Flight Readiness Report
Team Falcon 1

Planning out the Early Stages of the Rocket (August, Dr. Spiczak, and Robert)

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Advisor:

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Executive Summary:

Competition Parameters

This year's Midwest High-Power Rocket Competition requires student teams to design and construct a boosted dart, consisting of an unpowered upper stage that separates from the booster during flight. Scoring for the flight performance favors rockets that reach the highest altitude and rockets with the greatest separation between the dart and booster apogees. Parachute recovery is required for the booster, and the dart must safely land by the use of an electronically deployed recovery system. Teams must also capture down-looking on-board video during the entire flight, including the boost phase. To be deemed a successful flight, the booster and dart must remain stable until reaching apogee and the rocket components must be in a condition suitable for re-launch after landing.

Overview of Rocket Design

Standing at a height of 123 cm and a diameter of 10.2 cm, the rocket is designed with a more compact build than previous UW-River Falls designs that used more powerful motors. Two keychain cameras, pointing down from the booster and outward through the clear polycarbonate cylinder portion of the dart, will record footage for the entire duration of the flight, including separation. Both the dart and the booster are equipped with appropriate fin sets to support stable flight. The drag on the fins combined with the momentum of the dart will result in separation of the dart and booster sections. The dart portion of the rocket contains the electronics bay with an arduino board controlling a three-axis accelerometer and an altimeter to record flight parameters and deploy a parachute at apogee.

Team

Team Falcon One consists of five members. The team captain, Robert Dietrich, is a returning competitor from last year's competition and will earn his undergraduate degree in physics this spring. August Fritze (sophomore, physics and mechanical engineering dual degree), Justin Diercks (junior, computer science and physics/engineering dual degree), Farris Al-Humayani (freshman, pre-engineering), and Jose Bermeo (freshman, computer science) are the other members. Aside from Robert, the student team has minimal prior experience with rocketry, making this a fresh opportunity for most of the members to explore this fascinating field of study.

Budget

Team Falcon 1 was given a $1000 grant by the WSGC to subsidize the construction of the rocket. Additional expenses (e.g. travel, lodging) were covered by internal Falcon grants from UWRF. A thorough budget is available as the last segment of this report.

Design Features of Rocket:

Concept

The parameters of the competition challenge student teams to build a rocket that not only ascends to optimal altitude but also maximizes the distance between the apogees of the dart and booster. With these parameters, Team Falcon One designed a rocket that separates the dart from the booster immediately following engine burnout. The main booster section was designed with a larger diameter to increase drag upon separation so that it quickly lags behind the dart. In addition to attaining the highest possible dart altitude, down-looking footage must be captured for the entire portion of the flight. The rocket was designed with clear polycarbonate tubing in order to easily capture footage for the duration of the launch from the dart, with one camera mounted in the lower dart section looking directly downward internally and one camera looking out at an angle to see the entire launch exterior starting from the ground up. Both the dart and the booster will descend safely by coasting from individual parachutes. The booster has an automatic motor ejection charge while the dart's parachute ejection is controlled by the Raven III altimeter. Supporting the stability of the flight are the fins, an essential aspect of attaining an effective flight by the predictions of the OpenRocket and RockSim software.

Booster Engine and Lower Fin Set

Powered by the Cesaroni I445 motor, Team Falcon One's rocket was designed to hold minimal weight while being able to carry the essentials needed for a stable and sturdy flight. The booster body tube and motor mount tube were both cut from a blue tube obtained by Apogee Components. The booster body tube is 30 cm long and cut from a 10.2 cm diameter blue tube; its small size allows the shift in the center of gravity to be minimal and ensures that the rocket carries less mass to maximize apex altitude. The motor mount tube is 14.3 cm long with an outer diameter of 5.74 cm and positioned at the bottom of the rocket inside the booster body tube. Four centering rings cut from birch plywood (0.63 g/cm^3), spread equidistant along the motor mount tube, measure a diameter of 9.89 cm per ring and allows the motor mount tube to stay centralized inside the larger booster body tube. The engine block, also made from birch plywood, prevents the motor from moving forward during flight and measures 9.91 cm in diameter and 1.27 cm in length. The fin set is absolutely vital in providing high altitude and straight flight project. The fins were cut in a trapezoidal manner in accordance to the estimates of OpenRocket, which deemed that this particular design would be optimal in terms of the competition objectives.

Nose Cone

The nose cone, made from polystyrene with dimensions 24.1 cm in length and 7.87 cm in diameter, allows the rocket to secure aerodynamic motion during ascent. In order to add weight to the front of the rocket and shift the center of gravity to a desired position, the tip of the nose cone was filled with a small amount of copper BBs. While lead had been previously considered due to its density and cost effectiveness, copper was ultimately decided on because of its less destructive consequences to the environment in the case of a failed flight. A second nose cone is truncated to fit the bottom of the dart, acting as the transition piece between the booster and dart, and will continue flying attached to the dart after separation for enhanced stability.

Dart and Upper Fin Set

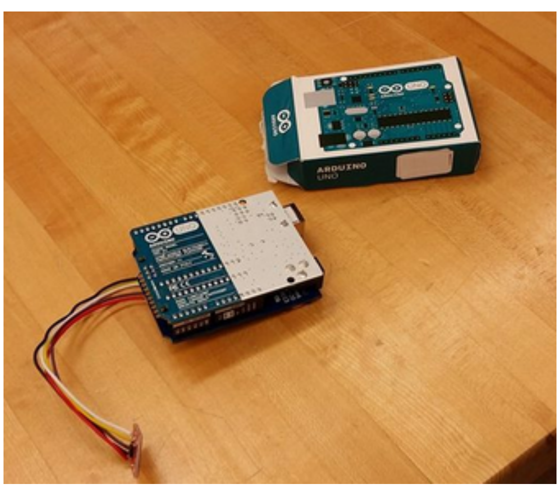
In order to record on-board footage while maintaining a smooth exterior, the rocket is constructed with clear polycarbonate tubing in a format that will easily allow footage to be captured for the duration of the flight. Attached to the dart are four triangular fins that will further increase the peak altitude and stabilize the rocket while ascending to apogee. OpenRocket estimates that even miniscule fins will drastically improve the performance of flight. Because of this, Team Falcon One opted to attach relatively small fins in order to reduce the overall weight of the dart. The fins for the rocket are made from 1/8” birch plywood (as was the booster’s fin set) and are 11 cm long and 3 cm wide.

Parachute

A 48” classic elliptical parachute will be used to guide the booster during descent for safe retrieval. Because of the dart’s light weight, a 24” circular parachute will be used for its descent. The dart’s parachute is designed to release shortly after reaching apogee, as determined by the Raven III altimeter’s programmed conditions.

Electronics

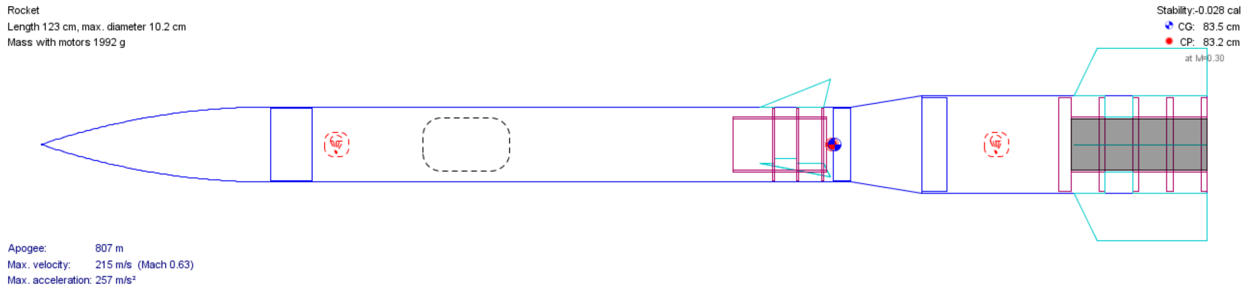
The Arduino Uno will read out the triple axis accelerometer and store data on board. The Raven III altimeter contains an axial and lateral accelerometer to compare with the triple axis Arduino. It also acts as a barometer, which can serve the role as a backup deployment to the accelerometer based deployment once apogee is reached.



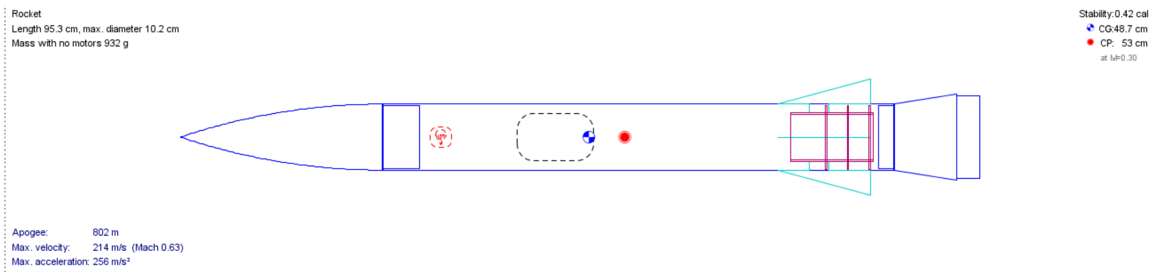
The Arduino Uno, for 3-axis accelerometer

Micro Cameras

Construction of Rocket:



*Booster and Dart **before** adding mass to nose cone, labeled with Center of Pressure (red) and Center of Gravity (white and blue)*



*Deployed Dart **before** adding mass to nose cone*

Cutting Fins

Fins for both the booster and the dart were cut in the physics department's machine shop on the UW-River Falls campus. 1/8" birch plywood was used to construct the fin set of the booster and the dart. The specific shape of the fins was designed for minimum drag while maintaining good separation and stability.

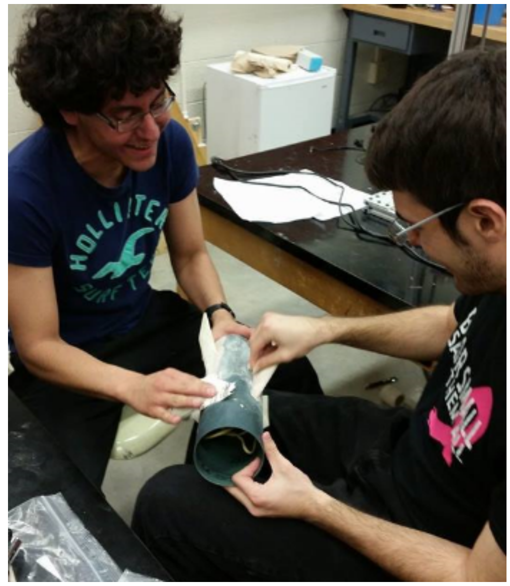
Second Nose Cone, truncated to fit bottom of dart for transition

The Nose Cone

In order to distribute weight on the rocket to shift the center of gravity, a small shot of copper BBs make up the tip of the dart's nose cone. Other than this, little was done in preparing the nose cone for flight.

Construction of Booster

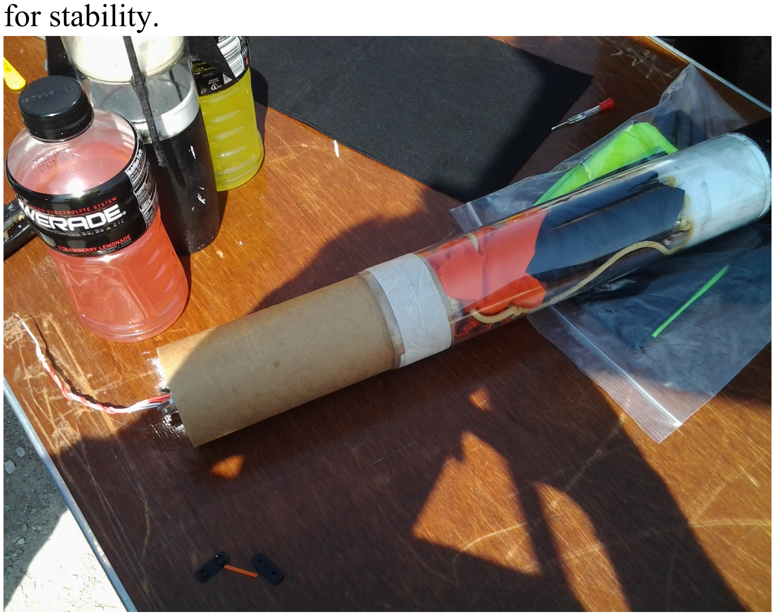
After crafting the booster, much sanding was required to smooth out the edges and prepare the outer framework for painting. Other tasks include cutting out the centering rings, constructing the engine block, and fitting in all the essential components into the booster body tube.



Sanding the Booster, Preparing for Paint

Construction of Dart

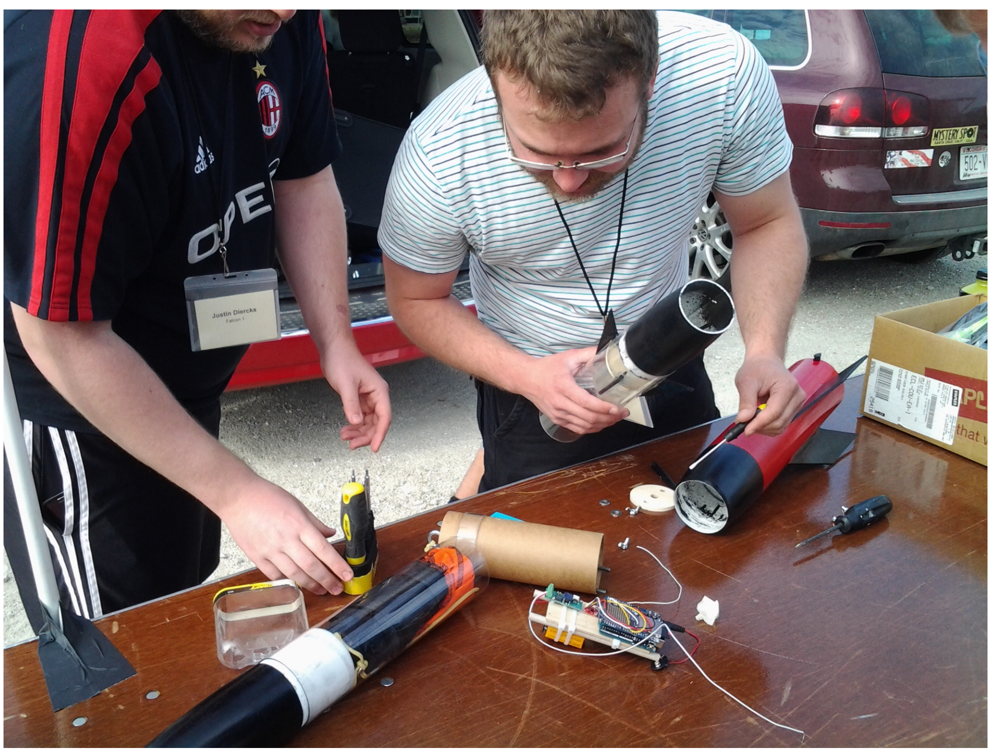
A clear polycarbonate mid-section houses the electronics bay with a pointed nose cone at the top. Weight is added in the tip of the nosecone, shifting the center of gravity forward for stability.



Cutting Centering Rings & Bulkheads

Cutting out the Centering Rings

Electronics Bay



Completed Rocket

Completed Framework of the Rocket, still requiring proper painting and implementation of electronics

Test Flight:

We used the WSGC competition as a test launch of our rocket. The rocket flew well until separation, then went unstable. The main booster was meant to be unstable (stability of the booster to apogee was not a requirement of the WSGC competition) having a deep pocket for the upside-down nosecone tail of the booster to set inside prior to separation, so that it would decelerate quickly to maximize separation from the dart. However, this instability coupled with high winds knocked the dart before it fully emerged from the pocket and it was unable to recover stability once the weighted nosecone tilted too far.

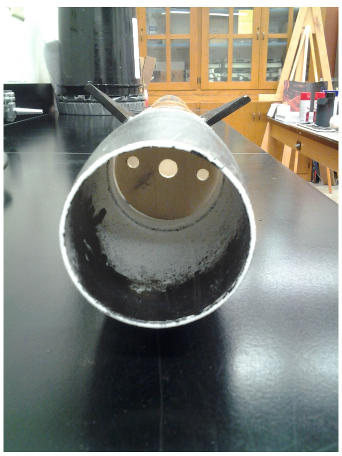
Pre-launch Safety Check

Downward image from on-board camera during test launch

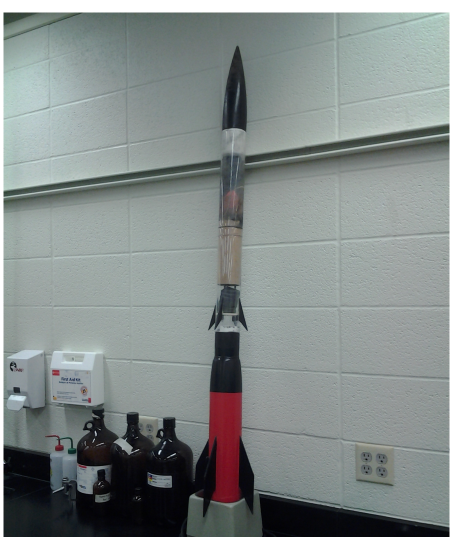
Improvements:

Based on our experience from the test flight, we have modified the design for both booster and dart to remain stable to apogee, until chutes are deployed. A full nosecone will be installed on the booster rather than merely a truncated transition piece, and this nosecone will extend up into the bottom of the dart, secured via a centering ring over the nose directly beneath the downward facing camera. This will also extend the mass of the electronics bay further forward, allowing us to reduce or eliminate the copper BBs required in the nosecone previously.

Centering ring in bottom of dart for tip of booster nosecone



Full rocket with dummy nosecone on booster



Budget:

Apogee Components

ITEM	DESCRIPTION	PRICE	QTY	TOTAL
Blue Tube	(Model 10505) 98mm	38.95	1	38.95
Blue Tube	(Model 10504) 75mm	29.95	1	29.95
Blue Tube	(Model 10502) 54mm	23.95	1	23.95
PNC-3.00"	(Model 20117) 75mm x 11.25" for Thick Wall Tubes	20.74	2	41.48
Centering Ring	(Model 13433) Centering Rings 54mm to 98mm	8.10	1	8.10
Centering Ring	(Model 13434) Centering Rings 75mm (Blue) to 98mm	8.10	2	16.20
Camera	(Model 09168) 808 Keychain Camera	41.35	2	82.70
Aero Pack	(Model 24068) 54mm Retainer (Flanged)	40.66	1	40.66
Chutes	(Model 29167) 48" Fruity Chutes: Classic Elliptical	113.42	2	226.84
Parachute Protector	(Model 29311) Sunward 18in Black	9.99	1	9.99
Parachute Protector	(Model 29304) Madow 12in	8.51	1	8.51
Cord	(Model 30327) Kevlar Cord 1500#	0.92	10	9.20
Ejection Canister	(Model 03071) Large Capacity, 5-pk	12.50	2	25.00
Terminal Block	(Model 09191) Terminal Block	3.25	2	6.50
			Subtotal:	568.03
			Fed-Ex:	33.21
			Total:	601.24

SparkFun Electronics

SKU	PRODUCT	PRICE	QTY	TOTAL
DEV-11061	Arduino Mega 2560 R3	45.95	1	45.95
SEN-09269	SparkFun Triple Axis Accelerometer Breakout - ADXL33!	14.95	1	14.95
			Subtotal:	60.90
			Shipping:	11.38
			Total:	72.28

Featherweight Altimeters LLC

Description	PRICE	QTY	TOTAL
Altimeter	165.00	1	165.00
		Subtotal:	165.00
		Tax:	10.00
		Total:	175.00

Total Cost: $848.52