2022 Midwest High-Power Rocket Competition

Elizabeth Bohlman, Brian Lee, Jacqueline Muller

Pioneer Rocketry: University of Wisconsin-Platteville

Abstract

The Minnesota Space Grant Consortium hosts the Midwest High-Power Rocket Competition every year. This year the competition involved designing and constructing a diverse fleet of three, five, or eight rockets. This fleet of rockets was to be diverse in construction techniques, shape, and size while following a theme. Each competition team was also tasked with constructing a standardized "core" kit rocket that counted toward the total number of rockets for the fleet. Points were awarded for design, flight, and accuracy of the simulation of each rocket. Pioneer Rocketry constructed eight unique rockets under the theme of mythical creatures. Since all three team members had previously obtained a L1 High Powered Rocketry Certification, the team constructed three L2 Certification rockets. The construction of a diverse armada of eight rockets presented the team with many challenges that granted the team learning experiences. On launch day, the team successfully launched only three rockets due to personnel and time constraints.

Thank you to the Wisconsin Space Grant Consortium and University of Wisconsin-Platteville for funding this team to participate in this year's competition.

Introduction

The Midwest Rocket Launch (MRL) competition is held annually by the Minnesota Space Grant Consortium each May. The launch takes place in North Branch, Minnesota. This year's launch took place on May 21st. The 2022 MRL competition involved design, construction, and flight of a fleet of rockets. Teams from across the Midwest attempted to design and fly various sizes of fleets. The fleets were required to consist of a diversity of designs of either three, five, or eight rockets, with one "core" kit rocket. The "core" rocket was required to fly on a standardized competition motor while the other rockets of the fleet flew on team/individual selected motors. Teams were required to attempt different levels of high-powered rocketry certifications depending on the number of rockets that were constructed. The armada of rockets is seen in Figure 1, below.

Figure 1: The finished armada of eight rockets.

Materials and Methods:

General rocket design. Due to the guidelines of the competition, the rockets had to fall within a few general limits. In addition to having the rockets vary in parameters such as diameter, motor, length, number of fins, and fin and body material, each rocket needed to fly safely and be recovered in re-flyable condition in order to count towards the overall score. Additionally, the stability of each rocket had to fall between 1 and 5 cal. and the descent rate could not exceed 24 ft/s. Due to these constraints, the team's goal was to design each rocket to be stable with a stability no greater than 3 cal. and with a safe descent speed. In order to reduce the descent speed of the larger rockets, dual deploy parachutes were implemented. Throughout design and construction, each rocket was simulated multiple times using the software OpenRocket to ensure it met the criterion listed above. All rockets had nose cones that were 3D printed using PLA and reinforced by epoxy. The construction and design of each rocket will be discussed in the upcoming sections.

The Bat (Core Rocket). The Bat was the core rocket for this year's competition. Being a kit rocket, the team originally constructed the rocket following the provided instructions. This rocket was a dual deploy rocket that flew on a Cesaroni H225-14A motor for its test flight and competition flight. It had three fins and was made out of a phenolic tube with an outer diameter of 3.1 in and a length of approximately 57.4 in The body tube was split into two sections with a coupler section between the two.

After construction, The Bat was flown for a test launch. Following this test flight, it was decided to make a few alterations to ensure that for its next flight the rocket would be more structurally sound. During descent of the test flight, the shear pin did not make a clear break, getting caught on the body tube. The pressure from the ejection charges was great enough to instead tear the nosecone off the body tube (further discussion on the test flight will be in the test flight portion of the report). In response, it was decided to shorten the body tube by an inch to remove the damaged portion. Additionally, the body tube was fiberglassed to provide more strength and prevent future tears. Finally, a simulation of The Bat was created in order to compare the expected values to the values found during the test flight. This simulation was updated before the competition flight to update the characteristics of the rocket. The simulation for The Bat can be seen in Figure 2.

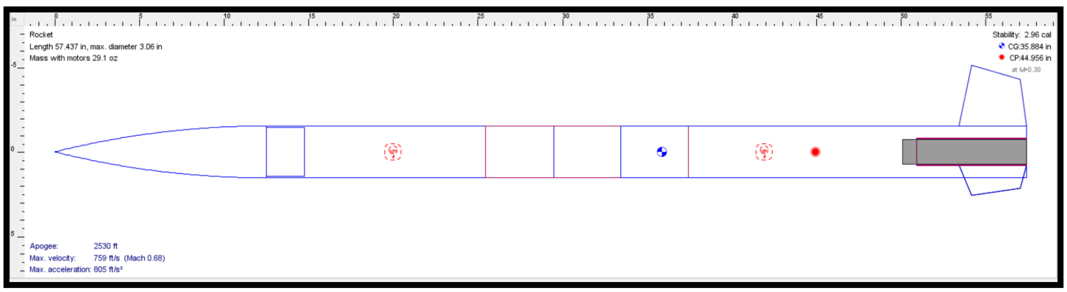

Figure 2: The OpenRocket simulation of The Bat

Cerberus. Cerberus was a team-built rocket. The nose cone for this rocket was an ogive series shape that was 3D printed using PLA and then strengthened with a layer of epoxy. This rocket had two sections of body tubes that were connected with a transition portion. The bottom body tube was a Uline cardboard tube with an outer diameter of 3.15 in and inner diameter of 3 in. The length of this body tube was 17 in. The top body tube was a cardboard tube with an outer diameter of 2.25 in, an inner diameter of 2 in and a length of 14 in The transition portion was 3D printed using PLA and strengthened using epoxy. The transition was 3 in long. This rocket had 3 fins at the base with a height of 3 in and laser cut from .25 in plywood. An Altimeter 2 was used to validate the simulated predictions. A Strattologger CF was used to deploy the 36 in main parachute at apogee. The OpenRocket simulation of Cerberus can be seen in Figure 3.

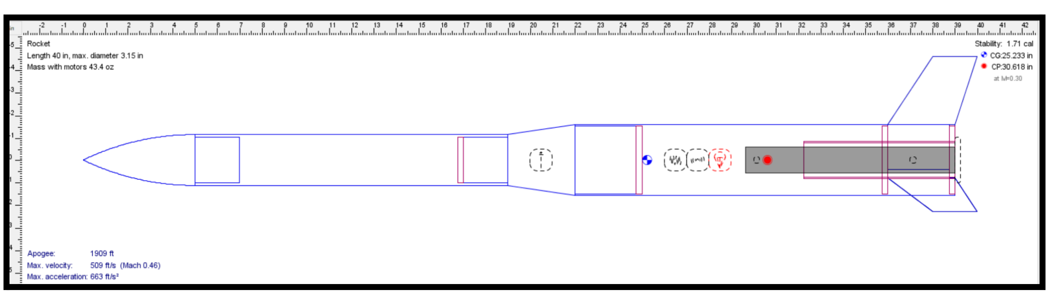

Figure 3: The OpenRocket simulation of Cerberus.

Couatl. Couatl was a Level 2 Certification rocket. It was designed with a 7 in long parabolic series nose cone. The nose cone was printed at a 45 degree angle to accommodate for the height constraints of the second printer being used. The body tube of the rocket was a Uline cardboard tube with an outer diameter of 3.15 in and a length of 48 in The body tube was fiberglassed to improve its strength. Couatl had 5 fins at the base of the rocket with an additional set of 3 fins located 10 in from the bottom of the rocket. The set of 5 fins were laser cut from .25 in plywood and were attached internally using a centering ring motor mount. The smaller 3 fins were constructed from .125 in G10 fiberglass and were centered on the outside of the body tube using a laser cut jig. Finally, all fins had epoxied fin fillets and were reinforced with tip-to-tip fiberglassing. To ensure a safe recovery, Couatl was designed with dual deploy parachutes. The OpenRocket simulation of Couatl can be seen in Figure 4, below.

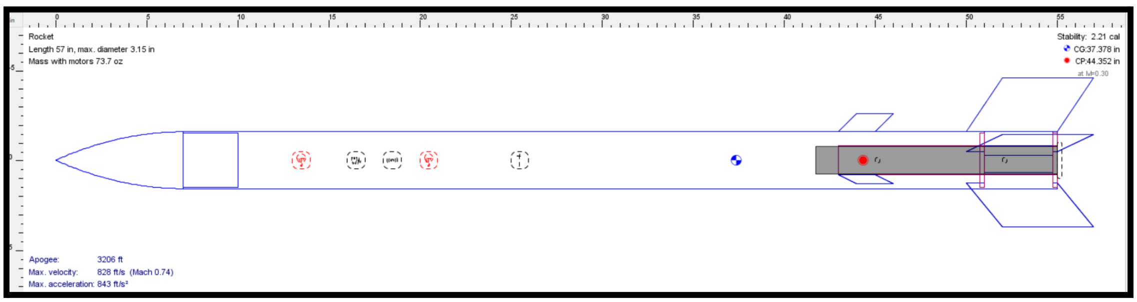

Figure 4: The OpenRocket simulation of Couatl

Cthulhu. Cthulhu was a Level 2 Certification rocket. The nose cone for this rocket was a Hakke series shape that was 3D printed using PLA and then strengthened with a layer of epoxy. The body tube of this rocket consisted of two sections. Both sections were Uline cardboard tubes with an outer diameter of 3.15 in and an inner diameter of 3 in The length of the top and bottom body tubes were 32 in and 28 in respectively. The rocket had a 2 in coupler between the two sections. This rocket has 4 fins at the base of the rocket. They were wavy freeform fins with a height of approximately 5.625 in These fins were laser cut from .25 in plywood and reinforced with a layer of fiberglass. An Altimeter 2 was used to validate the simulated predictions and a Strattologger CF was used to deploy the 20 in drogue parachute at apogee. The 48 in main parachute was deployed using a Jolly Logic Chute Release to deploy at 600 ft. The OpenRocket simulation of Cthulhu can be seen in Figure 5, below.

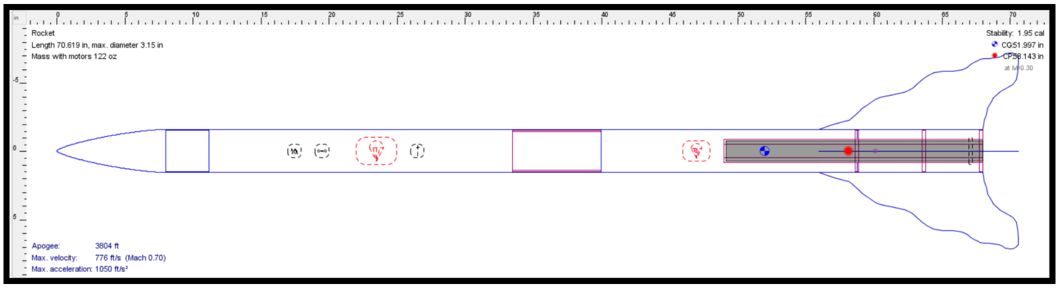

Figure 5: The OpenRocket simulation of Cthulhu

The Dragon. The Dragon was a team-built rocket that was designed with an ogive 6 in nose cone and a 36 in body tube. The nose cone of The Dragon was also printed at a 45 - degree angle to accommodate 3D printer height constraints. The parabolic series nose cone was 3D printed using PLA and then strengthened with a layer of epoxy. The body tube of the rocket was a Uline cardboard tube with an outer diameter of 3.15 in The 4 fins of The Dragon were designed to look like dragon fins with sharp edges and were laser cut out of .25 in plywood. An Altimeter 2 was used to validate the simulated predictions and a Strattologger CF was used to deploy the 36 in single main parachute at apogee. The OpenRocket simulation of The Dragon can be seen in Figure 6.

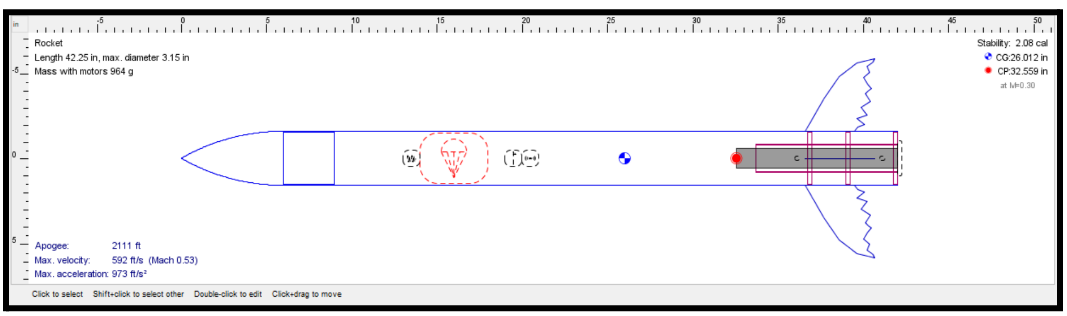

Figure 6: Simulation of The Dragon in OpenRocket

Kappa. Kappa was a team-built rocket. The nose cone for this rocket was an ellipsoid series shape that is 3D printed using PLA and then strengthened with a layer of epoxy. The length of the body tube was 34 in. This rocket had 5 fins at the base of the rocket with a height of 4 in laser cut from .25 in plywood. An Altimeter 2 was used to validate the simulated predictions, and a Strattologger CF was be used to deploy the 30 in main parachute at apogee. The OpenRocket simulation of Kappa can be seen in Figure 7.

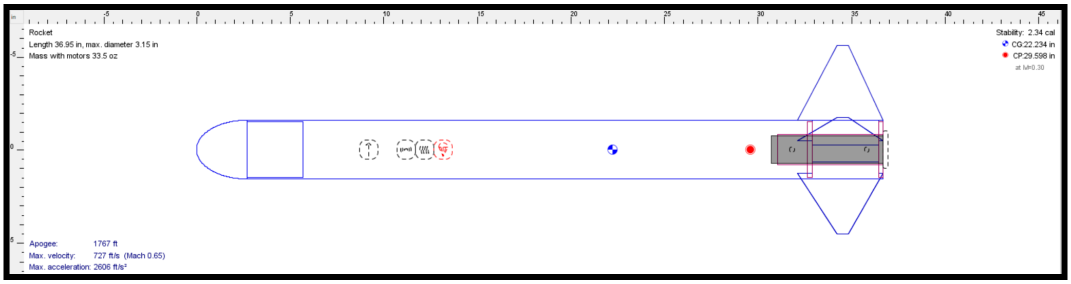

Figure 7: The OpenRocket simulation of Kappa

Phoenix. Phoenix was a Level 2 Certification rocket. The nose cone for this rocket was a parabolic series shape that was 3D printed using PLA and then strengthened with a layer of epoxy. The nose cone was printed at a 45 - degree angle to accommodate for the height constraints of the second printer being used. The length of the body tube was 38 in and was fiberglassed to improve strength. This rocket had 4 fins at the base of the rocket. These fins were freeform fins designed to resemble feathered wings. They had a height of 3.875 in. These fins were laser cut from .25 in plywood and reinforced with a layer of fiberglass. An Altimeter 2 was used to validate the simulated predictions and Strattologger CF was be used to deploy the 20 in drogue parachute at apogee. The 36 in main parachute was deployed using a Jolly Logic Chute Release to deploy at 600 ft. The OpenRocket simulation of Phoenix can be seen in Figure 8, below.

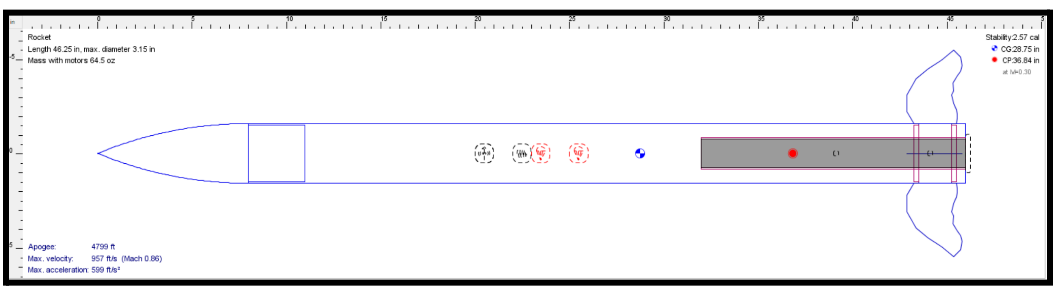

Figure 8: The OpenRocket simulation of Phoenix

Wyvern. Wyvern was a team built-rocket. The nose cone for this rocket was an ogive series shape that was 3D printed using PLA and then strengthened with a layer of epoxy. The length of the body tube was 44 in. This rocket had 4 fins at the base of the rocket with a height of 3 in and laser cut from .25 in plywood. An Altimeter 2 was used to validate the simulated predictions. A Strattologger CF was used to deploy the 36 in main parachute at apogee. The OpenRocket simulation of Wyvern can be seen in Figure 9.

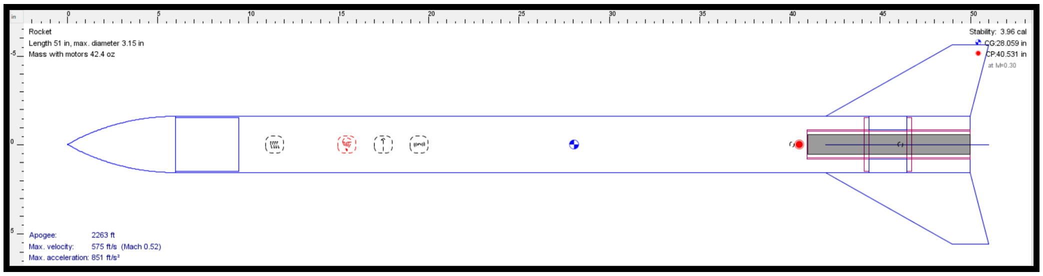

Figure 9 : The OpenRocket simulation of Wyvern

Results

Table 1: Summary of flight data for each rocket that was launched.

Rocket	Mass (g)	Motor	Altimeter	Apogee (ft)	Max Velocity	Max Acceleration
Cthulhu	~3515	Aerotech J570W-14	Altimeter 2	4820	500mph	23.1Gs
			Strattologger CF	4815	N/A	N/A
			Strattologger CF	4814	N/A	N/A
Couatl	~2228	Aerotech J420R-14 A	Altimeter 2	N/A	N/A	N/A
			Missileworks RRC2L	3749	1941 ft/s	N/A
Phoenix	~1942	Aerotech J270W-14	Altimeter 2	4472	296mph	21.9Gs
			Missileworks RRC2L	4400	1112 ft/s	N/A
The Bat	~1530	Cesaroni H225-14 A	Altimeter 2	N/A	N/A	N/A
			Strattologger CF	N/A	N/A	N/A
			Strattologger CF	N/A	N/A	N/A

Cthulhu and Couatl had successful flights and Level 2 Certifications. The creator of Phoenix succeed in the Certification exam but failed the launch due to a broken fin. The Bat did not go far off the launch pad due to the motor breaking through the casing, launching through the rocket body tube. The other four team rockets were not launched at the competition.

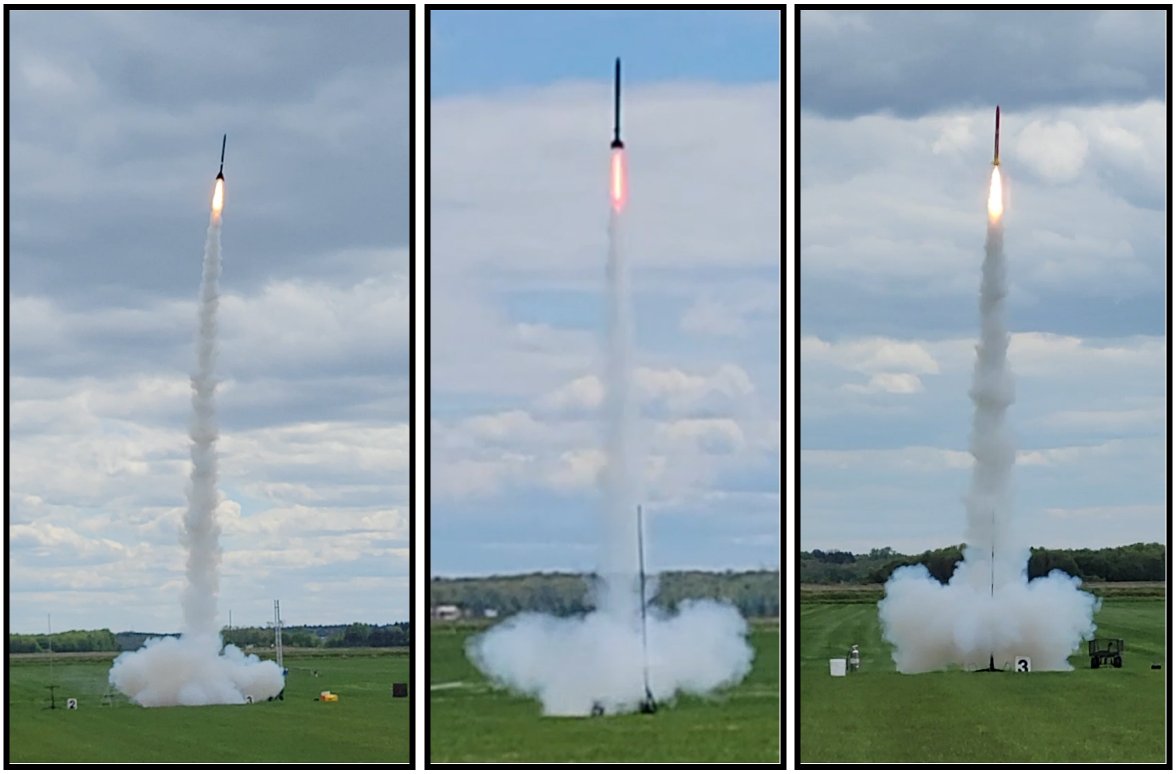

Figure 10 : From left to right, Cthulhu's, Coutal's, and Phoenix's launch off the pad.

Figure 11 : The Bat with the motor that launched through the rocket.

Discussion

Couatl. The simulated value of the apogee was 3257 ft while the recorded apogee was measured to be 3749 ft. Due to the difference in results, the team thought that there may have been calibration steps that were not completed for the setup of these devices. Another reason that these values may have been different was due to the second set of fins on this rocket. Since this set of fins were only an inch tall, there was a chance that the OpenRocket did not correctly simulate the fins. A third possible reason for this difference in values could be due to insufficient air holes for pressure to the avionics bay.

Cthulhu. Cthulhu was simulated to go up to 3751 ft, but all three altimeters on board measured an apogee of over 4810 ft. This was about 960ft higher than expected. Since the fins were a peculiar shape, the simulation may have not been able to accurately calculate the rocket's apogee. Revisiting the simulation revealed some mistakes in the accuracy of how the simulation was set up. The fin cross-section was marked as square instead of rounded. By making this one adjustment, the simulated apogee boosted from 3751 ft to 4625 ft. Though still not perfectly accurate, this resolved the surprising several hundred additional feet in apogee. It made sense that the fins would greatly affect the apogee due to the large size creating large amounts of drag for the rocket. By rounding off the edges, the rocket became more aerodynamic. Since the fins have a considerable amount of impact on the apogee, it was possible that the simulation could have taken more measures for accuracy.

Phoenix. The predicted apogee was 4868 ft while the actual apogee was 4472 ft. One of the fins of this rocket broke off, likely due to a few reasons. First, the fins of this rocket were small and thus less stable during flight. With this rocket reaching such a high apogee and with a high maximum velocity since the fins were small, they were more likely to break off during either flight or recovery of the rocket. Another reason why this fin likely broke off was due to the narrow connection point between the fins and the body tube. Although fiberglassing was done to strengthen the fins, one broke upon landing.

The Bat. Unfortunately, The Bat was unsuccessfully launched due to a major motor casing failure. Upon review of the rocket, after it was cleared to be safe by the safety crew at the launch, it looked like there was a failure of the motor casing. The team had used this specific casing before for previous rocket launches and was not completely sure why the casing failed. Due to the repeated use of the casing, the team suspected that the threads at the end of the casing were worn down and could no longer properly hold the plastic retention piece. In the future, Pioneer Rocketry plans to purchase a new casing and keep track of the number of times a casing is used as well as more closely inspect the condition of casings before use to avoid future failures similar to this one. Thankfully the rocket is still in flyable condition, and the team can attempt a future launch.

The Other Rockets. Unfortunately, Pioneer Rocketry was not able to launch all eight rockets in the armada. However, the team is happy to have launched three Level 2 Certifications with two of those attempts being successful. This shortcoming was due to the lack of team members at the launch, running short on time, and weather conditions. While this was not the outcome the team was hoping for, Pioneer Rocketry is grateful for the many opportunities this competition has provided the members of this team including the design and construction of a variety of rockets while learning more about electronics used in rocket recovery systems. The team plans to launch the remainder of the armada this fall. Each member is proud of the work they put into making the armada a reality, and will use what was learned in this experience in future competitions and beyond.

Acknowledgements

Pioneer Rocketry would like to thank the Minnesota Space Grant Consortium for organizing and hosting the competition and the Wisconsin Space Grant Consortium for funding for this competition. Additionally, Pioneer Rocketry thanks Nate Michek, our high-power mentor, and our club advisor, Katie Rabidoux, for the helpful suggestions throughout all stages of the competition. We would like to thank Tim Lehr and Gary Stroick, too, for all of the assistance they have provided. We would like to thank the University of Wisconsin-Platteville for the financial assistance provided to the club. Finally, we thank UW-Platteville Pioneer Farms for providing a suitable location for launch tests.