NASA ESMD Lunabotics Competition
and
Montana MULE

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Montana Space Grant Consortium
Angela Des Jardins, Director
spacegrant.montana.edu/

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Kennedy Education Office
Kennedy Space Center, Florida
www.nasa.gov/lunabotics/
Overview

- In May of 2010, NASA conducted the first annual *Lunabotics Mining Competition* at the Kennedy Space Center.

- This event was put on by the NASA ESMD Higher Education Project with the intent to "retain students in Science, Technology, Engineering and Math (STEM)"

- Twenty-two teams from universities around the nation attended the competition.

- The Montana MULE took First Place in the mining competition, delivering 21.6kg of regolith simulant, and

  won the *Joe Kosmo Award for Excellence* given to the team with the most overall competition points.
Competition Overview

- Students were to design a wireless-controlled robot to excavate lunar regolith simulant.
- The robot had 15 minutes to collect the regolith and deposit as much as possible into a collector.
- A minimum of 10kg of regolith needed to be deposited into the collector to qualify. The team with the most regolith deposited above 10kg would be the winner.
Competition Overview

• Each side of the sandbox was divided into two zones:
  1) the obstacle zone
  2) the mining zone

• The robot needed to traverse the obstacle zone (craters and rocks), pick up regolith from the mining zone, then return through the obstacle zone to deposit the regolith into the collector.

• Two robots competed at once, one in each side of the sandbox.

• Each robot was controlled using an 802.11 network, from an isolated room that showed a real-time view of the sandbox using cameras. Teams were required to connect to the competition network (they could not use their own).
Competition Overview

- Constraints were given for the design of the robots:

  1) Size
     - Width = 1.5m
     - Length = 0.75m
     - Height = 2m

  2) Mass
     - 80kg

  3) Technology
     - No technologies unfeasible for the moon could be used
     - For example: pneumatic tires, non-enclosed combustion engines, vacuums, sonar
     - Space-grade parts were not required

  4) Behavior
     - Robots were required to be mobile, and could not interfere with each other, modify the regolith, use the walls/floor of the arena as a collection aid, or dig outside the mining area.

Note: each robot was weighed prior to competition.
Competition Overview

- The competition included other elements beyond the design/construction of the robot:

  **Required**
  - Systems Engineering Paper (due 4/15/10)
  - Outreach Report (due 4/15/10)

  **Optional**
  - Slide Presentation (due 4/15/10)
  - Team Spirit Competition (at event)
  - Digital Video of Design Process (due 5/25/10)
  - Collaboration with a minority serving institution
  - Forming a interdisciplinary team (points for each STEM major represented)

- Teams competed for prizes in the Paper, Outreach, Team Spirit, and Slide Presentation categories. Completion of any category also contributed points to each team’s overall score, which determined the winner of the **Joe Kosmo Award for Excellence**.
The Competition

University of Alabama

Virginia Tech

Carnegie Mellon

Western Kentucky

Southern Indiana
The Competition

• What it really looked like…

The sandbox was housed in a ventilated tent.

Tevex suits and ventilation masks had to be worn inside the tent to prevent contact with the regolith

(Paul Dallapiazza, Steve Pemble, Ben Hogenson)

(Chris Ching)

(Steve Pemble)
The Competition

- What it really looked like…

Robots were loaded into the sandbox using a forklift.

The robot was driven from a control room that showed the sandbox on a monitor.

(Jack Ritter, Chris Ching, Jenny Hane)
MULE: Team Assembly

- The Lunabotics opportunity was introduced at a NASA faculty workshop on capstones in June of 2009. This workshop was attended by Dr. LaMeres.

- LaMeres, Lloyd, and Larson then spearheaded a cross-disciplinary senior capstone project based on the competition, recruiting additional departmental advisors.

- The Montana MULE team consisted of 8 students from 4 different departments:

<table>
<thead>
<tr>
<th>Faculty</th>
<th>Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hunter Lloyd (CS)</td>
<td>Chris Ching (CS)</td>
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<tr>
<td>John Paxton (CS)</td>
<td>Jennifer Hane (EE)</td>
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<tr>
<td>Brock LaMeres (EE)</td>
<td>Ben Hogenson (EE)</td>
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<tr>
<td>Ahsan Mian (ME)</td>
<td>Philip Karls (EE)</td>
</tr>
<tr>
<td>Mike Edens (MET)</td>
<td>Paul Dallapiazza (ME)</td>
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<td>Robb Larson (MET)</td>
<td>John Ritter (ME)</td>
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<td></td>
<td>Craig Harne (MET)</td>
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<tr>
<td></td>
<td>Steve Pemble (MET)</td>
</tr>
</tbody>
</table>

(Pemble, Dallapiazza, Ching, Hane, Hogenson, Harne, Ritter)
In September 2009, the entire team began with brainstorming conceptual designs and trading off requirements.

Once a design was selected, the student groups began working on their individual sub-system designs.

The design was broken into three main subsystems which corresponded to the individual capstone deliverables for each department:

1) Mechanical System
2) Electrical System
3) Computer Control System
MULE: Design Process

• **Mechanical**
  
  – The mechanical system was designed during the first semester and assembled during the second.
  – All parts except the chains and sprockets were custom fabricated at MSU.
  – Four motors and two linear actuators were used to drive the moving parts.
Design Process

• Electrical
  – The electrical system was designed and prototyped the first semester.
  – The interface to the computer system was designed and the final version assembled the second semester.
  – Sensors were included, but stripped from the final version due to lack of time.
Design Process

• **Computer**
  
  – Design of the computer system began the first semester; it was implemented the second semester.
  
  – The computer system handled all wireless communications and sent simple commands to the electrical system through a serial interface.
  
  – An embedded Linux board was originally used.
Design Process

- **Testing**

  - The mechanical system was tested without the control electronics using a relay switch box. This allowed all of the mechanical systems to be verified. The testing was conducted in a volleyball course at MSU.

(Hogenson, Hane, Dallapiazza, Ritter, Pemble, Ching, Harne) (Hogenson, Ching, Pemble, Dallapiazza, Ritter)
Outreach Events

- **Outreach**
  - These photos are from one of five outreach events conducted by the MSU team, for grade school students, MSGC researchers, and the general public.

4th grader Nikayla Wacha (pink) drives the MSU excavator using the Xbox 360 controller.

4th grader Anabelle Seybert (blue) drives the MSU excavator using the Xbox 360 controller.
• **Practice Days**
  – The first complete integration and test occurred at Kennedy.
  – Issues with the power system, loose screws, and an inability to connect to the competition network were found. MULE did not move during either practice run.
  – Emergency solutions included purchase of a rechargeable USB power supply and replacement of the embedded computer board with Steve Pemble’s laptop.
Competition Event

• **Test #3 Outside Test**

  - Unable to get inside the arena again, we did our final testing in a sandy patch outdoors.


• **Competition Day #1**

- The MULE was called late in the afternoon for its competition run. No team had dumped any regolith and very few robots even moved.

- The MULE moved, the buckets spun, and the hopper could dump

  **BUT…..**

a loose wire prevented the actuators from running and getting the buckets into the regolith; the digging head was retracted during the entire attempt.
• **Competition Day #2**

- Originally there was to be only one round, but the first day’s pitiful performance led the judges to grant everyone a second try.
- MULE deposited 21.6 kg of regolith during the second round, making it one of six robots to deposit dirt, and the only one to get more than the 10 kg needed to qualify.
2010 Winners

• **Honorable Mentions: Mining**
  – Team Pumpernickel from Auburn University, excavated 6.6 kg
  – iDigU from University of Southern Indiana, excavated 2.4 kg
  – Moonrockers from South Dakota School of Mines and Technology, excavated 2.2 kg
  – Luna Baggers from Milwaukee School of Engineering, excavated 0.8 kg
  – PiRATE from the University of Akron, excavated 0.6 kg

• **Other Categories**
  – Systems Engineering Paper
    • Team Pumpernickel from Auburn University
  – Outreach Project
    • Team AETHER from Embry Riddle Aeronautical University
  – Slide Presentation
    • ARTEMIS from Western Kentucky University
  – Team Spirit
    • iDigU from University of Southern Indiana
  – Joe Kosmo Award for Excellence
    • Montana MULE from Montana State University – Bozeman
Our Budget

• **What did this experience cost?**

**Materials & Supplies** $4,200
- Mechanical System ($1,650)
- Electrical System ($2,050)
- Computer System (used existing HW)
- Printing & Media ($500)

**Travel** $8,900
- Airfare ($4,200)
- Motel ($2,050)
- Rental Car ($600)
- Per Diems & Miscellaneous ($2,050)

**Shipping** $2,100

**Total** $16,200

Faculty support is also an important funding consideration, but this will vary greatly from one university to the next.
Conclusion

• Each student on the Montana MULE team said more than once that this was the single most valuable experience they had during their time at MSU.

• Enabling students to apply what they’ve learned in the classroom to a real design project is what capstones are meant for. An interdisciplinary design project forces the students to communicate across departmental boundaries.

• The NASA event allows the students to feel the pressure of competition.

• It also allows the students to see what students at other universities did, and gain confidence that their education has prepared them for successful careers.