

National Aeronautics and Space Administration



# 2011 NASA Lunabotics Mining Competition

**PTMSS/SRR**

**Ottawa, Canada**

**June 20, 2011**

**Rob Mueller,  
Chief, Surface Systems Office  
NASA KSC, NE-S  
Head Judge & Lead Technical Expert  
June 20, 2011**

**Gloria Murphy  
Project Manager  
NASA KSC EX-E**



# 2<sup>nd</sup> Annual NASA Lunabotics Mining Competition

May 26-28, 2011

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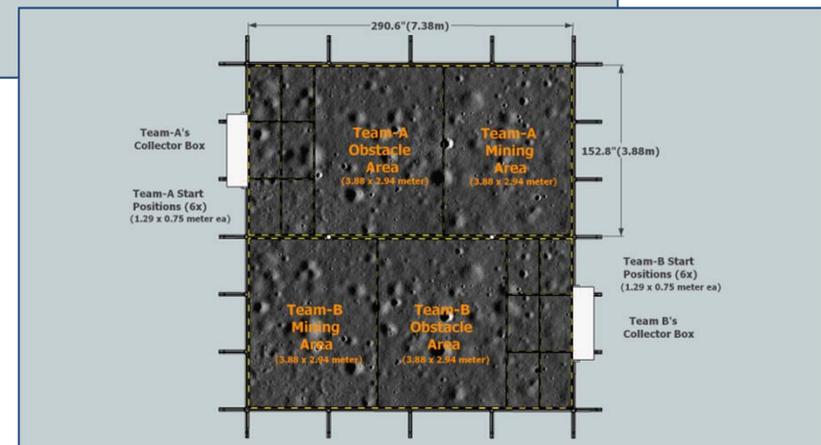
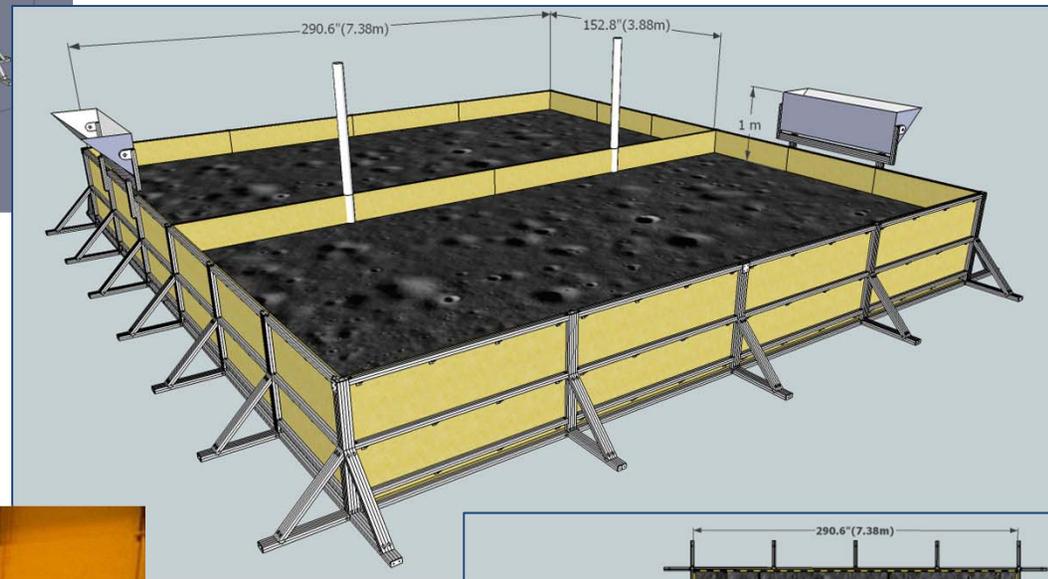
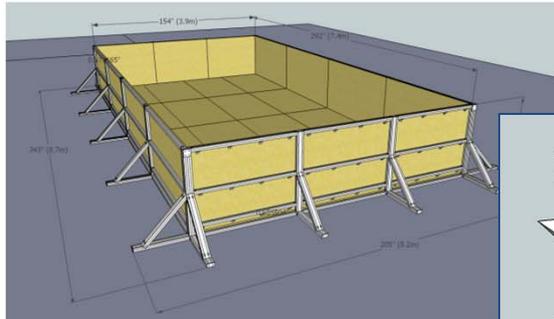
# What is a Lunabot?



- ◆ 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



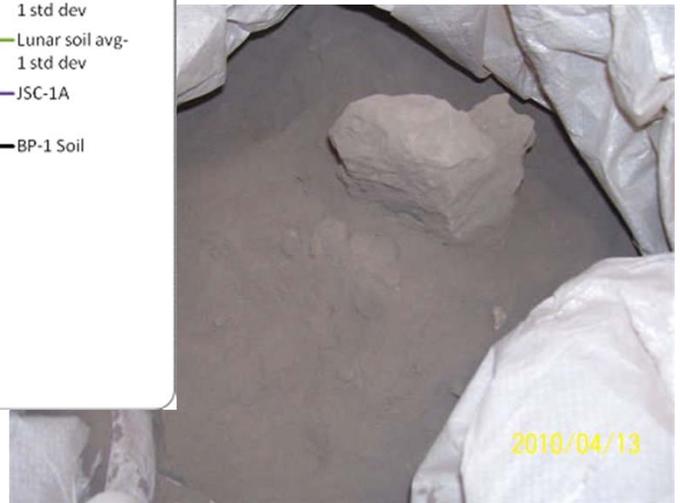
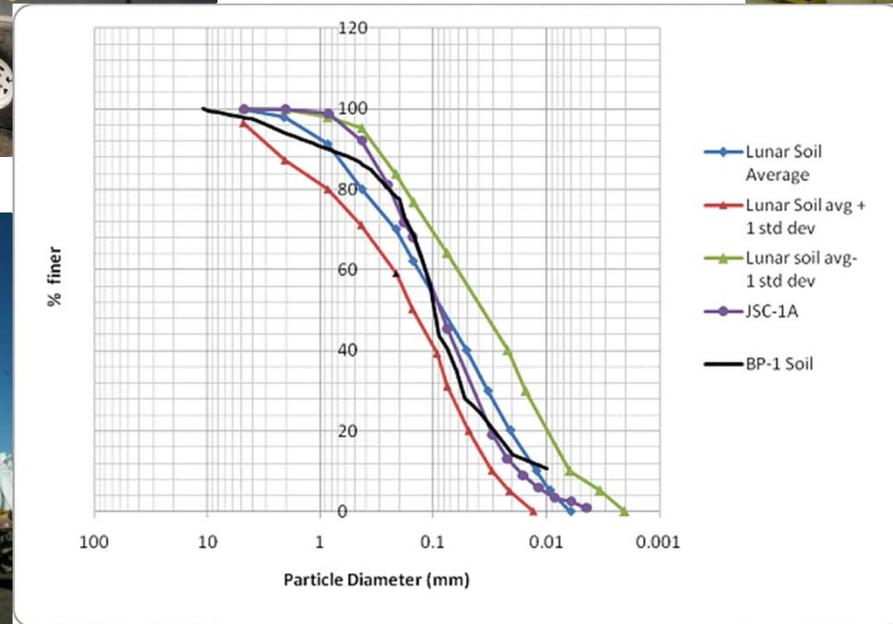
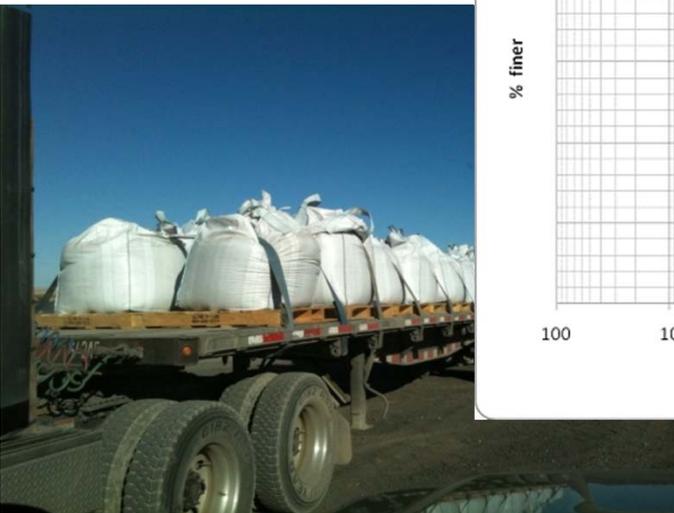
# LunArena



# 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**

# Competition Categories

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## ◆ On-site Mining

- 1<sup>st</sup>, 2<sup>nd</sup> & 3<sup>rd</sup> 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



Category	Required/ Optional	Due Dates	Award	Maximum Points
On-site Mining in the Lunarena	Required	May 26-28, 2011	First place \$5,000 scholarship and Kennedy launch invitations	30
			Second place \$2,500 scholarship and Kennedy launch invitations	25
			Third place \$1,000 scholarship and Kennedy launch invitations	20
			less than 10 kilograms will receive one point per kg	Up to 10
Systems Engineering Paper	Required	April 18, 2011	\$500 scholarship	Up to 20
Outreach to Informal or K-12 Education	Required	April 18, 2011	\$500 scholarship	Up to 20
Slide Presentation	Optional	April 18, 2011	\$500 scholarship	Up to 20
Team Spirit Competition	Optional	May 23-28, 2011	\$500 scholarship	Up to 15
Collaboration With a Minority Serving Institution	Optional	Feb. 28, 2011		10 Bonus Points
Multidisciplinary Team	Optional	March 7, 2011		Up to 10 Bonus Points

# Systems Engineering Senior Design Capstone Project



<http://education.ksc.nasa.gov/esmdspacegrant/LunarRegolithExcavatorCourse/index.htm>

**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](mailto:dbeale@eng.auburn.edu)

**Home** 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) <http://www.nasa.gov/directorates/esmd/home/index.html>. The NASA technical monitor 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."

**Chapter X**

**Lunar Engineering Handbook** 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" <http://regolith.csewi.org/>. Recent competitors and competition results can be seen at: <http://www.californiaspaceauthority.org/html/press-releasesandletters/pr080805-regolith-all-pics.html>

**Chapter 1**

**Chapter 2** 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.

**Chapter 3**

**Chapter 4**

**Chapter 5** This webpage contains the "Lunar Engineering Handbook", which is composed of the following chapters:

**Chapter 6** Chapter 1: Introduction to Lunar Excavator Design for Senior Project Students [Chapter1.htm](#)  
Chapter 2: Systems Engineering – The Systems Design Process [Chapter2.htm](#)  
Chapter 3: Systems Engineering Example of a Cube Satellite [Chapter3.htm](#)  
Chapter 4: Systems Engineering Tools [Chapter4.htm](#)  
Chapter 5: The Lunar Environment and Issues for Engineering Design [Chapter5.htm](#)  
Chapter 6: Component and Material Selection [Chapter6.htm](#)

**Chapter 7**

**Chapter 8**

# Categories & Awards



<p><b>Joe Kosmo Award for Excellence</b></p>		<p>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.</p>	<p>125 Point Max</p>
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# 44 Lunabotics Teams / 72 Registered 36 at the Competition



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 Syste  
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

## More University Teams



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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

# 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  
Sahastrajeet  
Ujjain Engineering College  
Octopod  
Amity University

# The Competition



West Virginia U Testing



Embry Riddle Prescott, Arizona LAR-E





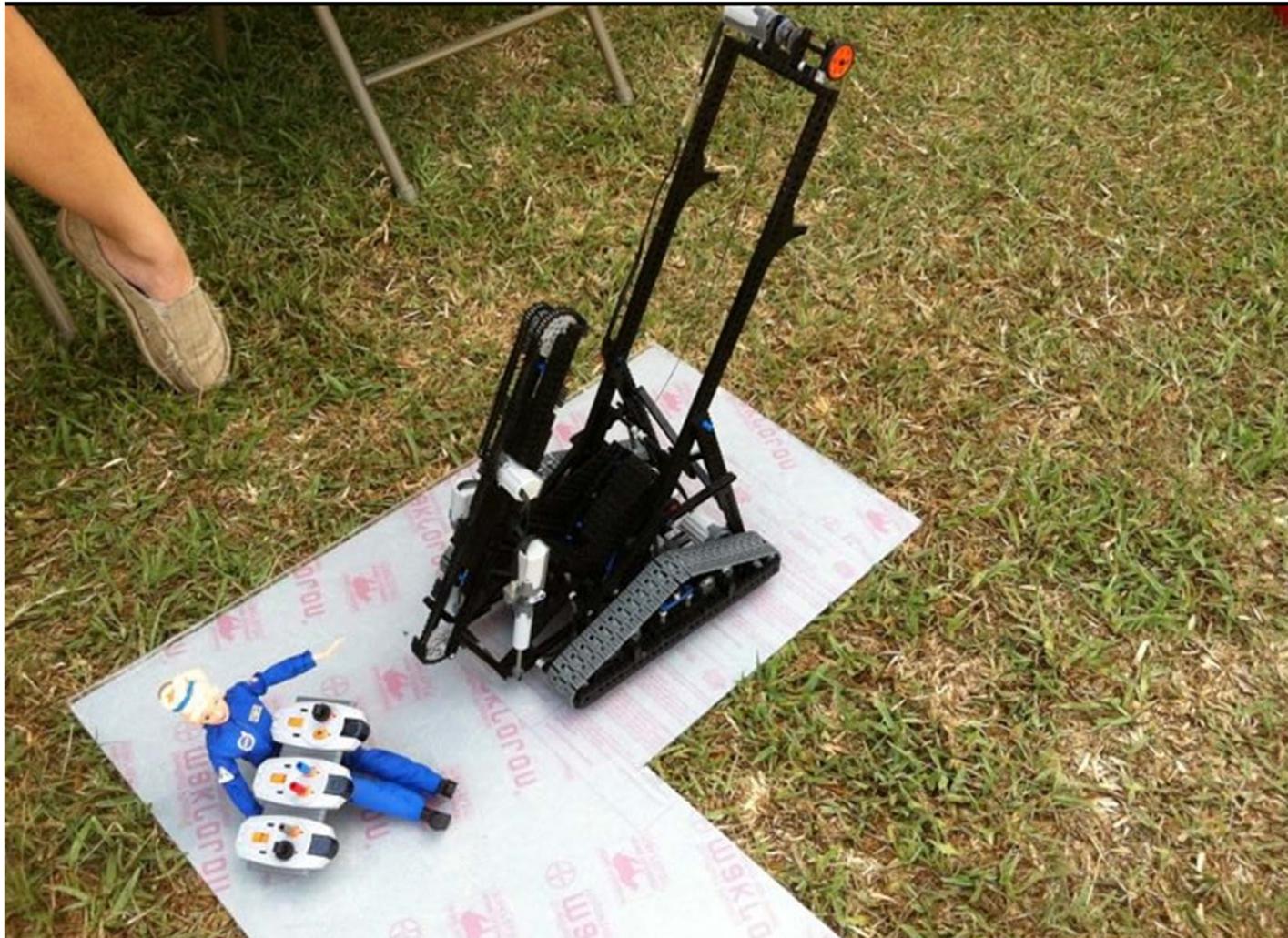
University of North Dakota with the Next Generation



# 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

A large outdoor jumbotron scoreboard for the Lunabotics competition. The scoreboard is black with white text. At the top left, the word "Lunabotics" is written in a large, bold font. To the right of the title is a small NASA logo. Below the title is a list of ten teams, each followed by its weight in kilograms. The teams are listed in descending order of weight. The scoreboard is mounted on a metal frame and is viewed from a low angle, looking up at the display.

Team	Weight (kg)
• 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

## 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



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## 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*



- ◆ 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 13<sup>th</sup> 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 O<sub>2</sub> 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.

## 2012 Lunabotics – New Rules!



- ◆ Current competitors do not produce Lunar like machines
- ◆ Not dust tolerant or robust
- ◆ They are playing to win
- ◆ We must change the rules to get a Lunar like prototype
  
- ◆ What should we do?
  
- ◆ Soliciting inputs form the Space Mining Community
  
- ◆ New Rules will be formulated in June/July 2011
  
- ◆ Lunabotics 2012 rules will be published in August 2011
  
- ◆ **Contact Rob Mueller – [rob.mueller@nasa.gov](mailto:rob.mueller@nasa.gov)**

# Many Thanks!



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- ◆ 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!

# The Competition

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Lunabotics 2011 Slide Show will be available on YouTube.com