UCI Rocket Project

2007-2008

University of California, Irvine
Henry Samueli School of Engineering

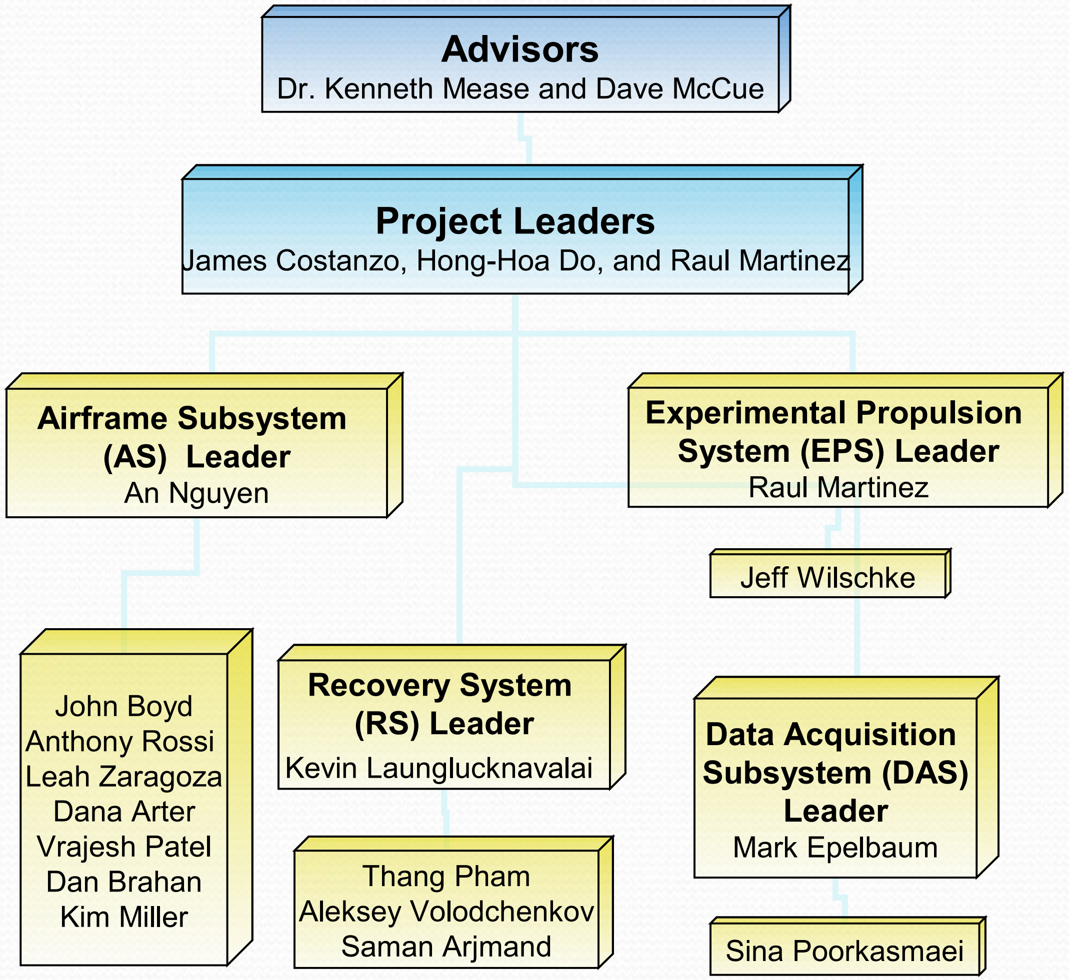
Advisors:
Dr. Kenneth Mease and Dave McCue

Members:
Hong-Hoa Do, Raul Martinez, James Costanzo, Jeffrey Wilschke, Mark Epelbaum, Anthony Rossi, Leah Zaragoza, Thang Pham, Kevin Launglucknavalai, John Boyd, An Nguyen, Aleksey Volodchenkov, Dana Arter, Vrajesh Patel, Saman Arjmand, Kim Miller, Dan Brahan

Goals and System Requirements

- Participate in Third Annual Intercollegiate Rocket Competition that hosted by the Experimental Sounding Rocket Association in Green River, Utah in late June.
  - Rocket must reach as close to 10,000 feet AGL as possible.
  - Rocket must accommodate a 10-lbs payload.
  - In-flight functions must be autonomously controlled by onboard electronics.
  - Recovery operations must be controlled autonomously by onboard electronics.
  - Recovery method must safely deliver the rocket back to the ground with minimal damage.
  - Flight data must be retrieved within 1 hour after recovery.
- Other goals:
  - Experimental motor must provide sufficient thrust.
  - Design and construction of motor must obey **ALL** local health and safety laws.
- **System Decomposition**
  - Airframe Systems (AS)
  - Data Acquisition Systems (DAS)
  - Recovery Systems (RS)
  - Experimental Propulsion Systems (EPS)

Team Organization



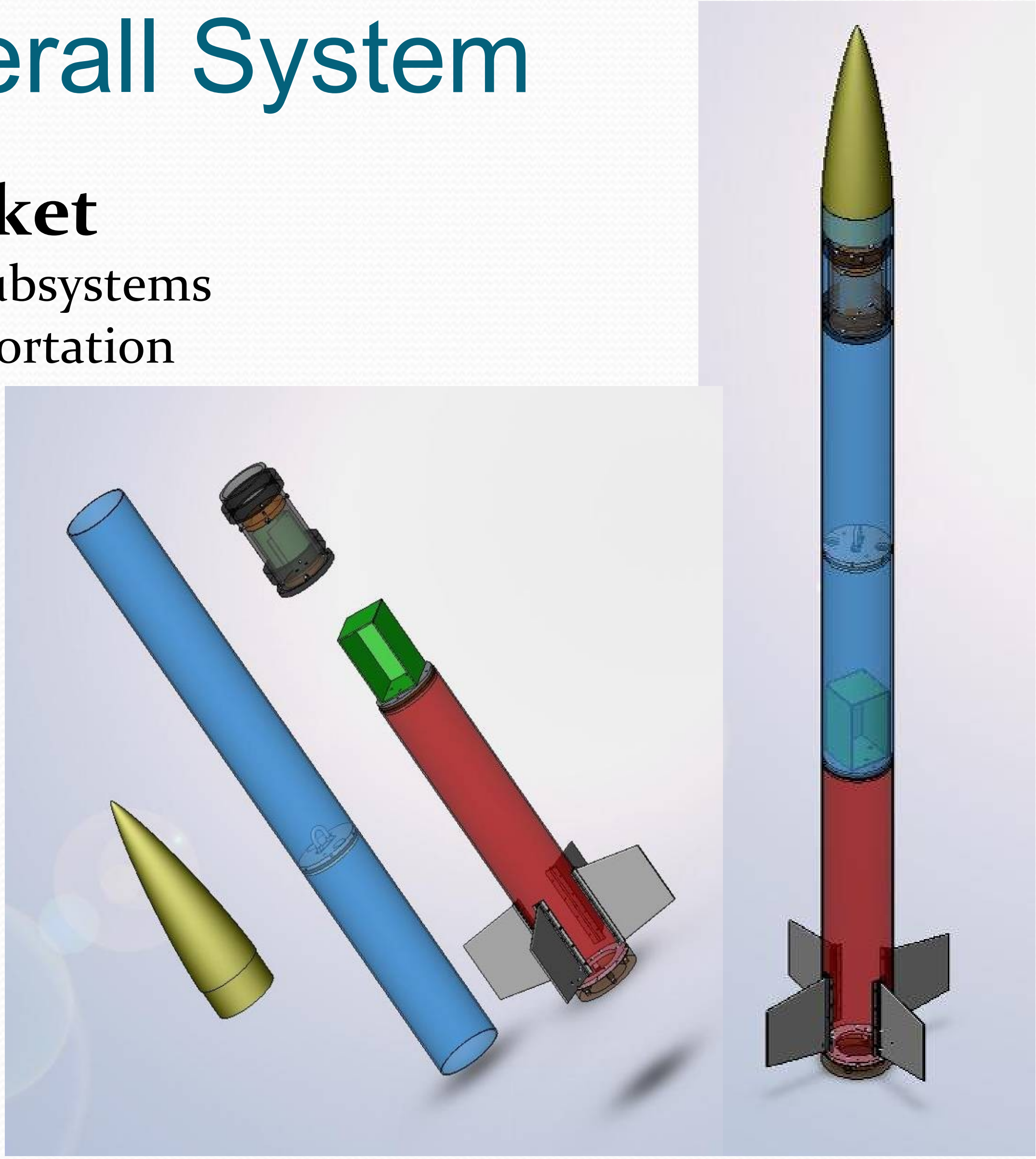
- Completely student led project
- 18 students from A.E, E.E.,M.E., and M.S.E.
- Main leaders meet with advisors weekly
- Sub-team leaders propose ideas to main leaders
- Weekly reports from subteam leaders, along with a project design review each quarter
- Subteams meet individually 1-2 times per week
- 2 general meetings per week with entire project and reports on status

Design of Overall System

- **Two-section rocket**
  - Easy accessibility to subsystems
  - Convenient for transportation

- **Four subsystems**
  - RS - (Blue)
  - DAS - (Green)
  - EPS - (Red)
  - AS - (Overall)

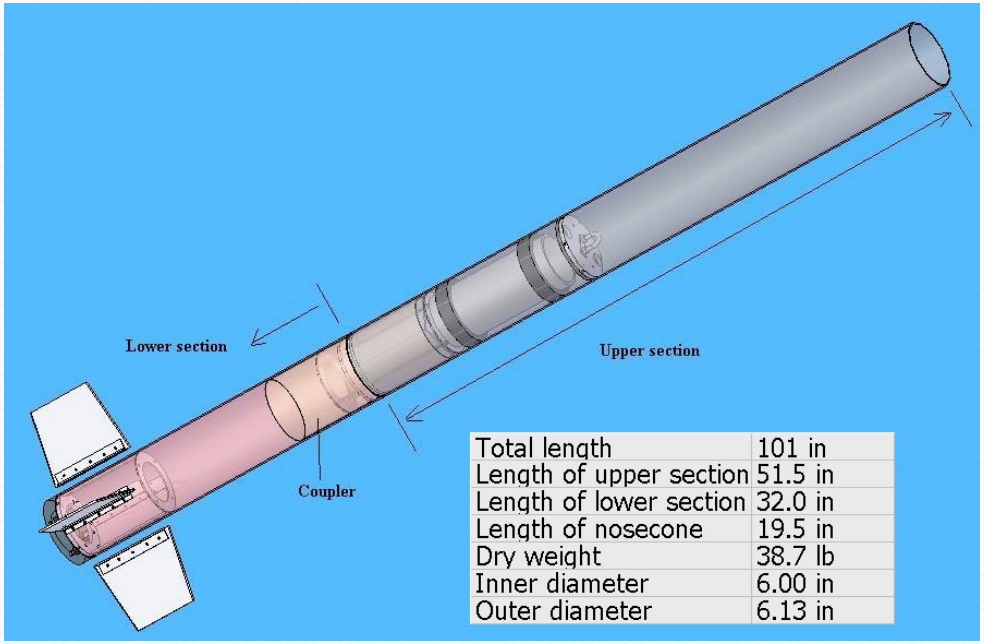
- **Propellant**
  - Consistent performance
  - Ease of operation



Student Designs

- Designed Von-Karman shaped nosecone to reduce drag
- Formulated several compositions of Ammonium Perchlorate Composite Propellant (APCP) to be used in experimental motor
  - Tested and gathered data
- Self-developed aerodynamic analysis code
  - Takes into account motor thrust curve as well as other factors
- Designed and built a 10-lbs payload to be used during rocket flight
  - Houses on-board electronics
  - Will record live video data during the rockets flight
  - Made of Ultra-High molecular weight polyethylene
- Aerodynamically accurate custom-shaped control surfaces

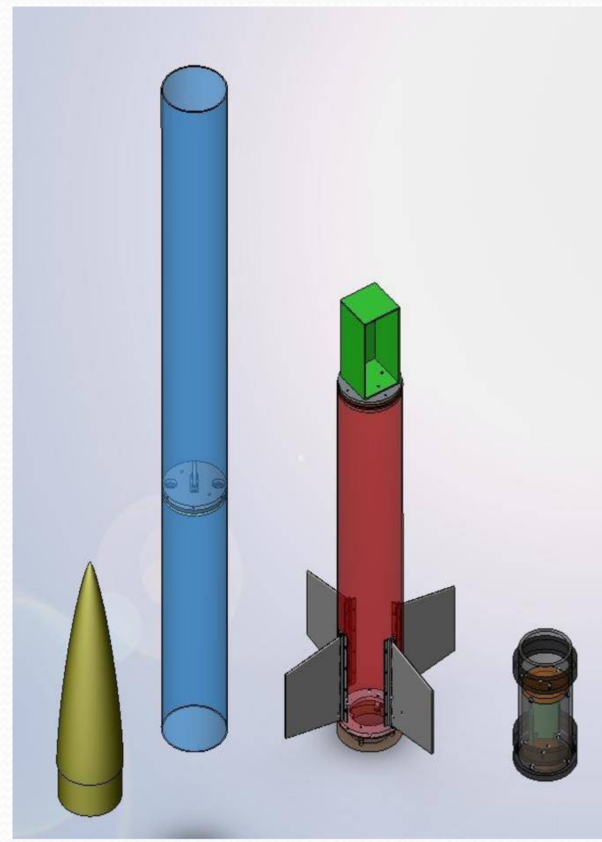
Airframe System



Total length	101 in
Length of upper section	51.5 in
Length of lower section	32.0 in
Length of nosecone	19.5 in
Dry weight	38.7 lb
Inner diameter	6.00 in
Outer diameter	6.13 in

Main Design:

- Light weight fiber-glass structure
- Two piece design for accessing electronics

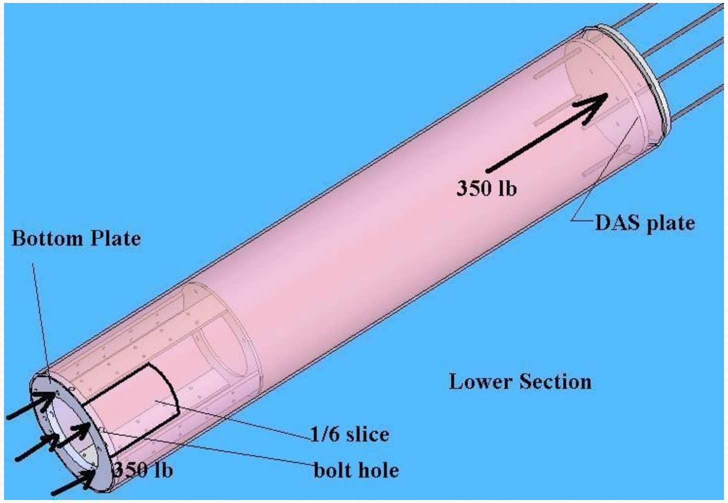


Requirements:

- To ensure smooth integration of other sub-teams components into the airframe
- To be as lightweight as possible
- To survive thrust and impact landing load

Structural Analysis

- For Parachute deployment and Landing
- Last year flight data shows:
  - → 10G impulse @ deployment
  - → 14G impulse @ landing



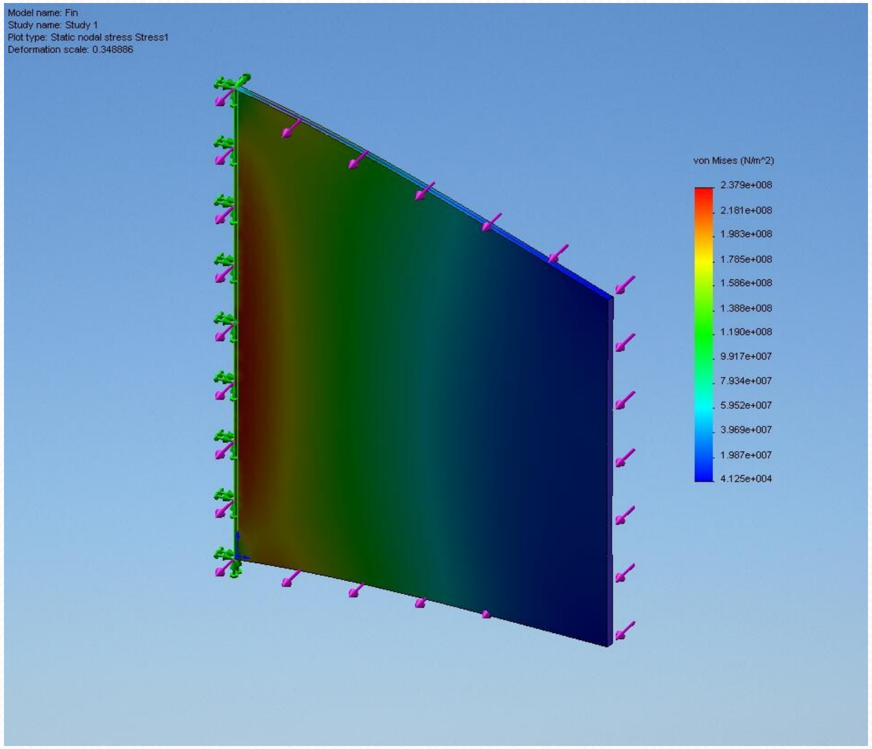
Fundamental Equations:

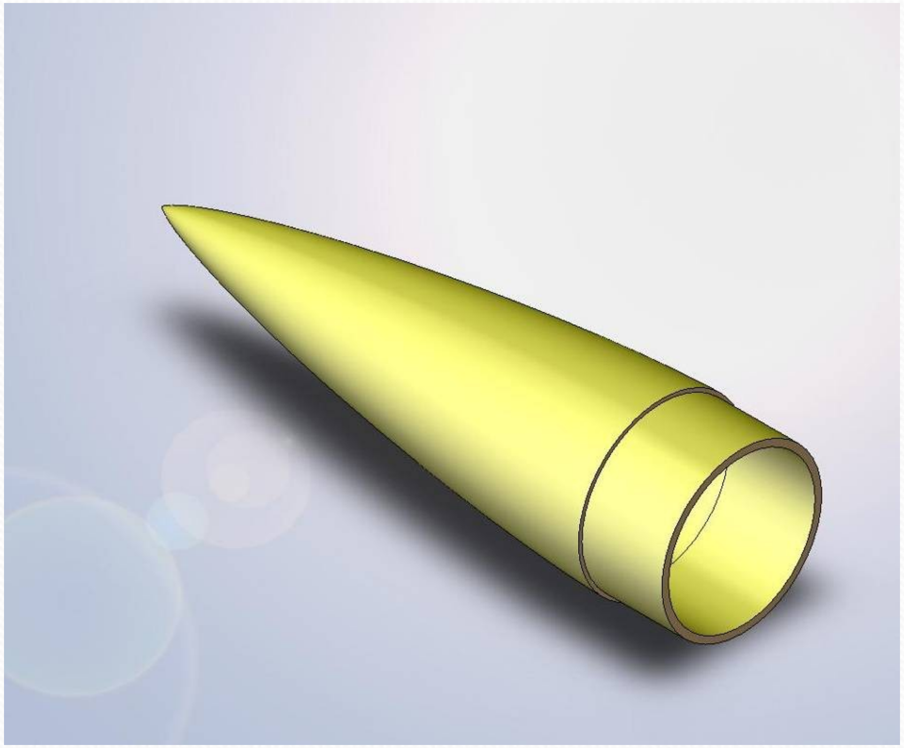
- σ_{ave} = P/A, where P is applied force, A is reference area
- $\sigma_{max} = k*\sigma_{ave}$, where k is compression factor
- n = Sy / σ_{max}, where n is the factor of safety (chosen as 1.3) and Sy is yield strength

From these equations, we found the minimum yield strength of the skin at 7.07 ksi, and therefore bought 10ksi strength fiberglass tubing

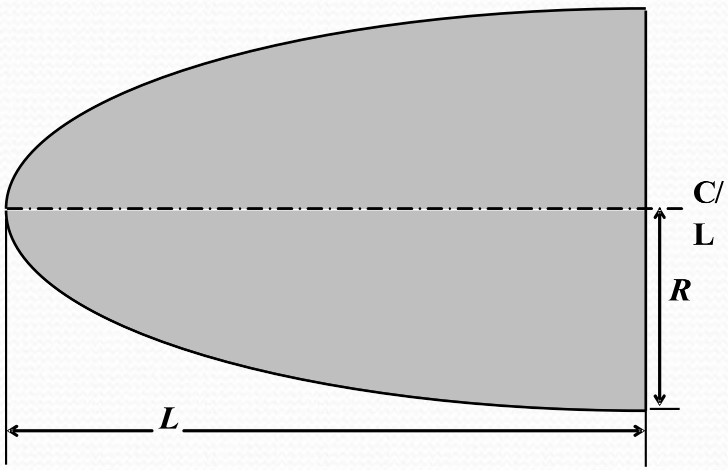
Aerodynamic Analysis

- Height and stability analysis
- Manufacturing of nosecone and fins
- Drag reduction
- Self-developed code and CFD confirm simulation analysis





Nosecone: Von Karman



HAACK drawing TBD

$$y = \frac{R\sqrt{\theta - \frac{\sin(2\theta)}{2} + C\sin^3\theta}}{\sqrt{\pi}} \qquad \theta = \cos^{-1}\left(1 - \frac{2x}{L}\right)$$

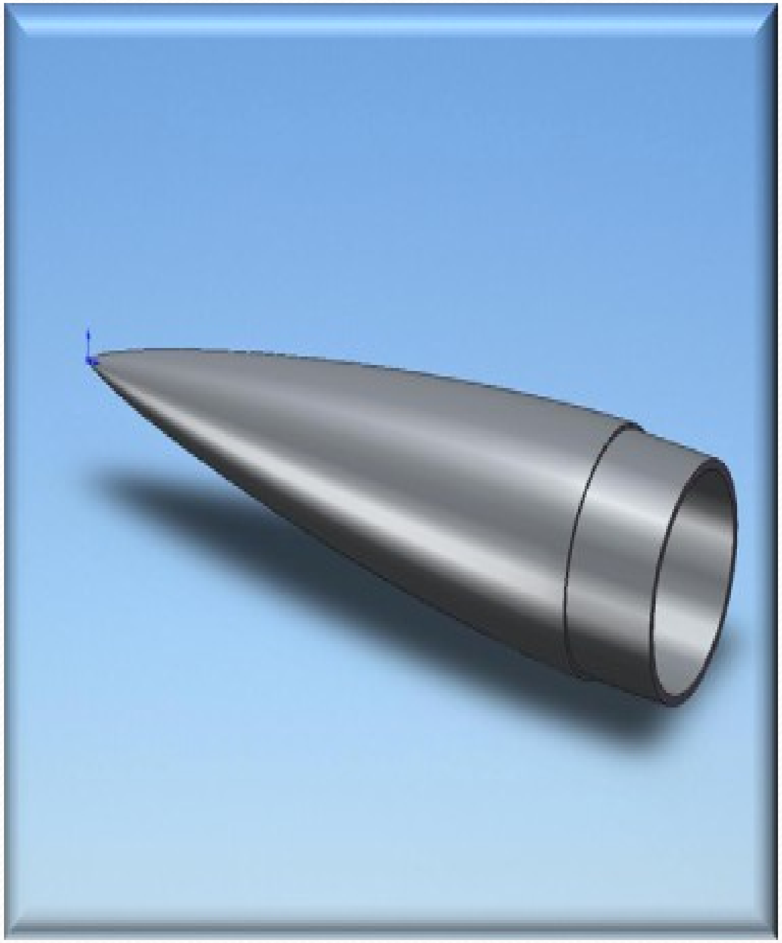
- Based off of Haack Series were C = 0 for Von Karman
- It minimizes wave drag for any given length and diameter
- In addition, the Von Karman is a common nose cone for above Mach 1 applications including missiles and military aircrafts

Why Not Conical?

- Because they make shock waves which lead to a loss in energy which in turn increases drag.
- The strength of the shock wave in a conical nose cone is greater so you get more drag.
- In addition, if the cone isn't developed correctly then the flow can't make it passed the turn angle and separation occurs.
- Also, the angle would be larger than we would like since the length of the nose cone is a limiting factor.

Manufacturing

- Used Solidworks to create model
- Male mold made from foam
- Female mold made from Bondo
- Vacuum bag fiberglass
- Bring two halves together
- Redo Base to fit in Rocket
- Fill in Divets and Sand
- Laminate

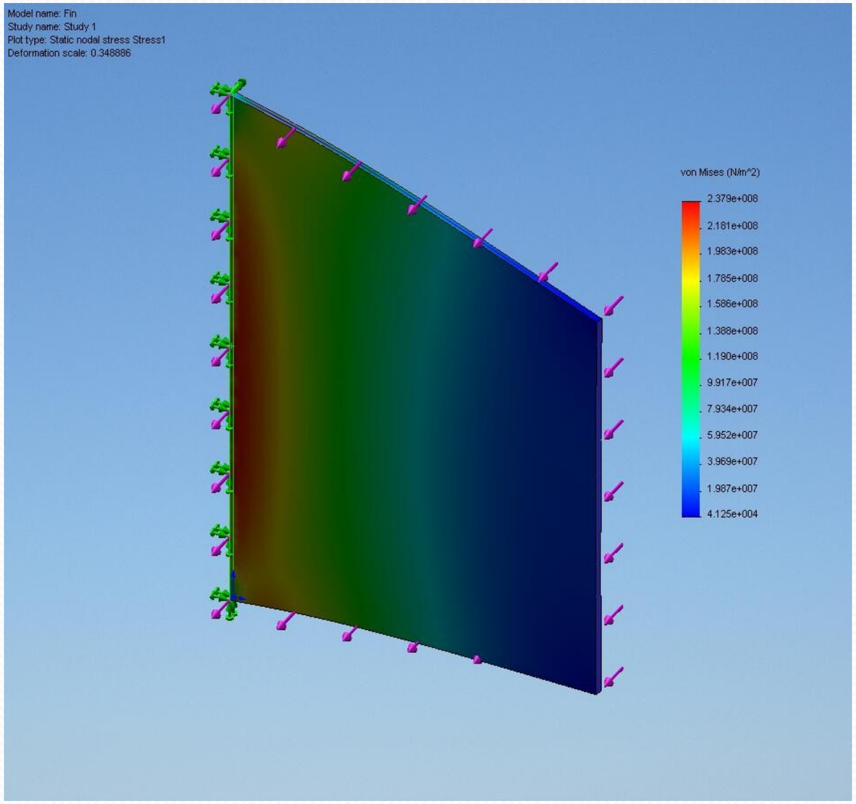


Fins

- Trapezoidal in Shape
- Larger surface area for more stability
- But increases drag
- We have calculated, from Barrowman's equations, that the center of pressure is about two diameters behind the center of mass

Fin Material and Manufacturing

- Made from G10-FR4 Garolite
- COSMOS analysis
- Cut from sheet and sanded down to size
- Leading edge rounded
- Trailing edge pointed



Coding

- Matlab
- Based off of Sounding Rocket Equations
- Integrate thrust curve
- Finds flight variables
- Used the Monte Carlo method/model (hence the shirts)

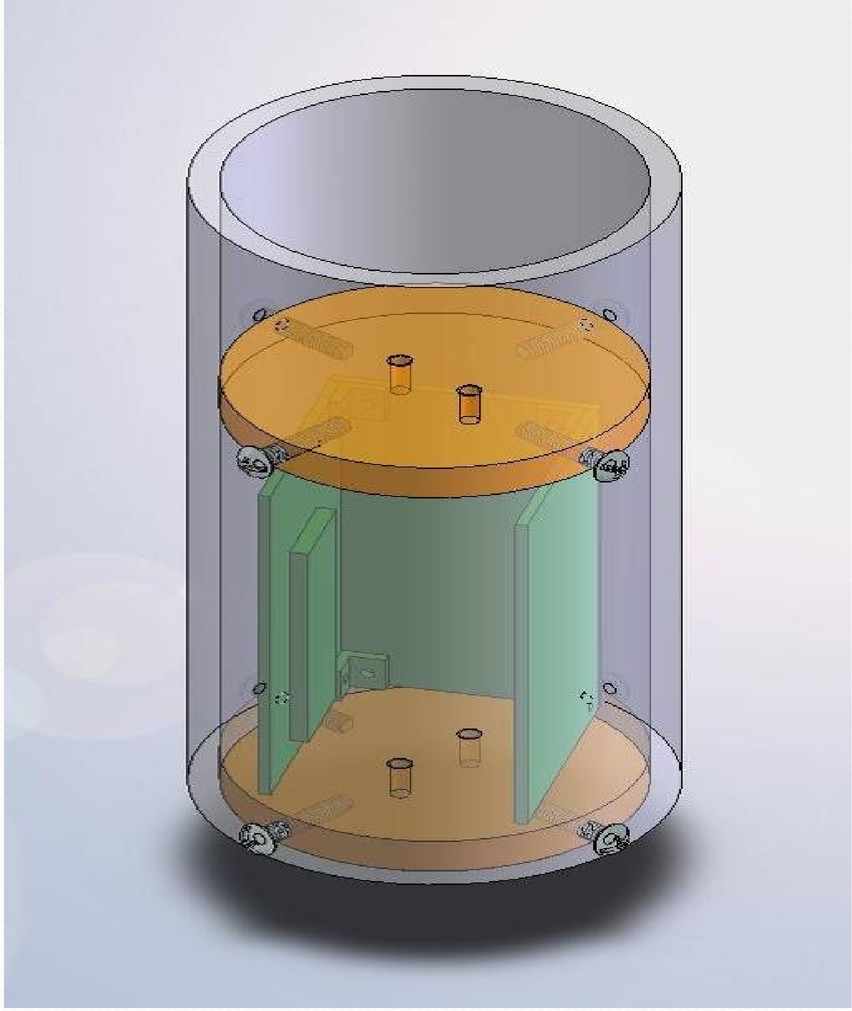
Payload Design

Dimensions:

- Total Length: 1 ft
- Outer Diameter: 5.035 in
- Inner Diameter:
- 4.385 in

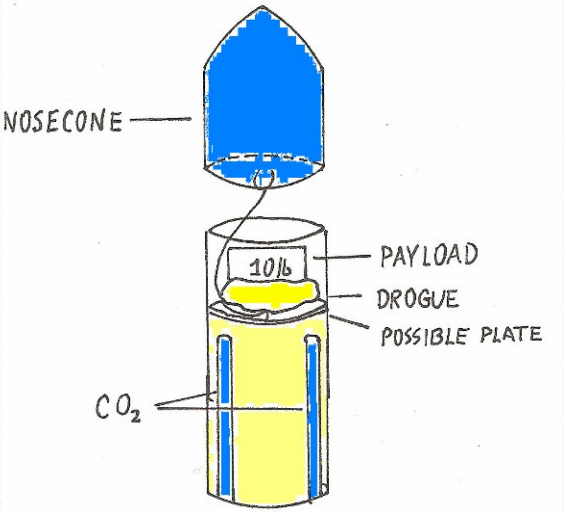
Material:

- Ultra-High Molecular Weight (UHMW) Polyethylene

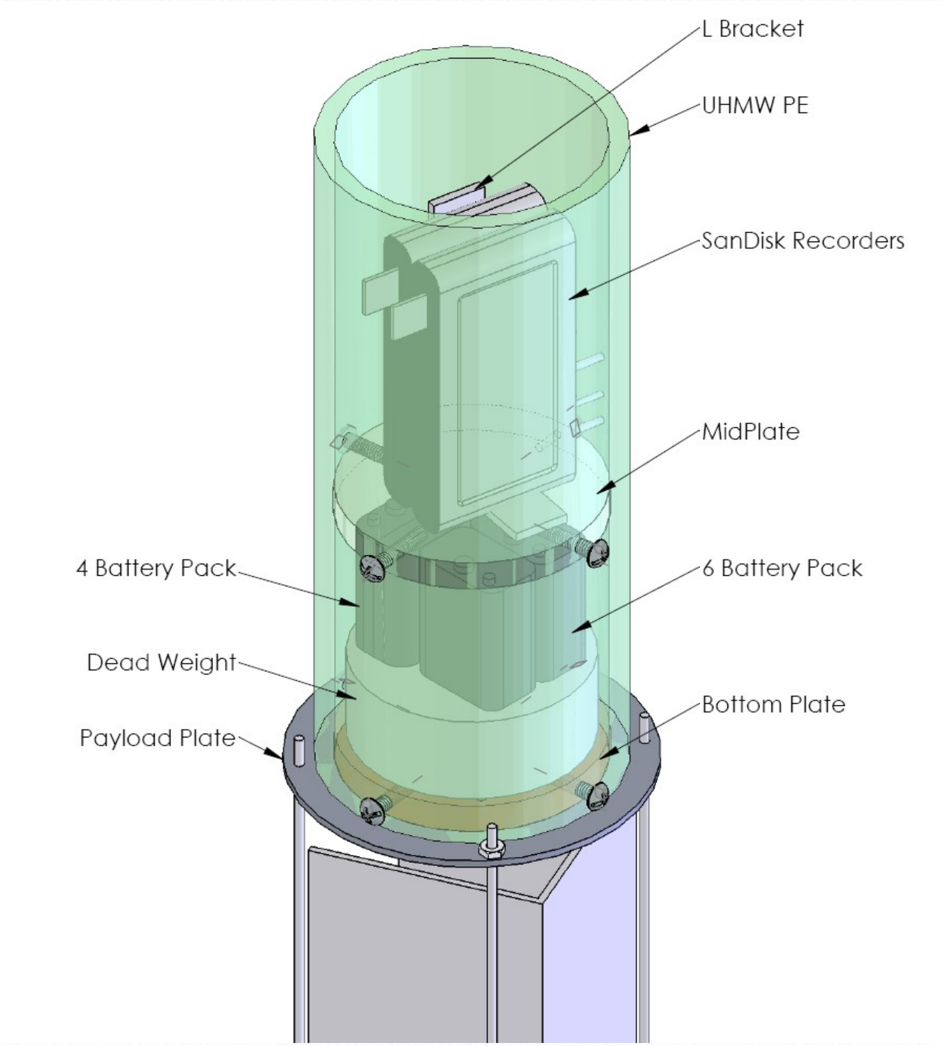


Payload Concept

- Designed for deployment via CO_2 expansion in the recovery system
- Performed multiple mock deployment tests
- Determined deployment idea was not feasible due to insufficient force



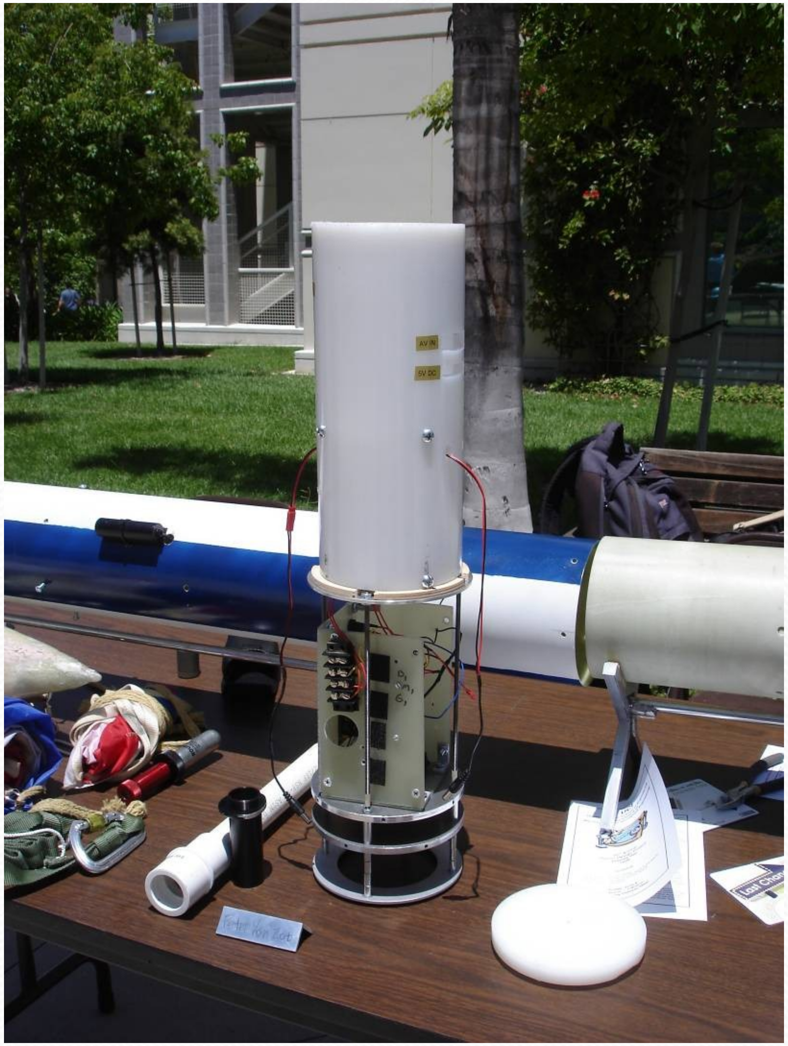
Payload Purpose



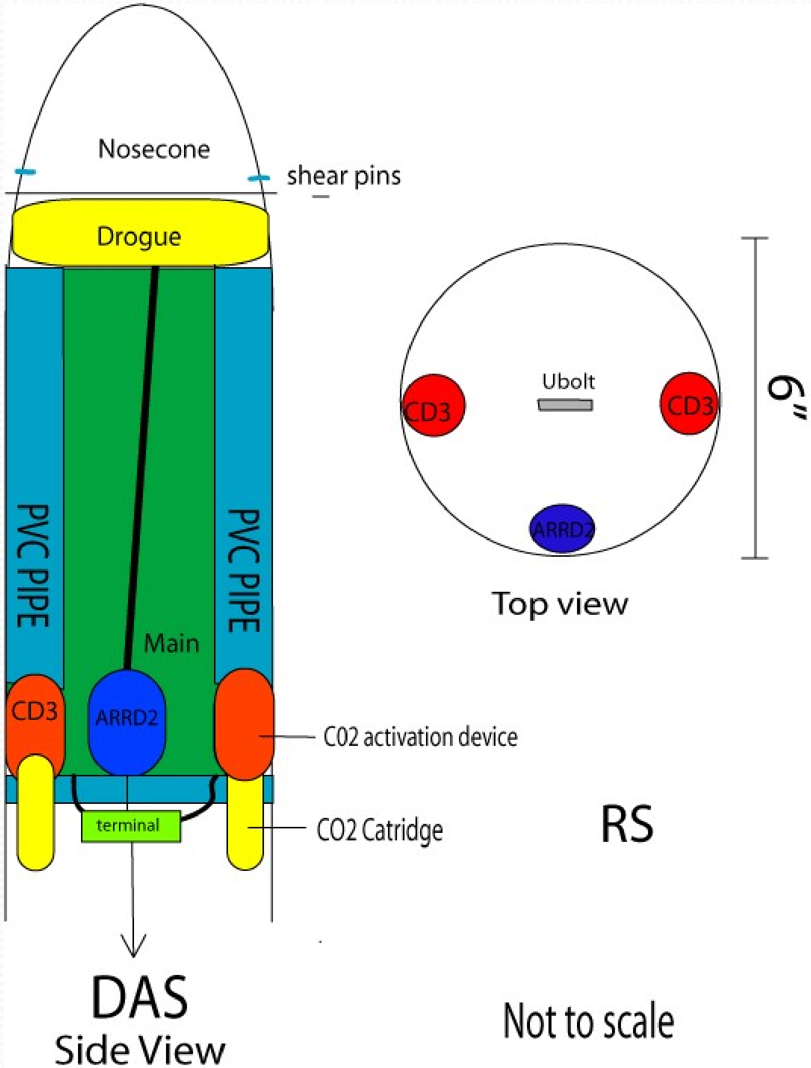
- Houses Sandisk recorders for recording camera video input
- Holds batteries for powering cameras and recorders
- Satisfies 10 lb requirement for competition

Assembly in Rocket

- Located on Payload System (PS) plate between Data Acquisition and Recovery Systems
- Contains holes that provide IR remote communication with Sandisk recorders on launch pad



Recovery Systems



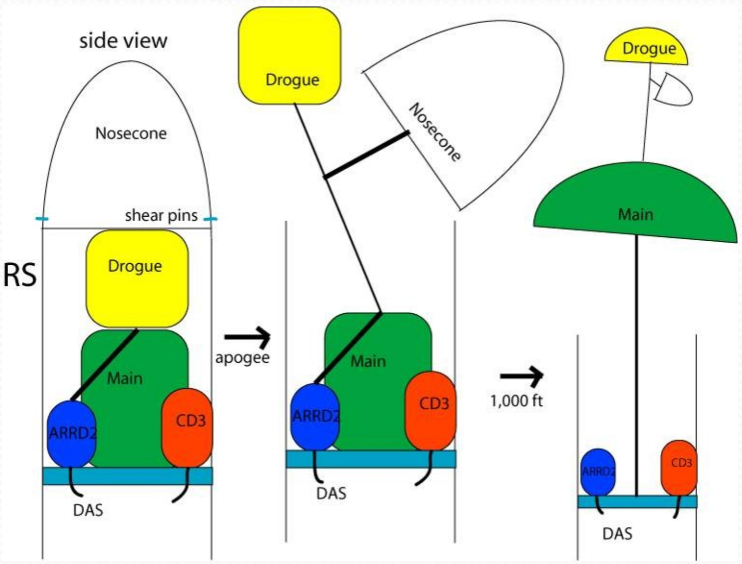
Requirements:

- Rocket touches down on ground at 14.9 ft/s with no damage to rocket integrity
- Recovery be a reusable system

Decisions:

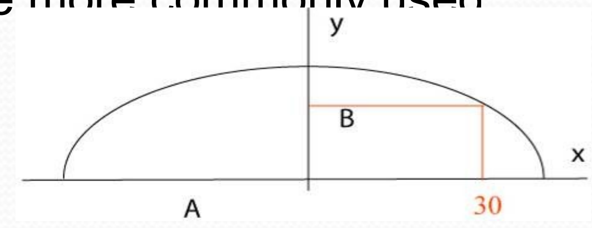
- Two stage deployment for faster recovery time
- Carbon Dioxide method for nosecone and payload ejection because no risk of fire damage
- Repair and manufacture parachute for design, test, and manufacturing experience

RS - Implementation



Deployment:

- Preliminary load analysis shows that shock plate will withstand largest parachute force
- All materials chosen to withstand large varying and unpredictable forces of the parachute deployment [i.e.. Rip Stop Nylon, Tubular Nylon]
- Carbon Dioxide deployment method is safe and is also easily adapted for higher altitude deployment unlike the more commonly used black powder



Parachute:

- Used Newton's Laws to calculate for size of parachute
- Thread and seaming method withstood sufficient forces when testing
- Repairing parachute from last year is a feasible solution if manufactured parachute does not meet required tests and benchmarks

$$F_{drag} = \frac{1}{2} p\, A\, C_d v^2$$

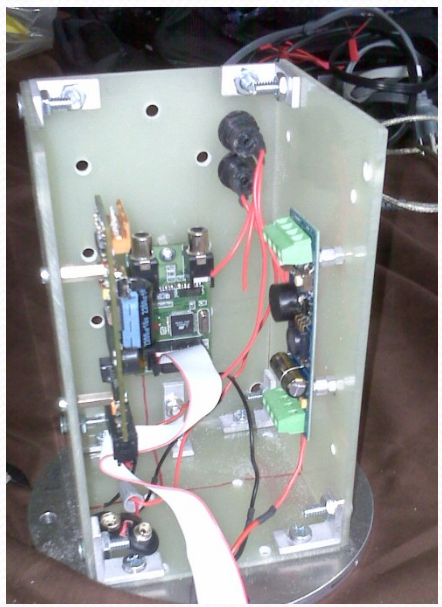
Data Acquisition System

Goal:

- Deploy critical systems and log all flight data for post analysis

Requirements:

- Deploy drogue and main chutes and log apogee altitude



Devices:

- 4”x4”x6” Electronics grade fiberglass box
- Houses: R-DAS and peripherals., RRC-X power
- Missile Works RRC2-mini used as redundant pyro and required altimeter (9V battery)

Missile Works RRC-X

Data Acquisition (Cont.)

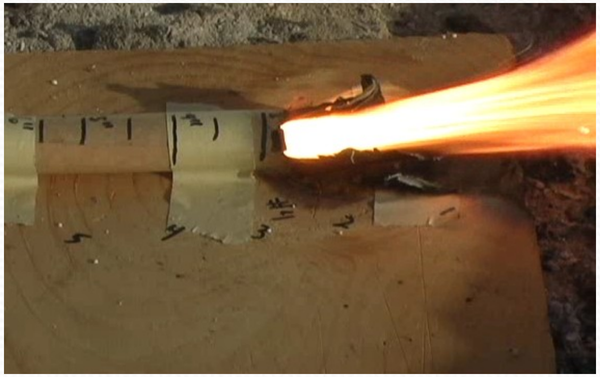
- **RDAS Capabilities**
  - Four independent igniter ports
  - Dual axis accelerometer
  - Pressure sensor
  - Expansion port
  - USB interface
- **On-Screen-Display (OSD)**
  - On screen information: elapsed time, altitude, acceleration, GPS position, etc.
- **Global Position System (GPS)**
  - Data-logging of: x, y, z and velocity
  - Actual flight path able to be mapped out on Google Earth

R-DAS

OSD GPS GPS Antenna

Propulsion System

- **Goal:**
  - Propel rocket to 10,000 ft AGL
  - To characterize a dependable solid composite propellant
- **Requirements:**
  - Must deliver required thrust to achieve appropriate altitude
  - Motor must be easily incorporated into the Rocket
  - Propellant must be intrinsically safe, will not ignite easily, and not be susceptible to detonation within combustion chamber



Manufacture

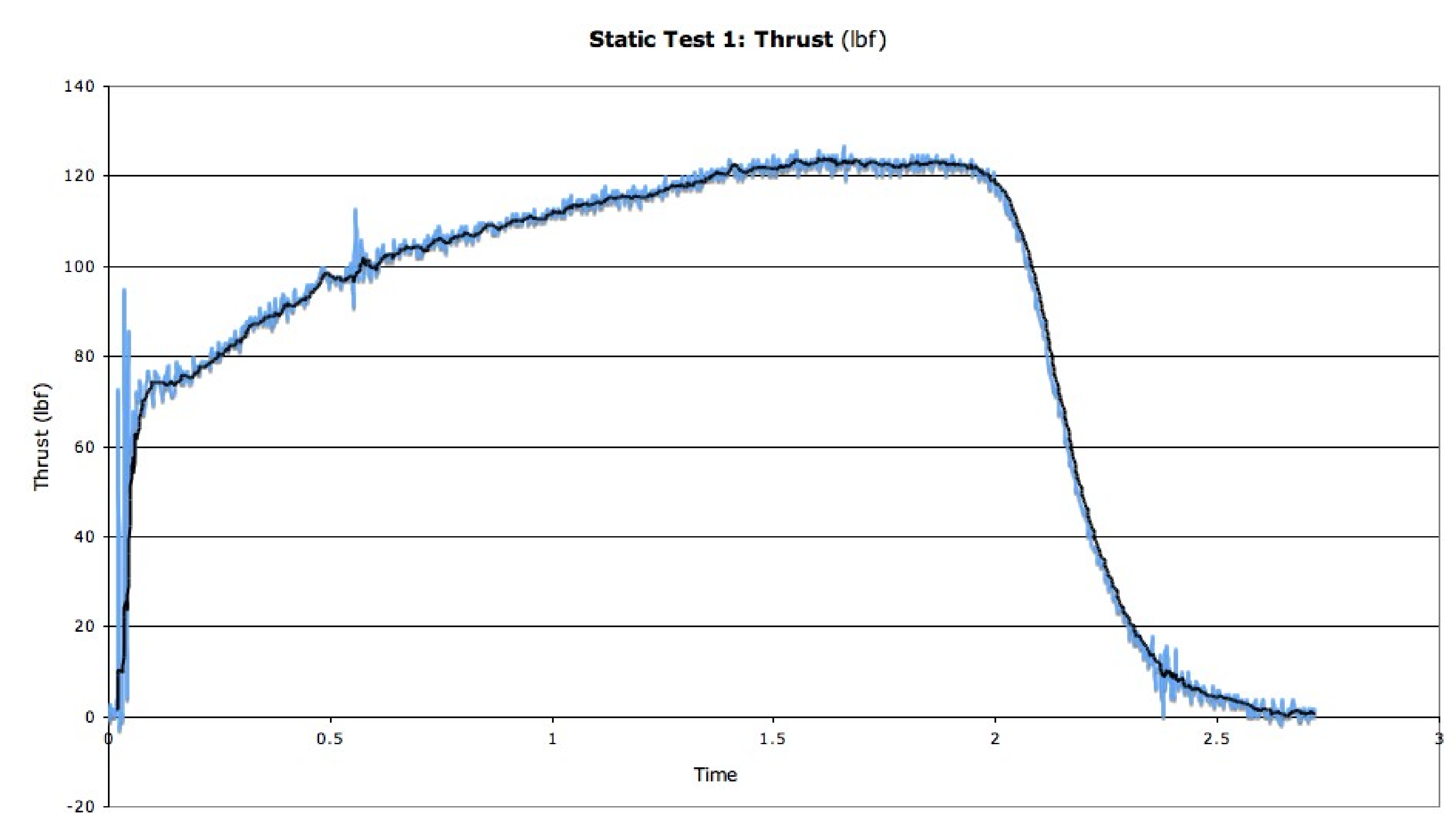
Process:

- Went out to Friends of Amateur Rocketry (FAR) facility
- Selected propellant from preliminary tests to make a enlarged batch
- After curing, propellant was tested in a small scale motor

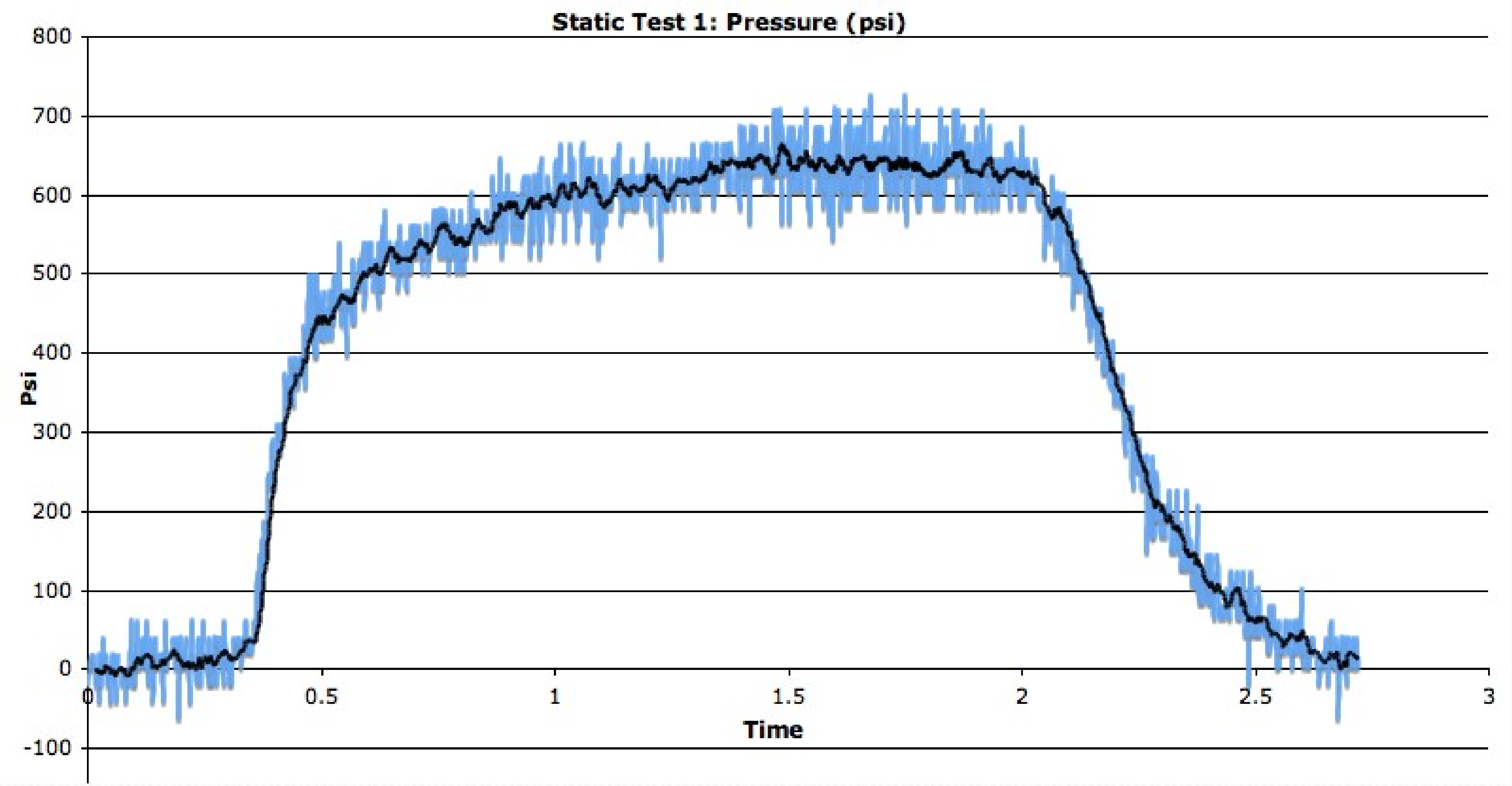
Testing

- Small scale motor was equipped with a pressure transducer and a load cell
- Data acquired from small scale experiments were analyzed to compute pressurized burn behavior in a full scale motor
- This experiment was conducted twice, each at a different combustion chamber pressure

Data From Test Results



Data From Test Results



Full Scale Motor

Scaling Up

- Using the same composition and calculated burn characteristics we scaled up the motor

Full Scale Testing

Results: Due to static test stand failure, motor casing was damaged and we had to resort to an alternative backup. This occurred on Sunday, June 22…5 days ago.

Plan B

- We chose the Aerotech M1939 motor
  - Previous successful launch record
  - Hardware was available from last year's project
  - Adjusting the rocket's mass, the motor will produce sufficient total impulse (2355 lb-s) to reach altitude

Bill of Materials

Item No.	Qty.	Unit	Description	Unit Price	Extension
1	1	2	CD3 components	-	$325.00
2	1	2	Tubular Nylon	$40.00	$40.00
3	1	25	Electric Matches	$0.80	$20.00
4	1	1	Caribeener	$10.00	$10.00
5	1	1	Nylon Thread	$40.00	$40.00
6	1	1	Black Powder	$20.00	$20.00
7	1	-	Ripstop Nylon Fabric	-	$300
8	1	1	Misc. (PVC pipes, Shear pins, etc.)	$12.50	$25.00
9	1	1	Black Powder	$12.50	$25.00
10	1	1	UHMW Polyethylene Round Tube	$26.50	$26.50
11	1	2	UHMW Polyethylene Rod 5" Diameter, 3" Long	$12.50	$25.00
12	1	2	Sandisk V-Mate Recorder	-	-
13	1	2	Cameras	-	-
14	1	20	AA Rechargeable Battery 700mAh NiCd 1.2v	$1.20	$24.00
15	1	2	Four AA battery pack	$1.79	$3.58
16	1	2	Six AA battery pack	$2.00	$4.00
17	1	1	Steel cylindrical weight	-	-
18	100	1	1/4"-20 screw 3/4" Long	$6.08	$6.08

Bill of Materials

19	1	1	1/4"-20 screw 1 1/2" Long	$0.85	$0.85
20	1	1	Hook and Loop Velcro pack with adhesive,	$9.82	$9.82
21	1	1	Zinc-plated Steel L-bracket	$1.83	$1.83
22	1	4	Threaded rods 10-24,	$0.81	$3.24
23	1	1	Steel plate. thickness 1/8"	-	-
24	1	2	SanDisk Mini SD flash-memory card	$4.99	$9.98
25	8	1	Fiberglass Tubing per ft.	$48.20	$385.60
26	1	1	Aluminum 6061-T6 Sheet	$15.26	$15.26
27	1	1	Aluminum 6061-T6 Sheet	$5.10	$5.10
28	1	1	Aluminum 6061-T6 Bar	$3.19	$3.19
29	1	1	Aluminum 6061-T6 Sheet	$10.17	$10.17
30	2	1	L-Channel bar per foot	$4.39	$17.56
31	1	1	Fiberglass Coupler per ft.	$48.20	$64.00
32	-	-	Nuts and Bolts	-	$30.00
33	1	1	Universal Flight Controller	$500.00	$500.00
34	4	1	Fiberglass Electronic Sheet	$5.00	$20.00

Bill of Materials

35	15	1	Ammonium Perchlorate (per lb.)	$11.52	$172.80
36	8	1	Finely Grained Alumninum	$14.28	$114.24
37	1	1	HTPB (bottle)	$68.00	$68.00
38	2	1	Graphite Nozzle	$46.00	$92.00
39	2	1	Phenolic Liner/Casting tube set	$36.00	$72.00
40	1	1	Fiberglassing Materials	-	$100.00
41	20	5	Igniters	$5.00	$100.00
			Subtotal		$2,689.80
42	1	1	**Last minute Motor purchase**		$500.00
			Subtotal		$3,191.80

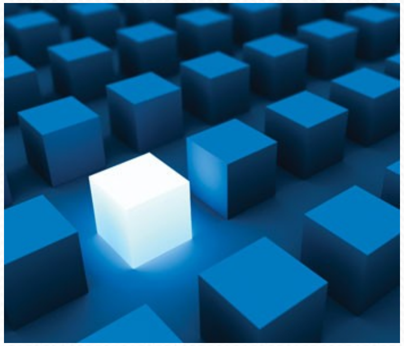
TOTAL COST = $3191.80

Manufacturing Information

- **Manufacturing Plan**
  - Develop efficient building method
  - Integrate rocket subsystems together
  - Perform critical testing
  - Assemble the entire rocket

- **Process**
  - For anything machined:
    - Assistance from shop owner (student made)
    - Precision designed
  - Anything else:
    - If inexperienced, obtain professional guidance
    - Practiced all local health and safety laws for any potentially hazardous manufacturing.

Innovations



- Extremely Lightweight Airframe
- Experimental motor creation
  - Load Cell Testing
  - Different propellant mixtures
  - Accurate data information for specific compositions
- Payload design
- Electronic data collecting and live video recording during flight
- Self-written code for aerodynamic analysis
- Parachute design for main Rocket
- Aerodynamically accurate nose cone and fins

Team Photo

Questions?

Thank you!