

BYU ASME Rocket Team

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Introduction

The BYU Rocket Team is a pioneer project. The team consists of students of all classes and various majors, mostly in engineering. The rocket team is organized into subgroups that have a crucial system design of the “Cosmos” rocket. Simple and safe sport rocketry techniques, such as basic materials use, do’s, don’ts, how-to’s, identifying center of gravity and center of pressure, and construction techniques were taught. Many problems during the construction phase were discovered and solved. In March 2009, a team member certified NAR Level 2 and in May the “Cosmos” rocket was launched.

What follows below documents the details of what materials and how “Cosmos” was constructed, with explanations of these materials were chosen and how they interface.

Design

Aerodynamics and Structure

Airframe

The airframe is made out of fiberglass, making the body lightweight and strong. The diameter was selected to be 6” in order to accommodate space for future braking system electronics in the motor mount. The fin can comes in two 4’ sections, a lower drogue parachute payload and upper main parachute payload, joined with a 1’ coupler tube. Three slots are cut 120° apart in the lower 4’ tube for fins.

Motor Mount

The motor fits inside a 3” diameter phenolic tube. The phenolic motor tube is held centered in the aft section of the rocket by three equally-spaced 3/8” plywood centering rings. The rings are epoxied to the phenolic tube and the lower 4’ fiberglass airframe. The rings are filleted with epoxy along every joint and foam epoxy fills in the gaps between the tubes and through-the-wall fins. The motor thrust effectively transfers from the aft end of the phenolic tube to the centering rings and the airframe.



Fins

Fin shape and size was determined to optimize aerodynamics, stability and altitude. The fins are cut in trapezoidal shape with a laser and all edges rounded. The fins are made of 1/8” G-10 fiberglass. The design utilized a through-the-wall construction, where the fin root was extended straight through the airframe until touching the motor tube. Epoxy fillets were added at all joints. On the outer airframe surface, the fillets are aerodynamically shaped with the end of a large popsicle stick.

Nosecone

The nosecone was made out of molded fiberglass webbing and a coated plastic for an Ogive shape. The inside contains a similar motor mount construction for a payload. A 3" ID PVC pipe was epoxied to the nosecone tip, followed by two equally spaced 3/8" plywood centering rings. The rings have three all-thread bolt and nuts epoxied to transfer the payload weight to the nosecone, relieving load stress from the aft centering ring.

Electronics

Altimeter

From the data gathered in Table 1 Error: Reference source not found we chose the PerfectFlite MAWD to track altitude and deploy the drogue and main parachute. This altimeter is perfect for the altitude contest requirements (note MSL, not AGL maximum height), it supplies ample current to the igniter, and it is capable of transmitting an RF signal (ideal for future projects). Much of the info desired on other altimeters shown was not available, so we sided with recommendations of PerfectFlite by local rocket club hobbyists.

Table 1—Altimeter Search Index

Altimeters	Price	Warranty	Max Ht	Data	Volt/Life	Mach & Delay	Deployment
Adept ALTs2-50K	\$121-134	N/A	15K,50K AGL	Beeps	12V/6hr	Capable	N/A
Gwiz HCX	\$235-335	N/A	70K+	LED	N/A	N/A	4stg, 8amps
Gwiz LCX	\$135	N/A	70K+	Beeps	N/A	N/A	3stg, 5amps
MW RRC2X	\$85	1 yr lmted	N/A	26mins	N/A	4, 8, 12s	2stg
Ozark ARTS2	\$190	N/A	N/A	Beeps, 26mins	12V/6hr	N/A	2stg
Perfectflite HA45	\$80	3 yr	45K MSL	Beeps, 5mins	9V/ N/A	0-24s	N/A
PerfectFlite MAWD	\$100	3 yr	25K MSL	Beeps, 5mins, RF	9V/24hr	0-14s	2stg, 5amps
Transolve P5	\$150	1 yr	20K	Beeps	N/A	None	N/A

Altimeter Housing

The altimeter is housed on a 3/8"plywood board inside the 12" fiberglass coupler. The ends of the coupler are two 3/8" plywood bulkheads with a pair of ejection charge cups and a U-bolt attached for the recovery system. Wires from the altimeter feed through the bulkheads into a junction box, which then feeds to the electric matches. The altimeter is powered by a pair of fresh 9V batteries, secured by plastic ties to the base. The batteries are wired in parallel. In case one battery fails during flight the other is acts as a backup.

The coupler and 4' upper body tube were secured together by ten screws. Three pressure escape holes for the altimeter and a power switch hole were drilled in the 6" overlap. Pressure holes were computed by the equation:

$$H = \frac{D * L * 0.006}{N}$$

D is the diameter of the altimeter chamber (in inches). L is the length of the chamber (in inches). 0.006 is a cabin pressure constant. N is the number of holes to be drilled. With a 6"

diameter body tube, 12” space for the altimeter chamber, and 3 holes 120° apart, a bit size close to 0.144” (5/32”) was used.

Recovery System

Parachutes

The rocket employs a dual deployment parachute recovery system. At apogee, the altimeter ignites black powder in one of the lower ejection canisters, pressurizing the drogue payload chamber, and separating the two halves. A 60” drogue parachute deploys, breaking the rocket’s aerodynamics for a quick descent. At 1500’, the altimeter triggers the upper chamber, deploying a 12’ main chute for a <15ft/sec final decent rate to the ground.

By recommendation, the parachute sizes were calculated by using the Utah Rocket Club’s online Parachute Size Calculator¹. We decided on a hemispherical design to minimize the size (and therefore cost) of the parachutes.

Shock Cords

Two 6’ x 3/4” Tubular Kevlar and two 20’ x 1” Tubular Nylon cord ends are sewn into loops. The Kevlar shock cords are attached by Quick Links to U-bolts at the base of both end altimeter bulkheads, where the ejection charges go off. The Nylon cords are attached with Quick Links to the Kevlar. The parachutes attach here as well. The free ends are attached to Quick Links, which attach to U-bolts on the rocket’s forward motor centering ring and the nose cone’s aft payload centering ring. The Kevlar serves as fire proof cord for the gunpowder blasts, while the Nylon serves as a cheaper, but flexible cord, to reduce the force applied by the two separated halves tugging on each other during the first moments of deployment.

18” square Nomex Parachute Protectors are slid over the Kevlar sections of shock cord. This serves as protection for the parachute and Nylon cords, from the ejection charge burst, which would destroy them, resulting in a catastrophic failure.

Black Powder Ejection Charges

To determine the amount of FFFFG black powder needed to deploy the recovery system, we used the following equation²:

$$B_p = D^2L * 0.004$$

D is the diameter of the chamber to pressurize (in inches). L is the length of the chamber (in inches). 0.004 is a cabin pressure constant representing 10psi. With a 6” diameter body tube and 36” space for the main parachute chamber, 5.2grams of powder was used. For the drogue chamber, with 12” of space, 1.7grams was used.

The ejection charges were placed in silly pipe end-fittings with Davey Fire electric match heads resting at the bottom. Wires were taped and run into a junction box with leads to the altimeter.

Propulsion

Commercial Motor

As a result of past experience, we chose to purchase a commercial motor. This evaded the Mechanical Engineering department's worries from previous year's launch, where they built their own motor, and demonstrated to them our awareness of NAR and TRIPOLI motor safety requirements. We are not experienced to make one ourselves, nor does BYU have a Low Explosives Users Permit for storage of it. Using a commercial motor meant a larger expense for the team, but ease of installation and safety (a huge priority).

We used RockSim³ to find the desired motor, fitting in a 75mm motor mount to achieve the contest criteria of 10,000' AGL while carrying a and 10lb payload. For our maiden voyage, we decided to choose a Cessaroni L1115 (full 'L'), which was the largest motor we could launch operating under a NAR Level 2 certification and keep us under the Utah Rocket Club's 10,000' AGL FAA limit. For the contest, we chose an M1850, which the simulator predicted would place us closest to the 10,000' contest goal while carrying a 10lb payload.



Necessary for the maiden voyage, but not necessary for the contest, our project lead certified NAR Level 2. Under our own university acquired insurance waiver for the event, we could work with vendors to order higher impulse motors above level 2 (L) for the event, given strict adherence to contest safety rules.

Payload

Initial design for the payload consisted of a GPS system, barometer, and atmospheric reading equipment. This design had to be abandoned due to the high cost of equipment. The next design worked on was for a glider/parasail that would deploy from the nosecone at 1,500' along with the main parachute. The RC type glider/parasail would have with a mounted camera. Due to time restrictions, this design was also abandoned but is being researched further for future competitions.

The current payload consists of a TRT Technology prototype wireless sensor. One is secured to the payload mount while another is loose, testing effects of impact forces to the sensor. A base station will be monitoring the prototypes. Additional weight was added to meet the contest's specifications—given the payload is light-weight.

Results

Simulation

The “Cosmos” rocket was simulated to insure its flying capability. RockSim by Apogee Components was used. The payload was located in the nosecone because the center of gravity would be forward of the center of pressure, insuring stability. Initially, an L1115 motor was selected for the launch, which RockSim predicted would send Cosmos to 10,180’. After construction, the rocket was weighed and actual weight measurements were entered into the simulation. In an understatement, team members were surprised the finished rocket weighed 10 lbs more than what the simulator predicted. This was due to unknown mass of bulkheads, hardware, and epoxy. The L1115 motor was still used for the maiden voyage, as scheduled. A higher impulse motor for the contest was found.

With respect to the M1850 motor used in the contest flight, the center of gravity is located 59” and center of pressure 79” from the tip of the rocket. This yields a margin of 3.25 calipers, for stability. The simulation results (Appendix) show that Cosmos is predicted to reach an altitude of 9,890’, only slightly below the contest goal of 10,000’ AGL.

Weights

After construction, the weight of the rocket was 42lbs (see Table 2). The components were measured separately, without the motor. The motor’s weight was unable to be measured except by the simulator due to government regulations, restricting motor handling until the team was at the launch site.

Table 2—Component Weights

Component	Approximate Weight (lbs)
Motor Mount	10
Altimeter Section	5
Nosecone	8
Shock cords & Parachute Protectors	2
Main Parachute Payload section	5
Drogue & Main Parachutes	2
Payload	10
Total Weight	42

Maiden Voyage (May 16th, 2009)

The maiden voyage was at a NAR regional launch outside of Faust, Utah. We used a Cessaroni L1115 motor. The payload was not included since the payload compartment was not yet completed. RockSim predicted 7,137’ AGL for this flight. Due to a miscommunication, the main parachute received from an outside provider was 10’ dia. instead of the anticipated 12’. The drogue was the requested size of 60”. Despite the error, we decided to launch. When activating the altimeter after loading it on to the launch pad, we discovered that it was not

possible to push the power button with as planned. A partial disassembly was required to analyze the problem. The power button was not aligned properly with the opening in the body tube. The problem was easily solved by using a longer wire and careful maneuvering to activate the altimeter. Due to a fairly strong wind, adjustments had to be made on the launch pad. Therefore, the effects of the A-stable rocket could not be judged accurately.

The rocket was launched and recovered successfully. Cosmos flew to 7,291', ~150' above what RockSim predicted, given the actual mass and center of gravity of the rocket. This was far below our target altitude of 10,000' for the contest. Therefore, we decided that a level three motor was needed. Furthermore, the main chute suffered a few minor burns and holes due to its proximity to the motor. This problem was also easily solved by acquiring additional Nomex parachute protector cloth.

Conclusion

We were able to design a rocket that met the specifications for the contest. The Cosmos rocket is the highest rocket any member of our team has launched. The design and construction helped us learn how to build a structurally sound rocket. We would like to expand our payload capability to other departments on campus or local businesses, working with the sciences to deploy devices that would further academic research and learning.



Appendix

RockSim Data

Engine selection

[M1850W-0]

Simulation control parameters

Resolution: 1000 samples / second.

Simulation method: Explicit Euler.

Simulation execution time: 2.207 Sec.

Launch conditions (For Green River, Utah)

Altitude: 4320.000 Ft.

Relative humidity: 15.000 %

Temperature: 90.000 Deg. F
Pressure: 29.914 In. Hg.
Wind speed: 0.000 MPH
Launch guide angle: 0.000 Degrees from vertical
Latitude: 39.000 Degrees

Launch guide data (default settings):

Launch guide length: 36.000 In.
Velocity at launch guide departure: 38.839 ft / s
The launch guide was cleared at : 0.200 Seconds
User specified minimum velocity for stable flight: 43.999 ft / s
Minimum velocity for stable flight reached at: 47.021 In.

Max data values:

Maximum acceleration: Vert: 279.233 Ft./s/s , Horz: 0.000 Ft./s/s , Magnitude: 279.233 Ft./s/s
Maximum velocity: Vert: 785.819 ft / s , Horz: 0.000 ft / s , Magnitude: 785.819 ft / s
Maximum range from launch site: 0.000 Ft.
Maximum altitude: 9889.019 Ft.

Conditions at engine ejection charge:

Recovery system data

P: Parachute Deployed at : 25.489 Seconds
Velocity at deployment: 0.009 ft / s
Altitude at deployment: 9889.019 Ft.

P: Parachute Deployed at : 150.477 Seconds
Velocity at deployment: 63.992 ft / s
Altitude at deployment: 1499.948 Ft.

Time data

Time to burnout: 6.500 Sec.
Time to apogee: 25.489 Sec.
Optimal ejection delay: 18.989 Sec.

Landing data

Successful landing
Time to landing: 199.242 Sec.
Velocity at landing: Vert: -30.180 ft / s , Horz: 0.000 ft / s , Magnitude: 30.180 ft / s

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References

¹ Utah Rocket Club. 2009. Parachute Size Calc. April 25, 2009 <http://uroc.org/index.php?option=com_wrapper&Itemid=627>

² Utah Rocket Club. 2009. Black Powder Calc. April 25, 2009 <http://uroc.org/index.php?option=com_wrapper&Itemid=628>

³ RockSim, Ver. 5.0, Apogee Components, Colorado Springs, CO, 2001