Flight Readiness Report

Team RedShift 7

University of Minnesota – Twin Cities

Wisconsin Space Grant Consortium
2014 Midwest Regional Rocket
Competition

Table of Contents

Executive Summary

Team RedShift 7 began in a seminar course at the University of Minnesota. We had the opportunity to continue from fall semester to enter the competition, and our team decided to do so. At the end of fall semester, we made a rocket of phenolic tubing according to regulations for the competition (72 inch height, K454 motor, 4-inch diameter), and launched it before winter break. Our motor ended the rocket in a CATO, and there were no salvageable body parts left, so we were left to start from scratch.

Continuing into spring semester, we realized quickly that as a team of all first-year students, we are both unique and less experienced than most. We are the only freshman team working in the lab, but are fortunate enough to have had the semester of experience behind us. We decided to get fiberglass enforced phenolic tubing, and a fiberglass nosecone, so that our rocket material would be stronger. We also got more body material to increase the height according to the new height regulation rule.

On March 29, half of our team attended an outreach event at a Girl Scout camp, while the other half launched the rocket to see how well we are within the altitude requirement. Within our avionics bay, we have a compartment for lead weights, so we needed to figure out how much weight to add to the rocket in order to lower the apogee to as close to 3000 feet as possible. Unfortunately the motor had a CATO again, but luckily most of the body was able to be re-used. We have been working to rebuild the lower section of body tubing including the motor mount, fins, body tube, and motor retention. We are also working on finishing the integration of our electronics, which have proven to be the most time consuming as we have the least experience with this portion of our rocket. The goal is to have one more test launch before the competition date.

Design Features of Rocket

The rocket is 84 inches long and 4 inches in diameter. We chose to make the rocket the maximum length (after the rules changed) in order to provide a large amount of space for the avionics bay while still leaving sufficient room for the parachutes. The airframe of the rocket is composed of pre-glassed phenolic (fiberglass-reinforced). We chose this material because our previous rocket, built last fall, made of quantum tubing, shattered near the end of the burn phase, so we decided to use a stronger material this time. We also replaced a plastic nosecone with a metal-tipped, fiberglass nosecone also in the interest of material strength.

In selecting our fins and configuration, we decided on a four-fin configuration on the booster section and four canard fins on the upper body. We chose this configuration for a couple of reasons. First, we wanted the rocket to reach as close to 3000 feet as possible, so we needed to introduce additional sources of friction. Second, instead of using larger bottom fins (which would have done the same job), we decided on canard fins, so the center of pressure would move forward, and the rocket would not be over-stable. Another alternative to canard fins would have been to add more weight (to bring the maximum altitude down), but adding large amounts of weight makes the rocket over-stable and brings the velocity off the rail dangerously low. Finally, we added a camera pod to further increase drag (bringing the maximum altitude down, closer to 3000 ft.) as well as allow for some nice video of the flight.

Design Features of Payload System

Our rocket's payload can be broken up into three distinct categories: flight avionics, sensors, and the microcontroller. Each of these various categories will be explored in detail in the following sections.

In addition to the competition-supplied Raven3 altimeter, our rocket incorporates our own Raven 3 to control back-up apogee, main, and back-up main parachute deployment. The Raven3 is our altimeter of choice due to our team's successful use of it in the past. Additionally, their data logs can yield valuable information about the success (or failure) of a launch and the included ultra capacitor gives around 10 seconds of power, should the Raven3 become disconnected from it power source during launch, hopefully enough time for the rocket to reach apogee and the drogue chute to be deployed.

Because one of the main mission-level requirements is to record acceleration vs altitude and speed vs altitude, the sensor pack is of upmost importance in our overall rocket design. We incorporated three methods to track the acceleration and speed of the rocket: Accelerometer, pressure, and GPS. For the accelerometer, the Adafruit 10-degree-of-freedom IMU (inertial measurement unit) breakout board was chosen. The primary reason this particular sensor pack was picked was because it includes a 3-axis accelerometer, 3-axis magnetometer, 3-axis gyroscope, barometric pressure, and temperature sensor. The accelerometer will return acceleration and, with corrections from the gyroscope and magnetometer, the velocity and altitude can also be found. While the IMU includes one barometric pressure sensor, two others are included in our design because two are needed to calculate airspeed using a pitot tube and the Bernoulli equation. For the two other pressure sensors, a Honeywell silicon pressure sensor, was chosen due to the operating range, sensitivity, and cost. Additionally, the barbed sensor tip allows for easy attachment to tubing. One of these sensors will be attached to the Pitot tube to monitor the dynamic pressure during the flight. The other Honeywell sensor will be mounted inside the avionics bay to measure static air pressure, in conjunction with the IMU's own pressure sensor. These two sensor's data will be compared to ensure accurate readings. We plan to calibrate this system when we perform our upcoming wind tunnel testing. The GPS sensor is the Adafruit Ultimate GPS breakout for Arduino. This was chosen due to the relatively low cost, small size, and availability. GPS data will include altitude, velocity, and location. This sensor will be used to compliment the readings from the accelerometer and pressure sensors, which are more standard methods for monitoring altitude and velocity. There are concerns that the GPS will be unable to achieve a satellite lock while waiting on the launch pad, in which case this data will be unusable. The data from the various sensors will be recorded in a csv file on a microSD card connected to the Arduino. After the flight the data will be imported to MS Excel, where it will more easily be analyzed. (Note – will you be able to do some calibration of your pitot tube system in known wind conditions, either in the wind tunnel or driving down the road at a known speed? Hope so.)

The microcontroller we chose to fly is the Arduino Uno (budget table says you are using and Arduino Mega), Revision 3. This microcontroller not only is small enough to fit inside our planned avionics bay easily, but it also has ample pins for connecting our various sensors. The Arduino Uno runs on software developed with Arduino IDE 1.0.5 revision 2. The microcontroller will be collecting data from each of the sensors at a rate of 200Hz (double check with Mike – I thought he wasn't able to run this fast) in order to obtain meaningful data during the short burn of the rocket motor and the remainder of the flight.

Our avionics bay features a sled 12” in length, with ample room for all of our sensors and electronics. Our Raven3, the competition Raven3, and the Arduino are all powered by separate 9V Duracell batteries, and are all controlled by three separate on/off screw switches. This is to ensure that a power outage in one will not affect the entire system. Additionally, the payload is vented with three ¼” vent holes, which double as access to the switches, so the Raven3 altimeters can calculate the correct altitude. One final feature of the avionics bay is a variable-ballast (AKA ballast) section near the top. In order to accurately achieve the targeted 3000 ft. altitude, weight can either be added or removed from the ballast section, depending on the launch day’s weather conditions and prior test launches and simulations.

Diagram of Rocket

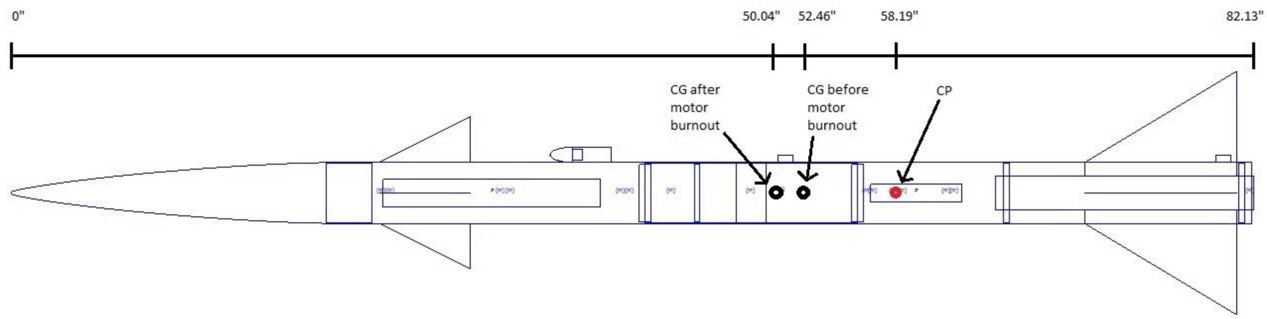
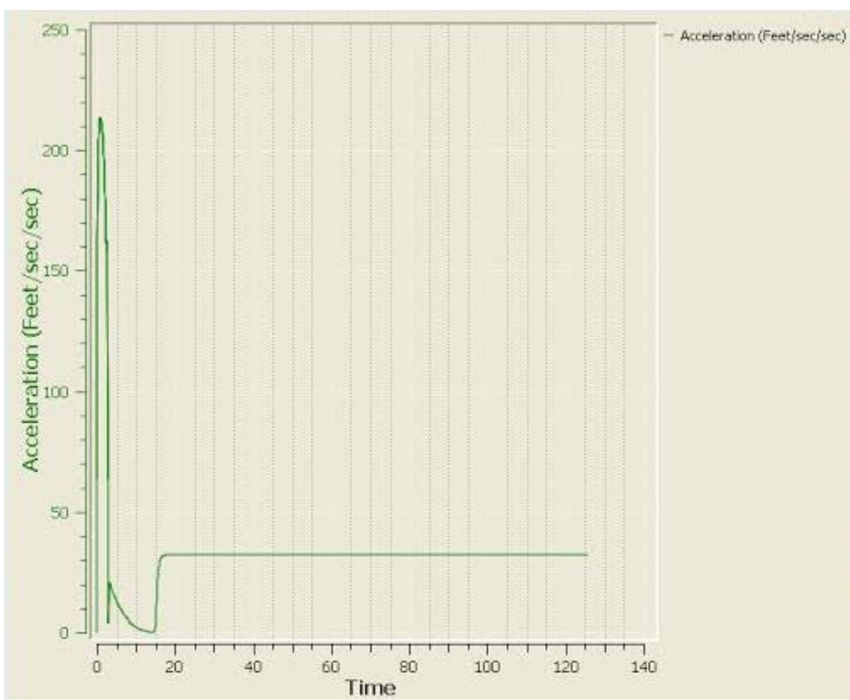


Figure 1: Diagram of Rocket. CP is located at 58.19 inches and is indicated by the red circle; CG with motor is located at 52.46 inches and is indicated by the aft black circle; CG after motor burnout is located at 50.04 inches and is indicated by the forward black circle. The locations on the figure are approximations.

Analysis of Anticipated Performance

During the boost phase, the rocket is expected to undergo a maximum acceleration of approximately 197.41 ft/s^2 (6.14 G's). The predicted maximum altitude of the rocket will depend on the wind conditions, but in ideal wind (0-2mph) conditions, apogee will be approximately be 3065.97 ft. when the rocket has no additional weight added to the avionics bay. We are intentionally overshooting the 3000 ft. goal to take into account wind and the fact that the simulation used seems to consistently overshoot the actual altitude based on experience.

These estimates were taken from simulations in RockSim 9 after loading a model of our rocket with the Cesaroni 1364-K-454-19A Skidmark motor. A graph of the estimated acceleration of the rocket vs. time is shown below.



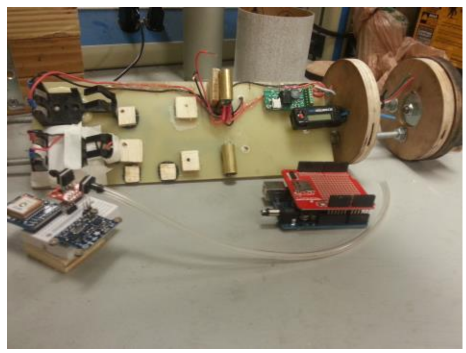
These estimated change according to the weather, however. Additional information with varying wind conditions is organized in a table below.

Wind Conditions	Max Altitude (ft)	Max Acceleration (ft/s^2)	Max Speed (ft/s)	Max Range from launch site (ft)
Calm (0-2 mph)	3065.97	197.41	444.2	280.34
Light (3-7 mph)	3044.21	197.41	444.05	609.25
Slightly Breezy (8-14 mph)	2985.71	197.41	443.69	1871.03
Breezy (15-25 mph)	2855.25	197.41	442.92	2935.21
Very Windy (25 mph)	2774.48	197.41	442.46	3573.56

Construction of Rocket

The first step in building the rocket was assembling the motor mount tube. The tube was cut to fit a K454 motor. We attached a forged eyebolt to the centering ring at the top of the motor mount tube in order to attach the shock cord to the lower half of the rocket. After the motor mount tube was fully assembled, it was epoxied into the lower airframe. The fins were then attached. The fiberglass wrapped phenolic airframe has slots in it so that the fins could be epoxied to the motor mount tube and to the surface of the rocket. A centering ring was epoxied at the bottom of the motor mount tube once all of the fins had been attached. A Highly Adaptive Motor Retainer (HAMR) system was attached to the bottom of the motor mount tube to hold the motor in place during the flight.

As the epoxy for the HAMR was curing, the canard fins were attached to the upper airframe. The canard fins were epoxied into dado slots in order to attach them more securely. After the canard fins were attached, a piece of plywood was epoxied to the inside of the upper airframe; this was done so that the screws for the camera pod would have something to screw into. The screws were filed down so that their sharp tips would not protrude and interfere with the parachute. Because the nosecone and avionics bay are separate from the main airframe, they were constructed while the epoxy was curing. A centering ring and bulk plate combination was used to attach the shock cord to the nosecone without permanently sealing the nosecone. The centering ring was epoxied into the nosecone and the bulk plate was attached to the ring with 2 nuts and bolts. This was done so that the bulk plate can be removed and the space in the nosecone can be used if needed, possibly for a GPS tracking radio in the future. The avionics bay has a sleeve on it so that it can act as a coupler tube between the upper and lower airframes. The inside of the avionics bay is divided into two sections that are divided by a bulk plate. The aft section houses the electronics. The forward section is for additional masses; the masses will be added to this section in order to reach the target altitude in the specific conditions without altering the center of gravity very much.



Top left: A piece of plywood for the camera pod. Top right: The camera pod.
Middle left: A sleeve is on the avionics bay. Middle center: Motor mount tube. Middle right: Avionics bay including Arduino, breadboard, and Raven sensors.
Bottom left: Dado slotting for the canard fins. Bottom right: Centering ring and bulk plate combination for the nosecone.

Photographs of Completed Rocket

Note: This was the rocket before a practice launch, during which part of the rocket was destroyed, so we will not be using this exact configuration for the competition.

Conclusion

As our third attempt at building and flying this competition rocket, our team is really hoping in the common saying, “third time’s the charm.” As the CATOs of our other rockets were unfortunate, we are hopeful for a successful flight with all parts ready before competition day. Our final rocket will stand 84 inches tall, with a 4-inch diameter. The body is made of fiberglass wrapped phenolic, and the nosecone is fiberglass with a metal tip. We have a four-fin configuration on the lower body, as well as four canard fins to move our center of pressure forward, and make the rocket more stable.

In the avionics bay, there is a shelf for lead weights that we can adjust the day of competition according to wind conditions, so the apogee is as close to 3000 feet as possible. In addition to the competition Raven, we will have our own to control back up charges for the dual deploy system. An Arduino Uno microcontroller is incorporated with sensors to measure acceleration, pressure, and GPS. This is to measure the acceleration vs. altitude and speed vs. altitude in multiple ways, in accordance with competition requirements. The Raven sensors, Arduino Uno, and a pitot tube with one of the pressure sensors will be housed on a 12-inch sled in the avionics bay. We also have a switch that allows the sensors to be turned on easily before flight.

Once the rocket is fully put together, the center of pressure is located at 58.19 inches from the tip of the nosecone. The center of gravity with motor is located at 52.46 inches and after motor burnout is located at 50.04 inches below the nosecone. According to RockSim 9, the maximum acceleration the rocket will attain should be 197.41 ft/s^2 with our K454 sized motor. The apogee approximations vary according to the wind conditions, but weight will be added on competition day according to these conditions to make the apogee prediction as close to 3000 feet as possible.

When constructing the rocket to integrate all necessary pieces, we epoxied most pieces together. We cut all centering rings and bulk plates ourselves, which were mostly used to screw in eyebolts for shock cord and parachutes to attach to. One parachute will be housed between the motor mount and avionics bay, while the other is above the avionics bay and below the nosecone. Just in case we needed access to the nosecone at a later time, we did not close it off, but put the eyebolt in a centering ring inside it. All separated parts of the rocket are attached with rivets and sheer pins, as well as coupler tubes.

Before competition date, we are hoping to do a few more things. This includes one more test launch to make sure all things are in order and that we have no issues with the integration of the rocket. We are also planning on gaining access to the school's wind tunnel in order to find the exact center of pressure and learn how the process of tunnel testing works. Lastly, we will paint the rocket and integrate all electronics into the avionics bay. The tasks will not necessarily be done in this order.

Not only have we gained experience with high power rocketry through this competition, but we have also gotten to decide and create ways to make our rocket unique and prepared within requirements. As a team, we have grown to work together according to our strengths, while also learning new things each day of the experience. When the competition day arrives, we hope to be as prepared as possible to do our best. Our rocket will accurately show the hard work and determination we have put into it.

Budget					
Part	**Supplier**	**Part #**	**Price**	**Qty**	**Total**
Pre-Glassed Phenolic Airframe (3.9")	PML	FGPT-3.9	$99.95	2	$199.90
Custom FG Airframe Cutting	PML	Cut-FG-TUBES	$2.00	3	$6.00
Custom FG Airframe Slotting	PML	SLOTTING-FGT	$6.00	4	$24.00
Custom FG Airframe Dado Slotting	PML	SLOTTING-FGTDADO	$6.00	4	$24.00
Fins (Lower, C-09)	PML	FIN-C-09	$11.63	4	$46.52
Fins (Canard, AMRAAM-4 Upper)	PML	FIN-AM4-UPR	$3.95	4	$15.80
Nosecone (4", filament)	RW	NC-FW4VK	$69.00	1	$69.00
Phenolic Coupler Tube (For av bay)	PML	CTF-3.9-36	$18.50	1	$18.50
HAMR Sleeve (54 mm)	PML	HAMR-54-SLV	$18.95	1	$18.95
DP-420	Barry & Sewall	N/A	$20.00	3	$60.00
Paint/Primer	HD	N/A	$4.00	4	$16.00
E-match	OWGR	N/A	$2.00	6	$12.00
Nomex Cloth (16”)	LOC	N/A	$19.00	2	$38.00
Shock Cord	LOC	N/A	$0.30	40ft	$12.00
Eyebolts	OWGR	N/A	$1.50	4	$6.00
IMU Sensor	Adafruit	1604	$50.00	1	$50.00
GPS	Adafruit	746	$40.00	1	$40.00
Pressure Sensor	Adafruit	992	$12.00	2	$24.00
Arduino Mega	Sparkfun	DEV-11601	$58.00	1	$58.00
Raven3 Altimeter	FeatherWeight	N/A	$155.00	1	$155.00
Mobius ActionCam HD Camera	Amazon	N/A	$90.00	1	$90.00
Videocamera Shroud	Etsy	N/A	$20.00	1	$20.00
K454 Skidmark Motor	OWGR	N/A	$115.00	1	$115.00
4 Grain Motor Casing	OWGR	Pro54	$79.15	1	$79.15
Miscellaneous Hardware	N/A	N/A	N/A	N/A	$50.00
			Total:		**$1,247.82**
Pre-Glassed Phenolic Airframe (3.9")	PML	FGPT-3.9	$99.95	1	$99.95
Custom FG Airframe Cutting	PML	CUT-FG-TUBES	$2.00	1	$2.00
Custom FG Airframe Slotting	PML	SLOTTING-FGT	$6.00	4	$24.00
			Grand Total:		**$1,373.77**

Note: Items listed before the first total were original purchases. Items listed after this were purchased to replace damaged parts.