NASA’s Student Launch Initiative:

Project ACE

- Seniors: 8
- Juniors: 2
- Sophomores: 6
- Interdisciplinary: 2
- Freshman: 5

Preliminary Design Review

Payload:

Fragile Material Protection
Agenda

1. Team Overview
2. System Analysis
3. Mission Performance
4. Safety
5. Educational Engagement
6. Administrative

   I. Airframe
   II. Electronic Payload
   III. Main Payload
   IV. Recovery
   V. Propulsion
Objectives

• Compete a high powered rocket that meets all specified criteria

• Reach an altitude between 5,125 ft. & 5,375 ft.

• Field a successful payload that produces useful vibration reduction data

• Transmit all data wirelessly to ground station
Team Structure

Team Overview
System Analysis
Mission Performance
Safety
Educational Engagement
Administrative

Propulsion
- Andrew G

Aerodynamics
- Torsten

Main Payload
- Justin

Electronics Payload
- Braden

Recovery
- Andrew S

Safety / Education
- Bryan

= Section

--- = 4th Year

--- = 3rd Year

--- = 2nd Year
Airframe Objectives

• Remain intact
• Reusable
• Protect internal components
Airframe
Dimensions and Subsections
Weight Breakdown

Total Weight: 35.19 lb
## Decision Matrix – Nosecone Shape

<table>
<thead>
<tr>
<th>Option</th>
<th>Cost</th>
<th>Drag</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ogive</td>
<td>Δ</td>
<td>О</td>
</tr>
<tr>
<td>Elliptical</td>
<td>О</td>
<td>Δ</td>
</tr>
<tr>
<td>Conical</td>
<td>О</td>
<td>‡</td>
</tr>
</tbody>
</table>
## Decision Matrix – Fin and Nosecone Material

<table>
<thead>
<tr>
<th>Option</th>
<th>Cost</th>
<th>Strength</th>
<th>Ductility</th>
</tr>
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<tbody>
<tr>
<td>Carbon Fiber</td>
<td>X</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>Fiberglass</td>
<td>O</td>
<td>Δ</td>
<td>Δ</td>
</tr>
<tr>
<td>ULTEM</td>
<td>X</td>
<td>O</td>
<td>O</td>
</tr>
</tbody>
</table>
## Decision Matrix – Body Tube

<table>
<thead>
<tr>
<th>Option</th>
<th>Cost</th>
<th>Strength</th>
<th>Ductility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon Fiber</td>
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<td>О</td>
<td>О</td>
</tr>
<tr>
<td>Fiberglass</td>
<td>Δ</td>
<td>Δ</td>
<td>Δ</td>
</tr>
<tr>
<td>Blue Tube</td>
<td>О</td>
<td>X</td>
<td>X</td>
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</table>
## Decision Matrix – Bulkhead Material

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<thead>
<tr>
<th>Option</th>
<th>Cost</th>
<th>Strength</th>
<th>Weight</th>
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<tbody>
<tr>
<td><strong>Aluminum</strong></td>
<td>X</td>
<td>O</td>
<td>Δ</td>
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<tr>
<td><strong>Plywood</strong></td>
<td>O</td>
<td>X</td>
<td>O</td>
</tr>
<tr>
<td><strong>Fiberglass</strong></td>
<td>Δ</td>
<td>Δ</td>
<td>Δ</td>
</tr>
</tbody>
</table>
Altimeter (Electronic Payload) Objectives

• Accurately measure apogee

• Retrieve flight data wirelessly

• Be able to track the rocket with GPS

• Waterproof compartment
# Altimeter Selection

## Decision Matrix – Altimeter

<table>
<thead>
<tr>
<th>Option</th>
<th>Cost</th>
<th>GPS Ability</th>
<th>Data Acquisition</th>
</tr>
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<tbody>
<tr>
<td>Altus TeleMega</td>
<td>Δ</td>
<td>0</td>
<td>0</td>
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<tr>
<td>Altus TeleMetrum</td>
<td>0</td>
<td>0</td>
<td>Δ</td>
</tr>
</tbody>
</table>

**Team Overview**

- **System Analysis**
  - Mission Performance
  - Safety
  - Educational Engagement
  - Administrative
Altimeter (Electronic Payload)

• Altus TeleMega
  • Located in nosecone
• GPS and Apogee
  • Easy to retrieve the data
  • Detailed flight data can be used to compare to OpenRocket/Rocksim
Altimeter Mounting
Altimeter Mounting

Ballast Studs (4X)
Plate Bolts (4X)
Removeable Mounting Plate
Mounting Ring
Damping Washers
Altimeter
Altimeter Bolts (4X)

5” O.D.
Payload Objectives

**NASA Given:**
- Protect unknown fragile object
- Envelop of 3.5 in dia. and 6 in length
- May not add nor remove material

**Team Created:**
- Reduce impact force by 50 percent
- Create valid mathematical model
- Reduce acceleration by 35 percent
Main Payload

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### Decision Matrix – Payload

<table>
<thead>
<tr>
<th>Option</th>
<th>Cost</th>
<th>Force Reduction</th>
<th>Acceleration Reduction</th>
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<tbody>
<tr>
<td>Parallel Spring System</td>
<td>Δ</td>
<td>X</td>
<td>O</td>
</tr>
<tr>
<td>Single Mounted Cylinder with Support Material</td>
<td>O</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Series and Parallel Spring System</td>
<td>Δ</td>
<td>O</td>
<td>O</td>
</tr>
</tbody>
</table>
Conceptual Design

- Concentric cylinder design
- Series and Parallel spring design
- Wire rope isolators for 360 vibration coverage
- Easily removable
- Variable fill design
Mathematical Design

Payload

Housing

Rocket

\[ M_1 \]

\[ M_2 \]

\[ M_3 \]

\[ k_1 \]

\[ k_2 \]

\[ c_1 \]

\[ c_2 \]

\[ F \]

\[ x_1 \]

\[ x_2 \]

\[ x_3 \]
\[ \Sigma F_y = 0 = M_1 \ddot{x}_1 = F + k_1(x_2 - x_1) + c_1(\dot{x}_2 - \dot{x}_1) \]

\[ \Sigma F_y = 0 = M_2 \ddot{x}_2 = -w_2 + k(x_2 - x_1) - c_1(\dot{x}_2 - \dot{x}_1) + k_2(x_3 - x_2) + c_2(\dot{x}_3 - \dot{x}_2) \]

\[ \Sigma F_y = 0 = M_3 \ddot{x}_3 = -w_3 + k_2(x_2 - x_3) + c_2(\dot{x}_2 - \dot{x}_3) \]
Mathematical Model

**Inputs**
- Thrust curve
- Impact force
- Parachute deployment force
- Spring constant (k) values
- Damping coefficient (c) values

**Outputs**
- Relative position graph
- Relative velocity graph
- Relative acceleration graph
- Relative force calculation
Recovery
Recovery - Objectives

- Two parachutes
  - Drogue at apogee
  - Main at low altitude
- 75 ft-lbf maximum Kinetic Energy
- Independent electronics
- Redundant altimeters
  - Lockable arming switches
  - Separate batteries
- Shear pins
- Tracking equipment and transmission
Recovery – Dual-Deployment

• Reduce ground track during descent
• Drogue parachute at apogee
• Main parachute at 1000 feet

http://www.arsabq.org/new_participants.htm
NASA SLI: University of Evansville
Recovery – Electronics

- Fully redundant, independent systems
- Black powder ejection charges
- Mounted to plywood sled
Recovery – Strength

• Aluminum bulkplates

• Steel U-bolts

• Tubular nylon tether

• 400 lbf max force
## Decision Matrix – Recovery Altimeter

<table>
<thead>
<tr>
<th>Option</th>
<th>Cost</th>
<th>Feature Set</th>
<th>Power Draw</th>
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</thead>
<tbody>
<tr>
<td>PerfectFlite CF</td>
<td>◦</td>
<td>◦</td>
<td>Δ</td>
</tr>
<tr>
<td>Stratologger</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AltusMetrum EasyMini</td>
<td>Δ</td>
<td>Δ</td>
<td>◦</td>
</tr>
<tr>
<td>Entacore AIM3</td>
<td>X</td>
<td>◦</td>
<td>◦</td>
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</table>

http://www.perfectflite.com/SLCF.html
## Decision Matrix – Recovery Harness

<table>
<thead>
<tr>
<th>Option</th>
<th>Cost</th>
<th>Strength</th>
<th>Elasticity</th>
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<tbody>
<tr>
<td>Elastic</td>
<td>O</td>
<td>X</td>
<td>X</td>
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<tr>
<td>Tubular Kevlar</td>
<td>X</td>
<td>O</td>
<td>Δ</td>
</tr>
<tr>
<td>Tubular Nylon</td>
<td>Δ</td>
<td>Δ</td>
<td>O</td>
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</table>

http://onebadhawk.com/1-tubular-nylon--2-loop.html
### Decision Matrix – Drogue Parachute

<table>
<thead>
<tr>
<th>Option</th>
<th>Cost</th>
<th>Descent Rate</th>
<th>Max Force</th>
</tr>
</thead>
<tbody>
<tr>
<td>24” Fruity Chutes Classic Elliptical</td>
<td>0</td>
<td>Δ</td>
<td>X</td>
</tr>
<tr>
<td>36” Fruity Chutes Classic Elliptical</td>
<td>0</td>
<td>O</td>
<td>Δ</td>
</tr>
<tr>
<td>48” Fruity Chutes Classic Elliptical</td>
<td>Δ</td>
<td>Δ</td>
<td>O</td>
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</tbody>
</table>

http://fruitychutes.com/parachute_recovery_systems/classic_elliptical_chutes.htm
## Decision Matrix – Main Parachute

<table>
<thead>
<tr>
<th>Option</th>
<th>Cost</th>
<th>Impact</th>
<th>Max Force</th>
</tr>
</thead>
<tbody>
<tr>
<td>72” Fruity Chutes Iris Ultra</td>
<td>O</td>
<td>X</td>
<td>O</td>
</tr>
<tr>
<td>84” Fruity Chutes Iris Ultra</td>
<td>O</td>
<td>Δ</td>
<td>Δ</td>
</tr>
<tr>
<td>96” Fruity Chutes Iris Ultra</td>
<td>Δ</td>
<td>O</td>
<td>Δ</td>
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</tbody>
</table>

http://fruitychutes.com/parachute_recovery_systems/iris ultra_parachutes.htm
## Recovery - Performance

<table>
<thead>
<tr>
<th>Wind Speed (mph)</th>
<th>Lateral Distance (ft)</th>
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<tbody>
<tr>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td>5</td>
<td>576</td>
</tr>
<tr>
<td>10</td>
<td>1296</td>
</tr>
<tr>
<td>15</td>
<td>2087</td>
</tr>
<tr>
<td>20</td>
<td>3046</td>
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</table>

<table>
<thead>
<tr>
<th>Section</th>
<th>Mass (lb)</th>
<th>Kinetic Energy (ft-lbf)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nose Cone &amp; Payload</td>
<td>9.19</td>
<td>20.9</td>
</tr>
<tr>
<td>Recovery Bay</td>
<td>4.32</td>
<td>12.66</td>
</tr>
<tr>
<td>Booster</td>
<td>10.03</td>
<td>29.4</td>
</tr>
</tbody>
</table>
Propulsion Objectives

• The vehicle should attain an apogee between 5,125 feet and 5,375 feet

• The vehicle should remain below Mach 1

• The motor mount should withstand propulsion forces and remain reusable for any following flights
### Decision Matrix – Centering Rings

<table>
<thead>
<tr>
<th>Option</th>
<th>Cost</th>
<th>Strength</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plywood</td>
<td>0</td>
<td>X</td>
<td>0</td>
</tr>
<tr>
<td>G10 Fiberglass</td>
<td>Δ</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Aluminum</td>
<td>Δ</td>
<td>0</td>
<td>X</td>
</tr>
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</table>
# Decision Matrix – Motor Mount Design

<table>
<thead>
<tr>
<th>Option</th>
<th>Cost</th>
<th>Safety</th>
<th>Against Regulations</th>
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<tbody>
<tr>
<td>Cluster Motor Mount</td>
<td>0</td>
<td>Δ</td>
<td>X</td>
</tr>
<tr>
<td>Single Motor Mount</td>
<td>X</td>
<td>Δ</td>
<td>0</td>
</tr>
</tbody>
</table>
Motor Mount Design

Inner Tube – Blue Tube
Bulkhead – Aluminum 6061 T6
Centering Rings – Aluminum 6061 T6
Exploded Motor Mount Design
<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Cesaroni Technology Inc</th>
<th>Animal Motor Works</th>
<th>AeroTech</th>
</tr>
</thead>
<tbody>
<tr>
<td>Make</td>
<td>L800</td>
<td>L1080BB-P</td>
<td>L850W</td>
</tr>
<tr>
<td>Total Impulse</td>
<td>3731 Ns</td>
<td>3686 Ns</td>
<td>3695 Ns</td>
</tr>
<tr>
<td>Altitude</td>
<td>5428 ft</td>
<td>5330 ft</td>
<td>5379 ft</td>
</tr>
<tr>
<td>Type</td>
<td>Reloadable</td>
<td>Reloadable</td>
<td>Reloadable</td>
</tr>
<tr>
<td>Max Thrust</td>
<td>1024 N</td>
<td>1258 N</td>
<td>1185 N</td>
</tr>
<tr>
<td>Weight(Empty)</td>
<td>3.79 lb</td>
<td>4.13 lb</td>
<td>3.54 lb</td>
</tr>
</tbody>
</table>
Down-Selected Motor

- Level 2 motor
- Motor Selection Criteria:
  - Altitude – No K class
  - Impulse
  - Thrust
  - Reloadable
- More design flexibility

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>AeroTech</th>
</tr>
</thead>
<tbody>
<tr>
<td>Make</td>
<td>L850W</td>
</tr>
<tr>
<td>Total Impulse</td>
<td>3695 Ns</td>
</tr>
<tr>
<td>Altitude</td>
<td>5379 ft</td>
</tr>
<tr>
<td>Type</td>
<td>Reloadable</td>
</tr>
<tr>
<td>Max Thrust</td>
<td>1185 N</td>
</tr>
<tr>
<td>Weight (Empty)</td>
<td>3.54 lb</td>
</tr>
</tbody>
</table>
## Decision Matrix – Fin Shape

<table>
<thead>
<tr>
<th>Option</th>
<th>Stability</th>
<th>Ease of Manufacturing</th>
<th>Likelihood of Damage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clipped Delta</td>
<td>∆</td>
<td>O</td>
<td>∆</td>
</tr>
<tr>
<td>Trapezoidal</td>
<td>X</td>
<td>Δ</td>
<td>O</td>
</tr>
<tr>
<td>Tapered Swept</td>
<td>O</td>
<td>Δ</td>
<td>X</td>
</tr>
</tbody>
</table>
Fins

- Root Chord: 11.5 in
- Tip Chord: 5.8 in
- Height: 7.5 in
- Surface Area: 63 in²
Predicative Altitude Assurance Plan

Verify four methods produce similar $C_d$ values

- CFD Data
- Wind Tunnel Data

Verify software ability to predict sub-scale altitude

- OpenRocket Altitude Prediction
- Rocksim Altitude Prediction

Test Flight Data

Verify four methods produce similar $C_d$ values

- CFD Data
- Wind Tunnel Data

Verify software ability to predict full-scale altitude

- OpenRocket Altitude Prediction
- Rocksim Altitude Prediction

Test Flight Data

Altitude Prediction

NASA S1: University of Evansville
Altitude Prediction: OpenRocket Software

• Program uses a model for the atmospheric conditions and for the wind

• Assumptions:
  • Ideal Gas
  • Wind speed uniaxial
  • Earth is flat
  • Wind turbulence based off wind farms

• Uses Runge-Kutta 4
Predicted Altitude

Altitude – 5,379 feet

• Over estimate because:
  • Software simulation
  • Uncertainty in weight

• Plan to add ballast
Rocksim Predicted Altitude

- **Altitude** – 5,368 ft
- Percent Difference of 0.2%
  - Based off of OpenRocket as original value
Basic Rocket Information

• Max Velocity and Acceleration – 592 ft/s and 208 ft/sec^2

• Mach Number – 0.53

• Thrust to Weight Ratio – 5.61:1

• Rail Exit Velocity – 69.2 ft/s
Stability

Stability: 3.69 cal.
Testing Plan

Wind Tunnel Testing
Parachute Testing
Payload Testing
Recovery/Test Ejection
Half Scale Model
Full Scale Model

Team Overview  System Analysis  Mission Performance  Safety  Educational Engagement  Administrative
Safety

• Overview and Requirements
  • Safety Officer Designation
  • Checklists
  • Certification and Liability
  • Monitor Rules and Regulations
Personnel Hazard Analysis

- **Fire**
- **Rocket Propellant**
- **Black Powder**
- **Craft/Exacto Knives**
- **Heavy Machinery**
- **Handheld Tools**
- **Epoxy Fumes**
- **Dust Particles**

*Full Analysis can be seen in PDR Report*
Failure Modes and Effects Analysis

Low Likelihood
- Motor Mishandling/Accidental Ignition
- Launch Failure
- Main Parachute Deployment Failure
- Drogue Parachute Deployment Failure
- Payload not Secured Properly

High Likelihood
- Excessively Tight Coupler
- Instability During Flight
- Altimeter/Electronics Malfunction

Major Severity
- Launch Failure
- Main Parachute Deployment Failure
- Drogue Parachute Deployment Failure
- Excessively Tight Coupler
- Instability During Flight
- Altimeter/Electronics Malfunction

Minor Severity
- Payload not Secured Properly

*Full Analysis can be seen in PDR Report*
Environmental Consideration Analysis

Major Severity

Low Likelihood

High Likelihood

Rocket Motor Ignition
Water
Debris from Rocket
Humidity
Strong Winds

Minor Severity

Epoxy Fumes
Dust Particles

*Full Analysis can be seen in PDR Report*
General Risk Assessment

**Low Likelihood**
- Mismanagement of Time
- Underestimation of Scope of Work

**Minor Severity**
- Limited Resources
- Increase in Safety Regulations

**Major Severity**
- Tight/Minimal Budget

**High Likelihood**

*Full Analysis can be seen in PDR Report*
Education Engagement Outreach Activities

• Engage 200 Students in STEM-related Activities
  • Emphasis on Middle School Students

• Activities
  • NTI STEMFest
    • Hydraulic Robotic Arms
    • Snap Circuits
  • Engineering Rocks
    • Egg Drop Competition
  • Webelos Day
    • Tennis Ball Launcher Optimization
### Schedule: Reporting

<table>
<thead>
<tr>
<th>ACTIVITY</th>
<th>Responsible</th>
<th>PLAN START</th>
<th>PLAN DURATION</th>
<th>WEEK</th>
</tr>
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<tbody>
<tr>
<td>Proposal</td>
<td>David</td>
<td>1</td>
<td>4</td>
<td>3</td>
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<tr>
<td>Preliminary Design Report</td>
<td>David</td>
<td>6</td>
<td>4</td>
<td>8</td>
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<td>PDR Presentation</td>
<td>David</td>
<td>8</td>
<td>2</td>
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<td>Interim Design Report</td>
<td>David</td>
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<td>5</td>
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<td>Critical Design Report</td>
<td>David</td>
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<td>5</td>
<td>12</td>
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<td>CDR Presentation</td>
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<td>23</td>
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<td>Post Launch Assessment</td>
<td>David</td>
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<td>1</td>
<td>22</td>
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<tr>
<td>Budget Creation</td>
<td>Bryan</td>
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<td>3</td>
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</table>

(Week 1 ends September 4th, 2016)
## Schedule: Design Phase

<table>
<thead>
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<th>ACTIVITY</th>
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<th>PLAN START</th>
<th>PLAN DURATION</th>
<th>WEEK</th>
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<td>Motor Type Selection</td>
<td>Andrew G</td>
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<tr>
<td>Motor Mount Design</td>
<td>Andrew G</td>
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<td>5</td>
<td>7</td>
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<tr>
<td>Rocksim Model</td>
<td>Andrew G</td>
<td>3</td>
<td>18</td>
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<tr>
<td>Body Component Selection</td>
<td>Torsten</td>
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<td>6</td>
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<tr>
<td>3D Rocket Model</td>
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<td>11</td>
<td>2</td>
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<td>CFD Model</td>
<td>Torsten</td>
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<tr>
<td>Payload A Design</td>
<td>Justin</td>
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<td>9</td>
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<td>Bryan</td>
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[Week 1 ends September 4th, 2016]
## Budget

### Itemized Cost + Contingency Based on Risk

<table>
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<tr>
<th>Item</th>
<th>Forecasted Amount</th>
<th>Pie Chart Color</th>
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<tr>
<td>Operating</td>
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<td>Travel / Lodging</td>
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<td>Electronic Payload</td>
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<td>Recovery</td>
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<tr>
<td>Educational Engagement</td>
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<td><strong>Total</strong></td>
<td><strong>$10,620.00</strong></td>
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![Budget Pie Chart](image-url)

**Team Overview**
- System Analysis
- Mission Performance
- Safety
- Educational Engagement
- Administrative

**NASA SLI: University of Evansville**
Thank you for your time!

Questions?