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# Preliminary Design Report

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# Executive Summary

Augsburg University entered into the Space Grant Midwest High-Power Rocket Competition 2017-18 for the first time this January. As part of the competition, the group of students have created this document to serve as a preliminary design report. The competition asks students to build a high powered rocket capable of controlling and orienting the roll of the rocket. To accomplish this task Augsburg's rocket will employ moveable flight surfaces. The flight surfaces will be controlled by Arduino processers and driven by two linear actuators. The rocket will be propelled by a Cesaroni 1190J355-17A 54mm rocket motor. The primary recovery system will be deployed by an isolated altimeter charge system. The motor has a built in ejection charge. This will be used as a backup parachute deploy and PVC pipe will distribute blast pressure to eject nose cone and parachute.

# Introduction

The Space Grant Midwest High-Power Rocket Competition is an opportunity for students to design, construct, and launch high powered rockets. A series of professional reports document the process and are evaluated by a panel of professional engineers. This is the first written document for the competition and its primary objective is to explain the Augsburg Aerospace Club's rocket design. This year's rocket will be judged on its ability to operate a roll control mechanism to minimize roll on the first launch and then on a second launch roll and hold the rocket at a series of specific orientation angles. To accomplish this task the rocket will adjust its flight control surfaces. The control surfaces will be controlled by an Arduino circuit and driven by a pair of linear actuators. The Arduino will adjust the angle based on feedback received on by its 9-degree-of-freedom IMU. The internal layout of the rocket was designed in openrocket after discussing blast pressure zones, motor size and mounts, fin control mechanism, electronics package, and the required electrical and mechanical connections. The rocket will be propelled by a Cesaroni 1190J355-17A 54mm rocket motor. The following report documents the design, analysis, and simulation of the project.

# Rocket Mechanical & Electrical Design

## Airframe and Propulsion System Specifications

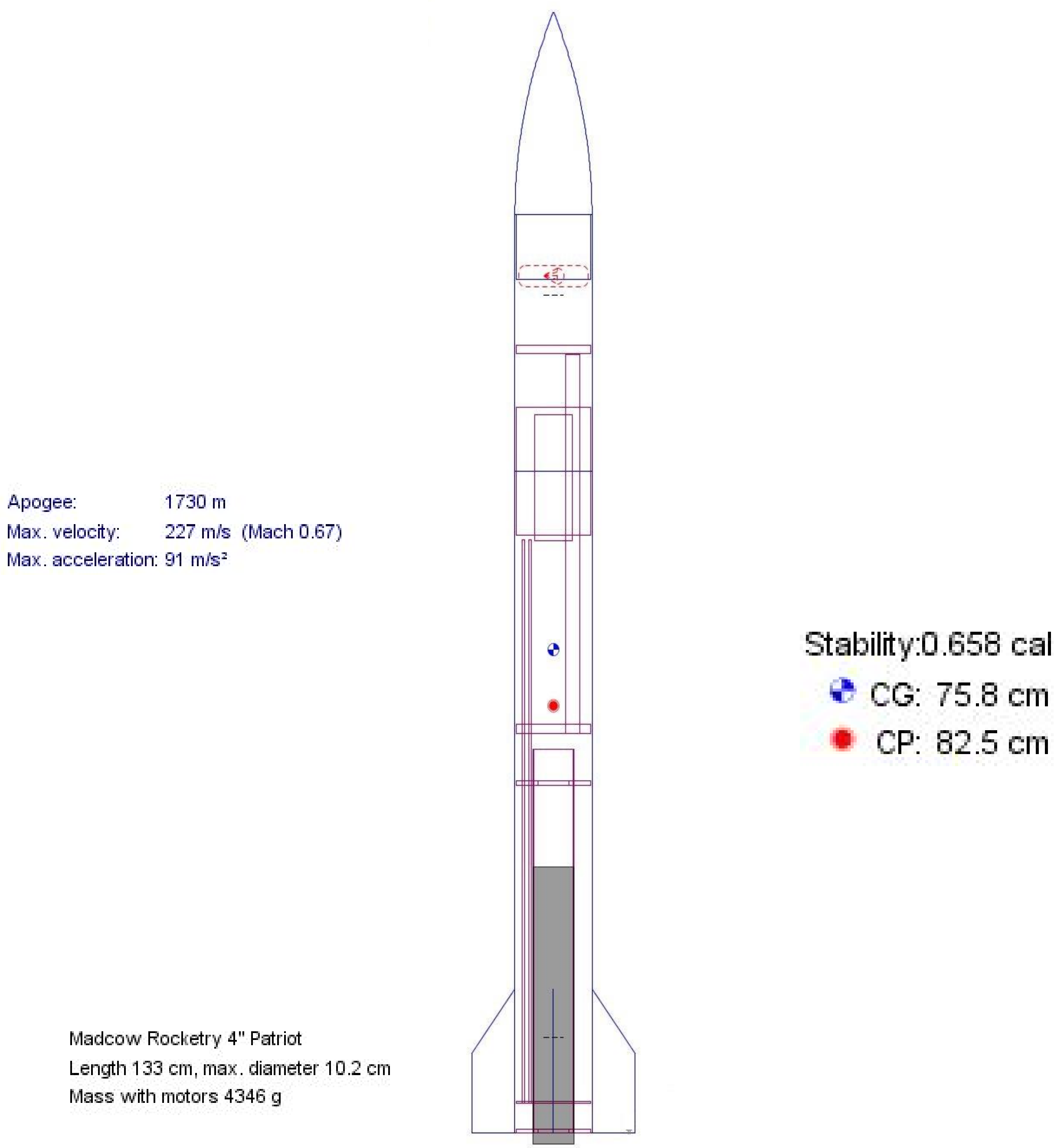
### Airframe Specifications

The rocket is a modified 4" Fiberglass Patriot Missile. It is 133 cm long, has a 10.2 cm diameter, and the total mass is 4346 grams with the 1190J355-17A 54mm rocket motor inserted. The rocket is split into three sections. The polystyrene nose cone is 24.1 cm and weighs 189 grams. The top portion of the rocket is 30.5 cm long, 0.127 cm thick and is built with fiberglass. The tube mass is 104 grams. The bottom fiberglass rocket tube is the same thickness and 78.7 cm long. The bottom tube is the same thickness and weighs 268 grams. There are four fins extending 5.72 cm along the bottom rocket tube's normal. This creates a total surface area of 84.73 cm^2 on each fin. The roll control portion of the fins are 1.5 cm and have approximately 10% movable surface area (10.1%).

### Propulsion System Specifications

The rocket is propelled by a Cesaroni 1190J355-17A 54mm rocket motor enclosed in a metal motor casing. The Loaded mass of the motor is 1175 grams, 669.0 grams of that are propellant. The motor is 32.9 cm long and is reloadable for multiple launches. The total impulse is 1189.5 Ns which classifies the motor in J-class. The maximum thrust is 4.4.3 N with an average thrust of 353.3 N. The rocket burn time is 3.369 seconds. After burnout the motor will weigh 495 g. A graph of the thrust curve is located in the appendix. Motor specs were obtained from this link:
http://www.pro38.com/products/pro54/motor/MotorData.php?prodid=1190J355-17A

## Diagram of Rocket



## Recovery System Design Specifications

The rocket uses a single deploy chute. The chute is made of Ripstop Nylon and has a diameter of 122 cm. The chute has an estimated drag coefficient of 0.75. In the open rocket simulation this parachute size landed the rocket at 27.5 ft/second. The chute will be protected from the ejection charge by blast resistant wadding. The chute will deploy one second after apogee by an altimeter system powered by a 9v battery source. The black powder ejection will be placed on the forward bulkhead. The forward region of the rocket will become pressured and pop the nose cone off the rocket. The built in motor blast will occur 2 seconds after apogee. The motor's blast pressure will be routed to the nose of the rocket through a schedule 80 PVC pipe. This is a backup charge and is in case the altimeter system fails to deploy.

## Avionics System Design Specifications

The avionics bay has three major functions, measure flight trajectories, control fin movement based on trajectory feedback, and activate chute charge. A tiny circuit Arduino will be responsible for the first two functions. An independent altimeter system is responsible for chute deployment. The Arduino will determine the rockets trajectory with an onboard nine-axis gyro inertial measurement unit (IMU). This component is an attachment shield to the Arduino board. An output circuit board and SD card reader are also attached to the Arduino in a stack. The open source Arduino code allows us to program outputs for the fin control system. The Arduino nine-axis IMU accurately determines rotation. The Arduino will use this input and proportional–integral–derivative (PID) controls to make more precise rotation adjustments. The Arduino is run on a Lithium Ion Polymer Battery (3.7V 150mAh). The voltage drop across this battery is too small to run the linear actuators. The 9v battery pack will power the linear actuators. Transistors connected to the Arduino will activate the actuators. The 9v battery pack will also power an altimeter. This code will be programmed to activate at apogee and deploy the chute.

The avionics bay will be a rectangular prism with a semi-circle cutout running the length of the AV bay. The side opposite of the cutout will open on a hinge to allow access to the system. Ribbon cable connectors will attach to the rocket components. The AV bay will use three zip ties to hold it in place, these are replaceable so the AV bay can be removed.

## Active Roll Design

The electronics in the previous section drive the mechanical systems described in this section. Two linear actuators are the first mechanical linkages in the system. Each actuator rests on a rigid rod. The rods rotate the fins clockwise and counter clockwise by applying pressure to a beveled block. As the block moves all four fins move together. When both actuators are inactive, two springs hold the fins in a neutral position. The angle of the fins is determined by program code comparing the torque each actuator is applying to the spring and fin resistive forces.

## Construction Solutions & Techniques

The Patriot Missile is a kit that comes with precut fins, a nose cone, and a fiberglass tube. The nose cone creates a friction fit with the fiberglass tube, which releases from the ejection pressure. The schedule 80 PVC tube is a major construction constraint. The blast diversion tube severely limits our accessibility because it must be mounted directly to the motor casing and the forward bulkhead. Once these components are in place the rocket's unpressurized zone will be unaccusable. A hatch in the fiberglass tube will give us access to the area so we can attach our AV bay.

## Structural Analysis of Scratch-Built Parts

The only scratch built structural part is the PVC pipe running through the center of the tube. Since the system is completely encased by the fiberglass tube, it will not experience outside forces. Instead the PVC must withstand the blast pressure. The max pressure can be calculated by dividing the energy from the blast by the volume of the lower pressurized region. This is then compared to the PVC pressure ratings supplied by the manufacturer.

# Predicted Performance

This section analysis is based on data from openrocket simulations.

## Starting Conditions

| | |
|---|---|
| Average Wind Speed | 2 m/s |
| Wind Speed Standard Deviation | 0.2 m/s |
| Turbulence Intensity | 10% |
| Launch Rod Length | 100 cm |
| Launch Latitude | 45.546028° |
| Launch Longitude | -92.924640° |
| Launch Elevation | 275 m |
| Launch Direction | Into wind |

## Launch Analysis

The launch time began at ignition. Two tenths of a second after launch, the rocket separated from the launch rod at 12.7 m/s. The burn continued until engine burn out at 3.4 seconds. The rocket was flying at 222.7 m/s vertical velocity. At which point the vertical acceleration was -36.25 m/s^2 due to air resistance.

## Flight Analysis

Flight began at motor burnout and ended 2.3 seconds after apogee where parachutes were deployed. In 14.6 seconds, the rocket rose 1,276 meter to an apogee of 1728.6 meters. Apogee occurred 18 seconds after launch. Ejection charges deployed at 20.3 seconds into the launch, 18 seconds after motor burnout.

## Recovery Analysis

After chutes deployed, the acceleration increased from -9.76 to 0.47 N/s^2. The rocket descended 1713.6 meters in 200.5 seconds. The vertical velocity did no exceed 9 m/s.

## Stability Analysis

This rocket has a 0.6 caliber stability rating under power based on the rocket diameter and the separation between center of mass and center of pressure. This is a low stability rating for a rocket this size. Stabilizing fins help maintain orientation and moving the AV bay to the forward bulkhead will help increase stability.

## Environmental Conditions Analysis

The Tripoli Minnesota launch site is located on a sod farm near North Branch Minnesota. The 90 day forecast on accuweather.com predicts highs near 70 degrees for May 19$^{th}$-21$^{st}$. For the same time period, the average high is 70 degrees with a low of 46 degrees. Historically, Minnesota has windy springs and falls.

# Safety

## Safe Flight & Recovery

- Propulsion thrust is reasonable for rocket weight
- Rocket is built with a durable material
- Parachute is deployed by an altimeter separate from fin control
- Altimeter is on a separate circuit from fin control
- Parachute has a backup blast charge for parachute ejection
- Rocket has more than two fins for stability during flight

### Material-Handling Procedures

Although many products in our rocket design are safe household materials, it is important to handle these with care. For sensitive electronics and other materials, we will use the new workspace in Hagfors Center. This space has good ventilation and a sprinkler system. The most dangerous material we will handle is black powder for our ejection charge. The powder will only be handled in well ventilated areas absent of heat, open flames, or other potential ignition. The rocket motor will be purchased and stored until launch by a level two certified rocket instructor. The motor will not be connected to an igniter until it is ready on the launch pad.

## Budget

Include value of registration fee, travel, and material costs

-$400 for entrance fee

-$200 travel expense (gas for carpool)

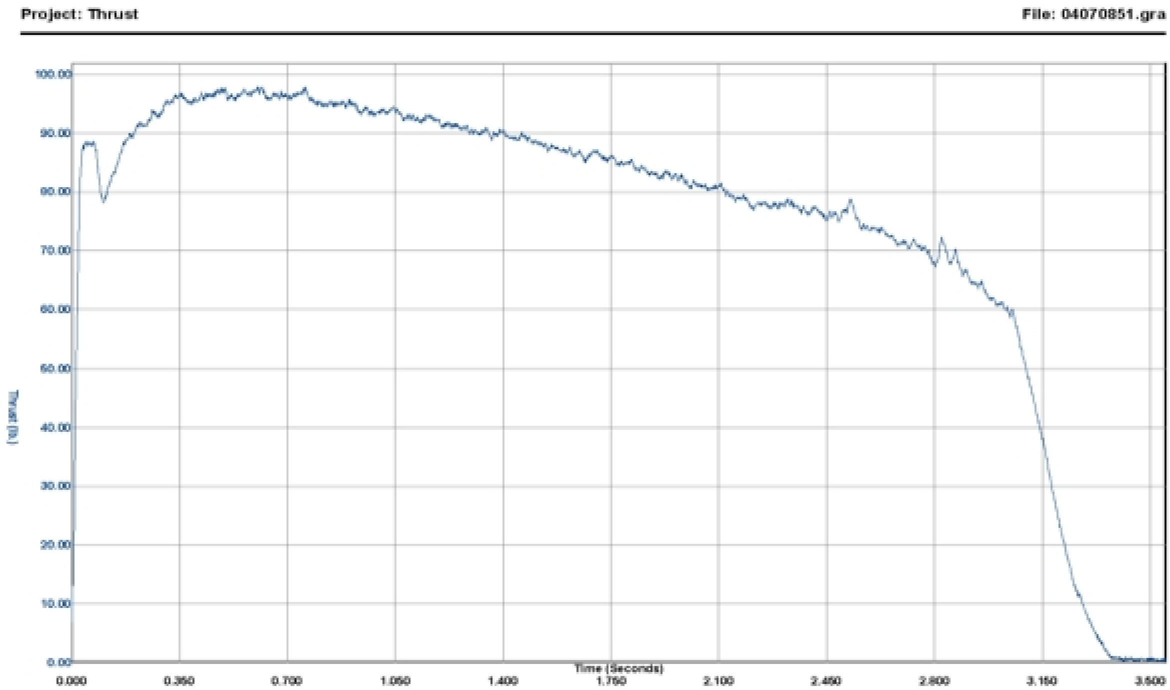
-$200 Patriot Missile 4” Fiberglass kit

-$200 Tiny Circuit electronic components

-$300 mechanical components (linear actuators)

# Appendix

## Thrust Curve




This curve is supplied by the manufacture.