Development of a Multistage High-Power Rocket

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Space Hardware Club at the University of Alabama in Huntsville
Region II Student Conference, March 19-21, 2017, Starkville, MS
Project URSA

- Project Goal
  - Design, manufacture, test, and fly a high powered rocket with two stages to at least 30,000 feet

The Team:

- Sparky Shelton
  - Team Manager

- Davis Hunter
  - Chief Engineer

- Upper Stage
  - Aaron Hunt
    - Subsystem Lead
  - Mike Zaluki

- Lower Stage
  - McKynzie Perry
    - Subsystem Lead
  - Brendan Luke
  - Jacob Zilke

Manufacturing Liaisons

- James Biaglow
- Nick Jordan
- Kyle Renfroe
- Daniel Dorey
## Concept of Operations

<table>
<thead>
<tr>
<th>#</th>
<th>Event</th>
<th>Initial Altitude (feet)</th>
<th>Max. Velocity (ft/s Mach#)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Combined Powered Ascent</td>
<td>0</td>
<td>3,370 0.93</td>
</tr>
<tr>
<td>2</td>
<td>Separation</td>
<td>2,750</td>
<td>3,000 0.83</td>
</tr>
<tr>
<td>3</td>
<td>Initial Coast</td>
<td>3,000</td>
<td>3,000 0.83</td>
</tr>
<tr>
<td>4</td>
<td>2nd Stage Powered Ascent</td>
<td>6,650</td>
<td>6,330 1.77</td>
</tr>
<tr>
<td>5</td>
<td>Coast to Apogee</td>
<td>11,000</td>
<td>6,200 1.74</td>
</tr>
<tr>
<td>6a</td>
<td>Sustainer Deploy</td>
<td>31,200</td>
<td>175</td>
</tr>
<tr>
<td>6b</td>
<td>Booster Deploy</td>
<td>6,250</td>
<td>94</td>
</tr>
<tr>
<td>7</td>
<td>Main Deploy</td>
<td>1,000</td>
<td>~25</td>
</tr>
</tbody>
</table>
System Overview

• Full System
  ▪ Total Length - 144 in
  ▪ Total Mass - 16,318 g
  ▪ Simulated Apogee - 31,232 ft
  ▪ Simulated Top Speed - 6,330 ft/s (Mach 1.77)
  ▪ Maximum Acceleration - 20.1 G
Airframe Overview

• Nose Cone
  ▪ Von Kármán Profile
  ▪ Section of Sears-Haack Body
  ▪ Optimized for Supersonic Flight

• Body Tubes
  ▪ G12 Fiberglass
  ▪ Sustainer - 0.1 inch thickness
  ▪ Booster - 0.125 inch thickness
Airframe Overview Cont.

• **Fins**
  ▪ Carbon Fiber Fins
  ▪ 1/16th inch thickness
  ▪ ABS Fin Brackets
  ▪ Aluminum bolts

• **Boattail**
  ▪ 3D Printed ABS
  ▪ Decreases pressure drag significantly
  ▪ Contains wiring for second stage ignition
Motors

• **Sustainer**
  - Aerotech L1090
  - 6 grain 54mm
  - Solid NH$_4$ClO$_4$ and White Thunder
  - 4% L (Level 2)

• **Booster**
  - Aerotech M1780
  - 4 grain 75mm
  - Solid NH$_4$ClO$_4$ and Mojave Green
  - 8% M (Level 3)

*Thrust curves courtesy of thrustcurve.org*
Motor Seating

- **Forward Motor Retention System**
  - Tapped forward closure
  - Eyebolt inserted through retention bulkhead
  - Bulkhead bolted into airframe

- **Centering Rings**
  - CNC machined polycarbonate
  - Eliminate need for motor tube
Recovery

• Drogue Parachutes
  ▪ Deploy at apogee of each stage
  ▪ Booster - 12 inches, 70 ft/s descent rate
  ▪ Sustainer - Drogue-less, 175 ft/s descent rate

• Main Parachutes
  ▪ Deploy at 1,000 feet AGL
  ▪ Booster - 60 inches, 27 ft/s descent rate
  ▪ Sustainer - 60 inches, 22 ft/s descent rate
Finite Element Analysis of Load Path Components

• Thrust Plates
  ▪ Yield Stress of 1060 Aluminum: 40 ksi
  ▪ Force: thrust of each motor in lbf
  ▪ Sustainer:
    – Maximum Stress 6.5 ksi
  ▪ Booster
    – Maximum Stress 3.2 ksi

• Transition
  ▪ Yield Stress of ABS Plastic: 4.5 ksi
  ▪ Force: max acceleration * mass of sustainer + weight of sustainer
  ▪ Maximum Stress: 0.438 ksi
Transition Breakdown

- Transition Components
  - ABS Aerobowl (Blue)
  - ABS Piston Plate (White)
  - Ejection Charge Plate (Grey)
- Dimensions
  - A - 3.000 inches
  - B - 2.062 inches
  - C - 6.925 inches
Sustainer Ignition Component Overview

• Sustainer Ignition
  ▪ Pyrogen Igniter (orange)
  ▪ Nylon Male/Female Connectors (pink/blue)
  ▪ Wires (red outline)
Separation and Ignition Sequence

A black powder charge pushes sustainer out of booster.

The sustainer coasts for a predetermined amount of time before ignition.

The sustainer motor is ignited by PET timer in avionics package.
Second Stage Ignition Delay

- If the velocity is too low, the risk of tilt increases
- Acceptable range between 3 and 6 seconds
- Wind conditions on launch day will be final determining factor
Avionics

**Upper Stage**
- **Recovery:** Two PerfectFlite Stratologgers
- **Staging:** Two MissileWorks PET 2+ Timers
- **Tracking:** SPOT Trace GPS tracker

**Lower Stage**
- **Recovery:** Two PerfectFlite Stratologgers
- **Tracking:** SPOT Trace GPS tracker
CNC Machining
- Haas VF-1 CNC Mill
- Coupler bulkheads, centering rings, thrust plates, retainer bulkheads, and nose cone tip

Additive Manufacturing
- Stratasys Fortus 360mc
- Avionics sled, fin brackets, boattails, and transition assembly
• Ground Testing
  ▪ Recovery ejection
  ▪ Transition
    – Binding and charge
• Flight Testing
  ▪ Upper Stage validation
    – Confirmed accuracy of sims
    – Validated hardware at Mach 0.93
  ▪ Boosted dart
    – Will fly using 1st stage final motor
    – Validate lower stage and staging event
This project would not be possible without:

- **Club Advisor**
  - Dr. Francis Wessling, *UAH MAE department*
- **Project Funding**
  - Dr. John Gregory & Alabama Space Grant Consortium
  - Dr. Mahalingam, *Dean of the UAH College of Engineering*
- **Team Members**
  - Sparky Shelton, Mike Zaluki, Brendan Luke, Jacob Zilke, Kyle Renfroe, Nick Jordan, Daniel Dorey
- **Manufacturing Advisor**
  - Steve Collins, *UAH Prototyping Specialist*
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