Student Launch Initiative

AIAA OC Section

2010 – 2011

AIAA OC SECTION

ASAT PRESENTATION

MAY 21, 2011

Agenda

- Team Introduction
- What is SLI?
- What project members learn
- Request for proposal
- Project Summary
- Vehicle Design
- Recovery
- Payload
- GPS System
- Flight Summaries
- Lessons learned
- Web Site
- Educational Outreach
- Questions

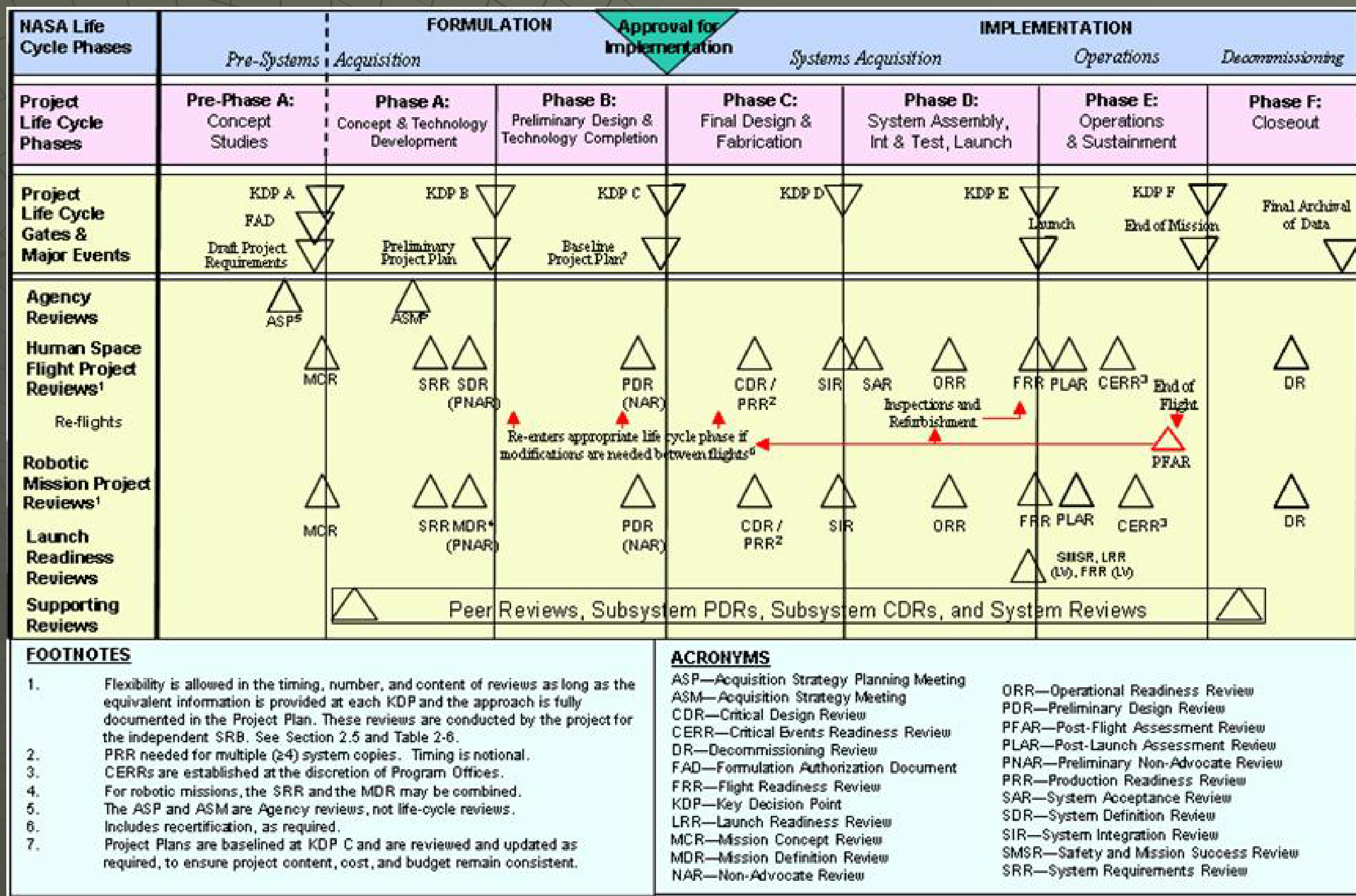
What is SLI

- NASA program by invitation only (Middle & High School):
  - Top 20 TARC (Team America Rocketry Challenge) teams
  - Top 2 Rockets for Schools teams
  - Awarded to school/organization of winning team – so team members can be added
  - If our first year is a success then the team is invited back for a second year
- Very different than TARC (or Rockets for Schools)
- This is not a contest
- Learning opportunity working with NASA including:
  - Design, construction, and test of a reusable launch vehicle and scientific payload

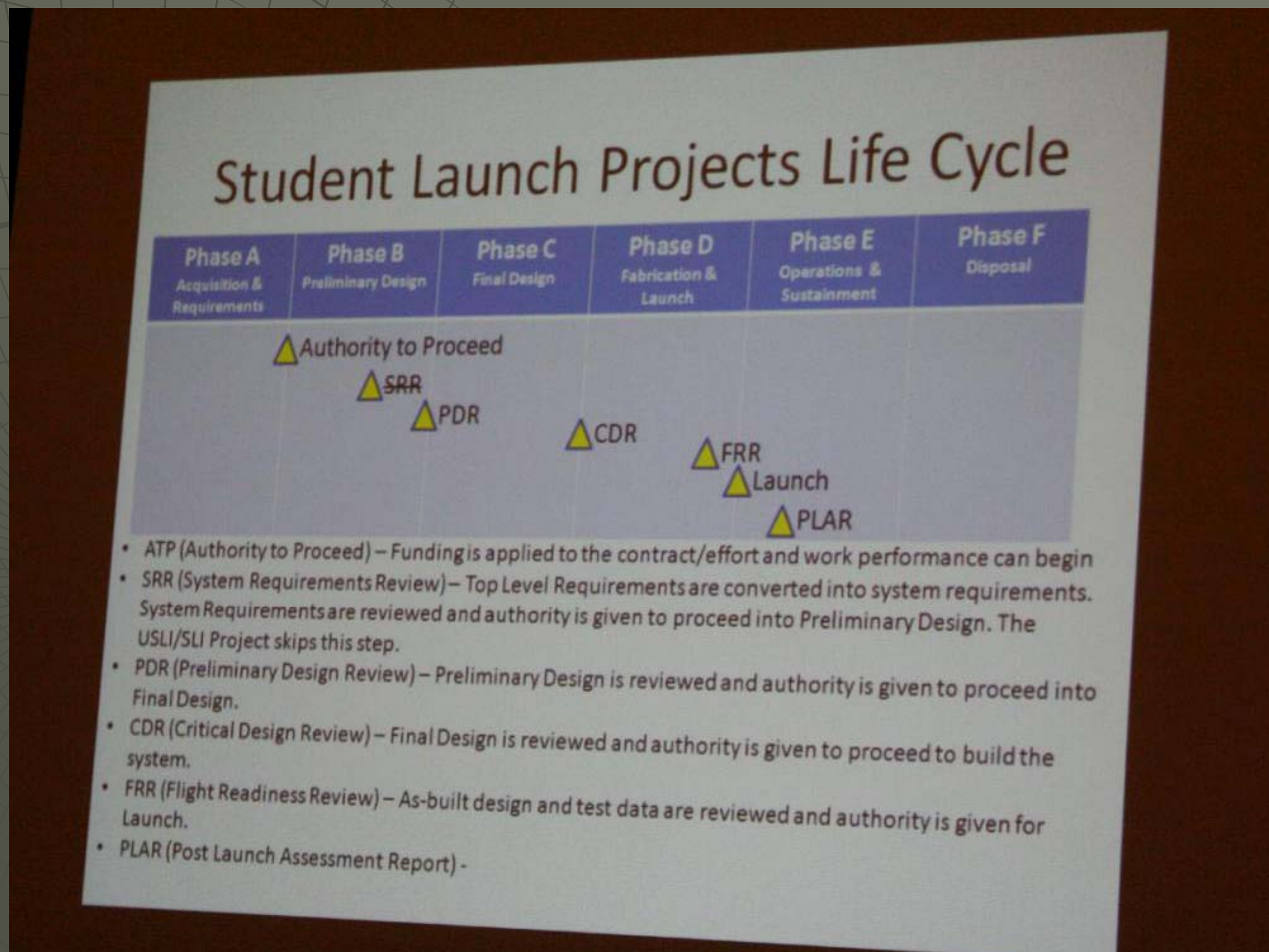
What is SLI (cont.)

- Requires an 8 month commitment
- The team learns and applies:
  - Design, construction, scheduling, purchasing, finance, logistic coordination, arranging press coverage, educational engagement, web site development, and documentation
- Teams members should have diverse interests & skills:
  - Engineering, mathematics, science, technology, English, journalism, art, and business
- Designed to interest students in Science, Technology, Engineering and Math
- Organized similar to NASA project life cycle

Project Members Learn Real Life Engineering Methods



Scaled down…


Student Launch Projects Life Cycle
Phase A
Acquisition & Requirements
Phase B
Preliminary Design
Phase C
Final Design
Phase D
Fabrication & Launch
Phase E
Operations & Sustainment
Phase F
Disposal
Authority to Proceed
SRR
PDR
CDR
FRR
Launch
PLAR
ATP (Authority to Proceed) – Funding is applied to the contract/effort and work performance can begin
SRR (System Requirements Review) – Top Level Requirements are converted into system requirements. System Requirements are reviewed and authority is given to proceed into Preliminary Design. The USLI/SLI Project skips this step.
PDR (Preliminary Design Review) – Preliminary Design is reviewed and authority is given to proceed into Final Design.
CDR (Critical Design Review) – Final Design is reviewed and authority is given to proceed to build the system.
FRR (Flight Readiness Review) – As-built design and test data are reviewed and authority is given for Launch.
PLAR (Post Launch Assessment Report) -

Teamwork

Presentation/People Skills

3 - WebEx with Marshall Space Flight Center

Youth Groups

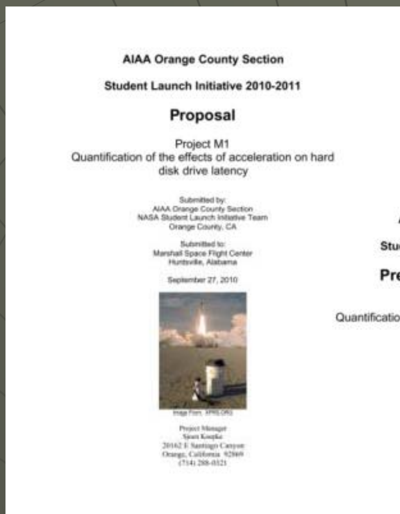
Youth Expo Fair

Huntsville Rocket Fair

Engineering Tools



Technical Writing


AIAA Orange County Section
Student Launch Initiative 2010-2011
Proposal
Project M1
Quantification of the effects of acceleration on hard disk drive latency
Submitted by:
AIAA Orange County Section
NASA Student Launch Initiative Team
Orange County, CA
Submitted to:
Marshall Space Flight Center
Huntsville, Alabama
September 27, 2010


AIAA Orange County Section
Student Launch Initiative 2010-2011
Preliminary Design Review
Project M1
Quantification of the effects of acceleration on hard disk drive latency
Submitted by:
AIAA Orange County Section
NASA Student Launch Initiative Team
Orange County, CA
Submitted to:
Marshall Space Flight Center
Huntsville, Alabama
November 19, 2010
Project Manager
Website: http://AIAAOCRocketry.org


AIAA Orange County Section
Student Launch Initiative 2010-2011
Critical Design Review
Project M1
Quantification of the effects of acceleration on hard disk drive latency
Submitted by:
AIAA Orange County Section
NASA Student Launch Initiative Team
Orange County, CA
Submitted to:
Marshall Space Flight Center
Huntsville, Alabama
January 24, 2011
Project Manager
Website: http://AIAAOCRocketry.org


AIAA Orange County Section
Student Launch Initiative 2010-2011
Flight Readiness Review
Project M1
Quantification of the effects of acceleration on hard disk drive latency
Submitted by:
AIAA Orange County Section
NASA Student Launch Initiative Team
Orange County, CA
Submitted to:
Marshall Space Flight Center
Huntsville, Alabama
March 21, 2011
Project Manager
Website: http://AIAAOCRocketry.org


AIAA Orange County Section
Student Launch Initiative 2010-2011
Post Launch Assessment Review
Project M1
Quantification of the effects of acceleration on hard disk drive latency
Submitted by:
AIAA Orange County Section
NASA Student Launch Initiative Team
Orange County, CA
Submitted to:
Marshall Space Flight Center
Huntsville, Alabama
May 9, 2011
Project Manager
Website: http://AIAAOCRocketry.org

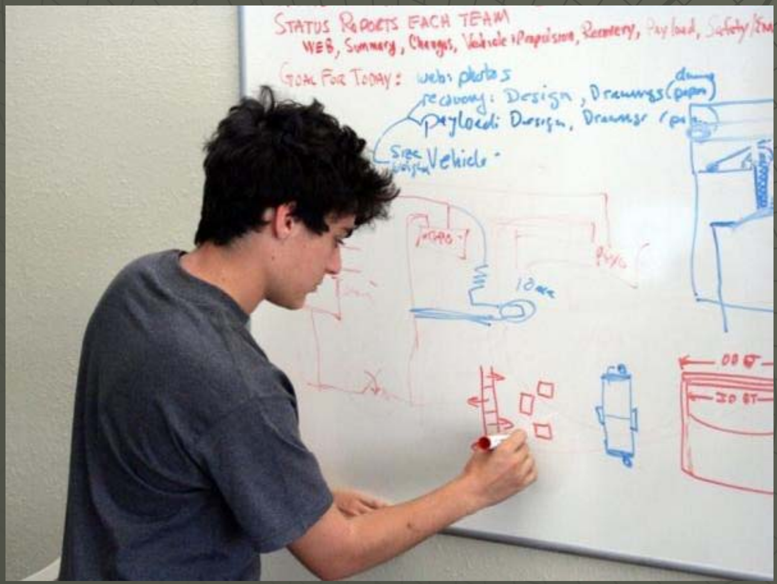
Nearly 300 pages with drawings in five separate documents

Proposal
Preliminary Design Review
Critical Design Review
Flight Readiness Review
Post Launch Assessment Review

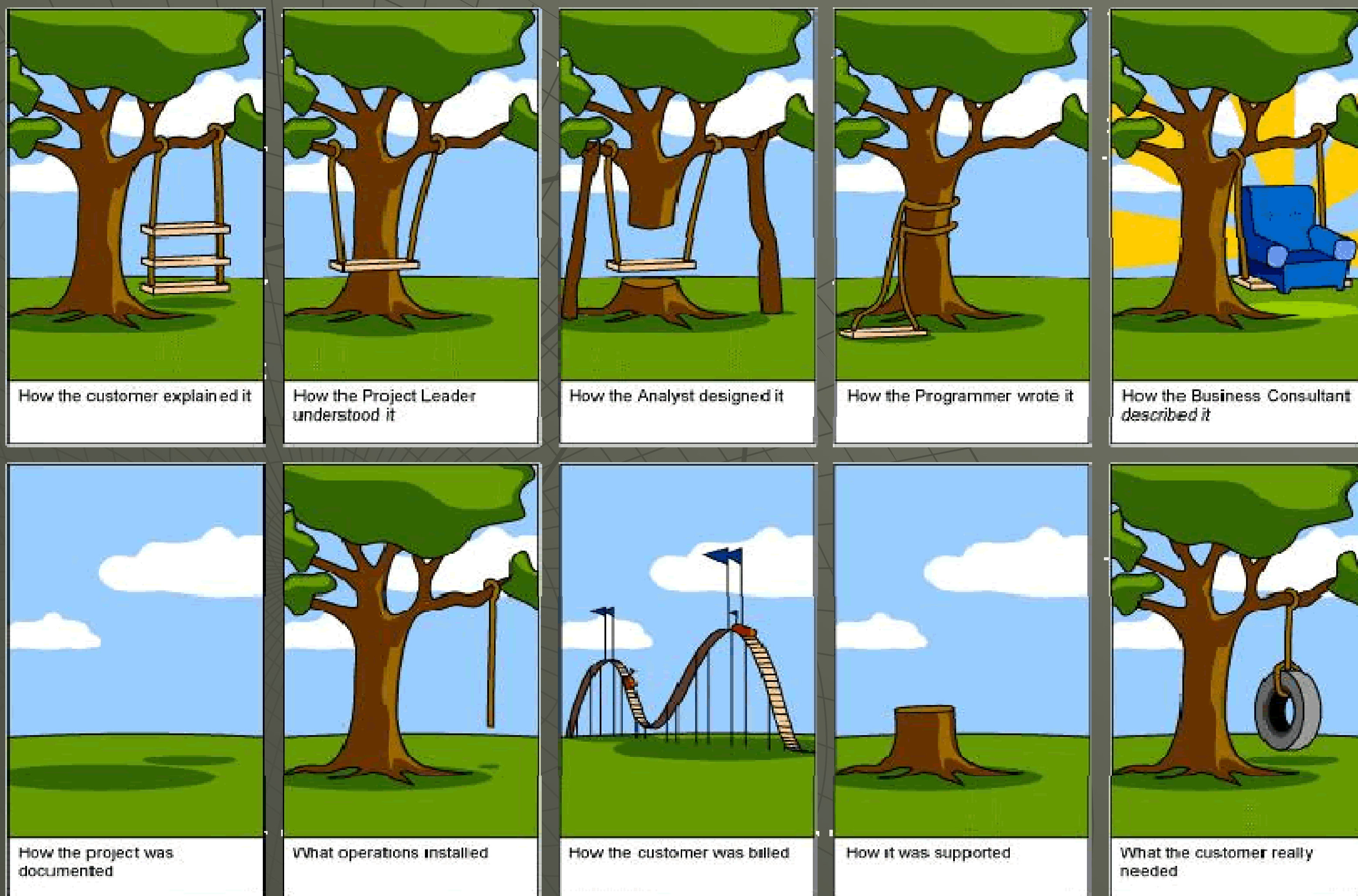
Communications…

I know that you believe you understand what you think I said,

but I'm not sure you realize that what you heard is not what I meant



… and Planning



NASA Request for Proposal

- Design a reusable vehicle delivering a science or engineering payload to an altitude of 1 mile
- The total impulse provided by the entire vehicle shall not exceed 2,560 Newton-seconds (“K” class)
- The vehicle shall remain subsonic from launch
- The vehicle must be prepared for flight in < 4Hrs
- Vehicle must return after flight within 2500 ft of pad
- The recovery system shall:
  - Use dual deploy (drogue at apogee + main at altitude)
  - Drogue: 50-100 ft/s Main: 17-22 ft/s
  - Use redundant altimeters armed on the pad
- The payload shall collect data and analyze that data using the scientific method
- Students must do 100% of the work

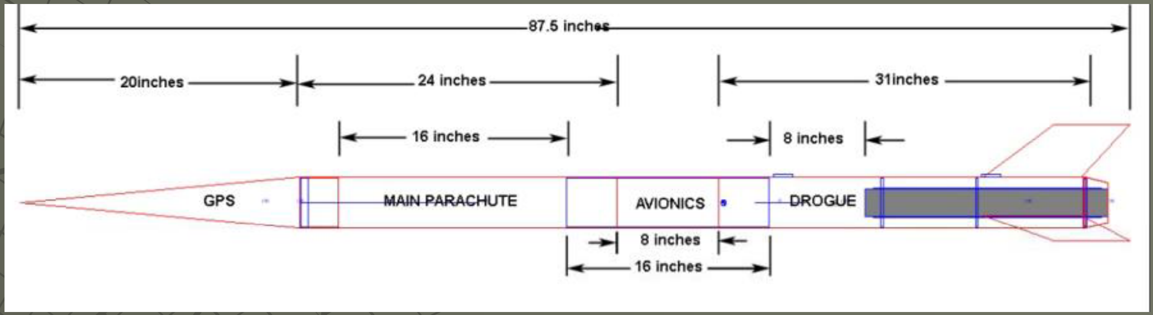
Project Summary

- Aug 2010 - NASA submits Request for Proposal
- Sept 2010 - We respond with our proposal
- Oct 2010 - NASA accepts our proposal
- Nov 2010 - Establish web presence
- Nov 2010 -Research, write, post and present (WebEx) PDR
- Dec 2010 – Jan 2011- Design, build and fly .65 scale model
- Jan 2011 - Research, write, and present (WebEx) CDR
- Feb - Mar 2011 - Build and fly full size rocket with payload
- March 2011 - Research, write, and present (WebEx) FRR
- April 2011 - Travel to Huntsville, exhibit at rocket fair and fly rocket
- May 2011 - Write and submit PLAR

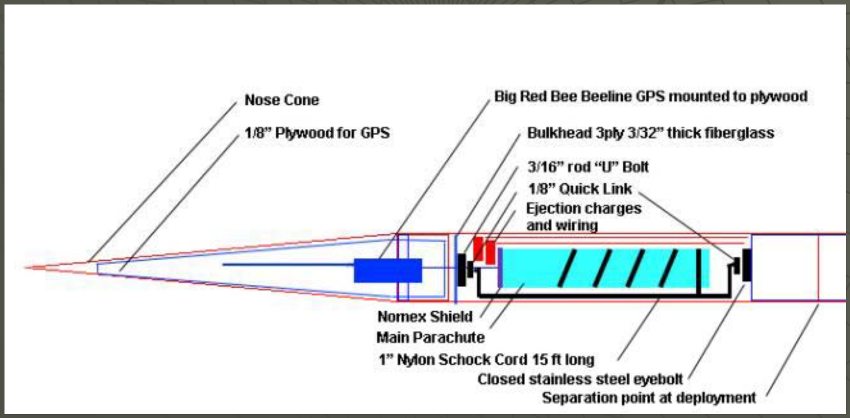
Vehicle Design – Black Brant

Parameter	Details
Length/Diameter	87.5 inches
Diameter	4 inches
Material (body and fins)	Fiberglass
Center of Pressure / Center of Gravity	62.02 inches / 52.48 inches (from tip of nose cone)
Stability Margin	2.36
Launch Rail type / Length	1 inch / 6 feet
Rail Exit Velocity	55 ft/sec
Weight liftoff/descent	17.75 lbs / 13.85 lbs
Motor (K635) Average Thrust	635 Newtons (142.75 lbs)
Thrust to weight ratio	8.04:1
Maximum Ascent Velocity	686.10 ft/sec (.60 mach)
Maximum Acceleration	434.94 ft/s/s
Peak Altitude	5266 ft

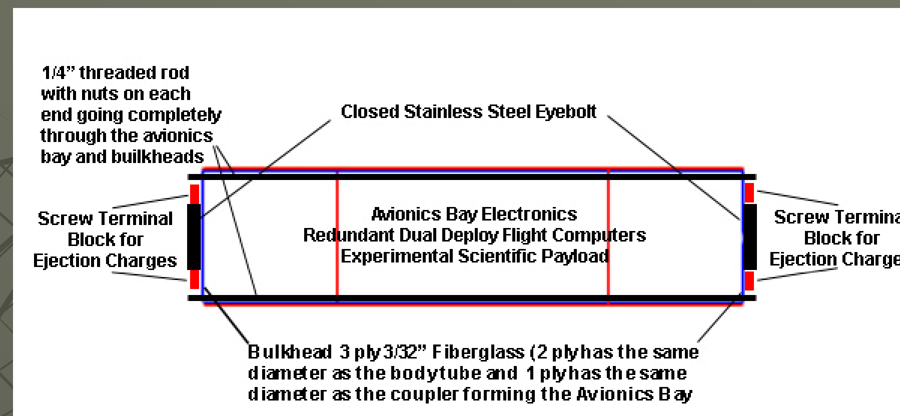
Vehicle - Details



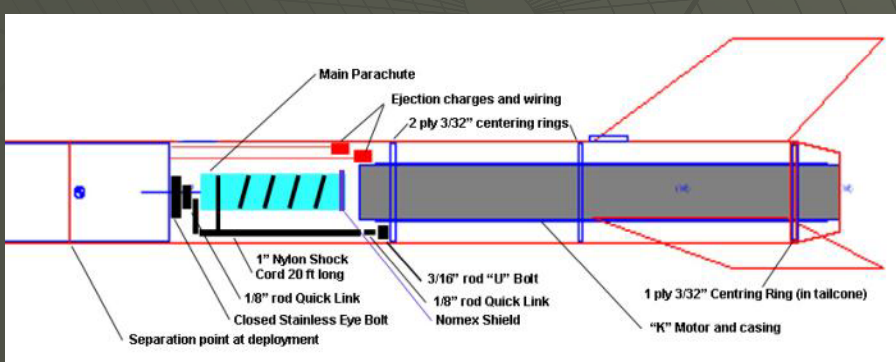
Forward Section



Avionics Bay



Aft Section

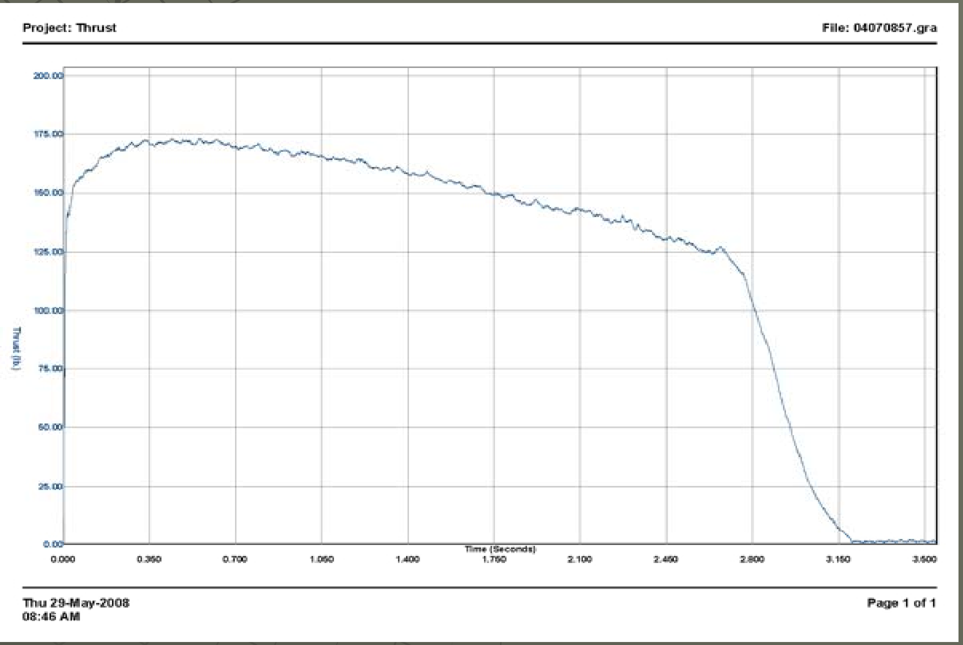


Engine

- Target altitude is 5,280 feet
- Vehicle must remain subsonic from launch until landing
- Motor must lift almost 19 pounds of vehicle and payload with GPS
- Once design was completed launches were simulated using Rocksim (a CAD program for rocket design and simulation)
- Motor selected is Cesaroni K635 Redline
- This selection gives margin if larger or smaller motor is required

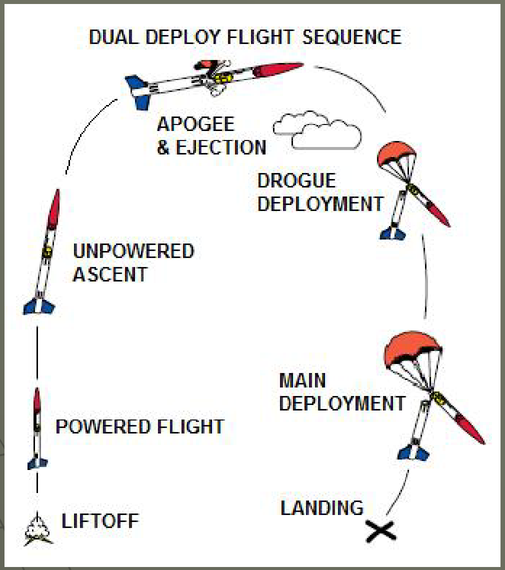
Cesaroni K635 Red Lightning

Brandname	Pro54 1994K635-17A	**Manufacturer**	Cesaroni Technology
Man. Designation	1994K635-17A	**CAR Designation**	1994-K635-17A
Test Date	7/6/2003		
Single-Use / Reload / Hybrid	Reloadable	**Motor Dimensions mm**	54.00 x 488.00 mm (2.13 x 19.21 in)
Loaded Weight	1989.90 g (69.65 oz)	**Total Impulse**	1749.50 Ns (393.64 lb.s)
Propellant Weight	1281.00 g (44.84 oz)	**Maximum Thrust**	728.70 N (163.96 lb)
Burnout Weight	658.40 g (23.04 oz)	**Avg Thrust**	656.00 N (147.60 lb)
Delays Tested	17 - 7 secs	**ISP**	139.30 s
Samples per second	1000	**Burntime**	2.66 s
Notes	Red Lightning™		



Recovery - Dual Deployment

- Electronics: MAWD Perfect Flight, HCX G-Wiz Partners
- The electronics will "back" one another up in case one pyro (either drogue or main) does not fire.
- Drogue Parachute will be deployed at apogee



- Backup charge at 2 seconds after apogee
- Main Parachute will be deployed at 900 ft
- Backup charge at 700 ft

Recovery Electronics

Main Flight Computer

- G-Wiz Partners HCX 56G
- 1.10” x 5.50” 45 grams
- Accelerometer based altitude
- Pyro output at Apogee
- Pyro output at 900 ft altitude
- 9VDC at 65ma for 3 hour battery life
- Separate CPU and Pyro batteries
- Two Safety interlock switch on body tube (1-CPU and 1-Pyro)

Backup Flight Computer

- PerfectFlite MAWD
- .90” x 3.00” 20 grams
- Barometric pressure based altitude
- Pyro output at Apogee + 2 seconds
- Pyro output at 700 ft altitude
- 9VDC at 8ma for 28 hour battery life
- One battery for both CPU and Pyro
- Safety interlock switch on avionics bay

Black Powder Charges

- Ejects both drogue and main parachutes
- Calculated by using an online calculator
- Need a minimum of 8.4 psi – we chose 16 and 20 psi to give safety margin
- Main 'chute uses 2.5 grams of black powder (on-line calculator)
  - Body tube with the main is 4" diameter x 18" long
- Drogue 'chute uses 1.74 grams of black powder (on-line calculator)
  - Body tube with the drogue is 4" diameter x 14" long

Black Powder Charge

Calculating the black powder charges is a two step process

- Pressure needed to shear pins (#2 screws - 3x35lbs each) and eject the parachute. We will use 200lbs (drogue) and 250 lbs (main) to shear pins, overcome friction and eject.

  Surface Area = $\pi * r^2 = 3.14 * 2^2 = 12.56\ in^2$

  For 200 lbs / 12.56 in^2 = 15.9 PSI

  250 lbs / 12.56 in^2 = 19.9 PSI

- Amount of black powder to reach that pressure
- Grams of Black Powder = $C * D^2 * L$

  Where: D = Diameter of the airframe in inches L = Length of the airframe in inches C = 0.006 for 15psi and 0.008 for 20 psi.

  For a 4” diameter airframe of 17” long, we require

  200 lbs (16 psi) = .0064 * 4^2in * 17in = 1.74 grams

  250 lbs (20 psi) = .008 * 4^2in * 17in = 2.17 grams (used 2.50g for added safety)

Parachute Size & Descent Rates

- Rocket mass = 221.65 oz
- Drogue chute diameter = 24 in.
- Main chute diameter = 72 in.
- Calculated projected velocity for each chute with online calculator and by hand
- $v^2 = 2F_D / (\rho)(C_D)(A)$
  - $C_D = 1.00$
  - $F_D = mg = (6.285 \text{ kg})(9.8 \text{ m/s}^2)$
- Hand: v_{drogue} = 60.99 ft/s   Online: v_{drogue} = 68.57 ft/s
- Hand: v_{main} = 17.43 ft/s   Online: v_{main} = 19.59 ft/s
- Required: Drogue 50-100 ft/s Main: 17-22 ft/s

Payload
What are we testing for

- Hypothesis is that high "G" forces and vibration will dramatically increase the latency time of a hard disk drive
- Method
  - Linux script gets a file from the hard drive
  - The script measures the time that takes
  - Record the time to the thumb drive
  - Repeat as fast as possible (approx 100ms)
- Control: Run test while stationary and record
- Experiment: Run same test at launch

Payload

- G-Wiz Partners HCX flight computer - measures acceleration of the rocket
- Toshiba hard drive – test subject; we will run a Linux script on the hard drive over and over again; the time the hard drive takes to run the script each time is measured
- Simple net computer/Linux computer – the mini computer that will execute the Linux script on the hard drive; it will be initialized automatically; the flight data will be recorded on a flash drive inserted into this computer
- Power converter – Keeps a steady flow of power to the payload components

Payload Details

On power up, the Linux computer starts executing a shell script that repeatedly writes and reads 32 K Bytes of zeros to the hard drive, logging the time this takes to a flash thumb drive

Program Source Code

```
#!/bin/sh
PATH=/bin
while true
do
   date >>/var/ftp/LEXAR/log.txt
   time dd if=/dev/zero of=/dev/sda2 bs=65536
      count=32 skip=64>>/var/ftp/LEXAR/log.txt
      2>&1
   time sync >>/var/ftp/LEXAR/log.txt 2>&1
   time dd if=/dev/zero of=/dev/sda2 bs=65536
      count=32 skip=128>>/var/ftp/LEXAR/log.txt
      2>&1
   time sync >>/var/ftp/LEXAR/log.txt 2>&1
   tail -n 10 /var/ftp/LEXAR/log.txt
done
```

Program Output (Log File)

```
Fri Feb 11 22:36:49 UTC 2011
8+0 records in
8+0 records out
real 0m 0.10s
user0m 0.00s
sys  0m 0.06s
Fri Feb 11 22:36:49 UTC 2011
8+0 records in
8+0 records out
real 0m 0.20s
user0m 0.00s
sys  0m 0.06s
Fri Feb 11 22:36:49 UTC 2011
8+0 records in
8+0 records out
real 0m 0.16s
user0m 0.01s
sys  0m 0.05s
```

GPS TRACKING

Transmitter in Vehicle

- Big Red Bee Beeline GPS
- RF: 17mW on 433.920 MHz
- Battery and life: 750mAh 10 Hrs
- Size: 1.25" x 3" 2 ounces

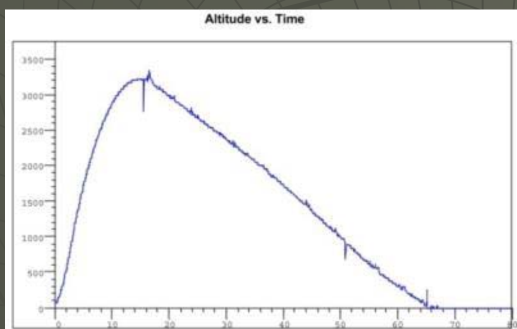
Ground Station

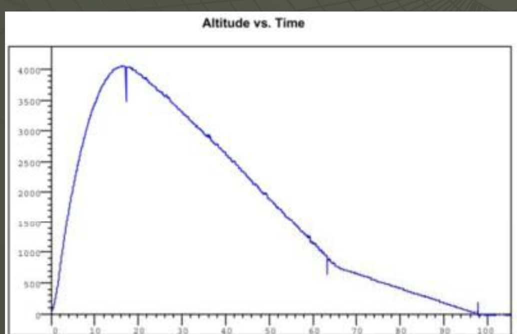
- Receiver: Yaesu VX-6R
- TNC: Byonics Tiny Track 4
- GPS: Garmin eTrex Vista

- Beeline receives GPS position
  - Encodes as AX.25 packet data
  - Sends as 1200 baud audio on 433.92 MHz
- VX-6R receives at 433.92 MHz and extracts audio
- TinyTrack 4 converts audio to digital NMEA location data
- Garmin displays the digital location data on human screen

Full Scale Test Flight Analysis





- First Flight (Partially Successful)
  - Cesaroni K400 (1597 Newtons 3.2 sec burn)
  - Wind was heavy (15mph)
  - Vehicle was stable but weathercocked
  - All ejection charges fired at proper times
  - Main did not fully deploy
  - Reached 3339 ft at apogee
- Second Flight (Fully Successful)
  - Cesaroni K500 (1596 Newtons 4 sec burn)
  - Wind was light/moderate (5-8 mph)
  - Vehicle was stable and flew straight
  - Drogue deployed just after apogee as programmed
  - Main deployed at 900 feet as programmed
  - Reached 4059 ft at apogee

Final Flight - Huntsville

Parameter	RockSim	Flight Data from HCX
Altitude	5266 ft	5512 ft
Maximum Speed (ft/s)	686 ft/s	643 ft/s
Maximum Air Speed (mach)	.61	.58
Altitude at maximum airspeed	1031 ft	980 ft
Maximum Acceleration (ft/s)	435 ft/s	284 ft/s
Maximum Acceleration (“G’s”)	13.59 G’s	8.82 G’s
Altitude of maximum acceleration	22.73 ft	31.28 ft
Time to booster burn-out	3.13 seconds	2.86 seconds
Altitude of booster burn-out	1234 ft	983.9 ft
Time to apogee	17.66 seconds	18.2 seconds

Full Scale Huntsville Flight Analysis

- Final Flight (Huntsville - Fully Successful)
  - Cesaroni K635 (1749 Newton sec 2.6 sec burn)
  - Wind was light (under 5 mph)
  - Vehicle was stable and flew straight
  - Drogue deployed just after apogee as programmed – backup charge ignited as well
  - Main deployed at 900 feet as programmed – backup charge went off at 700 ft as programmed
  - Reached 5512 ft at apogee

Payload Analysis & Results

- The final launch at Huntsville was not alike the last two launches, but we found an outstanding measurement in our data:
- 32+0 records in
- 32+0 records out
- real 1m 37.96s
- user 0m 0.00s
- sys 0m 0.22s
- real 0m 0.16s
- user 0m 0.00s
- sys 0m 0.03s
- The increase in force caused a tremendous increase in hard drive latency.
- Electromechanical hard drives are not suitable for launch—we recommend a solid-state drive.

Huntsville Launch Video

Construction Details

Process	Details
 	All fiberglass surfaces are fully scuffed and scratched before they are epoxied.
 	After scuffing the surfaces are fully cleaned with Isopropyl alcohol to remove dust and any oils or other contamination. All parts are epoxied together using West Systems Epoxy.
 	Since the bulkheads were only 3/32" thick, three bulkheads were glued together for added strength Fillets are applied to all joints for added strength

Construction Details cont'd

Process	Details
 	The Avionics bay uses closed eye bolts since the stresses at ejection can open eyes that are not continuous or welded shut "U" Bolts are used on the centering rings and top bulkhead also for strength
 	To assure things fit properly we dry-fit parts together and inserted an engine casing – centering ring "U" bolt, quick link, shock cord. To assure fins aligned properly we used a fin jig
 	Fiberglass tape was applied to the body tube – fin joint to help reinforce that area Whenever possible, ferrules were crimped on to the end of wires to keep the strands together and make certain there is good connection

Lessons Learned from this project

Lesson	Original Fault	Was it successful
Simplify wiring, color code everything, allow extra space, use ferrules to keep the wires together	The scale model avionics was too crowded, hard to trace. Some wires did not make good contact in terminal blocks	Yes it was successful but we learned we have to be careful so we don't stress the key switches
Always use shear pins to avoid drag or impulse separation	We did not use shear pins and we deployed the main when the drogue deployed	Yes because a subsequent flight deployed drogue and main separately as designed
Stick with your plan and do not let on-site "mentors" sway you	We listened to an on-site mentor when he said we did not need shear pins – rocket was too small	Yes – with all of our research, engineering, and design we did know better than he did
Always test in conditions closest to the final conditions	We tested our black powder charge without the parachute in place to verify the airframe would separate. We should have included the parachute	Yes – in subsequent ground tests successful on flight #2

Website

- AIAAOCRocketry.org
- SLI 2010-2011
  - Documents
  - Calendar
  - Photos/Videos
  - Manuals
  - MSDS

Educational Outreach

- Cloverdale 4-H club
- Girl Scouts workshop
- Girl Scouts Launch
- Presentation to AIAA Orange County Section
- Booth at Youth Expo promoting SLI, AIAA, and NAR
- Presentation to Tarbut V’ Torah High School
- Presentations to Sunny Hills High School Science classes to get involved
- Articles published in The Foothill Sentry and the Sunny Hills High School Accolade

Thank you AIAA for your support

Questions?