Northwest Indian College Space Center

Team SkyWalkers

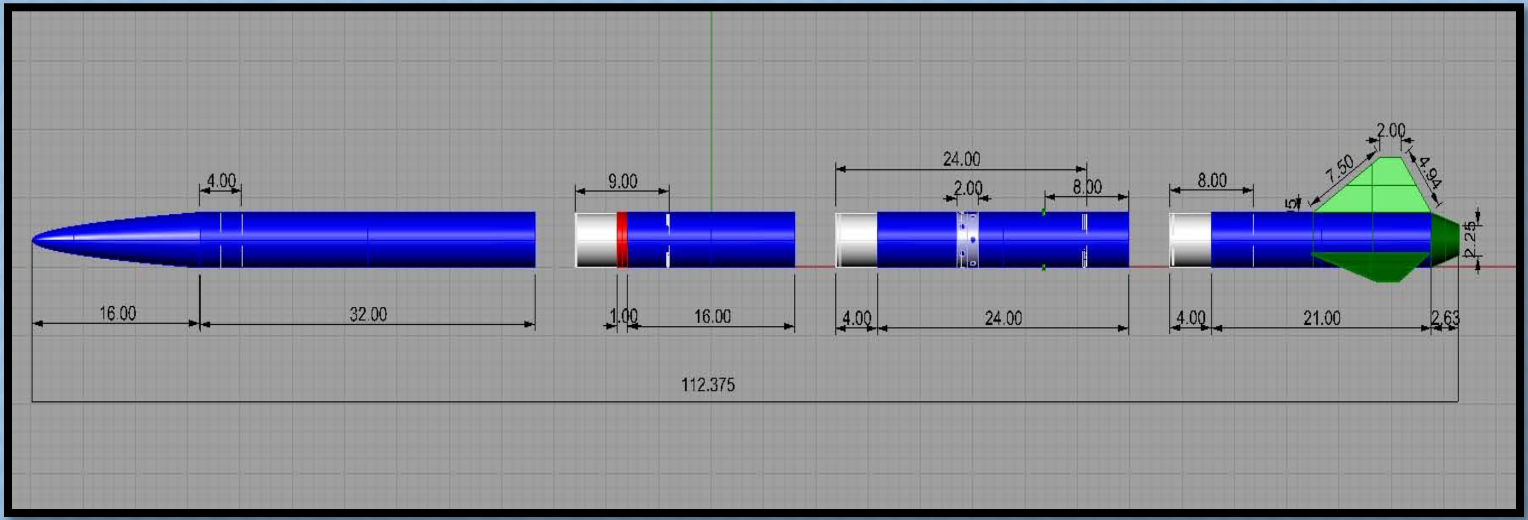
Flight Readiness Review

Northwest Indian College Space Center

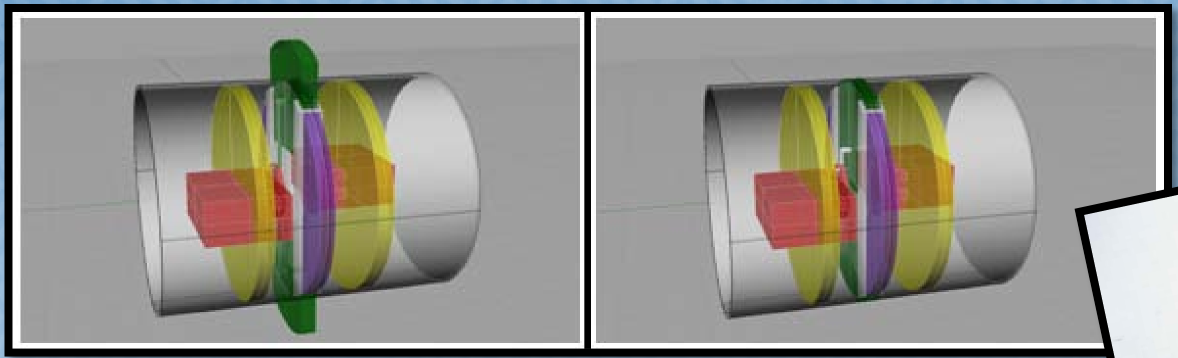
Xwlemi Elh>Tal>Nexw Squl

Launch Vehicle Design and Dimensions

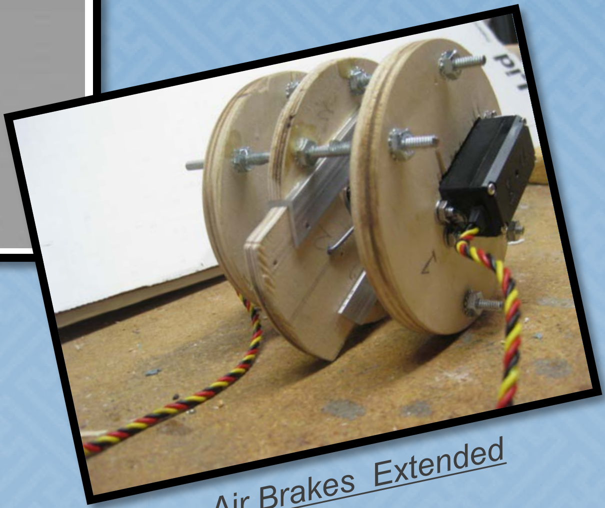
Length	112.38	Diameter	4.03
Weight	23.95 lbs	Fin Span	12.03
Center of Gravity	71.46	Center of Pressure	76.29
Static Stability	3.1 (1.2 w/CTI L640 motor)		



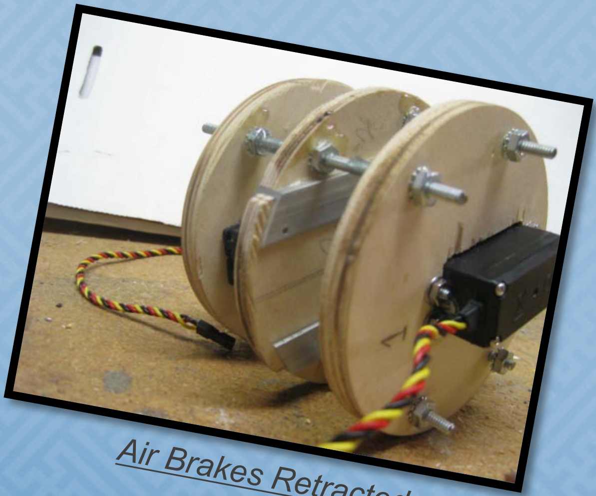
Key Design Features (Power Management)



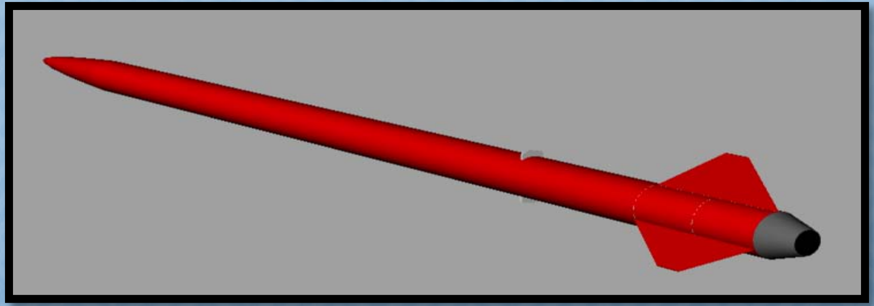
Air Brakes (L) Extended and (R) Retracted



Air Brakes Extended

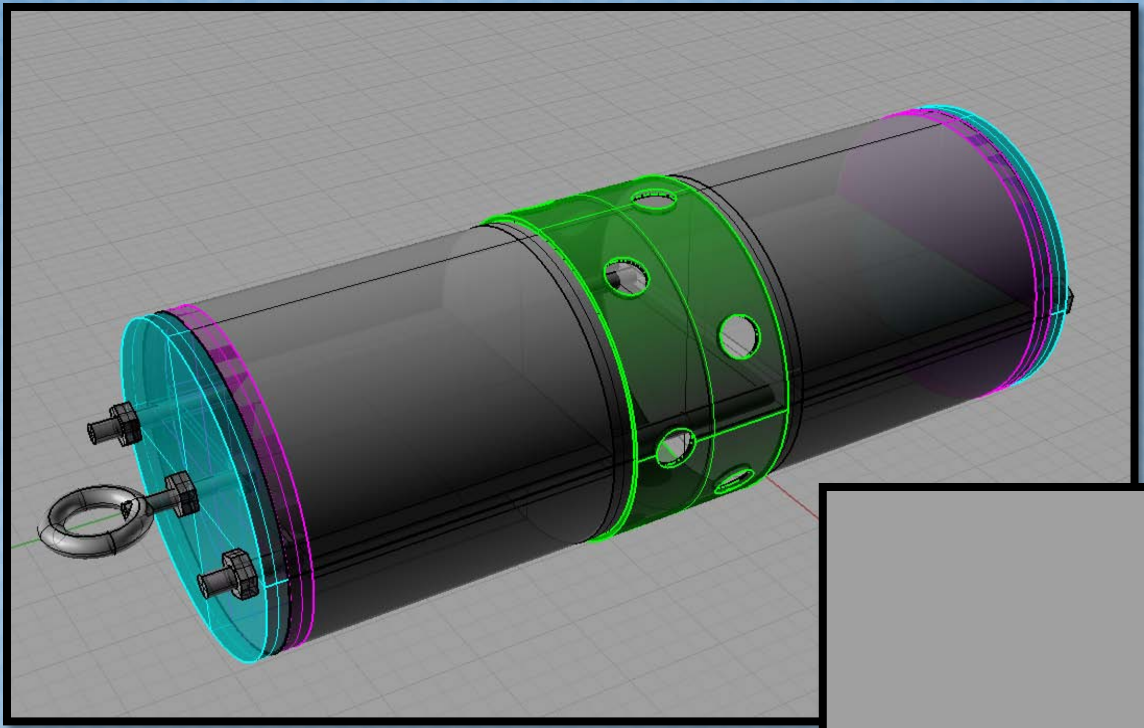


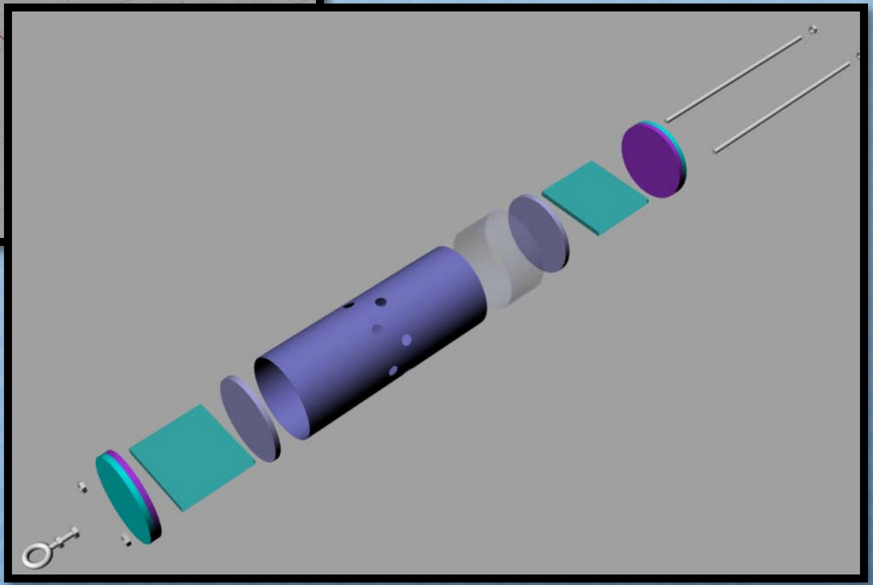
Air Brakes Retracted



Position of the Air Brake System

Key Design Features (Science Payload Bay)

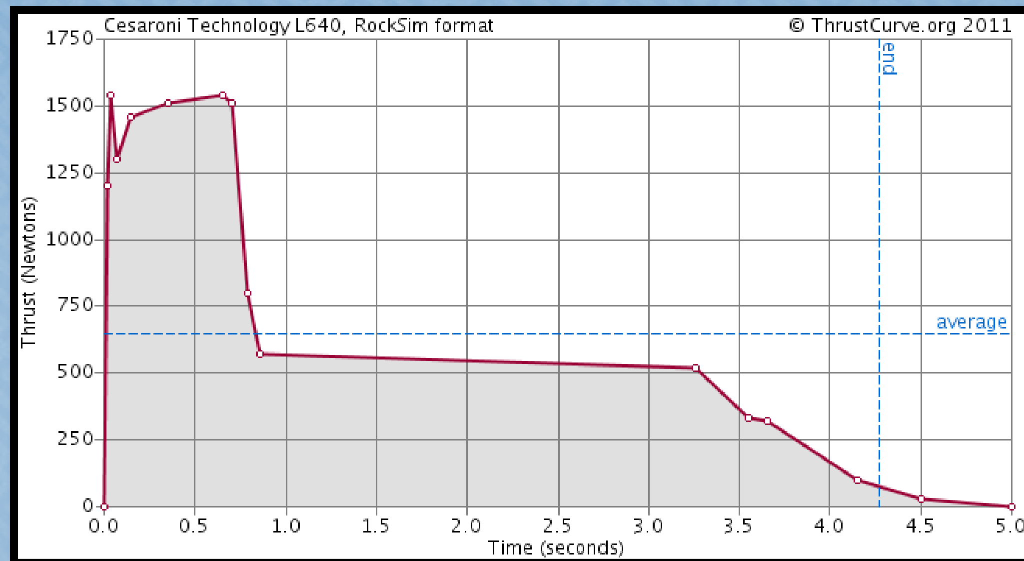




Motor Description

Manufacturer:	Cesaroni Technology
Entered:	Jul 4, 2009
Last Updated:	Feb 9, 2010
Mfr. Designation:	2772-L640-P
Brand Name:	2772-L640-P
Common Name:	L640
Motor Type:	reload
Delays:	P
Diameter:	54.0mm
Length:	64.9cm
Total Weight:	2244g
Prop. Weight:	1293g
Cert. Org.:	Canadian Association of Rocketry
Cert. Designation:	2772-L640-DT-P
Cert. Date:	
Average Thrust:	638.4N
Maximum Thrust:	1590.0N
Total impulse:	2772.2Ns
Burn Time:	4.3s
Isp:	219s
Case Info:	Pro54-6GXL
Propellant Info:	Dual Thrust

Basic Information



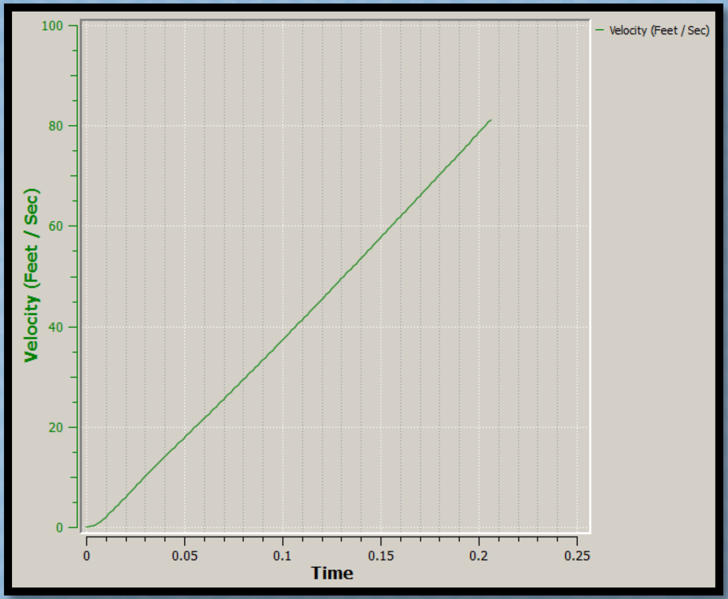
L640 Thrust Curve

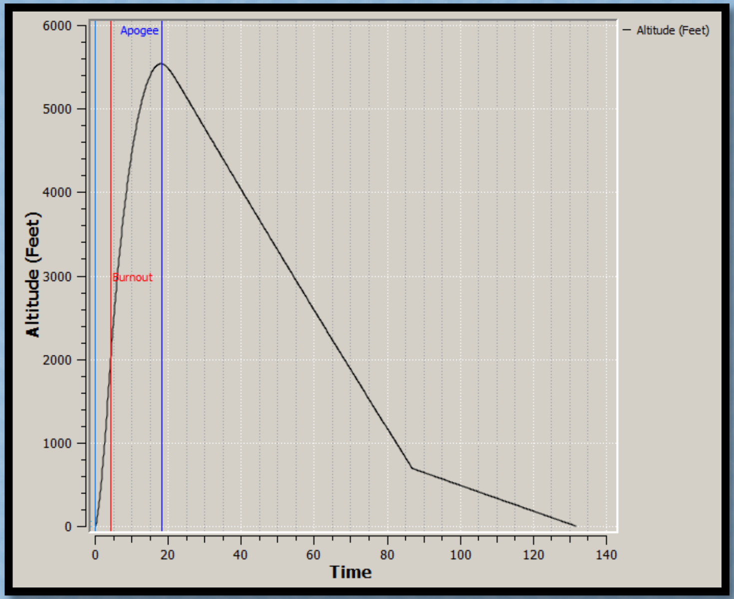
- Motor has enough thrust to get the rocket safely off the launch rail.
- Motor has enough thrust to achieve the predicted altitude.

Motor Description (cont)

Need to make certain that:

1. Motor has enough thrust to get the rocket safely off the launch rail.
2. Motor has enough thrust to slightly exceed 5280'.





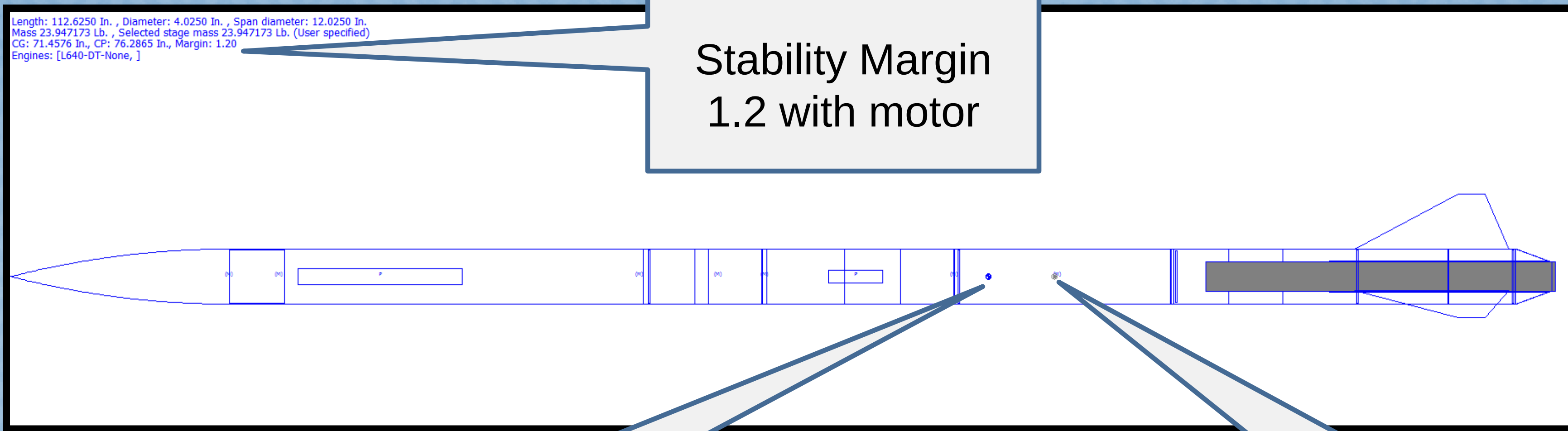
Launch guide data:

- Launch guide length: 96.0000 In.
- Velocity at launch guide departure: 81 ft/s
- The launch guide was cleared at 0.206 Seconds
- User specified minimum velocity for stable flight: 43 ft/s
- Minimum velocity for stable flight reached at 30 In.

Altitude data:

- Maximum altitude: 5536.84542 Ft.

Static Stability Margin



Stability Margin
1.2 with motor

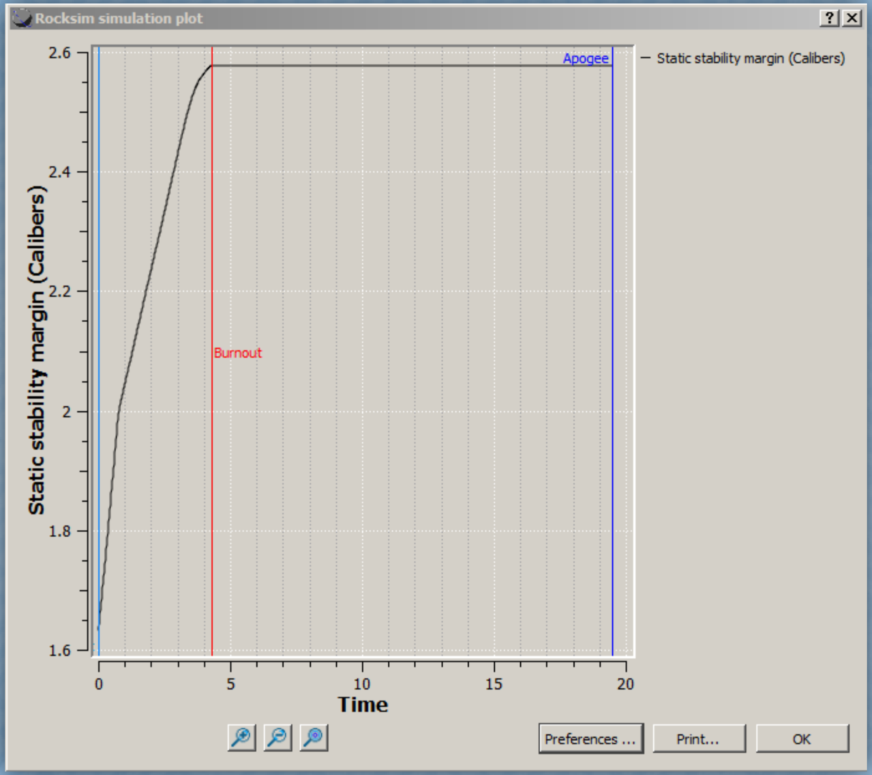
Center of Gravity
71.46

(Measurements from tip of nose cone.)

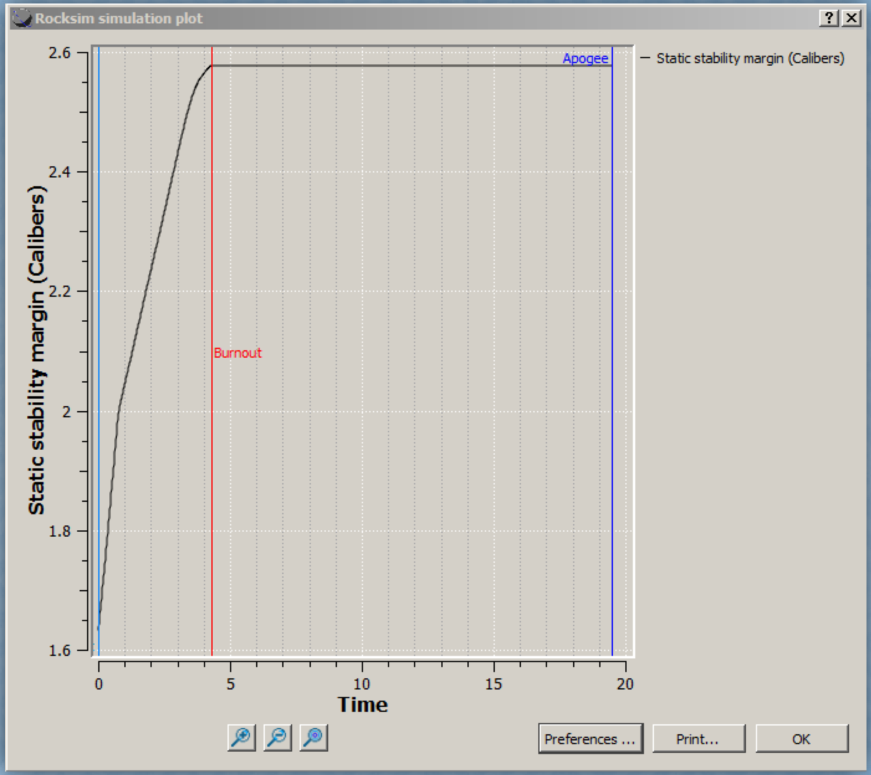
Center of Pressure
76.29

Stability Margin = (CP-CG)/Diameter

Static Stability from Liftoff to Apogee



Static Stability with Air Brakes Retracted



Static Stability with Air Brakes Extended

Thrust-to-Weight Ratio & Launch Velocity

Thrust to Weight Ratio = Pounds of Thrust/Weight of Skybolt

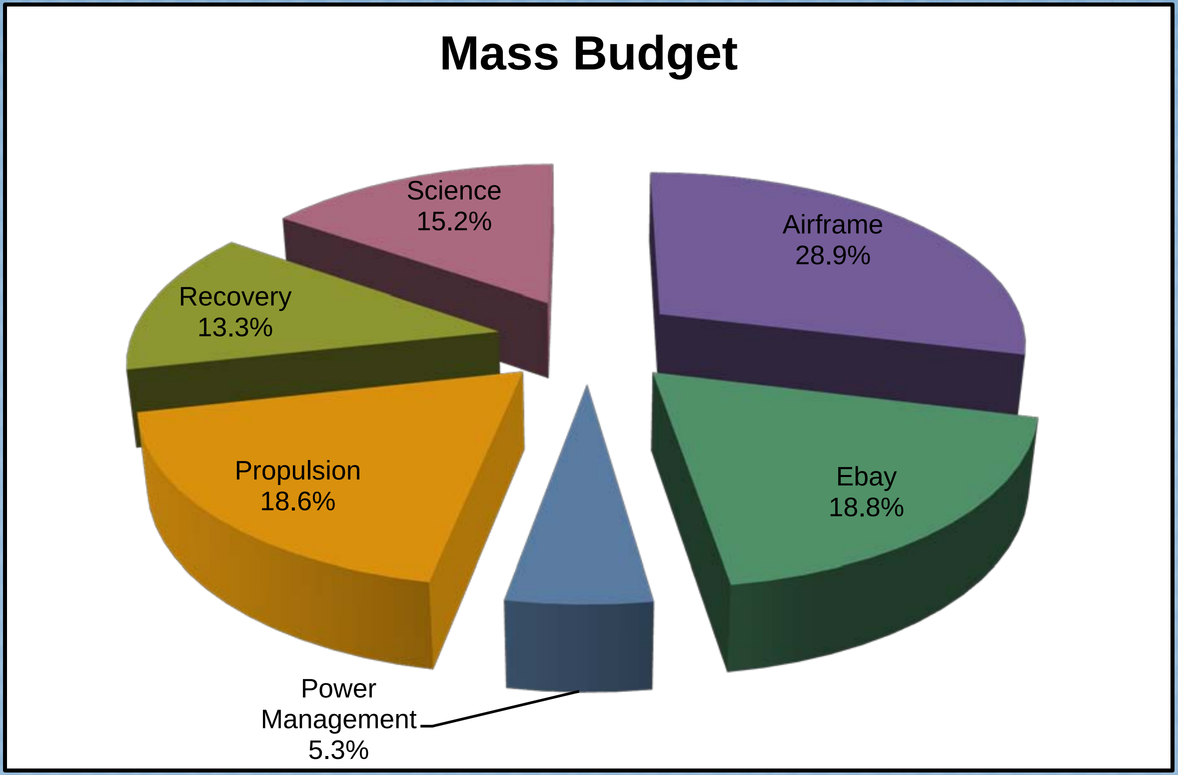
Motor	Maximum Thrust (lbs)	Loaded Weight (lbs)	Ratio	Altitude	Lift Off (fps) (need 43 fps)
CTI L640	357.45	23.95	12.92	5537	81.12

Rail Exit Velocity
81.12 fps

Mass Statement

System	Component	Mass (lb)
Airframe	Aft Airframe	0.857
Ebay	Aft Ebay Bulkplate	0.077
Ebay	Aft Ebay Eyebolt	0.125
Propulsion	Aft Motor Mount Center Ring	0.075
Science	Fin Can Bulkplate	0.077
Science	Aft Science Bay Eyebolt	0.125
Ebay	Avionics (altimeters, batteries)	0.750
Recovery	Drogue Parachute	0.375
Recovery	Drogue Recovery Harness	0.980
Ebay	Ebay Coupler	0.478
Ebay	Ebay Ring	0.071
Airframe	Epoxy	0.250
Airframe	Fin Can	1.125
Airframe	Fin Can Eybolt	0.125
Airframe	Fin Can Tube Coupler	0.478
Airframe	Fin Set	0.902
Airframe	Fwd Airframe	1.714
Ebay	Fwd Ebay Bulkplate	0.077
Ebay	Fwd Ebay Eyebolt	0.125
Propulsion	Fwd Motor Mount Center Ring	0.075
Science	Fwd Science Bay Bulkplate	0.077
Science	Fwd Science Bay Eyebolt	0.125
Recovery	GPS Unit	1.000
Recovery	Main Parachute	1.880
Recovery	Main Recovery Harness	1.580
Propulsion	Mid Motor Mount Center Ring	0.075
Airframe	Nose Cone	0.823
Airframe	Nose Cone Bulkplate	0.077
Airframe	Nose Cone Eyebolt	0.125
Airframe	Paint	0.250
Power Management System	Power Management System	1.250
Airframe	Science Bay Tube Coupler	0.478
Science	Science Payload (sensors, transmitter, cameras	1.250
Airframe	Science Payload Bay	0.625
Airframe	Tailcone	0.170
Ebay	Threaded Rod	0.375
	Total Mass=	**19.021**

Mass Budget and Mass Margin



The selected motor has reserve power for six extra pounds, which is about 25% of the designed weight. This extra weight will not adversely affect the stability margin or the target altitude. It moves the CG 2" forward.

Recovery Information

Drogue

- 20 foot 9/16” tubular nylon harness connected to ¼” solid eyebolts with quick links at either end.
- 18” LOC Precision parachute
- 20 inch fire retardant wrap around parachute
- 93 fps descent rate

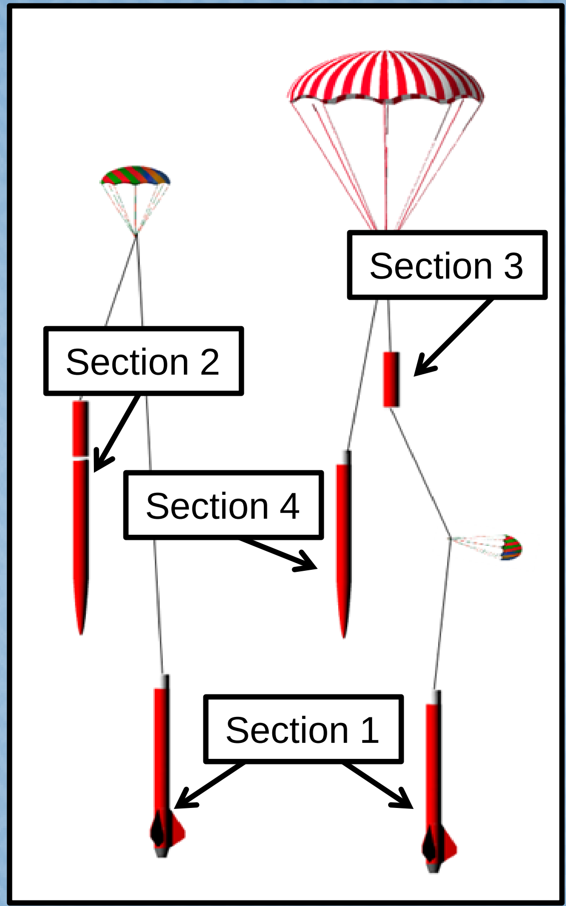
Main

- 30 foot 9/16” tubular nylon harness connected to ¼” solid eyebolts with quick links at either end.
- 52” B2Rocketry Skyangle Classic
- 20 inch fire retardant wrap around parachute
- 21 fps descent rate

Kinetic Energy Computations

Section	Component	KE
Section 1	Fin Can	1074
	Science Bay	
	Drogue Bay	
Section 2	Ebay	1324
	Main Bay	
	Nose Cone	
Section 3	Ebay	
Section 4	Main Bay	
	Nose Cone	

KE while descending with drogue parachute



Section	Component	KE
Section 1	Fin Can	56
	Science Bay	
	Drogue Bay	
Section 2	Ebay	
	Main Bay	
	Nose Cone	
Section 3	Ebay	19
Section 4	Main Bay	50
	Nose Cone	

KE at landing under main parachute

$KE = 1/2mv^2/32.2$ (ft/lbs)

75 ft/lbs is maximum allowed.

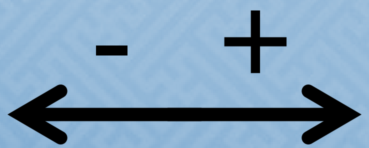
Drift Predictions

Drift Distance from Launch Pad				
Guide Rail Angle	Wind Speed (Kts)			
	0-2	3-7	8-14	15-25
0	224	450	729	2276
5	1134	1614	1656	2311
10	2058	2457	2673	4166
15	2640	2888	4108	4079
20	3433	3794	4543	4817
-5	-644	-185	71	1228
-10	-1583	-1300	-912	71
-15	-2585	-2310	-1397	-1113
-20	-3266	-3011	-2344	-1636

Altitude				
Guide Rail Angle	Wind Speed (Kts)			
	0-2	3-7	8-14	15-25
0	5537	5530	5506	5487
5	5491	5497	5525	5517
10	5340	5375	5423	5455
15	5128	5179	4978	5363
20	4788	4882	4892	5112
-5	5485	5470	5425	5330
-10	5324	5270	5222	5052
-15	5073	5000	4992	4781
-20	4761	4670	4548	4357

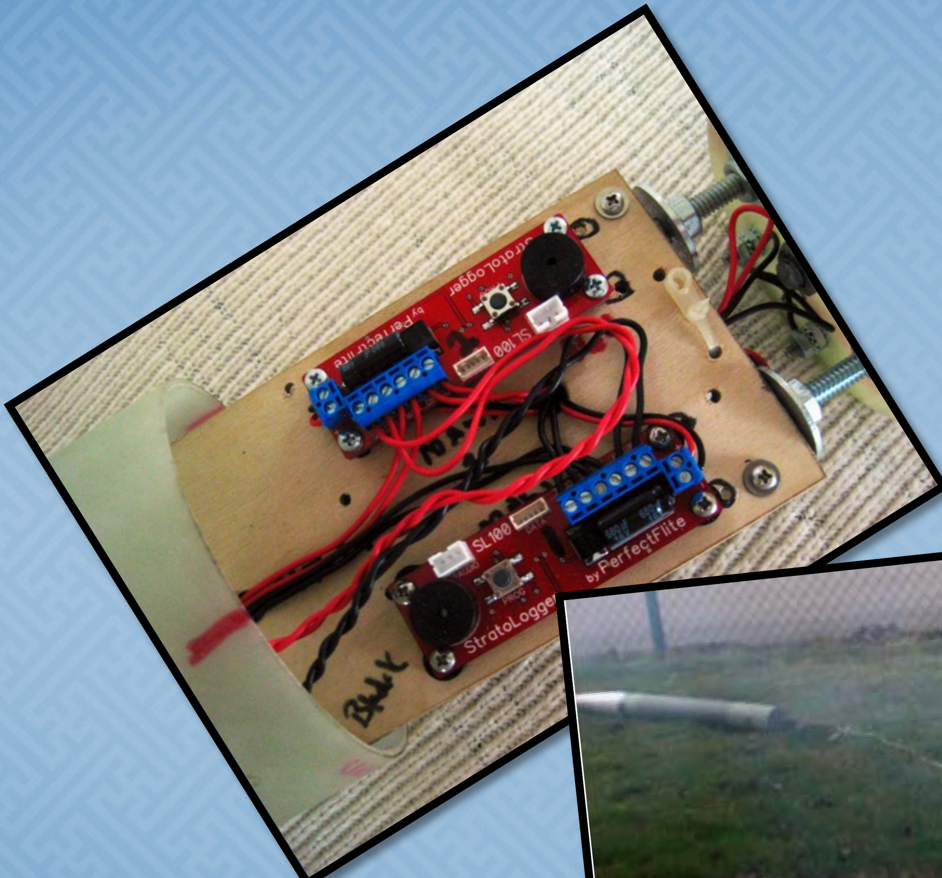
Dark Green are the optimal altitudes and corresponding drift distances for the given wind speed and guide rail angle.
Light Green are the acceptable drift distances that are less than the 2500 feet limit.

Wind Direction



Guide Rail Tilt Angle & Landing Direction

Test Plans and Procedures



Black Powder Ground Test

Dual PerfectFlite StratoLogger Altimeters

Recovery System Properties

Drogue Parachute				
Manufacturer/Model	LOC Precision			
Size	18"			
Altitude at Deployment (ft)	5,280			
Velocity at Deployment (ft/s)	0.02			
Terminal Velocity (ft/s)	92.80			
Recovery Harness Material	Tubular Nylon			
Harness Size/Thickness (in)	9/16"			
Recovery Harness Length (ft)	20			
Harness/Airframe Interfaces	3/8' closed steel eyebolt			
Kinetic Energy During Descent (ft-lb)	Section 1	Section 2	Section 3	Section 4
	1074	1324		

Main Parachute				
Manufacturer/Model	Sky Angle Cert3 Xlarge			
Size	89 sq ft			
Altitude at Deployment (ft)	700			
Velocity at Deployment (ft/s)	92.80			
Landing Velocity (ft/s)	21.24			
Recovery Harness Material	Tubular Nylon			
Harness Size/Thickness (in)	9/16"			
Recovery Harness Length (ft)	30			
Harness/Airframe Interfaces	3/8" closed steel eyebolt			
Kinetic Energy Upon Landing (ft-lb)	Section 1	Section 2	Section 3	Section 4
	56		19	50

Recovery System Tests

Ground Tests

1. Black Powder Amount Calculations
2. Radio Frequency Interference
   a. GPS
   b. Radio Transmitter/Receiver
   c. Sensors
   d. Micro Controllers

Flight Tests

Post Flight Altimeter Data

Radio Frequency Interference Tests

RF Interference Test Results	GPS	900 HMz Transmitter	UV	Illuminance	Barometric Pressure	Temperature	Humidity	Servo 1	Servo 2	Altimeter 1	Altimeter 2	Arduino 1	Arduino 2 w/datalogger
GPS		?	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
900 HMz Transmitter	OK		OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
UV	OK	OK		OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Illuminance	OK	OK	OK		OK	OK	OK	OK	OK	OK	OK	OK	OK
Barometric Pressure	OK	OK	OK	OK		OK	OK	OK	OK	OK	OK	OK	OK
Temperature	OK	OK	OK	OK	OK		OK	OK	OK	OK	OK	OK	OK
Humidity	OK	OK	OK	OK	OK	OK		OK	OK	OK	OK	OK	OK
Servo 1	OK	OK	OK	OK	OK	OK	OK		OK	OK	OK	OK	OK
Servo 2	OK	OK	OK	OK	OK	OK	OK	OK		OK	OK	OK	OK
Altimeter 1	OK	OK	OK	OK	OK	OK	OK	OK	OK		OK	OK	OK
Altimeter 2	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK		OK	OK
Arduino 1	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK		OK
Arduino 2 w/datalogger	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	

We did a wide variety of component combination testing to ensure there was no interference among the various electronic items, in particular interference with the altimeters and the ejection charge capabilities.

The one questionable area is the GPS tracker. Its response was very intermittent and we are performing additional testing to eliminate the transmitter as the cause of the intermittencies.

Black Powder Tests

Black Powder for Drogue Parachute

Volume =	178.135	in^3
Dia =	4.025	inch
Len =	14	inch
Mass of BP =	3	grams
Pressure =	32.621	psi
Ejection F =	415.071	Lb/f

Black Powder for Main Parachute

Volume =	305.375	in^3
Dia =	4.025	inch
Len =	24	inch
Mass of BP =	5	grams
Pressure =	31.715	psi
Ejection F =	403.541	Lb/f

Mass=	m	
ejection force=	F	
Pressure=	P	
Volume=	V	
Gas property=	R	=22.16
BP coefficient=	T	=3307
Diameter=	d	

Formulas Used

m=PV/R/T
F=P*(pi/4)*d^2

P=mRT/V
F=P*pi*d^2

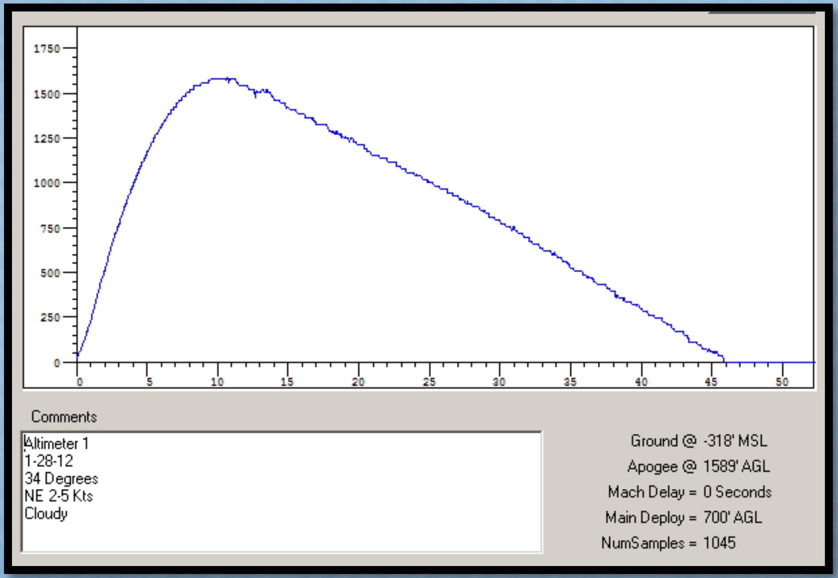
m=F*(length)/R/T
P=F/(pi/4*d^2)

Time Line

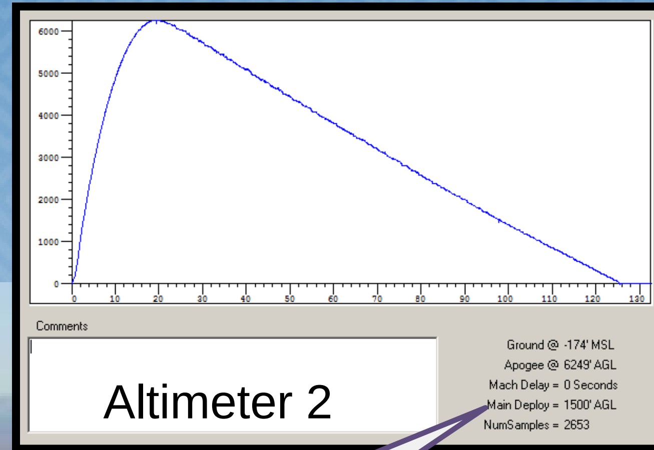
Proposal Submitted	Completed	09/06/11
Scale Rocket	Design Complete	10/05/11
Scale Rocket	Construction Complete	10/17/11
	Completed Flight Test	11/12/11
Selection Notification	Selected!	10/17/11
USLI Team Teleconference	Completed	10/21/11
Web Presence Established	Completed	11/04/11
Competition Rocket	Initial Design Considerations	09/09/11
Competition Rocket	Design Finalized	10/20/11
	Construction Started	10/28/11
	Construction Complete	11/22/11
	Recovery System Ground Test-Completed	11/23/11
	Test Flights as needed	01/28/12 –Flight 1 Completed
		02/18/12 – Flight 2 Completed
		03/18/12 – Flight 3 Completed
		04/07/12
Science Payload	Initial Design Considerations	09/06/11
Science Payload	Design Finalized (Completed)	10/31/11
	Construction Started	11/01/11
	Construction Complete	02/15/12
	Operational Testing	02/15/12
	Testing Complete	03/20/12
	Test Flight	03/31/12
Preliminary Design Review Submitted	Completed	11/27/11
Preliminary Design Review Presentation	Completed	12/06/11
Critical Design Review Submitted	Completed	01/25/12
Critical Design Review Presentation	Completed	02/07/12
Flight Readiness Review Submitted	Completed	04/21/12
Flight Readiness Review Presentation		04/11/12
Launch		04/21/12
Post flight Analysis Review		05/07/12
Announcement of Winning USLI Team		05/18/12

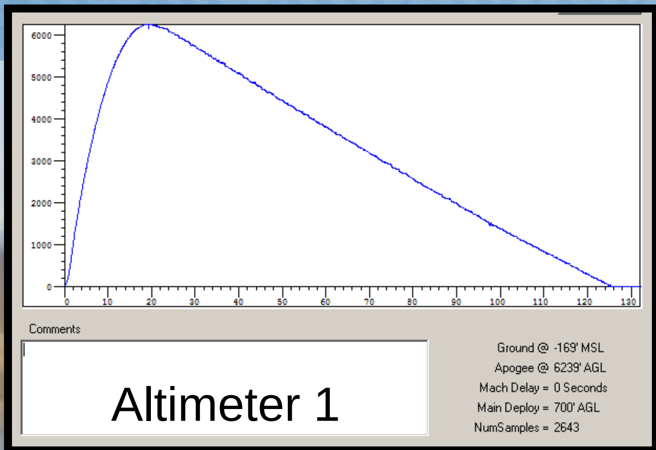
Flight Test #1

Flight Test #1 1/28/12



Flight Tests #2





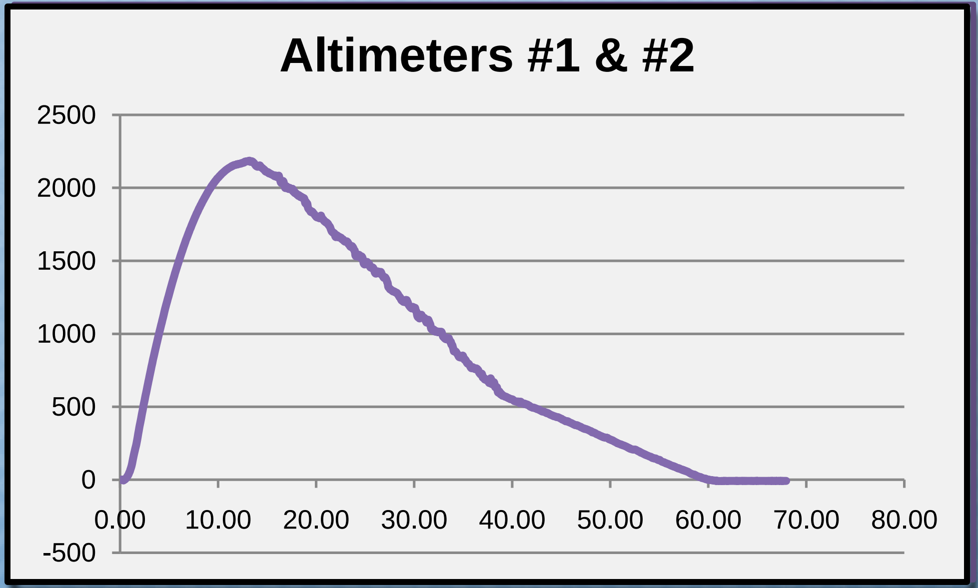
Note: Main Deploy 1500’

Flight Test #2 2/4/12

Fin Can upright in mud

Flight Test #3

Flight Test #3 3/18/12



Flight Test Data

	Test #1		Test #2		Test #3	
Weather	28-Jan		4-Feb		18-Mar	
Ceiling	5500		Clear		4000	
Temperature	38		58		46	
Wind	NE 10-15		NE 10-15		SW 3-6 kts	
Motor Reload	CTI J330		AeroTech K1275		CTI J760	
Altimeter Data	MAWD 1	MAWD 2	MAWD 1	MAWD 2	Stratologger 1	Stratologger 2
Altitude	1589	1576	6239	6249	2183	2184
Main Deploy	700	1500	700	1500	700	650
Flight Duration	45.9	45.95	125.05	125.3	60	60

Flight #1 – Empty, preliminary test of design and recovery system.

Flight #2 – Simulated payload weight, test with competition comparable reload.

Flight #3 – Fully loaded instrumentation flight with new altimeters, data recording and transmission.

Requirements Verification status

Requirement	Design Feature	Verification	Status
1. Option 2: The Science Mission Directorate (SMD) at NASA HQ will provide a $3,000 sponsorship to any team that chooses to build and fly a deployable science payload meeting the following criteria:	SMD Payload	Inspection	Work in Progress
The payload shall gather data for studying the atmosphere during descent and after landing. Measurements shall include pressure, temperature, relative humidity, solar irradiance and ultraviolet radiation. Measurements shall be made at least every 5 seconds during descent and every 60 seconds after landing. Surface data collection operations will terminate 10 minutes after landing.	Arduino microcontroller-based sensors	Test	Work in Progress
The payload shall take at least 2 pictures during descent and 3 after landing.	Multiple Cameras oriented appropriately	Test Flight	Cameras purchased
The payload shall remain in an orientation during descent and after landing such that the pictures taken portray the sky toward the top of the frame and the ground toward the bottom of the frame.			Completed
The data from the payload shall be stored onboard and transmitted wirelessly to the team's ground station at the time of completion of all surface operations.	RDAS-Tiny transmitter & receiver	Test Flight	Completed
Separation of payload components at apogee will be allowed, but not advised. Separating at apogee increases the risk of drifting outside of the recovery area. The payload shall carry a GPS tracking unit. Minimum separation altitude shall be 2,500 ft.	Not Applicable	Not Applicable	Not Applicable

2. The launch vehicle shall deliver the science or engineering payload to, but not exceeding, an altitude of 5,280 feet. above ground level (AGL). One point will be deducted for each foot achieved below the target altitude. Two points will be deducted for each foot achieved above the target altitude. Any team whose vehicle travels over 5,600 ft. according to their competition altimeter will be disqualified from being able to receive the overall competition award and will receive a score of zero for the altitude portion of their total score.	Design through Rocksim 9, Power Management System	Test	Work in Progress
3. The vehicle shall carry one Perfect Flight STRATOLOGGER or ALT15 altimeter for recording of the official altitude used in the competition scoring. Teams may have additional altimeters to control vehicle electronics and payload experiments. At the flight hardware and safety check, a NASA official will mark the altimeter which will be used for the official scoring. At the launch field, a NASA official will also obtain the altitude by listening to the audible beeps reported by the altimeter. The following circumstances will warrant a score of zero for the altitude portion of the competition:	Two PerfectFlite STRATOLOGGER altimeters	Inspection	Completed
a. The official, marked altimeter is damaged and/or does not report an altitude after the team's competition flight.	Safe Recovery will preclude this	Inspection	Work in Progress
b. The team does not report to the NASA official designated to record the altitude with their official marked altimeter by 5:00 pm on the day of the launch.	Check list will preclude this	Inspection	Work in Progress
4. The recovery system electronics shall have the following characteristics:			
a. The recovery system shall be designed to be armed on the pad.	Locking key switches installed	Inspection	Completed
b. The recovery system electronics shall be completely independent of the payload electronics.	Payload electronics in separate science by		
c. The recovery system shall contain redundant altimeters. The term "altimeters" includes both simple altimeters and more sophisticated flight computers.	Designed with two independent systems		
d. Each altimeter shall be armed by a dedicated arming switch.	Locking Key Switches		
e. Each altimeter shall have a dedicated battery.	Designed with two independent systems including batteries		
f. Each arming switch shall be accessible from the exterior of the rocket airframe.	Locking switches located on ebay ring		
g. Each arming switch shall be capable of being locked in the ON position for launch.	Switches that lock with a key are installed		
h. Each arming switch shall be a maximum of six (6) feet above the base of the launch vehicle.	Switches located 64 inches from base of rocket		

Requirement	Design Feature	Verification	Status
5. The recovery system electronics shall be shielded from all onboard transmitting devices, to avoid inadvertent excitation of the recovery system by the transmitting device(s).	Ebay lined with aluminum foil	Inspection	Completed
6. The launch vehicle and science or engineering payload shall remain subsonic from launch until landing.	Designed with Rocksim 9 to stay subsonic	Test Flight	Completed
7. The launch vehicle and science or engineering payload shall be designed to be recoverable and reusable. Reusable is defined as being able to be launched again on the same day without repairs or modifications.	Designed with Rocksim 9	Test Flight	Completed
8. The launch vehicle shall stage the deployment of its recovery devices, where a drogue parachute is deployed at apogee and a main parachute is deployed at a much lower altitude. Tumble recovery from apogee to main parachute deployment is permissible, provided that the kinetic energy is reasonable.	Designed with Rocksim 9, using drogue at apogee and main at 700 feet	Test Flight	Completed
9. Removable shear pins shall be used for both the main parachute compartment and the drogue parachute compartment.	6 (3 each on main and drogue end of ebay) - #2-56 nylon screws will be shear pins	Ground Testing	Completed
10. The launch vehicle shall have a maximum of four (4) independent or tethered sections.	Designed with three	Inspection	Completed
a. At landing, each independent or tethered sections of the launch vehicle shall have a maximum kinetic energy of 75 ft-lbf.	Designed via calculations	Simulation	Completed
b. All independent or tethered sections of the launch vehicle shall be designed to recover with 2,500 feet of the launch pad, assuming a 15 mph wind.	Designed with Rocksim 9	Simulation analysis	Completed
11. The launch vehicle shall be capable of being prepared for flight at the launch site within 2 hours, from the time the waiver opens.	Designed as required	Check lists	Completed

Requirement	Design Feature	Verification	Status
12. The launch vehicle shall be capable of remaining in launch-ready configuration at the pad for a minimum of 1 hour without losing the functionality of any onboard component.	Battery power calculated to last at least 2 hrs for each device using a battery	Simulation analysis	Work in Progress
13. The launch vehicle shall be launched from a standard firing system (provided by the Range) using a standard 10 - second countdown	Designed as required	Test	Completed
14. The launch vehicle shall require no external circuitry or special ground support equipment to initiate the launch (other than what is provided by the Range).	None are necessary as designed	Inspection	Completed
15. Data from the science or engineering payload shall be collected, analyzed, and reported by the team following the scientific method.	Data analysis will be examined post flight	Testing will follow payload completion prior to the competition flight	Work in Progress
16. An electronic tracking device shall be installed in each independent section of the launch vehicle and shall junction with an electronic, transmitting device, but shall not replace the transmitting tracking device.	Garmin GPS unit in nose cone	Ground tested complete. Flight test to follow	Completed
17. The launch vehicle shall use a commercially available solid motor propulsion system using ammonium perchlorate composite propellant (APCP) which is approved and certified by the National Association of Rocketry (NAR), Tripoli Rocketry Association (TRA) and/or the Canadian Association of Rocketry (CAR).	Designed to use CTI/Aerotech reloadable motor	Inspection	Completed
18. The total impulse provided by the launch vehicle shall not exceed 5,120 Newton-seconds (L-class). This total impulse constraint is applicable to any combination of one or more motors.	Designed as required, L motor largest permissible	Inspection	Completed

Requirement	Design Feature	Verification	Status
20. The following items are prohibited from use in the launch vehicle:			
a. Flashbulbs. The recovery system must use commercially available low-current electric matches. b. Forward canards. c. Forward firing motors. d. Rear ejection parachute designs. e. Motors which expel titanium sponges (Sparky, Skidmark, MetalStorm, etc.). f. Hybrid motors.	None of these have been included in the rocket design	Inspection	Completed
21. Each team shall use a launch and safety checklist. The final checklist shall be included in the FRR report and used during the flight hardware and safety inspection and launch day.	Check lists are designed	Inspection and actual testing	Completed
22. Students on the team shall do 100% of the work on the project, including design, construction, written reports, presentations, and flight preparation with the exception of assembling the motors and handling black powder charges.	Implemented as required	Inspection	Work in Progress
23. The rocketry mentor supporting the team shall have been certified by NAR or TRA for the motor impulse of the launch vehicle, and the rocketeer shall have flown and successfully recovered (using electronic, staged recovery) a minimum of 15 flights in this or a higher impulse class, prior to PDR.	Implemented as required	Inspection	Completed

Requirement	Design Feature	Verification	Status
19. All teams shall successfully launch and recover their full scale rocket prior to FRR in its final flight configuration.			
a. The purpose of the full scale demonstration flight is to demonstrate the launch vehicle's stability, structural integrity, recovery systems, and the team's ability to prepare the launch vehicle for flight.	Test flights scheduled prior to FRR	Test flight	Completed
b. The vehicle and recovery system shall have functioned as designed.	Extensive ground testing where possible, test flights for the vehicle	Test flight	Completed
c. The payload does not have to be flown during the full-scale test flight.			
▪ If the payload is not flown, mass simulators shall be used to simulate the payload mass.	Measured mass of actual payload will be either substituted or the payload will be flown	Test flight	Completed
▪ If the payload changes the external surfaces of the launch vehicle (such as with camera housings and/or external probes), those devices must be flown during the full scale demonstration flight.	Test flight will be with rocket as its designed		Work in Progress
d. The full scale motor does not have to be flown during the full scale test flight. However, it is recommended that the full scale motor be used to demonstrate full flight readiness and altitude verification.	Both smaller and a full scale motor will be used in test flights	Test flight	Completed
e. The success of the full scale demonstration flight shall be documented on the flight certification form, by a Level 2 NAR/TRA observer.	Our mentor and 3 other NAR L2 individuals are available		Work in Progress
f. After successfully completing the full-scale demonstration flight, the launch vehicle or any of its components shall not be modified without the concurrence of the NASA Range Safety Officer.	No changes will be made.		Work in Progress

Requirement	Design Feature	Verification	Status
24. The maximum amount teams may spend on the rocket and payload is $5000 total. The cost is for the competition rocket as it sits on the pad, including all purchased components and materials and the fair market value of all donated components and materials. The following items may be omitted from the total cost of the vehicle:			
a. Shipping costs. b. Ground Support Equipment. c. Team labor.	Implemented as required	Inspection/Test Flight	Completed

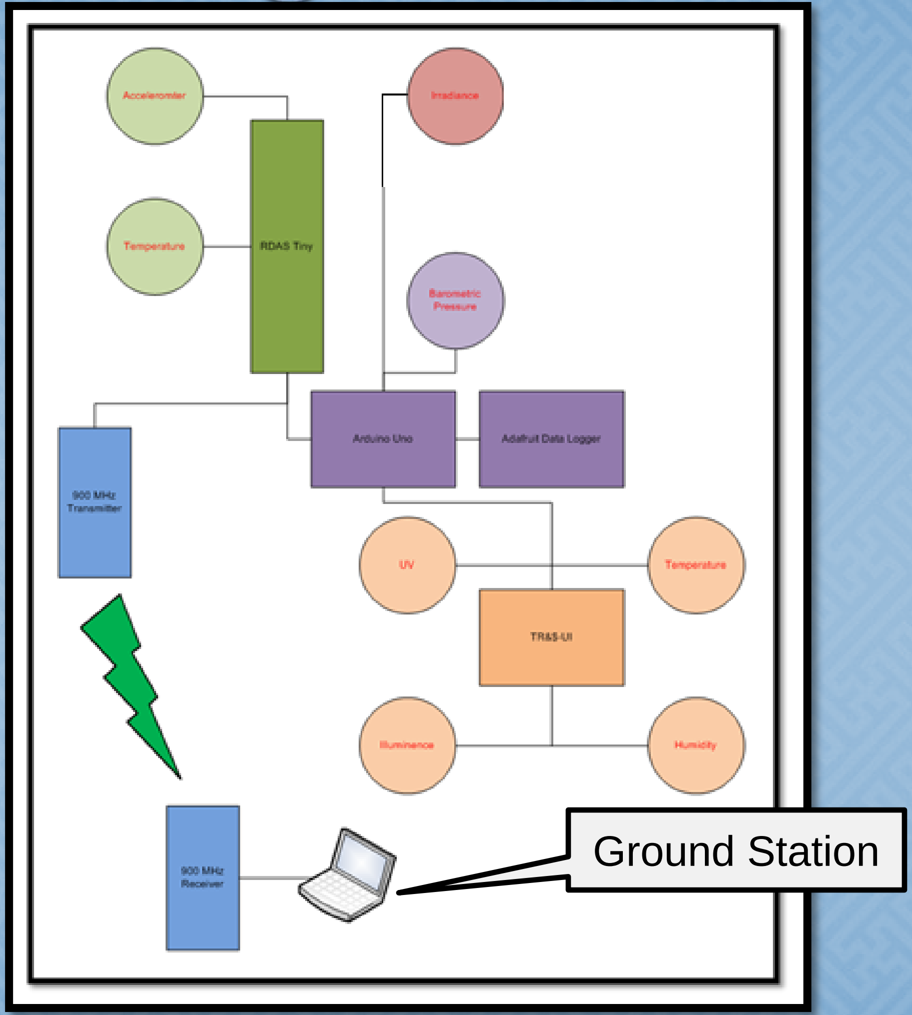
Payload Test Plan

- Test each component as it’s built
- Gather baseline data for each component
- Integrate one component at a time and verify it’s functioning satisfactorily
- Verify non-interference among components
- Ground test entire system
- Flight test payload

Payload Subsystems

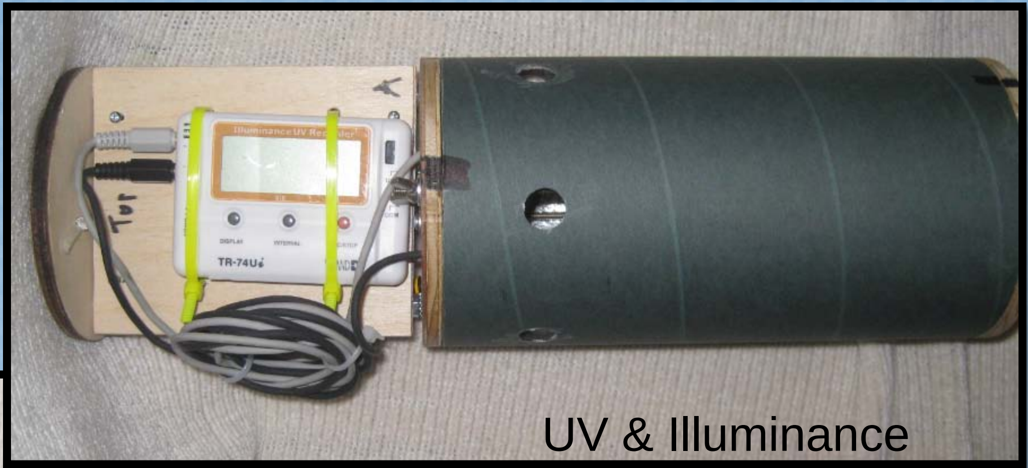
Sensors	silicon photo detector	These will be used to take readings on descent and after landing.
	temperature/humidity sensor	
	UV sensor	
	pressure sensor	
Controllers	Arduino Uno Microcontroller	This will be used to activate the devices and integrate the data collected.
Data Logger	Adafruit Data Logger	The data logger collects the data directed through the micro controller from the sensors. It stores this data for retrieval after landing.
Power Management	Arduino Pro Mini	This takes the readings from the barometric sensor and velocity and calculates when to deploy the velocity reduction system flaps.
	HiTec HS 645MG Ultra Torque Servo	This controls the velocity reduction system flaps.
	BMP 085 Barometric Sensor	

Payload Integration



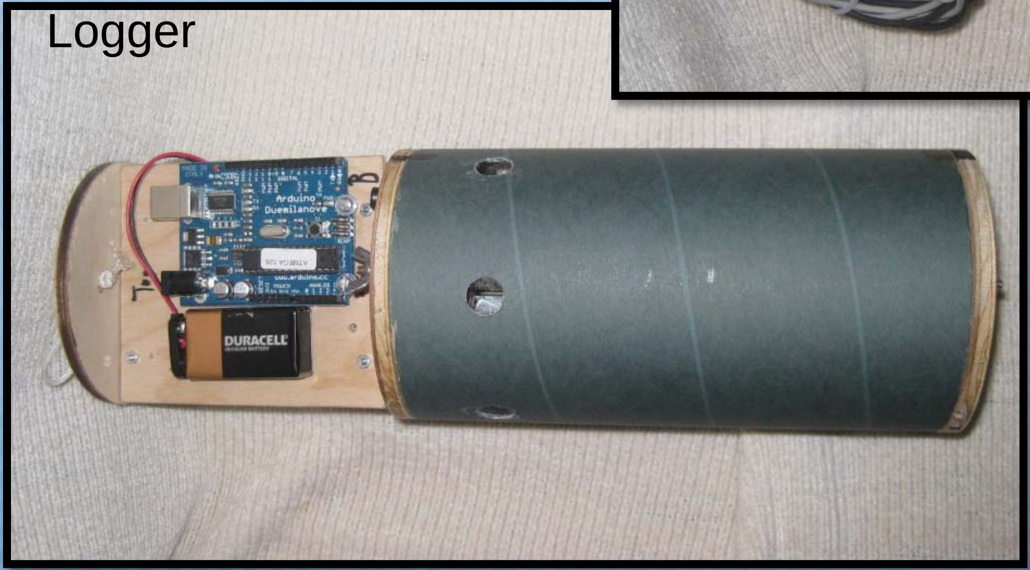
Instrumentation Block Diagram

Science Payload



UV & Illuminance Data Logger

Arduino-based Barometric Pressure & Data Logger



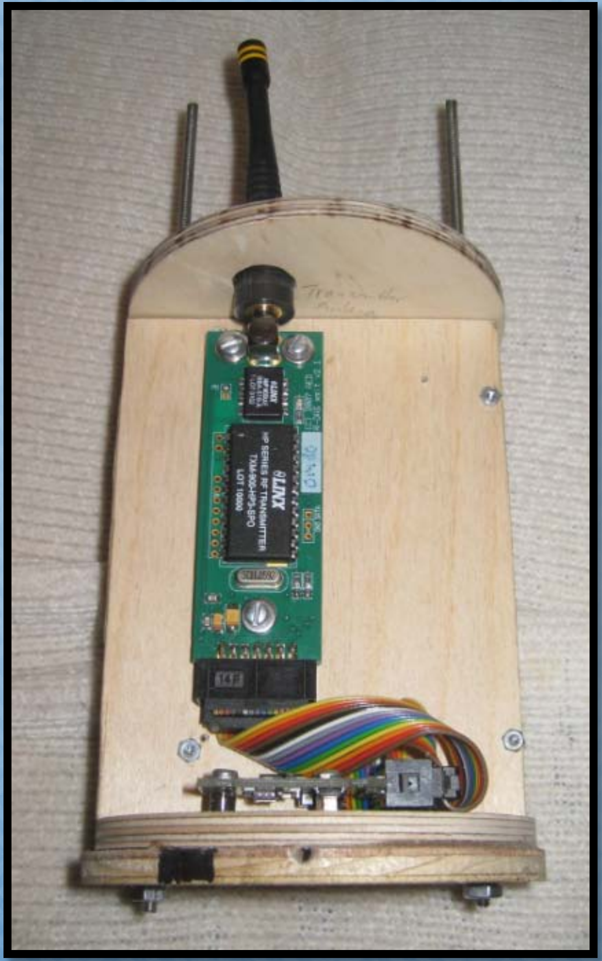
Science Payload (cont)

UV & Illuminance data logger showing UV sensor (black) and Illuminance sensor (white)

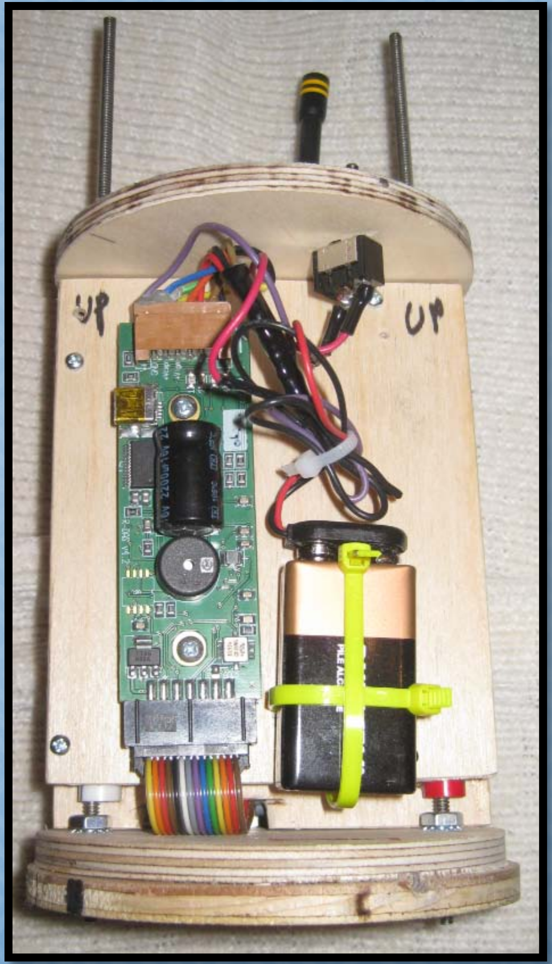
Transmitter antenna & reflective foil covered sensor compartment

Science Payload (cont)

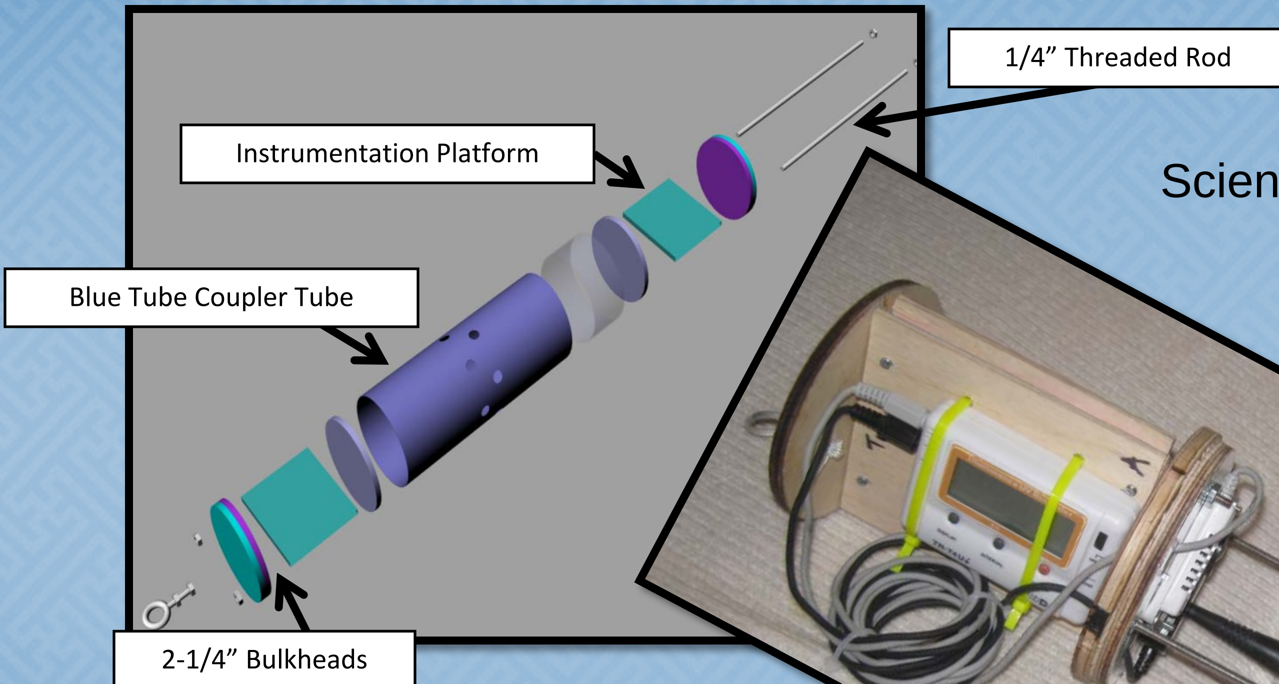
900 MHz Transmitter

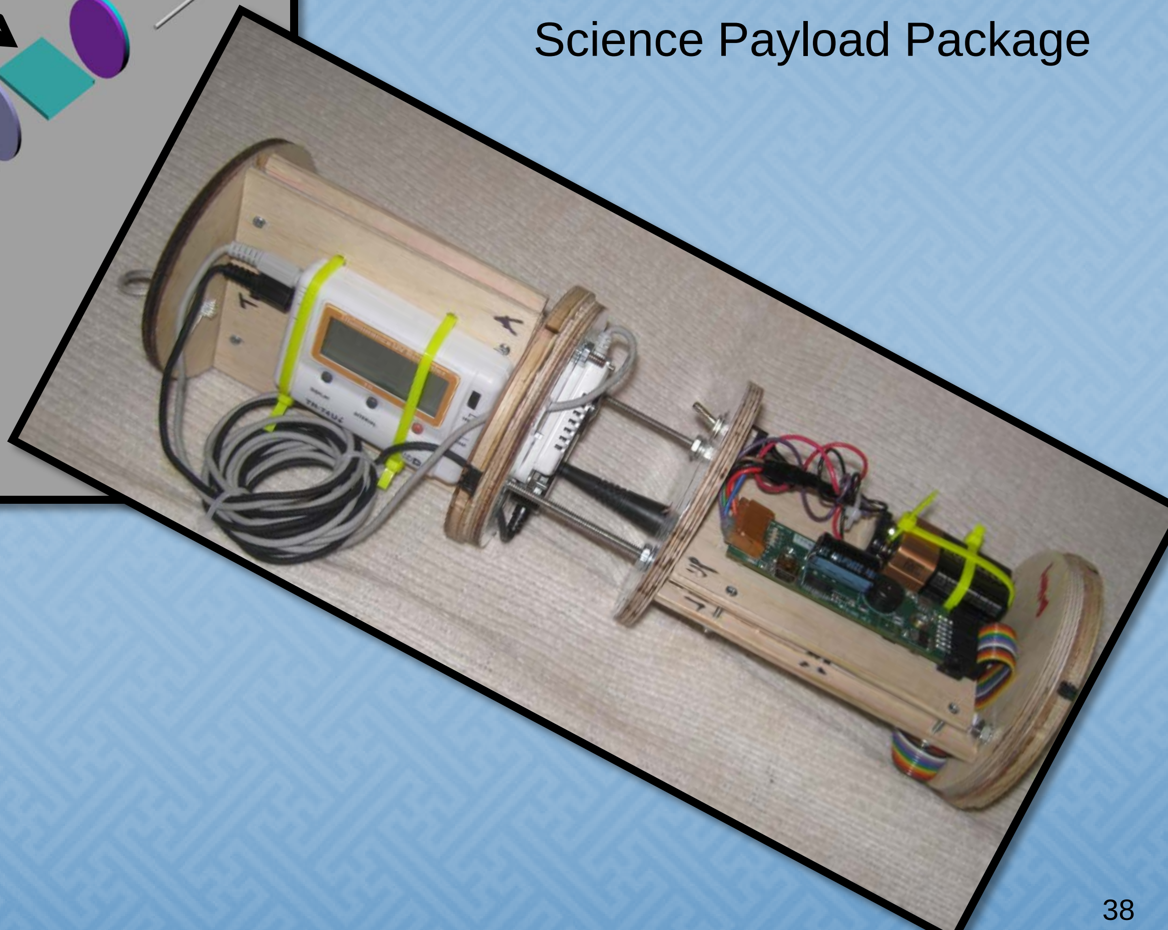


RDAS Tiny Altimeter with Analog Ribbon Cable



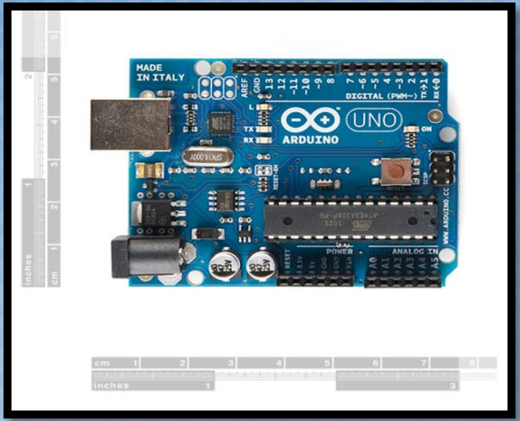
Science Payload (cont)



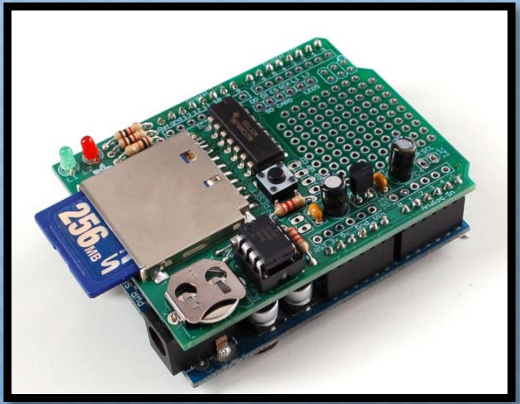


Science Payload Package

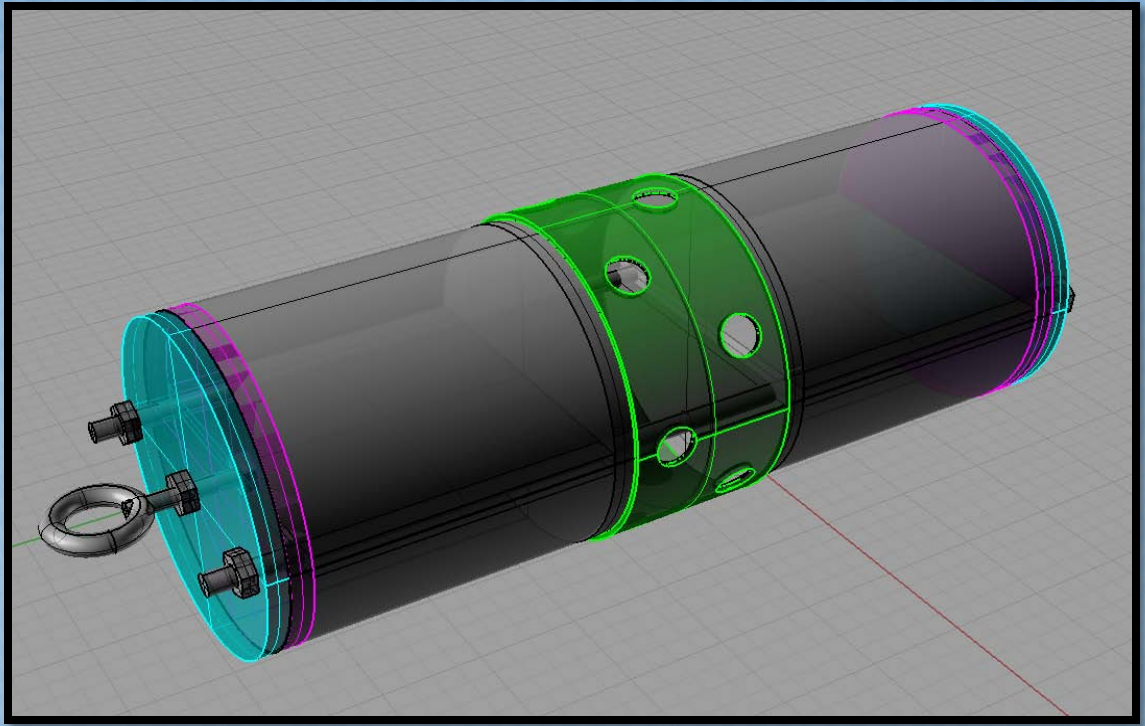
Final Payload Design Overview

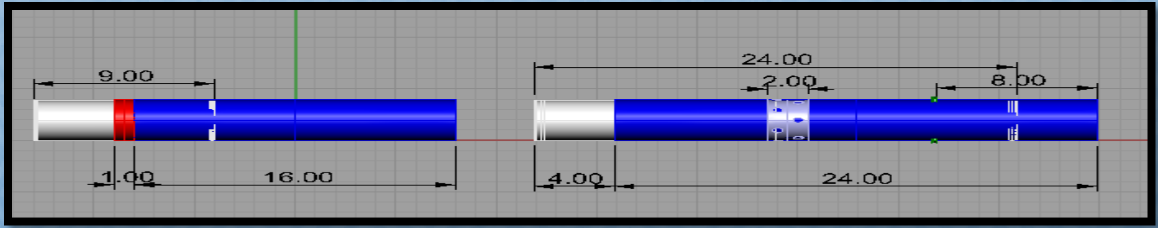


Arduino Uno



Adafruit Data Logger installed on Uno

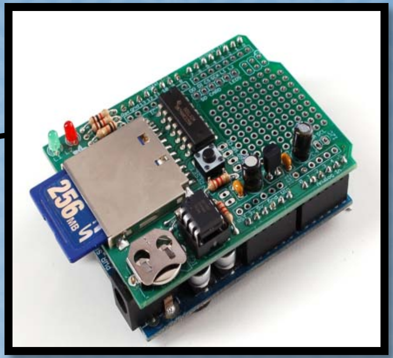


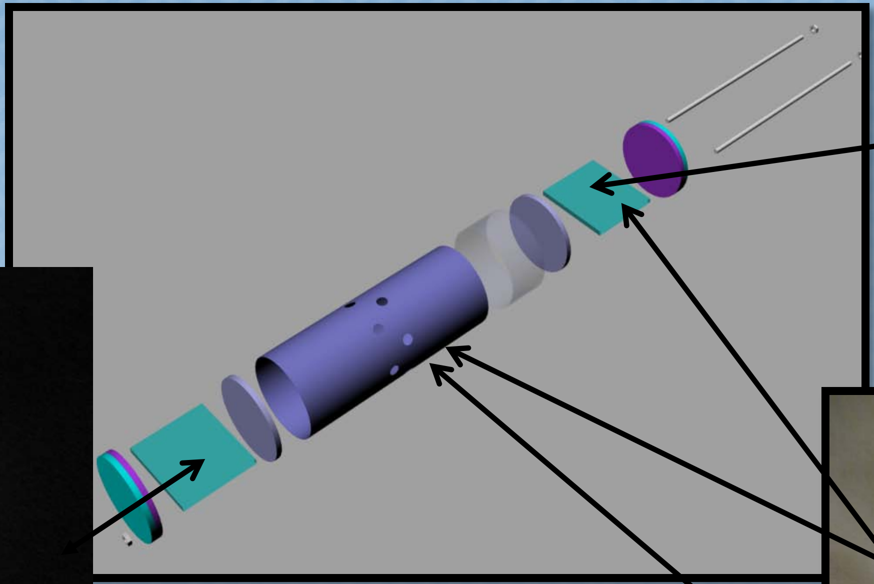


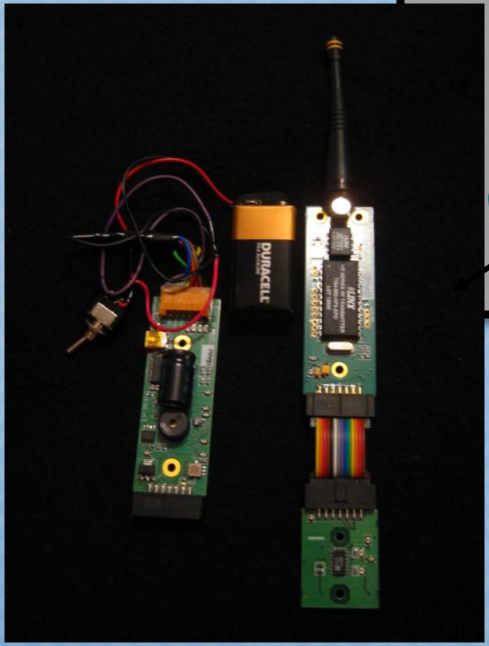
Ebay, Drogue Parachute Bay, and Science Payload Bay

Final Payload Design Overview

Arduino







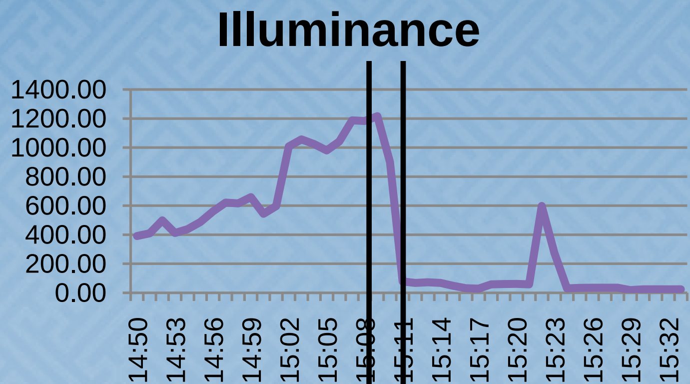
900 MHz
Transmitter

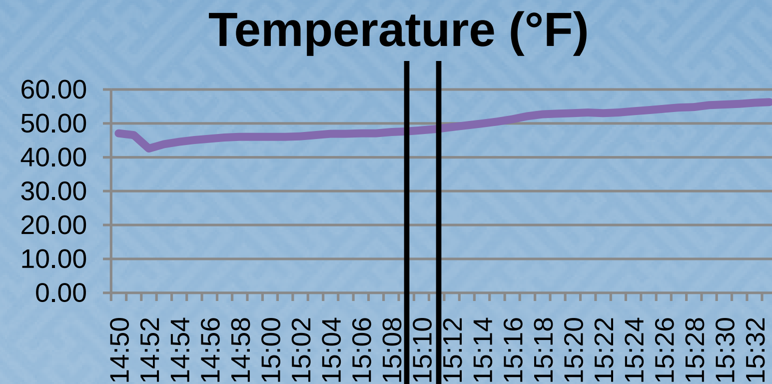
TR74UI

Payload Verification

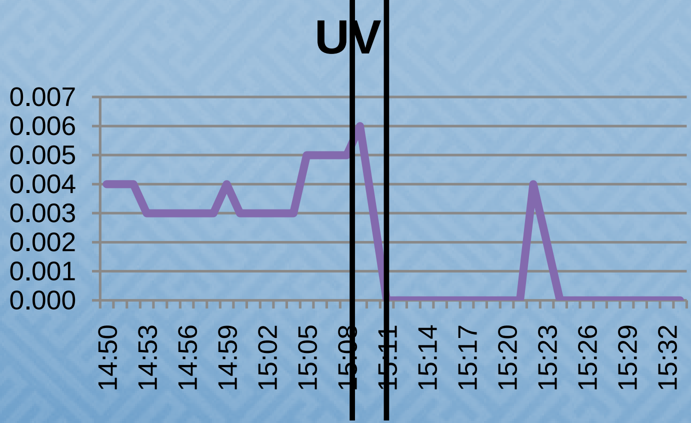
Requirement	Design Feature	Verification	Status
The payload shall gather data for studying the atmosphere during descent and after landing. Measurements shall include pressure, temperature, relative humidity, solar irradiance and ultraviolet radiation. Measurements shall be made at least every 5 seconds during descent and every 60 seconds after landing. Surface data collection operations will terminate 10 minutes after landing.	Arduino microcontroller-based sensors	Test	Completed
The payload shall take at least 2 pictures during descent and 3 after landing.	Multiple Cameras oriented appropriately	Test	Cameras purchased
The payload shall remain in an orientation during descent and after landing such that the pictures taken portray the sky toward the top of the frame and the ground toward the bottom of the frame.			Completed
The data from the payload shall be stored onboard and transmitted wirelessly to the team's ground station at the time of completion of all surface operations.	900 MHz transmitter &receiver	Test	Completed

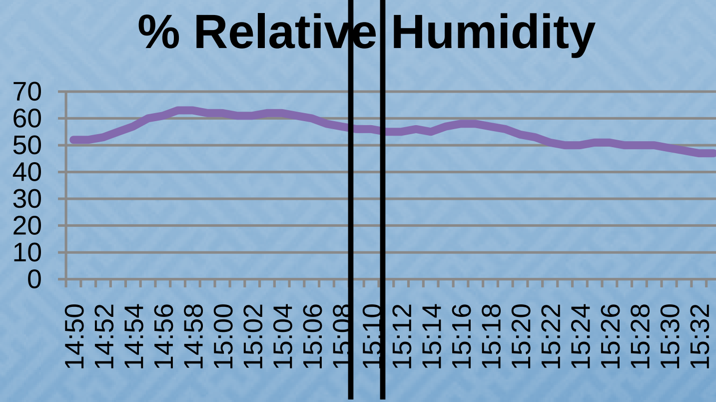
Payload Flight Test Results



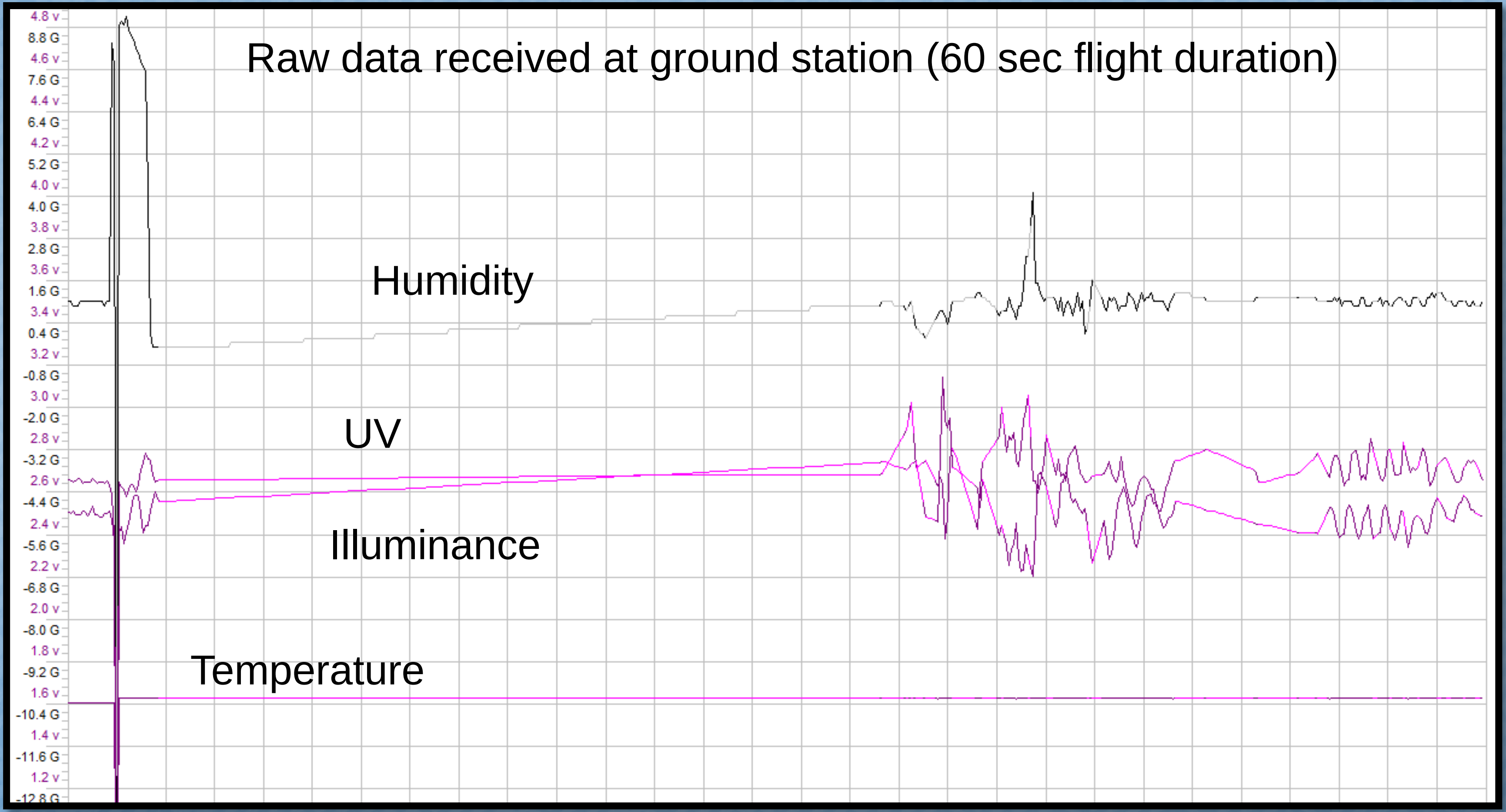


Longitudinal bars indicate flight time





Payload Flight Test Results



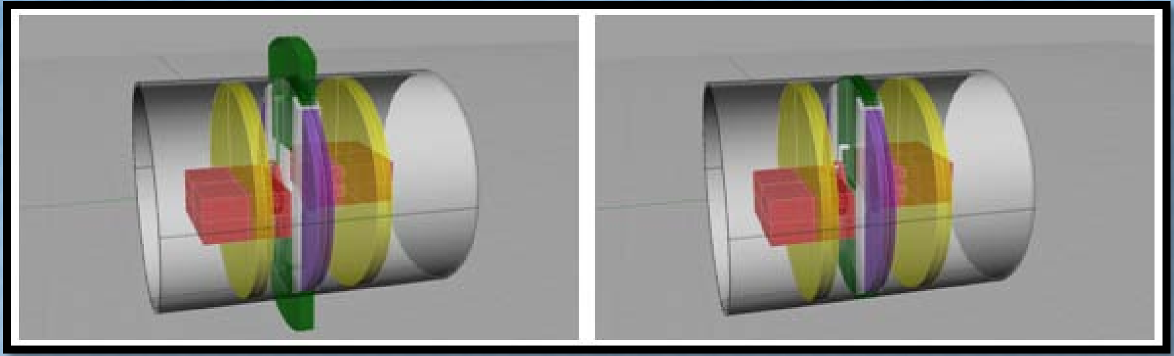
Trajectory Numerical Simulation Program

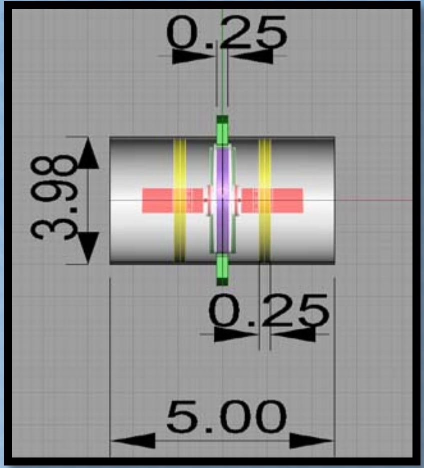
Rocket	**USLI**			**Chute diam**	**Dc**	**2**				
Rckt Mass (empty)	**Mr**	**10.99**		**Time Incr**	**dt**	**0.1**				
Eng. Case mass	**Me**	**0.772**		**Mass Decr (propellant burned)**	**dm**	**0.31897019**		**Avg. Thrust**		
Propellant mass	**Mp**	**1.177**		**Grav. Const**	**gc**	**9.8**		**650.59**		
Diameter, rocket	**Dr**	**0.10244**		**Area, (widest part)**	**A**	**0.008241932**				
Impulse, motor(N-sec)	**Im**	**2437**		**Chute area**	**A_2**	**3.141592654**		**True Impulse**		
Thrust (Newtons)	**Ta**	**659**		**Burn Time**	**tb**	**3.69**		**2400.66**		
Air Density (kg/m^3)	**rho**	**1.2**		**Eject time**	**te**	**17.97**	**Peak kph**	**Peak (m)**	**Peak (ft)**	**Peak mph**
Drag coef	**Cd**	**0.52**					**148.26**	**1192.41**	**3911.10**	**331.66**

Flight Time t	Drag Force Fd	Thrust Ft	Net Force F	Mass M	Acceleration Acc	Velocity (m/s) V	Altitude (m) Y	Rocket Area Area	mph	Air Density rho
0.0	0.00	0.00	-126.80	12.94	0.00	0.00	0.00	0.01	0.00	1.22
0.1	0.00	1065.32	938.83	12.91	72.74	7.27	1.09	0.01	16.27	1.22
0.2	0.19	1020.05	893.69	12.88	69.41	14.21	2.86	0.01	31.80	1.22
0.3	0.71	990.12	863.54	12.84	67.24	20.94	5.29	0.01	46.84	1.22
0.4	1.54	966.76	839.67	12.81	65.54	27.49	8.37	0.01	61.50	1.22
0.5	2.66	949.45	821.55	12.78	64.29	33.92	12.08	0.01	75.88	1.22
0.6	4.04	932.14	803.17	12.75	63.01	40.22	16.42	0.01	89.98	1.22
0.7	5.68	914.83	784.53	12.72	61.70	46.39	21.37	0.01	103.78	1.22
0.8	7.56	897.52	765.66	12.68	60.37	52.43	26.91	0.01	117.28	1.22

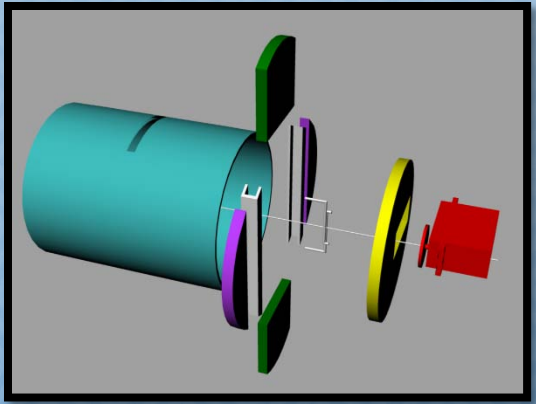
Sample data with CTI L640 motor

Power Management System

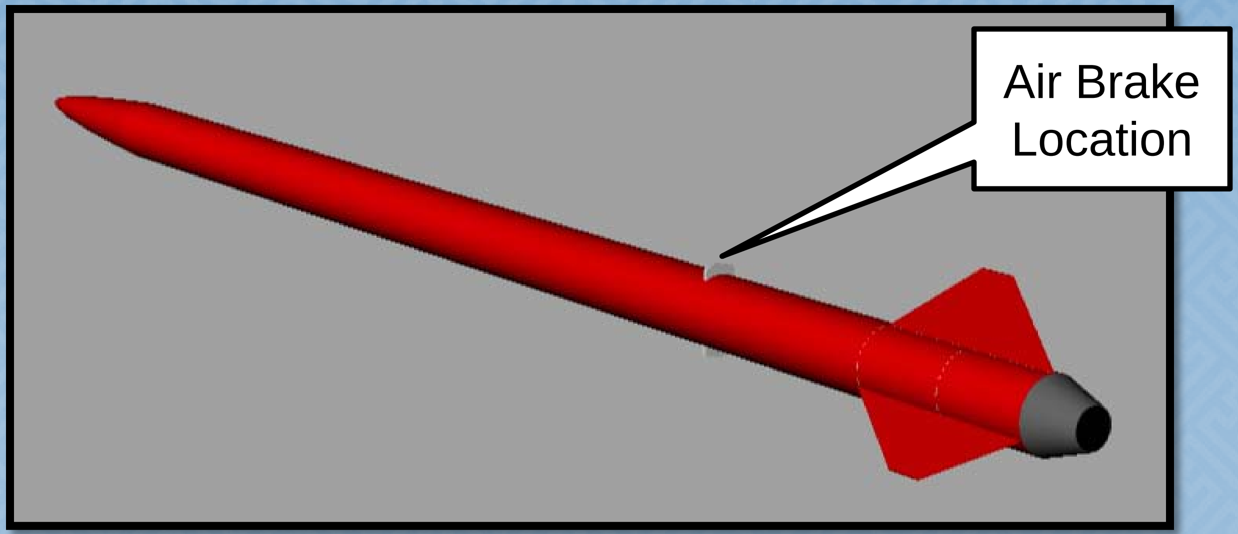




Velocity Reduction System



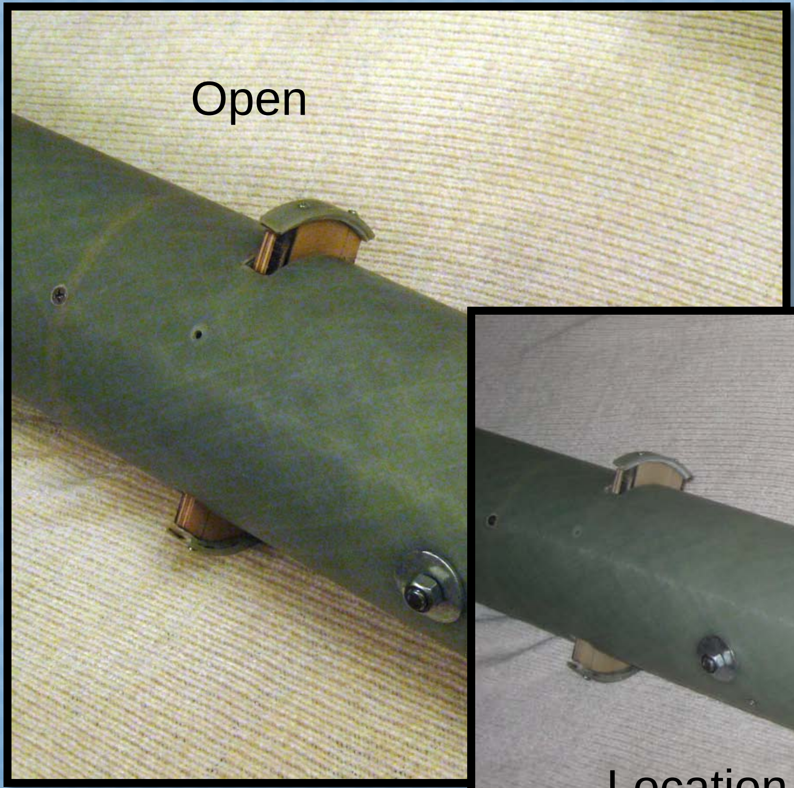
Power Management System

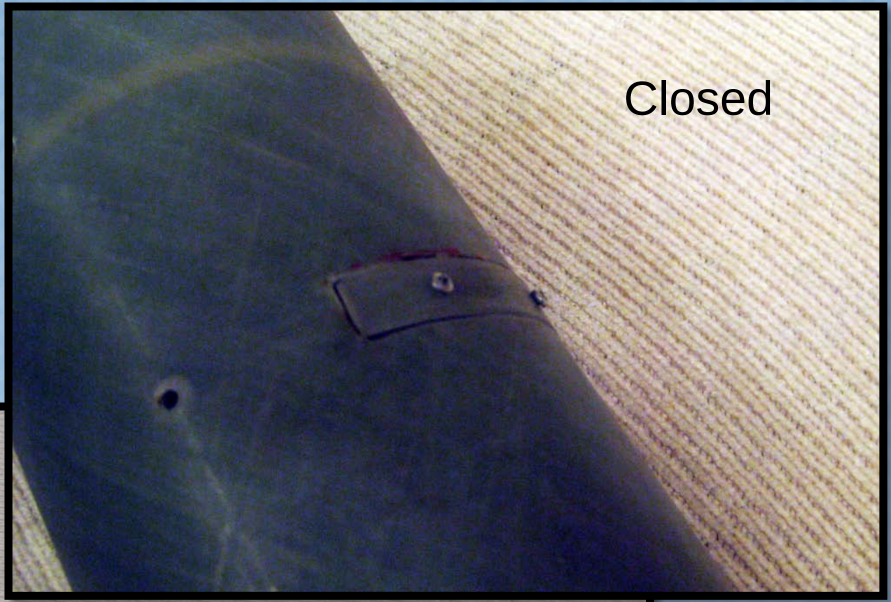


Power Management System Concept with Arduino-Controlled Hi Torque Servo Controlled Velocity Reduction System

Rocksim indicates that the CP moves 0.25 inches forward with the dams extended. The CD increases from 0.52 to 7.0. There is no measureable difference in static stability with the dams extended or retracted.

Power Management System





Internal & external Interfaces

Connecting the Components

Three different connection methods are used:

1. Those that need intermittent access use #6, #8, or #10 T-nuts and screws.
2. Temporary connections between the ebay and the two parachute compartments use nylon shear pins. The shear pins prevent the rocket from premature separation due to a combination of drag, inertia, and momentum. The shear pins are, however, designed to fail when the black powder ejection charge is ignited.
3. Permanent connections use West System epoxy.

Bulkheads and Centering Rings

The bulkheads provide recovery harness mounts, confine the different components, and protect the components and electronics from black powder charges ignited during recovery system deployment. Eye-bolts are used on the bulkheads to provide a connection point for the recovery harnesses. The material for all bulkheads is 3/16 inch G10 fiberglass.