1) Competition
2) 2019 OSU USLI Team
3) OSU Rocket and Rover
4) Performance and Results
What is USLI?

NASA University Student Launch Initiative:
• 8 month competition
• 45 universities competed
2019 Competition

- Rocket had a target altitude of 4,500 ft.
- Carried a ground deployable rover payload
Mission Overview

1. Launch
2. Motor burnout
3. Separation at apogee
4. Drogue parachutes deploy
5. Main parachutes deploy
6. Landing
7. Rover deployment
8. Soil collection
9. Scientific experiment

Not to Scale
1) Competition
2) 2019 OSU USLI Team
3) OSU Rocket and Rover
4) Performance and Results
2019 OSU USLI Team

- 12 ME
- 2 ECE
- 3 CS
- 14 Volunteers
1) Competition
2) 2019 OSU USLI Team
3) OSU Rocket and Rover
4) Performance and Results
Launch Vehicle Overview

- Total Length: 129.375 in.
- Total Weight: 56.9 lbf
- Airframe Inner Diameter: 6.25 in.
Launch Vehicle Design
Airframe

21.75 in.  54 in.  52 in.
Aft Section

- Trapezoidal Fins
- 52 in. Body Tube
  - 24 Fiberglass (Fore)
  - 28 Carbon Fiber (Aft)
- Motor Retention
  - G12 Fiberglass Motor Tube
  - 3x Plywood Centering Rings
  - 6061 Aluminum Retainer
Canister and Coupler

- **G12 Fiberglass**
- **Coupler**
  - 5 ⅛ in. within Nosecone
  - 6 ⅞ in. within Fore Body Tube
- **Canister: 23.5 in. Long**
  - 7 in. within Fore Body Tube
  - 16.5 in. within Aft Body Tube
- **Contains:**
  - Camera System
  - Aft Electronics Bay
  - Aft Parachutes
Pressure Seal

Cap on each electronic bay
- Six $\frac{1}{4}$-20 bolts compress a Santoprene rubber sheet
- Removable
- Minimizes needed charge size
- Radially mounted
- Provides a mounting point for parachutes
Fore Ejection Bay

- Located aft of fore parachutes
  - RF shielded
  - Pressure sealed
  - Fore parachute mounting point

- Specifications
  - Weight: 2.02 lbf
  - Length: 6 in.
  - Additively manufactured mount
Fore Avionics Bay

- Located within the nosecone
  - RF transparent
  - Conserves space
  - Pressure sealed

- Specifications
  - Weight: 0.65 lbf
  - Length: 5in.
  - Additively manufactured mount
Aft Ejection and Avionics Bay

- Located aft of aft parachutes
  - RF shielded
  - Mounting point for aft parachutes

- Specifications
  - Weight: 2.33 lbf
  - Length: 8.5 in.
  - Additively manufactured mount
Camera System

- Five cameras consist of:
  - 2 GoPro HERO3s
  - 1 GoPro HERO5
  - 2 YI 4K Action Cameras

- Five recording combined into 360° video
- Lightweight and durable
BEAVS

- **Active System**
  - Four blades extend through airframe
  - Driven off central gear
  - Control system utilizes ATU sensors

- **Passive System**
  - Coupled ballast bays in Fore and Aft
  - Adjust apogee altitude & maintain CG
BEAVS

- **Active System**
  - Electronic systems not present for full scale flight
  - Mechanical systems present in flight

- **Passive System**
  - First full scale flight - 0.0 lbf
  - Second full scale flight - 2.0 lbf
# Ballast Bays

<table>
<thead>
<tr>
<th>Wind Speed (mph)</th>
<th>Fore Ballast (lbf)</th>
<th>Aft Ballast (lbf)</th>
<th>Stability (calibers)</th>
<th>Apogee Altitude (ft)</th>
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<tbody>
<tr>
<td>0</td>
<td>0.14</td>
<td>1.03</td>
<td>2.10</td>
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<tr>
<td>5</td>
<td>0.10</td>
<td>0.98</td>
<td>2.10</td>
<td>4500</td>
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<tr>
<td>10</td>
<td>0.06</td>
<td>0.93</td>
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<td>4500</td>
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<tr>
<td>15</td>
<td>0.02</td>
<td>0.88</td>
<td>2.10</td>
<td>4500</td>
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<tr>
<td>20</td>
<td>0.00</td>
<td>0.71</td>
<td>2.11</td>
<td>4500</td>
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</table>
Radial Bolt Testing

- **Passing Condition**
  - Withstands 75 G

- **Test Procedure**
  - Instron - Compression test bulkheads and aluminum ring

- **Status - Complete**
  - Plywood bulkhead - failure
  - Plywood with aluminum ring - success
  - Aluminum ring - success
Airframe Structures Testing

- **Passing Condition**
  - Withstands 15 G

- **Test Procedure**
  - Instron - Compression test fiberglass airframe section with holes

- **Status - Complete**
  - Handled 46.5 G
  - Not tested to failure
Final Motor Choice

Cesaroni L2375-WT

- Total Impulse: 1,103 lbf-s
- Avg. Thrust: 534 lbf
- Max Thrust: 586 lbf
- Rail Exit Velocity: 83.4 ft/s
- T/W: 10.30
Stability Margin

- Stability: 2.14 calibers
- Center of Gravity: 71.0 in.
- Center of Pressure: 84.7 in.
## Predicted Altitude in Huntsville, AL

<table>
<thead>
<tr>
<th>Wind Speed (mph)</th>
<th>OpenRocket Predicted Altitude (ft)</th>
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<tbody>
<tr>
<td>0</td>
<td>4,642</td>
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<tr>
<td>5</td>
<td>4,637</td>
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<tr>
<td>10</td>
<td>4,625</td>
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<tr>
<td>15</td>
<td>4,607</td>
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<tr>
<td>20</td>
<td>4,571</td>
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</table>

*Simulated with 0.0 lbf ballast*
## Mass Statement

<table>
<thead>
<tr>
<th>Section</th>
<th>Weight (lbf)</th>
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</thead>
<tbody>
<tr>
<td>Body</td>
<td>19.9</td>
</tr>
<tr>
<td>Bays</td>
<td>13.2</td>
</tr>
<tr>
<td>Recovery</td>
<td>8.56</td>
</tr>
<tr>
<td>Rover</td>
<td>6.01</td>
</tr>
<tr>
<td>Motor</td>
<td>9.17</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>56.9</strong></td>
</tr>
</tbody>
</table>

### Pie Chart

The pie chart represents the distribution of weights among different sections.

- **Body**: 34.6%
- **Bays**: 23.0%
- **Recovery**: 14.7%
- **Rover**: 10.6%
- **Motor**: 16.1%
Recovery

- Toroidal Main Parachutes
  - Packed in deployment bag with Kevlar blanket
- Cruciform Drogue Parachutes
- Nylon 1 in. shock cord
Recovery - Parachute Information

- MATLAB script determined:
  - Descent time
  - Landing kinetic energy

- Output determined:
  - 1.5 ft drogue parachutes
  - 8 ft main parachutes
Recovery - Aft Layout

Not to Scale
Recovery - Ejection Charge

- **Fore Section**
  - 4.0 g Primary
  - 6.0 g Backup
  - 4.0 g Deployment Bag Charges (x2)

- **Aft Section**
  - 5.5 g Primary
  - 8.0 g Backup
  - 4.0 g Deployment Bag Charges (x2)
# Recovery - Velocity & Kinetic Energy

<table>
<thead>
<tr>
<th>Weight (lbf)</th>
<th>Section</th>
<th>Nosecone</th>
<th>Fore</th>
<th>Aft</th>
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<tbody>
<tr>
<td>Weight</td>
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<td>5.1</td>
<td>18.2</td>
<td>20.1</td>
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</table>

<table>
<thead>
<tr>
<th>Velocity (ft/s)</th>
<th>Section</th>
<th>Tumbling</th>
<th>Drogue Only</th>
<th>Main &amp; Drogue</th>
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</thead>
<tbody>
<tr>
<td>Fore</td>
<td>115.0</td>
<td>111.0</td>
<td><strong>15.1</strong></td>
<td></td>
</tr>
<tr>
<td>Aft</td>
<td>116.0</td>
<td>112.0</td>
<td><strong>14.2</strong></td>
<td></td>
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<tr>
<td>Nosecone</td>
<td>115.0</td>
<td>111.0</td>
<td><strong>15.1</strong></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Kinetic Energy (ft-lbf)</th>
<th>Section</th>
<th>Tumbling</th>
<th>Drogue Only</th>
<th>Main &amp; Drogue</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fore</td>
<td>3,740.7</td>
<td>3,485.0</td>
<td><strong>64.2</strong></td>
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<tr>
<td>Aft</td>
<td>4,207.5</td>
<td>3,922.4</td>
<td><strong>62.7</strong></td>
<td></td>
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<tr>
<td>Nosecone</td>
<td>1,042.0</td>
<td>970.8</td>
<td><strong>17.9</strong></td>
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</table>
## Recovery - Descent Times & Drift

<table>
<thead>
<tr>
<th>Wind Speed</th>
<th>0 mph</th>
<th>5 mph</th>
<th>10 mph</th>
<th>15 mph</th>
<th>20 mph</th>
<th>Descent Time (s)</th>
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<tbody>
<tr>
<td>Drift of Fore Section (ft)</td>
<td>0</td>
<td>492</td>
<td>984</td>
<td>1,476</td>
<td>1,967</td>
<td>67</td>
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<tr>
<td>Drift of Aft Section (ft)</td>
<td>0</td>
<td>519</td>
<td>1,039</td>
<td>1,558</td>
<td>2,077</td>
<td>71</td>
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<tr>
<td>OpenRocket Simulation</td>
<td>2</td>
<td>369</td>
<td>711</td>
<td>1,071</td>
<td>1,394</td>
<td>68</td>
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</table>
Recovery - Separation Demonstration

- **Passing Condition**
  - 5 consecutive tests fully separate launch vehicle
  - Expel drogue and retain main
  - Expel main

- **Test Procedure**
  - Assemble launch vehicle
  - Secure airframe
  - Ignite charges

- **Status - Complete**
Recovery - Pressure Demonstration

- **Passing Condition**
  - All three e-matches ignite in the correct order

- **Test Procedure**
  - Assemble altimeter sleds
  - Create a pressure seal inside bays
  - Pull air out with a vacuum

- **Status - Complete**
  - All three e-matches ignited
  - Timing was correct on auxiliary port
Avionics and Ground Station
Avionics - Active Tracking

- Rocket-locating transmitters
  - Collects, logs, and transmits GPS data from GPS, GLONASS, and BeiDou satellite networks

- 900 MHz and 433 MHz RF transmission bands
  - Not working simultaneously, configurable via software
  - XBee Pro (900 MHz transceiver) runs at 250 mW
  - TI CC 1200 (433 MHz transceiver) runs at 40 mW
Avionics - Testing

● Battery Life Tests
  ○ Both configurations work under full power draw for 8+ hours

● Primary Band Test
  ○ Continuously transmitted past 2,500 ft reliably
Interfaces with Ground Station

- **Launch Vehicle Interface**
  - 900 MHz and 433 MHz RF transmission of GPS coordinates from flight ATUs
  - 900 MHz transmission of PLEC trigger signal from ground station to PLEC
  - PC displays data over serial monitor

- **Rover Interface**
  - Ground station sends position coordinates to rover over 900 MHz band
  - Sends launch vehicle airframe locations and scientific base station
Vehicle Demonstration Flight
Test Launches
Launch Footage
Full Scale: Data Analysis

Maximum Altitude: 4548 ft

Maximum Velocity: 588 ft/s

Maximum Acceleration: 621 ft/s²
Full Scale: Fore Section Analysis

- Maximum Altitude: 4548 ft
- Impact Velocity: 11.7 ft/s
- Fore Impact Kinetic Energy: 38.5 ft-lbf
- Nosecone Impact Kinetic Energy: 10.7 ft-lbf
- Descent Time: 72.6 s
Full Scale: Aft Section Analysis

- **Maximum Altitude**: 5079 ft
- **Impact Velocity**: 11.5 ft/s
- **Aft Impact Kinetic Energy**: 65.9 ft-lbf
- **Descent Time**: 79.6 s
Full Scale: Drift Analysis

Drift Distance vs Time

Overhead View of Drift Profile
Payload Mechanical
Payload Overview

- Total Length: 13.95 in.
- Total Weight: 6.01 lbf
Chassis

- Connection Blocks - Aluminum
- Rods - Carbon Fiber
- Tail - Three Ply Carbon Fiber
Drivetrain

- Two independently-controlled motor/wheel assemblies mounted within rover chassis

Brushed DC motors sized to climb 30° slopes
Drivetrain

- 6.00 in. diameter PLA wheels
  - Urethane foam tire
- Compressed tires (1) exert force on airframe interior
- Tires quickly expand upon ejection (2)
  - Increases ground clearance by 0.50 in.
**SCAR**

- **Soil Collection**
  - Auger fed into soil

- **Soil Retention**
  - Two independent doors
Navigation

1. Drive Motor Controller - Bidirectional PWM
2. Magnetometer - Heading as angle from North in 1 degree increments
3. GPS - Multi sample implementation with accuracy of 30 ft in any direction
4. Sonar - Directional detection of obstacles
Collection and Retention

1. Auger and Retention Motor Controllers
2. Motor Encoders
3. Accelerometer - Levelness sensing
4. Transceiver - Receives coordinates of the airframe and scientific base station
5. Teensy 3.6 Microcontroller
Mobility Testing

Rover Orientation

Object Avoidance

30° Slope Climb
Rover Printed Circuit Board

- Protoboard functionality testing - complete
- Final PCB - incomplete
- Protoboard Shield PCB - incomplete
Payload Software
Rover Software

1. Reliably move away from launch vehicle
2. Soil collected and sealed
3. Receive GPS data and sample count via RF
4. Travel to the coordinates given
5. Dock and deposit soil sample into a collection chamber for analysis
6. Exit the base station to retrieve additional soil samples until sample count is reached
Beaglebone CV Testing

- Successful circle detection with no false positives
- Minimal extra lines drawn by Canny threshold
Rover Navigation Testing

- **Object avoidance - Complete**
  - Allow rover to navigate with obstructions

- **Radio Frequency Communication - Incomplete**
  - Send GPS coordinates to the rover at varying distances

- **Docking - Incomplete**
  - Allow rover to climb base station and deposit soil
Payload Ejection and Retention
Payload Ejection and Retention

- Consists of 3 systems
  - Payload Wrap Assembly
  - Removable Retention Assembly
  - Payload Ejection Controller (PLEC)
- Integrates into airframe to the Fore Hard Point (FHP)
Fore Hard Point

- Removable radial bolted assembly
  - Funnel for integration
  - Bulkheads for PEARs retention
  - Removable for safety procedures in event of failed payload ejection

- Pass through bulkhead
  - Epoxied in airframe to create pressure seal
Payload Wrap Assembly

- Fiberglass wrap
- Plywood bulkheads for ejection protection
- Kevlar harness retains rover and attaches to retention devices on removable assembly
Ejection and Retention

- Wrap retained to removable assembly
  - Two L2 Tender Descenders and ARRD
- Ejected with black powder charges
  - Primary: 1.2 g
  - Backup: 2.0 g
Payload Ejection Controller

- Controls retention devices and ejection charges
  - Sequential e-match ignition tested
- Mounted on removable assembly
- Contained within RF shielded case
- Armed with DPST switch
Integration in Fore Airframe

- Pressure seal between PEARs bulkhead and FHP
- Fore ballast bay mounted on threaded rod fore of FHP
- PLEC armed from exterior once on the launch rail
PEARS Testing

- Successful ground testing of ejection sequence
- Successful retention and deployment during test flights
PEARS Testing
Payload Demonstration Flight

- Scheduled for March 16th in Brothers, OR
  - Will be flown with Cesaroni L25375-WT
- Flight will also act as Vehicle Demonstration Re-Flight
  - Max ballast configuration
Scientific Experiment

- Modular Experiment Design
  - Mapping of pH samples
- Rover navigates up ramps
  - CV sees circles on ground station
- Rover deposits soil into grate
1) Competition
2) 2019 OSU USLI Team
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4) Performance and Results
Competition Launch
Payload Deployment
Payload Mission
STEM Engagement Event Pictures
# STEM Engagement Events

<table>
<thead>
<tr>
<th>Date</th>
<th>Event</th>
<th>Engagement Number</th>
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<td>Oct. 26</td>
<td>Yamhill-Carlton Rocketry</td>
<td>27</td>
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<tr>
<td>Oct. 31</td>
<td>Discovery Days</td>
<td>950</td>
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<tr>
<td>Nov. 9</td>
<td>Veneta Elementary</td>
<td>350</td>
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<td>Nov. 14</td>
<td>OSU Women’s Basketball</td>
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<td>Nov. 27</td>
<td>OSU Honors Colloquium</td>
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<tr>
<td>Dec. 15</td>
<td>Evergreen Air &amp; Space</td>
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<tr>
<td>Dec. 19</td>
<td>Westview High School</td>
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</tr>
<tr>
<td>Jan. 18</td>
<td>Lenox Elementary</td>
<td>520</td>
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<tr>
<td>Jan. 19</td>
<td>Cub Scout Lock-In</td>
<td>250</td>
</tr>
<tr>
<td>Jan. 26</td>
<td>Western University</td>
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<tr>
<td>Jan. 26</td>
<td>Reaching for the STARS</td>
<td>500</td>
</tr>
<tr>
<td>Feb. 19</td>
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<tr>
<td>Feb. 28</td>
<td>Philomath Middle School</td>
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**Total: 3,362**
Summary of Requirements

NASA Requirement Verifications

<table>
<thead>
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<th>Category</th>
<th>Completed</th>
<th>Incomplete</th>
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<tbody>
<tr>
<td>General</td>
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<td>Launch Vehicle</td>
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<td>21</td>
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<td>24</td>
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<tr>
<td>Safety</td>
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<td>9</td>
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Team Derived Requirement Verifications

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<td>Payload</td>
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<td>12</td>
</tr>
<tr>
<td>Safety</td>
<td>15</td>
<td>10</td>
</tr>
</tbody>
</table>
2018-2019 Competition Results

Team Achievements:
- Completed 5 rocket launches
- Rover successfully deployed
- Taught 4,820 K-12 students

Scoring:
- 4th Overall out of 45 Teams
  - 1st in Launch Vehicle Award
  - 3rd in Project Review Award
  - 3rd in Altitude Performance
  - 3rd in Rocket Fair Display
Acknowledgments

- Oregon Space Grant Consortium
  - Catherine Lanier
  - Jack Higginbotham
  - Shirley Campbell
- Oregon State College of Engineering
  - Dr. Squires
- Oregon Rocketry
  - John Lyngdal, Joe Bevier, Alan Hammond
- Industry Sponsors