Designing and Flying an Experimental Sounding Rocket

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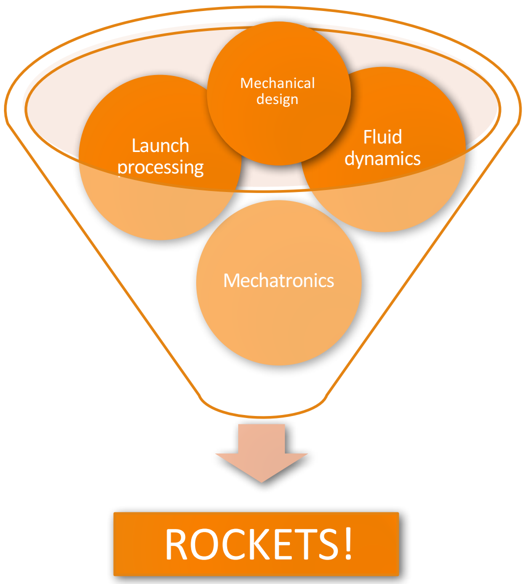
SPONSOR: FAMU-FSU
COLLEGE OF ENGINEERING
ADVISOR: DR. RAJAN KUMAR

Who We Are

- We are a team of highly motivated young engineers
- We have a diverse background of engineering experience
- We enjoy solving complex problems
- We all share a passion for spaceflight



IREC Competition

- **Location:** Truth or Consequences, New Mexico
- **Date:** June 20-24, 2017
- **Challenge:** To propel an experimental scientific payload to 10,000 feet in altitude
- **Purpose:** To promote experimentation in the field of sounding rocketry

Figure 1: Spaceport America[1]

Competition Requirements

- Payload
  - 8.8 lbs
  - CubeSat outer dimensions (10cm x 10cm x 11.35cm)
  - Scientific experiment or technology demonstrations (recommended)
- Recovery
  - Dual Deployment required for vehicles 1,500+ ft
- Electronics
  - 1 COTS altimeter
  - Redundant electronics
  - Radio beacon

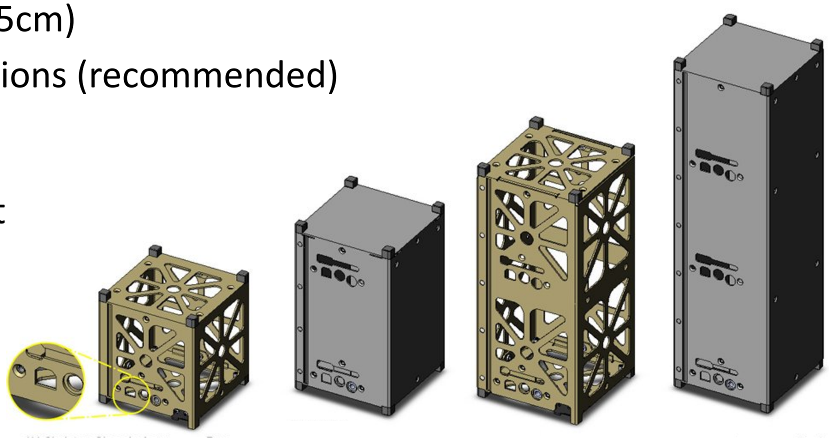


Figure 2: CubeSat Sizes[2]

Point Breakdown (1,000 Points Total)

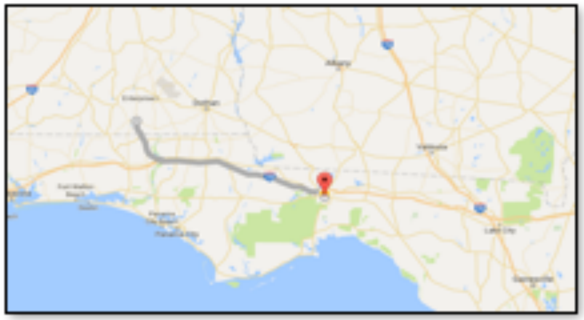
- Entry Form and 3 Progress Updates **(100)**
- Project Technical Report **(200)**
  - Analysis
- Design Implementation **(200)**
  - Competency of Design and Construction
  - Degree of SRAD
- Flight Performance **(500)**
  - Apogee
  - Successful Recovery
- Unsafe or Unsportsmanlike Conduct **(-20)**

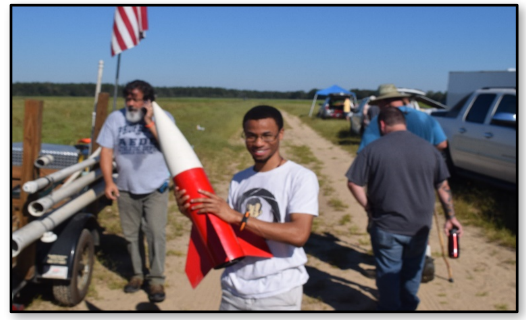
Spaceport America Cup

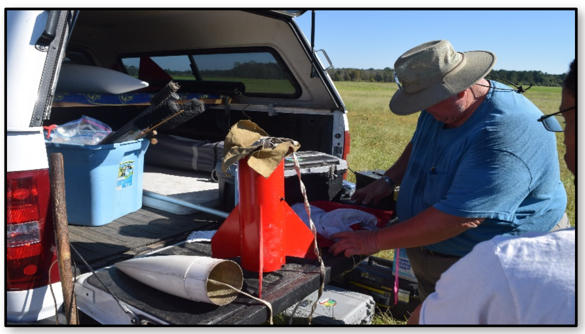
Intercollegiate Rocket Engineering Competition
Rules & Requirements Document

Figure 3: Competition rules document coverpage [3]

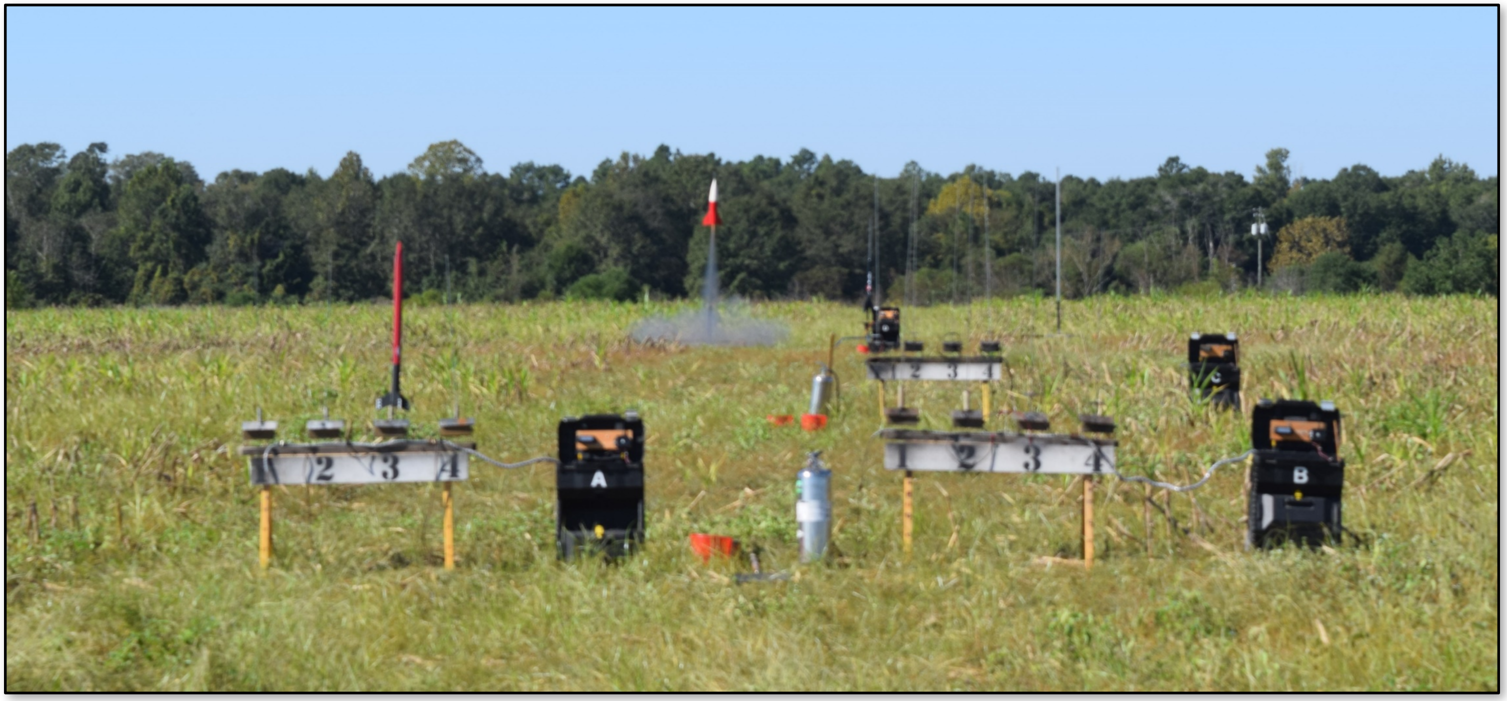
Our Approach to the Problem







Our Approach to the Problem



Layout of a Sounding Rocket

Payload
- Perform some scientific experiment

Avionics
- Need to log altitude data
- Eject parachutes at right altitude

Parachutes
- Need two

Rocket motor
- Generally contains solid fuels
- Can be reused

Developing a Model

- It is necessary to predict the performance of the vehicle
- Need to know how high vehicle will go based on liftoff mass and motor
- Determine if the rocket will be stable
- Determine if the rocket is safe from buckling under immense loads
- *Many coupled equations are in play!*

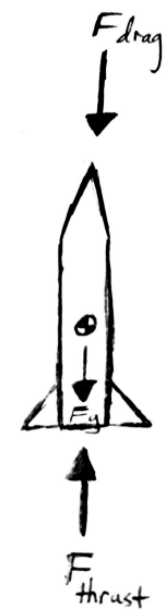


Figure 4: Hand drawn free body diagram

Flight Simulation

We created a simplified mathematical model to predict the flight of the vehicle:

What the model includes

- Form drag
- Skin friction drag
- Variable atmospheric pressure
- Variable thrust
- Variable vehicle mass

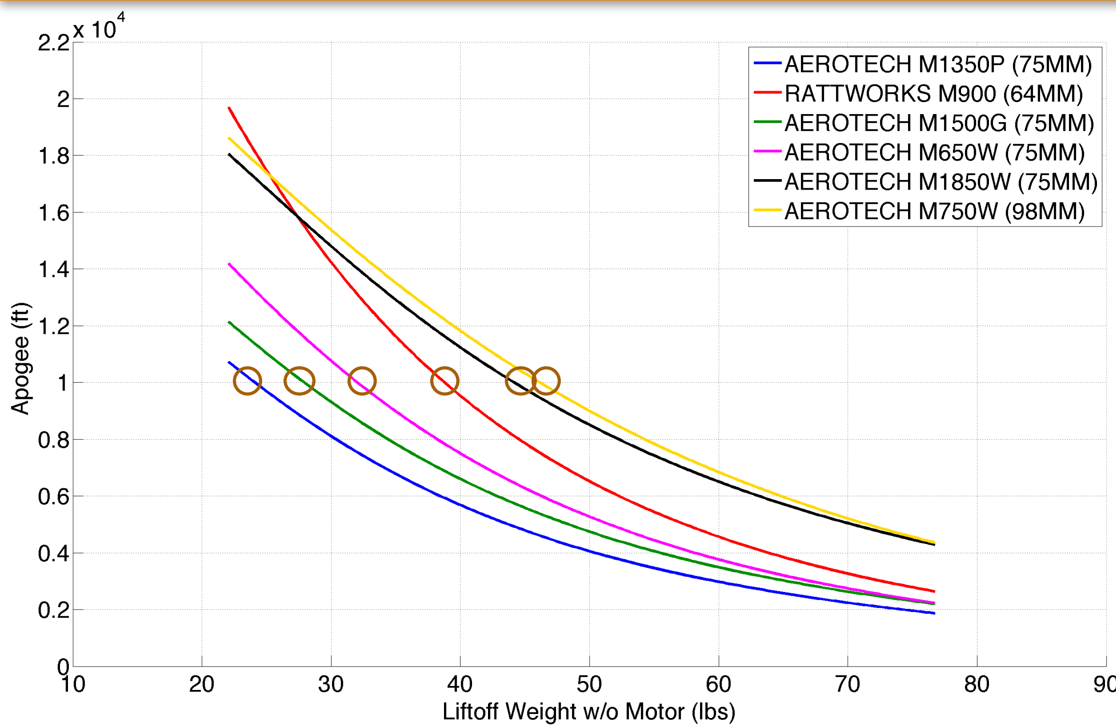
What it doesn't

- Compressibility effects
- Nonlinear propellant burn rate
- Wave drag

What the model suggests

The model shows that of any single subsystem, the **propulsion** element has the greatest impact on overall system performance

Motor Performance Comparison



To reach our target altitude:

M1350P ~ 23 lbs. vehicle weight

M1500G ~ 27 lbs. vehicle weight

M650W ~ 32 lbs. vehicle weight

M900 ~ 38 lbs. vehicle weight

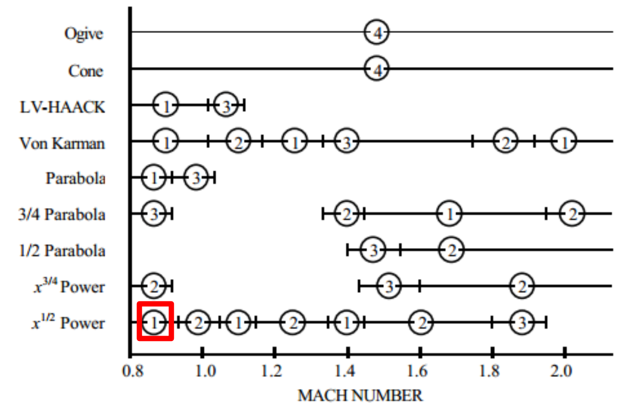
M1850W ~ 44 lbs. vehicle weight

M750W ~ 46 lbs. vehicle weight

Nose Cone Shape Optimization

- Cone shape has an influence over the drag experienced by the rocket.
- For our expected velocity, a cone with $x^{\frac{1}{2}}$ profile would be desired
- To create this profile, a plot is made by graphing the following equation and revolving it around the x axis.

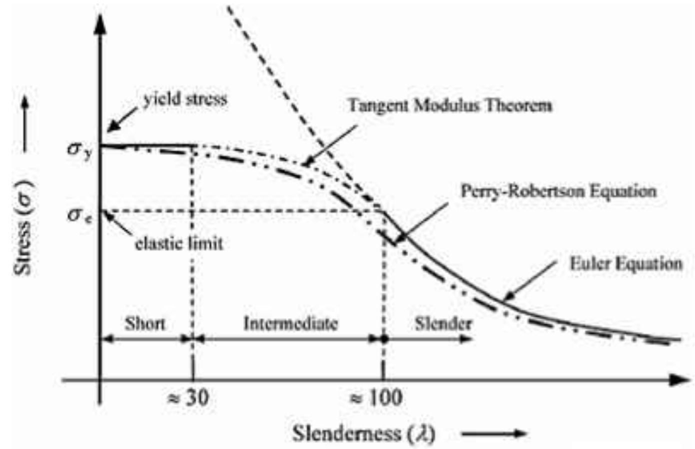
$$Y = Radius\ of\ tube \left(\frac{x}{Length\ of\ nose\ cone}\right)^{0.5}$$

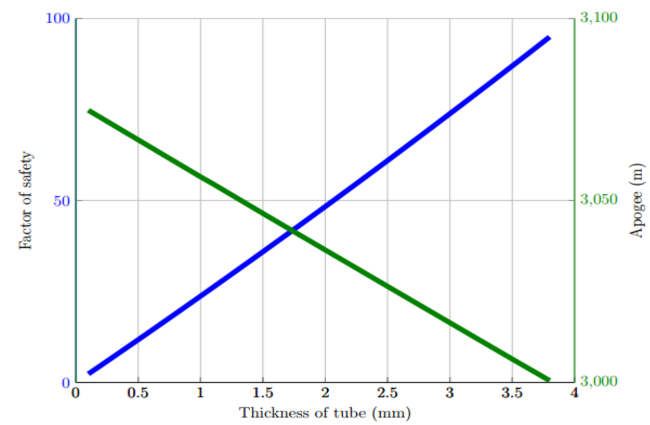


Comparison of drag characteristics of cone profiles between Mach 0.8 – 2.0

Buckling Analysis

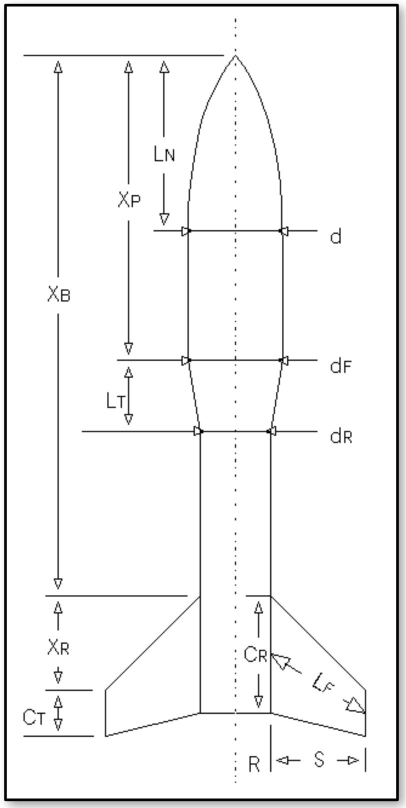
- Axial compression of thin fiberglass tubes is a concern
- Utilize Johnson-Euler buckling failure theory
  - Key parameter is slenderness ratio
  - Predicts how much stress before buckling failure
- Factor of safety is ratio of expected stress to predicted stress





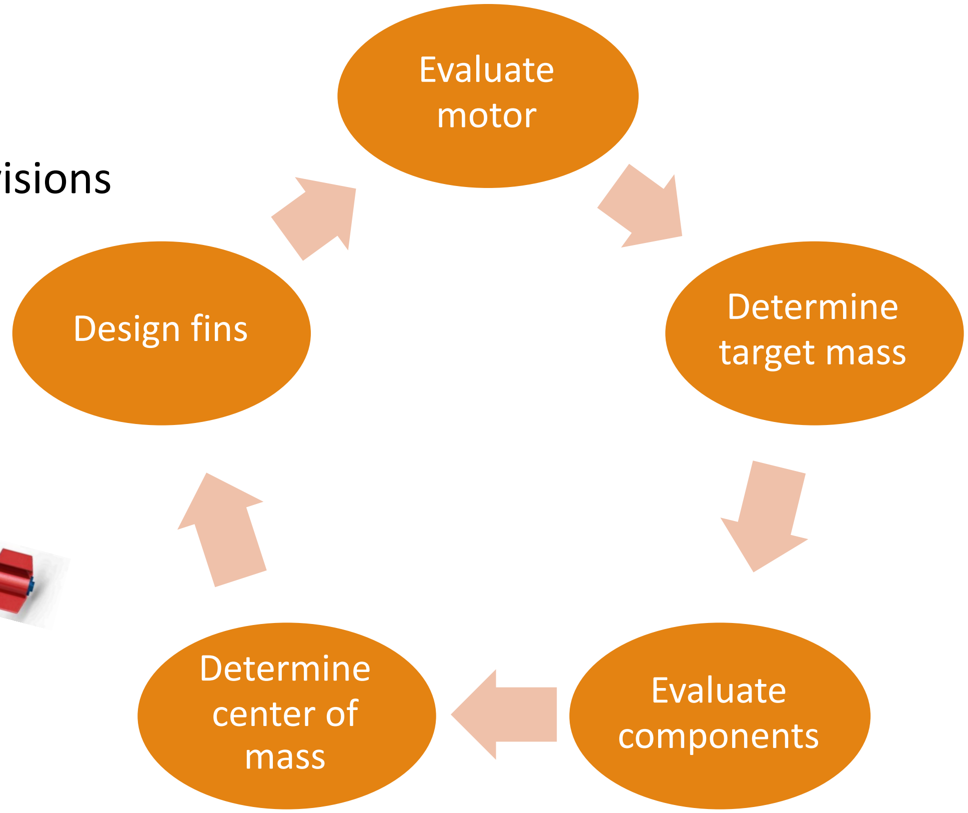
Stability Analysis

- The rocket needs to fly straight (up)
- Relationship between center of mass and center of pressure determines stability
- Barrowman devised set of equations to determine CP location using rocket geometry
- Fins play the most important role!



Design Process

- In total, we went through 5 design revisions before settling on our final layout.



The Final Design

- Length: 87 in
- Mass: 54.3 lb
- Rocket ID: 6 in
- Rocket OD: 6.14 in
- 4 segments
- Fiberglass Body

Figure 4: Rendering of the rocket

Booster Segment

- Aerotech M1845 motor (98mm)
  - 4.53 second burn
  - Rocket will experience 6.65 G's
- Wooden centering rings
- Fiberglass fins

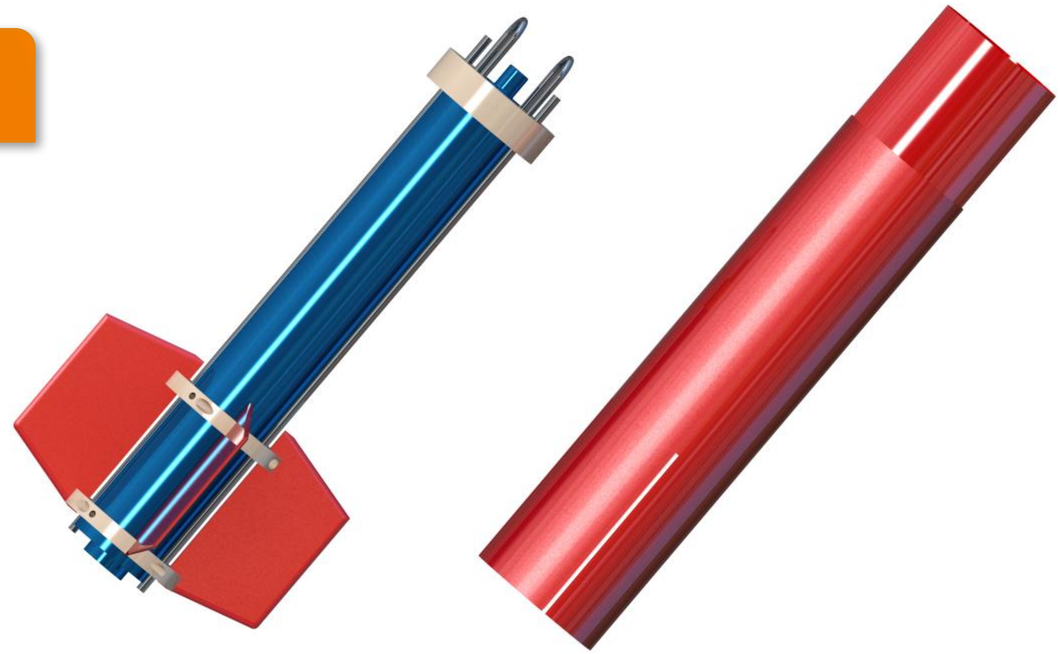


Figure 5: Booster section and surrounding tube

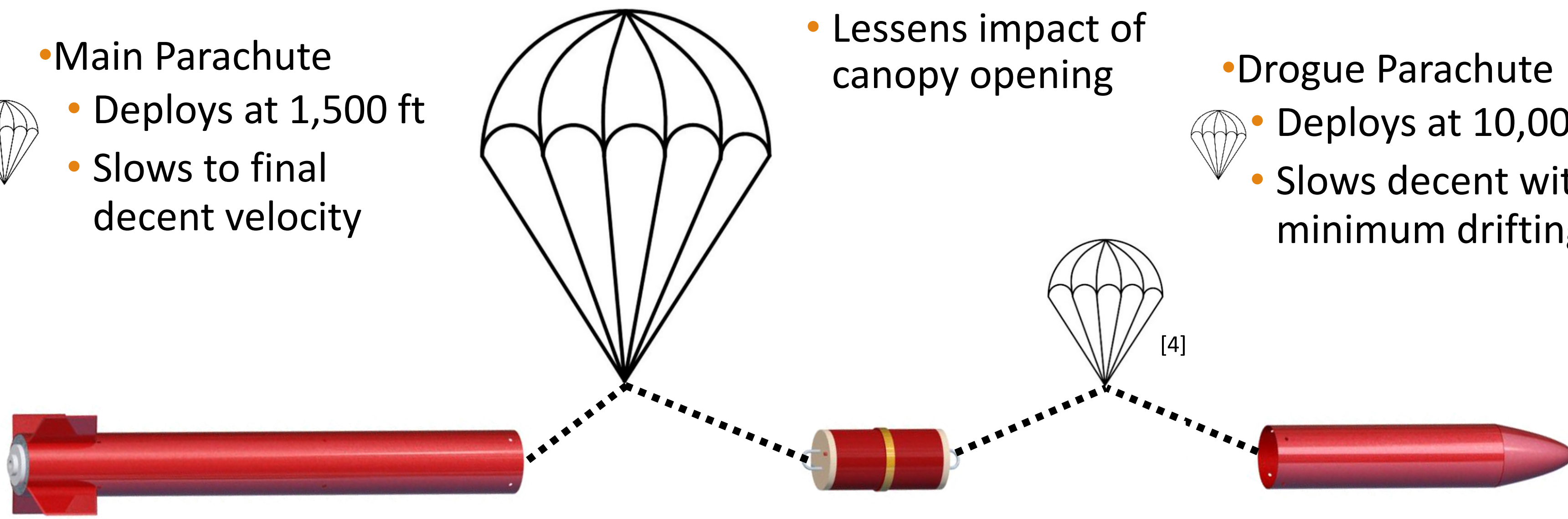
Dual Deployment

Shock Chord

- Keeps segments together in decent
- Lessens impact of canopy opening

- Main Parachute
  - Deploys at 1,500 ft
  - Slows to final decent velocity

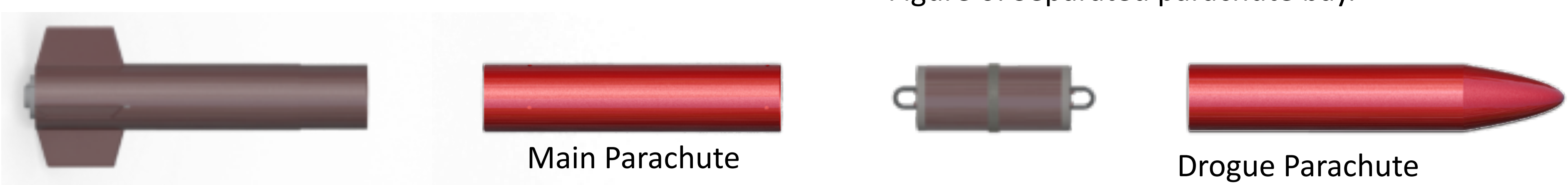
- Drogue Parachute
  - Deploys at 10,000 ft
  - Slows decent with minimum drifting



Parachute Bays

- Drogue parachute: Rocketman 3ft parachute
  - Decent rate of 90 ft/s
- Main parachute: XL B2 parachute
  - Decent rate of < 17 ft/s
- “Zipper-less” design

Figure 6: Separated parachute bay.



Avionics Bay

- Fiberglass outer body
- Ejection charges
- Exposed ring for Altimeters
- Parachute Mounting U-bolts
- Redundant electronics
  - Commercial Flight Controller
  - Student Designed Flight Controller

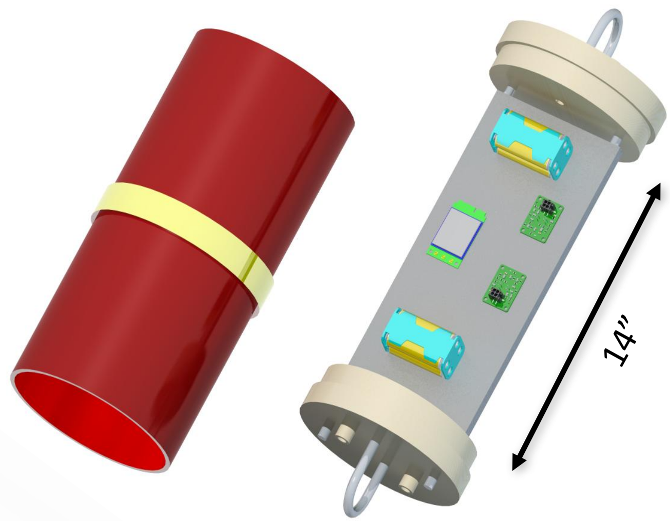


Figure 7: Avionics sled and bay body section[5] [6] [7]

Nosecone and Payload

- 3D printed nose epoxied to fiberglass tube
- Centering Rings hold CubeSat unit
- CubeSat contains 8.8lb payload
- 3U CubeSat payload

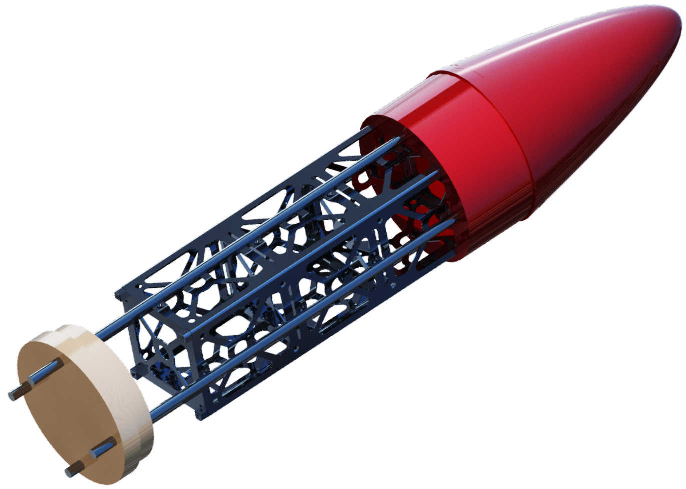
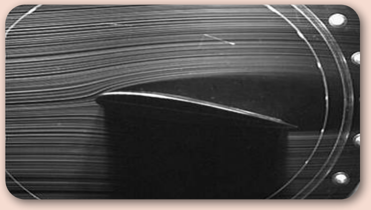
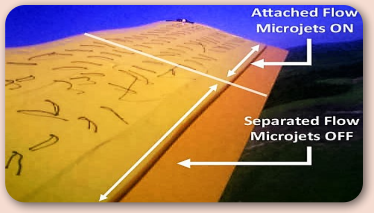
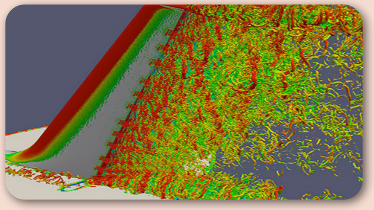


Figure 8: Payload Section

Research Payload – Active Flow Control





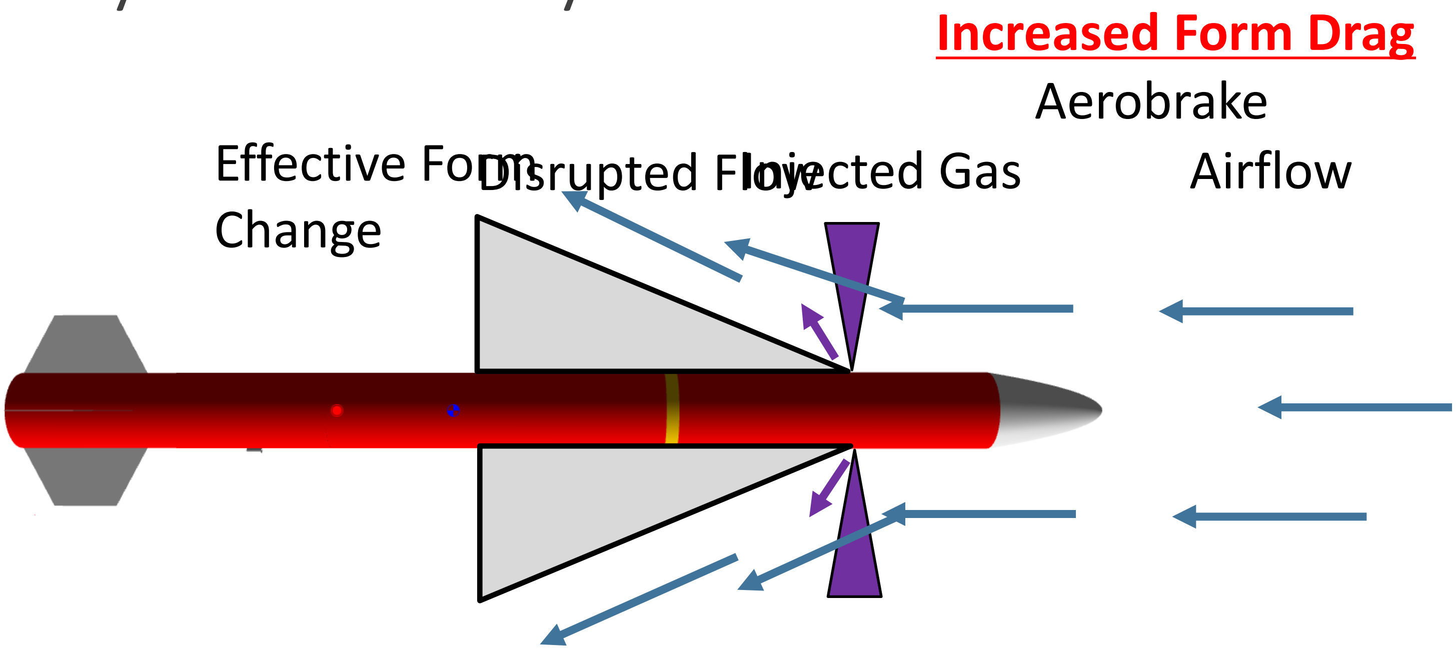


Active flow control studies the effects of injecting momentum into a flow field [13]

The injection of momentum can reattach flow to a surface [14]

Applications include lowering drag on aircraft, missile, and launch vehicle designs [15]

Payload Theory

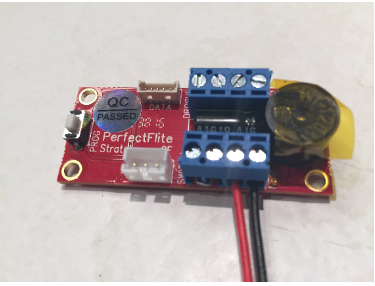


Research Payload Components

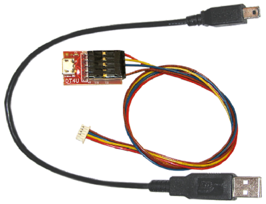
- Payload must follow competition's pressure vessel requirements
- Compressed gas (9oz HPA tank)
- 12V Battery pack
- Regulator
- Adapters
- On/off valve
- Splitter and nylon tubing

Build Status of Commercial Flight System

- Received and assembled
- Functional build
  - Speaker
  - Barometric sensor
  - Data cable and software
- Intended Dual-Deployment test
  - Timing e-matches
  - Black powder test



StratologgerCF



DT4U Cable

Igniter Test

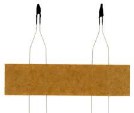
SRAD Avionics

- Determine altitude and orientation
- Log flight data
- Activate experiment
- Deploy parachutes
- Transmit GPS coordinates

BMP183

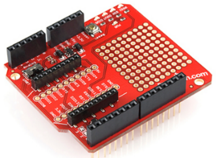
9-DOF IMU

MircoSD Card Reader



Igniters

Arduino Uno

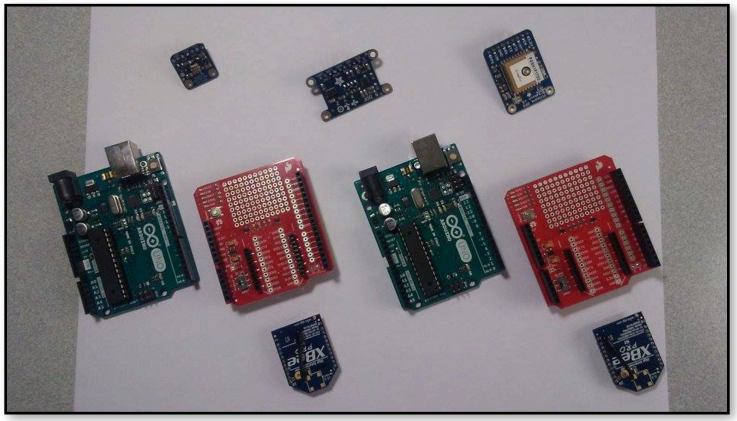


Xbee Shield

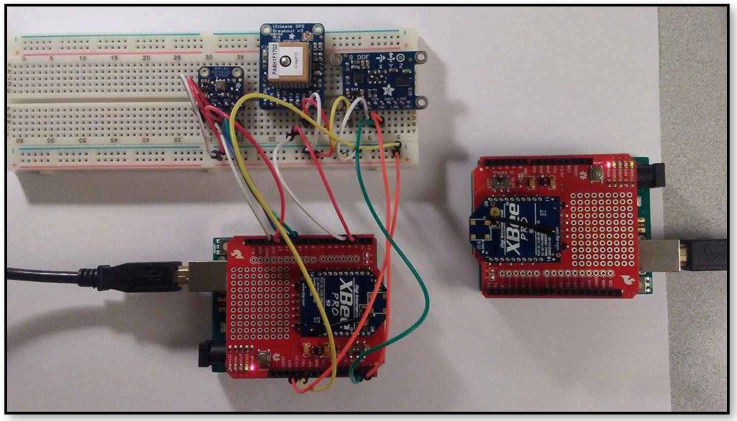
Ultimate GPS

Xbee Pro 60 mW

Build Status – SRAD Avionics



Avionics components



Testing setup

Budget

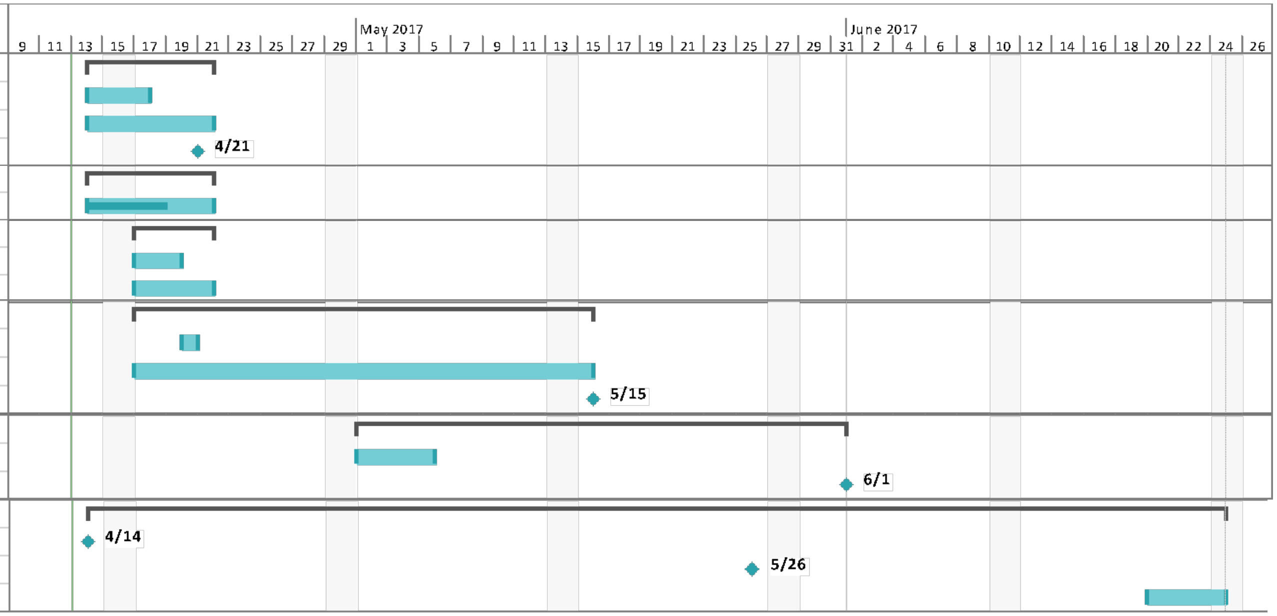
Component	Cost ($USD)
Body & Fiberglass	400
Nosecone & Payload	450
Recovery	385
Avionics	260
Booster & Test Motor	2,160
Manufacturing Materials	135
Competition Fees	900
Travel	1,300
TOTAL	**5,960 of 7,000**
Amount Spent	**3,135**

Safety

- Fiberglass Construction
  - PPE: respirators, safety glasses, nitrile gloves, etc.
  - Area Setup: fans, plastic sheet, etc.
- Ground Testing
  - On-campus
  - Supervised by EH&S and COE safety coordinator
- Flight Test
  - Off-Campus rocketry site
  - Distance is safety
  - External arming switches

Gantt Chart

ID	Task Name	Duration	Start
11	**Booster**	**6 days?**	**Fri 4/14/17**
12	Install rail button	2 days	Fri 4/14/17
13	Install centering rings/fins	6 days	Fri 4/14/17
14	Order motor grains	0 days	Fri 4/21/17
16	**Avionics**	**6 days**	**Fri 4/14/17**
17	Complete avionics segment	6 days	Fri 4/14/17
19	**Recovery**	**5 days**	**Mon 4/17/17**
20	Install mounting hardware	3 days	Mon 4/17/17
21	Test deployment of recovery system	5 days	Mon 4/17/17
23	**Payload and Nosecone**	**21 days**	**Mon 4/17/17**
24	Order any payload parts	1 day	Thu 4/20/17
25	Weigh/ Integrate payload	21 days	Mon 4/17/17
26	Complete payload/nosecone section	0 days	Mon 5/15/17
28	**Test Launch**	**23 days**	**Mon 5/1/17**
29	Schedule test launch	5 days	Mon 5/1/17
30	Test launch	0 days	Thu 6/1/17
32	**ESRA Dates**	**51 days**	**Fri 4/14/17**
33	Payments	0 days	Fri 4/14/17
34	All remaining paperwork	0 days	Fri 5/26/17
35	Competition	5 days	Tue 6/20/17



References

[1] Vyonyx ltd

[2] http://www.americaspace.com/?p=72686

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[4] http://www.clipartbest.com/parachute-clip-art

[5] https://grabcad.com/library/battery-pack-2

[6] https://grabcad.com/library/printed-circuit-board-4

[7] http://www.pro38.com/products/pro24/pro24.php#

[8] http://openrocket.sourceforge.net/

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[10] http://www.mouser.com/ProductDetail/Digi-International/XBP9B-DMWT-012/?qs=NnxJOTDiCpOOEE6pVdOjDg%3D%3D&gclid=CLPj7J3T2dECFUkDhgodvHAEDw

[11] ttps://www.tinkerforge.com/en/doc/Hardware/Bricks/IMU_V2_Brick.html

[12] https://www.urbanwebsites.com/sabalan-enterprises/index.html

[13] http://www.webstaurantstore.com/nemco-45050-stainless-steel-hex-nut-for-easy-frykutters/59245050.html

[14] https://woodcraft-assets-weblinc.netdna-ssl.com/Images/products/600/152976.jpg

Thank you!
Questions?