2011 NASA Lunabotics Mining Competition

Rob Mueller,
Chief, Surface Systems Office
NASA KSC, NE-S
Head Judge & Lead Technical Expert
June, 2011
2nd Annual NASA Lunabotics Mining Competition
May 26-28, 2011

LUNABOTICS MINING
Design it.
Build it.
Dig it.

COMPETITION
What is a Lunabot?

- Robot Controlled Remotely or Autonomously
- Visual and Auditory Isolation from Operator
- Excavates Black Point 1 (BP-1) Simulant
- Weight Limit - 80 kg
- Dimension Limits - 1.5m width x .75m length x 2m height
- Designed, Built and Tested by University Student Teams
LunArena

Human Spaceflight Architecture Team
Black Point 1 (BP-1) Lunar Regolith Simulant

Discovered during 2009 Desert RATS field testing near Flagstaff, AZ
Overview

- Design, build & compete remote controlled robot (Lunabot)
- Excavate Black Point 1 (BP-1) Lunar Simulant
- Deposit minimum of 10 kg of BP-1 within 15 minutes
- $5000, $2500, $1000 Scholarships for most BP-1 excavated
- May 23-28, 2011
- Kennedy Space Center, FL
- International Teams Allowed for the First Time
Benefits

- The Lunabotics Mining Competition is a university-level competition designed to engage and retain students in science, technology, engineering and mathematics (STEM).
- NASA will directly benefit from the competition by encouraging the development of innovative lunar excavation concepts from universities which may result in clever ideas and solutions which could be applied to an actual lunar excavation device or payload.
- Prepare Students for Future Workforce
- 25' x 25' Regolith Bin for New Technologies Development (ISRU & HRS)
- Trigger New Concepts for Regolith Excavation Technologies
- Community Awareness of Future KSC Activities
- Outreach to local middle schools, FIRST Robotics, Girl Scouts and Boys & Girls Club
- KSC Visitor Center Tourist Attraction and Educational Event

2011 NASA Lunabotics Mining Competition
Competition Categories

◆ On-site Mining
  • 1st, 2nd & 3rd Place for most lunar simulant deposited in collector within 15 minutes
  • Minimum of 10 kg required to place
◆ Systems Engineering Paper (mandatory)
◆ Outreach Project (mandatory)
◆ Slide Presentation (optional)
◆ Team Spirit (optional)
◆ Joe Kosmo Award for Excellence
## Categories & Awards

<table>
<thead>
<tr>
<th>Category</th>
<th>Required/Optional</th>
<th>Due Dates</th>
<th>Award</th>
<th>Maximum Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>On-site Mining in the Lunarena</td>
<td>Required</td>
<td>May 26-28, 2011</td>
<td>First place $5,000 scholarship and Kennedy launch invitations</td>
<td>30</td>
</tr>
<tr>
<td>Systems Engineering Paper</td>
<td>Required</td>
<td>April 18, 2011</td>
<td>Second place $2,500 scholarship and Kennedy launch invitations</td>
<td>25</td>
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<tr>
<td>Outreach to Informal or K-12 Education</td>
<td>Required</td>
<td>April 18, 2011</td>
<td>Third place $1,000 scholarship and Kennedy launch invitations</td>
<td>20</td>
</tr>
<tr>
<td>Slide Presentation</td>
<td>Optional</td>
<td>April 18, 2011</td>
<td>less than 10 kilograms will receive one point per kg</td>
<td>Up to 10</td>
</tr>
<tr>
<td>Team Spirit Competition</td>
<td>Optional</td>
<td>May 23-28, 2011</td>
<td>$500 scholarship</td>
<td>Up to 15</td>
</tr>
<tr>
<td>Collaboration With a Minority Serving Institution</td>
<td>Optional</td>
<td>Feb. 28, 2011</td>
<td>10 Bonus Points</td>
<td></td>
</tr>
<tr>
<td>Multidisciplinary Team</td>
<td>Optional</td>
<td>March 7, 2011</td>
<td>Up to 10 Bonus Points</td>
<td></td>
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</table>
ESMD Course Material: Fundamentals of Lunar and Systems Engineering for Senior Project Teams, with Application to a Lunar Excavator

Contact: David Beale, dbeale@eng.auburn.edu

This webpage was created for student teams in a capstone design course who will be designing a lunar regolith excavator. Your project is sponsored and defined by NASA's Exploration Systems Mission Directorate (ESMD). The NASA technical mentor is Robert P. Mueller of Kennedy Space Center (KSC), who is NASA's Surface Systems Lead Engineer. Your project directive is to "investigate concepts for Lunar Regolith excavation equipment and propose solutions in the form of completed designs and prototypes."

Industry and universities have been independently designing lunar excavator prototypes for several years now. Some of these prototypes have been competing at the "Regolith Excavation Challenge," Recent competitors and competition results can be seen at:

By the way, the prize is $500,000!!! To date no design teams have been able to create an excavator that under the rules of the competition can achieve the regolith production rate needed to win. NASA is also considering creating an annual student competition.

**What's Inside: The Lunar Engineering Handbook**

This webpage contains the "Lunar Engineering Handbook," which is composed of the following chapters:

- Chapter 1: Introduction to Lunar Excavator Design for Senior Project Students [Chapter 1](http://education.ksc.nasa.gov/esmdspacegrant/LunarRegolithExcavatorCourse/index.htm)
- Chapter 3: Systems Engineering Example of a Cube Satellite [Chapter 3](http://education.ksc.nasa.gov/esmdspacegrant/LunarRegolithExcavatorCourse/index.htm)
- Chapter 4: Systems Engineering Tools [Chapter 4](http://education.ksc.nasa.gov/esmdspacegrant/LunarRegolithExcavatorCourse/index.htm)
- Chapter 5: The Lunar Environment and Issues for Engineering Design [Chapter 5](http://education.ksc.nasa.gov/esmdspacegrant/LunarRegolithExcavatorCourse/index.htm)
- Chapter 6: Component and Material Selection
- Chapter 7:
## Categories & Awards

| Joe Kosmo Award for Excellence | A school trophy, Kennedy launch invitations, and up to $1,500 travel expenses for each team member and one faculty advisor to attend NASA Desert RATS. | 125 Point Max |

Human Spaceflight Architecture Team
44 Lunabotics Teams / 72 Registered

ALEX
Auburn University
LunarTechs
California State University, Sacramento
Collaborating with Modesto Junior College

Mile High Miners
Colorado School of Mines
LAR-E (Lunar All-terrain Regolith Excavator)
Embry Riddle Aeronautical University, Prescott
Moon Pi
Embry-Riddle Aeronautical University, Daytona
The HEXCAVATOR Project
Florida State University
Cheese Graters
Harvard University
ISU Lunabotics - Team LunaCY
Iowa State University
Henderson Moon Shredders
ITT Technical Institute Henderson, NV
Golden Eagles
John Brown University
Munabotics
Marquette University
R&T Robotics Team
Middle Tennessee State University
Collaborating with Tennessee State University

Manatee Mining System
Milwaukee School of Engineering
Montana MULE 2.0
Montana State University
Montana School of Mines
Montana Tech at University of Montana
Aggies Lunabotics Team
New Mexico State University
HOPE
Oakton Community College
NYU-Poly Atlas
Polytechnic Institute of New York University
SDSM&T Moonrockers
South Dakota School of Mines and Technology
Lunar Solutions
Temple University
Texas A&M University at Prairie View
Texas A&M University at Prairie View
Dust Devil
The University of Akron
Collaborating with Elon University
Alabama Lunabotics
University of Alabama
Space Hogs
University of Arkansas - Fayetteville

2011 NASA Lunabotics Mining Competition
More University Teams

NMIMS-UH Space Miners
University Of Houston
Collaborating with NMIMS, India
Illinois Robotics In Space (IRIS)
University of Illinois at Urbana-Champaign
LunaCats
University of New Hampshire
49er Luna Miners
University of North Carolina in Charlotte
Raptor
University of North Dakota
University of Portland Robotics
University of Portland
Lunar Ash Borers
University of Southern Indiana
Virginia Tech
Virginia Polytechnic Institute and State

Mountaineers
West Virginia University
A.R.T.E.M.I.S.
Western Kentucky University

2011 NASA Lunabotics Mining Competition
International University Teams

**Bangladesh**
- BRACU_ChondroBot
- BRAC University

**Canada**
- Production
- Laurentian University
- McGill LunarEx Team
- McGill University

**Colombia**
- IAC COLOMBIA
- Instituto de Astrobiologia Colombia
- RoboCol
- Universidad de Los Andes

**India**
- Gurutva (Gravity in English)
- Birla Institute of Technology, Mesra
- The Trailblazers
- Chitkara Institute of Engineering and Technology
- STRIKERS
- CT Institute of Engineering Management and Technology
- The Illuminati
- GITAM University
- STEER (Saveetha Team of Enigmatic Engineering Robotics)
- Saveetha University
- Sahasrajeet
- Ujjain Engineering College
- Octopod
- Amity University

2011 NASA Lunabotics Mining Competition
The Competition
West Virginia U Testing
University of North Dakota with the Next Generation
University of North Dakota with the Next Generation
Colorado School of Mines, Lego Scaled Prototype
Team Spirit in abundance!
Team Spirit in abundance!
Jumbotron Scoreboard

Lunabotics

- Laurentian: 237.4 kg
- North Dakota: 172.2 kg
- West Virginia: 106.4 kg
- Embry Riddle-Prescott: 85.4 kg
- Auburn: 80.0 kg
- Virginia Tech: 79.0 kg
- Colorado: 72.0 kg
- Alabama: 63.2 kg
- John Brown: 50.0 kg
- Southern Indiana: 37.6 kg
The Competition

More Photos
Regolith Mining Scores (Kg)

1) Laurentian - 237.4
2) North Dakota - 172.2
3) West Virginia - 106.4
4) Embry Riddle - Prescott - 85.4
5) Auburn - 80.0
6) Virginia Tech - 79.0
7) Colorado School of Mines - 72.0
8) Alabama - 63.2
9) John Brown - 50.0
10) Southern Indiana - 37.6
11) South Dakota School of Mines - 34.0
12) Temple University - 33.6
13) University of Akron - 32.0
Results

2011 Winners by Category:

- On Site Regolith Mining Award Winners (see note below) 1st Place - Laurentian University, Ontario, Canada - 237.4 kilograms
- 2nd Place - North Dakota University - 172.2 kilograms
- 3rd Place - West Virginia University - 106.4 kilograms
- Judges Innovation Design Award to Embry Riddle Aeronautical University, Prescott, Arizona Campus
- Communications Efficiency Award to Laurentian University
- Team Spirit Award - University of Alabama Honorable Mention - North Dakota University, Embry Riddle Daytona Campus & West Virginia University
- Slide Presentation Award - Embry Riddle Daytona
- Outreach Project Award - Montana School of Mines
- Systems Engineering Paper Award - John Brown University, Arkansas

- The Joe Kosmo Award for Excellence (to the school with the best overall results from all categories): North Dakota University

2011 NASA Lunabotics Mining Competition
Statistics

- 36 teams actually competed from 23 USA states and 4 foreign countries (India, Bangladesh, Colombia and Canada)
- 72 teams registered, 44 submitted a Systems Engineering paper
- 50% Attrition Rate – every team that came to KSC is to be commended
- The team that placed 13th this year would have won the competition last year
- The winning team mined an equivalent of about 1 ton per hour of regolith
- The Constellation ISRU requirement to make 10 metric tons of O2 required about 1,000 tons of regolith per year
- A lunabot could meet this requirement in about 8 months if only operating with one 8 hour shift per Earth day.
- None of the machines would have survived the lunar environment or lifetime as designed, even if space qualified hardware were used
- The cost of the lunabots ranged from $5,000 to $25,000
- The team sizes ranged from 2 to 17 members, average of about 10
- Two semesters were spent designing and building for college credit
- The youngest team member was 7 years old.

2011 NASA Lunabotics Mining Competition
Many Thanks!

- Thank you to 14 Judges from Industry, Academia and NASA
- Over 100 Volunteers from NASA KSC
- NASA KSC Management – Mr. Bob Cabana and Directors
- KSC R&T Board
- KSC Visitor’s Center - Delaware North
- Caterpillar – Gold Sponsor
- Newmont Mining – Silver Sponsor
- Harris – Silver Sponsor
- Honeybee Robotics – Bronze Sponsor
- KSC Surface Systems Office
- KSC EX – Gloria Murphy, Susan Sawyer and staff
- Moral support from our families and co-workers!