Preliminary Design Report

Wichita State Rocket Club

Wichita State University

Dr. Steven Klausmeyer

Dr. Atri Dutta

Atri.Dutta@wichita.edu

(316)-978-5208

Luke Hansen

lthansen@shockers.wichita.edu

(913)-908-4546

Luke Hansen, Sam Atchity, Kayle Schapmann, Ruth Darsey, Ian Buhman, Shireen Fikree, Darin Parker, Chris Kahn, Zeke Kaszycki, Samantha Cosgrove, Daniel Bohnenkamper

Scientific Projectile with Advanced Drag system and Electronics

S.P.A.D.E.

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Executive Summary

The strongest factor influencing the design was the motor selection. Aerotech brand motors were selected because of their reliability. The second strongest Aerotech K motor was chosen because the strongest was significantly wider and had a much shorter burn time. This would have required a stronger and heavier airframe, which was not an attractive option due to the desire to use a low impulse J motor. The chosen J motor offers small impulse and low average thrust while having a long burn time; therefore, minimizing dynamic pressure and allowing for improved performance.

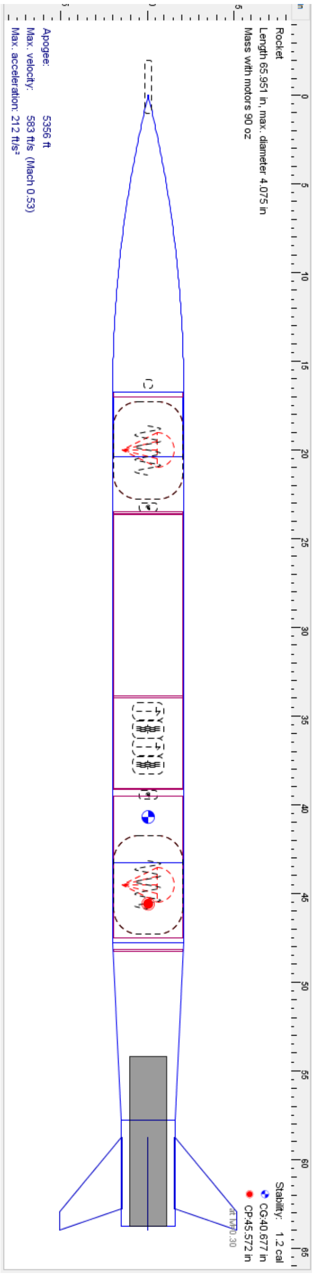
Airbrakes and ballast are used to compensate for the difference in power. The ballast allows the airbrakes more time to slow the rocket after the motor has burned. The airbrakes are actuated by a servo motor and fold out from the airframe.

The rocket was designed using OpenRocket and performance was simulated using Simulink and MATLAB.

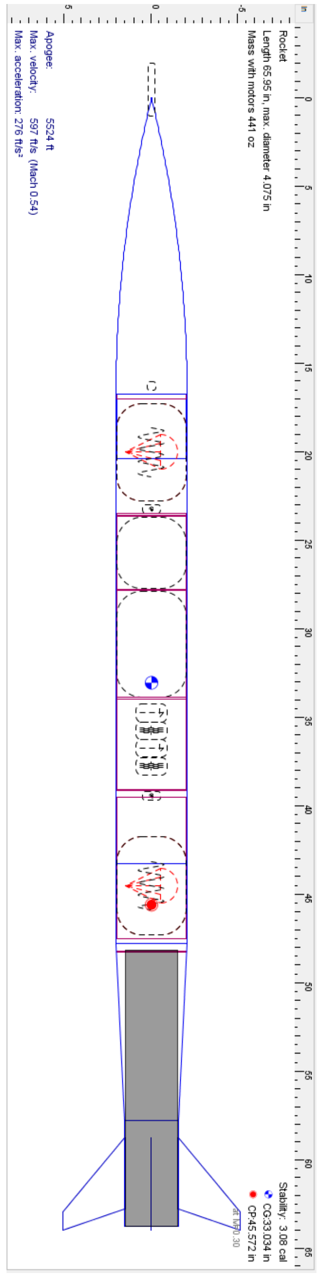
The electronics, payload, ballast and airbrakes will be mounted inside their own tube which will be inserted into the airframe before flight. Data will be written to and recovered from a SD card.

Airframe

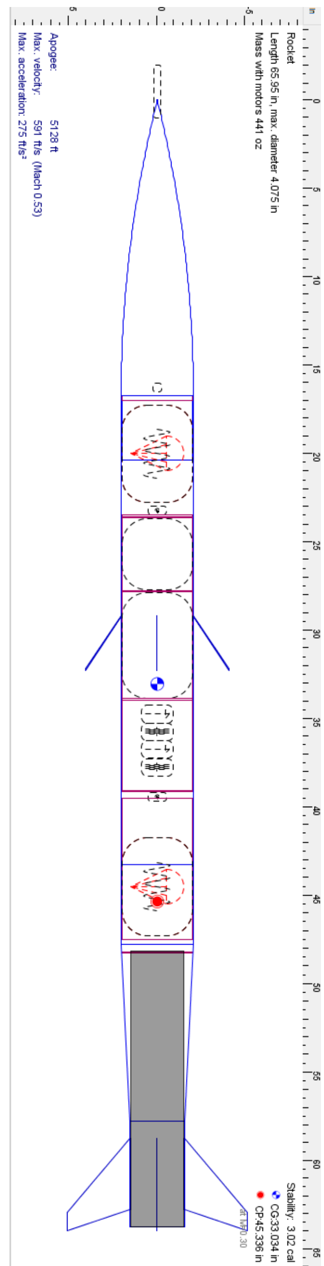
The fore section is a 4 inch diameter quantum tube of 26.5 inches in length. The polycarbonate nosecone is 16.75 inches long with an additional 3 inch long coupler. The aft section will be 3D printed ABS with a 4 inch diameter by 4.5 inch long section of tube and a 10 inch conical transition down to 3.15 inches diameter, followed by a 6 inch long by 3.15 inch diameter tube with 4 fins. The fore and aft sections will be joined with an 8 inch phenolic coupler. The weakest component of the airframe has a compressive strength of 7,650 psi and is subjected to a load of 975 psi for a minimum factor of safety of 7.49.



J-90



K-1000



K-1000 with Airbrakes

Risk Mitigation

In order to minimize the coning effect, the rocket body was made as short as possible and the fins were made to have as much surface area as possible without sacrificing aerodynamics or strength. The fins will be integral to the aft section and coated in fiberglass, increasing strength and decreasing the risk of the fins shearing off upon landing.

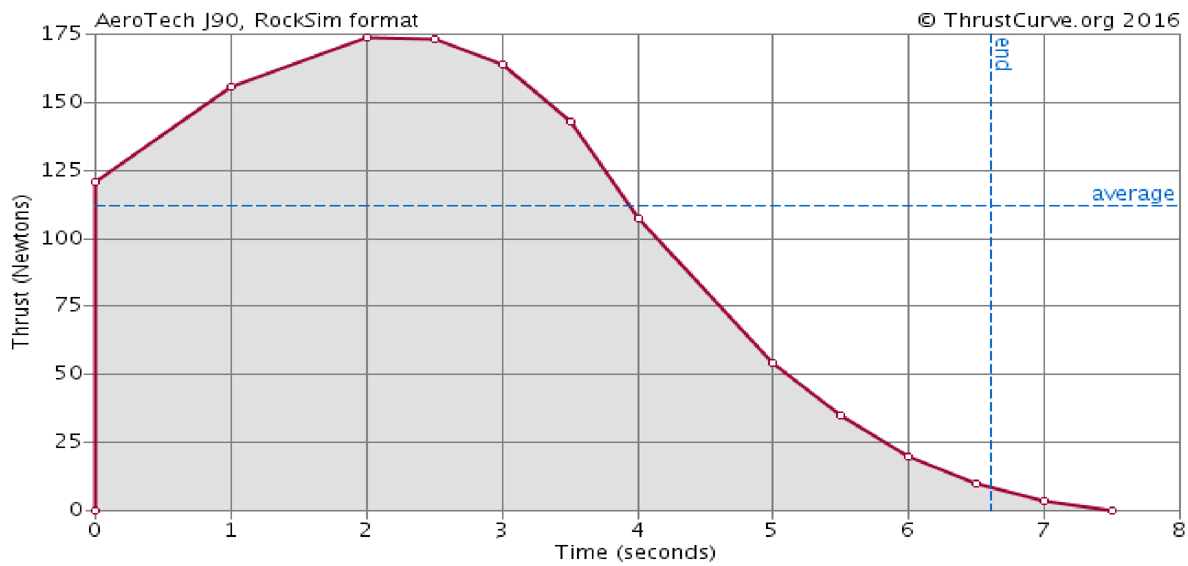
Propulsion Systems

The motors selected for this competition are the Aerotech J-90 and K-1000.

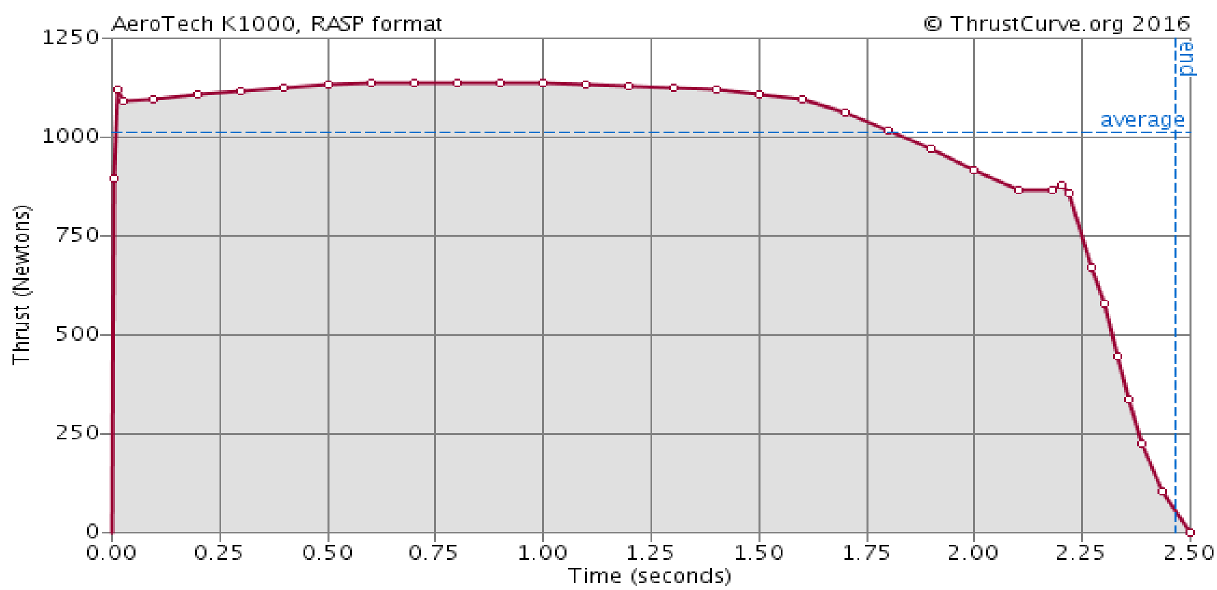
Motor Data

Motor	Diameter	Length	Total Weight	Fuel Weight	Average Thrust	Maximum Thrust	Burn Time
J-90	2.13 in	9.57 in	1.88 lb	0.94 lb	20.23 lb	42.27 lb	6.9 s
K-1000	2.95 in	15.08 in	5.74 lb	2.72 lb	239.66 lb	376.35 lb	2.4 s

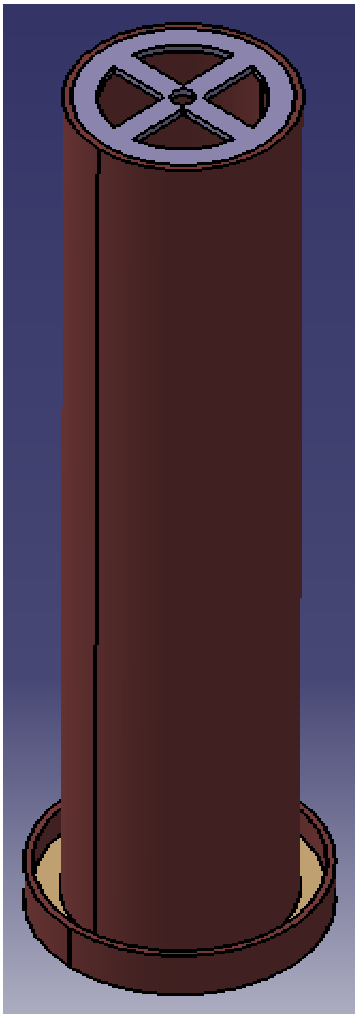
*Data from thrustcurve.org



J-90 Thrust curve (from thrustcurve.org)



K-1000 Thrust Curve (from thrustcurve.org)



J-90 Motor Mount Adapter

Recovery System

The recovery for the J-90 configuration includes 36” diameter drogue and 36” diameter main parachutes. The recovery for the K-1000 configuration includes 72” diameter drogue and 72” diameter main parachutes. The K-1000 does not come with a built-in motor ejection charge, thus a backup system will be used. The J-90 does come with a built-in motor ejection charge, which will be utilized. Both systems are controlled by a Featherweight Raven 3 altimeter with a Perfectflite Stratologger as a backup deployment system on a separate circuit. The deployment charges for both systems are nitrocellulose based. The anticipated ground hit velocity for the J-90 configuration is 20.1 ft/s and is 21.6 ft/s for the K-1000 configuration. The ground hit velocities were estimated using OpenRocket. The shock cord is Kevlar rated for 1800 lbs and the quick link connections are rated for 750 lbs. The maximum tug force is estimated at 315.76 lbs.

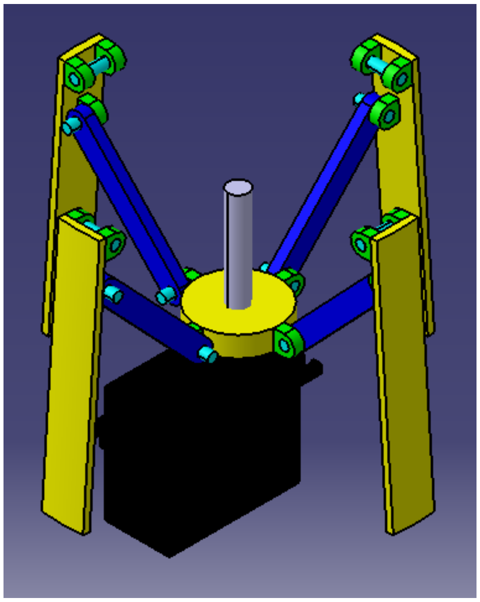
Avionics and Payload

The payload assembly will consist of 3 sleighs mounted in a phenolic tube secured by 2 threaded rods. The phenolic tube will be bolted to the airframe during flight.

To prevent the K-1000 configuration from surpassing the apogee of the J-90 configuration before the motor has fully burned and to allow time for the airbrakes to slow the rocket, a ballast is used. The ballast is 265 ounces of number 9 lead shot and candle wax to prevent the weight from shifting. The ballast will have 2 brass tubes running through it to allow to threaded rods to pass through.

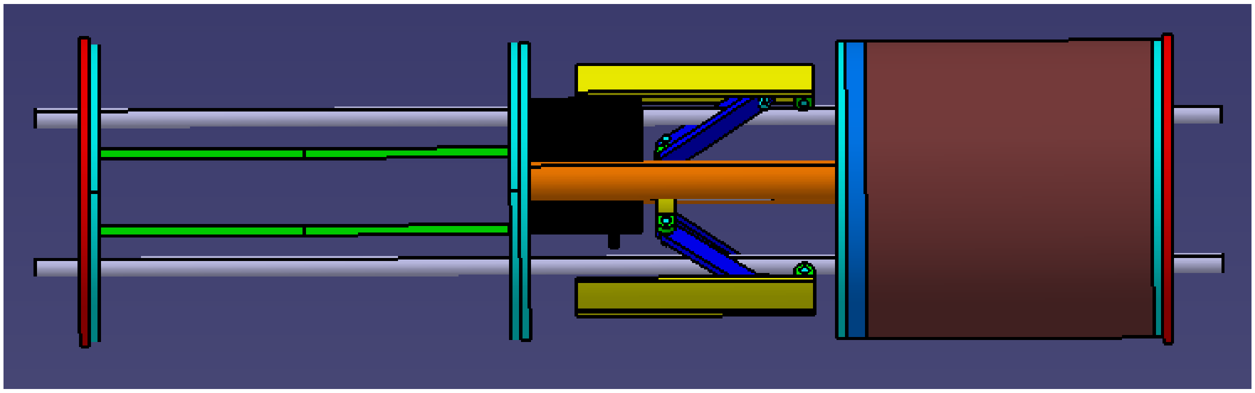
The airbrakes will not be flush with the airframe, but will line up with slots in the airframe. The airbrakes will be hinged at the top and middle and will be opened in a manner similar to an umbrella. A carbon fiber link will attach each of the 4 airbrakes to a bearing with a threaded center. The bearing will ride on a worm gear controlled by a servo motor. An altimeter, accelerometer and pitot tube will be used to judge the position and momentum of the rocket as well as the forces acting on the rocket. This data will be compared to the previous flight and the airbrakes will be adjusted using a PID controller. The controller will consist of an Arduino microcontroller, a 3-axis accelerometer, an altimeter, and a pitot tube. This system will also serve as the non-commercial data collection package. The flight data will be written to a SD card.

The non-commercial data collection package as well as the commercial altimeters will be mounted on the avionics sleigh. The non-commercial data collection package will use a pitot tube to record the rocket's velocity. The rocket separation and parachute deployment events will be recorded by detecting a lack of continuity in wires running the length of the rocket. The up and down video system will consist of 2 keychain cameras with lenses built into the launch rails.



Airbrake Assembly

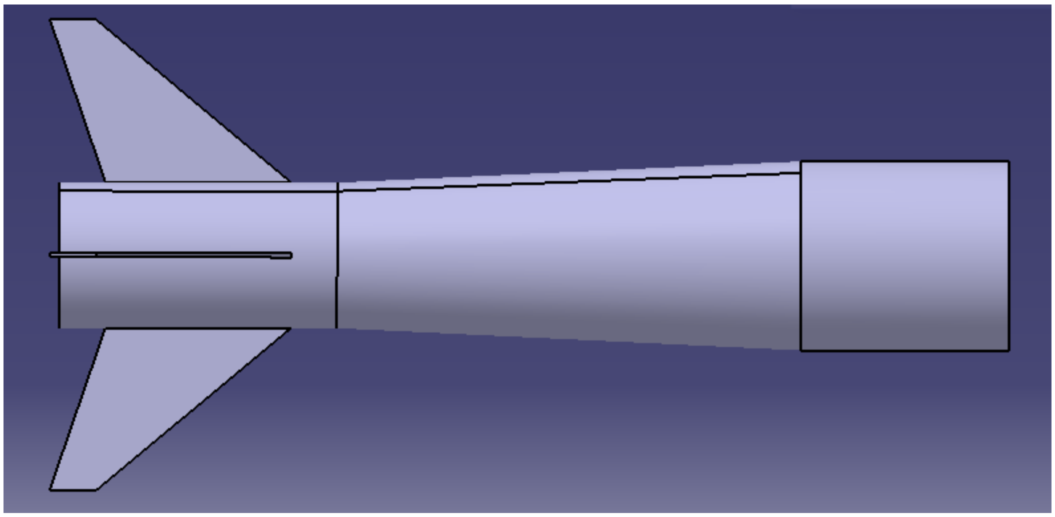
Payload Bay Assembly



Avionics Sleigh Airbrakes Sleigh Ballast Sleigh

Construction

The entire aft section will be 3D printed using ABS plastic and fillets will be added to each fin using epoxy and chopped carbon fiber. Each fin will be reinforced with a layer of fiberglass. Phenolic tubing will be used for the couplers and the J-90 motor mount adapter. The fore body tube will be made from quantum tubing. The nosecone is a commercial polycarbonate nosecone. Sections will be joined using #2-56 nylon shear pins.

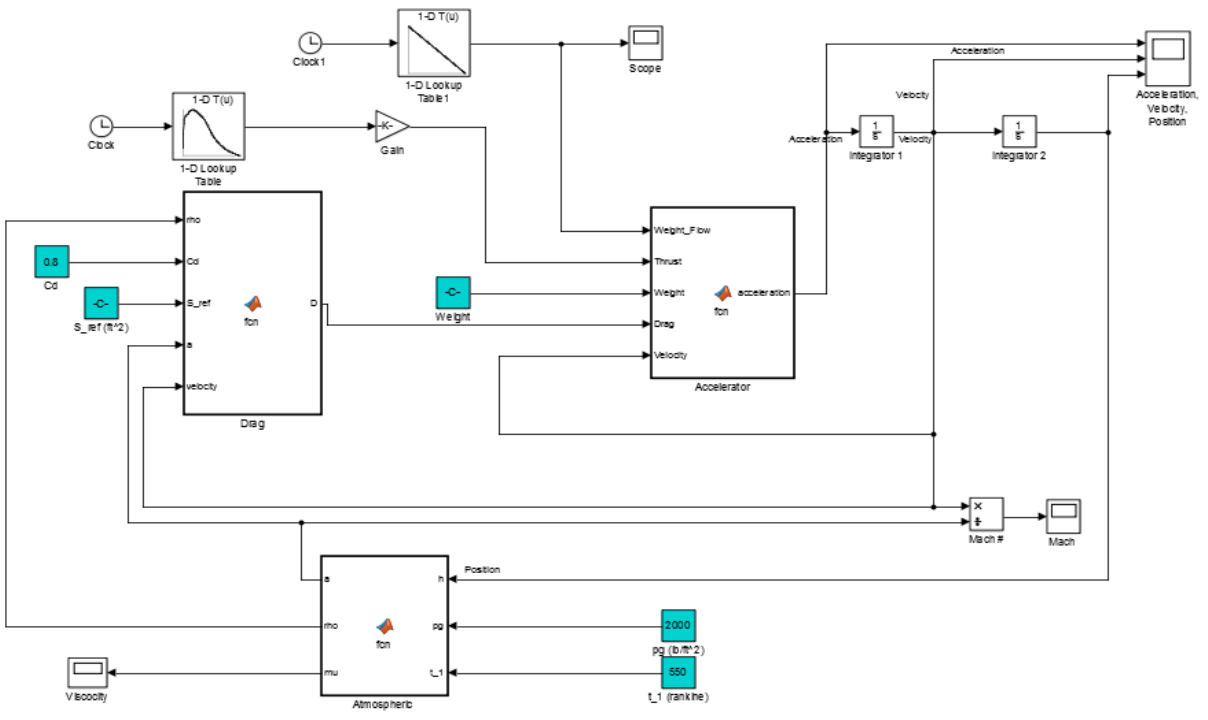


Aft Section

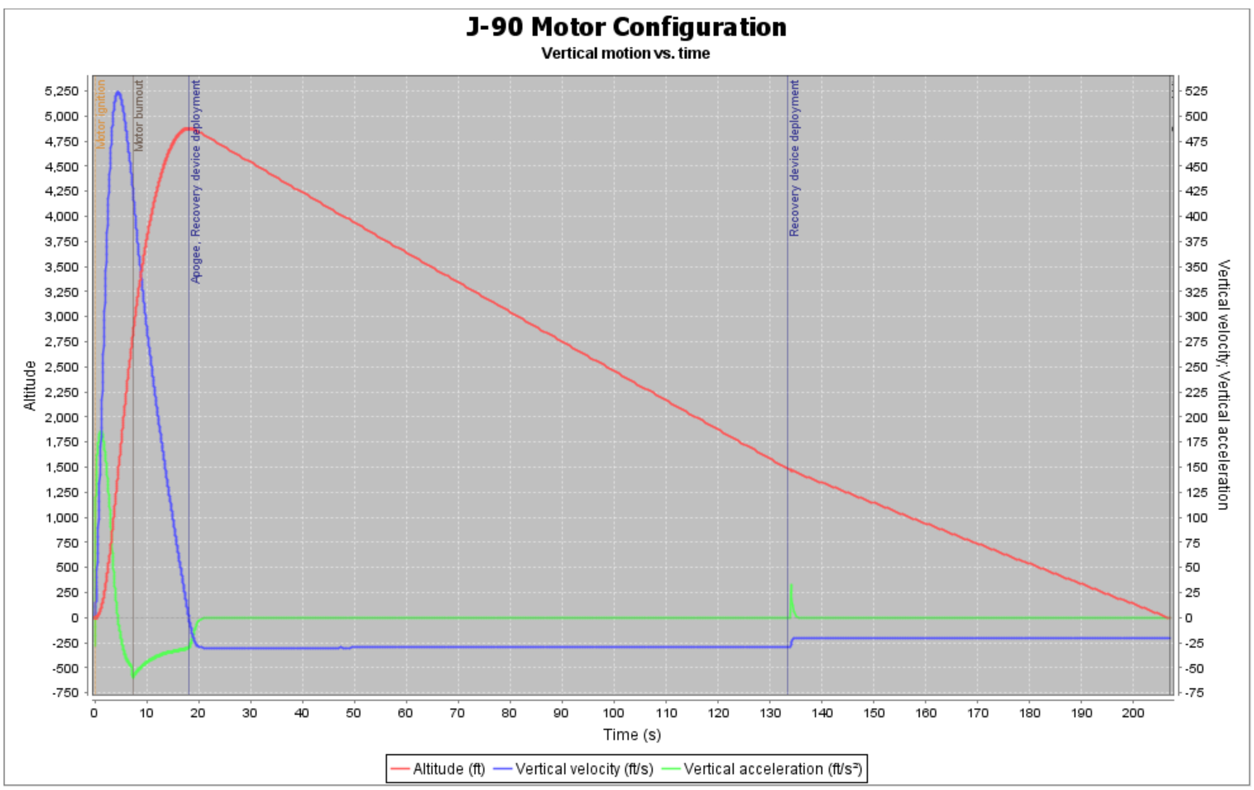
The payload bay will be a phenolic coupler tube. The sleighs will be made of laser cut plywood bulkheads and platforms. The hinges and arms that actuate the airbrakes will be carbon fiber and secured with cotter pins. The flaps will be cut out of quantum tubing.

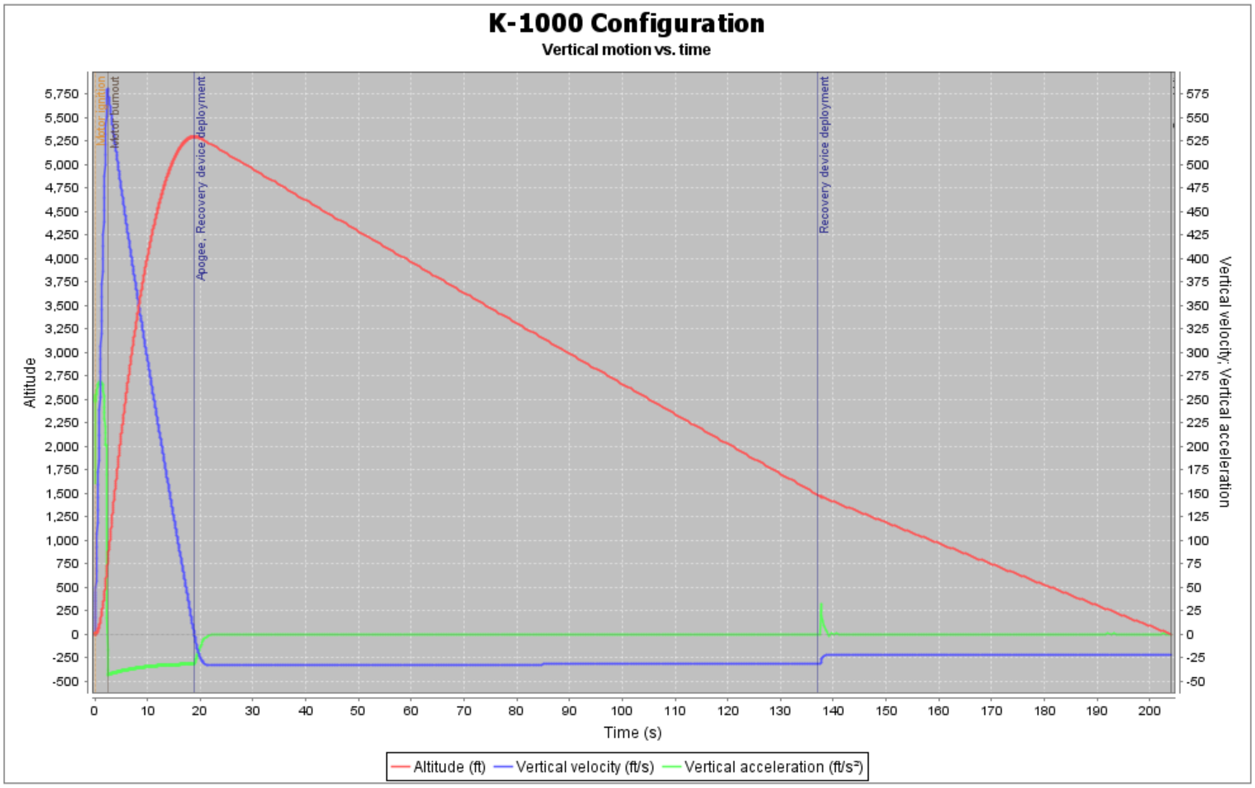
Predicted Performance

Performance estimates were made using OpenRocket and MATLAB with Simulink.



Simulink Diagram





Launch Data

Motor Configuration	Thrust to Weight Ratio	Velocity Off Rod
J-90	3.20:1	54.1 ft/s
K-1000	8.48:1	72.2 ft/s

Flight Data

Motor Configuration	Peak Acceleration	Peak Velocity	Peak Altitude
J-90	186 ft/s^2	524 ft/s	4890 ft
K-1000	269 ft/s^2	581 ft/s	5300 ft

*K-1000 data was estimated without the effects of the airbrake system on drag

Recovery Data

Motor Configuration	Ground Hit Velocity	Tug Force at Main Deployment
J-90	20 ft/s	56.63 lbs
K-1000	21.8 ft/s	315.76 lbs

*Both configurations will deploy drogue parachutes at apogee and main parachutes at 1495 ft

Stability

J-90

Mach Number	Center of Gravity	Center of Pressure	Stability Caliber
0.1	38.58 in	43.90 in	1.30
0.2	38.58 in	44.00 in	1.33
0.3	38.58 in	44.16 in	1.37
0.4	38.58 in	44.39 in	1.43
0.5	38.58 in	44.71 in	1.5

K-1000

Mach Number	Center of Gravity	Center of Pressure	Stability Caliber
0.1	32.53 in	44.11 in	2.84
0.2	32.53 in	44.21 in	2.87
0.3	32.53 in	44.37 in	2.91
0.4	32.53 in	44.60 in	2.76
0.5	32.53 in	44.72 in	3.04

*Dimensions are from the tip of the nosecone

*Numbers estimated using OpenRocket and verified using MATLAB

Environmental Conditions

Calculations were done assuming a standard atmosphere of 59 degrees Fahrenheit and a 5 mile per hour crosswind. To design for the largest possible load, the wind direction is assumed to be normal to the surface of two fins.

Safety

Material Handling

Chopped carbon fiber will be handled with gloves. Epoxy will be handled with gloves and sticks in a well-ventilated area. Spray paint will also be used in a well-ventilated area. Fiberglass and fiberglass resin will be handled with gloves, respirators and in a well-ventilated area. Safety glasses will be during all operations.

Assembly

As all parts will be laser cut, 3D printed or commercially manufactured, assembly will consist of sanding to fit and epoxying the parts together.

Launch Procedures

Both motors will be assembled. The avionics payload sleigh will be inserted into the payload tube along with 2 spacers and clamped in place using the 2 threaded rods. The payload tube will be inserted into the rocket and bolted in place. The J-90 motor mount adapter will be inserted into the aft end of the rocket, bolted to a bulkhead at the top and bolted to the airframe at the bottom. The ejection charges will be packed and inserted into the rocket. The parachutes will be attached to the shock cord and the couplers will be secured with shear pins. The J-90 motor will be inserted into the rocket and secured with a screw-on retention system. Once on the pad all systems will be turned on magnetically. The ignitor will then be inserted into the motor and connected to the firing system.

Upon recovery, the ejection charges, motor mount adapter and payload bay will be removed. A SD card containing the flight data will be copied for judging. The flight data from the altimeters will be downloaded for judging. The avionics will be repackaged. The avionics sleigh, airbrakes sleigh and ballast sleigh will be inserted into the payload tube and clamped in place using 2 threaded rods. The ejection charges will be packed and inserted into the rocket. The parachutes will be attached to the shock cord and the couplers will be secured with shear pins. The K-1000 motor will be inserted into the rocket and secured with a screw-on retention system. Once on the pad all systems will be turned on magnetically. The ignitor will then be inserted into the motor and connected to the firing system.

Upon recovery, the ejection charges, motor mount adapter and payload bay will be removed. A SD card containing the flight data will be copied for judging. The flight data from the altimeters will be downloaded for judging.

Budget

Registration	$ 400.00
Hotel Rooms	$1320.00
Gas	$ 210.00
Nosecone	$ 28.00
Body Tube	$ 21.00
J-90 Casing	$ 85.00
K-1000 Casing	$ 240.00
K-1000 Fuel	$ 380.00
J-90 Fuel	$ 220.00
Accelerometer	$ 35.00
Altimeter	$ 40.00
Pitot Tube	$ 34.00
Chopped Carbon Fiber	$ 10.00
High Speed Servo Motor	$ 22.00
ABS Spool	$ 12.00
Kevlar Shock Cord	$ 20.00
No. 9 Lead Shot	$ 40.00
Featherweight Raven 3 Altimeter	$ 165.00