

National Aeronautics and Space Administration



NASA Lunabotics Mining Competition: 2012 Results & Taxonomy / 2013 Rules

**Space Resources Roundtable (SRR)
Planetary & Terrestrial Mining Sciences
Symposium (PTMSS)**

Toronto, Canada

May 5-8, 2012

Presented by Rob Kelso, PISCES Director, ret. NASA JSC

**Rob Mueller,
Lunabotics Head Judge
Senior Technologist,
Surface Systems Office
NASA Kennedy Space Center, (KSC)
Florida**

**Gloria Murphy
Lunabotics Project Manager
Education & External Relations
NASA Kennedy Space Center
Florida**



4th Annual NASA Lunabotics Mining Competition: May 20-24, 2013 Kennedy Space Center - Visitor's Center



Annual NASA Lunabotics Mining Competition A Centennial Challenges Spinoff for University Teams



Held Annually since 2010



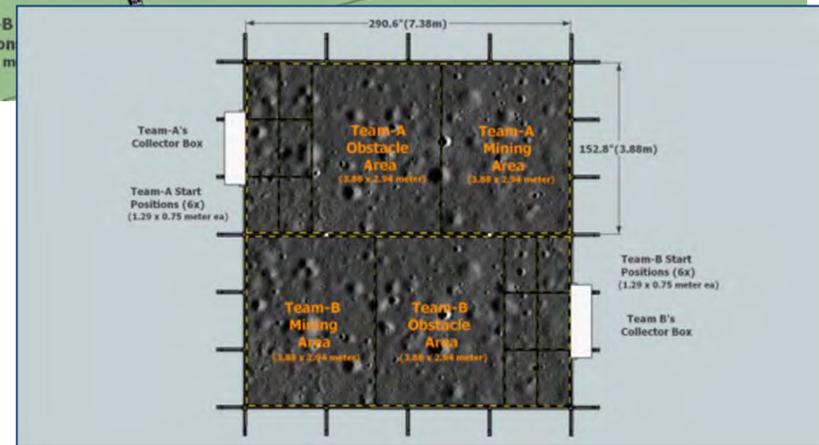
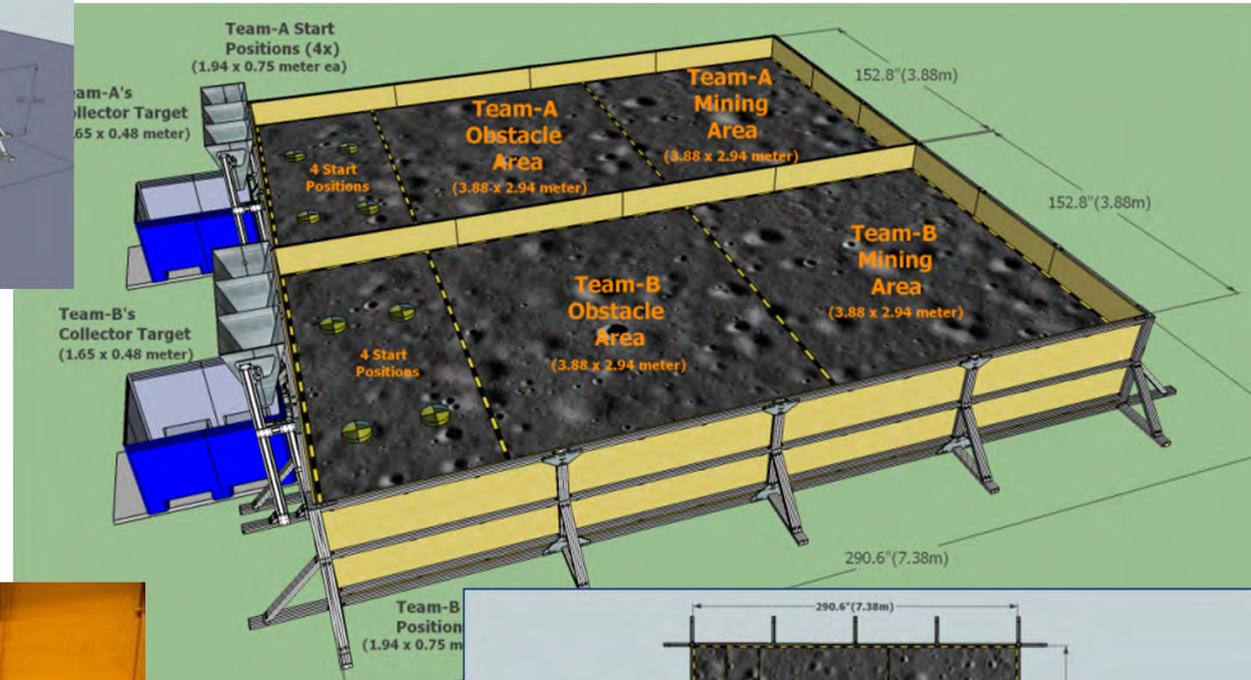
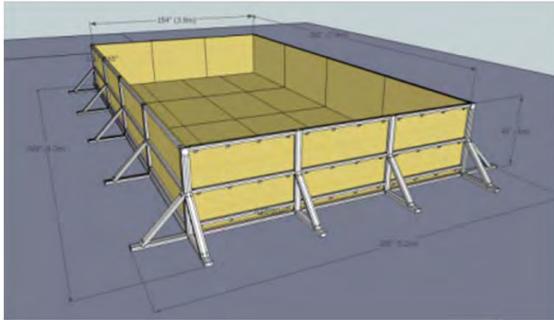
What is a Lunabot?



- ◆ 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 .75m height
- ◆ Designed, Built and Tested by University Student Teams



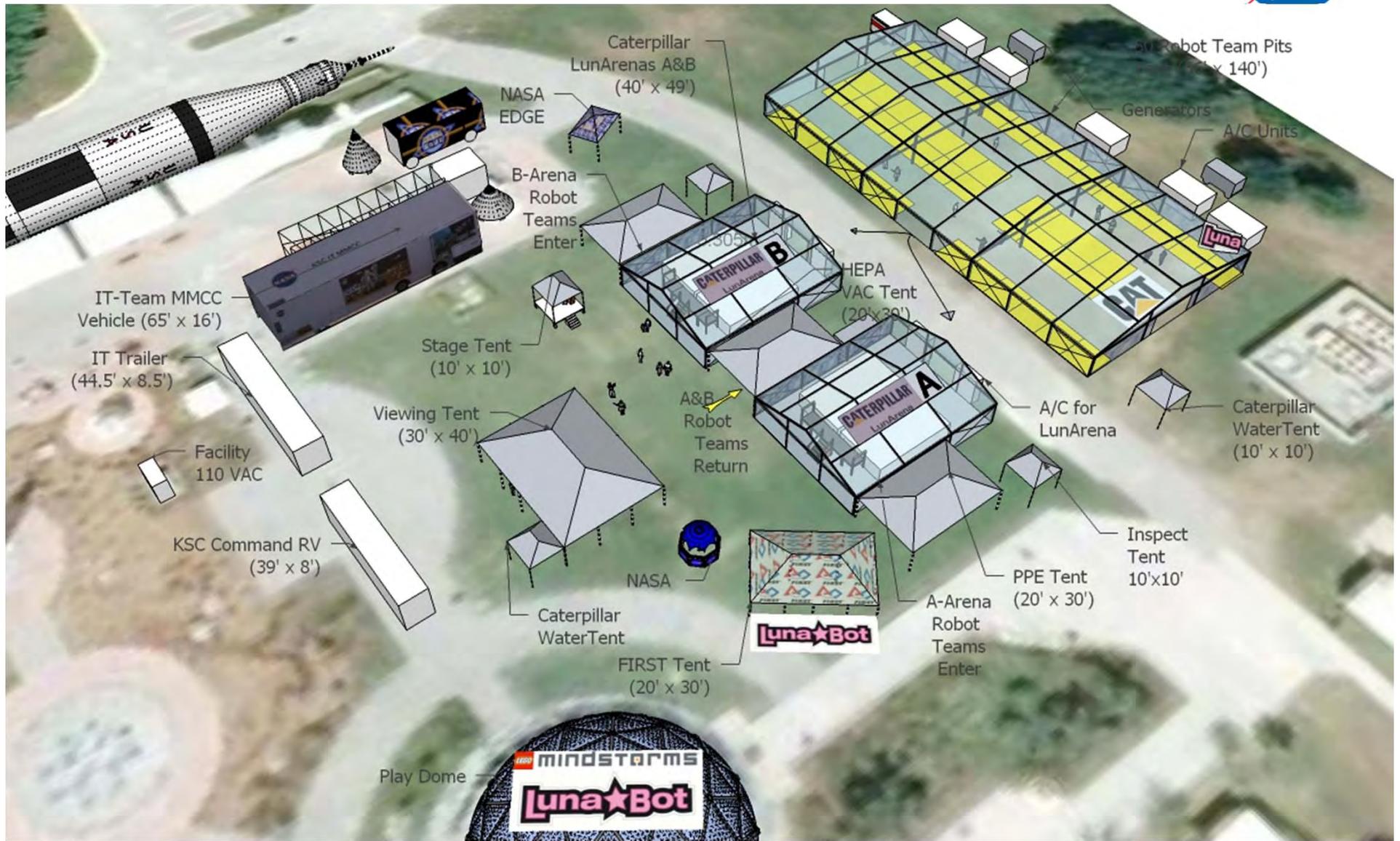
LunArena (~25 ft x 25 ft each)



New Permanent Steel Lunarena Bins this Year (4 X) 115,000 lbs of BP-1 Regolith Simulant Each!



Competition Layout @ KSC Visitors Center Rocket Garden



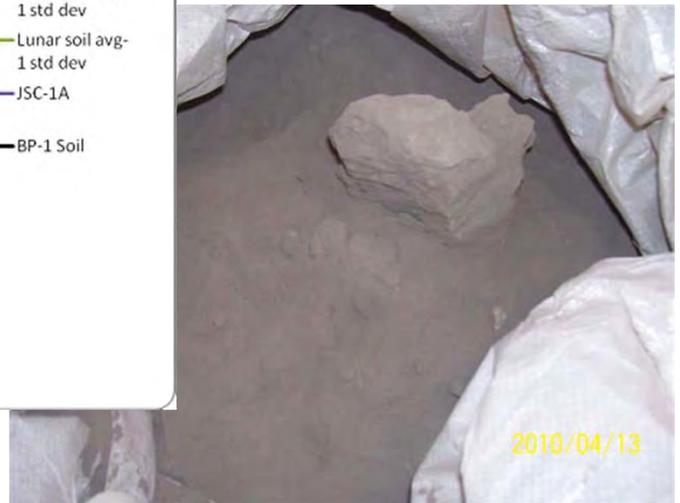
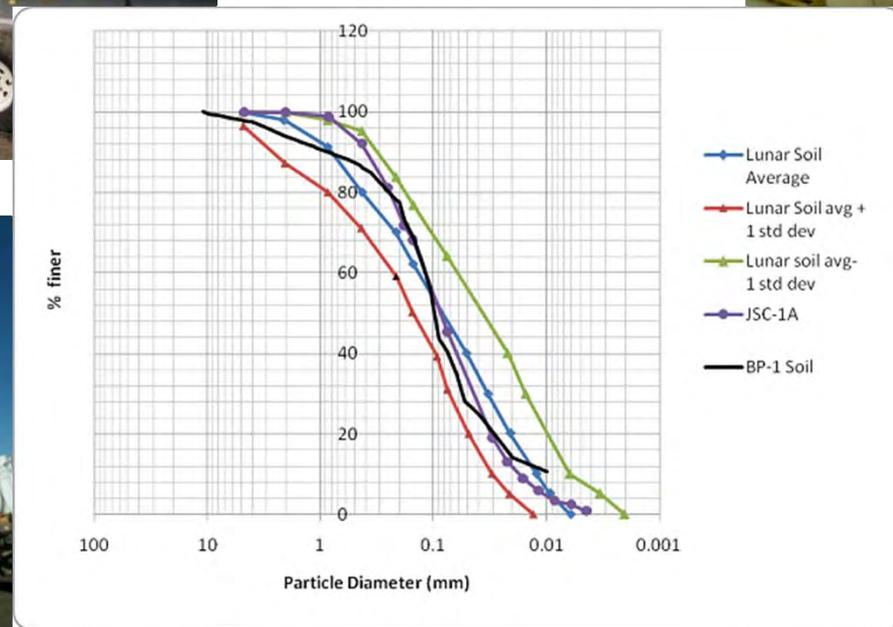
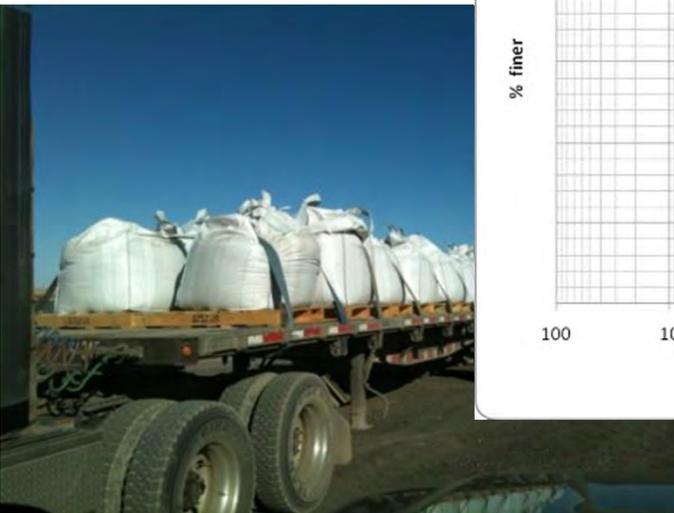
Lunabot Design Taxonomy



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 10 minutes: 2 Competition Attempts Allowed**
 - **\$5000, \$3000, \$2000, \$1000 Scholarships for most points scored in several judging criteria**
 - **Held Annually: May 20-24 in 2013**
 - **Located at Kennedy Space Center, FL Visitor's Center**
 - **International Teams Invited**
-

Judging Criteria for Lunabotics: 2013



Table 1: Mining Category Scoring Example

Mining Category Elements	Specific Points	Actual	Units	LunaPoints
Pass Inspections				1000
Regolith over 10 kg	+3/kg	110	kg	+300
Average Bandwidth	-1/50kb/sec	5000	kb/sec	-100
Lunabot Mass	-8/kg	80	kg	-640
Report Energy Consumed	+20	1	1= Achieved 0= Not Achieved	+20
Dust-Tolerant Design (30%) & Dust-Free Operation (70%)	0 to +100	70	Judges' Decision	+70
Full Autonomy	500	1	1= Achieved 0= Not Achieved	+500
Total				1150

Benefits – Multiple Dimensions of Success



- ◆ **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 (crowd sourcing)**
 - ◆ **Prepare Students for Future Workforce – Hands on Experience!**
 - ◆ **25' x 25' Regolith Bin for New Technologies Development**
 - ◆ **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**
 - ◆ **Industrial Sponsors can hire the best talent from all Lunabotics Teams**
 - ◆ **Students get job opportunities**
-

Competition Categories



- ◆ **On-site Mining (\$3,000; \$2,000; \$1,000)**
 - 1st, 2nd & 3rd Place Prizes for most lunar simulant deposited in collector within 2 x 10 minute rounds
 - Minimum of 10 kg required to qualify for a prize
- ◆ **Systems Engineering Paper (mandatory) \$500**
- ◆ **Outreach Project (mandatory) \$500**
- ◆ **Slide Presentation (optional) \$500**
- ◆ **Team Spirit (optional) \$500**
- ◆ **Best Use of Social Media (optional)**

Grand Prize:
Joe Kosmo Award for Excellence \$5,000





Lunabotics 2012 University Teams (Statistics)

- ◆ 72 Teams Registered
 - ◆ 57 Teams Arrived at KSC (79% Success Rate)
 - ◆ 55 Teams Competed at KSC (76 % Success Rate)
 - ◆ 13 Teams Qualified with >10 Kg of regolith mined (24 % Success Rate)
 - ◆ 0 Teams were successful with full autonomy (0% Success Rate)

 - ◆ Over 600 students participated / 3,000 viewers average on NASA Edge Streaming
 - ◆ Over 100 community volunteers at the 2012 competition
 - ◆ 17 Judges from across the USA
 - ◆ Support from industrial sponsors
 - ◆ Support from NASA HQ
 - ◆ Support from ASCE & AIAA
 - ◆ Career Fair (7 students hired)
 - ◆ College Recruitment Event for High School Students (\$14,000 in Scholarships)
-

Lunabotics 2012 International University Teams



◆ 19 International Teams

◆ 8 Countries Represented

- Bangladesh (3)
- Canada (3)
- Columbia (2)
- India (8)
- Mexico (1)
- Romania (1)
- South Korea (1)
- USA (38)



◆ Goal: Every Continent Represented!

Lunabotics Mining Competition 2012: Results



◆ Joe Kosmo Award for Excellence (Grand Prize)

The University of Alabama in collaboration with Shelton State Community College

◆ On-Site Mining Award

First Place - Iowa State University in collaboration with Wartburg College

Second Place - The University of Alabama in collaboration with Shelton State Community College

Third Place – Milwaukee School of Engineering

◆ Judges Innovation Award

Polytechnic Institute of NYU

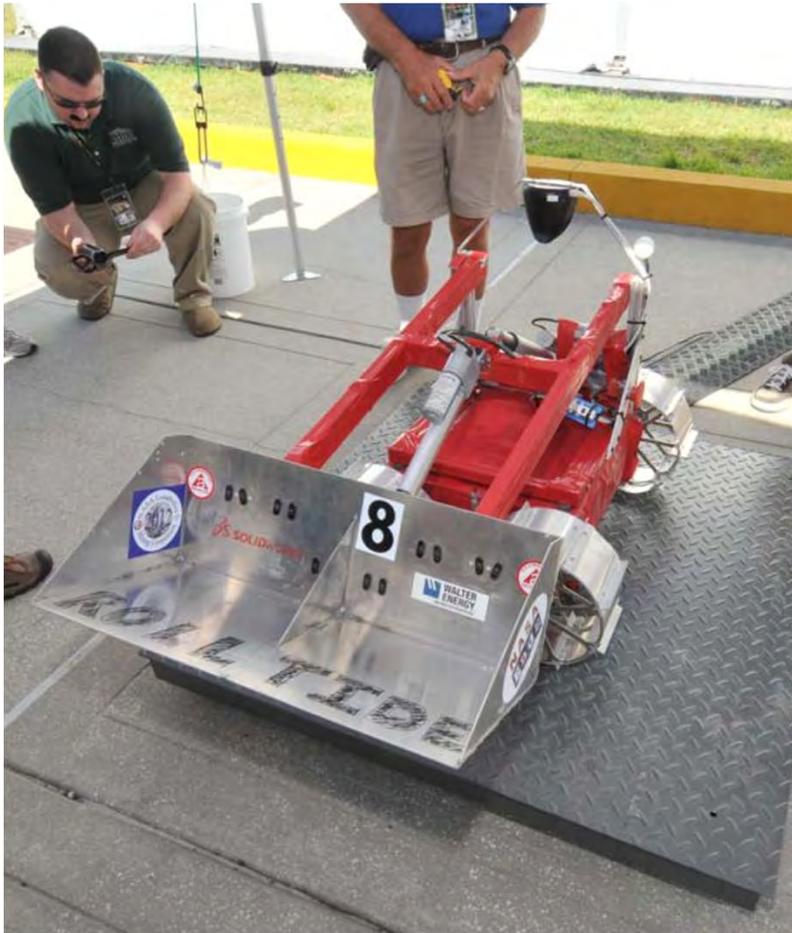
◆ Efficient Use of Communications Power Award

Iowa State University in collaboration with Wartburg College

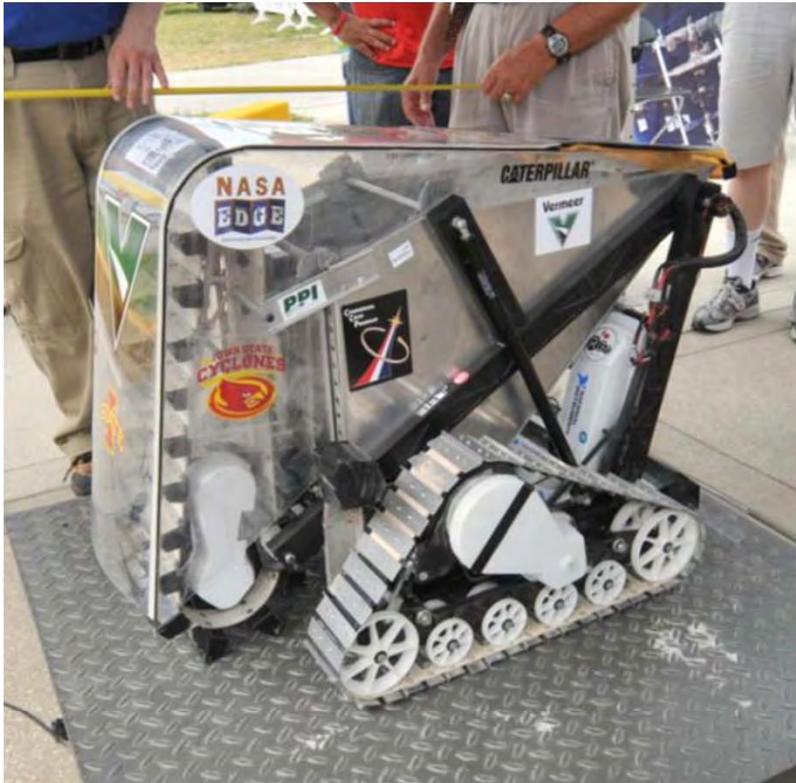
◆ Best Use of Social Media

Universidad de Los Andes of Colombia

2012 Joe Kosmo Award for Excellence (Grand Prize) University of Alabama & Shelton Comm. College



2012 On-Site Mining Award Iowa State University with Wartburg College



Teams that Qualified in the On Site Mining Category (>10Kg Excavated in a round) 13 / 55 Teams



1	Iowa State University	LunaCY	1191
2	The University of Alabama	Alabama Lunabotics: Team NASACAR	920
3	Milwaukee School of Engineering	Regolith Raiders	848
4	John Brown University	Eaglenauts	785
5	Auburn University	Aubotics	684
6	Polytechnic University of NYU	Atlas	442
7	Laurentian University	Laurentian Lunabotics	419
8	Montana State University - Bozeman	Montana ALE (Autonomous Lunar Excavator)	406
9	University of New Hampshire	UNH LunaCats	376
10	West Virginia University	Mountaineers	298
11	Florida Institute of Technology	Pandia	251
12	Middle Tennessee University	Raider Robotics	233
13	Universidad Autónoma Metropolitana	LUNABOTICS UAM TEAM	160

Robot Mobility Method



Robot Mobility Method	# of machines employing mobility method	Lunabotics 2012
Two tracks	26	10
Four fixed wheels	24	17
Four fixed wheels with grousers	12	13
Stationary with swivel	5	1
Four individually steerable wheels	4	1
Four fixed wheels with super profile	2	3
Six fixed wheels	2	4
Eight Fixed Wheels		1
Whegs/Legs		1
Four individual steerable tracks	1	
Four steerable wheels with grousers	1	
Four wheels with grousers and suspension	1	
Six fixed wheels with grousers	1	
Stationary	1	
Three wheels (one steerable)	1	
Two tracks and two wheels (half track)	1	
Two very wide tracks	1	
Four fixed tracks	1	

Regolith Excavation Mechanisms



Regolith Excavation Mechanism	# of machines employing excavation mechanism	Lunabotics 2012
Bucket ladder (two chains)	29	10
Bucket belt	10	6
Front End Loader	10	14
Scraper	8	8
Auger plus conveyor belt / impeller	4	3
Backhoe	4	0
Bucket ladder (one chain)	4	1
Bucket wheel	4	2
Bucket drum	3	4
Claw / gripper scoop	2	0
Drums with metal plates or brush (street sweeper)	2	1
Bucket ladder (four chains)	1	0
Magnetic wheels with scraper	1	0
Rotating tube/scoops entrance	1	1
Vertical auger	1	0
Rotating Scoop		1

Regolith Storage Mechanism



Regolith Storage Mechanism	# of machines employing storage mechanism	Lunabotics 2012
Hopper	56	30
Scoop	14	11
Scraper	3	4
Backhoe scoop	1	0
Bucket drum	1	4
Bulldozer	1	0
Inside tube body	1	2

Regolith Dumping Mechanism



Regolith Dumping Mechanism	# of machines employing dumping mechanism	Lunabotics 2012
Raising / tilting hopper	32	21
Tilting / raising scoop	9	13
Conveyor belt (with attachments)	8	4
Chute	5	2
Raising hopper with back chute	5	1
Bucket ladder	3	1
Ramp plus rotating valve bottom	3	
Angled auger	2	2
Angled vibrating hopper (stationary)	2	
Cable pulling up bottom of hopper	2	1
Horizontal belt / back opens	2	
Separate lifting ramp/storage bin	2	
Tilting / raising scoop with overhead dump	2	
Raising whole robot on second robot, then tilting hopper with chute	2	
Swivel of backhoe arm, rotating scoop	2	1
Raising bucket drum, counter rotate	1	4
Rotating scoop (overhead)	1	1
Clamshell scoop opening	1	

Is the Most Popular Winning Design the Best Lunabot Regolith Mining Design for the Moon??



2009: Paul's Robotics WPI



2010: Montana State U

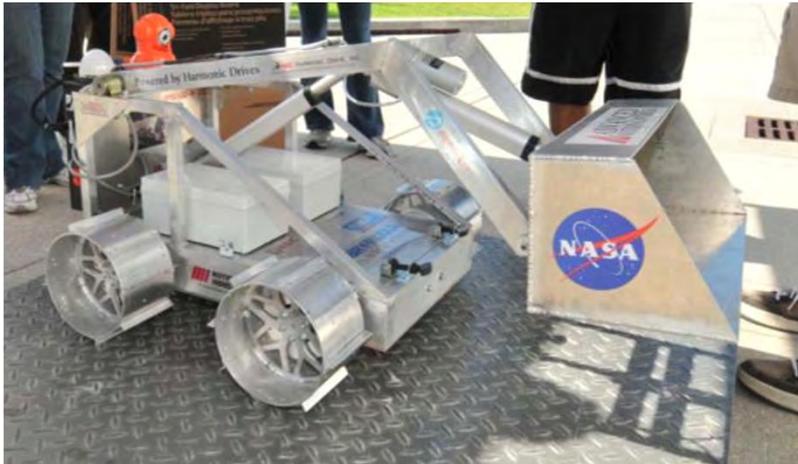


2011: Laurentian University



2012: Iowa State U

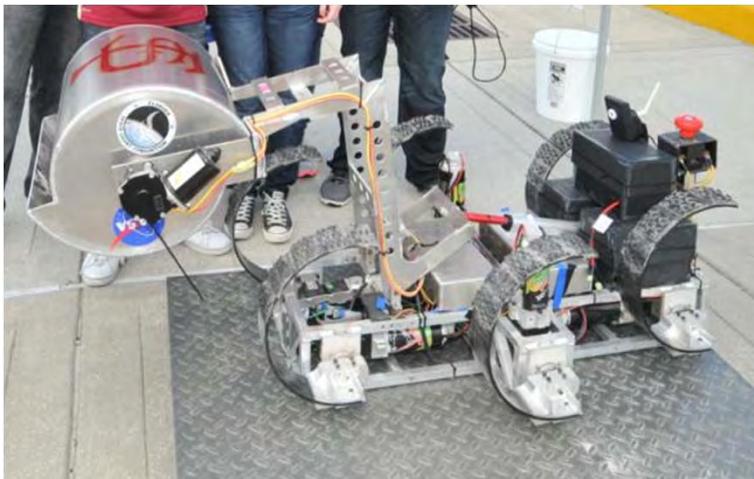
Or are these designs better?



2012: Embry Riddle Daytona



2011: U North Dakota



2012: FAMU/ Florida State U



2012: Montana State U

Why we do it



"They said this was the greatest experience they have had in college," LaMeres said. "They learned more about the application of engineering in one week than all their classes combined."

Montana State University



Conclusions



- ◆ Various competitions during the last five years have demonstrated that **STEM inspiration is possible and successful** with lunar regolith excavation competitions.
- ◆ **Students are drawn to the real nature of the task**, and industrial partners have expressed a high degree of interest in employing engineers with the mechatronic skills needed to build a lunabot system.
- ◆ The future is bright for these types of competitions and the Lunabotics Mining Competition is planned to **be held annually** to meet this demand for exciting challenges, that result in **superior engineering solutions and personal growth**.
- ◆ **NASA and the nation will benefit by having a better workforce and a plethora of clever ideas to investigate for future space exploration missions.**

Thank You!!



NASA SALUTES THE LUNABOTICS MINING COMPETITION SPONSORS

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Spacecraft Mechanisms Corporation

Google LUNAR XPRIZE

MOONBOOTS
A SPACE-TOUR-OPERATOR-LEADER-OR-INITIATOR-PROJECT

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NASA

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BACKUP

NASA Regolith Excavation Challenge: 2007-2009



- ◆ In 2005 the United States of America congress funded a program of contests to stimulate innovation and competition in technical areas of interest to NASA.
- ◆ This program consists of the NASA Centennial Challenges, a collection of public contests designed to stimulate technological innovation in areas that benefit space exploration. The intent was to build on historic and current prize experience.
- ◆ The Regolith Excavation Centennial Challenge was won in 2009 by Paul's Robotics, Worcester Polytechnic Institute, MA. - \$500,000 prize

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

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.

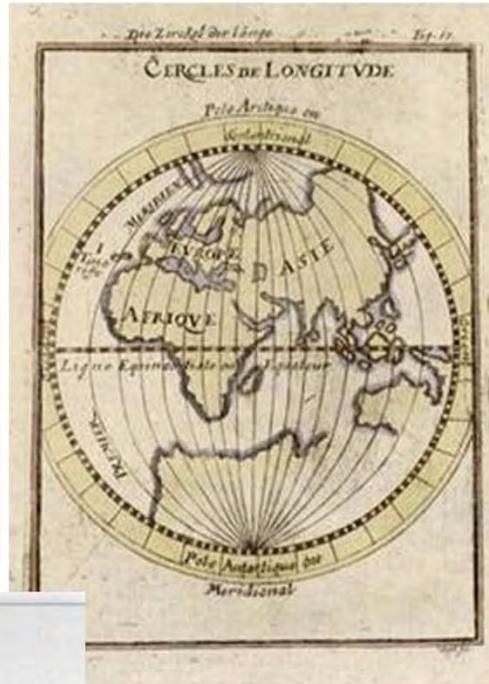
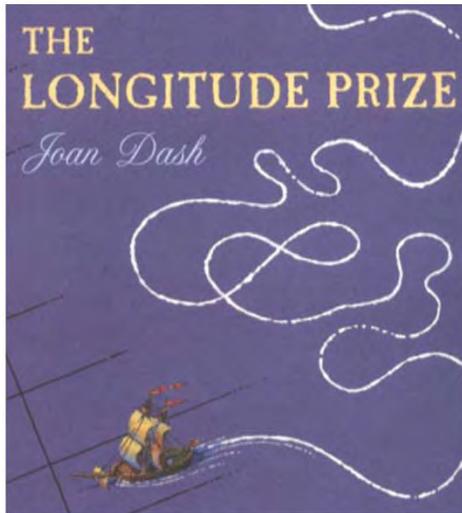
Chapter 3

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 7 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](#)

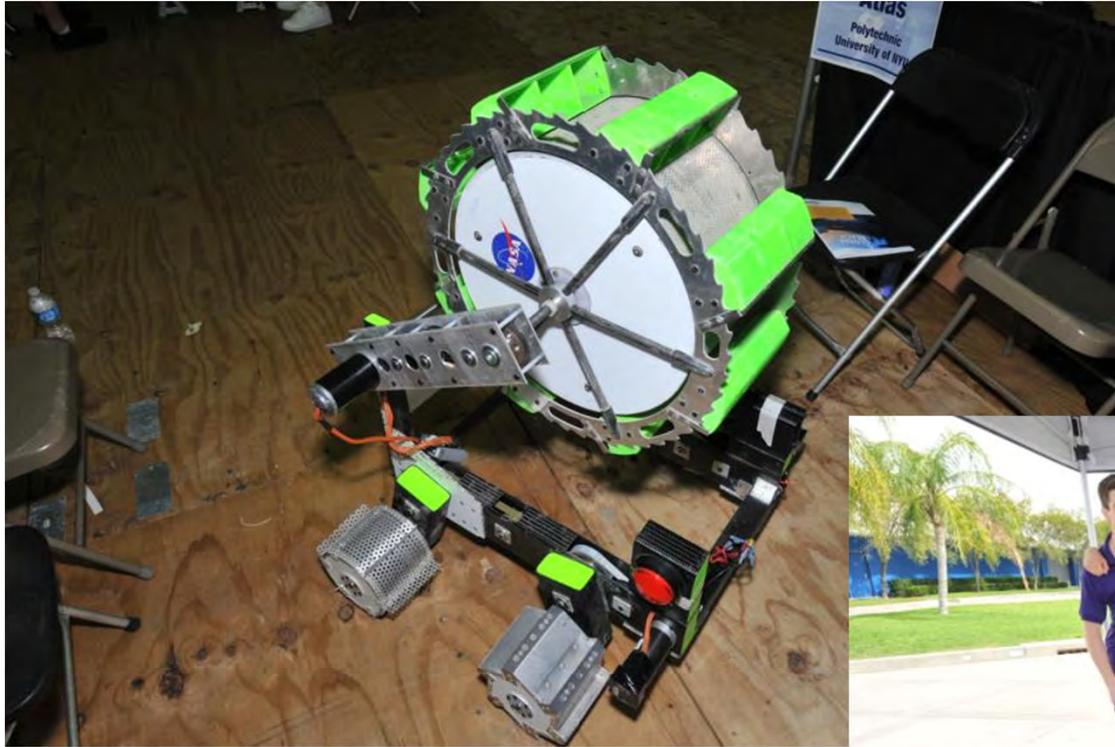
Introduction: Historical Leveraged Prizes



- Longitude Prize : 1714-1765 (51)
- Orteig Prize: 1919-1927 (8)
- Ansari X Prize: 1996-2004 (8)



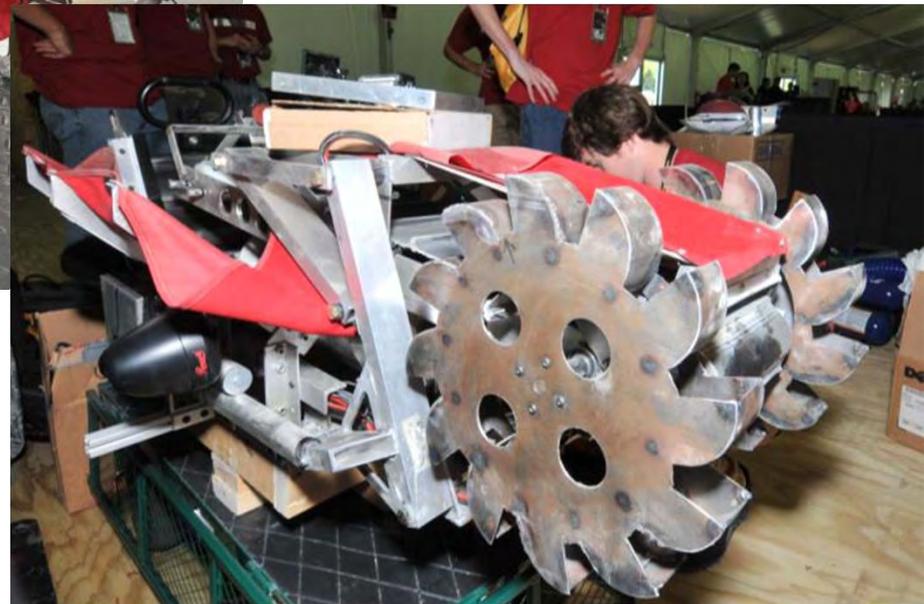
2012 Innovation Award: Polytechnic Institute of NYU



2012 Innovation Honorable Mention: Florida State University and FAMU



2012 Innovation Honorable Mention: University of Alabama and Shelton State C.C.



Lunabotics Mining Competition 2012: Results



-
- ◆ **Slide Presentation and Demonstration Award**
First Place - The University of Alabama in collaboration with Shelton State Community College
Second Place - West Virginia University
Third Place - Universidad de Los Andes of Colombia

 - ◆ **Outreach Project Report Award**
First Place - Iowa State University in collaboration with Wartburg College
Second Place - Montana State University - Bozeman
Third Place - John Brown University

 - ◆ **Systems Engineering Paper Award**
First Place - Montana State University - Bozeman
Second Place - John Brown University
Third Place - University of Illinois at Urbana-Champaign

 - ◆ **Team Spirit Award**
First Place - The University of Alabama in collaboration with Shelton State Community College
Second Place - Instituto de Astrobiologia Colombia IAC
Third Place - Polytechnic Institute of NYU
-

2012 Lunabotics Team Spirit: In Abundance!



Acknowledgements



HEO MD Education Lead, Mr. **Jerry Hartman** who has been instrumental to the success of these competitions in 2010,2011 & 2012. OCT Human Robotic Systems Project: Dr. **Rob Ambrose**, Dr. **Bill Bluethmann** and Dr. **Brian Wilcox**

Mr. **Robert Cabana**, Center Director of KSC and **Dr. Pat Simpkins**, Eng. Director who were highly supportive of hosting this competition and provided inspiration to hundreds of students.

In addition, outstanding project management was provided by Ms. **Gloria Murphy**, at NASA KSC who is the ESMD Space Grant Manager & Lunabotics Mining Competition Project Manager. Ms. **Susan Sawyer** provided coordination for all aspects of the events and served as the interface between the student teams and NASA and is highly commended for the dedication and efficiency provided in planning and daily operations.

Mr. **Jack Fox** is the Chief of the NASA KSC Surface Systems Office and has been highly supportive and helpful in all aspects of organizing and hosting this event.

The Centennial Challenges Lunar Excavation Competition was managed by Mr. **Ken Davidian** and Mr. **Andrew Petro** in the Innovative Partnerships Program (IPP) office at NASA HQ and brought to a successful conclusion with a \$500,000 prize awarded in 2009.
