

National Aeronautics and Space Administration



2011 NASA Lunabotics Mining Competition

PTMSS/SRR

Ottawa, Canada

June 20, 2011

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

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



2nd Annual NASA Lunabotics Mining Competition

May 26-28, 2011



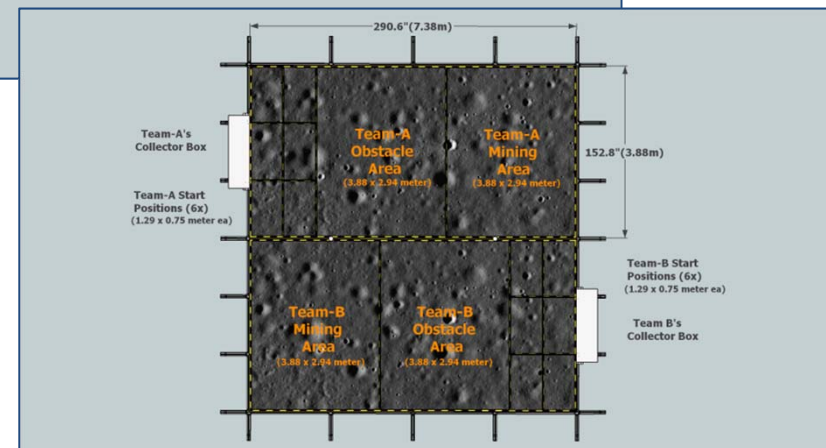
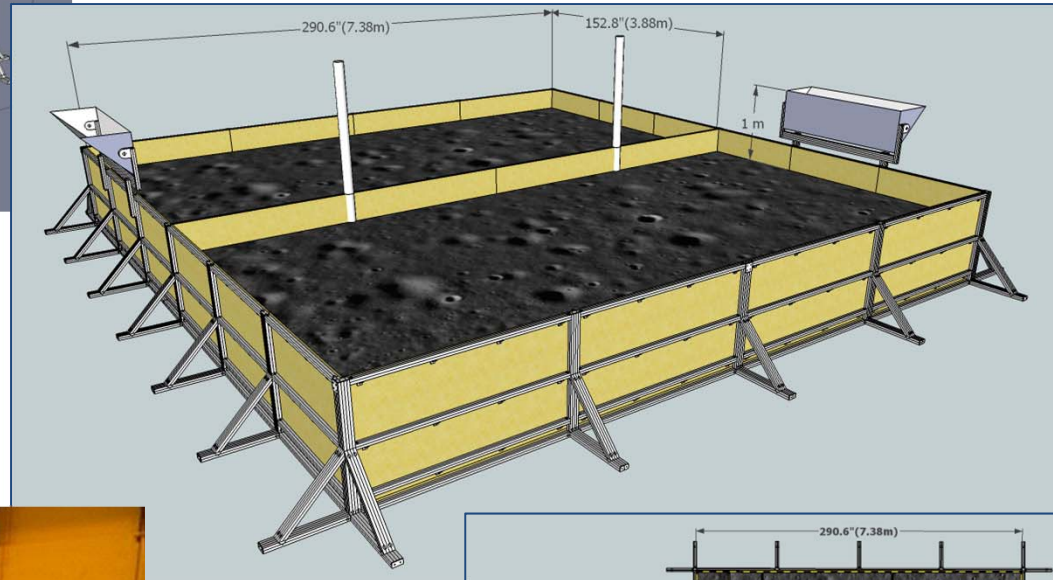
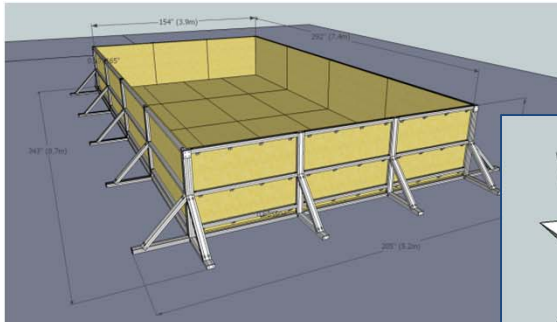
What is a Lunabot?



- ◆ 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



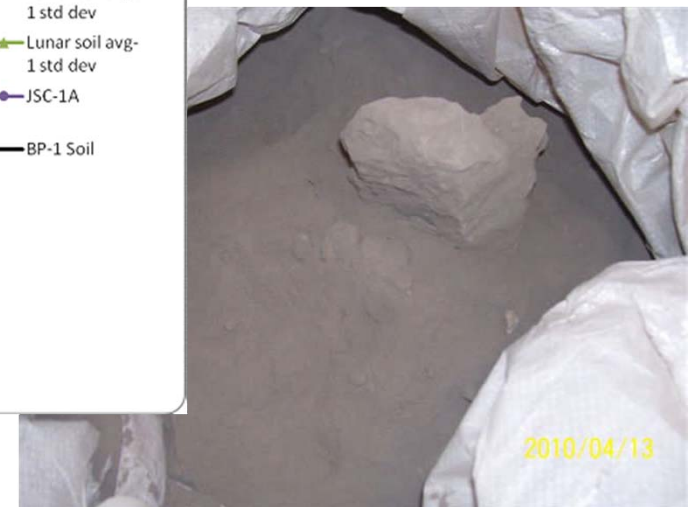
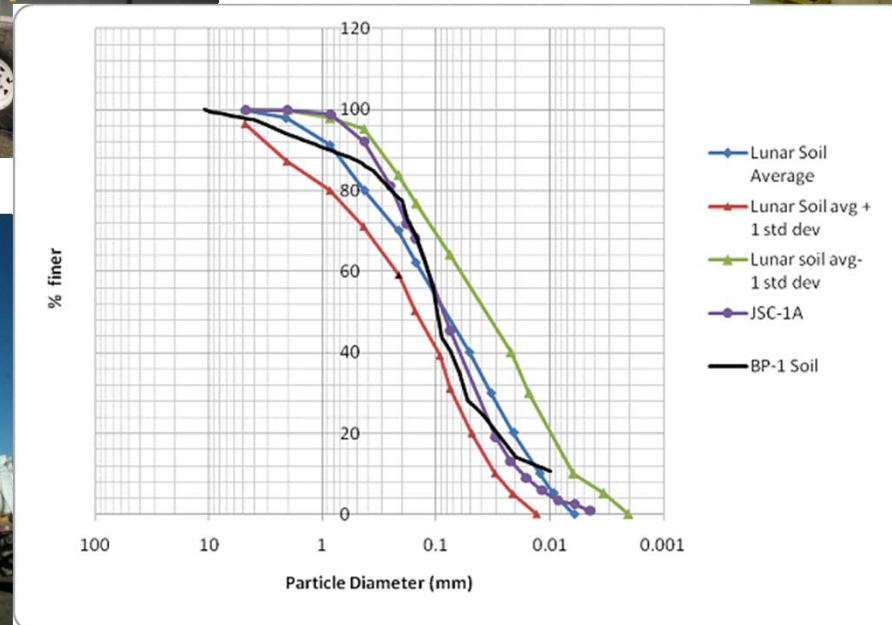
LunArena



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



◆ 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

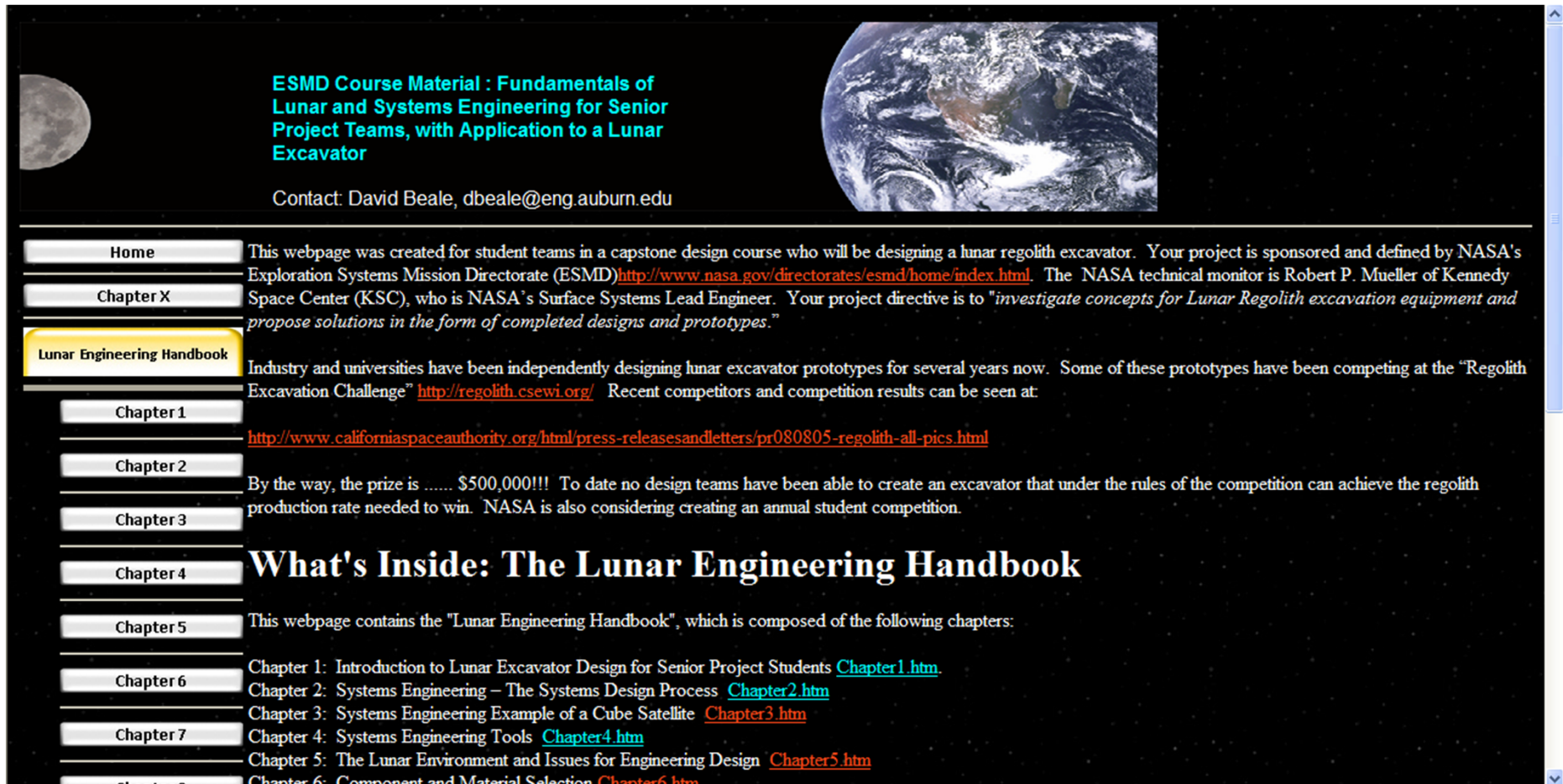


Category	Required/ Optional	Due Dates	Award	Maximum Points
On-site Mining in the Lunarena	Required	May 26-28, 2011	First place \$5,000 scholarship and Kennedy launch invitations	30
			Second place \$2,500 scholarship and Kennedy launch invitations	25
			Third place \$1,000 scholarship and Kennedy launch 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>



The screenshot shows the 'ESMD Course Material : Fundamentals of Lunar and Systems Engineering for Senior Project Teams, with Application to a Lunar Excavator' website. It features a navigation menu on the left with links to Home, Chapter X, Lunar Engineering Handbook, and Chapters 1 through 7. The main content area includes a header with a moon and Earth image, contact information for David Beale, and a detailed description of the course project. It also mentions the 'Regolith Excavation Challenge' and provides a link to the 'Lunar Engineering Handbook'.

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

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 **What's Inside: The Lunar Engineering Handbook** 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 7 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](#)

Categories & Awards



<p>Joe Kosmo Award for Excellence</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



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





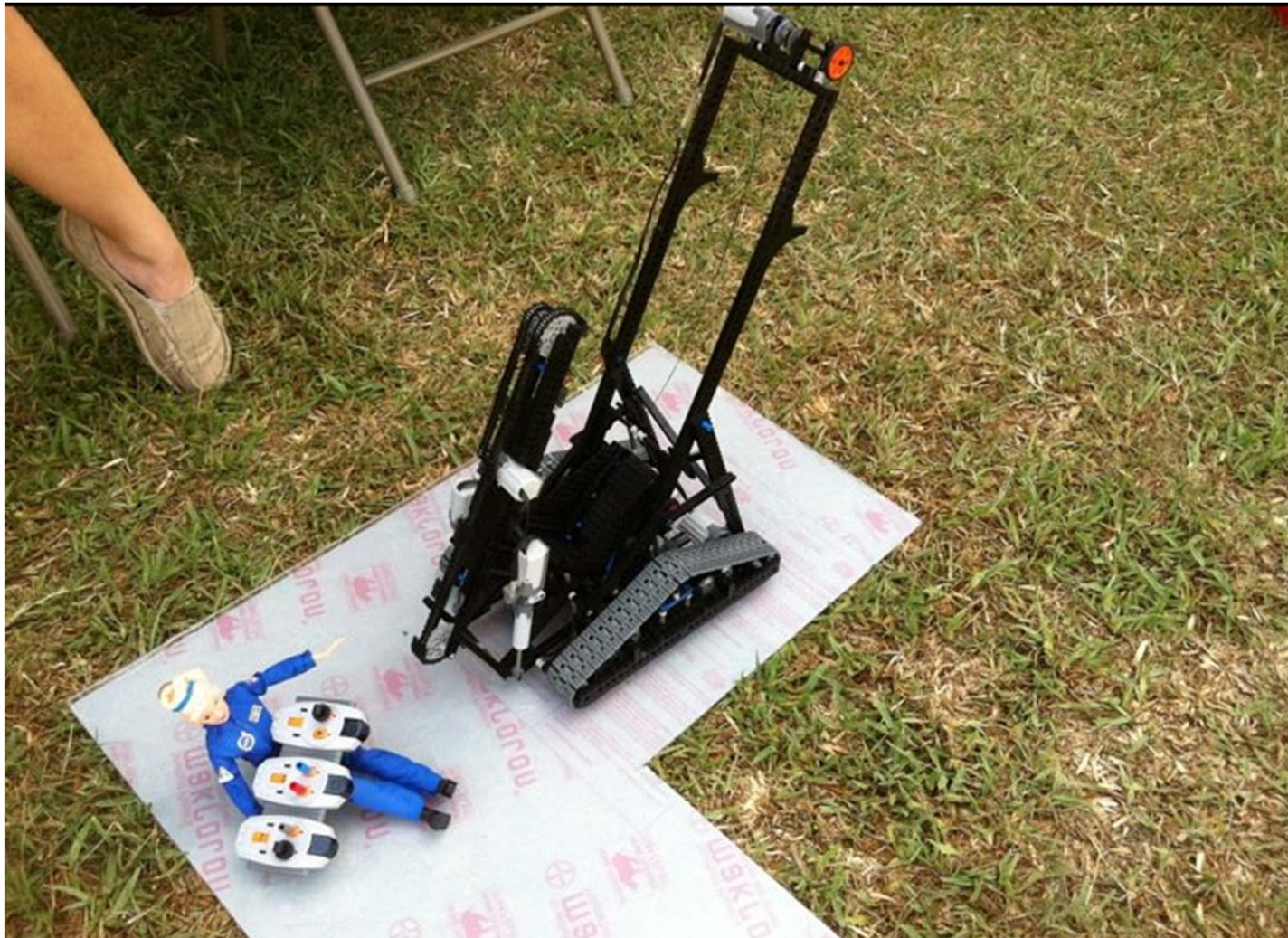
University of North Dakota with the Next Generation



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 red text. It lists ten teams and their corresponding weights in kilograms. A small NASA logo is visible in the top right corner of the scoreboard. The bottom of the scoreboard features a red, textured graphic that resembles a lunar surface or a rover's wheel.

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

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



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 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.

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**

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



Lunabotics 2011 Slide Show will be available on YouTube.com