C.E.R.T.

Century College Engineering Rocket Team

2014/2015

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Boosted Dart Rocket Team

Table of Contents

Executive Summary

This report consist of our team's main design features of the rocket, the design features of the payload system. We will go into detail about where the Center of Pressure is located, Center of Mass with a full payload and for the combined booster and dart, and also Center of Mass after motor-burnout of the dart, booster and combined. We also talk about the rockets anticipated performance. Here we will discuss the rockets maximum altitude for the booster and the dart. The peak acceleration for the booster and dart. Also the time of flight vs. the acceleration graph for the booster and the dart. Finally we share the team's budget information. Including all past purchases, registration fee and if any, travel fees.

Design Features of Rocket

Airbrake Design and Revisions

The initial design for our rocket called for a carbon composite airframe with a 6062 Aluminum airbrake with three baffles that sat between the booster fins and around the motor. It was a passive release design that was activated by a break in an electrical circuit that was carried from the booster through the dart and back into the booster. This would have been an extremely light design because of its simplicity it had no need for strong internal components. If we had more resources we could have been successful with this design. But high level testing would have had to have been done and we did not have a test mule for such testing. To date, our fastest rocket hit a peak velocity of 240 mph (108) meter/second so we would not be able to accurately test the forces that would be applied to the airbrake. The second revision of our rocket had a revised airbrake. This airbrake was to be powered by a Figelli micro linear actuator (see appendix). It also sat higher in the airframe, above the motor, then the previous version and was twice the size. The calculated weight, without a battery was 450 grams.

Construction

For construction we decided to cut each component in half lengthwise through the center and build female molds around that. This came under the advisement of Steve Schults of Ion Aircraft. The reasoning for this is that if we were to use carbon sleeving the ratio of carbon to resin would not be correct and we would not have the weight benefit of the carbon composite. Also, halving each component allows us to easily build all of the internal components and to the layups without having to work inside of a tube. Using a resin based composite allows us to easily fasten components together with nearly as much strength as if they were molded together.

For the actual construction of the pieces we are going to use Century's engineering departments neighbor the prosthetics lab to do vacuum infusion. Vacuum infusion is the cleanest most efficient way to make reasonably priced carbon fiber parts.

The main body tube molds are made from PVC tubing. The molds for the nosecone, transition and fins are made of 3D printed ABS plastic.

Material

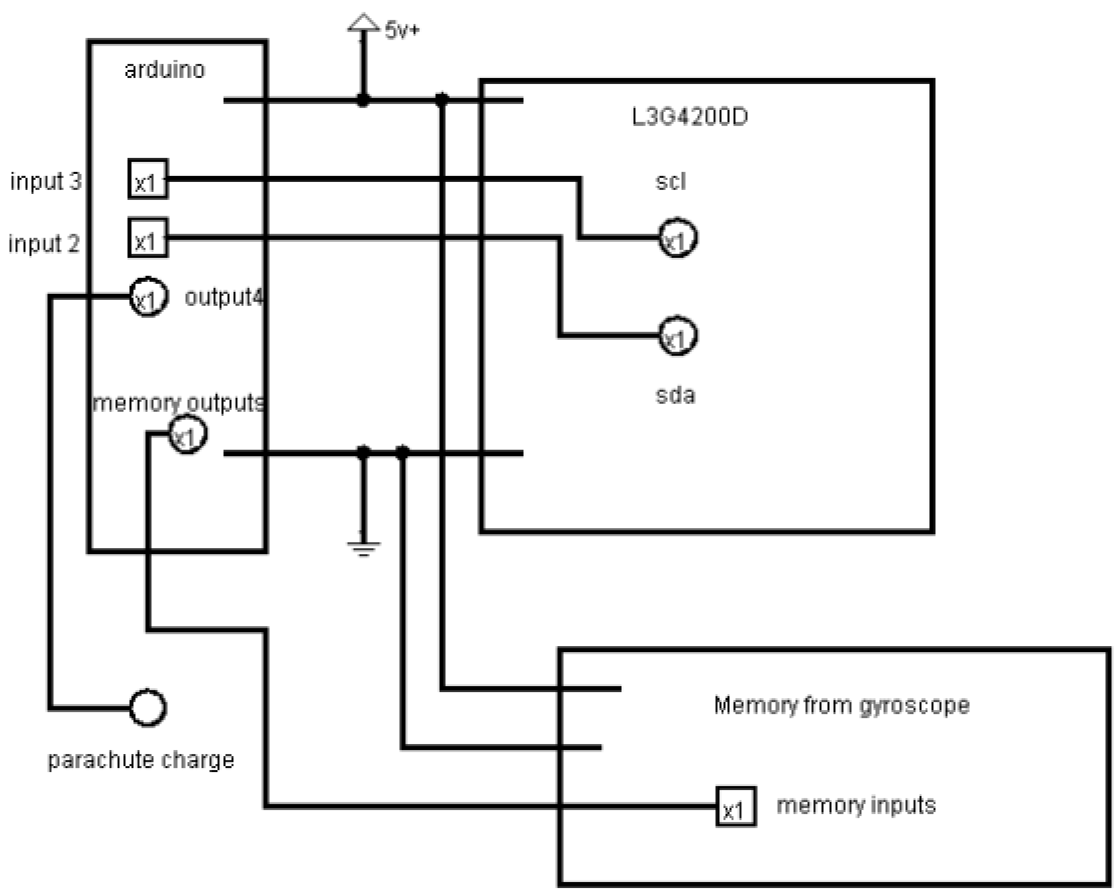
The carbon shell shall all be comprised of 1.5mm (.060”) of material throughout the entirety of the main body except for the load carrying points for the parachute mounts. To achieve the 1.5mm desired thickness we will use a 3 layer layup with a 45 degree material rotation from the body with each layer altering directions. The nosecone, dart tube, dart transition, booster transition, booster tube and all of the fins are made of the same material.

All of the internal components that are not related to recovery are made of 3D printed ABS plastic. This includes centering rings, the electronics bay module, and bulkheads. This process is easily available to us and gives us the ability to quickly make revisions to any design if need be.

Design Features of Payload System

Electronics

The objective for the electronics end of this project is to track x, y, z roll and store it for later review. For this project we are using an Arduino micro for our microcontroller this has advantages in this setting for its small size and wide array of available chips that can be used with it. We are using a 3 axis gyroscope L3G4200D from the parallax website. This is very useful to use for its high sensitivity along with low power draw allowing for our other functions to work properly. This is our basic diagram for the gyroscope this is a very simple wiring which allows for basic function of the gyroscope.



Then we also have our parachute charge so we have an active system to deploy the parachute in a controlled manner after we hit apogee.

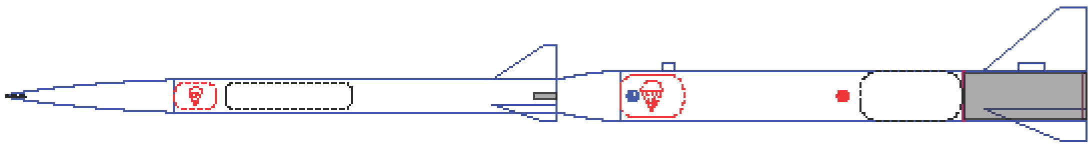
Diagram of Rocket Identifying the dimensioned locations for the:

-CP (center of pressure) for the booster, dart, and combined rocket
-CG1 (center of mass with the fully loaded rocket motor) for the combined Rocket
-CG2 (center of mass after motor-burnout) for the booster, dart, and combined

All of the design data for the rocket is included in the next few pages. One comment we would like to make is the center of gravity will be further forward in the booster then the simulation shows because of extra material needed for the dart mount.

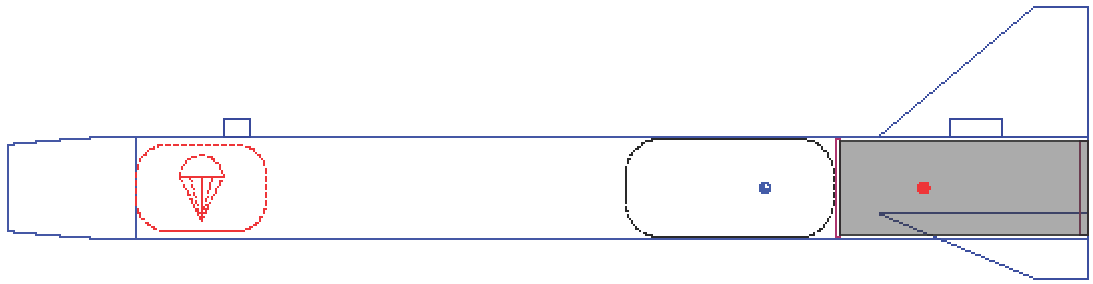
Rocket

Rocket Design



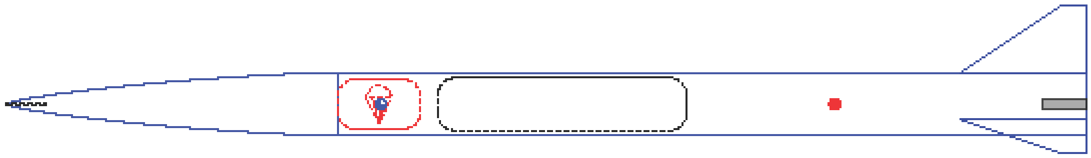
Rocket
Stages: 2
Mass (with motors): 1689 g
Stability: 4.13 cal
CG: 740 mm
CP: 988 mm

Rocket Design



Rocket
Stages: 1
Mass (with motor): 1009 g
Stability: 1.53 cal
CG: 438 mm
CP: 530 mm

Rocket Design



Rocket
Stages: 1
Mass (with motor): 685 g
Stability: 7.16 cal
CG: 226 mm
CP: 499 mm

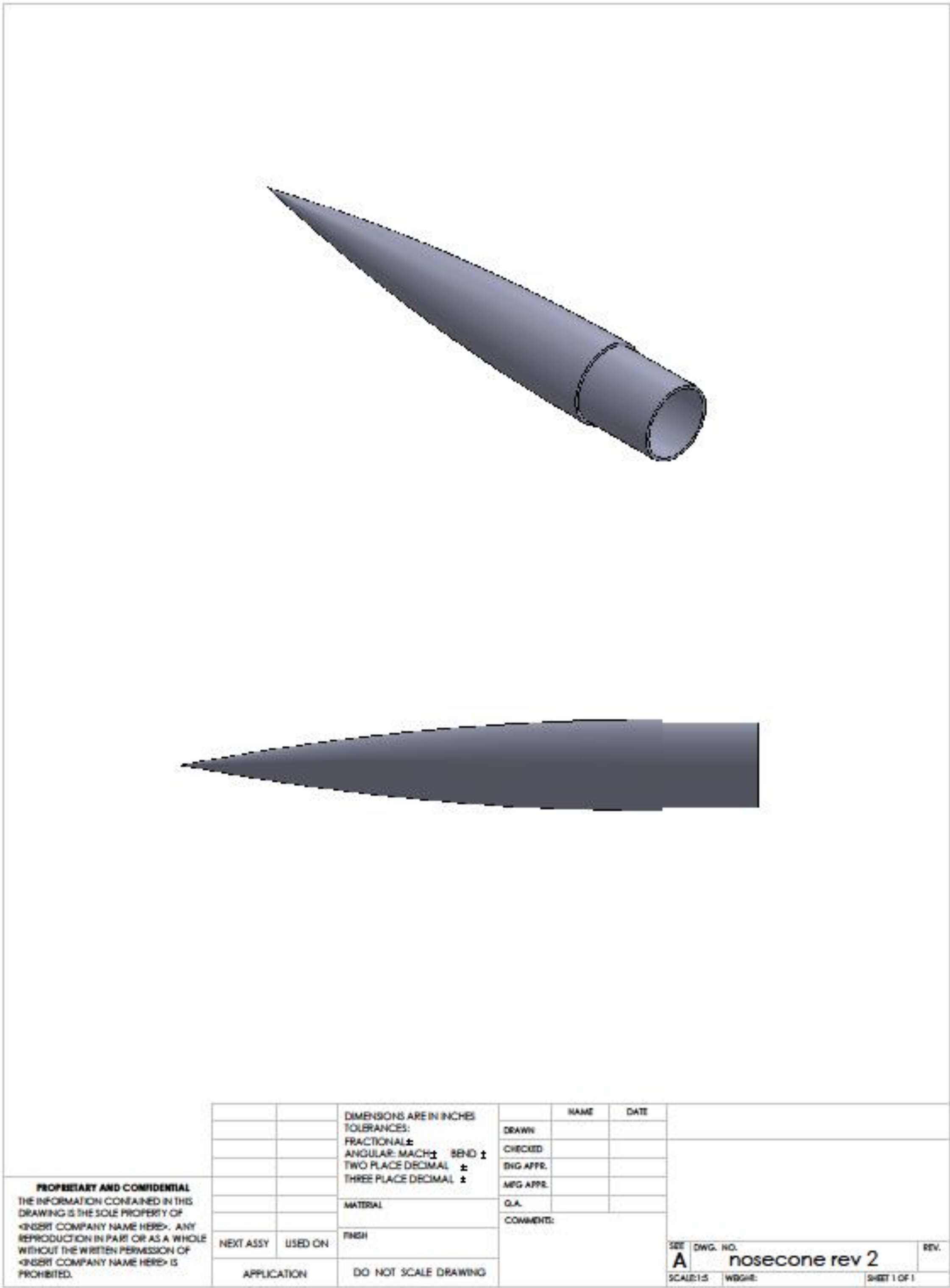
Parts Detail

Sustainer

Nose cone	Carbon fiber (1.78 g/cm³)	Haack series	Len: 200 mm	Mass: 39.2 g
Mass component		Dia_{out} 2 mm		Mass: 250 g
Body tube	Carbon fiber (1.78 g/cm³)	Dia_{in} 35.1 mm Dia_{out} 38.1 mm	Len: 450 mm	Mass: 138 g
Freeform fin set (3)	Carbon fiber (1.78 g/cm³)	Thick: 2 mm		Mass: 19.2 g
Mass component		Dia_{out} 32 mm		Mass: 200 g
Parachute	Ripstop nylon (67 g/m²)	Dia_{out} 800 mm	Len: 50 mm	Mass: 36.9 g
Shroud Lines	Elastic cord (round 2 mm, 1/16 in) (1.8 g/m)	Lines: 6	Len: 300 mm	

Booster stage

Transition	Carbon fiber (1.78 g/cm³)	Fore Dia: 38.1 mm Aft Dia: 60 mm	Len: 75 mm	Mass: 61.4 g
Body tube	Carbon fiber (1.78 g/cm³)	Dia_{in} 57 mm Dia_{out} 60 mm	Len: 550 mm	Mass: 270 g
Freeform fin set (3)	Cardboard (0.68 g/cm³)	Thick: 2 mm		Mass: 23 g
Engine block	Cardboard (0.68 g/cm³)	Dia_{in} 54 mm Dia_{out} 54 mm	Len: 5 mm	Mass: 0 g
Bulkhead	Aluminum (2.7 g/cm³)	Dia_{out} 57 mm	Len: 2 mm	Mass: 13.8 g
Mass component		Dia_{out} 57 mm		Mass: 0 g
Parachute	Ripstop nylon (67 g/m²)	Dia_{out} 1000 mm	Len: 75 mm	Mass: 60.2 g
Shroud Lines	Elastic cord (round 2 mm, 1/16 in) (1.8 g/m)	Lines: 6	Len: 700 mm	
Launch lug	Cardboard (0.68 g/cm³)	Dia_{in} 8 mm Dia_{out} 10 mm	Len: 15 mm	Mass: 0.288 g
Launch lug	Cardboard (0.68 g/cm³)	Dia_{in} 8 mm Dia_{out} 10 mm	Len: 30 mm	Mass: 0.577 g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ANGULAR: MACH± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
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ENG APPR.
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REV.
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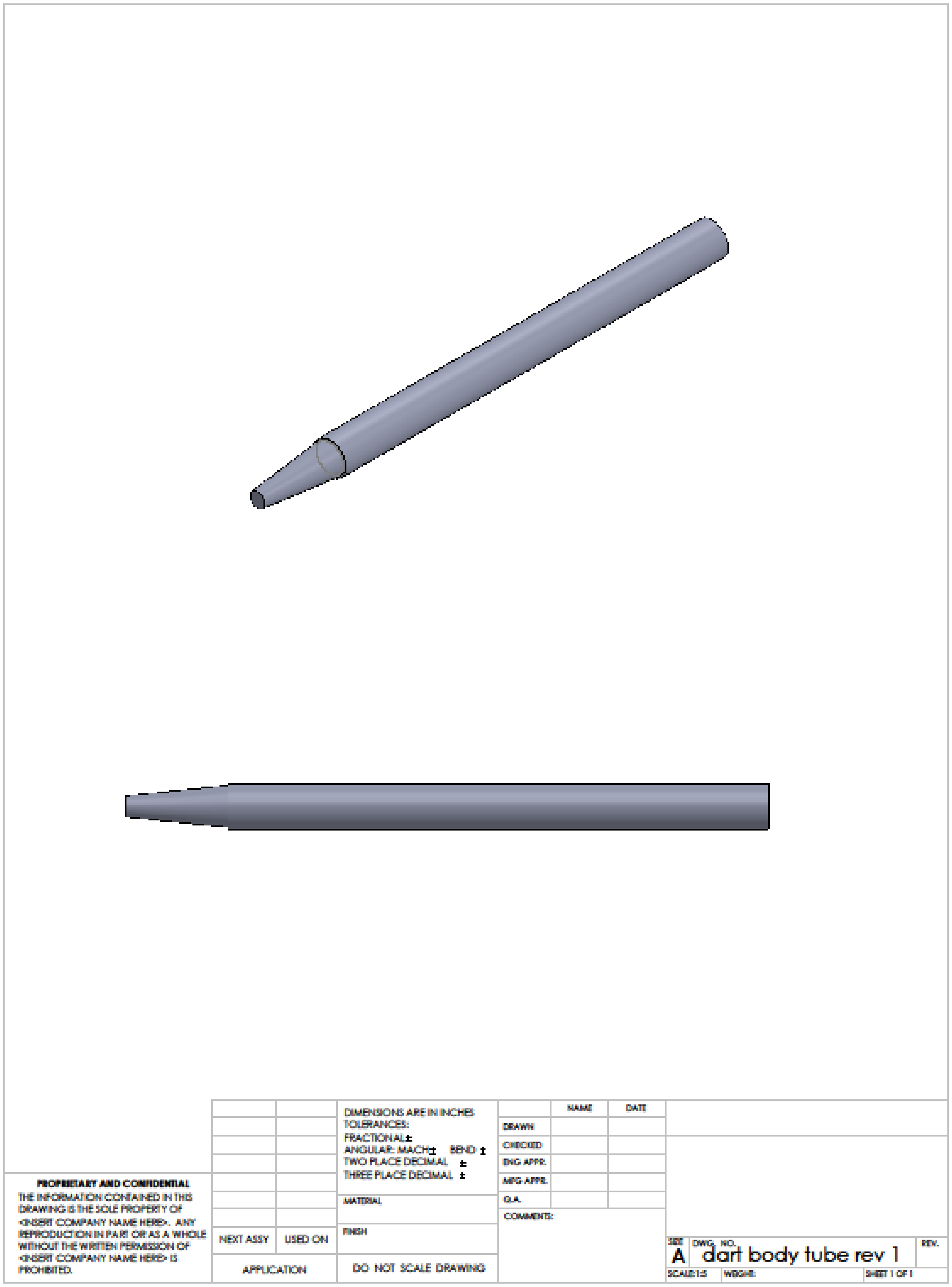
WEIGHT:
SHEET 1 OF 1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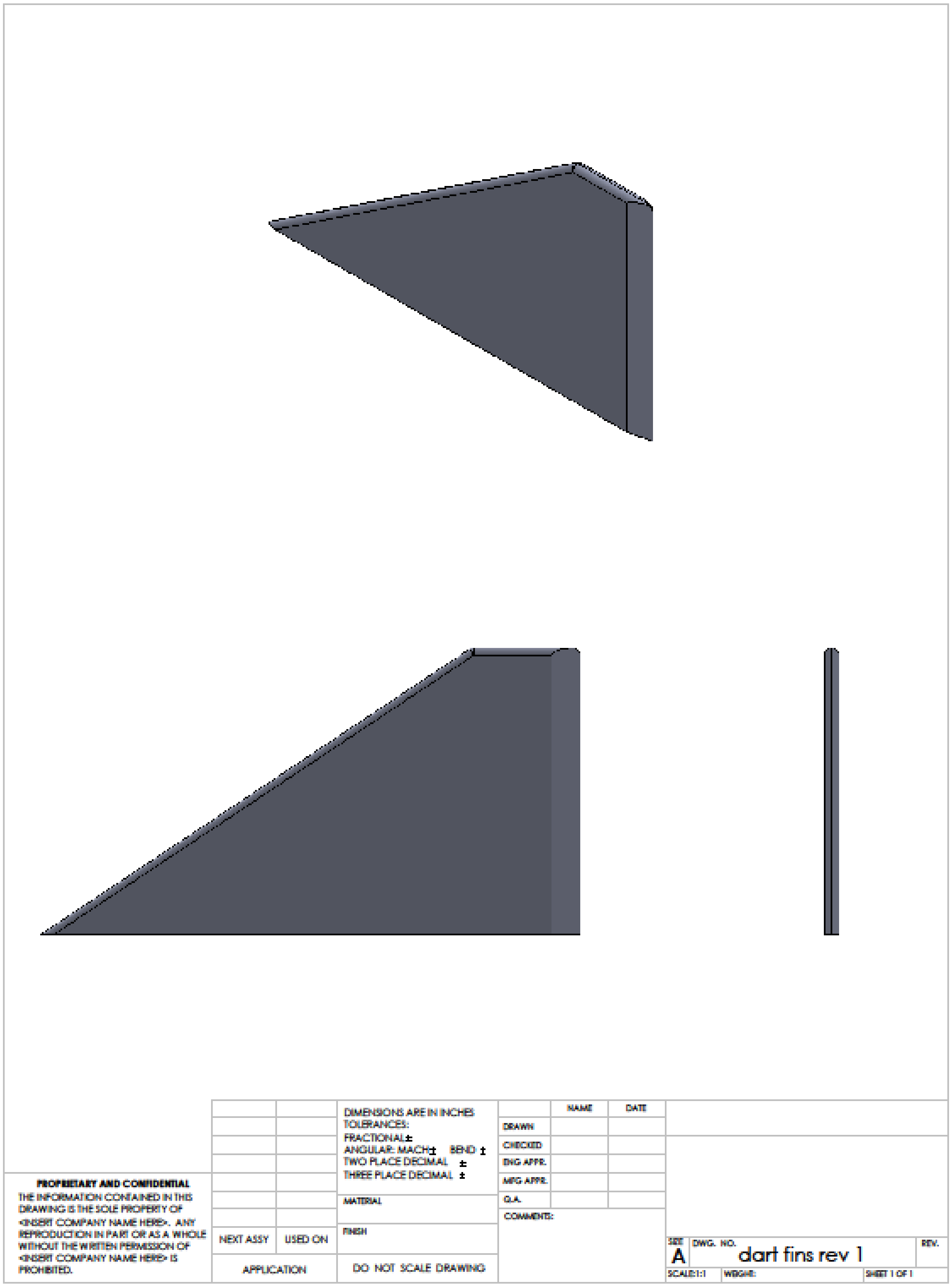
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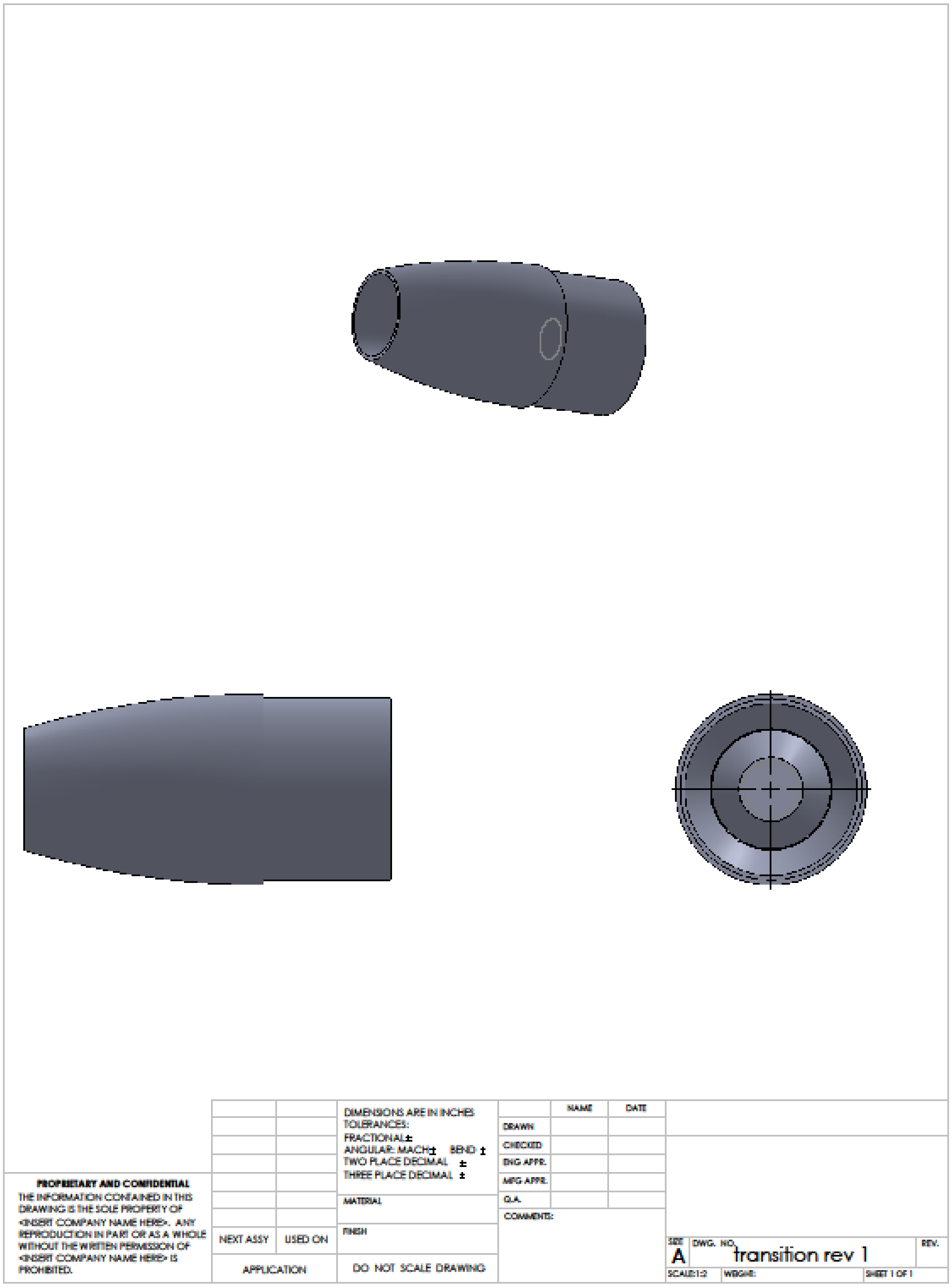
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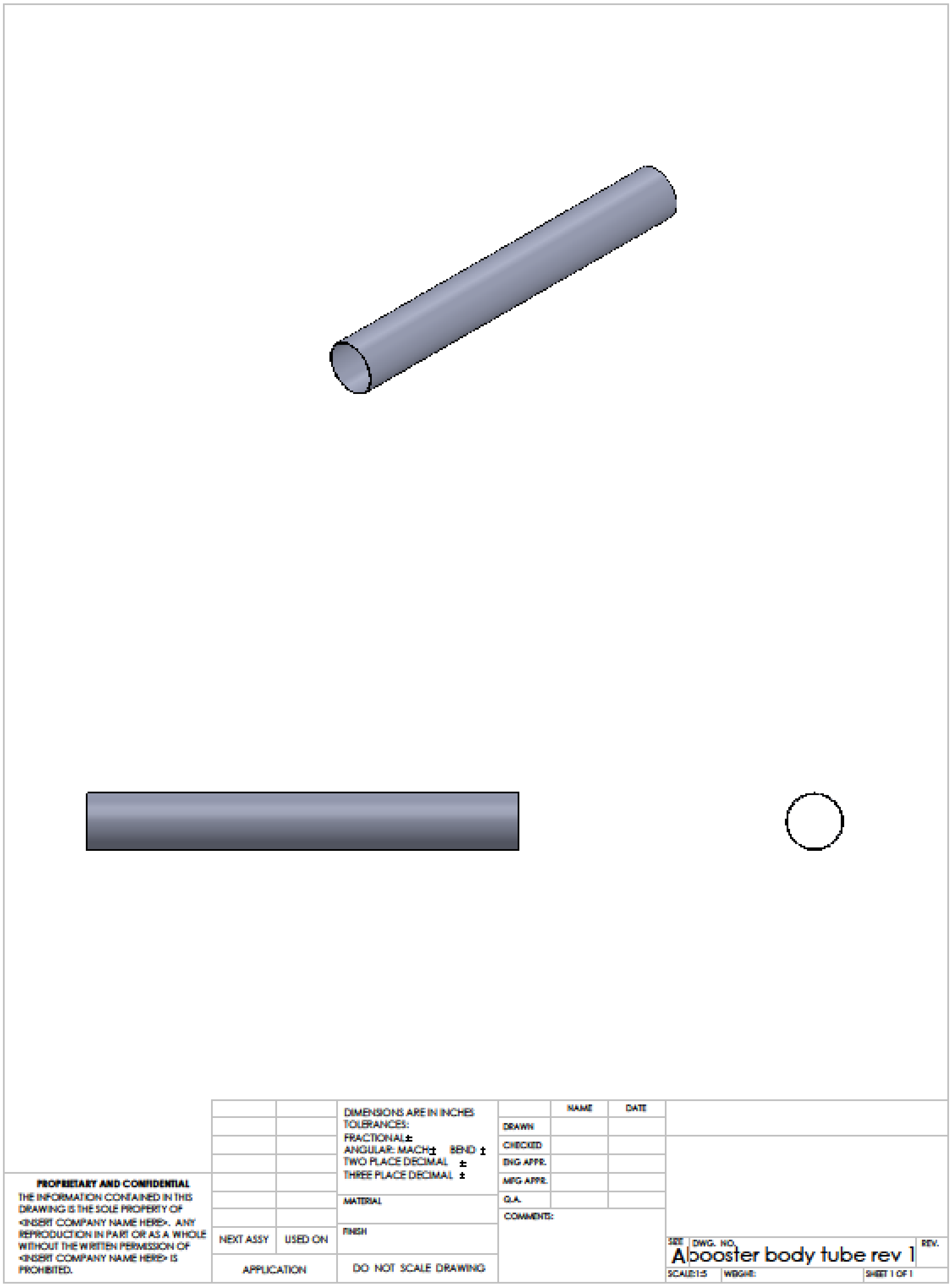
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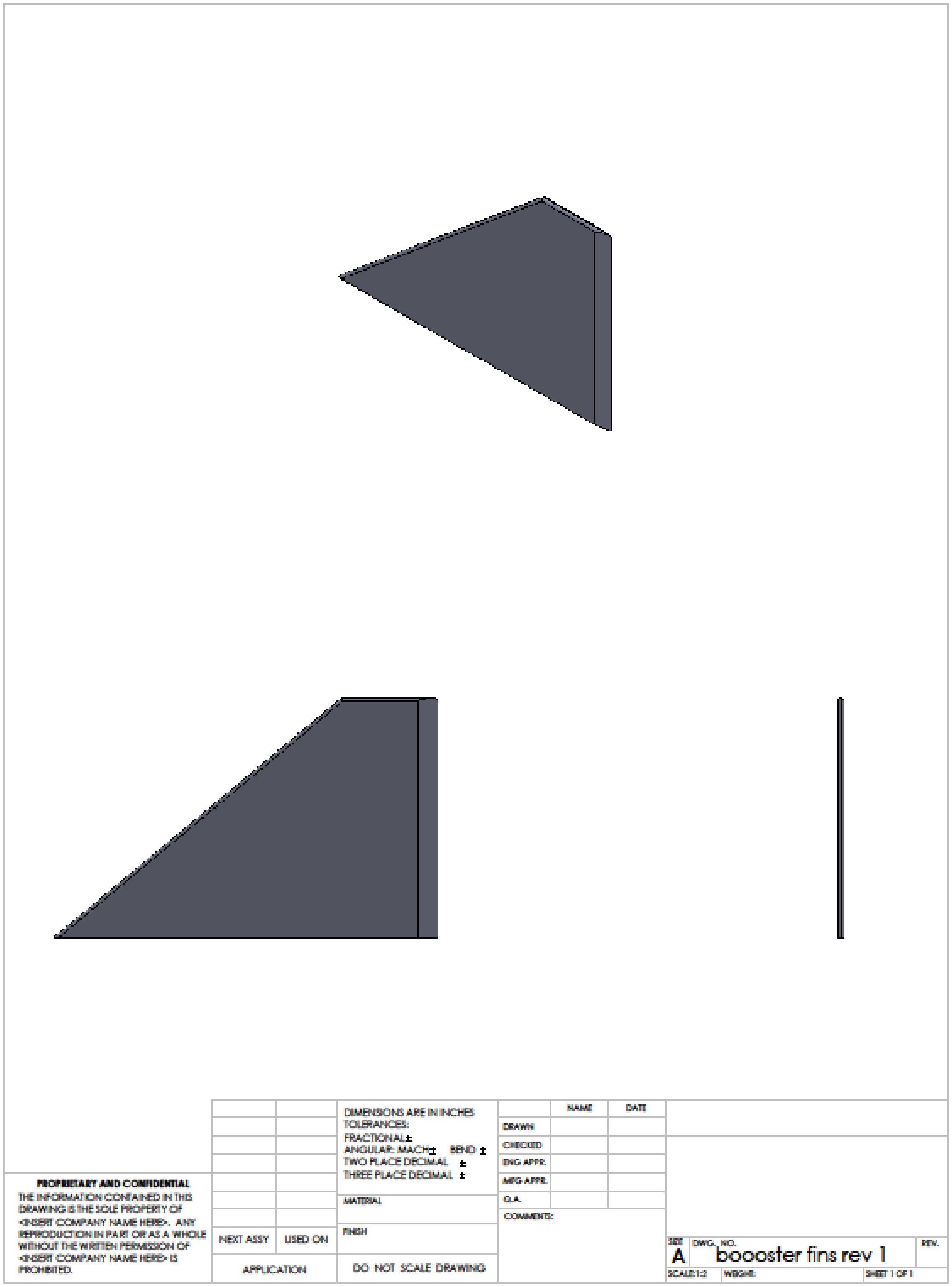


Analysis of the Anticipated Performance

We used OpenRocket to perform all of our simulations. Using this tool is how we decided to not incorporate an airbrake by showing us how important it is to transfer as much energy into the dart as possible. We ran simulation after simulation changing one variable at a time to configure the rocket to its optimum design.

As seen In Chart 1 (Sustainer Altitude Vs. Time) we achieved a simulated maximum altitude of 1699 meters. Our goal is to achieve an actual value of 1700 meters. To achieve this value we had to add an additional 250 grams of weight into the nose of the dart. By doing this we lowered our terminal velocity from Mach .93 to Mach .80. This added weight gives the dart a higher value of kinetic energy at separation. Therefore, with the higher value of energy in the dart and the lower velocity after separation, a larger value for time is needed in the differential equation for the forces to make the first integral of our altitude, velocity, equal to zero. Also the lower terminal velocity means a lower values for external friction forces.

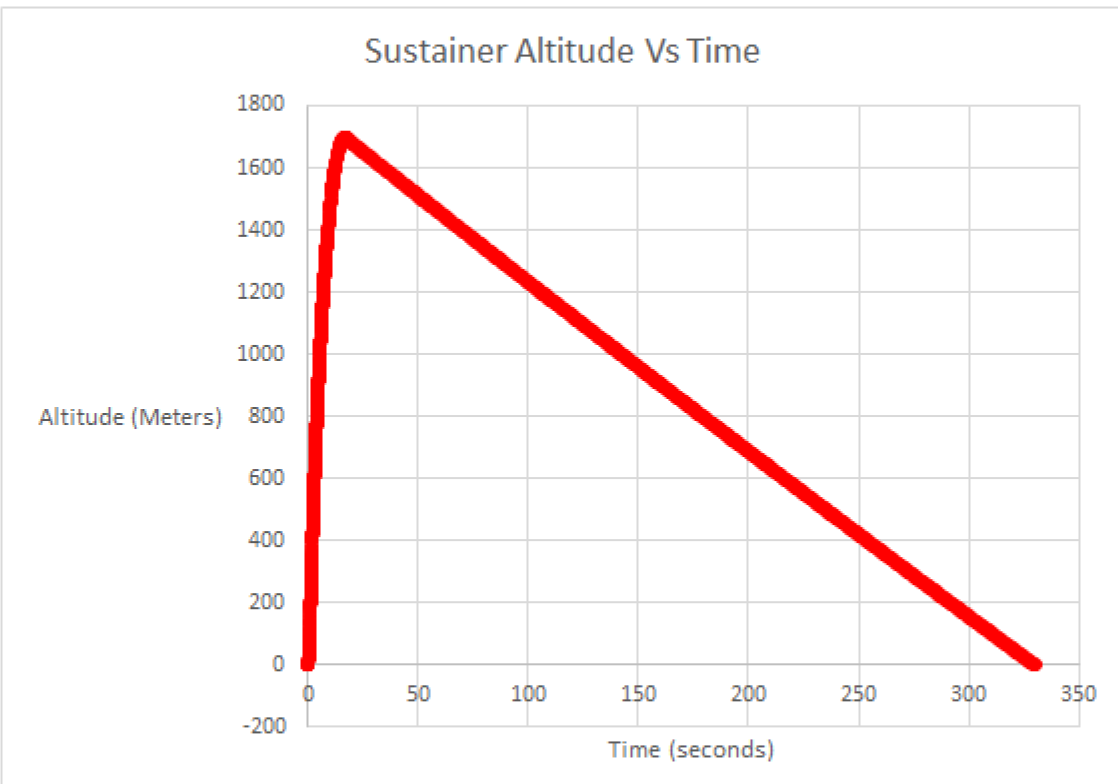


Chart 1

Chart 2 represents our Dart Acceleration Vs Time. The max acceleration is 314 meters/(sec*sec) and the max velocity is 272 meters/sec. As stated before these maximum values are not the highest we could achieve but the slope of the velocity curve after burnout is as flat as we could reasonably get it. It takes the dart approximately 16 seconds to reach apogee.

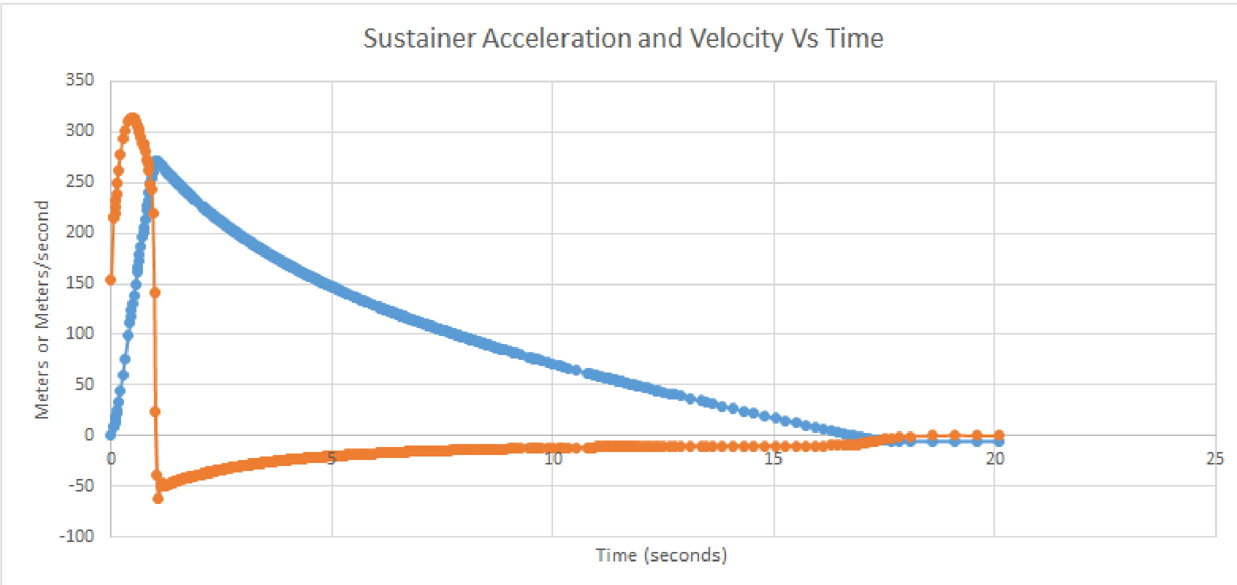


Chart 2

Chart 3 represents the Booster Altitude Vs Time. Initially when we were planning on incorporating an airbrake into our design we had a goal of keeping the booster under the altitude of 600 meters. The sacrifices were too large to accomplish this goal so our next priority was to make the booster as light as possible to transfer as much of the motors energy into the dart as we could. With the post motor burnout mass ratio of the dart to the booster so great the value of energy kept in the booster is small. It is small because of its low separation velocity and weight. Not much energy is needed from external forces to remove the kinetic energy from the booster.

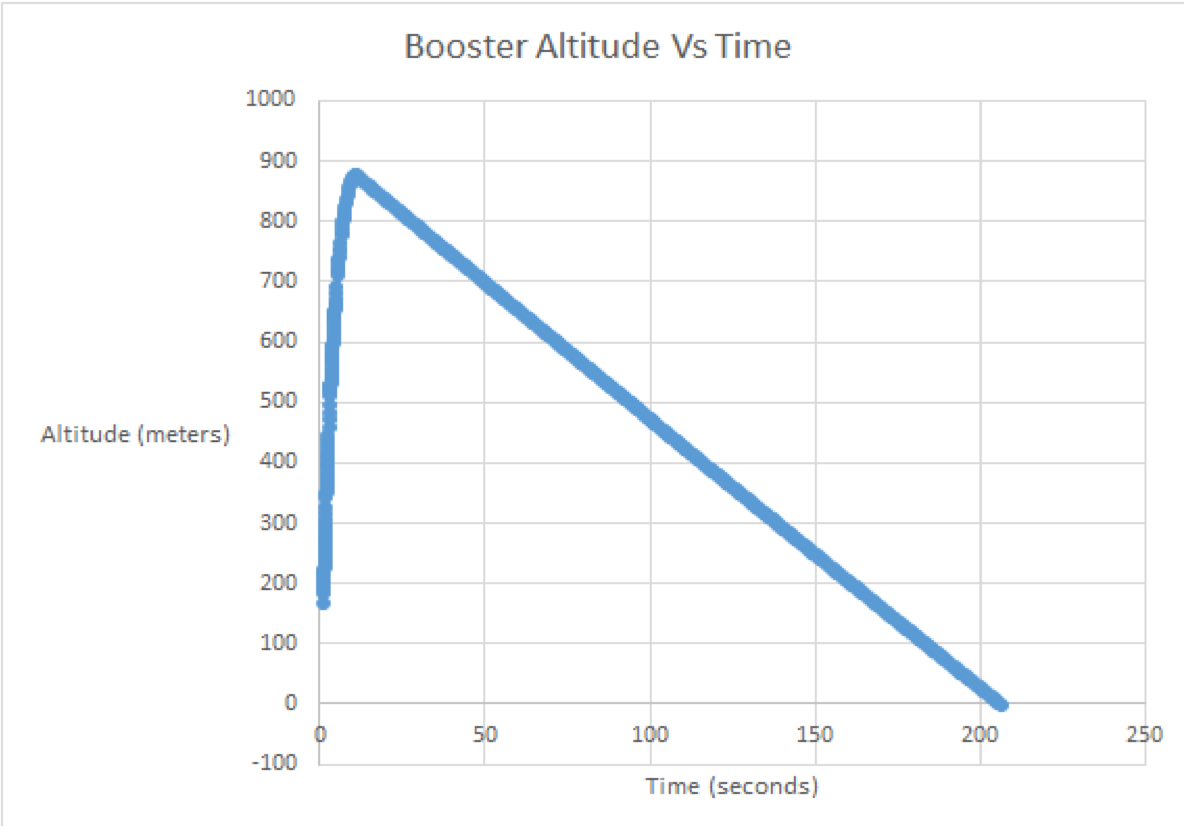
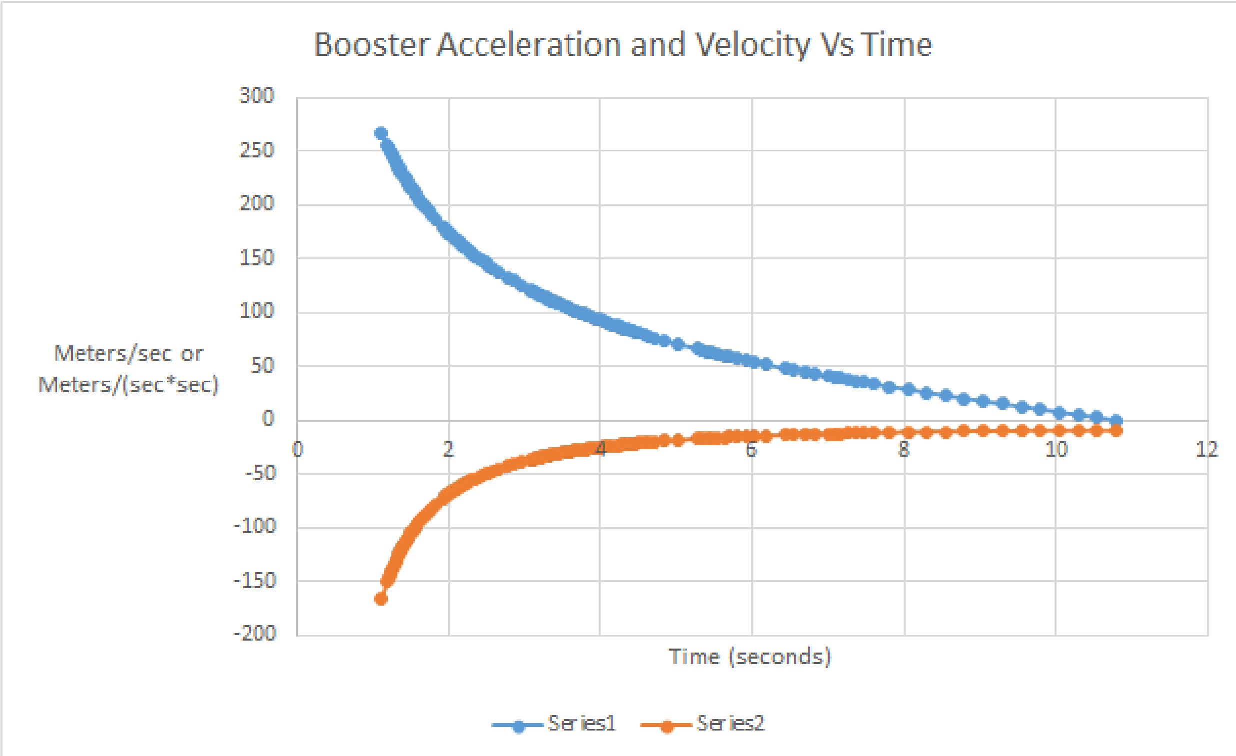


Chart 3

Chart 4 represents the Booster Acceleration and Velocity Vs Time after separation. Open rockets simulation does not export the redundant data that occurred before separation than can be found in the dart data. The slope of the velocity line is a higher magnitude for the booster then it is for the dart. However, we do believe that these numbers will measurably better in practice then in simulation because of the design of our mounting system for the dart creating a large air dam at the nose of the booster.


Booster Acceleration and Velocity Vs Time
300
250
200
150
100
50
0
-50
-100
-150
-200
Meters/sec or
Meters/(sec*sec)
0
2
4
6
8
10
12
Time (seconds)
Series1
Series2

Budget

(Planned, including (value of) Registration fee and Competition Travel)

We were given a $1400 budget by Century College for this project.

Item	Quantity	Cost
Entrance Fee	1	$400
Carbon fiber	6 yards	$350
Epoxy resin	1 Qt.	$45
Hardener	1 Qt.	$45
Mold building supplies	1	$50
Electronics	1	$100 – donations
Rocket Supplies	1	$350
Total………………………………………………………………………...		$1340

Since all of us are local to the Twin Cities north metro we will not have any travel expenses. Any remaining money left in our budget shall be used for Pizza.