SEDS-UCF
Hybrid Motor High-Powered Rocket Project

Florida Space Grant Consortium Hybrid Rocket Competition

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University of Central Florida

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1.0 Executive Summary

For our project, we designed, built, and launched a hybrid-powered rocket for the Florida Space Grant Consortium's Hybrid Motor Powered Rocket Competition. The goal of the project was to launch a rocket that would reach a maximum altitude the closest to 2000 feet as possible. In this report, we have included methodology and simulation data for our design – including background information on hybrid rockets, a hazard analysis, a failure mode and effect analysis, rocket schematics, design details, and launch simulation data, based on varying factors.

Our main purpose in participating in the Florida Space Grant Consortium Hybrid Rocket Competition is to gain experience in the construction and launch of hybrid rocketry via a design-based project atmosphere. In order to build larger, more complex rockets in the future, it is important to learn the concepts involved in hybrid rocketry, from the propulsion process, to the motor assembly, to various safety precautions to take. This project is in an effort to educate the involved individuals, acting as a training device in the aforementioned areas.

Hybrid rockets function by burning a solid fuel grain by the catalysis of a liquid or gaseous oxidizer. For the rocket to have thrust, the oxidizer passes through a port in the solid fuel grain and reacts with the solid fuel, which causes the hot exhaust gases. When the oxidizer reacts with a layer of the fuel, this fuel will vaporize and later react with any unused oxidizer, producing more combustion gases.

For our design, we have chosen to build a single-stage rocket powered by a RATTworks H70 hybrid rocket motor. The lower segment consists of the hybrid motor and restraints, while the upper segment consists of the nose cone, an upper bulkhead, and the payload capsule bay. The RATTworks motor was chosen primarily due to its overall simplicity of its design, its level of reusability, and physical dimensions. The selection of the remaining components was based on the motor's size and thrust. For our flight computer, we are using the Ozark ARTS2, as it has accelerometer and barometric sensors, dual-pyro channels, and sophisticated programming and recording ability – all of which is needed to have accurate launch data.

Using the RockSIM software program, we were able to calculate the maximum weight allowable for the rocket – under perfect conditions. Factoring in wind and other launch conditions, the optimum launch simulation would be for the rocket to launch to about 2,050-2,100 feet on the simulation software. The final design simulations show that with a weight of about 700 grams (including payload bay, bulkheads, and motor supports), we should be able to reach the target apogee, given near-perfect launch conditions. Based upon the simulations, even with the wind, the rocket will launch to 2019.7 feet, assuming the motor is fully fueled. In both cases, the rocket will hit the ground with a velocity of -22.4198 feet per second. For optimum performance, the ejection delay should be between 8.8 and 8.9 seconds after launch.

2.0 Project Description

2.1 Project Guidelines

A. Project Objectives

The objective of the Florida Space Grant Consortium Hybrid Motor High Powered Rocket Competition is to successfully design, build, and launch a hybrid-powered rocket. The competition consists of two separate categories with unique objectives; the first is to reach a maximum altitude and the second is to fly the rocket as close to 2000 feet in altitude as possible.

B. General Project Guidelines

The design of the rocket is bound by specific guidelines.

I. The rocket can be built from scratch or from a kit.
II. The engine must be a hybrid motor rated "G" or from a lower class (160 Newton-seconds or less). The engine can be a scratch built or purchased from a company.
III. Points will be awarded for the phases of the competition. The flight is worth 80% and the teams Engineering Notebook is report is worth 20% of the total points.
IV. All teams that submit a proposal will be able to take part in the competition and compete for the prizes. At least 6 teams will be selected and awarded their budget of up to $1000 to build the rocket. For teams that design their own engines, static testing and data from two test launches is expected. The grant can be used for supplies, motors, kits and travel. Salary and capital expenditure is not allowed.
V. Teams will have their rockets and motors inspected for safety by a NEFAR representative just before launch.
VI. Motor delay recovery system deployment is allowed.

C. Altimeter Specifications

A recording barometric altimeter must be used to record data for competition. While it is the duty of the Contest Director to provide the flier with the launch site specifications so the altimeter may be calibrated to the correct base altitude, it is up to flier to provide proof of a properly calibrated altimeter to the Contest Director upon request. The graph or other flight profile display provided by a recording device will be examined for accuracy. If it is shown that a sudden peak in altitude is attributable to the ejection charge, that peak will be not be used to determine the recorded altitude. The altitude just prior to or just after that sudden peak will be the official recorded altitude. Altimeters with altitude sensors other than barometric sensors, such as accelerometers or magnetic apogee detection, may be used to deploy the recovery systems. However, they are prohibited from use in determining the actual altitude.

2.2 Project Purpose

Our main purpose in participating in the Florida Space Grant Consortium Hybrid Rocket Competition is to gain experience in the construction and launch of hybrid rocketry via a design-based project atmosphere. In order to build larger, more complex rockets in the future, it is important to learn the concepts involved in hybrid rocketry, from the propulsion process, to the motor assembly, to various safety precautions to take. This project is in an effort to educate the involved individuals, acting as a training device in the aforementioned areas.

For the propulsion process, it is necessary to acquire knowledge regarding the difference in function of the different shapes of fuel grains and which one of them could work successfully, depending on the style and shape of the rocket itself. Also, besides its shape, understanding the composition of the grain is also important. Motor assembly will help us acquire a vast amount of knowledge in the mechanical and theoretical operation of hybrid motors and will help us know all the aspects of the functioning motor. Very importantly, assembly safety will play a major role in our future development as engineers. This knowledge will train us and will help us be prepared for future hybrid projects, as well as many other projects involving rocketry; no matter if it is solid or liquid, since hybrid rocketry has elements of both liquid and solid rocketry.

3.0 Background Information

3.1 Hybrid Research

A. Hybrid Rocket Process

Hybrid rockets function by burning a solid fuel grain by the catalysis of a liquid or gaseous oxidizer. For the rocket to have thrust, the oxidizer passes through a port in the solid fuel grain and reacts with the solid fuel, which causes the hot exhaust gases. When the oxidizer reacts with a layer of the fuel, this fuel will vaporize and later react with any unused oxidizer, producing more combustion gases [University of Illinois Project Prometheus]. The most commonly used hybrid oxidizer is nitrous oxide [Ukrocketman]. Other oxidizers used for hybrid rocketry include liquid and gaseous oxygen (LOx and GOx, respectively), hydrogen peroxide (H_2O_2), nitric acid (NO_3), and nitrogen tetroxide (N_2O_4). Commonly used fuel grains include but are not limited to polyethylene (PE), poly-methyl methacrylate (PMMA or Plexiglas), poly-vinyl chloride (PVC), and hydroxyl-terminated poly-butadiene (HTPB).

B. Advantages and Disadvantages of Hybrids

Hybrid rockets are complex in comparison to solid rockets, having both liquid and solid components. However, the better performance of a hybrid rocket makes up for its complexity. Hybrid performance competes with that of liquid systems. Hybrids compare similarly to liquid rockets and require only half of the plumbing that liquid rockets need. This makes a hybrid rocket more reliable because there are fewer parts that could fail. Also, they are lighter due to the fewer number of heavy parts than solid rockets. To add on, hybrid rockets are more cost-effective compared to liquid and solid systems, not to mention safer to build and contain and are more ecologically friendly, given that you choose the correct type of propellant. Lastly, the fuel grain of a hybrid rocket, which is inert, is stronger than a manufactured solid rocket propellant, adding to its reliability [MIT Rocket Principles].

C. History of Hybrid Rocketry

With a new idea as hybrid rocketry came important dates and events. The very first hybrid rocket in the world was created in Russia on August 17, 1933, by S.P. Korolev and M.K. Tikhonravov, members of GIRD [Scientific Research Group for Repulsion Engines], with a maximum altitude of about 1500 meters and a thrust of 500 N [Space Services Australia]. A Gaseoline-collophonium mixture and liquid oxygen were used as the fuel grain and the oxidizer, respectively. The idea of hybrid rocketry was brought into America in 1938, when the Californian Rocket Society made burn tests of coal with gaseous oxygen. G.E. Moore at General Electric made some burn tests from 1951 to 1956 by using polyethylene and 90% hydrogen peroxide (H_2O_2). In 1956, the beginning of an intense amount of research started for the future O.N.E.R.A. hybrid rocket in France. On April 25, 1964, the O.N.E.R.A. was successfully launched, with a thrust of 10 000 Newtons. The propellants used in this project were Nylon-metatoluene-amine and a nitric acid-nitrous tetroxide mixture. The most recent hybrid rocket-related milestone is that of the successful launch of SpaceDev's SpaceShipOne, which was the first manned private mission to space. The propellants used for the SpaceShipOne were nitrous oxide (N_2O) as the oxidizer and hydroxyl-terminated polubutadiene (HTPB) as the fuel grain.

D. Works Cited

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3.2 Hazard Analysis

A. Hazard Analysis: The Handling and Use of Nitrous Oxide and Pyrotechnic Materials

Step	Hazards	Causes	Preventative Measures
1. Prepare fuel with electric match and igniter grain	a) Premature ignition b) Electric match does not ignite igniter grain	a) Ignition switch attached to soon, and no safety on b) Electric match not in igniter grain	a) Attach ignition switch to igniter just before launch, use safety switch b) Use tight holes in igniter grain to hold match
2. Set up ground support	a) N_2O over pressurized b) N_2O leak	a) High ambient temperatures b) Compression valve failure, high pressure valve failure, electronics failure	a) Insulate N_2O tank, keep in shade b) Use new compression valves each launch, use pressure gauge on valve, use voltmeter to check electronics
3. Enable rocket for launch	a) Premature ignition	a) Electronic failure/short, safety switch not engaged	a) Test electronics, use safety switch
4. Begin filling oxidizer tank	a) Valve failure	a) N_2O over pressurized, electronic failure	a) Insulate N_2O tank, keep in shade, use new compression valves each launch, use pressure gauge on valve, use voltmeter to check electronics
5. Pre/Post launch storage of Nitrous	a) N_2O leak b) N_2O over pressurized	a) Valve failure b) High ambient temperatures	a) Check electronics b) Insulate N_2O tank, keep in shade

3.3 Failure Modes & Effects Analysis

A. Pre-Flight Failure Modes and Effects Analysis

Pre Flight	Failure Mode	Cause	Effect	Severity	Probability	Hazard*
Prepare Motor	Injector, fuel grain, or nozzle not installed right	Rushed assembly or damaged components	Motor failure	Moderate	Occasional	6
	Motor not installed in the correct manner	Rushed assembly	Dislodged / brake motor mounts	Major	Uncommon	6
Prepare Recovery System	Ejection charge not installed correctly	Rushed assembly	Parachute malfunction	Major	Uncommon	6
	Heat shield not properly installed	Rushed assembly	Burned parachute	Major	Uncommon	6
Prepare Flight Computer	Dead or used battery	Left on too long	Recovery malfunction	Major	Uncommon	6
	Bad programming	Software Error	Data loss	Moderate	Remote	2
	Bad or overused wiring	Bad inspection	Short	Major	Uncommon	6
Set up of Ground Support	Valve Failure	Over pressurization	Free flow	Major	Occasional	9
	Dead Firing Battery	Bad charging	Will not fire	Minor	Remote	1
	Bad wiring	Mishandling	Premature firing	Major	Uncommon	6
Load Oxidizer	Over pressurization of N_2O	Valve closing error	Motor failure	Major	Uncommon	6
	Compression Fitting Failure / Burst Disk	Rushed install	Motor failure	Major	Uncommon	6

*Hazard Rating is based on the Severity Rating (scale of 1-4) multiplied by the Probability rating (scale of 1-4).

B. Mid-Flight Failure Modes and Effects Analysis

Flight	Failure Mode	Cause	Effect	Severity	Probability	Hazard*
Launch Procedure	Launches at extreme angle	Launch lug detachment	Off course and ballistic	Catastrophic	Remote	4
	Igniter failure	Damaged components	Motor does not fire	Minor	Occasional	3
Powered Flight	Total motor failure	Over pressurization	Vehicle failure	Catastrophic	Uncommon	8
	Vehicle break up	Structural failure	Total Failure	Catastrophic	Uncommon	8
Glide Stage	Destabilization of rocket	Fin failure	Veers off course	Major	Uncommon	6
	Wind Shears	Bad Weather	Veers off course	Major	Remote	3
Recovery System Deployment	Recovery charge failure	Damaged charge	Ballistic Descent	Catastrophic	Occasional	12
	Burned or tangled chute	Bad installation	Hard landing	Major	Uncommon	6
Rocket Decent from Apogee	Recovery system failure	Burned shroud lines	Hard landing	Major	Uncommon	6
	Crosswinds push rocket off course	Windy conditions	Veers off course	Moderate	Remote	2

*Hazard Rating is based on the Severity Rating (scale of 1-4) multiplied by the Probability rating (scale of 1-4).

C. Post-Flight Failure Modes and Effects Analysis

Post Flight	Failure Mode	Cause	Effect	Severity	Probability	Hazard*
Landing	Rough landing	Recovery error	Possible equipment damage	Major	Uncommon	6
Rocket retrieval	Inability to find rocket	Bad landing	Data and rocket loss	Moderate	Uncommon	4
Flight data acquisition	Inability to find rocket before power loss	Damaged flight computer	Data loss	Moderate	Uncommon	4
Power down of electronics	Premature power down	Damaged equipment	Data loss	Moderate	Uncommon	4
Resetting of electronics	Damaged components	Human error	Future failures	Major	Occasional	9

*Hazard Rating is based on the Severity Rating (scale of 1-4) multiplied by the Probability rating (scale of 1-4).

4.0 Design Specifications

For our design, we have chosen to build a single-stage rocket powered by a RATTworks H70 hybrid rocket motor. The lower segment consists of the hybrid motor, wood/foam restraints to keep it in place, and a bulkhead to keep the motor from ejecting forward. The upper segment consists of the nose cone, an upper bulkhead, and the payload capsule bay. The capsule bay is a removable section containing the flight computer, batteries, and ejection charges. The entire bay is able to screw into the upper segment into the upper bulkhead. The parachute connects at one end to the lower bulkhead, and at the other to the lowest part of the payload bay, thus connecting the upper and lower segments of the rocket.

In order to have the maximum impulse allowable in the competition, we went with the H70 hybrid motor. The RATTworks motor was chosen primarily due to its overall simplicity of its design, its level of reusability, and physical dimensions. The selection of the remaining components was based on the motor's size and thrust. In order for the rocket to launch to as close to 2000 feet as possible, the rocket had to have enough drag ability and be weighted down to compensate for the maximum altitude potential of the motor. The selection of body tubes, the nose cone, and fins were in an effort to have a precise launch height capability.

Using the RockSIM software program, we were able to configure our exact design and run launch simulations. Based upon the RockSIM design, we were able to calculate the maximum weight allowable for the rocket – under perfect conditions. Factoring in wind, less than full thrust from the engine (from not being fully fueled), and other launch conditions, the optimum launch simulation would be for the rocket to launch to about 2,050-2,100 feet on the simulation software. The final design simulations show that with a weight of about 700 grams (including payload bay, bulkheads, and motor supports), we should be able to reach the target apogee, given near-perfect launch conditions.

For our flight computer, we are using the Ozark ARTS2, as it has accelerometer and barometric sensors, dual-pyro channels, and sophisticated programming and recording ability – all of which is needed to have accurate launch data. Using data from test launches, we will be able to modify our design to a further extent, in order to optimize the total mass of the rocket for it to reach the 2000 feet.

4.1 Engine Details

A. Motor Specifications

For our rocket's design, we chose to use a RATTworks H70 29mm hybrid motor. This motor was optimal for our design based upon its thrust capability, physical size, and overall simplicity in its usage.

The following are motor design specifications from RATTworks:

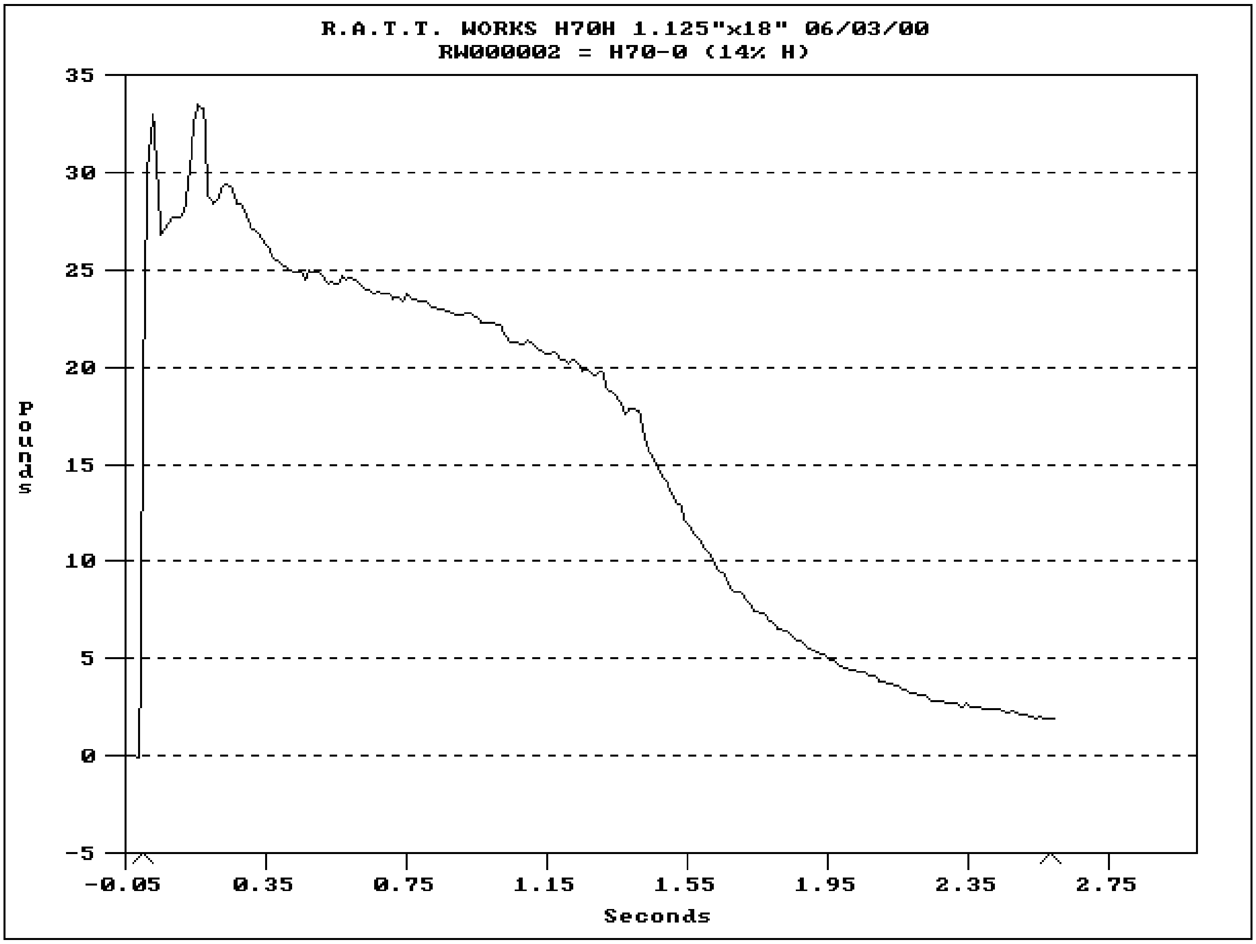
- Diameter: 29mm
- Length: 18" (457mm)
- Average Thrust: 15.4 lbs. (68.5 N)
- Peak Thrust: 34.5 lbs. (153.5 N)
- ISP: 167.3 sec.
- Burn Time: 2.57 sec.
- Weight (Empty): 207.5 g
- Weight (Loaded w/o N2O): 251.5 g
- Weight (Loaded w/ N2O): 352.7 g
- N2O Weight (750 PSI): 0.223 lbs. (101.2 g)
- Tank Volume: 8.29ci (135.8cc)

B. Motor Components

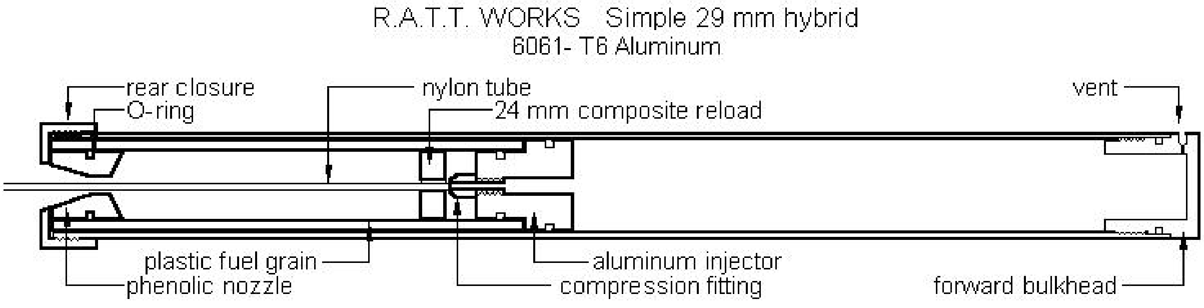
The following are the primary components of our hybrid motor:

- Motor casing and oxidizer tank (Monotube)
- Polypropylene fuel grain
- Floating injector
- Graphite nozzle
- Forward bulkhead
- Rear nozzle enclosure
- Fill hose (type H 1/8" nylon)
- 1/16" compression fitting
- O-rings

C. Engine Thrust Curve



D. Engine Component Diagram



(www.rattworks.net)

4.2 Rocket Design

A. Rocket Parts List

Nose cone Apogee - 19470 - PNC-56 (BT-70 size), Material: Polystyrene PS

- Nose shape: Hollow Ogive, Len: 11.0850 In., Dia: 2.2170 In. Wall thickness: 0.0550 In. Body insert: OD: 2.1600 In., Len: 2.7500 In.
- CG: 8.6841 In. , Mass: 2.3822 Oz. Radius of gyration: 0.0865995 (m) , 8.65995 (cm) Moment of inertia: 0.000506471 (kgm^2) , 5064.71 (gcm^2)

Body tube Apogee - 10160 - 56 mm (BT-70 size), Material: Paper

- OD: 2.2170 In. , ID: 2.1800 In. , Len: 16.8504 In.
- CG: 8.4252 In. , Mass: 1.3955 Oz. Radius of gyration: 0.125261 (m) , 12.5261 (cm) Moment of inertia: 0.000620742 (kgm^2) , 6207.42 (gcm^2)

Tube coupler Apogee - 13042 - AC-56A (Fits BT-70 size tubes), Material: Paper

- OD: 2.1700 In., ID: 2.1100 In., Len: 4.0000 In. Location: 15.0000 In. From the front of Body tube
- CG: 0.0000 In. , Mass: 0.4162 Oz. Radius of gyration: 0.0351052 (m) , 3.51052 (cm) Moment of inertia: 1.45409e-05 (kgm^2) , 145.409 (gcm^2)

Parachute Aerocon - 36 in. nylon, Material: Rip stop nylon

- 1 parachute, Shape: 8 sided Dia: 36.0000 In., Spill hole: 7.0000 In.
- CG: 0.0000 In. , Mass: 3.1000 Oz. Radius of gyration: 0.0454176 (m) , 4.54176 (cm) Moment of inertia: 0.000181282 (kgm^2) , 1812.82 (gcm^2)

Mass Payload Bay (estimate)

- CG: 0.0000 In. , Mass: 24.6918 Oz. Radius of gyration: 0 (m) , 0 (cm) Moment of inertia: 0 (kgm^2) , 0 (gcm^2)

Body tube Apogee - 10160 - 56 mm (BT-70 size), Material: Paper

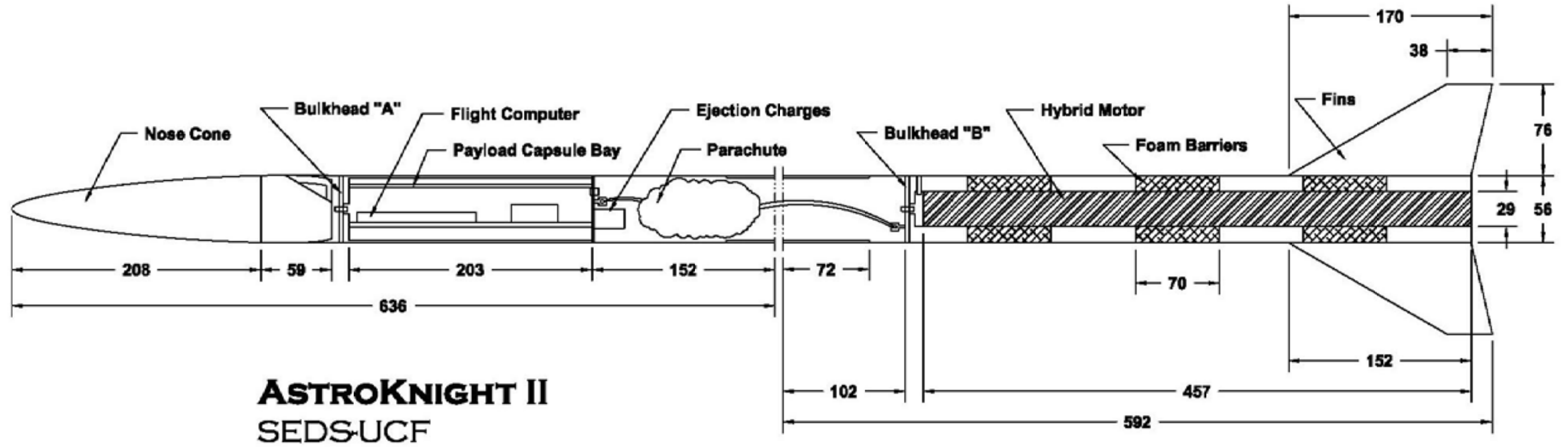
- OD: 2.2170 In. , ID: 2.1800 In. , Len: 22.0000 In.
- CG: 11.0000 In. , Mass: 1.8220 Oz. Radius of gyration: 0.162698 (m) , 16.2698 (cm) Moment of inertia: 0.00136728 (kgm^2) , 13672.8 (gcm^2)

Fin set Apogee - - Rising Star, Material: Balsa

- Planform: trapezoidal, Root chord: 6.0000 In., Tip chord: 1.5000 In., Semi-span: 3.0000 In., Sweep: 5.2000 In., Mid-Chord: 4.2074 In. Misc: Location: 0.0000 In. From the base of Body tube Thickness: 0.1250 In. Profile: rounded
- CG: 4.1800 In. , Mass: 0.3125 Oz. Radius of gyration: 0.0431944 (m) , 4.31944 (cm) Moment of inertia: 1.65292e-05 (kgm^2) , 165.292 (gcm^2)

4.3 Schematics

2007-08 FLORIDA SPACE GRANT HYBRID ROCKET COMPETITION



ASTROKNIGHT II
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Part Specifications:

Hybrid Motor
- RATTworks H70 Hybrid Motor
- Average Thrust: 15.4 lbs. (68.5 N)
- Peak Thrust: 34.5 lbs. (153.5 N)
- I(sp): 167.3 sec.
- Burn Time: 2.57 sec.
- Weight (Empty): 207.5 g
- Weight (Loaded w/o N2O): 251.5 g
- Weight (Loaded w/ N2O): 352.7 g
- N2O Weight (750 PSI): 0.223 lbs. (101.2 g)
- Tank Volume: 8.29ci (135.8cc)

Flight Computer
- Ozark ARTS2 Flight Computer
- Accelerometer & Barometric Sensors
- Two fully configurable pyro channels
- Used for chute deployment
- 82 sec rec. time at 200 Samples/Sec
- Realtime Altitude, Velocity, GPS pos

Body Tube
- Apogee BT-70 Body Tubes
- Apogee AC-56A Airframe Couplers

Nose Cone
- Apogee PNC-56A Blow Molded Nose Cone
- Material: Styrene
- Fits BT-70 Size Body Tube
- Weight: approximately 54.5 grams

Fins
- Apogee Rising Star Balsa Fins

Parachute
- Aerocon 36" Chute

All dimensions in millimeters

Michael P. Green
ver. 2.1

ASTROKNIGHT II

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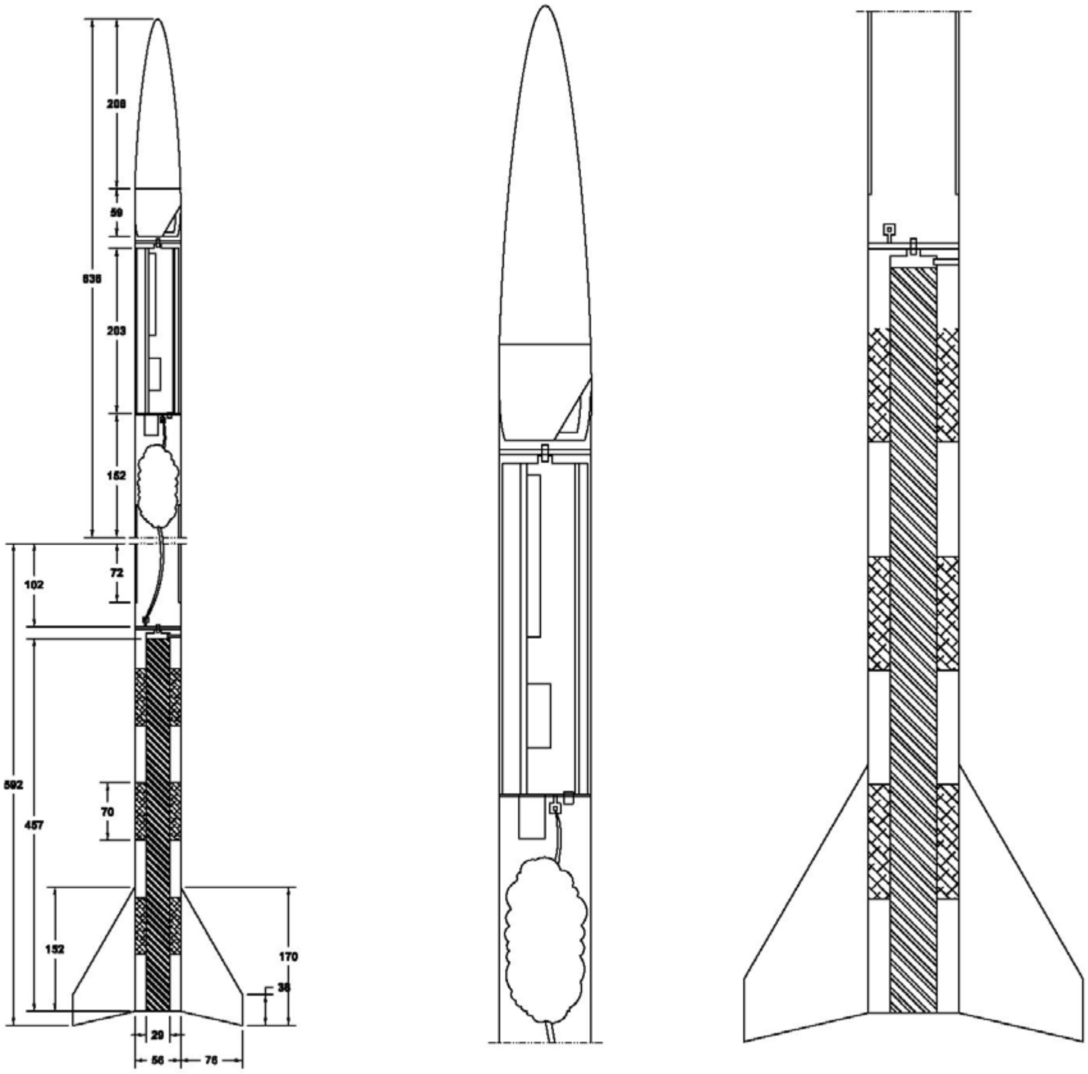
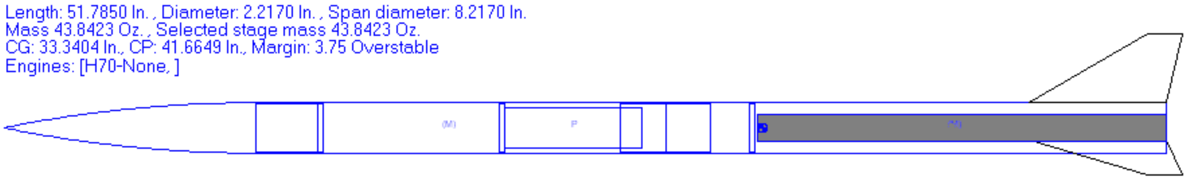
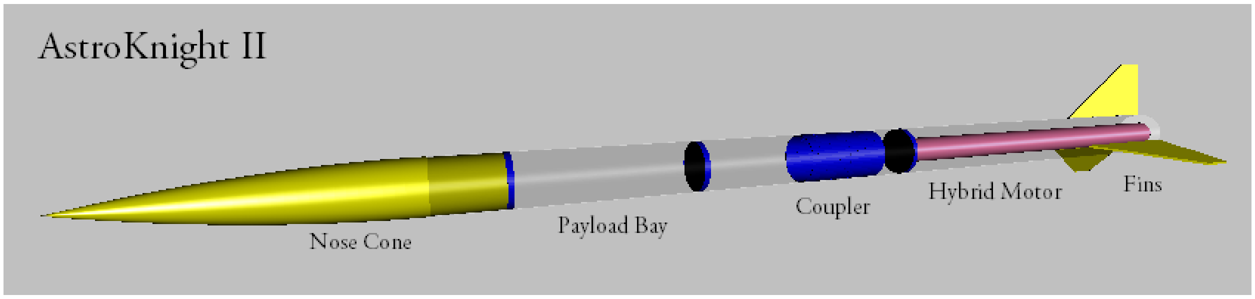


5.0 Launch Predictions and Data

The following graphic shows a 2D representation of our rocket, generated using the RockSim computer software. The total length of the rocket is 51.79 inches with a 2.217-inch diameter and span of 8.217 inches. The total mass of the rocket will be 43.84 ounces. Based upon the CG and CP estimations, the rocket will be slightly over-stable, compensating for the maximum height potential by the hybrid motor in our rocket's design. Based upon the simulations, the rocket will be able to fly to just over 2000 feet, depending on the pressurization level of the motor and wind conditions at launch.



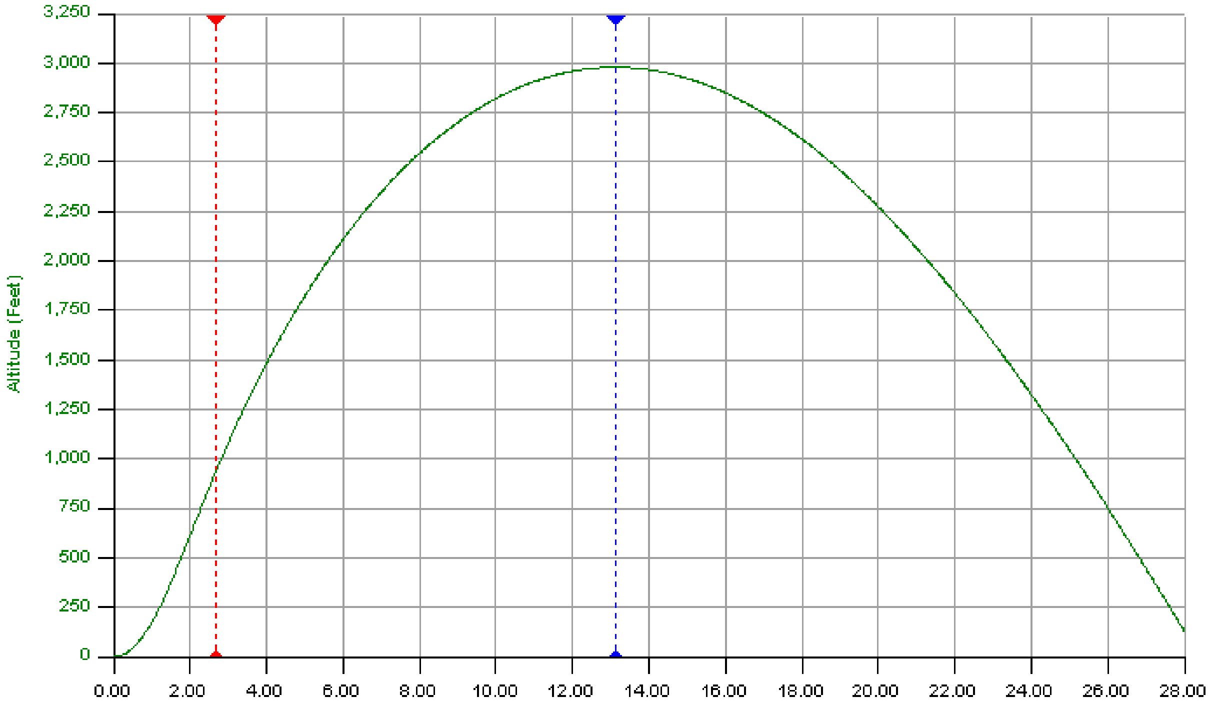
The following shows a 3D representation of our rocket, generated by RockSim.



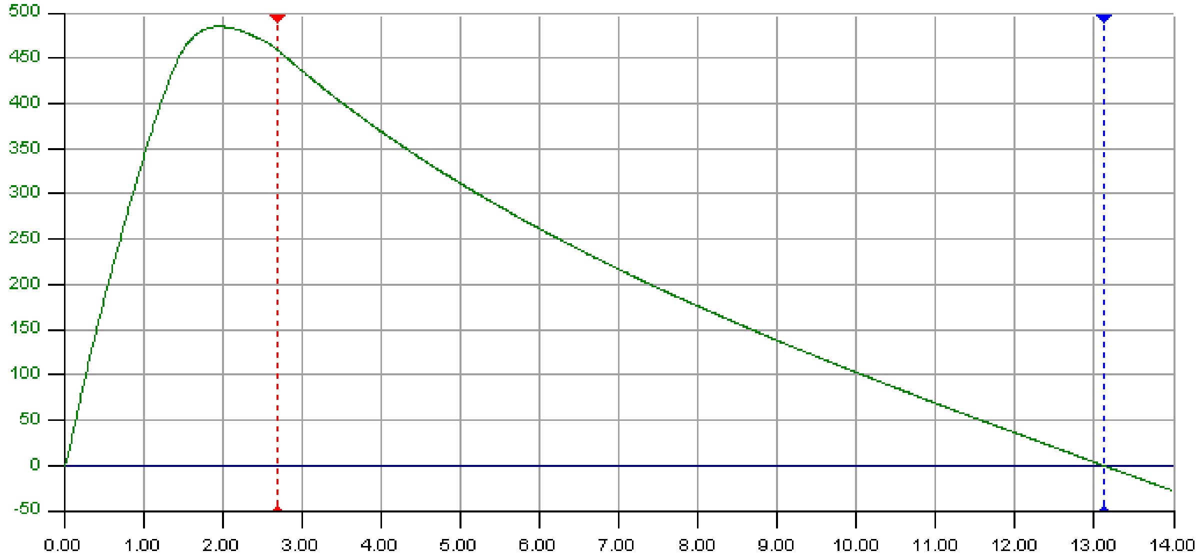
The maximum altitude of the launch will depend directly on the total mass of the rocket and the conditions during launch. The next pages show graphs of the altitude, velocity, acceleration, and drag force for the launch of our rocket in two separate conditions – first with a total payload mass of 350 grams, and second with a mass of 700 grams. In order to get closer to the 2000 feet limit, the mass will have to weight close to 700-750 grams, assuming perfect launch conditions. The next page shows a comparison of a launch in calm wind versus a slight breeze. Based upon the data, for our rocket to reach 2000 feet, the weight will have to be limited to 750 grams, and the wind at launch cannot exceed 10-13 mph. Based upon the simulations, even with the wind, the rocket will launch to 2019.7 feet, assuming the motor is fully fueled. In both cases, the rocket will hit the ground with a velocity of -22.4198 feet per second. For optimum performance, the ejection delay should be between 8.8 and 8.9 seconds after launch.

5.1 Launch Simulations

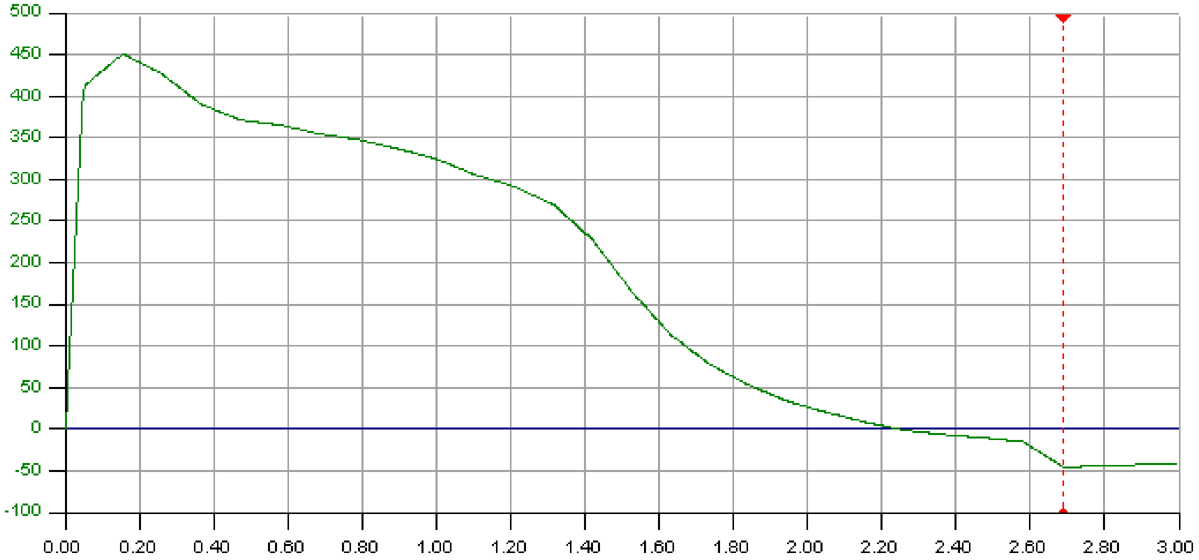
A. RockSim Data (350 gram Payload Bay)



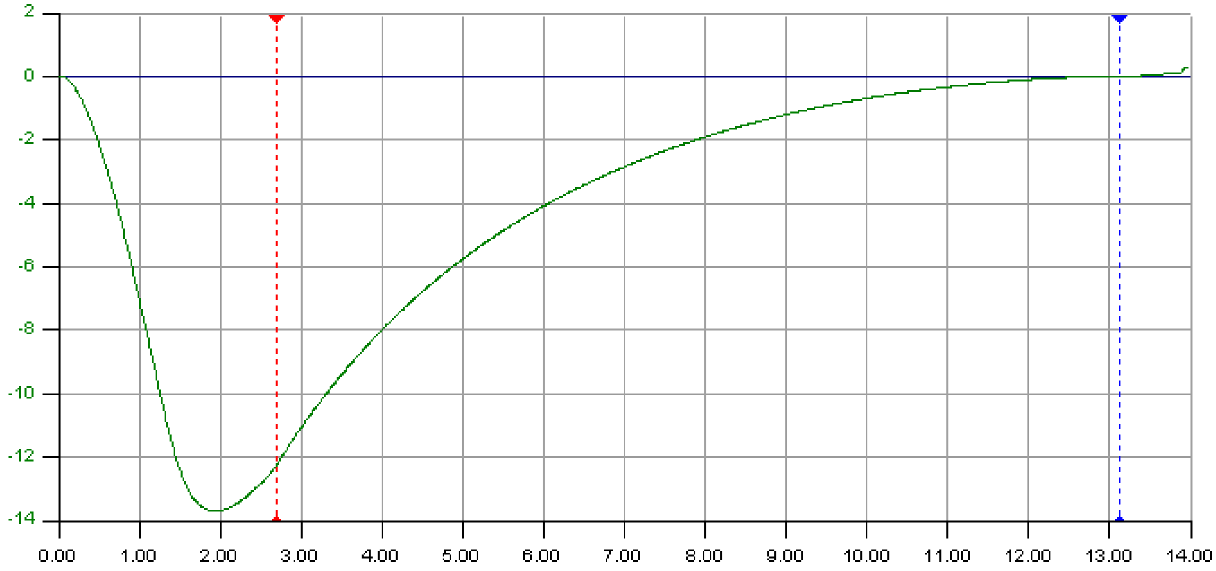
Altitude v. Time (350g Payload)



Velocity v. Time (350g Payload)

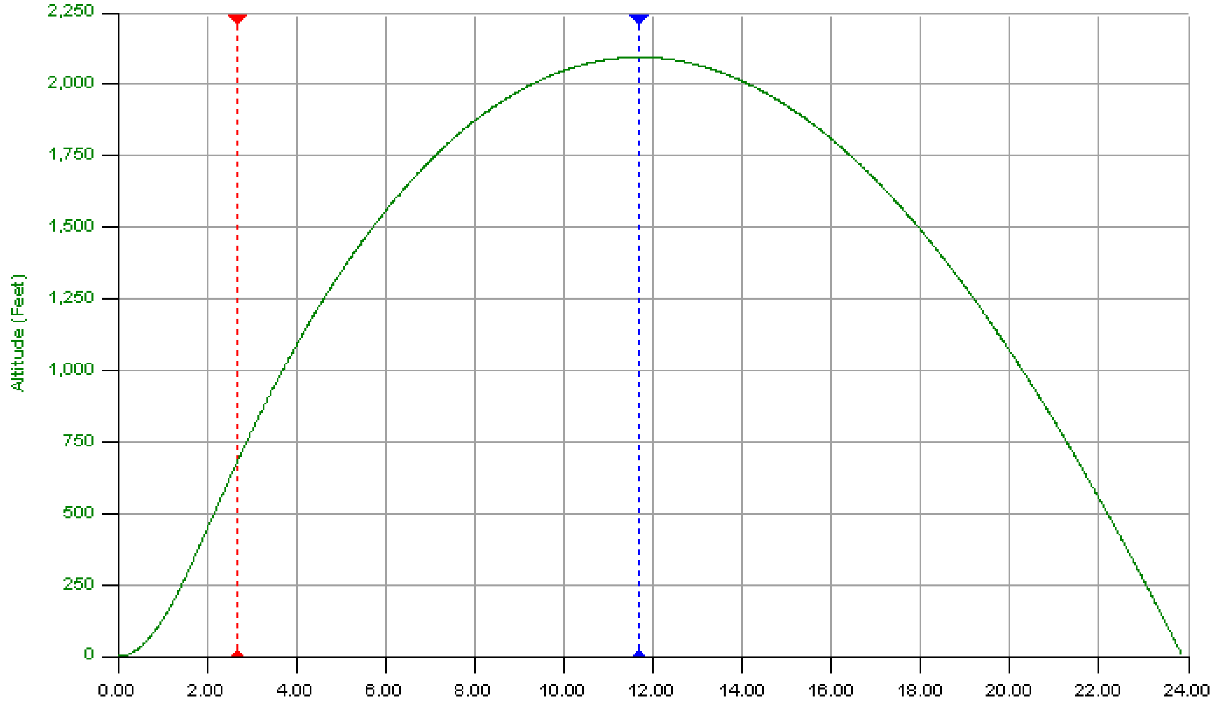


Acceleration v. Time (350g Payload)

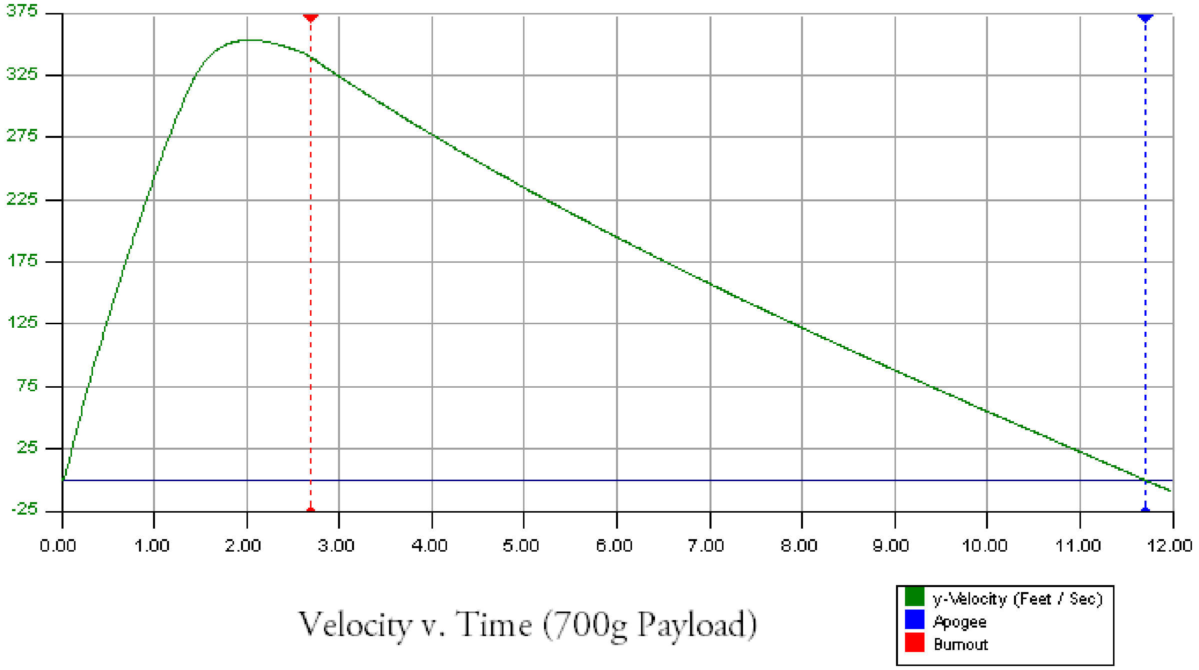


Drag Force v. Time (350g Payload)

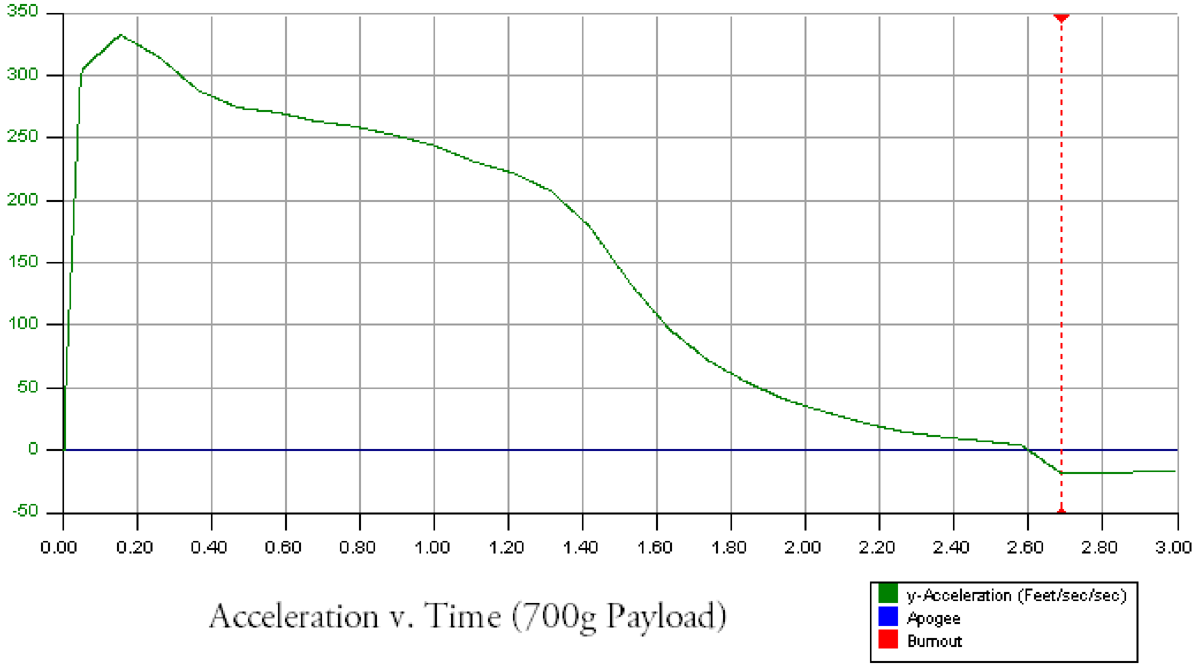
B. RockSim Data (700 gram Payload Bay)



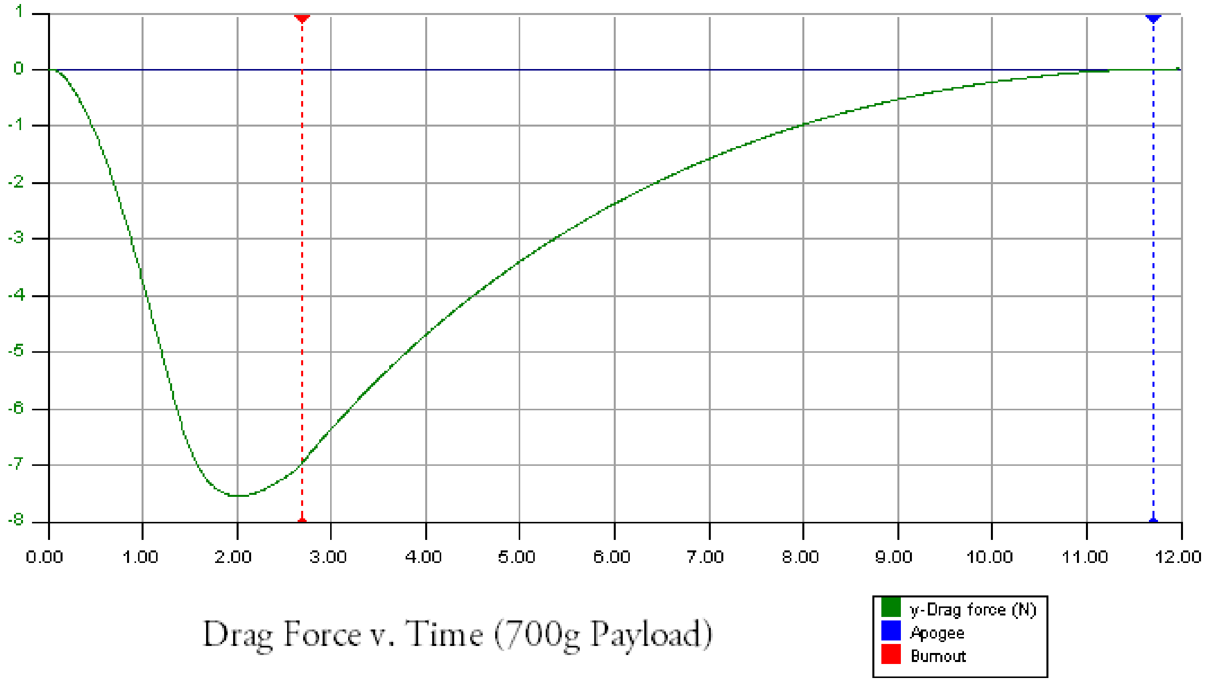
Alititude v. Time (700g Payload)



Velocity v. Time (700g Payload)



Acceleration v. Time (700g Payload)



Drag Force v. Time (700g Payload)

C. Final Simulation Data

Launch conditions:

Relative humidity: 50.000 %
Temperature: 59.000 Deg. F
Pressure: 29.9139 In.
Wind turbulence: Fairly constant speed (frequency: 0.010000 rad/second)
Launch guide angle: 0.000 Degrees from vertical

Launch guide data:

Launch guide length: 36.0000 In.
Velocity at launch guide departure: 41.6261 ft/s
The launch guide was cleared at: 0.174 Seconds
Minimum velocity for stable flight reached at: 40.9064 In.

Max data values	Calm winds (0-2 MPH)	Slightly breezy (8-14 MPH)
Maximum Acceleration (y)	299.382 Ft./s/s	299.382 Ft./s/s
Maximum Velocity (y)	351.7244 ft/s	345.6547 ft/s
Maximum range from launch site	105.19712 Ft	1025.21354 Ft.
Maximum altitude	2080.21958 Ft.	2019.71407 Ft.

Recovery system data	Calm winds (0-2 MPH)	Slightly breezy (8-14 MPH)
Parachute Deployed at:	11.660 Seconds	11.489 Seconds
Velocity at deployment:	7.9485 ft/s	49.7106 ft/s
Altitude at deployment:	2079.29574 Ft.	2019.71402 Ft.
Range at deployment:	-90.39665 Ft.	-512.08531 Ft.
Range at landing:	68.27698 Ft.	1025.21354 Ft.
Velocity at landing:	-22.4198 ft/s	-22.4198 ft/s

Time data	Calm winds (0-2 MPH)	Slightly breezy (8-14 MPH)
Time to burnout:	2.689 Sec.	2.689 Sec.
Time to apogee:	11.660 Sec.	11.489 Sec.
Optimal ejection delay:	8.971 Sec.	8.800 Sec.
Time to landing:	103.512 Sec.	97.056 Sec.