entire AGSE autonomous routine is executed by an Arduino Mega 2560 receiving inputs from microswitches while sending outputs to drivers and relays as well as a LCD board. Each stage during the autonomous sequence contains microswitches for end stops as well as a timer for extra safety. Interrupts are incorporated into the autonomous sequence in order to pulse an amber light at one hertz as well as pausing the sequence should the pause button be pushed.

Execution Result

Upon our arrival in Huntsville we ran the full autonomous sequence thirty-five times in order to ensure that the AGSE had not sustained damage during transportation. During this process the sequence failed a total of three times. Two of these failures were attributed to a connector which was broken during transport. This connector was re-soldered. The third failure was due to human error during the placement of the payload. During the competition run, the entire autonomous sequence ran without error. However, the final rail angle was eighty-four degree (one degree off of the target angle). This was likely due to the angle being measure on the rocket body (we always tested by measuring the launch rail angle). The entire sequence took fifty-three seconds.

Educational Engagement

Throughout the school year, we have been involved in many outreach events, where we set up poster about our projects and help kids build pneumatic rockets. During outreaches, we are able to interact with a variety of visitors such as professors, parents, and students, and share our knowledge about our different projects and rocket science. Outreach is a major part of our club because we believe it is important to pass on the knowledge and encouraging the new generation of scientists to dive further in aeronautics.

Summary of Experience

Lessons Learned

The most important lesson we learned through participating in this competition is the importance of teamwork. A successful completion of our project would not have been possible without the cooperation of team members and their willingness to devote large amounts of time and energy to the project. Each of the team members brought their own set of skills and expertise, and together we were able to effectively work towards our goal.

In addition, we learned the importance of organization. Creating a timeline with events helped us stay on schedule, and proved to be incredibly beneficial. The schedule helped us ensure a successful completion of our project and also helped us keep organized throughout the year.

Overall, as a result of participating in the MAV challenge, our team has learned numerous valuable lessons which we will take along with us in the future.

Summary of Project and Trip to Huntsville

Our vehicle flew to an apogee of 5,056 feet AGL; it weathercocked and underflew due to the high wind speeds on launch day. Both parachutes deployed at apogee, most likely due to shear pins failure in high wind. This flight has taught us how to be more careful and perform better in the future.

Our AGSE, Autonomous Ground Support Equipment, performed well in 53 seconds and all functions worked properly. However, the launch angle of the rail was one degree lower than the required 85 degrees due to a difference in measurement methods used by contest official during contest and our team during practice runs.

The Rocket Fair was very fun and interactive, with students from all over the U.S. sharing their projects and educating each other of effective ways to tackle problems encountered during the phase of the project. Students, mentors, staff and professionals alike had an elevated urge to explore and understand new possibilities of the project. Our display gained a lot of attention, especially because we also had our AGSE demonstration. It was interesting to see the many people that were surprised of the size of our rocket and AGSE, and we were happy to explain to them how and why we took that approach.

The tours including the Marshall Space Flight Center and the Davidson Center for Space Exploration were very interesting and informative. Overall, we had a very valuable experience throughout the entirety of the MAV journey, because we learned and shared a great amount of knowledge. Going through the full NASA design process taught us so much about what real-world engineering projects. We are honored to have been given the opportunity to compete in the MAV competition, because it introduced us to a new level of expertise.