



NASA 5th Annual Robotic Mining Competition for Universities: Robot Configurations and Results

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

Golden, Colorado School of Mines

June 10-11, 2014

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

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



5th Annual NASA Robotic Mining Competition (RMC) : May 21-23, 2014 Kennedy Space Center - Visitor's Center

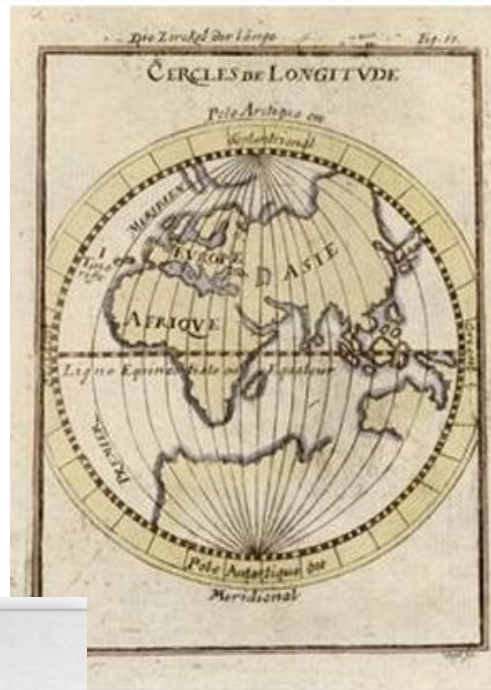
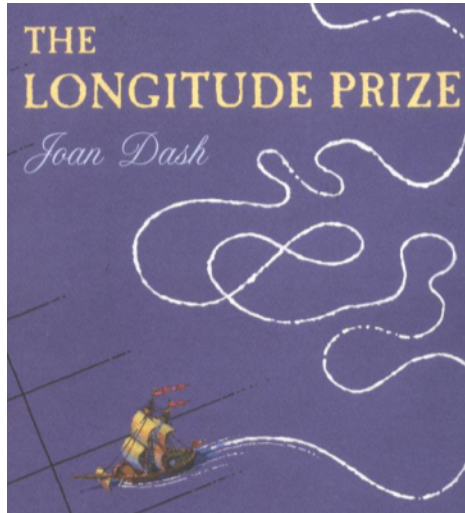


Update about a successful University Robotic Competition
held annually by NASA at Kennedy Space Center



Big Anticipation: Would a team achieve full autonomy this year??

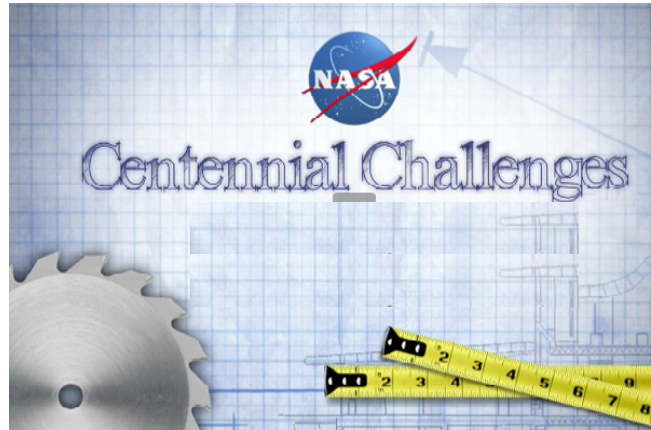
Introduction: Historical Leveraged Prizes



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



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

5th Annual NASA Robotic Mining Competition

A Centennial Challenges Spinoff for University Teams



Held Annually since 2010



2010-2013



2014 and beyond

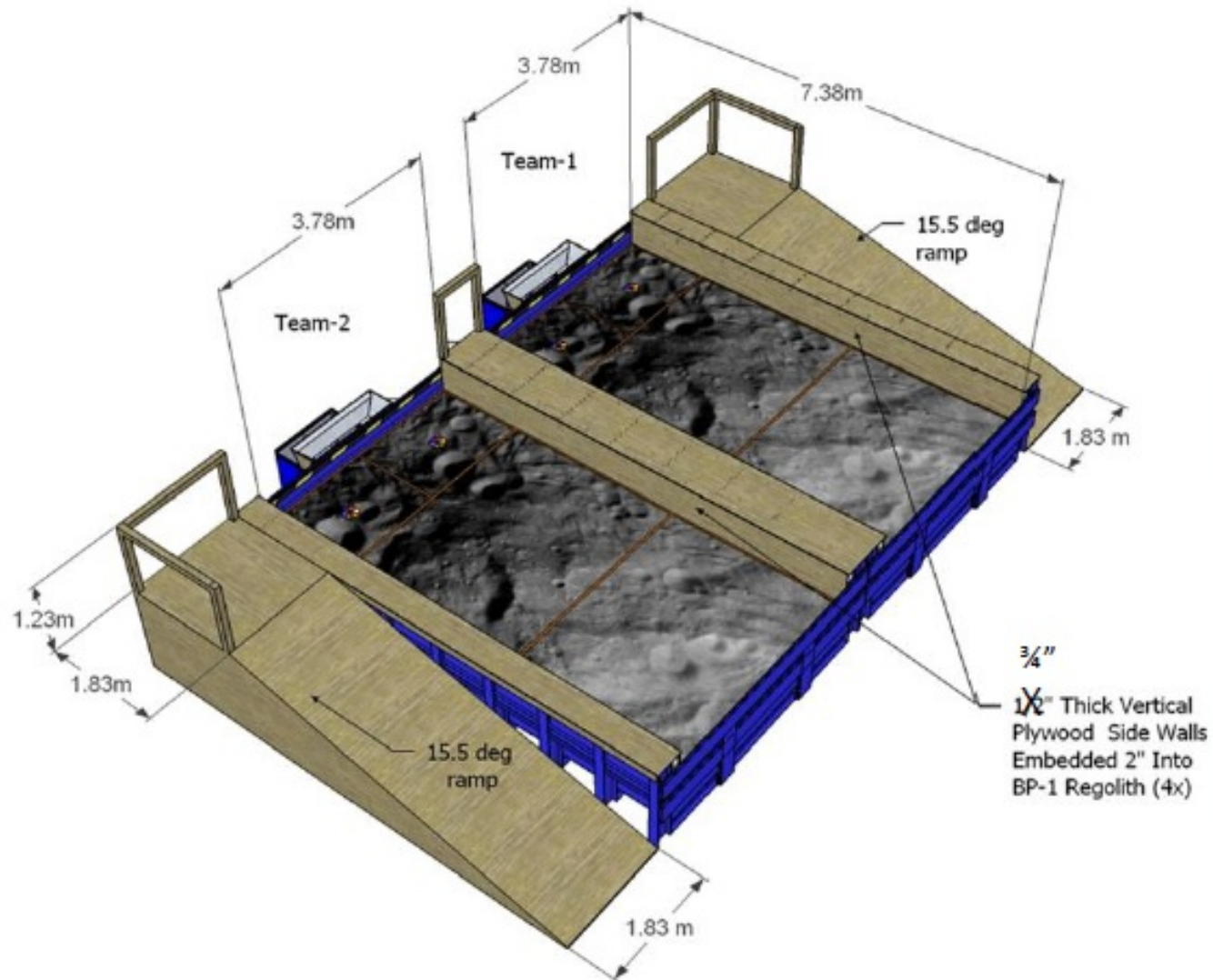
What are the RMC Robot Requirements?



- ◆ 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



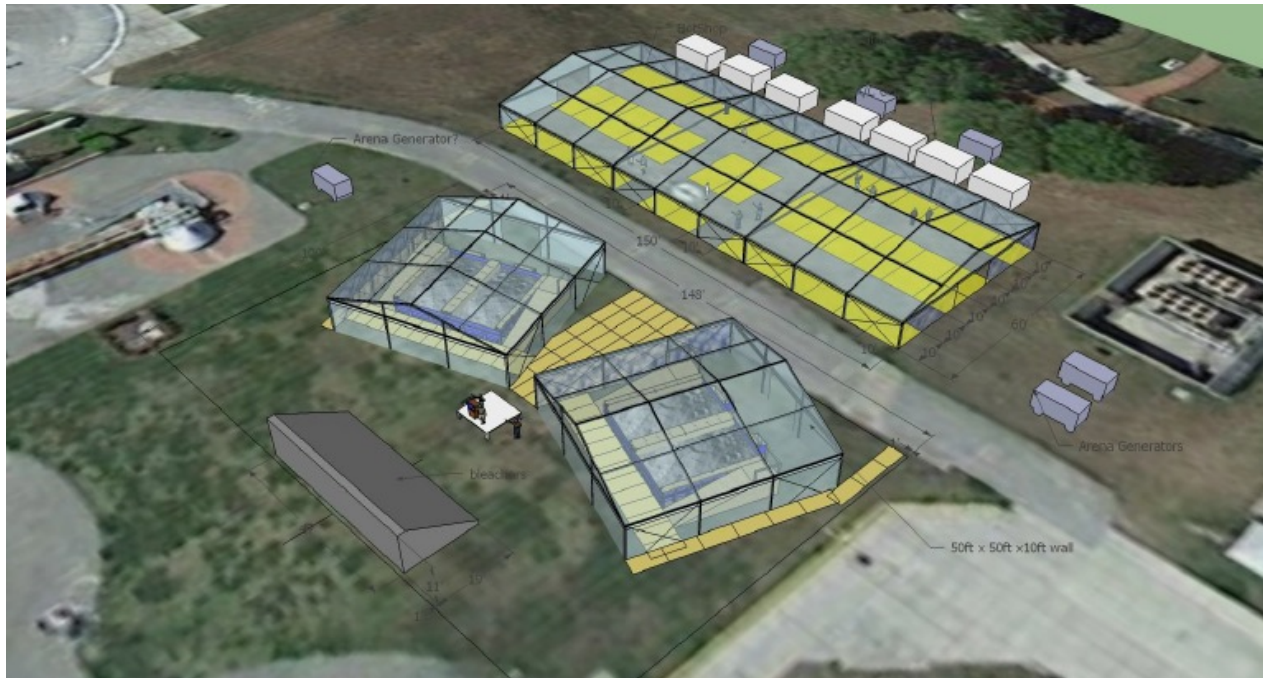
Robo Arena (~25 ft x 25 ft each)



Permanent Storage Steel Bins (4 X) 115,000 lbs of BP-1 Regolith Simulant Each!



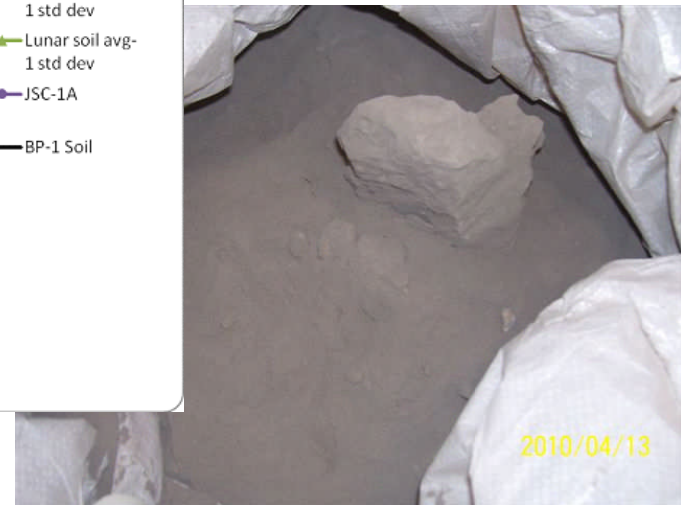
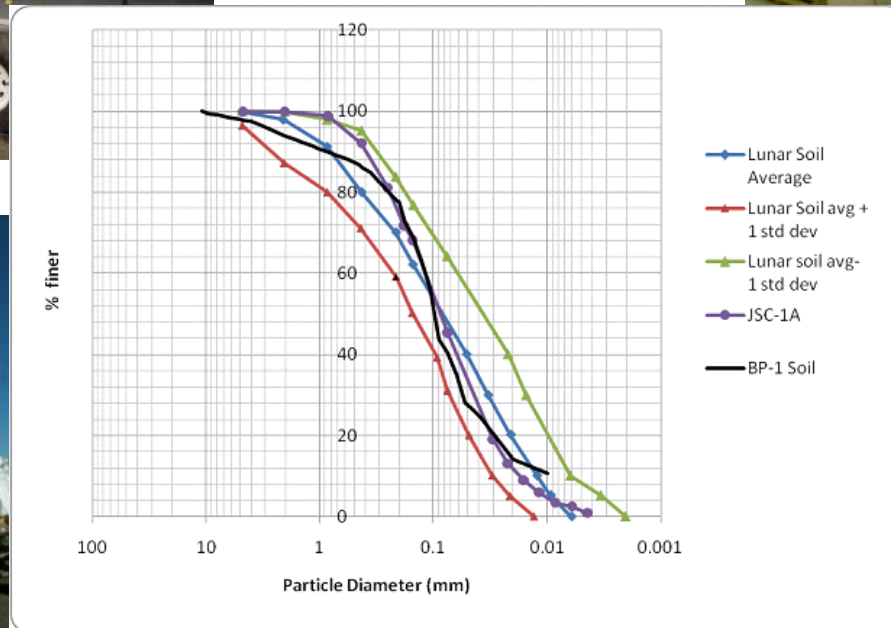
Competition Layout @ KSC Visitors Center Rocket Garden



Black Point 1 (BP-1) Basalt Regolith Simulant



Discovered during 2009 Desert RATS field testing near Flagstaff, AZ





- **Design, build & compete remote controlled mining robot**
- **Excavate Black Point 1 (BP-1) Regolith 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 21-23 in 2014**
- **Located at Kennedy Space Center, FL Visitor's Center**
- **Domestic USA Teams Only Invited in 2014**
- **World Cup International Final - Planned in Hawaii in 2015**
- **NASA will send the RMC winner to the World Cup to represent the USA**

Judging Criteria for RMC: 2014



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 Robotic 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 RMC Teams**
- ◆ **Students get job opportunities**

◆ 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



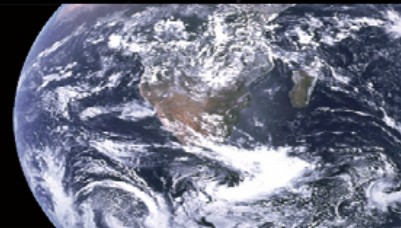
Systems Engineering Senior Design Capstone Project



<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:

Chapter 1

<http://www.californiaspaceauthority.org/html/press-releasesandletters/pr080805-regolith-all-pics.html>

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

What's Inside: The Lunar Engineering Handbook

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 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](#)

Competitors



- Arizona State University
- Case Western Reserve University
- Colorado School of Mines
- Embry-Riddle Aeronautical University, Daytona Beach
- Florida Institute of Technology
- Florida International University
- Hampton University
- Iowa State University
- John Brown University
- Kapi'olani Community College
- Miami University
- Milwaukee School of Engineering
- Mississippi State University
- Montana State University
- Montana Tech of the University of Montana
- NYU Polytechnic School of Engineering
- Oakton Community College
- South Dakota School of Mines & Technology
- Temple University
- Texas A&M University Corpus Christi
- The University of Akron

- The University of Alabama in collaboration with Shelton State Community College
- University of Alaska Fairbanks
- University of Arkansas
- University of Central Florida
- University of Florida
- University of Illinois at Chicago
- University of Illinois at Urbana-Champaign
- University of Michigan
- University of Nebraska-Lincoln
- University of New Hampshire
- University of North Carolina at Charlotte
- University of North Dakota
- University of South Alabama
- University of Virginia
- Virginia Tech
- Washington University in St. Louis
- West Virginia University
- Wright State University

RMC 2014: Results



Joe Kosmo Award for Excellence (Grand Prize)

***Alabama Astrobotics - The University of Alabama in collaboration with
Shelton State Community College***

On-Site Mining Award

First Place: *Mountaineers - West Virginia University*

Second Place: *NASAbotics - Florida Institute of Technology*

Third Place: *Alabama Astrobotics - The University of Alabama in collaboration with
Shelton State Community College*

Judges Innovation Award

Aurora Robotics - The University of Alaska, Fairbanks

Efficient Use of Communications Power Award

UNH LunaCats - University of New Hampshire



Systems Engineering Paper Award

First Place: Alabama Astrobotics

The University of Alabama in collaboration with Shelton State Community College

Second Place: C.H.R.I.S.T.E.E.

The University of Akron

Third Place : IRIS-4

The University of Illinois at Urbana-Champaign

Outreach Project Report Award

First Place: Mountaineers

West Virginia University

Second Place: Cyclone Space Mining

Iowa State University

Third Place: C.H.R.I.S.T.E.E.

The University of Akron

Team Spirit Award

First Place : Alabama Astrobotics

The University of Alabama in collaboration with Shelton State Community College

Second Place: C.H.R.I.S.T.E.E.

The University of Akron

Third Place: Cyclone Space Mining

Iowa State University



Caterpillar Autonomy Award:

Iowa State University – Full Autonomy – Winners (Most Regolith)

University of Alabama – Full Autonomy

Slide Presentation and Demonstration Award

First Place: Alabama Astrobotics The University of Alabama in collaboration with
Shelton State Community College

Second Place: Mountaineers West Virginia University

Third Place: Three way tie

Cyclone Space Mining Iowa State University

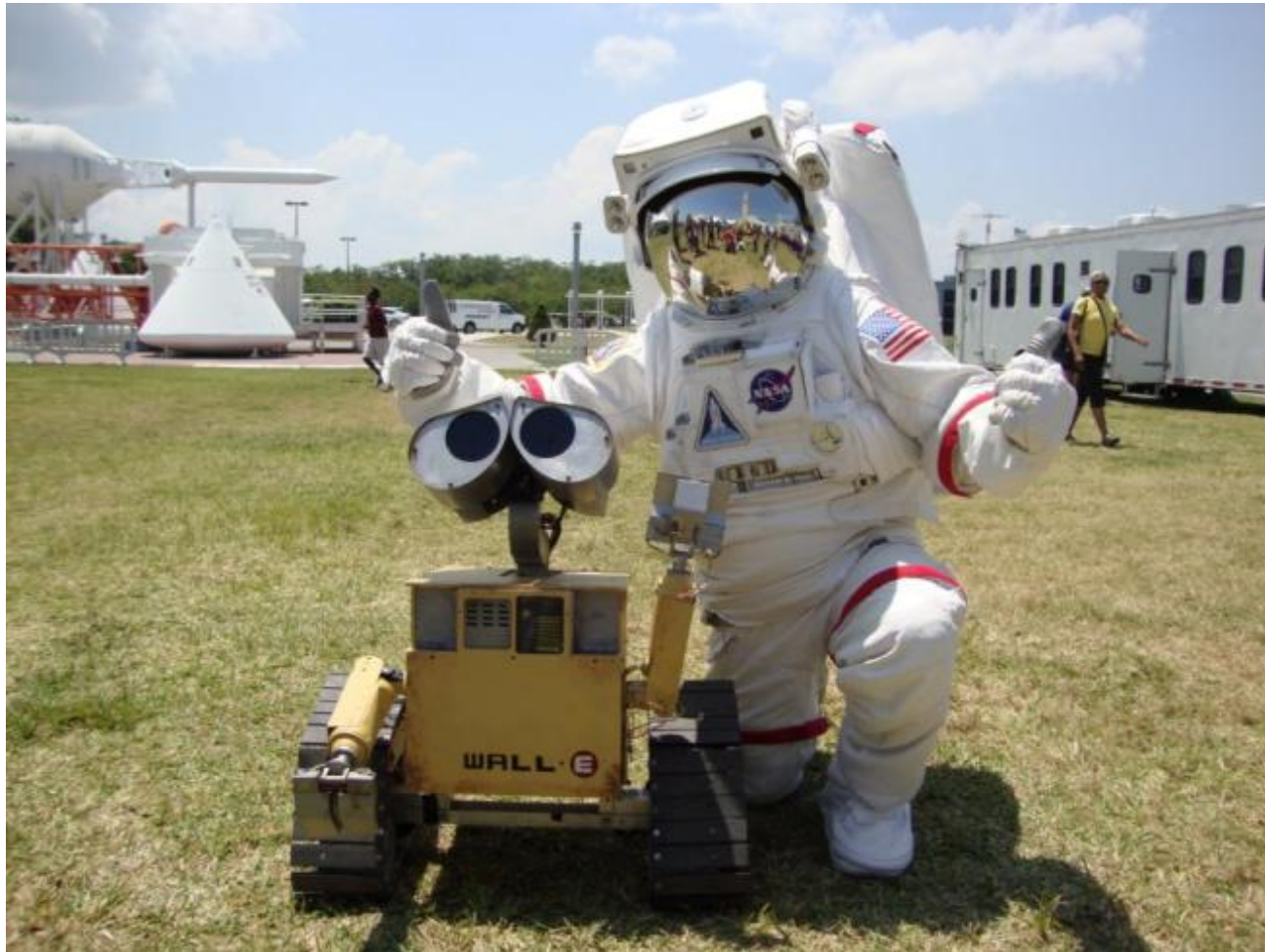
C.H.R.I.S.T.E.E. The University of Akron

49er Miners The University of North Carolina-Charlotte

Pit Pride Challenge Award

First Place: C.H.R.I.S.T.E.E. The University of Akron

2014 RMC Team Spirit: Never a Dull Moment!



RMC Robot Design Configurations

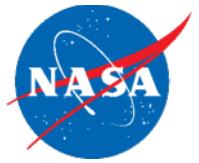


Regolith Excavation Mechanisms



- Bucket ladder (two chains)
- Bucket ladder (one chain)
- Bucket ladder (four chains)
- Bucket belt
- Front End Loader
- Scraper
- Auger plus conveyor belt / impeller
- Backhoe
- Bucket wheel
- Bucket drum
- Claw / gripper scoop
- Drums with metal plates or brush (street sweeper)
- Magnetic wheels with scraper
- Rotating tube/scoops entrance
- Vertical auger
- Rotating Scoop

Winning Design Configurations - 2014



West Virginia U :
1st Place Mining Competition

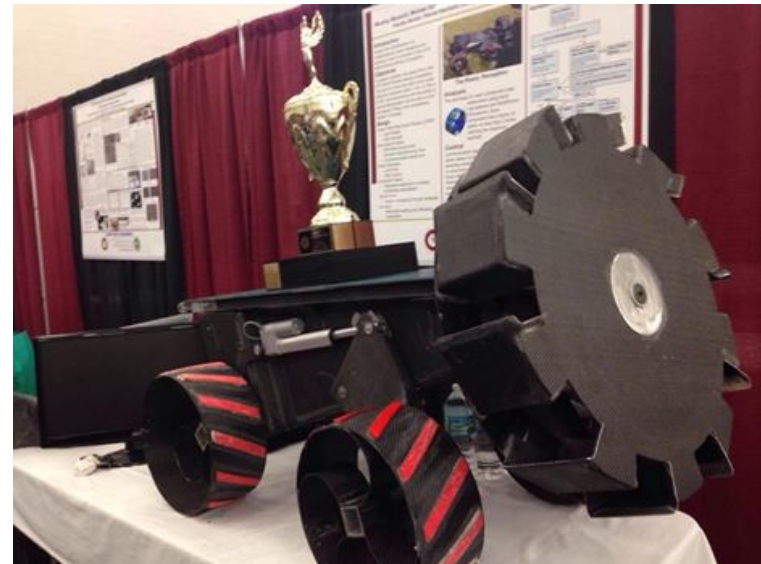
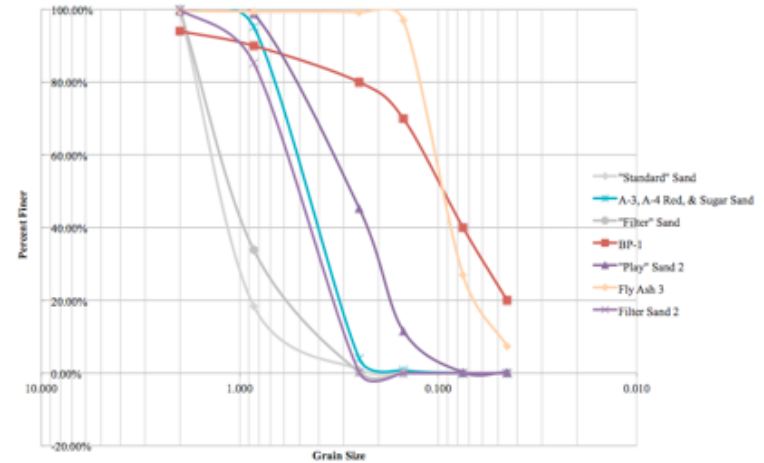
U Alabama:
Overall Prize Joe Kosmo Award



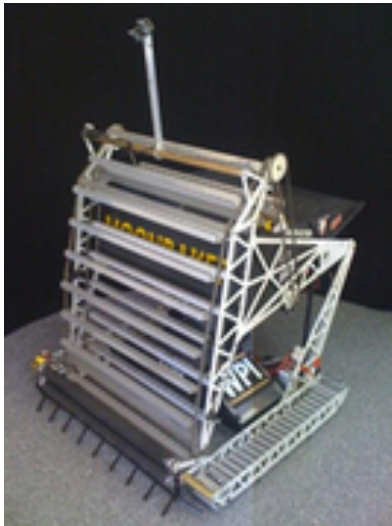
Innovation 2014 – Florida Tech



~30 Kg Mass!



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



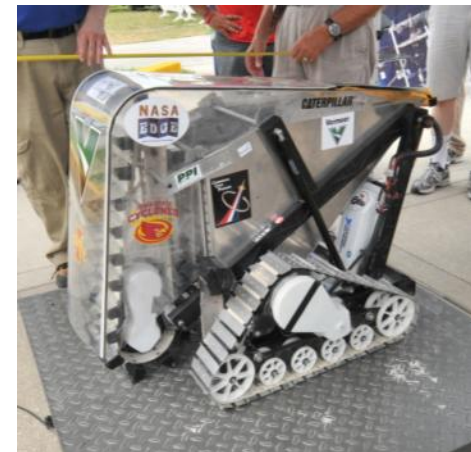
2009: Paul's
Robotics WPI



2010: Montana State U

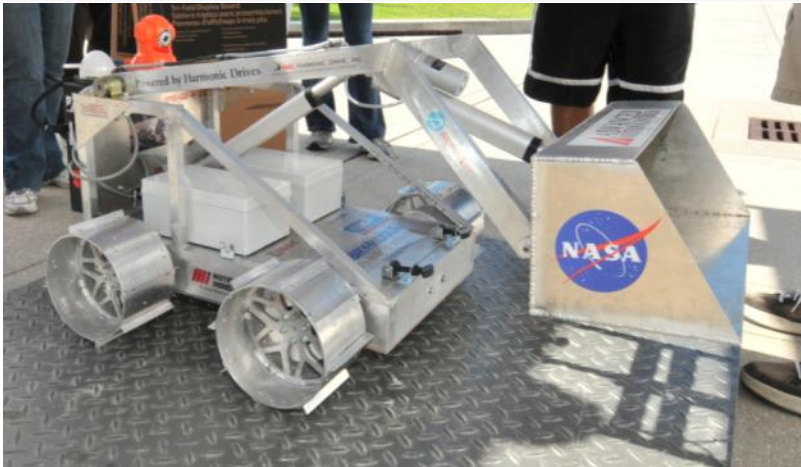
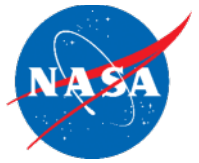


2011: Laurentian University



2012: Iowa State U

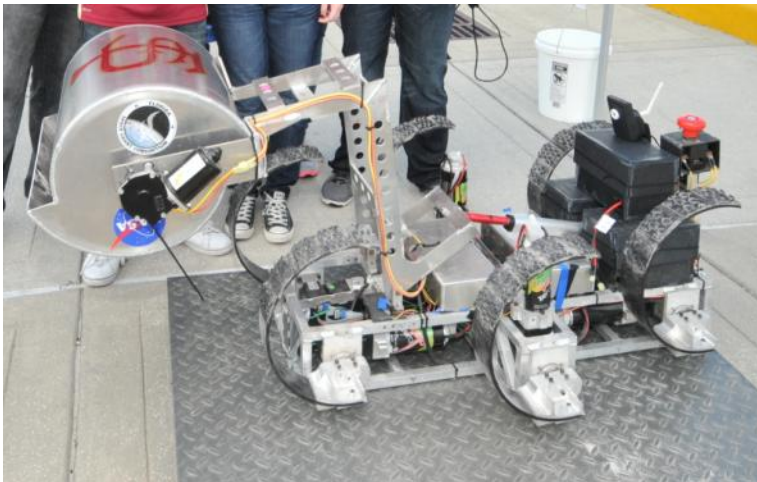
Or are these designs better?



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





- ◆ Our competitions during the last five years have demonstrated that **STEM inspiration is possible and successful** with 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 robotic excavation system.
- ◆ The future is bright for these types of competitions and the Robotic 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!!



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