Pioneer Rocketry

2019 WSGC Collegiate Rocketry Competition

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Abstract

The Wisconsin Space Grant Consortium hosts the annual Collegiate Rocket Launch Competition every year. The goal of the competition this year was to design and build a rocket to fly to between 700 and 1000 ft and deploy an autonomous ground excursion vehicle upon landing. The rocket, Istanbul, used a CTI J357 motor to lift it to an apogee of 896 ft, and successfully deployed the ground excursion module after landing. On the second flight attempt, Istanbul achieved an apogee of 742 ft, much closer to the predicted apogee of 750 ft. Unfortunately, during this second flight, Istanbul landed in water, disqualifying the flight. Pioneer Rocketry is very proud to have placed first in this competition, winning the title of Mission Grand Champion.

Rocket Operation Assessment

Flight anomalies analysis The rocket, Istanbul, had two successful flights. The air frame did not sustain any damage, despite landing in water during the second flight, and the team was able to recover the rocket quickly. During the first flight, the Ground Extrusion Module (GEM) had some coding issues and the rocket overshot the predicted altitude by 146 ft. The team mitigated the anomalies for the second flight by debugging the rover code and installing weights to bring the apogee down. During the second flight, Istanbul landed in water, damaging flight electronics. No GEM distance was recorded on the second flight because the team had to intervene to remove it from the water.

Propulsion system and flight path assessment The rocket safely and successfully performed two launches on the competition launch day. The apogees for the two flights were 896 ft and 742 ft and were quite different due to internal modifications between flights. The rocket flew vertically on both flights, with no weathercocking observed. Each motor ignited perfectly with no chuffing or any other anomalies shown in Fig. 1. Upon further observation, the rocket exceeded the altitude expectations during the first flight due to the data collected from an underperforming motor on a prior test flight. This data was used to predict the competition altitude which was much lower than the true performance of the motor. The team had anticipated this possibility and utilized a modular weight system to reduce the apogee on the second flight. As a result of the weight system, the flight reached 742 ft, an 8 ft difference from the predicted altitude.

Fig. 1: (Left) Istanbul taking off during the first flight. (Right) Istanbul during the second flight.

Recovery system analysis The rocket's fully redundant StratoLoggers performed nominally. The altimeters successfully detonated their ejection charges at apogee. The charges were able to successfully eject both the parachute and the GEM. The motor backup was not relied upon during either of the competition flights. The rocket was recovered on an 84 in parachute and descended at 11.2 ft per second shown in Fig. 2. During descent the rocket drifted by approximately 900 ft during the first launch and 200 ft for the second.

Fig. 2: Istanbul in descent for the first launch.

Rocket location and recovery analysis Locating the rocket posed no difficulty, as the team saw the rocket land nearby each time. Recovery after the first flight was without incident. Recovery after the second flight involved removing the rocket and GEM from a pond. Both flight landings are shown in Fig. 3. The rocket suffered no structural damage from the water. The GEM suffered some minor deformation that did not materially affect its performance. Upon investigation, the deformation occurred when the GEM was pulled forcefully from the pond via the shock cord. The GEM disconnected itself from the shock cord, the wheels began to spin, showing the electronics were fully working when it was removed from the pond.

Fig. 3: (Left) The rocket after the first flight. (Right) The rocket after the second flight.

Pre and post launch procedure assessment Pioneer Rocketry prepared checklists with tasks to be completed the day before the launch, on launch day, before the rocket was taken to the pad, and after the rocket was recovered. Due to experiences from prior test flights, the team was able to adjust checklists before the day of competition which in turn made a more efficient use of time during the competition. The team was able to work quickly and efficiently to prepare, launch, and recover the rocket safely. Improvements needed to checklists and plans would include checklists for splashdowns. After the second flight landed in a pond, the team was able to work outside of the plan effectively to recover the rocket with no damage. Another change would be for future competitions, the team will update the checklists to add a place to check off procedures for more than one flight.

Payload System Performance

Distance traveled by GEM After the first flight, the GEM successfully detached itself from the shock cord. The rocket was no longer located near the GEM because the winds re-inflated the parachute and dragged the rocket away. Due to some programming problems, the wheels only moved for two seconds every two minutes resulting in the GEM moving 1 in. After the first flight the team troubleshooted the bugs in the program. During the second flight the rocket and GEM landed in water. The team picked up the GEM and rocket out of the water as soon as they landed to salvage as many materials as possible. Once out of the water, the GEM still detached from the shock cord and began moving. No distance was recorded due to the handling of the rocket and GEM.

Description of quality of motion on the ground Testing of the GEM's movement was done before flights on the terrain of Richard Bong State Recreation Area. The GEM was able to easily traverse both the rough grassy terrain and the gravel parking area without the flight program. Since there were issues in the flight program, the GEM only moved an inch after the first flight shown in Fig. 4. After the second flight, the GEM landed in water, so its ability to move well was not able to be demonstrated.

Fig. 4: GEM movement from the marker.

Discussion of overall payload performance and possible improvements The overall performance of the GEM was affected by a bugged program and damaged cameras. The program could have had a better plan, a simpler design, and more time writing and debugging. While nothing could have been done to prevent the landing in water, the GEM could have been made to also be buoyant and maneuver in water. Due to design choices there was no simple way to accomplish water resistance. The internal GEM camera could not record longer than 3 minutes at a time, resulting in no video of the first deployment. To resolve the recording issue, two cameras were added to the wheels of the GEM as shown in Fig. 5. These cameras were not properly charged and died before launch. For accurate recordings, well charged, working cameras should be used.

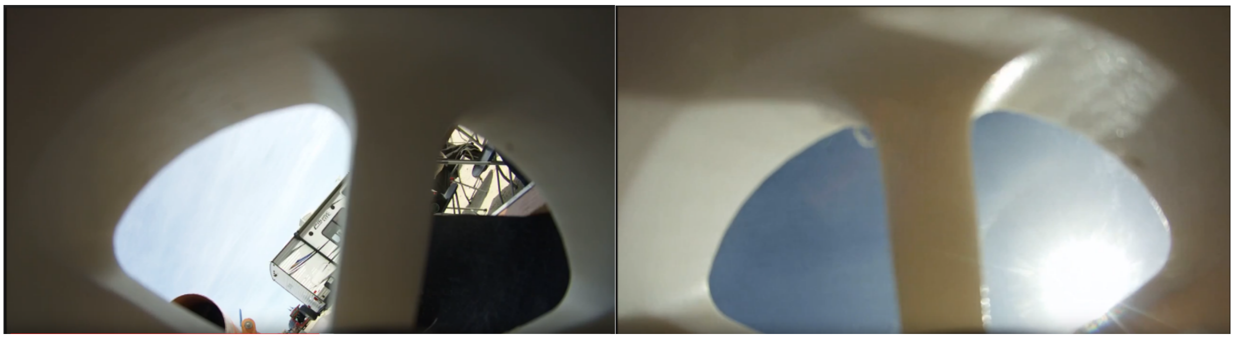

Fig. 5: View from the GEM cameras before the second flight.

Actual and predicted flight performance During the first flight, there was a large difference between the simulated apogee and the actual apogee. This difference is due to the simulation being adjusted to an apogee of a previous flight featuring a motor that the team suspected of underperforming. The difference of altitude between the first and second flights was due to the inclusion of a modular nose weight system. The rocket's predicted altitude vs time is shown in Fig. 6, and the measured altitude vs time for both flights are shown in Fig. 7.

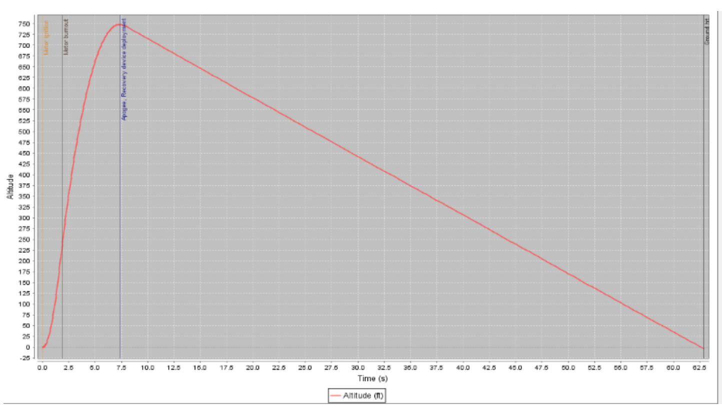

Fig. 6: Altitude vs time simulation, showing a predicted altitude of 750 ft.

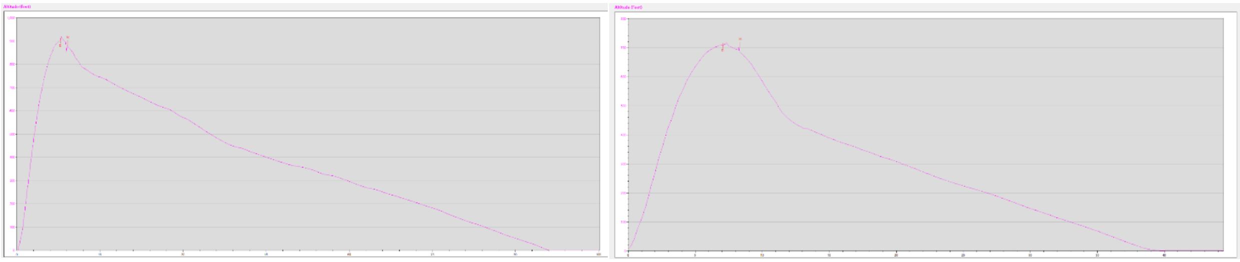

Fig. 7: Altitude vs time data from the StratoLogger on the first (left) and second (right) flight, showing an altitude of 896 ft and 742 ft respectively.

Acceleration comparison The team accurately modeled the acceleration vs time curve for the flight, as seen in Fig. 8. Unfortunately, due to landing in water on the second flight, acceleration data could not be retrieved from the Raven altimeter.

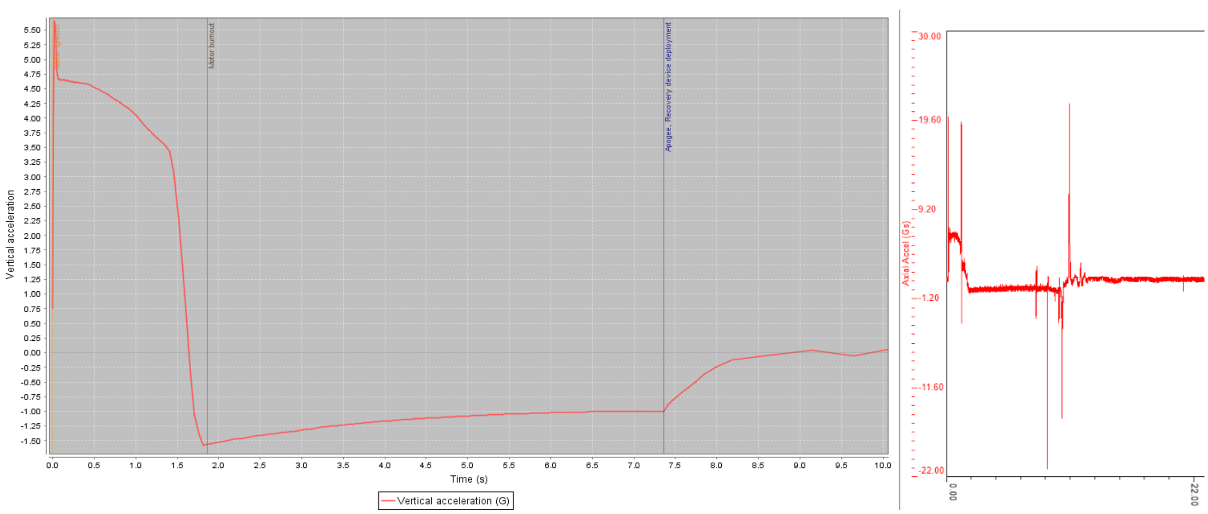

Fig. 8: Acceleration vs time simulation (left) and Raven data (right), showing a predicted maximum acceleration of 5.65 G, and an observed maximum sustained acceleration of 6.3 G.

Conclusion

The CRL competition provided many unique challenges that needed to be solved. The challenges included designing a rocket to integrate a deployable rover and stay under 1000 ft as well as designing a rover to move on the terrain. The team, shown in Fig. 9, was able to successfully overcome these challenges through many test rockets and several test flights. The GEM also posed unique challenges such as being integrated with the rocket, releasing itself before driving away from the rocket, and taking video. The team solved the problems through many design variations and test flights. The rocket safely achieved altitudes of 896 ft and 742 ft and the GEM successfully deployed and traveled about 1 in on rough terrain. For the second flight the rocket was able to reach within 10 ft of its altitude target, and the rover ran on a fully functioning program. Unfortunately, the water landing that occurred caused the flight to not count toward the competition. The team has learned much from this experience and are excited to have had this opportunity to compete in this year's competition.

Fig. 9: Pioneer Rocketry CRL team of 2019.

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