WSGC CRL Proceeding Report[1]

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Abstract

Our team participated in the 2018 WSGC collegiate rocket launch competition. Our rocket design was a 3-inch diameter, 80-inch length, 3 finned rocket that used an Aerotech I600R motor. In addition to having a successful launch, our goal was to capture a 360-degree photograph using a Samsung Gear 360 camera. We used a modified umbrella that houses the camera on its handle. As the rocket descends, the weight distribution of the umbrella causes it to land nearly handle side up, thus taking a clear 360 picture above the grass. A Rocksim flight simulation gave a predicted altitude of 3400 ft and a predicted maximum acceleration of 714 ft/s^2.

Design for 360 Degree Image Capture

Selection process and comparison. At first, we considered putting cameras on the fins of the rocket. In this design, we would have had a camera on each fin. We moved on from this design to the mechanical arm design because we were worried about the tall grass getting in the way. Our next idea was to use a mechanical arm with the camera on the end to take the picture. We would have had mechanical arms on both sides each with a camera attached. This would have allowed us to take multiple pictures and choose the one with the best orientation. Our biggest concern with the mechanical arm was the complexity of the parts involved. Our third main idea was to attach the camera to the parachute in order to get a picture from the top down right before the parachute hits the ground. We considered this idea because we were concerned about the tall grass in the field getting in the way and it seemed simpler than the mechanical arm design. Ultimately, this idea had to be modified because the entire rocket and all its parts had to be on the ground. We also considered having a weighted beach ball with the camera inside early on. Another early idea was to use a helicopter like design to control the descent of the rocket. Both of these ideas were really interesting, but a little too complicated.

[1] Thanks to WSCG, UWWC SGA and Tripoli Rocketry for their support.

Method selected. Our final design choice was to go with the umbrella concept, but to attach the camera to the tip of the umbrella rod. This idea was a modification of the parachute idea. This modified idea would ensure the camera could take a picture without getting stuck underneath the parachute after the rocket had landed. The camera would then be able to take the picture from an elevated position above the tall grass and all components of the rocket would be completely landed per the competition rules. To make this idea work, we had to do a lot of testing with the umbrella itself. We had to make sure the umbrella was weighted so it would land rod up and we had to find a way to mount the camera on the end of the umbrella rod. Originally, we planned to wrap the umbrella and the main shoot in a jolly logic altimeter that would activate around 300 ft in order to release the umbrella and the main chute. This was done to try and avoid tangling with the drogue chute. During our test launch, we found that our 3 in. rocket did not have enough space to hold the jolly logic, the umbrella, and the main chute and we had to forgo the jolly logic. We also had to make the rocket longer to make room for the umbrella to fit comfortably in the rocket.

Onboard data recording system. The data recording system had 2 parts to it. The altimeters recorded the rocket's altitude data and flight data. We used an RRC3 altimeter alongside the competition's Raven 3 altimeter. Both of these altimeters were located in our electronics payload. The Samsung gear 360 camera recorded video of the rocket and stored this video on a micro-SD card. We then used the software that came with the gear 360 camera to get a 360-degree image from this video.

Accommodations made for image capture system. The biggest accommodation made for the image capture system was the inclusion of the umbrella because the camera is mounted on the umbrella. The umbrella had to fit inside the rocket along with the chutes. Originally, the jolly logic was to accompany the umbrella, but to save space, we had to forgo the jolly logic.

Rocket Mechanical and Electrical Design

Mechanical design. The rocket had a 3-inch diameter and was 80 inches long. With everything packed inside, the rocket's, stability was about 5.5 calipers. After motor burnout the stability was about 7 calipers.

Electrical design. Our electronics payload was very simple. Our electronics payload had space for both the RRC3 and the competition Raven 3 altimeter as well as space for batteries. To save space, the RRC3 was bolted to one side of the payload sled and the Raven was bolted to the other side. A sketch of the electrical layout is shown in Fig. 1 and the electronics payload tube is shown in Fig. 2,3.

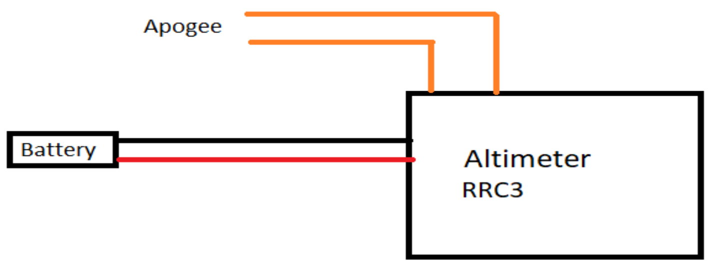


Fig. 1. A simple sketch of the components and wiring included in the electronics bay for the rocket. Sketch was created and screenshotted by team member Joseph Gawrys.

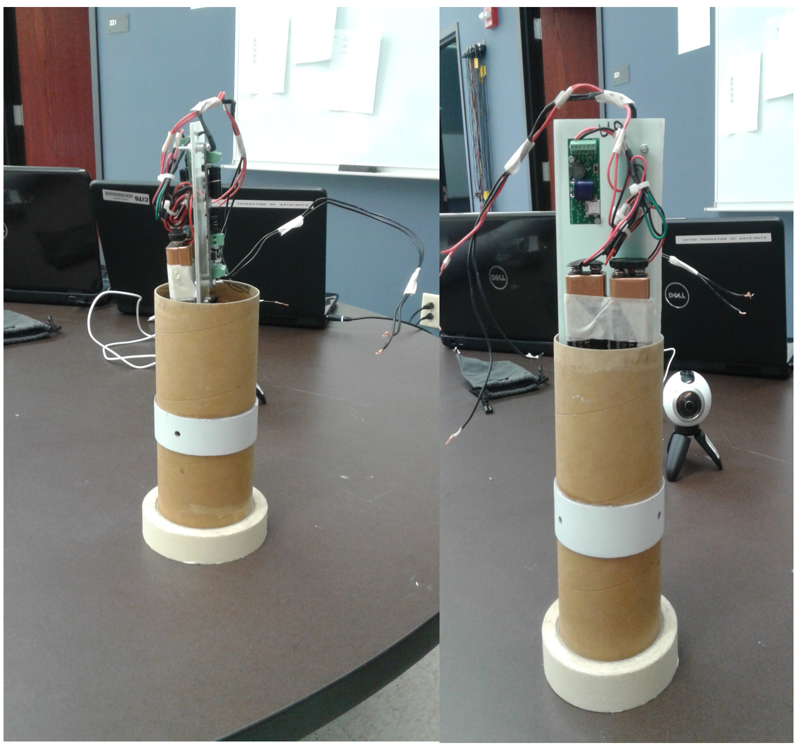
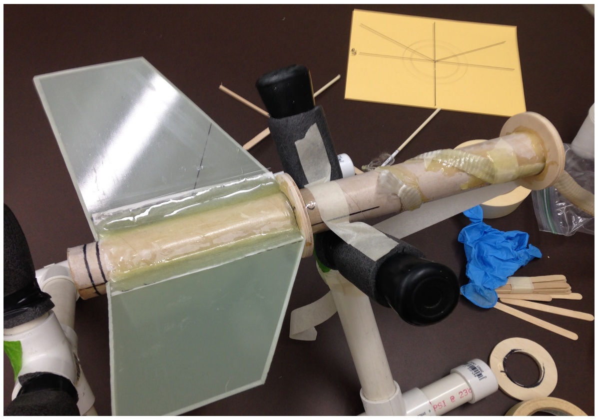


Fig. 2,3. Pictures of the electronics payload tube with the components tightened down and wired up on the tray. Pictures were taken by a team member.

Recovery system. The main chute was a 58” Top Flight Standard chute, and the drogue chute was a 24” Top Flight Crossfire chute. The shock cord was 1” tubular nylon. It’s mounted to the nose cone using two d-rings. The electronic deployment used an RRC3 sport altimeter.

Avionics system. Our rocket used a Missleworks RRC3 to record altitude data and blow the chutes. We chose the RRC3 because of its reliability. It releases the drogue at apogee and the main chute at 300 ft. The RRC3 was bolted to the electronics payload. There was also space for the competition Raven 3 altimeter and space for batteries in the electronics payload.

Planned construction solutions and techniques. The rocket fins were cut from G10 stock. In order to attach the fins, we chose to cut slots into the motor casing and attach the fins directly to it. The rocket design used 7 ply ½ inch birch plywood bulkheads. The motor backup is accessible. Pictures of the motor casing construction are shown in Fig. 4,5.



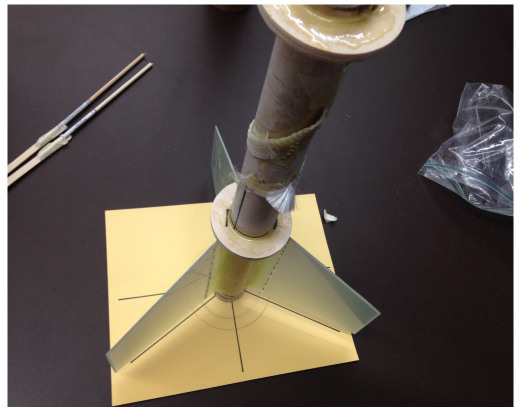


Fig. 4,5. Pictures of motor casing construction including the attachment and alignment of the fins. The fins were attached to the motor casing using epoxy. The lines on the yellow piece of paper were used to help space the fins as evenly as possible. Pictures were taken by a team member.

Structural analysis of custom-made parts. We had to take apart the umbrella in order to attach the camera to the end of the umbrella rod. This process took multiple attempts with multiple umbrellas to secure the camera to the umbrella without breaking the umbrella.

Downed rocket location aid. A Wildman brand telemetry transmitter was placed on the rocket to aid in location. The receiver beeps when the facing the transmitter, allowing for easy location.

Predicted Flight Performance Analysis

Rocket parameters and initial design. A 4 in. diameter rocket was also considered, but we went with a 3 in. diameter rocket because we decided to focus on achieving the target altitude. The rocket was originally designed in Rocksim and the length was adjusted to try and get the best stability. Fiberglass was used to coat the phenolic airframe for an improved finish. The I600R motor was the best for reaching the target altitude. The initial Rocksim design is shown in Fig. 6.

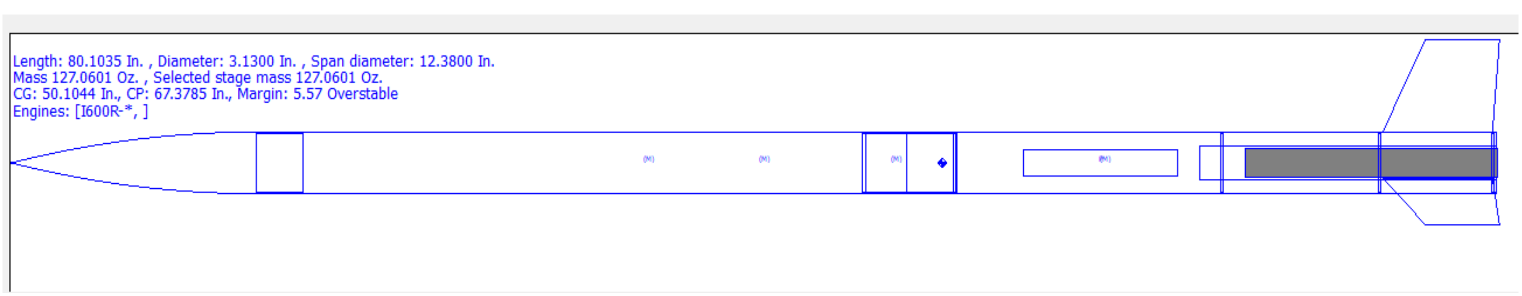


Fig. 6. A picture of the initial rocket design from Rocksim. Picture is a screenshot taken from Rocksim by a team member.

Predicted performance and test launch performance. In order to estimate the performance, we ran a Rocksim simulation on an updated model that matched the dimensions of the fully constructed rocket as closely as possible. The apogee of the rocket's flight was predicted to be 3400 ft by a Rocksim simulation when using a I600R motor. The peak acceleration was predicted to be 714 ft/s^2. This simulation assumed minimal wind and ideal flying conditions. Our actual prediction during our test launch was that the rocket would go about 3300 ft. due to weather conditions not taken into account by the simulations. During the test launch, the rocket was flown once. The rocket's altitude was 3411 ft. during this flight. The main chute and the umbrella got stuck in the rocket body and did not deploy because of charge timing, but the rocket landed safely and suffered minimal damage thanks to the drogue chute.

Flight simulations and flight data. In order to predict the rocket's performance, multiple flight simulations were run in Rocksim. Each simulation can also output a graph of the predicated performance over time. A screenshot of the various simulations run is shown in Fig. 7 and the graph from one simulation is shown in Fig. 8.

24	23	[I600R-*]	3455.35	556.59	714.50	12.24	105.86	3425.88
25	24	[I600R-*]	3022.88	490.82	630.82	12.23	79.38	2997.01
26	25	[I600R-*]	3455.81	556.60	714.50	12.24	105.80	3426.31
27	26	[I600R-*]	3455.77	556.60	714.50	12.24	105.80	3426.28
28	27	[I600R-*]	3455.71	556.60	714.50	12.24	105.81	3426.21

Fig. 7. A picture of the various Rocksim simulations that were run. Our altitude predictions were based off the Rocksim simulations. Picture is a screenshot taken from Rocksim by a team member

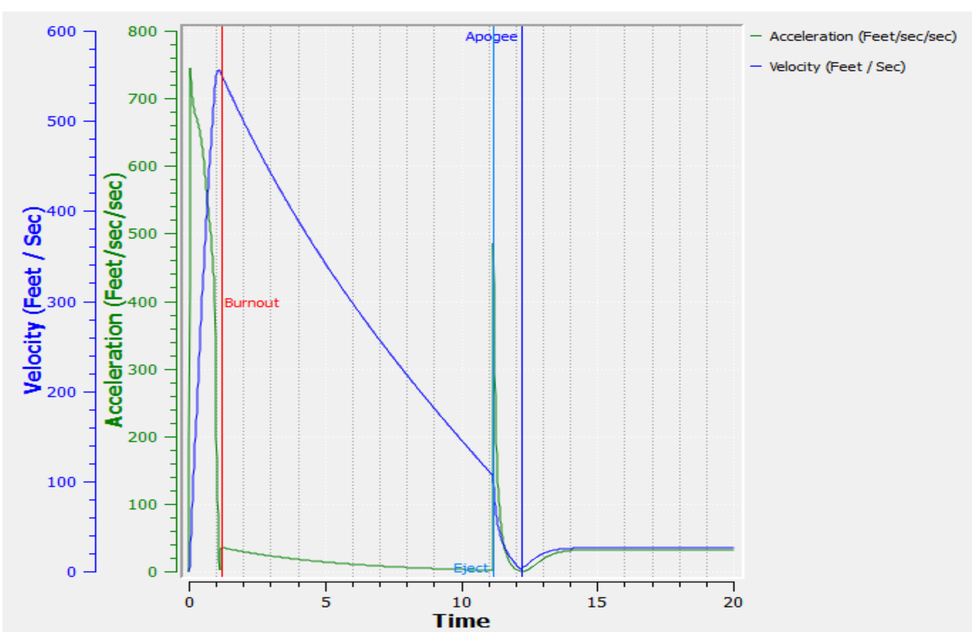


Fig. 8. Initial Rocksim Simulation with velocity and acceleration curves. Picture is a screenshot taken from Rocksim by a team member.

Environmental conditions analysis. In order to examine the effects of different wind speeds on rocket flight, a few additional simulations with varying wind speeds were run in Rocksim.

Additional design features. The main additional design feature included in our rocket build was the camera-umbrella package. The camera was attached to the tip of the umbrella rod and the umbrella tethered to the payload section and to the main chute.

Assessment of Rocket Operations

Propulsion system and flight path assessment. During both flights, the motors burned for the expected timeframe and did not experience any issues. The flight paths of the rocket were stable and smooth, and its flight path angle was vertical from the launchpad.

Recovery and system analysis. The rocket was recovered in a flyable condition with no damage to the airframe or fins. The payload section was completely intact, and both charges were deployed. The 360 Camera remained undamaged and operable. On the second flight, however, most of the rocket was submerged in the water. Luckily, nothing suffered permanent damage. During each launch, the rocket landed relatively close to the launch pad and our tracking device was not needed in order to locate the rocket.

Pre and post-launch procedure assessment. Prior to the launch we prepped the electronics payload and packed the chutes. The RRC3, used to deploy the chutes, and the Raven III were activated at the pad by twisting together the connection wires. After the launch, the rocket safely descended. It was located and checked over for damage. It was then carried back to the table for prepping.

Flight Performance Comparison

Table of performance characteristics

	Motor	Predicted Altitude		Actual Altitude (Raven 3)			Actual Altitude (RRC3)		
Flight 1	I600R	3300 ft		3267 ft			3281		
Flight 2	I600R	3000 ft		3150 ft			3173		

Fig. 9. A table of altitude data comparing our predicted and actual altitudes from our 2 competition launches. Table was created by team member Max Read and a screenshot was taken of the table.

Predicted altitude and acceleration

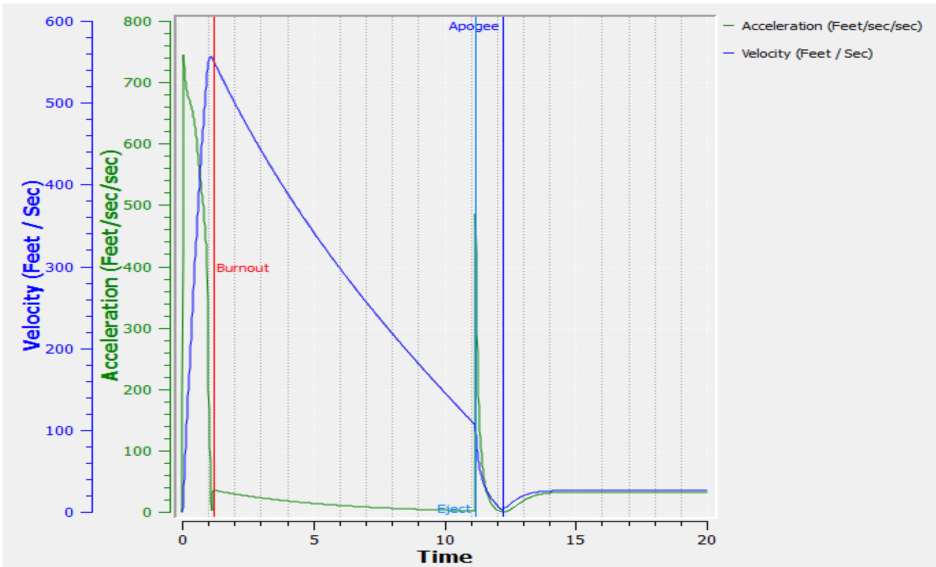


Fig. 10. An graph of predicted performance from an updated Rocksim Simulation after changes were made to the rocket design. Picture is a screenshot taken from Rocksim by a team member.

The rocket's flight was modeled in Rocksim. We adjusted our estimate to account for weather conditions and other unaccounted for variables. Our estimated altitude was 3,300 ft. for the first flight. Because we went above the target altitude during our first flight, we angled the rocket at the launch pad on our second flight and adjusted our estimated altitude to 3,000 ft. A graph of this predicted flight data is shown in Fig. 10.

Actual altitude and acceleration

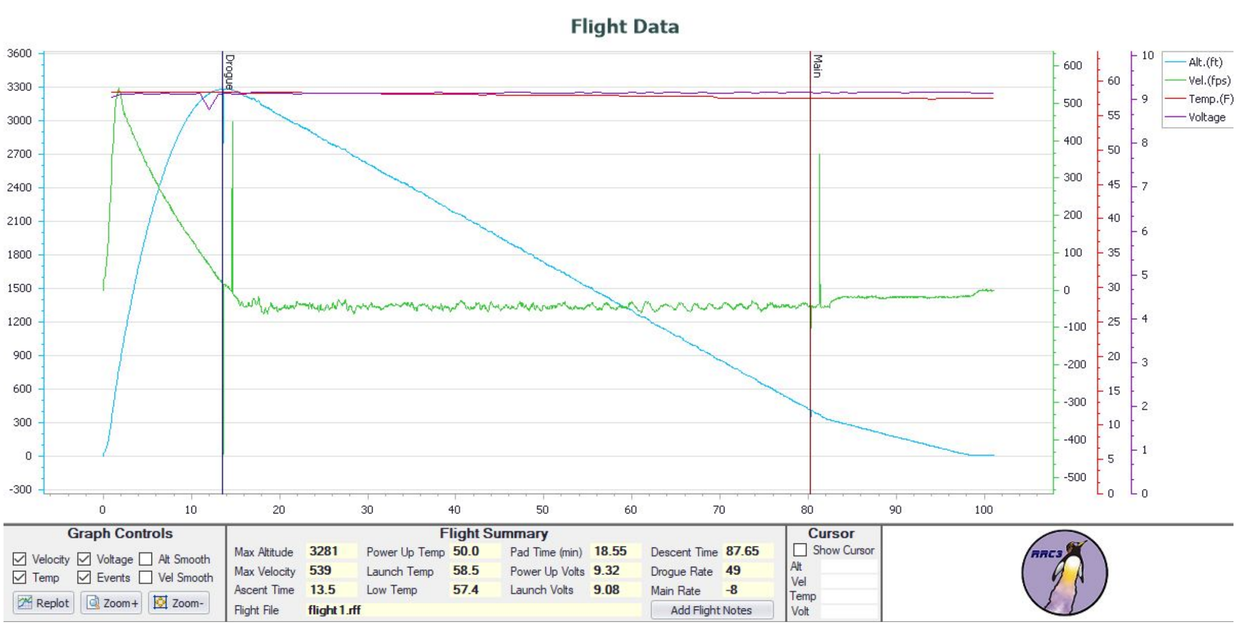


Fig. 11. Plot of altitude vs. time during the first flight. Data is from RRC3 altimeter. Picture is a screenshot taken from the program Missile Works Data Acquisition and Configuration Software by a team member.

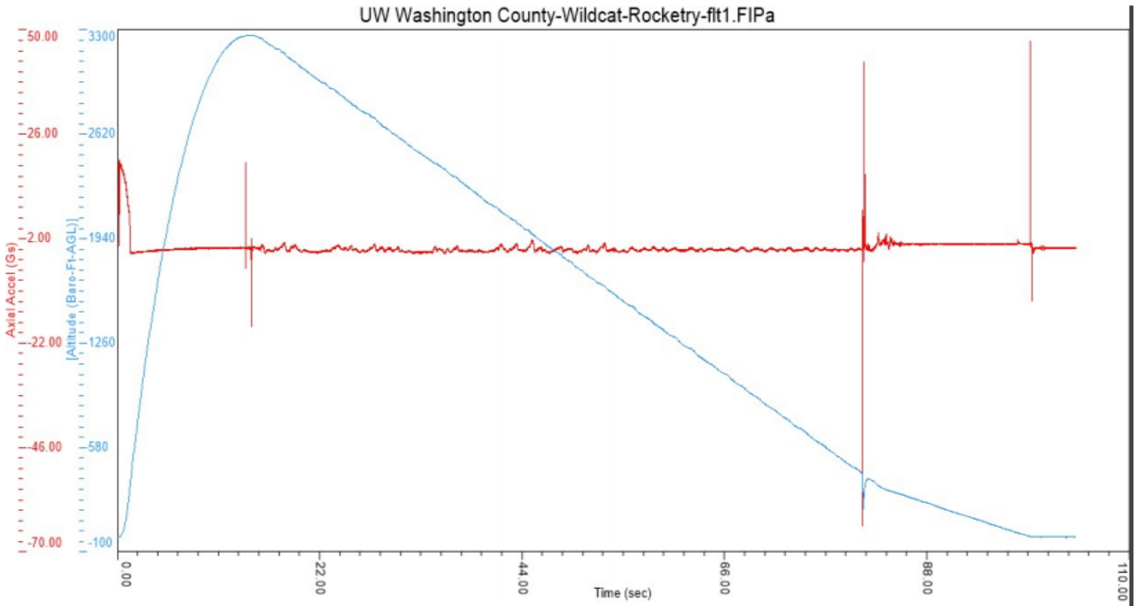


Fig. 12. Plot of Altitude vs. time during the first flight. Data is from Raven 3 altimeter. Picture is a screenshot taken from the Raven 3 data acquisition software by Dr. William Farrow of WSGC.

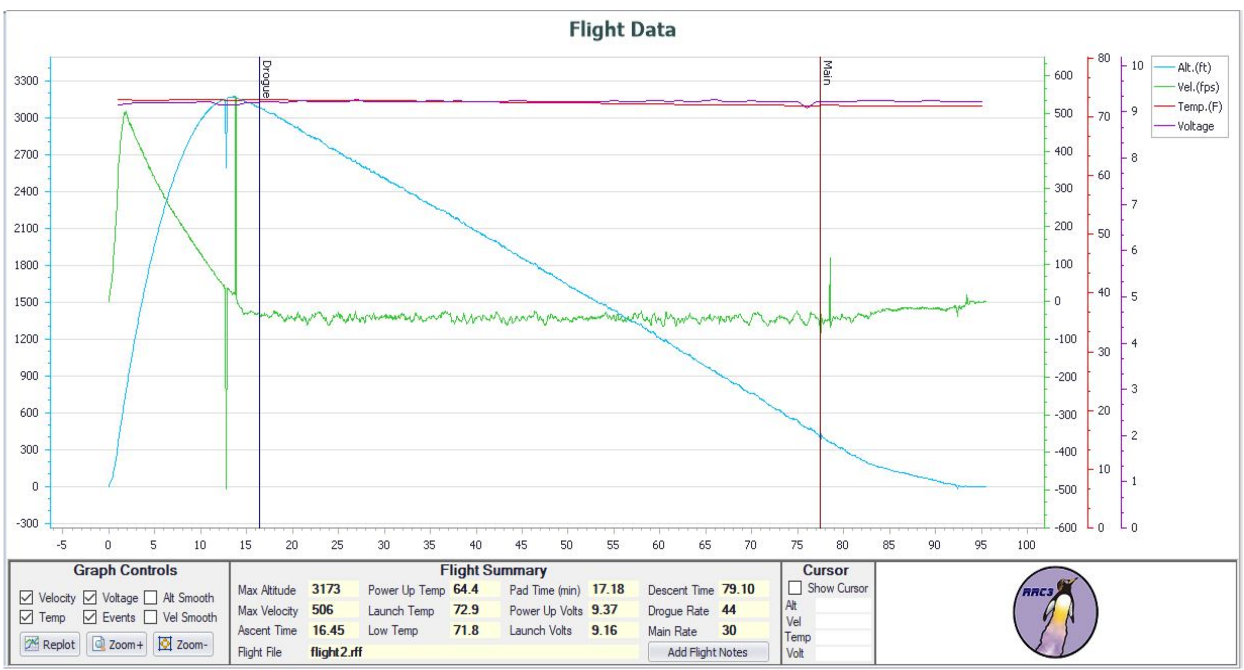


Fig. 13. Plot of altitude vs. time during the second flight. Data is from RRC3 altimeter. Picture is a screenshot taken from the program Missile Works Data Acquisition and Configuration Software by a team member.

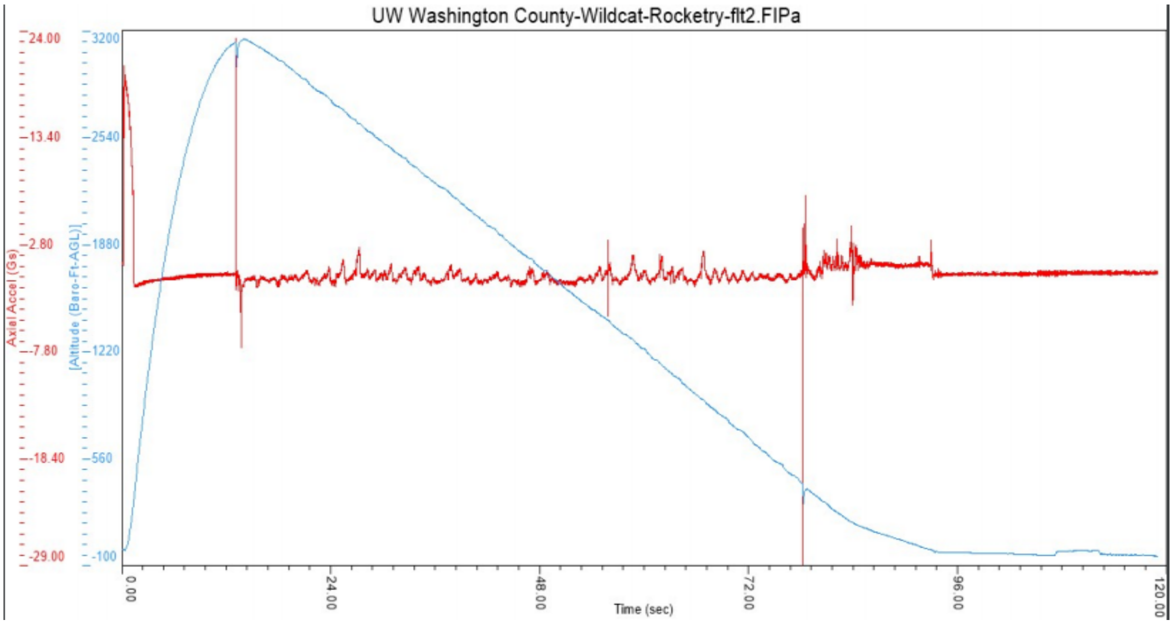


Fig. 14. Plot of Altitude vs. time during the second flight. Data is from Raven 3 altimeter. Picture is a screenshot taken from the Raven 3 data acquisition software by Dr. William Farrow of WSGC.

Discussion of results. The estimated altitude for the first flight was 3,300 ft. for the first flight, which is a difference of about 1% from the altitude of 3,267 ft. recorded by the Raven 3. This prediction was close to the actual altitude. In order to get closer to the target altitude of 3,000 ft. we angled the rocket 7 degrees from the vertical on the launchpad. The estimated altitude for the second flight was 3,000 ft., which is a difference of about 5% from the altitude of 3150 recorded by the Raven 3. The estimated peak acceleration of the rocket was about 750 ft/s/s or about 23 Gs. The rocket actually experienced a peak acceleration of about 20 Gs during both launches. This is a 15% difference, but considering we were most interested in the rocket’s altitude this is acceptable. Fig. 11 through Fig. 14 show the altimeter data acquired from these flights and Fig. 9 shows a small summary of our predicted and actual flight data.

Payload Performance

360-degree photo

Fig. 15. The 360-degree photo captured during the launch. Photo was taken as a snapshot from the video captured using the gear 360 Action Director Software that came with the camera. Snapshot was taken by team member Kota Grauden.

Discussion of 360-degree camera performance. The 360-degree camera performed well during our launches. During each launch the umbrella-camera system successfully deployed and captured video that we used to get the 360-degree photo. The umbrella did not stay perfectly upright, but the videos turned out well and allowed us to get a quality full 360-degree photo. The rocket can be seen towards the bottom left of the image. The picture is near horizontal because this picture was taken just before the umbrella was pulled over on its side by the parachute. This could be avoided and improved on by adding more weight to the bottom of the umbrella to stabilize itself after it has landed. The captured 360-degree photo is shown in Fig. 15.

Potential improvements. Overall, our rocket performed well and as expected. One way to potentially improve our rocket design would be to add weight, so we would be able to get closer to our target altitude. The 3 in. rocket was lighter than originally anticipated.

Conclusion. After a mixed-result test launch, we were hopeful that our rocket would perform well during the competition after some modifications were made. With increased rocket length, we had more space to pack the parachutes and umbrella system. During the competition launch, the rocket performed well as expected and got a quality 360-degree photo after landing.

Acknowledgement. Thanks to WSGC for hosting the competition and providing funding for our team to participate. Thanks to UWWC SGA, we had a generous budget to work with this year. Thanks to advisors Guy Campbell and Swapnil Tripathi for advising the team. Thanks to Tripoli Rocketry for assistance during launches.