Preliminary Design Report

University of Wisconsin-River Falls

Rocketeers

Team Leader:

Andrew Larson, andrew.larson@my.uwrf.edu, 715-220-7832 (cell)

Student Team:

Andrew Larson

Cavan Maher

Grace Zeit

Jacob Hanson-Flores

Faculty Adviser:

Dr. Glenn Spiczak, glenn.spiczak@uwrf.edu, 715-338-0484 (cell)

Mentor:

Joe Schneider

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Executive Summary:

Competition Parameters

The 2017 Midwest High-Power Rocket competition “requires student teams to construct an ‘adaptable’ single stage, dual deployment high-power rocket system.” The adaptable rocket must fly two separate times, to the same highest apogee, using two very different motors. The rocket must safely land via parachute recovery system. Teams must also capture video of the apparent “adaptability” mechanism and also that of drogue and main parachute deployments. Prediction of the rocket’s apogee must be predicted by the students and then tested with on-board data collection. The fabrication of the rocket is to be entirely completed by students.

Overview of Rocket Design

At a length of 139 cm and a diameter of 10.2 cm, the rocket requires an extensive amount of uniform drag to successfully complete the competition. Our chosen motors are the Aerotech J135W-L and K1100T-L. Each has a 14 sec delay. The J135 uses White Lightning propellant and the K1100 uses Blue Thunder propellant. The airframe flaps will be adjusted to protrude a certain amount and for the time required to cut the altitude 50% when using the highest power motor. The airframe flaps are approximately 25 sq.cm each so that four flaps in each of two sections will provide sufficient area to more than double the effective drag, depending on how long they are deployed.

Team

The UWRF Rocketeers team consists of four members. The team Leader, Andrew Larson, is a first time high-power rocket competitor and will earn his degree in Mechanical Engineering. Cavan Maher is a first-time high-powered rocket competitor and is working toward degrees in Physics and Mathematics. Grace Zeit is in the Applied Physics for Industry & Engineering program and has been a team leader on a previous collegiate high-powered rocket team. Jacob Hanson-Flores is a first-time high-powered rocket competitor working on a dual-degree in physics and engineering.

Design Features, Mechanical & Electrical Design:

Rocket Airframe

The requirements of the competition challenges student teams to design and build an “adaptable” rocket that reaches the same maximum altitude with two very different engines and different launches. With these parameters in mind, the airframe design dimensions are 139 cm long with a diameter of 10.2 cm made of G12 fiberglass with deployable flaps. These flaps will be released mechanically with a small servo motor, and once released the pressure of the wind will automatically deploy them further. As the rocket comes closer to apogee, a set of springs will return the flaps to the normal airframe aided with neodymium magnets to lock them back in place. The flaps are designed to significantly increase the drag causing dramatic negative acceleration. The rocket will be equipped with an downward facing camera mounted on the outside to capture this process on video. An upward facing camera will also be mounted to the airframe to capture the parachute deployments.

Recovery System

The rocket incorporates a dual deployment system, controlled by the TeleGPS, consisting of a drogue and single main parachute. The small drogue will deploy at apogee and slow the descent while minimizing the amount of drift prior to the release of the main parachute. The drogue is a 30” elliptical from Fruity Chutes weighs 3.1oz with a 15.9 cubic inch packing volume, providing a main chute deployment speed of 25 mph. To meet the competition landing velocity requirement of 24 ft/sec, the main chute is 48” diameter ultra-compact design from Fruity Chutes with a drag coefficient of 2.4 weighing 4.3 oz. with a packed volume of 26 cu.in. Both parachutes will be secured 1500 lb. test Kevlar cord.

Propulsion System

The propulsion system we are using for the first flight incorporates an Aerotech J135W-L motor, which will provide an average thrust of 157 N, with a maximum thrust of 274 N. The burn will last 6.8 sec, which provides a total impulse of 1069 N*s. The dimensions of the motor are 54.0 mm in diameter and 368 mm long. The total weight of the engine will be 1141 g, with 633 g being propellant weight. The second motor type is the Aerotech K1100T-L motor, which provides an average thrust of 1100 N, and provides a maximum thrust of 2004 N. Its burn lasts for 1.6 seconds, providing a total impulse of 1472 N*s. The dimensions of the motor are 54.0mm in diameter and 437mm in length. The total weight of the motor is 1336 g, with 773g being propellant weight. For each of the motors, there is a 14 second delay between the end of the burn and the secondary charge that initializes the recovery system. These motors are reloadable, and have already been purchased. We will be given these at both the competition location and the test flight location once the rocket passes inspection immediately prior to launch.

Avionics/Payload System

An Arduino Uno will be used to control the servo motor with the aid of an altimeter. A Raven III altimeter, which contains an axial and lateral accelerometer will be used as a back-up. The use of an Altus TeleGPS will be used for mapping the 3d flight profile and dual deployment of parachutes as well as barometric pressure, accelerometer, altimeter and 70cm ham-band transceiver.

A 9 degree-of-freedom Inertial Measuring Unit will be used for measuring speed and acceleration throughout the flight. The 9 DOF is achieved using accelerometers, gyroscopes, and magnetic field sensors for each of three axes, so this unit will also provide orientation and rotation data for a complete understanding of the entire flight profile for analysis.

Cameras

Two Mobius MiniCam cameras will be mounted on the outside of the airframe, with a small shroud similar to the prototype shown here to ease the airflow around the rectangular camera body. The downward facing camera is shown here. The standard USB is pictured for scale. These cameras allow for 1080p HD video at 60fps and are also much more reliable than the keychain cameras often used in the past.

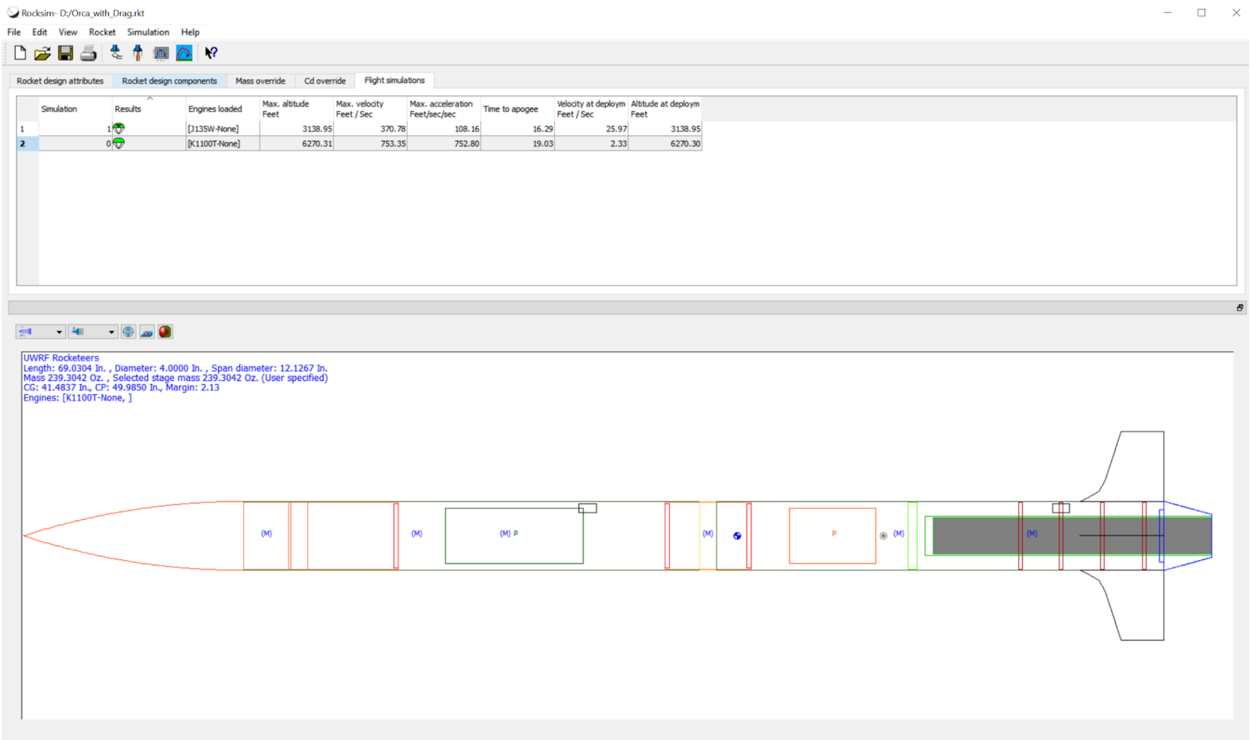
Construction Solutions & Techniques
All 3D design files, laser cut patterns and wood forms are retained in the University of Wisconsin-River Falls Physics Department. All 3D printed and laser cut components were designed using SolidWorks. MatterControl and Cura were used to prepare STL files for 3D printing. Nosecone and fiberglass materials were cut using a rotary tool and hacksaw.

Structural Analysis
The 3D printed parts are designed and built using the same techniques, machinery, and materials as have been used and flown on previous high-powered rocket flights without any issues as recently as last year. Other structural components have been purchased from high-powered rocketry vendors and similar electronics components from reputable vendors have been used on previous rocket flights.

Risk Mitigation Analysis
Risk has been reduced with redundancy in systems. The design incorporates two cameras, two sets of drag flaps, and two methods of parachute deployment. The two cameras view mainly up & down, but each also views a small mirror showing the hemisphere behind the camera as well as the main view in front of the camera, so that if any one camera fails there will still be lower quality video available for that hemisphere. The drogue chute deploys either with the delayed charge from the motor or the altimeter apogee sensor. Two sets of drag flaps can be deployed depending on the assessment of needed drag.

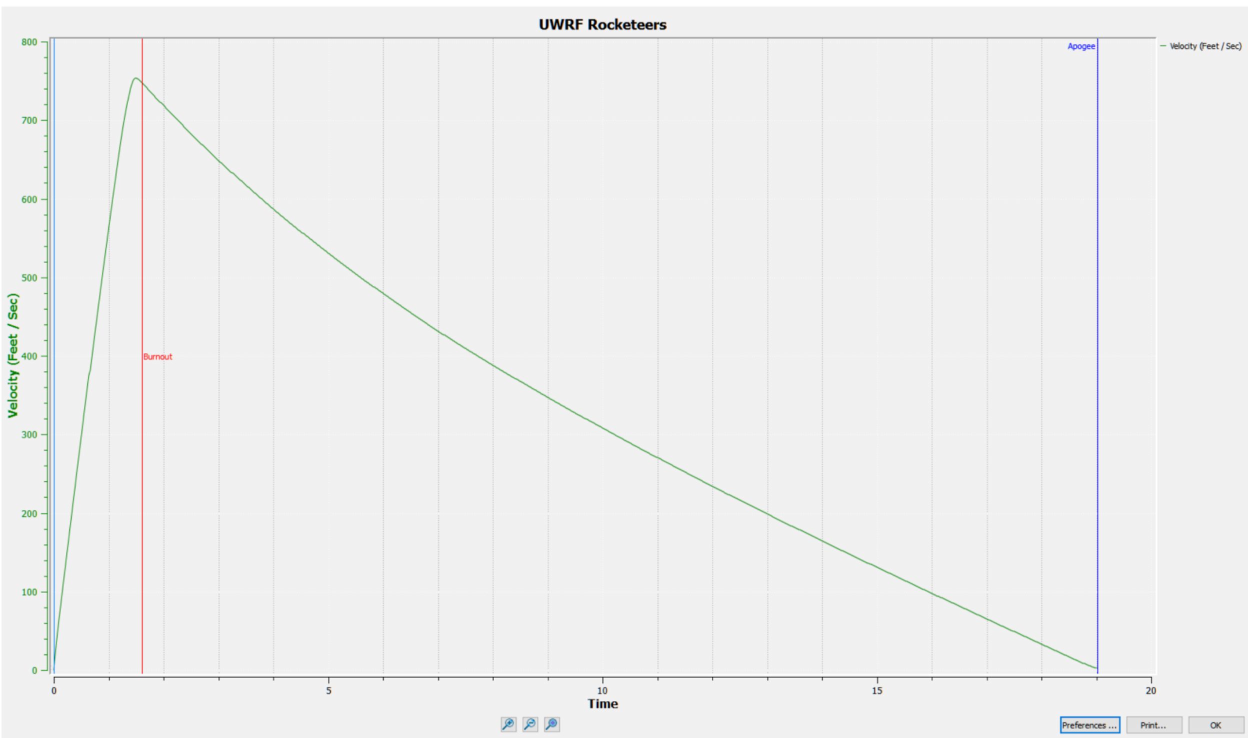
Diagram of Rocket:

The configuration as simulated in RockSim, with the drag flaps not deployed, are noted in the figures below, with the center-of-pressure at 49.99 cm and center-of-gravity at 41.48 cm as noted, resulting in a 2.13 stability margin for the K1100 configuration.



Analysis of Predicted Performance

The motor selection was chosen so that the higher power motor configuration would reach twice the altitude if there were no drag system, so that our challenge was to design an adaptable drag system to reduce the altitude as close to 50% as possible. The peak altitude with the JK1100 is predicted to be 6260 ft and the peak altitude with the J135 is 3139 ft, without drag deployed, which is in fact 50.0% of the more powerful engine.



The velocity vs. time plot for the K1100 configuration without drag is shown here, with a maximum velocity of 753 ft/sec. The plot for the J135 motor is similar except the maximum velocity is 370.78 ft/sec, which is nearly 50% of the higher power setup, as expected.

Graphs of the thrust vs time for each motor are displayed below. A short burn time was chosen for the higher power motor to maximize the coasting time during which the drag system will be deployed.

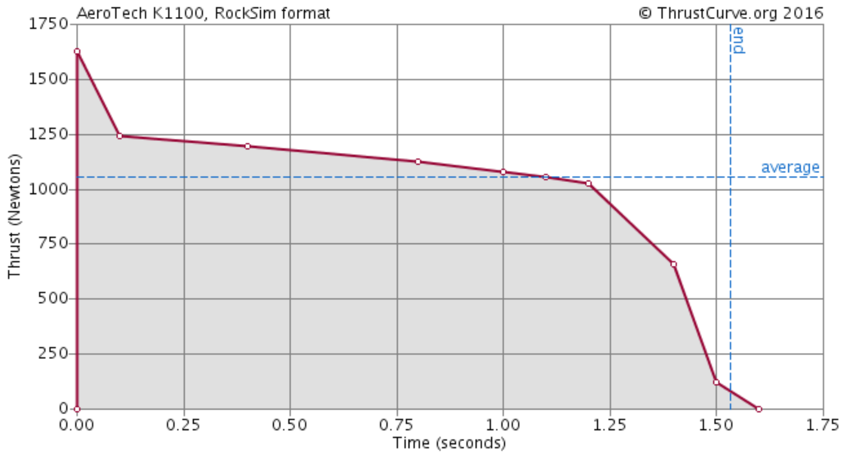


Figure 1: Thrust vs. time for Aerotech K1100T-L motor

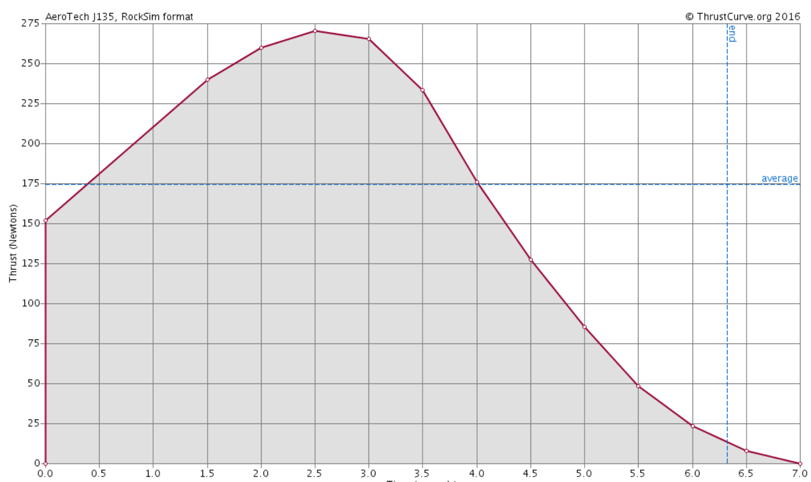


Figure 2: Thrust vs. time for Aerotech J135W-L motor.

Innovation

The innovative aspect of this rocket is the drag deployment mechanism that is spring loaded so that upon release of the locking pins, post burn, the high speed air pressure upon the flaps will deploy them further. As the rocket slows nearing apogee the air pressure will significantly reduce so that if the algorithm to initiate the manual retraction mechanism has not yet engaged then the springs will automatically retract the flaps.

Safety

Safety is paramount. Standard practices are reviewed and followed by all team members, such as storing & handling of electronics or materials such as paint, epoxy, etc. Ejection charges must only be handled in small amounts in well ventilated areas. The pre-flight checklist to ensure all aspects are properly addressed for launch is below:

Recovery Systems

- [ ] Visually inspect all cords and connection points
- [ ] Ensure parachute properly folded and loaded
- [ ] Visually inspect ejection charges

Electronic Systems

- [ ] Confirm 7.2V main battery
- [ ] Confirm 3.3V camera battery
- [ ] Visual confirmation of SD card on flight computer
- [ ] Flight 1=Disconnect servo | Flight 2=visually observe servo initialization
- [ ] Power on main switch in nosecone
- [ ] Confirm "ready" LED on main computer
- [ ] Confirm loaded position of competition altimeter
- [ ] Power on GPS/recovery system controls
- [ ] Turn on video capture, visually confirm power up sequence camera 1
- [ ] Turn on video capture, visually confirm power up sequence camera 2

Propulsion System

- [ ] Model/Type confirmed:
- [ ] Mass:_________g
- [ ] Install Motor
- [ ] Ensure motor retainer fully secured

Airframe

- [ ] Visual inspection of nosecone
- [ ] Visual inspection of sheer pins
- [ ] Visual inspection of fins

Operational Items

- [ ] Secure nosecone on rocket
- [ ] Capture photograph of rocket on launch pad
- [ ] Continuity of ignition wires

Budget:

The UWRF Rocketeers team earned a $2,000 USE grant from the UWRF office of undergraduate research to subsidize the construction of the rocket.

Estimated Budget

Item	Cost ($)
Meals	$100.00
Travel	$100.00
Registration Fees	$400.00
Total	$600.00

ADXL345 6DOF sensor	$39.95		1		$39.95
Power HD 1501MG high-torque servo	$19.95		2		$39.90
Power HD AR3606HB continuous rotation servo	$14.95		2		$29.90
Arduino RB-ARd35 Motor Shield Rev3	$23.50		1		$23.50
Apogeerockets 4” 5:1 fiberglass nosecone	$39.95		1		$39.95
TeleGPS	$214.00		1		$214.00
Bluetooth module for Arduino HM10	$16.99		1		$16.99
Subtotal					$404.19

Additional components are itemized in the table on the following page.

Item	Cost ($)	Weight (g)	Qty	Unit	Total Cost
G-12 Body Tube 98 mm	$0.77	1824	152	cm	$117.00
G-12 Coupler	$20.78	277	2	ea	$41.56
tailcone assembly	$12.00	97.0	1	ea	$12.00
G-10 Sheet 1' x 1'	$28.00	346	2	ea	$66.00
Parachute	$74.65	75.2	1	ea	$74.65
Bulkhead 98 mm	$6.00	33.1	5	ea	$30.00
4" Centering Ring	$4.85	20.8	2	ea	$9.70
2 pack of large rail guides	$10.00	11.2	1	ea	$10.00
Mobius Mini Camera	$75.00	28.3	2	ea	$150.00
Transition	$35.00	100.3	1	ea	$35.00
Eye Bolt	$0.50	36.2	3	ea	$1.50
sheer pins	$2.95	1	2	ea	$5.90
Kevlar Harness 25' x 7/16"	$35.00	5/ft	1	ea	$35.00
Jolly Logic Alt. THREE	$99.95	10.5	1	ea	$99.95
Aerotech J460T-L motor	$72.99	789	2	ea	$145.98
Aerotech K1100T-L moto	$112.99	1336	2	ea	$225.98
Total Cost					$1,060.22

Team Photo:

The following montage shows the four team members. Clockwise from center-top, Andrew is holding the small rocket from the practice launch post-recovery, Jacob is with the small rocket and full-scale rocket, Grace next to the small rocket with last year's rocket at left in the background, Cavan recovering the small rocket.