Raziel Post-Flight Report

Version 1.0, Written by Andrew A.

Purpose & Scope

This document details the performance of the MIT Rocket Team and Projects Raziel and Virgo following the 2017 Spaceport America Cup in Las Cruses, New Mexico. This document touches on the flight performance, the team performance, lessons learned from the competition, and improvements to be made on the system and team levels.

Timeline

The competition took place over the course of 5 days (June 20th – 24th). The Team was in Las Cruses from June 19th – 25th:

Date	Activity	Notes
June 19	Arrive, prepare for conference day	
June 20	Conference day	2 people picked up from El Paso airport due to travel delays
June 21	Base camp prep, group photo	
June 22	Launch Day 1	
June 23	Launch Day 2	Intended flight day
June 24	Launch Day 3, Awards Banquet	Actual flight day
June 25	Leave	

Technical Summary: Raziel

Project Raziel was the MIT Rocket Team's entry into the 2016-2017 Spaceport America Cup 10k COTS category. The design was intended to leverage and iterate elements from the design of Project Therion, while maximizing the amount of student-built hardware. It was originally designed to fly on a team-made experimental propellant, Xaphan Blue, which was ultimately descoped due to failures in testing. Every other major subsystem of the rocket was student designed and built.

Item	Value
Dry Mass	58 lbs
Loaded Mass	70 lbs
Motor	Aerotech M2500T
Airframe Material	Fibreglast S-glass, 3000 series epoxy

See Appendix A for the technical report, which contains a detailed summary of the technical aspects of the project.

Raziel As-Built Configuration

Raziel flew with the same body tubes as the flight test, as well as an upgraded nose cone.

See Technical Report for details.

Competition Performance: Raziel

Raziel was scored as follows:

Administrative	Technical Report	Design Implementation	Flight Performance	Penalties	Total
75/100	152/200	200/200	402.7/500	0/0	829.7/1000

The administrative score is being disputed at the time of this document's writing, as all the dropbox timestamps fall within the acceptable range for the deliverable submissions. However, the 1st place team, UBC, received 862.7 points, outscoring us in Administrative (100/100) and Flight Performance (490.7/500), despite shortfalls in Design (125/200) and Technical Report (147/200). The change in administrative score alone would not have changed the outcome of the competition, but does put the Team painfully close.

Raziel obtained the following flight data:

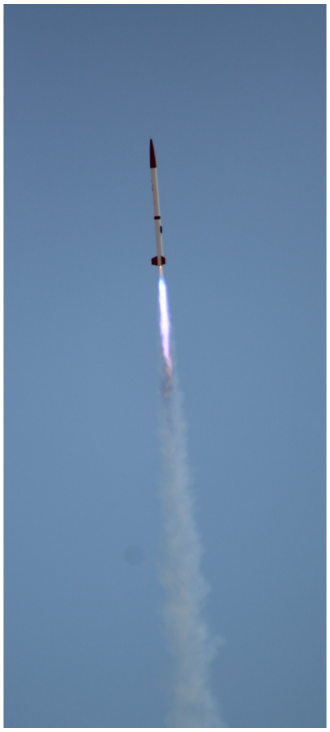
Flight Computer	Apogee (ft)	Notes
Telemetrum	10851	
Stratologger	*10845*	*Data recovered after sent to manufacturer*
Pyxida	9433	No data after apogee
Average	10205 *(10376)*	Spaceport alt. *(after full recovery)*

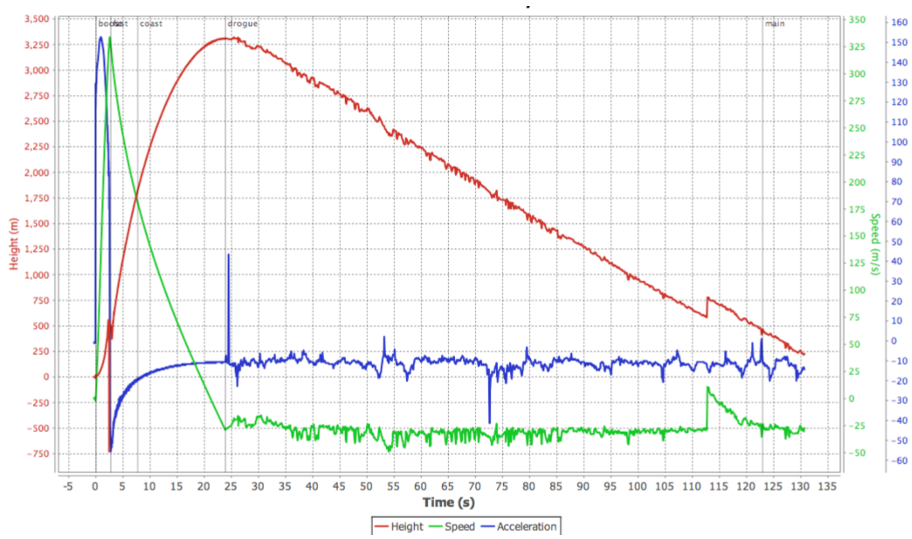
The judges accepted an altitude that was the average of the two flight computers that were functional after landing, giving a final altitude reading of 10205 feet, which is 205 feet above the altitude simulated earlier in the day. This discrepancy could be due to over-performance of the motor, or a higher ambient temperature than expected at launch.

The onboard cameras did not obtain any video. Ground-based video was obtained using a GoPro Hero4 Session for launch only. One onboard camera overheated, another was not activated due to time constraints, and the third ran out of battery on the pad.

Flight profile

Raziel launched at around 1pm. The flight data shows that the motor burnt for 2.58 seconds, delivering 9800 Ns of impulse.





The Telemetrum data, combining GPS with barometric, is shown above. The jump in altitude near 112s is likely due to an updated GPS packet that affected the altimeters filter. It is unlikely due to a drop in pressure associated with the main chute being pulled out because the altitude was still above 1500 feet, the primary deployment altitude, and it was appropriately vented. A shock can also be seen just before burnout, and is reflected in the Stratologger data as well. Both altimeters' Mach lockouts worked successfully.

At apogee, the drogue deployed nominally. This was verified by ground observations of the chute. Raziel completed the drogue descent phase of flight nominally. At 1500 feet, the nose cone was successfully separated from the airframe. However, the main chute remained inside its deployment bag until just before landing. The main chute did not inflate, and the airframe and payload impacted the ground at 25 m/s. Raziel landed about a quarter mile from the base camp, or about a half mile from the launch pad.

After landing, the rocket was approached carefully, and the safety of the radioactive source was verified. The Team then reset the payload, and attempted a nominal deployment after the payload was unwrapped from recovery webbing.

The airframe was largely unharmed after landing, with the exception of a broken fin. The fin can was designed to have removable fins for this exact purpose.

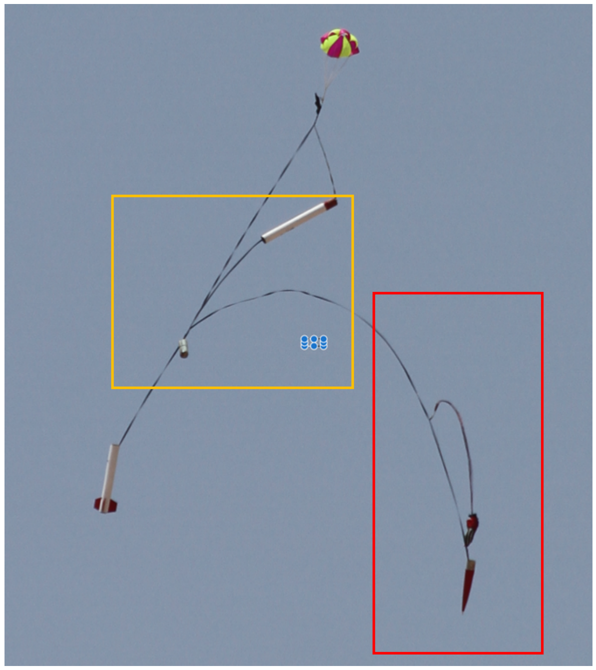
The avionics bay also largely withstood the landing, with a few broken pieces from the 3D printed adapters. The flight computers had some additional damage, and no data was taken from the Stratologger as a result. However, the flight computers with nylon pins fared better, as the nylon sheared, absorbing some impact energy. The motor case was unharmed.

Anomaly analysis

Even though the drogue chute deployed nominally at apogee, the main chute did not inflate. This contrasted the result from the flight test in April, where the main chute successfully inflated.

After the flight test in April, it was found that the nose cone had deployed at apogee (~6000 feet). During the same flight, the main parachute deployed at an altitude higher than intended: 1500 feet instead of 1000. The main parachute had 4500 feet where it did not inflate, even though the design intent was that it would inflate directly after the nose cone separation. The conclusion after the flight test was that the nose cone had barely enough acceleration to break the shear pins, and the chute eventually made it out of the deployment bag by relatively small, sequential tension forces on the webbing. The mitigation for this anomaly was to increase the size of the shear pins on for the nose cone, and re-test. This campaign was shown to be successful during the competition flight.

However, the following picture was taken during the competition flight:



Here, a flaw in the recovery subsystem is revealed in the red box, and a tangling event between the payload (within the sabot) and the nose cone/main chute line in the yellow box.

The length of webbing running from the nose cone to the main parachute attachment point is 10 feet long. However, the deployment bag is attached 2 feet forward of the nose cone, allowing the deployment bag to get out of the nose cone shoulder. The distance between the deployment bag attachment point and that of the main chute is about 8 feet. The shroud lines are 8 feet long, and the bottom few inches of the chute plus the length of deployment bag make this chain nearly 10 feet long.

Since the combined length of the packed main and associated components was longer than that of the webbing to the nose cone alone, there was no way to ensure that significant tension would be applied to ensure the deployment bag and main chute were separated so the main could inflate. This is shown in the picture above, where the webbing to the nose cone is fully extended below the main chute's shroud lines, which are slack. This evidence supports the anomaly from flight test 1 – when the main parachute deployed significantly after the nose cone deployment. The main was likely pulled out by tumbling forces slowly pulling out the main chute in small bursts during most of the descent during flight test 1.

Potential mitigations for the above include increasing the length of webbing between the nose cone and the main attachment point, or otherwise reorganizing the system such that the distance between the deployment bag attachment point and the the main chute attachment point is shorter than the length of webbing between those two points.

Avionics Performance

Pyxida was armed properly using the ground station before launch, and recorded data from launch until apogee, which it detected at an estimated 9433 feet (measured as 2876 meters). The Telemetrum and Stratologger were safely and successfully armed using the pull-pin switches on the pad.

Pyxida performed somewhat abnormally until apogee, showing low-frequency oscillations in its altitude measurements. A brownout is suspected at apogee.

Payload Performance

Before flight, the payload suffered a malfunction that required most of it to be redesigned, and caused the flight to slip. The payload was never restored to the same state, but was in a functional state at the time of launch.

During flight, the payload did not prematurely separate, verifying that the paracord system held the sabot together under flight load conditions, tangling, and tumbling.

Since the impact velocity was higher than intended, the payload withstood a higher landing load than it was designed for. The impact caused the following damage:

The payload did not deploy nominally due to shorted and deformed wires in the deployment electronics, and deformed parts in the motor housing for the CO_2 deployment system.

Propulsion Analysis

The OpenRocket model was not validated by a mass measurement of the rocket prior to flight. The best estimates used were from measurements taken in Cambridge.
Using the model estimated mass of Raziel, and the averaged flight data from the Telemetrum, Pyxida, and Stratologger, we get an estimated delivered impulse of 9800 Ns, 400 Ns above the quoted 9600 Ns of the M2500T.