Space Grant 2015 Design Report

UNIVERSITY OF ILLINOIS

STUDENT SPACE SYSTEMS

Table of Contents:

Executive Summary

Student Space Systems, a rocketry organization at the University of Illinois, was founded in 2013 with the goal of eventually launching a student-built rocket to the edge of space. In an effort to train new members and develop new technology, Student Space Systems (SSS) has committed itself to forming a team each year to compete in the NASA Space Grant Midwest High-Power Rocketry Competition.

Last year, a team of freshmen from Student Space Systems placed first at the 2013-2014 Space Grant Midwest Rocket Competition, in the process developing an Arduino-based radio telemetry system.

This year, a new team of SSS students has decided to take on the Midwest competition, once again developing innovative rocket designs and avionics packages to achieve the goals of the competition. The SSS team consists of a core of underclassmen in Aerospace Engineering, as well as a group of Electrical Engineering and Computer Science students. These two teams are cooperating to minimize the size of the rocket in order to achieve the competition goals. The avionics team has proceeded with the intention to minimize the size of the avionics package in the dart, along the way learning aspects of circuit design and programming to build a custom avionic package-on-a-chip. With this core of devoted members, Student Space Systems is looking forward to competing in the Midwest High-Power Rocket Competition in May.

Rocket Design Features

The rocket consists of two stages: a booster and an unpowered dart. The stages will separate due to drag after the motor completes its burn. In order to maximize the separation of the stages during flight, as well as the altitude of the dart, several design elements come into play.

In order to achieve maximum altitude of the dart, the combined rocket should have a minimized drag coefficient, as well as an optimized mass. A small total mass will leave the dart with too little momentum after motor burnout (and dart separation), and too great a mass will decrease the velocity at motor burnout. A convenient analogy is throwing a crumpled paper ball contrasted with throwing a baseball.Although one might be able to throw a light paper ball faster than a heavier baseball, it is common intuition that one can throw a baseball much farther. This is due to a greater momentum-to-drag ration. We are aiming to tune this ratio for both the dart and booster to achieve maximum dart altitude and dart-booster separation.

The dart was designed to have to have a smaller drag coefficient as well as to have a larger mass than the booster. These are achieved by minimizing the diameter of the dart at 1.5 inches, and building it out of fiberglass to increase its mass. Through this design, the dart will have a much greater momentum-to-drag ratio than the booster, which has a 4 inch diameter and is made out of phenolic. This ensures maximum separation in altitude between the dart and the booster. The overall low drag profile of the combined rocket, as well as a relatively light mass, maximizes the altitude of the dart.

In order to connect the dart and the booster, a transition segment was designed onto the top of the booster. This section is designed to minimize friction between the two segments while also preventing any “wobbling” of the dart that could lead to aerodynamic instability. The transition section will be constructed out of a plastic 4 inch nose cone. The top of the nose cone will be sawed off at a diameter just larger than the size of the dart. Within this section a section of tube with the same diameter as the dart will be connected to the top of the sawed-off nose cone, as well as at the bottom of the nose cone with a centering ring. A coupler will extend out of the rear of the dart several inches, and will slide into the tube in the nose cone. This design will minimize friction and provide adequate stability for the dart.

The downward camera on the dart will be placed in this coupler section to reduce drag. Because the competition requires video of the complete flight and the video is blocked by the booster, a periscope system is needed in order to redirect the camera’s view while the sections are still connected. The periscope consist of a lens and two mirrors that refocus the camera’s view and directs it down the side of the booster. One of the mirrors will be mounted outside the rocket and will be protected by a fairing that will minimize the drag that occurs.

In its current design, the dart will descend on one small parachute. The fiberglass structure of the dart should provide greater impact resistance. If testing proves this parachute to be inadequate, an extra section of dart tubing will be used to create a second parachute bay above the avionics payload bay to allow for dual deployment. The booster, due to its relatively low maximum altitude, will descend on a single parachute.

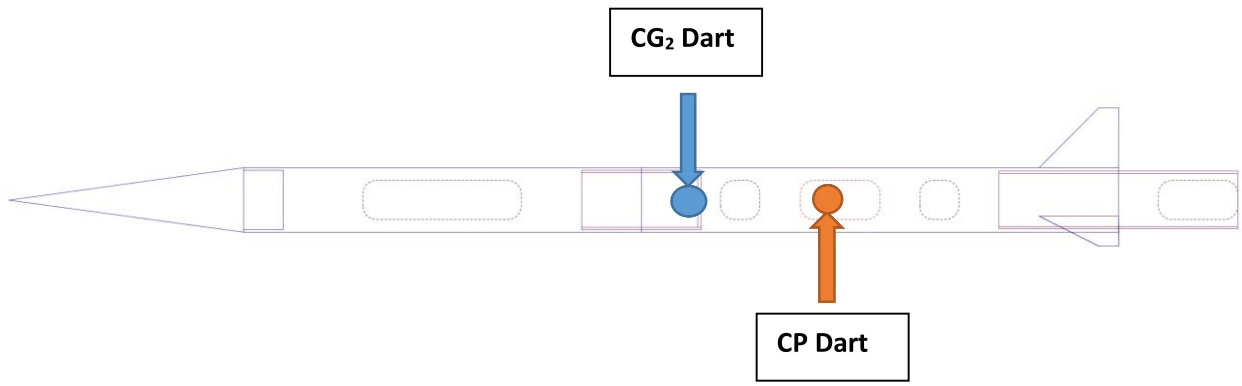
Payload Design Features

In order to record data, we are constructing our own personal circuit board, with two parts. The main avionics package, responsible for the collection of rotational data, could not be built through normal means, such as an Arduino. Most commercial controllers and computers are larger in size than the intended diameter of the dart. In order to collect data, we decided to build our own system-on-a-chip, centered around an ATmega328 chip. This will be soldered onto a custom-printed circuit board, with all sensor and components (gyroscope, barometer, memory) integrated into the board. This circuit will include an XBee radio so that live altitude and rotational data can be received and displayed on the ground. The board will be mounted on a specially constructed sled.

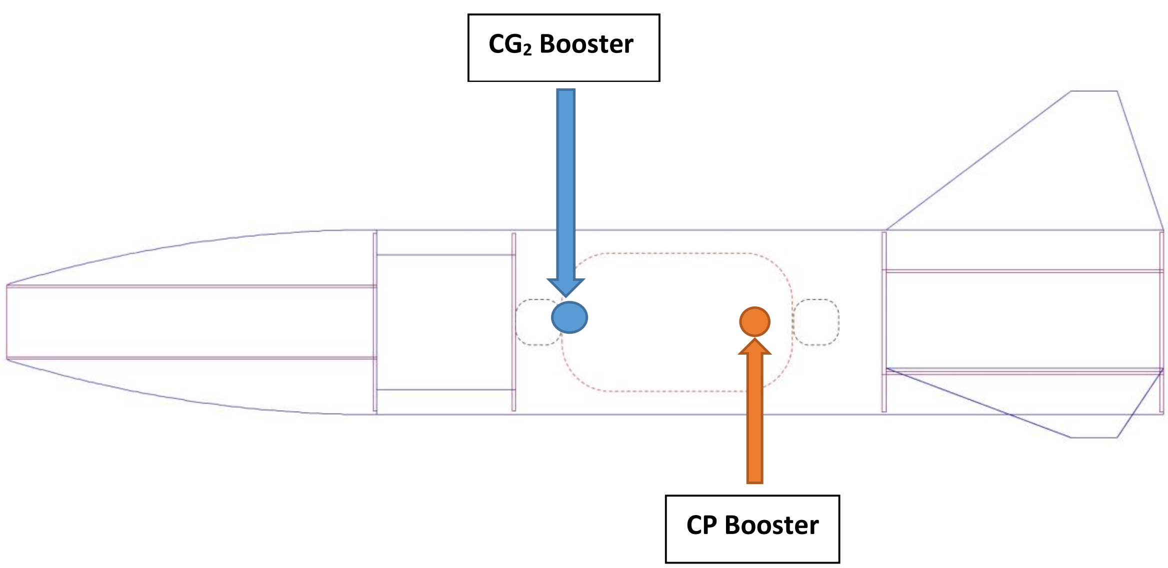
For the onboard video, a camera, similar to a smartphone camera, will be connected to an ARM MCU via I2C, which will then store the video data on a connected SD card over SPI. These components will be built into a custom circuit board and mounted in the rear section of the dart.

Diagram of Rocket

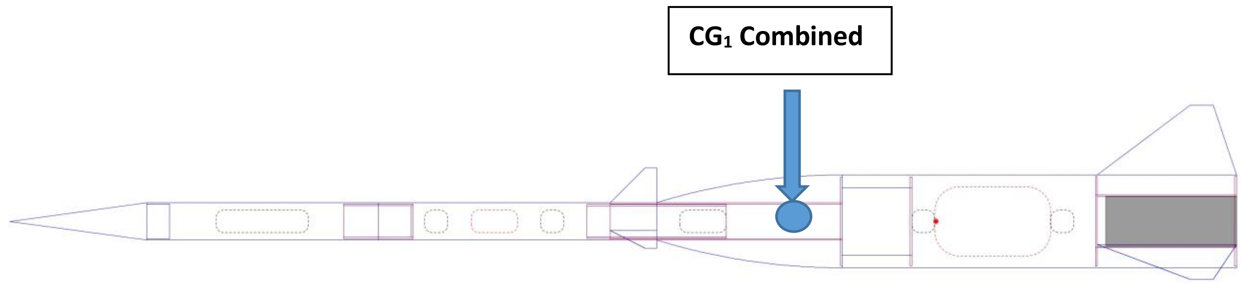
Dart:



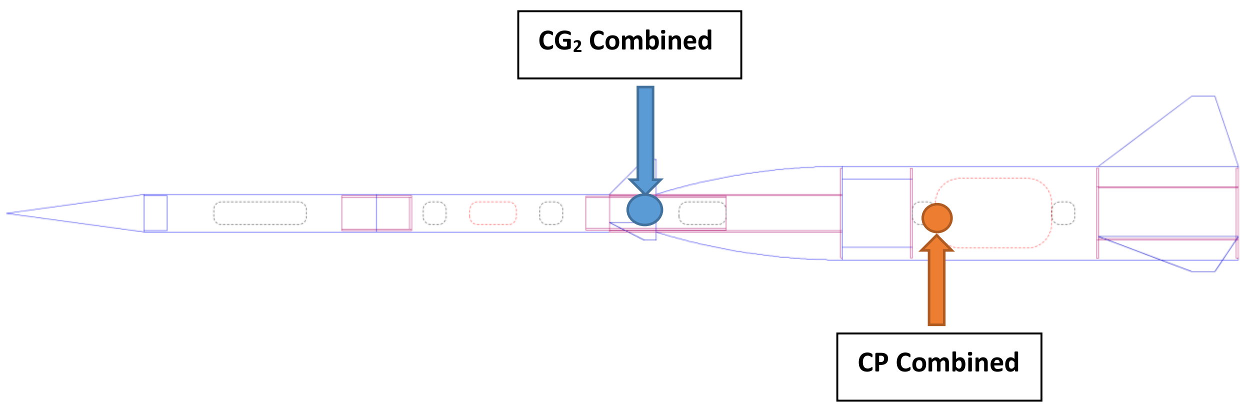
Booster:



Combined Rocket (Fully Loaded):



Combined Rocket (Motor Burn-out):



Analysis of Anticipated Performance

We estimated the anticipated performance of our rocket using an OpenRocket simulation. We constructed an OpenRocket model of the rocket design, using accurate dimensions and masses to the best of our ability. We then used the software to simulate and plot the motion of the rocket for the beginning of the flight.

Reference for the Graph:

Point A: maximum acceleration is reached

Point B: The engine burns out. Air resistance causes negative acceleration.

Point C: (occurs at same time as B) Dart and booster separate as they begin to decelerate. They have reached maximum velocity at this point.

Point D: The booster reaches apogee.

Point E: The dart reaches apogee.

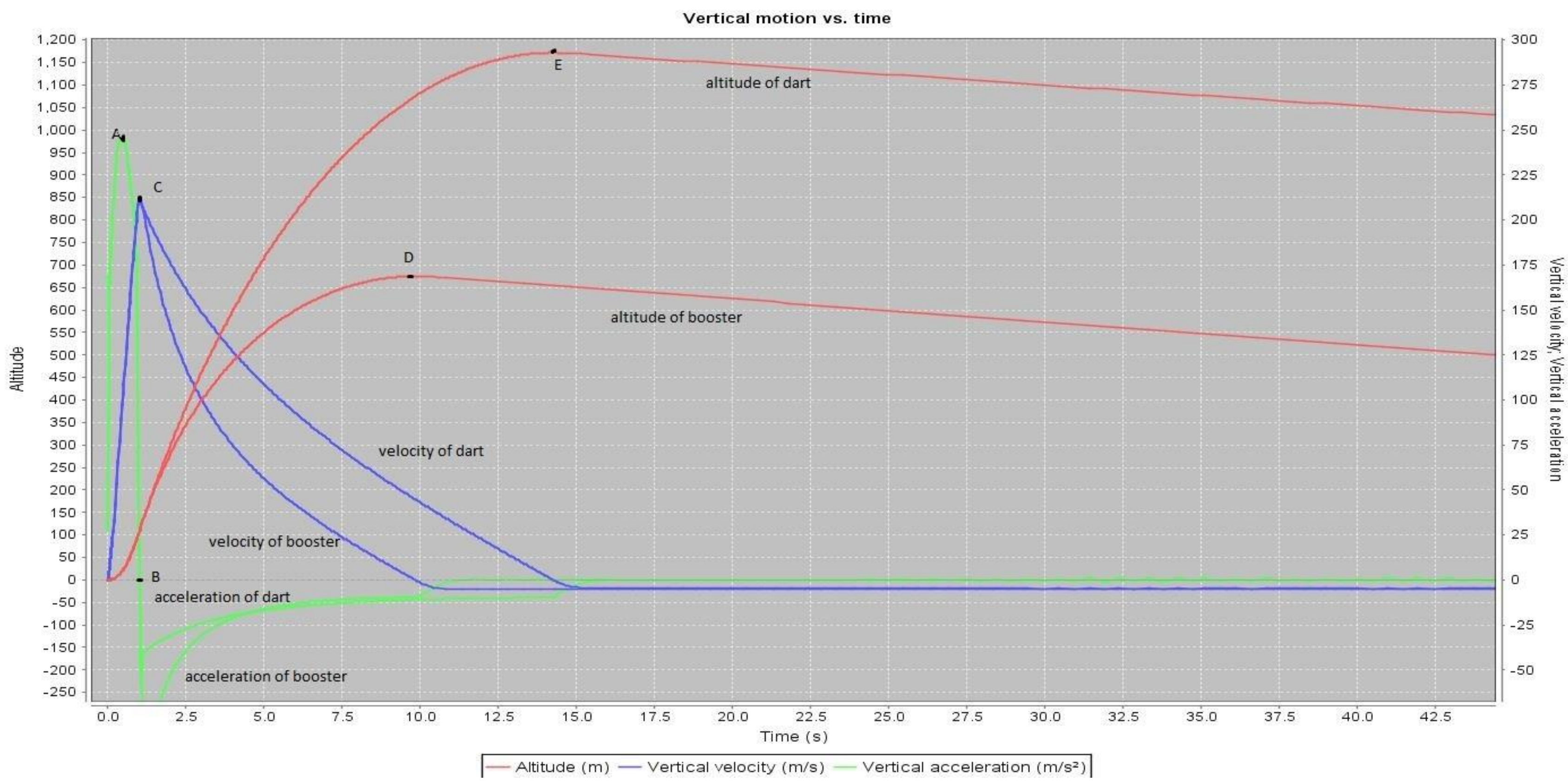
Estimated maximum altitude of booster (point D): **670m**

Estimated maximum altitude of dart (point E): **1160m**

Estimated peak acceleration of booster (point A): **250 m/s^2**

Estimated peak acceleration of dart (point A): **250 m/s^2**

Note that peak acceleration occurs when thrust reaches the maximum value – that is, while the booster stage is still active and the dart and the booster are still attached.


Vertical motion vs. time
Altitude
Vertical velocity, Vertical acceleration
Time (s)
A
B
C
D
E
altitude of dart
altitude of booster
velocity of dart
velocity of booster
acceleration of dart
acceleration of booster
Altitude (m)
Vertical velocity (m/s)
Vertical acceleration (m/s²)

Planned Budget

Rocket Parts:

Part	Number	Cost
Plastic Ogive Nosecone - Pinnacle - Diagram 4 - 3.90”	1	$21.95
38 mm Fiberglass nose cone	1	$24.49
Fiberglass 38 mm Airframe - 48” long	1	$59.27
Fiberglass 38mm Coupler (6 inches long)	3	$38.70
Fiberglass 38 mm bulkhead disk - Proline	2	$7.30
3.9” Body Tube - 34 inches	1	$11.50
54mm Motor Mount Tube	1	$8.09
98mm to 54mm centering rings	2 2-packs	$16.20
98mm plywood bulkhead	2	$8.10
G-10 Fin material (for both booster and dart) 0.093” - 8”x12”	3	$47.22
Test Motor	1	$53
Motor Casing	1	$43
Extra expenses	-	$50
Total Cost		$388.82

Electronics:

Part	Number	Cost
Altimeter/Barometer	1	$14.95
XBee Pro	2	$37.95
XBee Sockets	2	$1.00
XBee usb connector	1	$24.95
IMU	1	$39.95

PCB Board	1	Free
XBee Sockets	4	$1.00
Camera Electronics	-	$200
DIY-Duino Parts	-	$20
Total Cost	-	$339.80

Travel Expenses:

Expense	Cost
Car/Gas	$525
Hotel Stay	$200
Total Cost	$725

Total Expenses

Expense	Cost
Rocket Parts	$388.82
Electronics	$339.8
Travel Expenses	$725
Total Cost	$1453.62