National Aeronautics and Space Administration

2012 Lunabotics Mining Competition: Results & Taxonomy

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

Golden, Colorado

June 5-7, 2012

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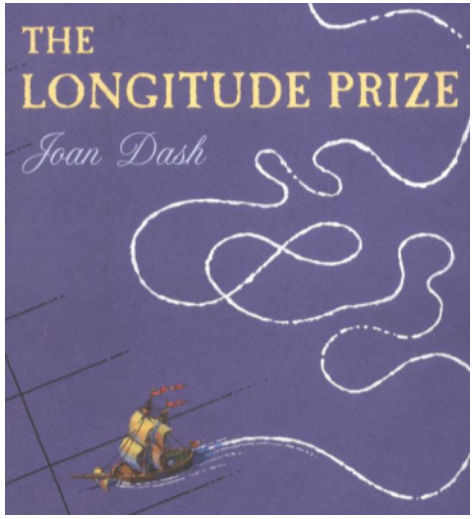
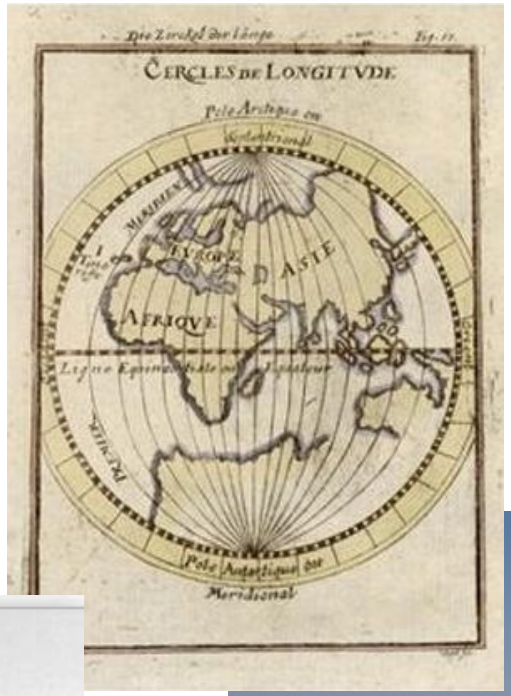
3rd Annual NASA Lunabotics Mining Competition: May 23-26, 2012
Kennedy Space Center - Visitor's Center

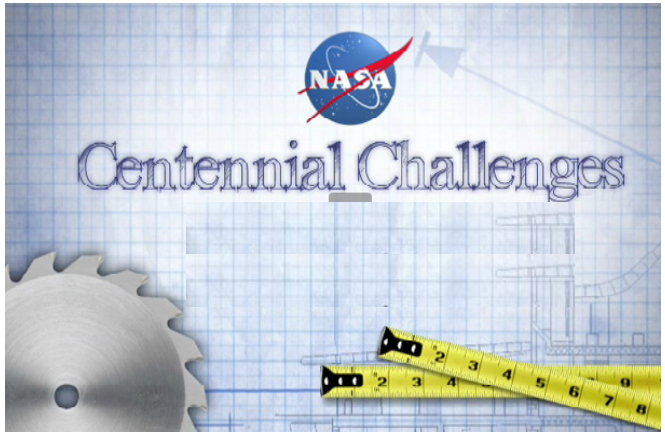
Introduction: Historical Leveraged Prizes





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

NASA Regolith Excavation Challenge: 2007-2009



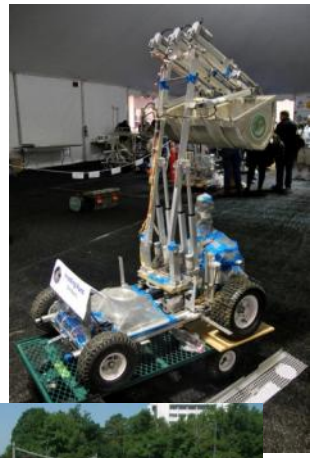
- In 2005 the United States of America congress funded a program of contests to stimulate innovation and competition in technical areas of interest to NASA.
- This program consists of the NASA Centennial Challenges, a collection of public contests designed to stimulate technological innovation in areas 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

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

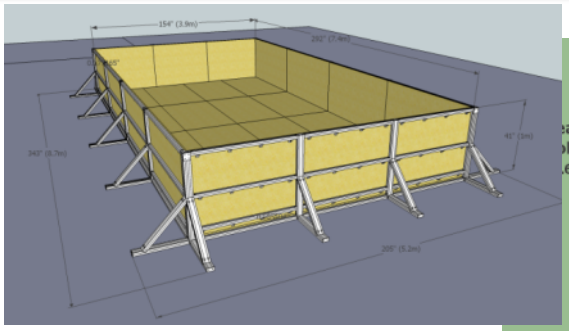
Held Annually since 2010

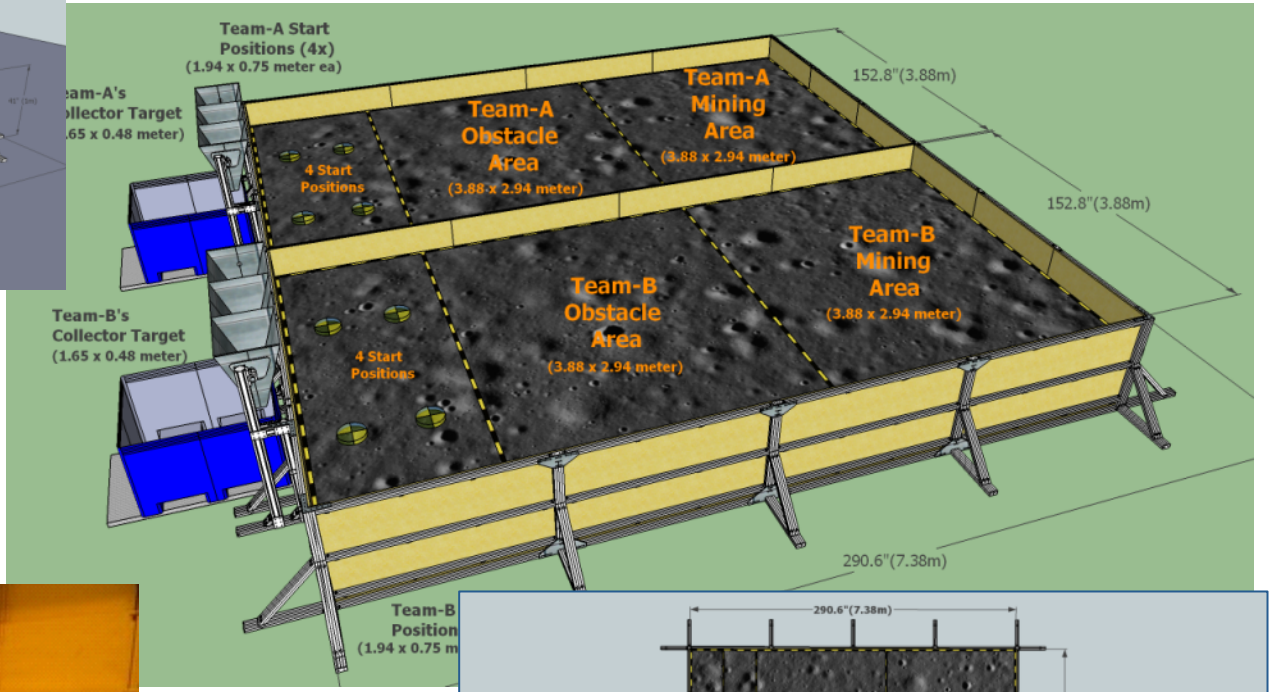
What is a Lunabot?

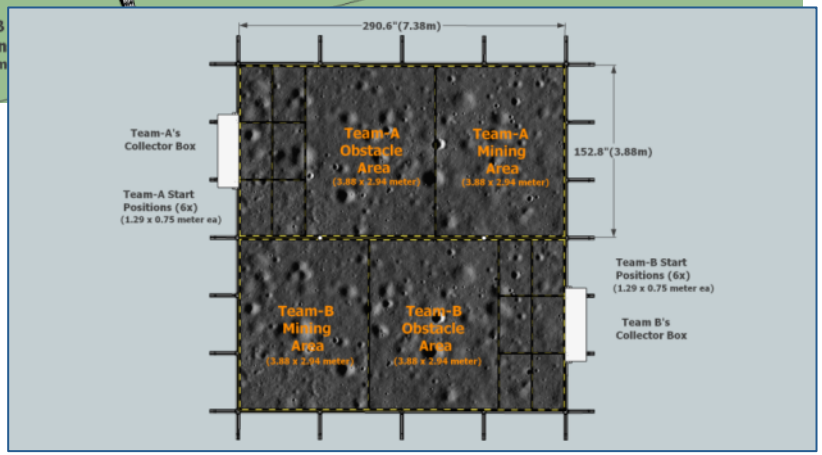
- Robot Controlled Remotely or Autonomously
- Visual and Auditory Isolation from Operator
- Excavates Black Point 1 (BP-1) Simulant
- Weight Limit - 80 kg
- Dimension Limits - 1.5m width x .75m length x .75m height
- Designed, Built and Tested by University Student Teams



LunArena (~25 ft x 25 ft)

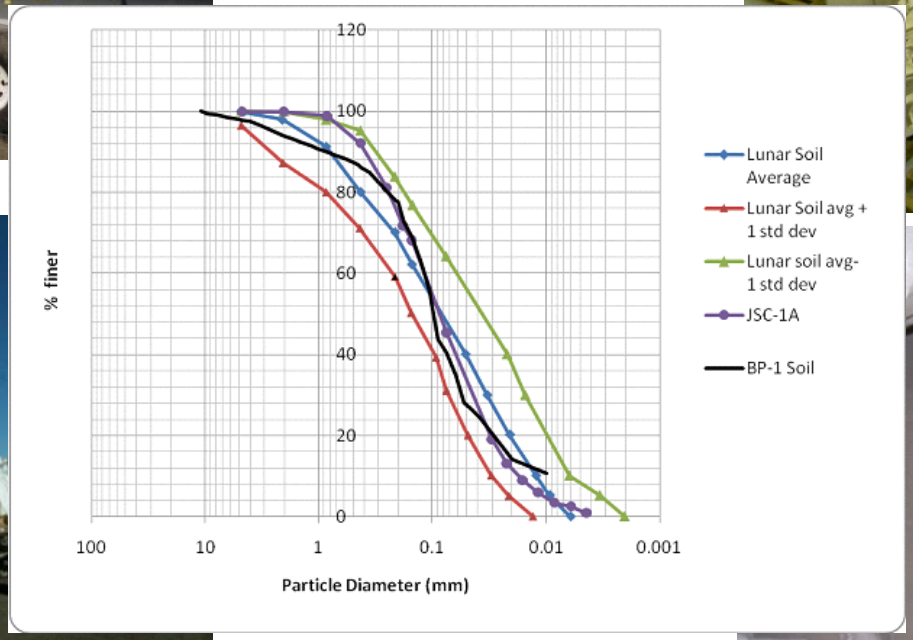


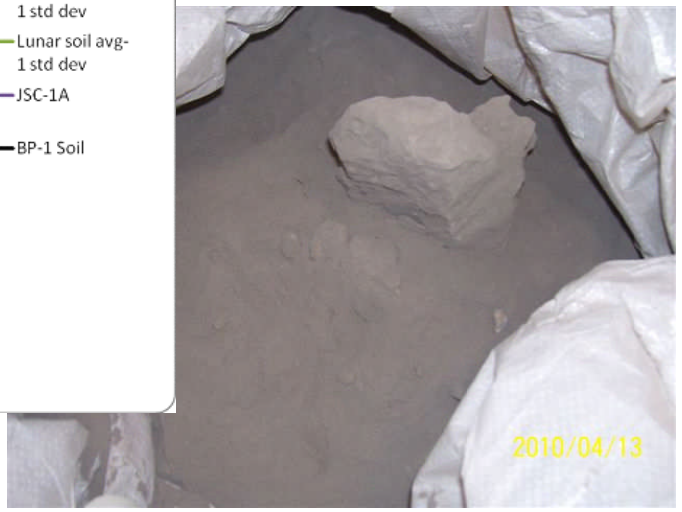




Black Point 1 (BP-1) Lunar Regolith Simulant

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 23-26 in 2012
- Located at Kennedy Space Center, FL Visitor's Center
- International Teams Invited

Judging Criteria for Lunabotics: 2012

Mining Category Elements	Specific Points	Actual	Units	LunaPoints
Pass Inspections				1000
Regolith over 10 kg	+2/kg	110	kg	+200
Average Bandwidth	-1/50kb/sec	5000	kb/sec	-100
Lunabot Mass	-10 /kg	80	kg	-800
Report Energy Consumed	+100	1	1= Achieved 0= Not Achieved	+100
Dust Tolerant Design & Dust Free Operation	0 to +200	150	Judges' Decision	+150
Autonomy through Obstacles	+250	0	1= Achieved 0= Not Achieved	0
Full Autonomy	+500	0	1= Achieved 0= Not Achieved	0
Total				**550**

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

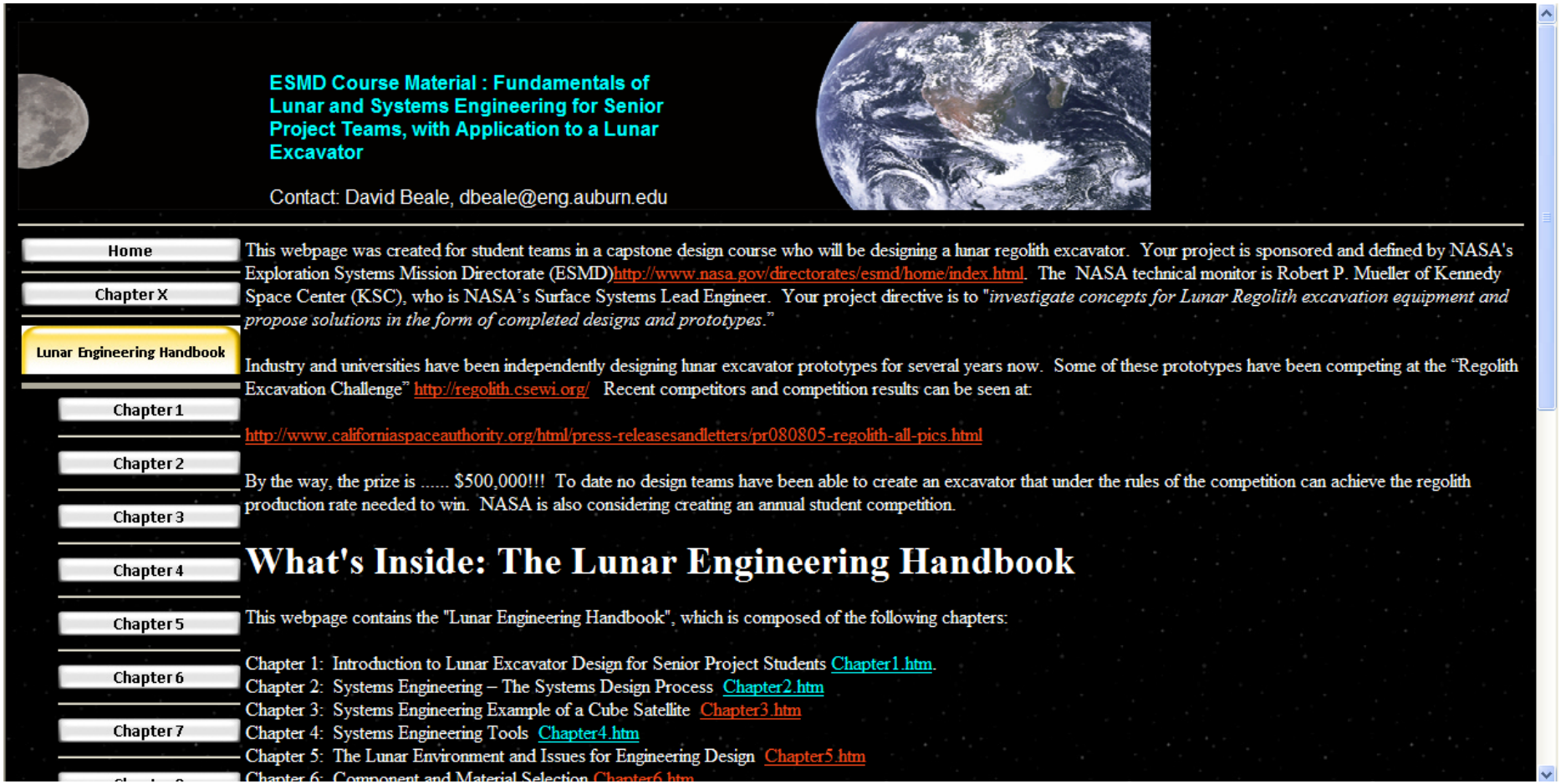
Competition Categories

- **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

Systems Engineering Senior Design Capstone Project

http://education.ksc.nasa.gov/esmdspacegrant/LunarRegolithExcavatorCourse/



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

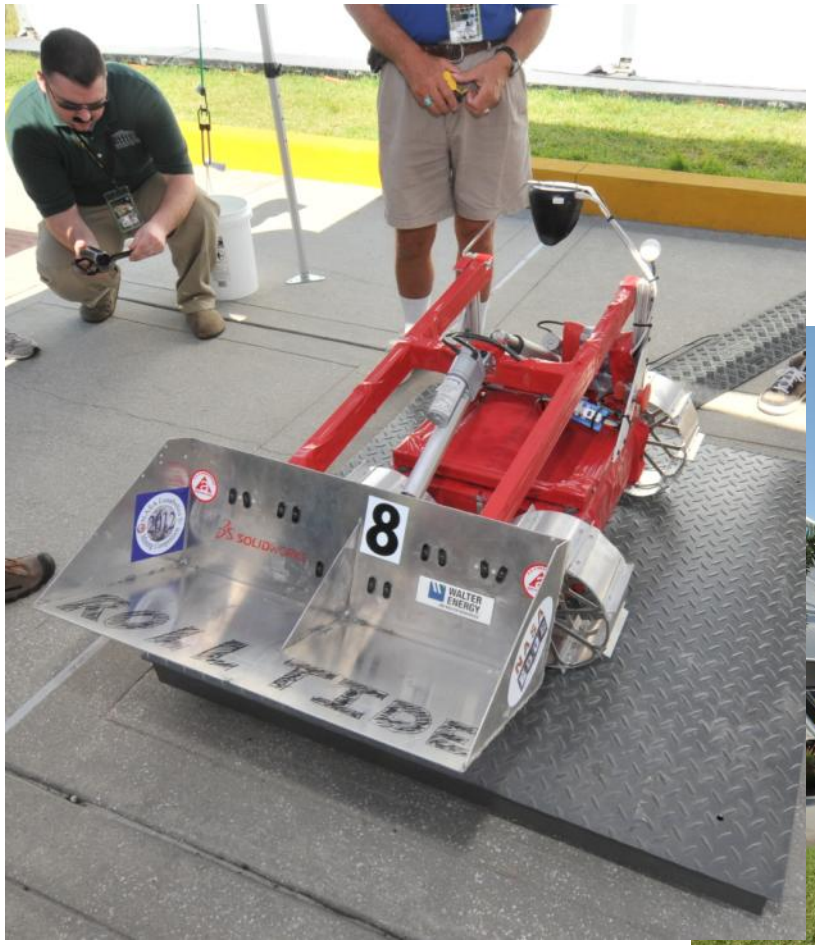
- **Efficient Use of Communications Power Award**

  Iowa State University in collaboration with Wartburg College

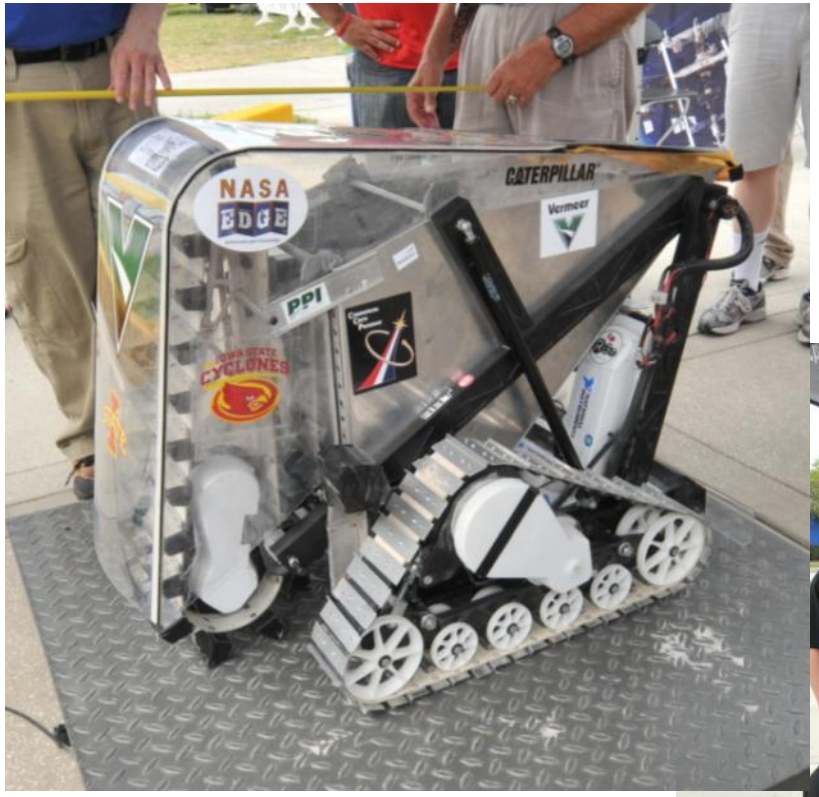
- **Best Use of Social Media**

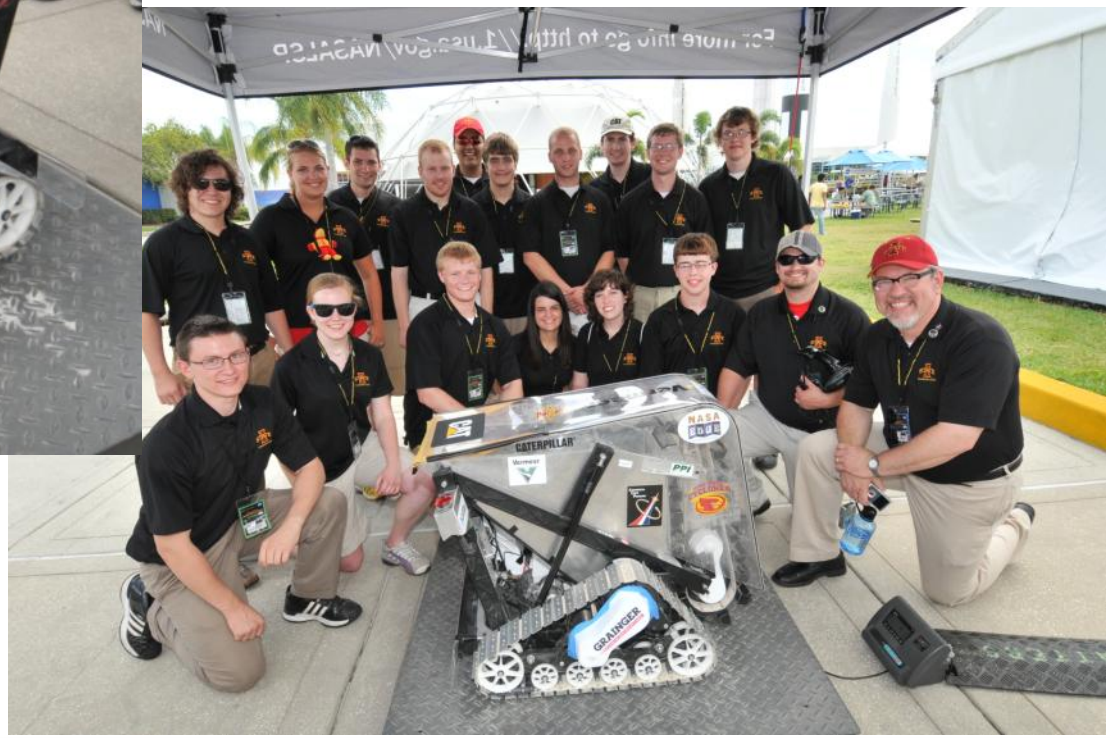
  Universidad de Los Andes of Colombia

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

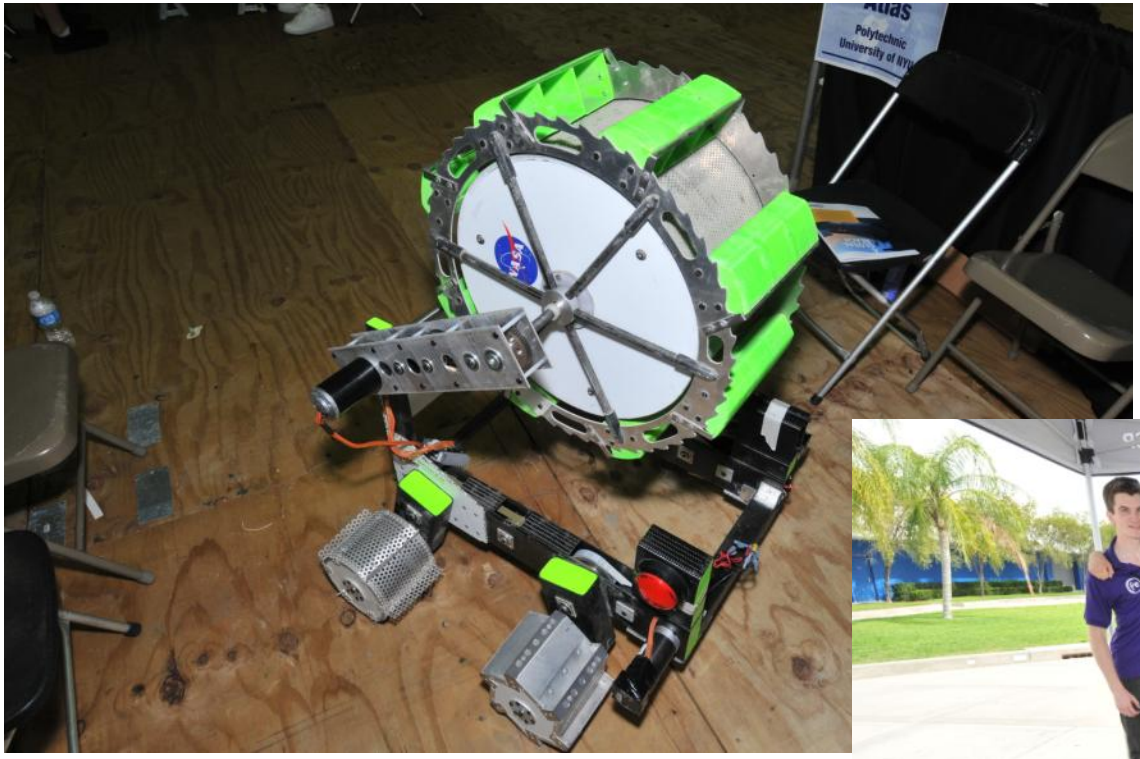


2012 On-Site Mining Award
Iowa State University with Wartburg College



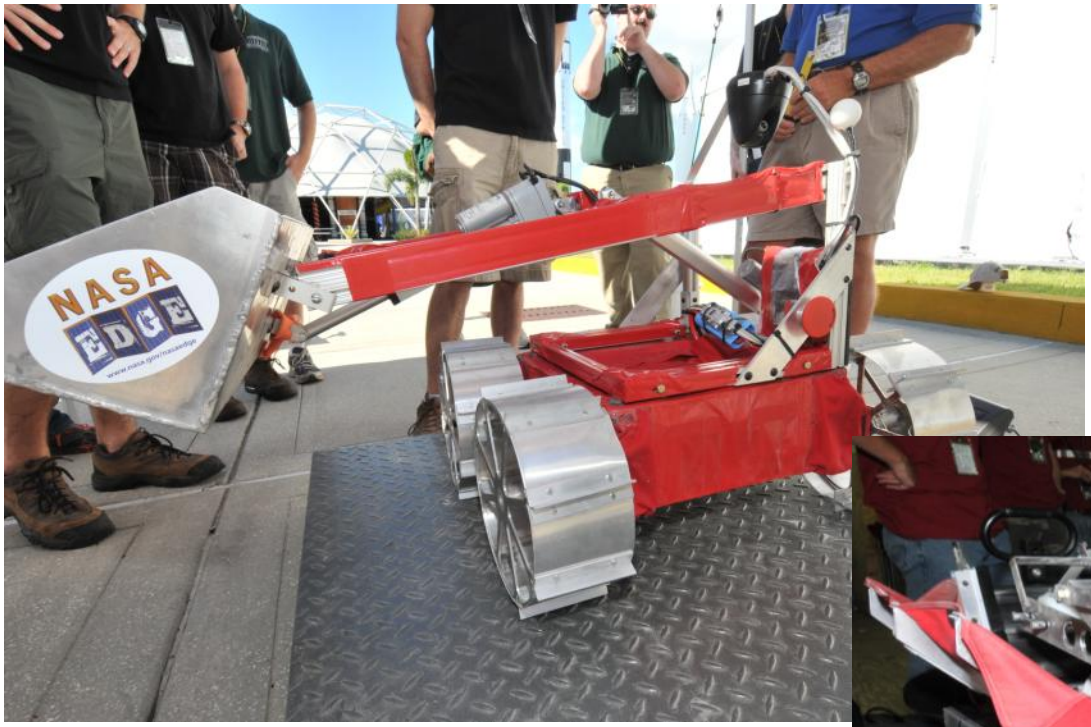


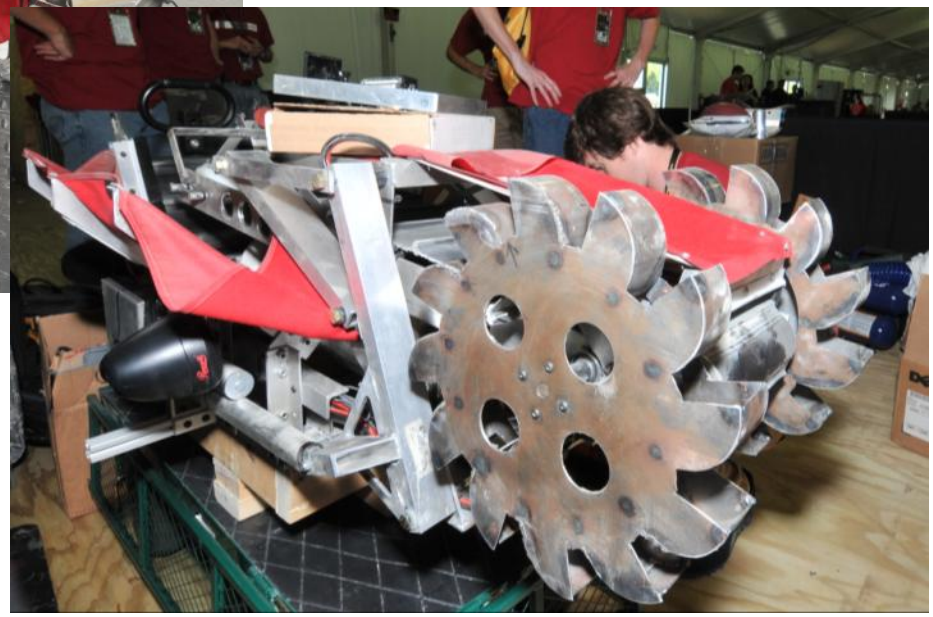
2012 Innovation Award: Polytechnic Institute of NYU



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

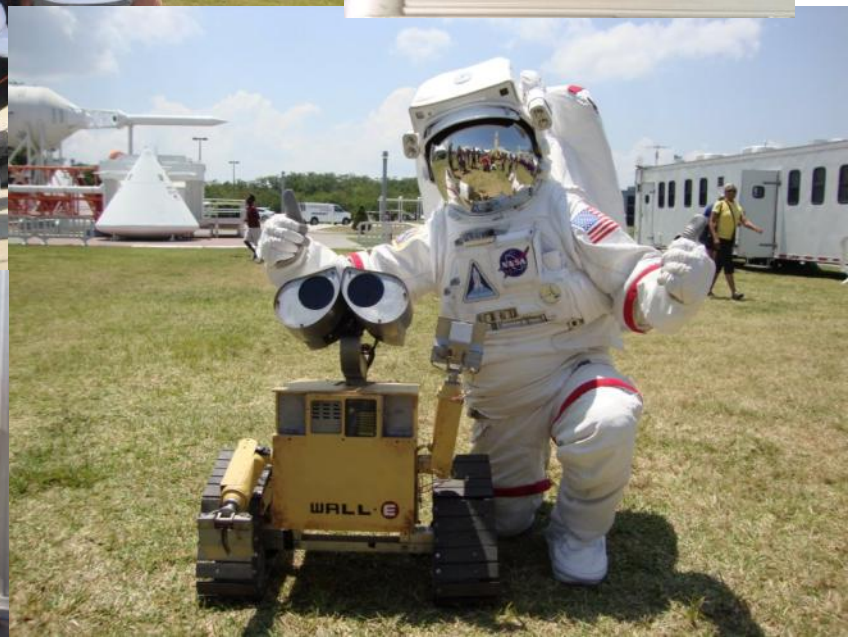
- **Systems Engineering Paper Award**
  - First Place - Montana State University - Bozeman
  - Second Place - John Brown University
  - Third Place - University of Illinois at Urbana-Champaign

- **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

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

2012 Lunabotics Team Spirit: In Abundance!



Lunabot Design Taxonomy

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

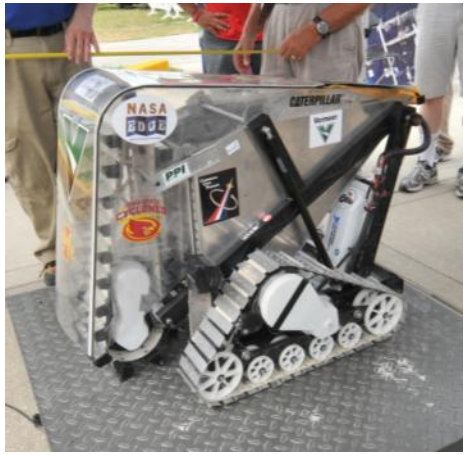
Regolith Dumping Mechanism	# of machines employing dumping mechanism	Lunabotics 2012
Raising / tilting hopper	32	21
Tilting / raising scoop	9	13
Conveyor belt (with attachments)	8	4
Chute	5	2
Raising hopper with back chute	5	1
Bucket ladder	3	1
Ramp plus rotating valve bottom	3	
Angled auger	2	2
Angled 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

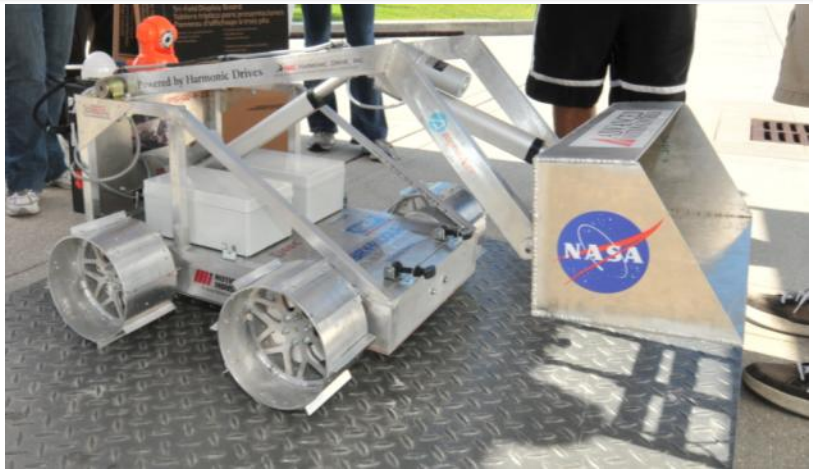
2010: Montana State U

2011: Laurentian University



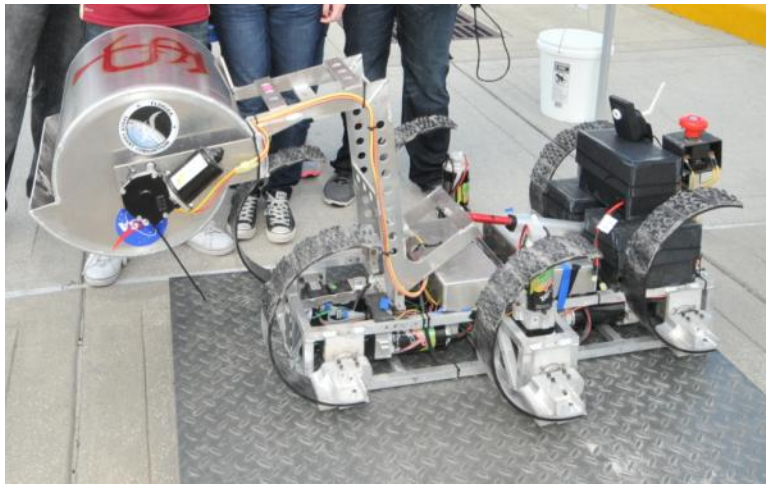
2012: Iowa State U

Or are these designs better?



2012: Embry Riddle Daytona

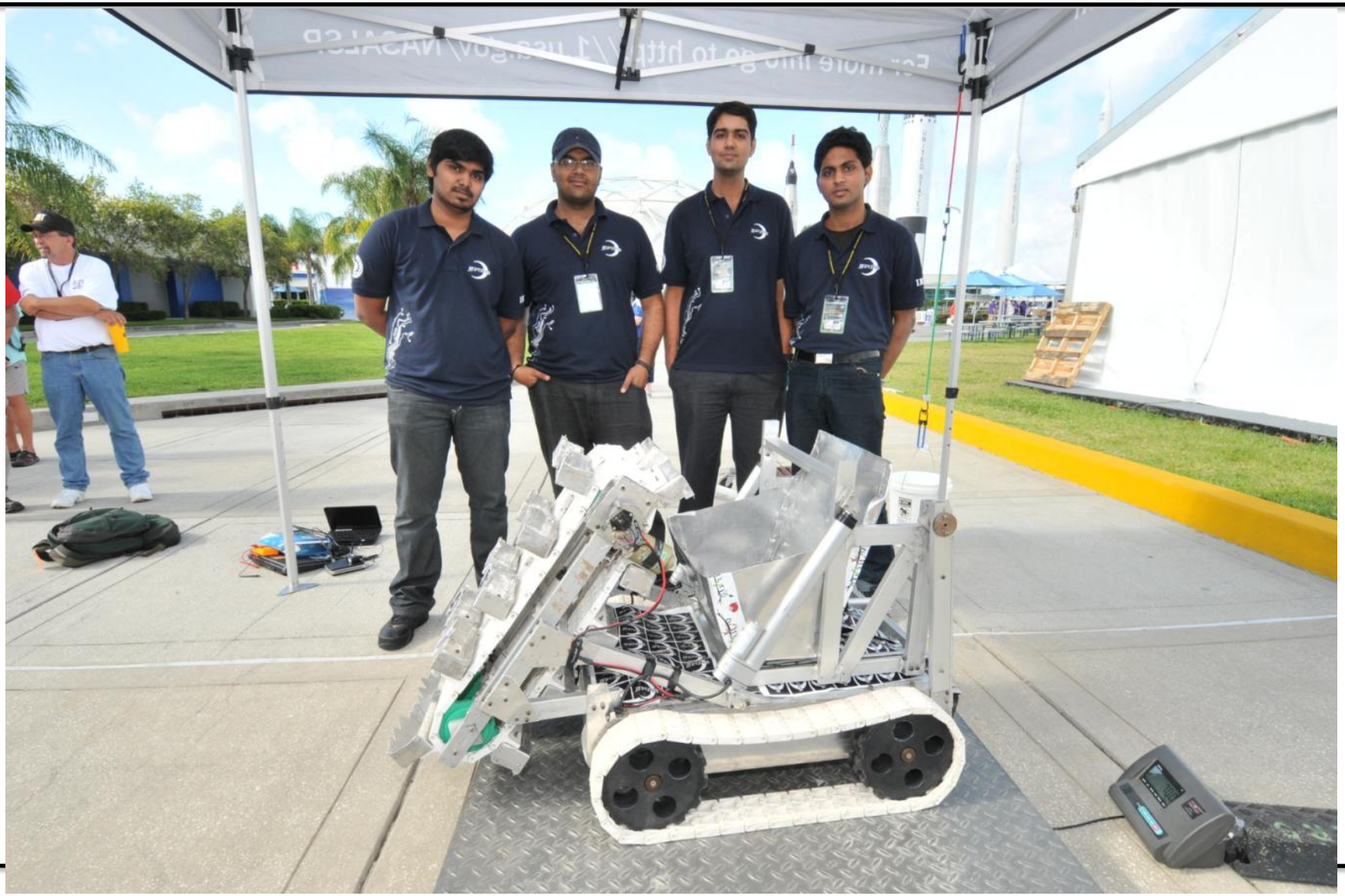
2011: U North Dakota



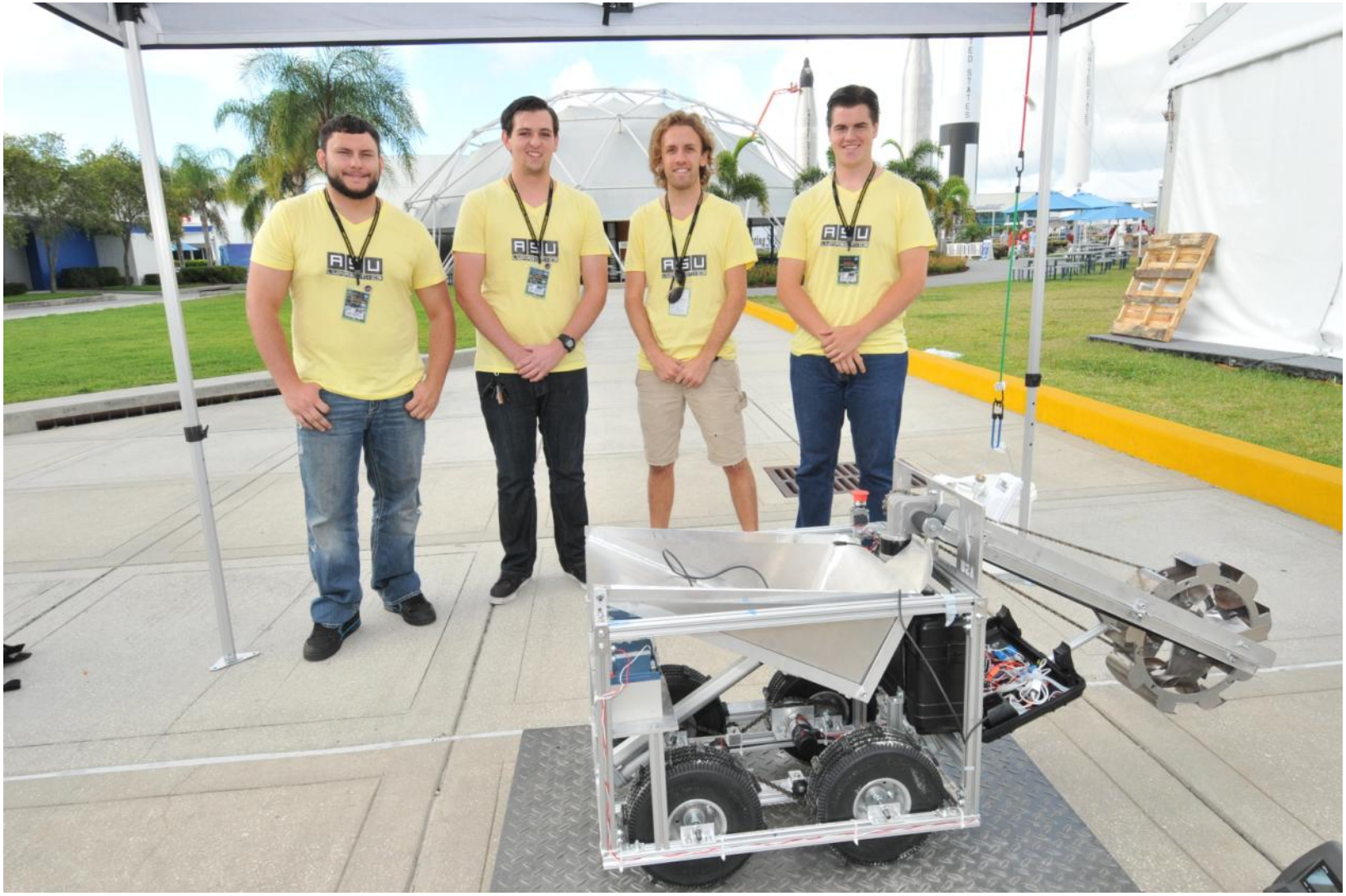
2012: FAMU/ Florida State U

2012: Montana State U

BIRLA Inst. Tech. - Tracks – Bucket Belt – Dump Bin

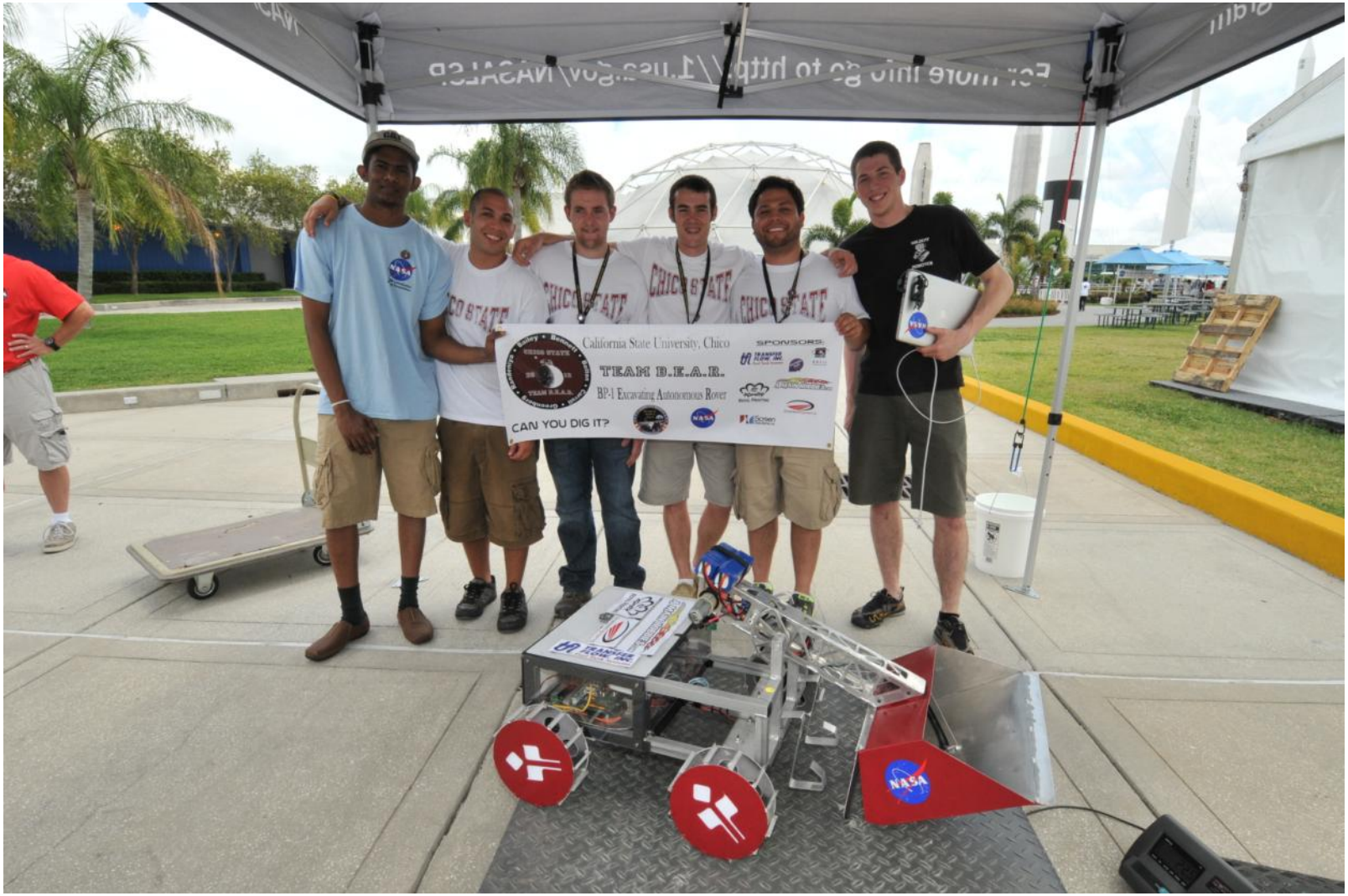


Arizona State – Wheels - Bucket Wheel – Dump Bin



Auburn U – Wheels - Front End Loader

Cal State Chico– Front End Loader – Trap Door

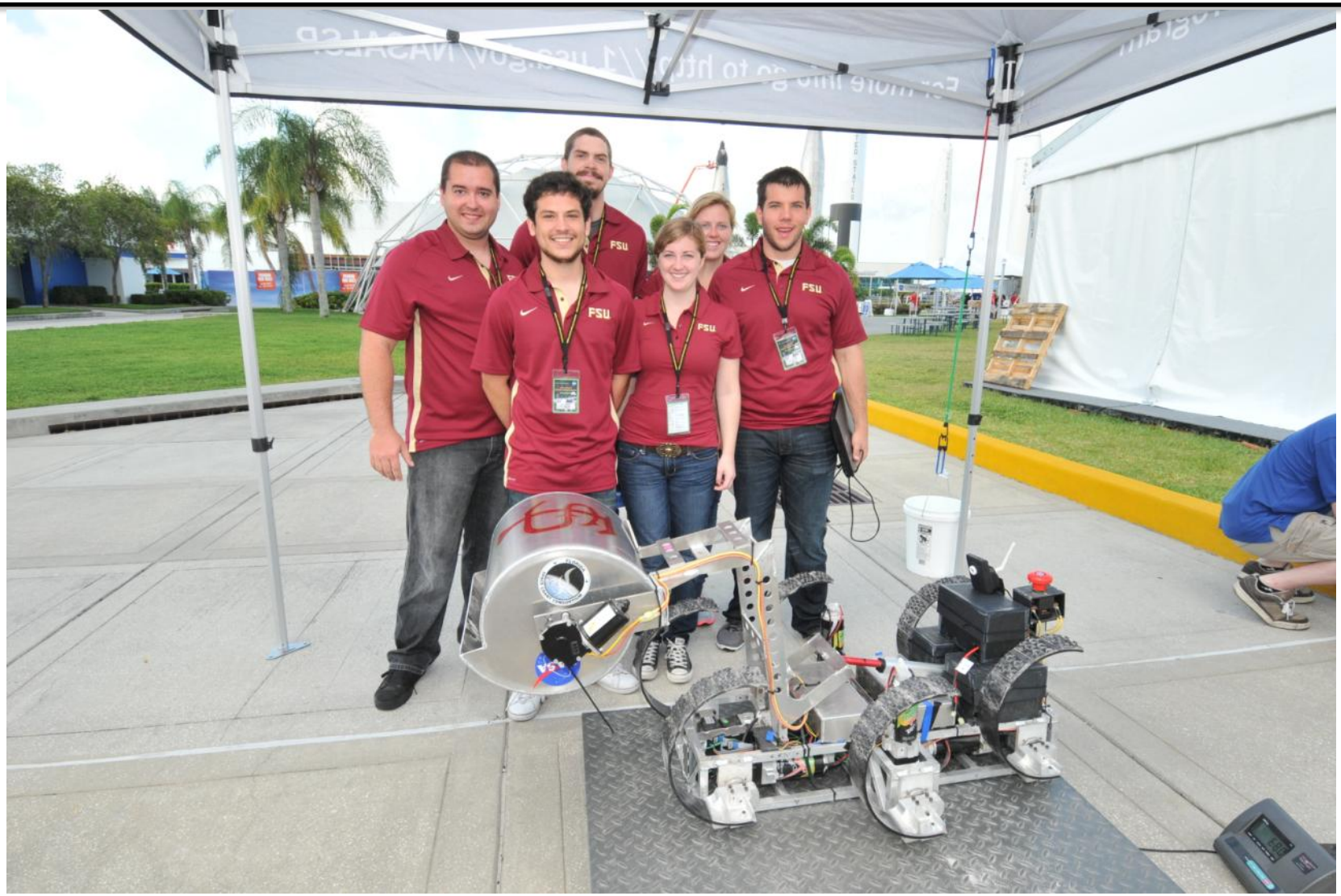


Colorado School of Mines- Wheels – Bucket Ladder– Bucket

Concordia U – Tracks – Bucket Chain– Bucket

Embry-Riddle Daytona – Wheels – Front End Loader

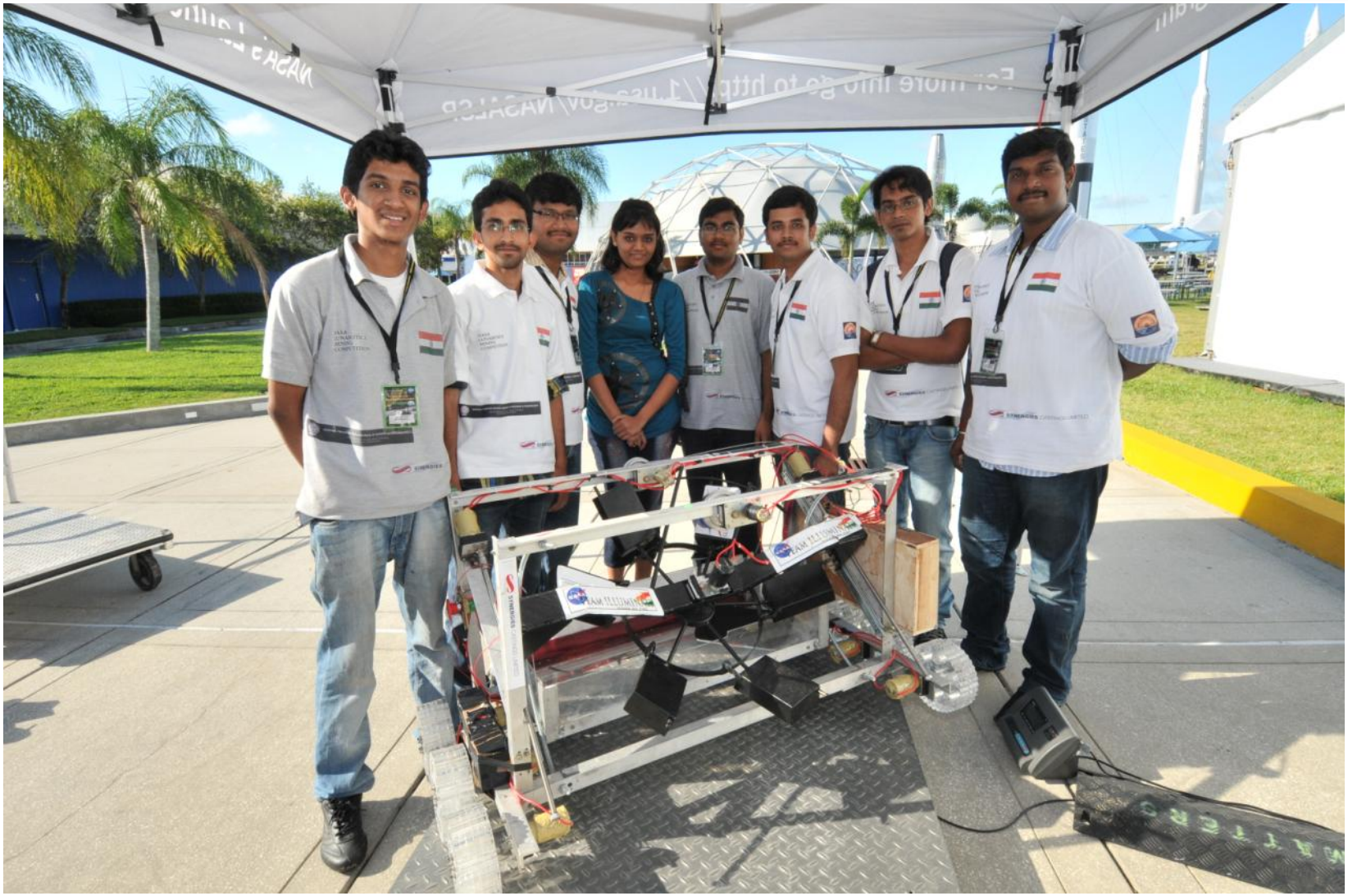
FAMU Florida State U – Whegs– Bucket Drum



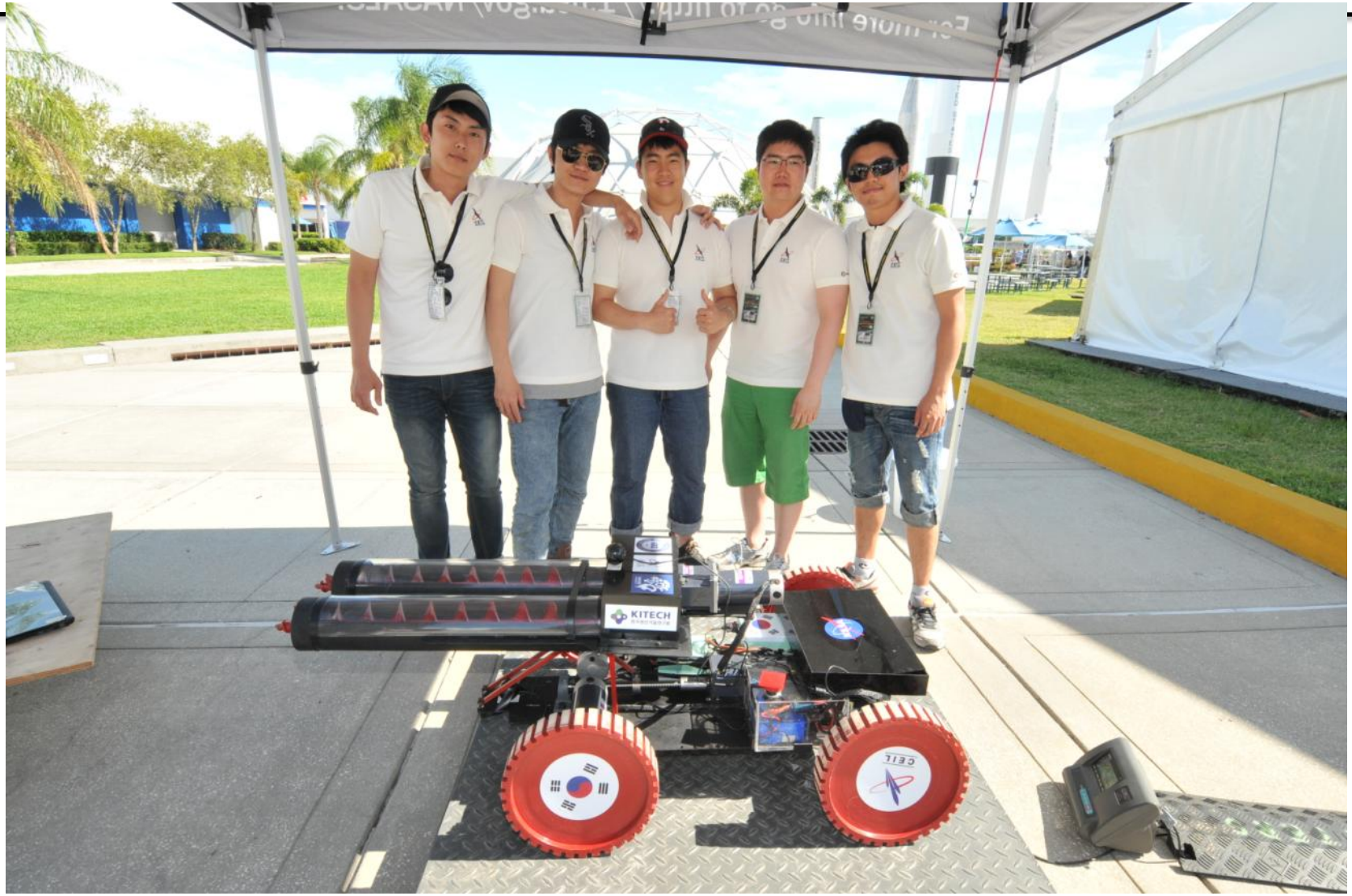
Florida Inst. Technology – Wheels – Front End Loader

Florida International U – Wheels – Auger Blower- Bucket

GITAM – Wheels – Circular Scoops – Bucket

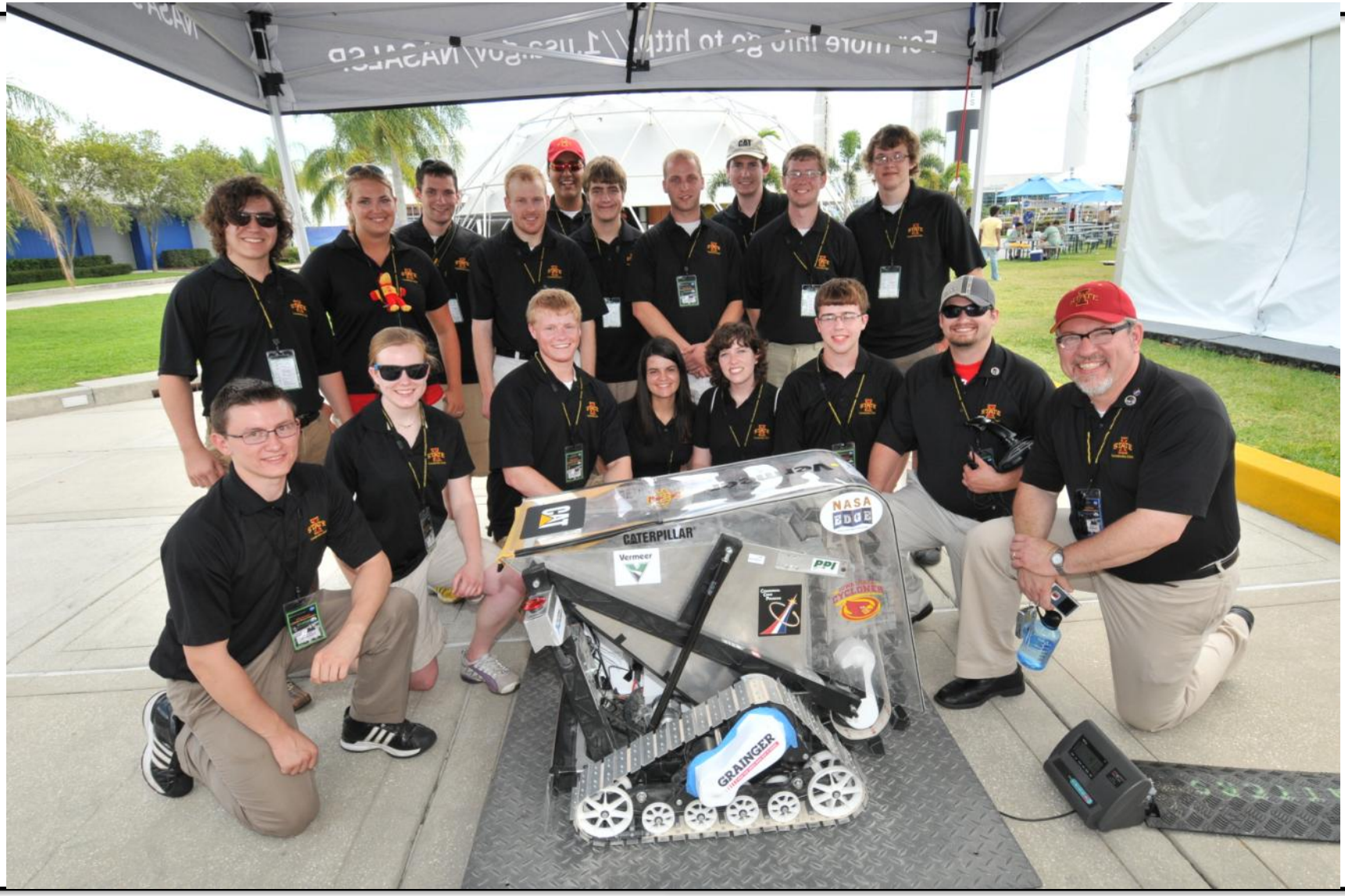


Hanyang U– Wheels – Double Auger Tubes

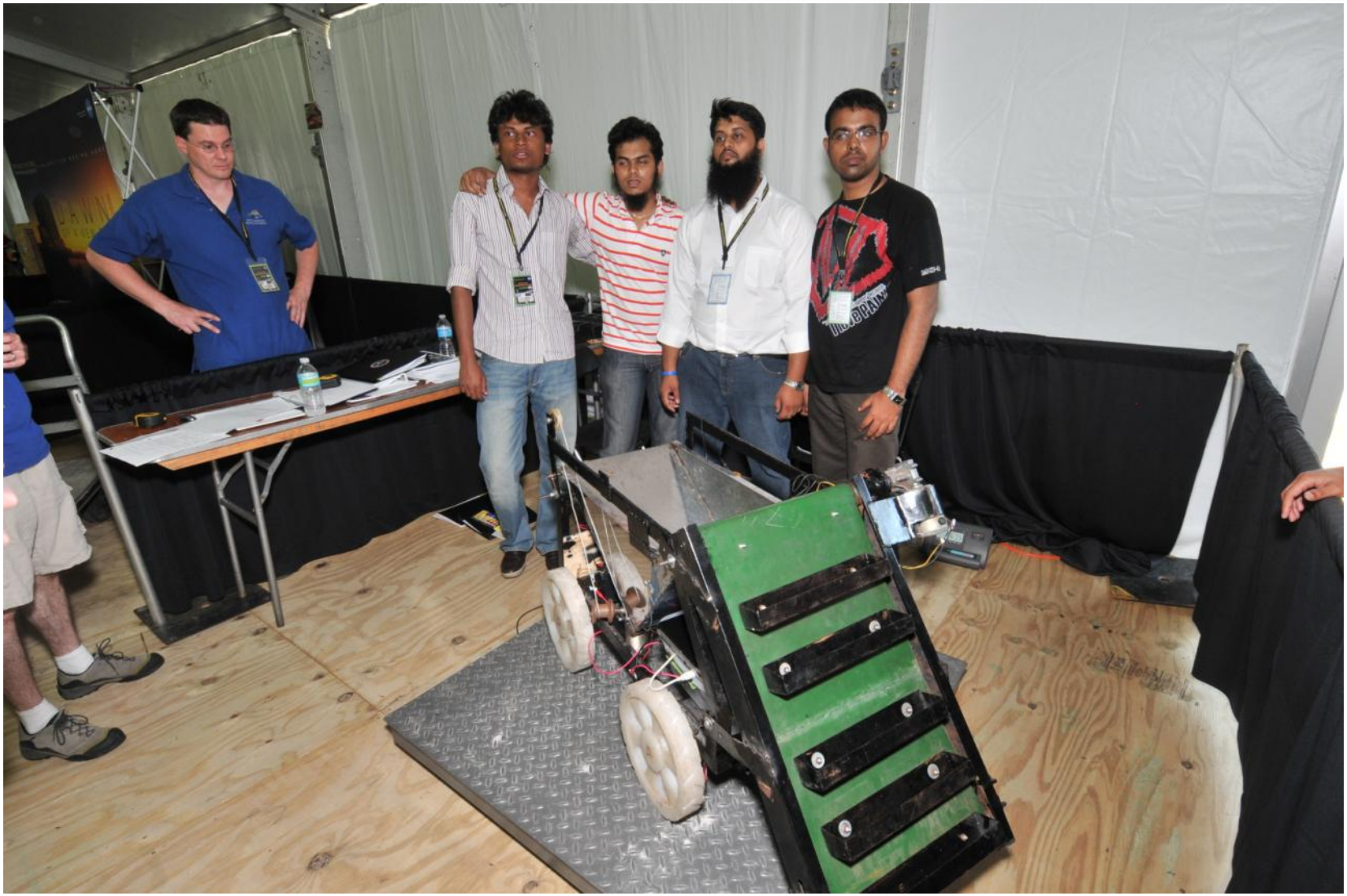


Inst. De AstroBiologia – Wheels – Bucket Chain– Bucket

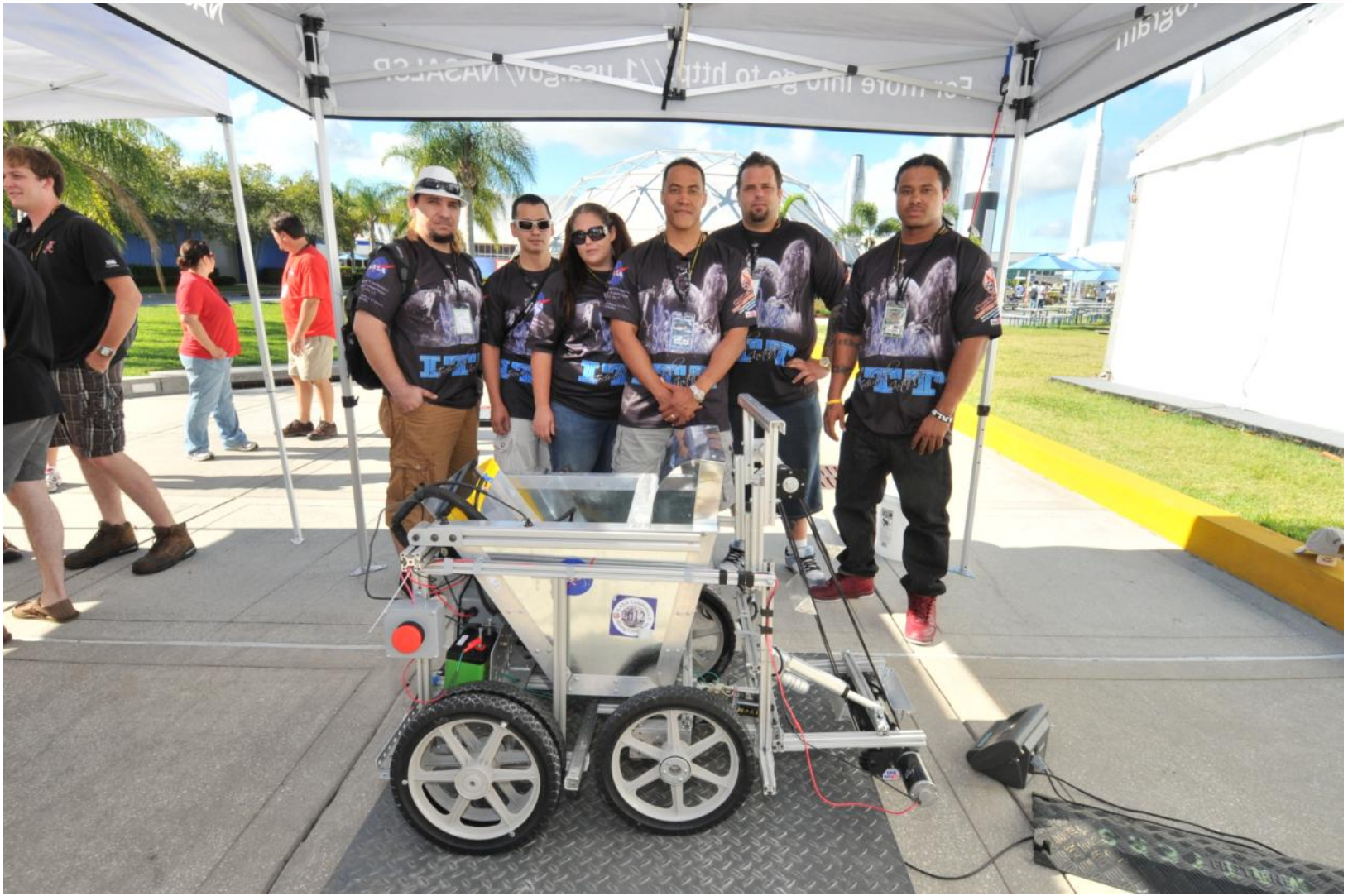
Iowa State– Tracks – Bucket Chain– Bucket



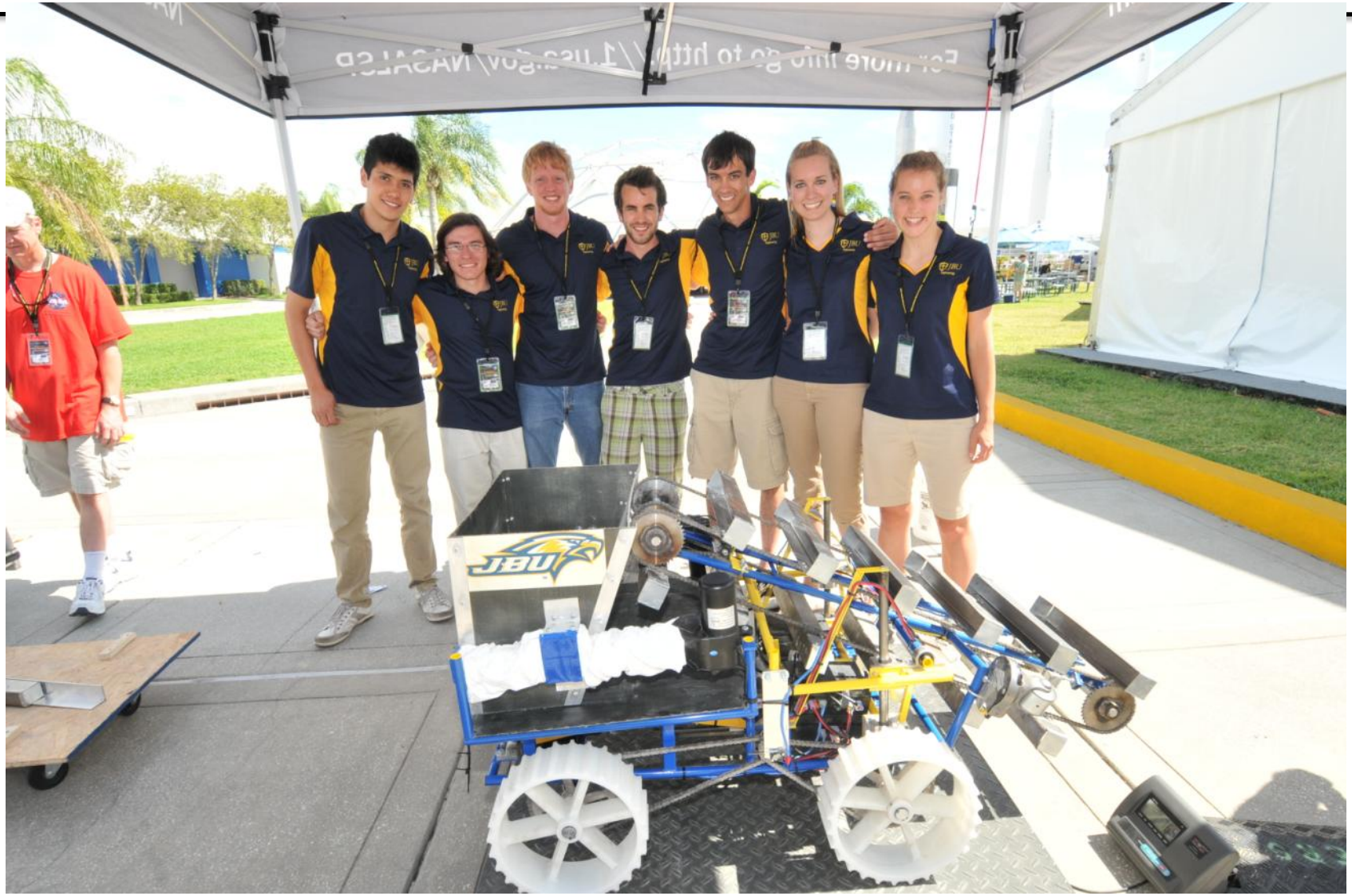
Islamic U of Tech – Wheels – Bucket Conveyer – Bucket



ITT Tech – Wheels – Bucket Chain– Bucket



John Brown U – Wheels – Bucket Chain– Bucket



KIRORI-MAL– Wheels –Overshot Loader – Bucket

Laurentian U – Wheels – Bucket Chain– Conveyer

Miami University – Tracks – Overshot Loader – Bucket

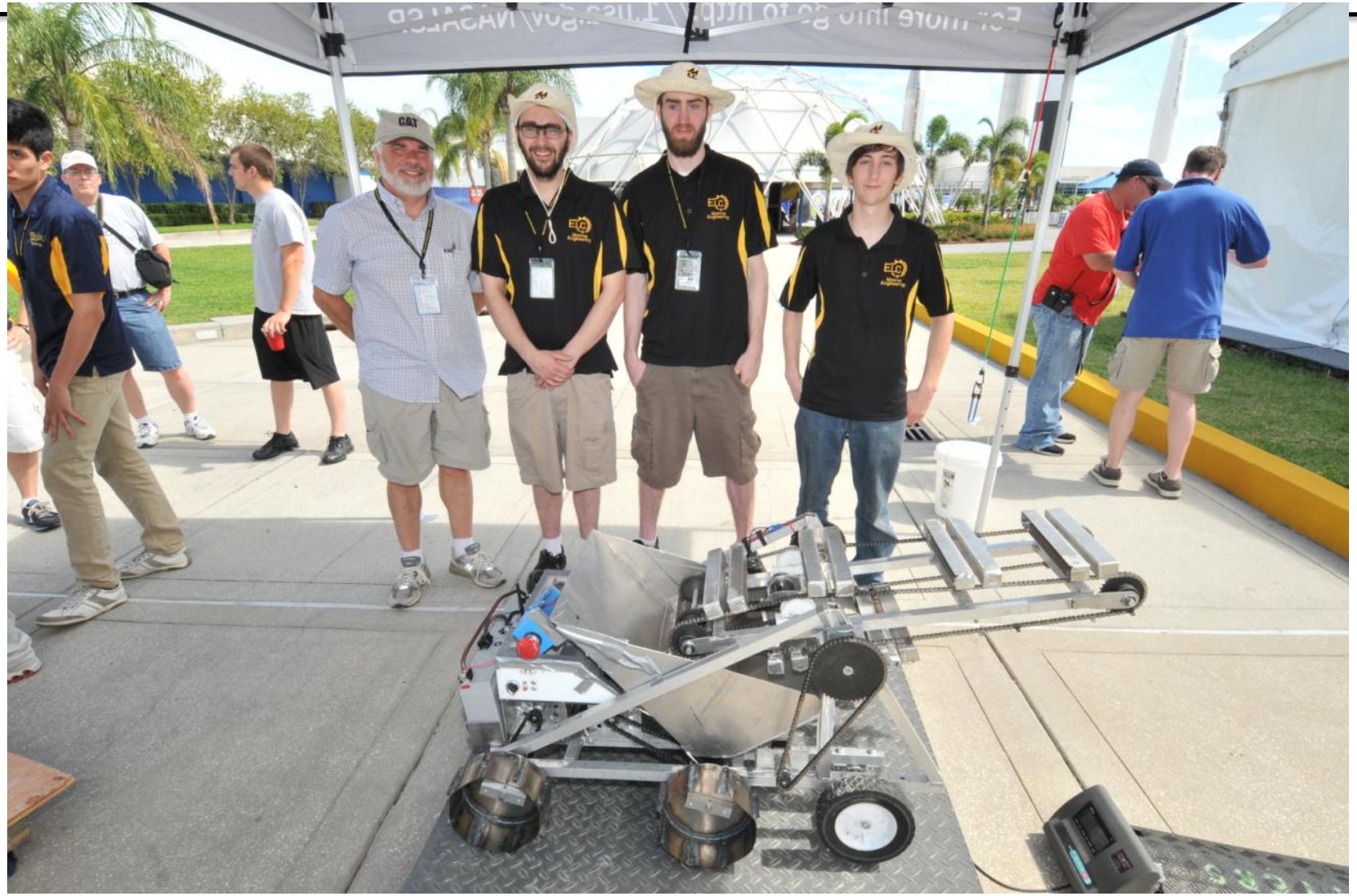
Middle Tennessee U – Wheels – Sweeper Brush - Bucket

MIST– Tracks – Bucket Chain– Bucket

Milwaukee SOE – Wheels – Bucket Chain

Modesto JC – Wheels – Scraper– Bucket

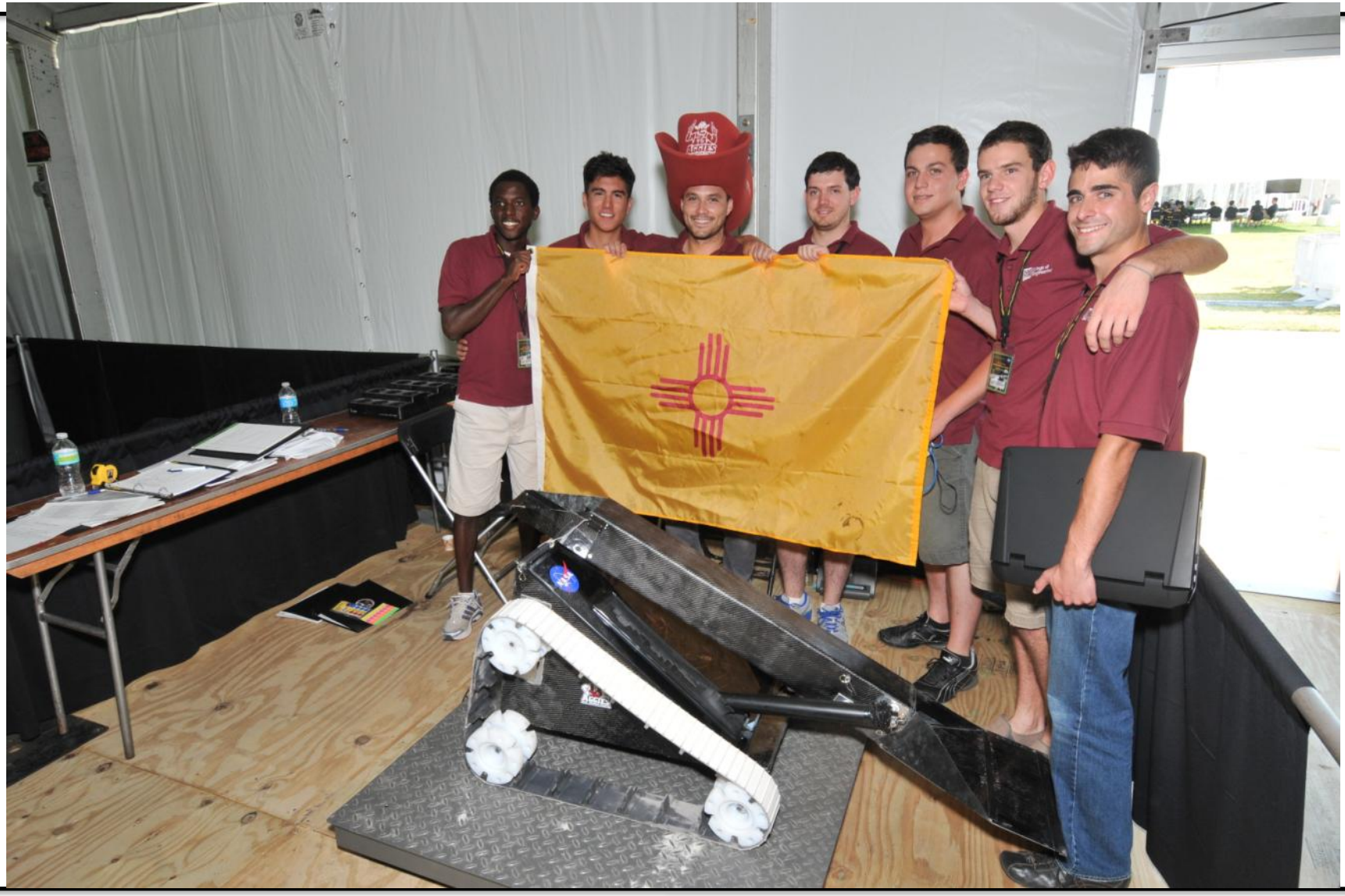
Monroe CC – Wheels – Bucket Chain– Bucket



Montana State – Wheels – Bucket Drum

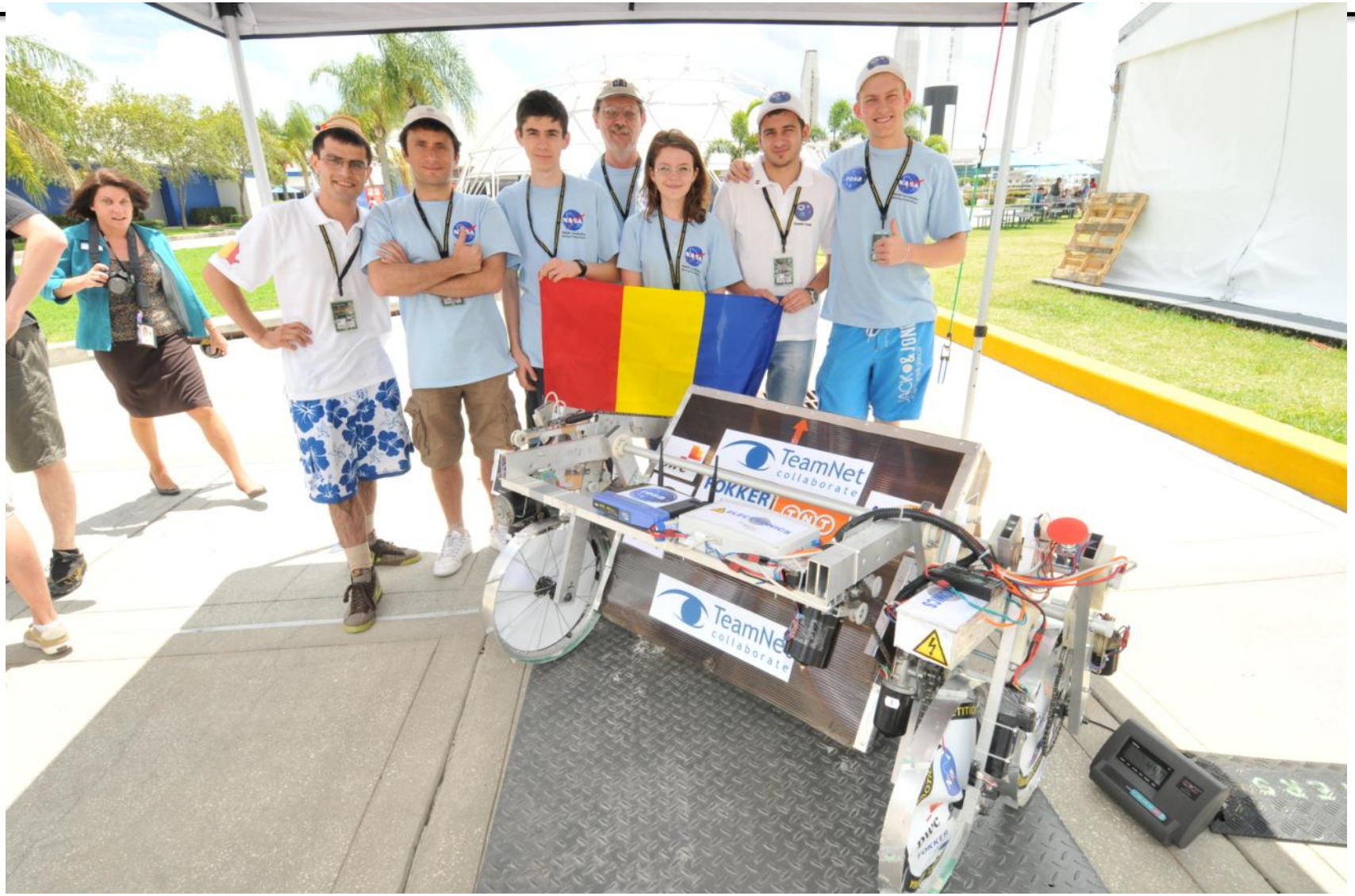
Montana Tech – Tracks – Overshot Loader – Bucket

New Mexico State– Tracks – Scraper - Chute



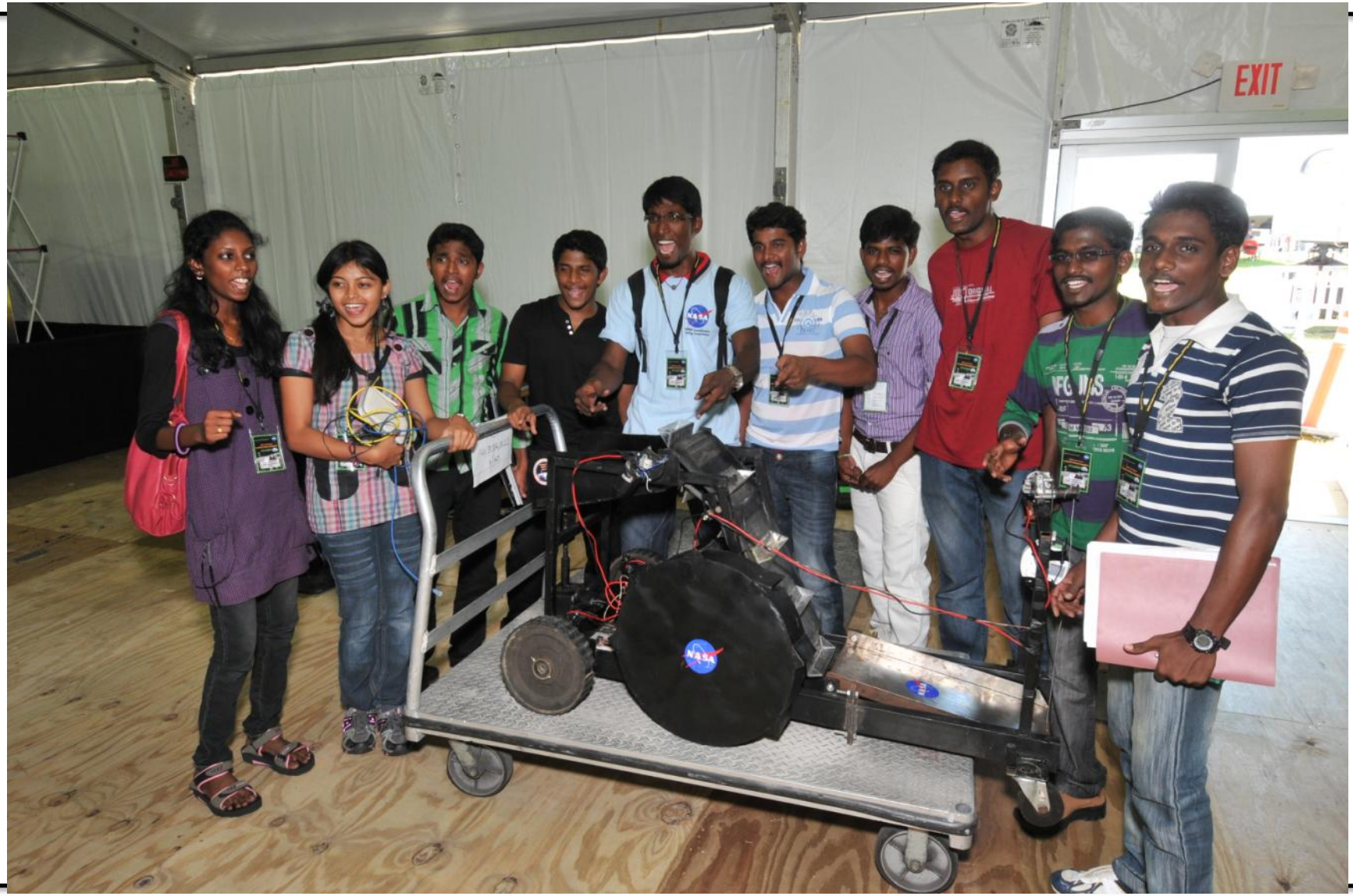
NMIMS – Wheels – Overshot Scraper– Bucket

Politech Bucharest– Wheels – Bucket Drum – Bucket



Polytech U of NYU – Wheels – Bucket Drum

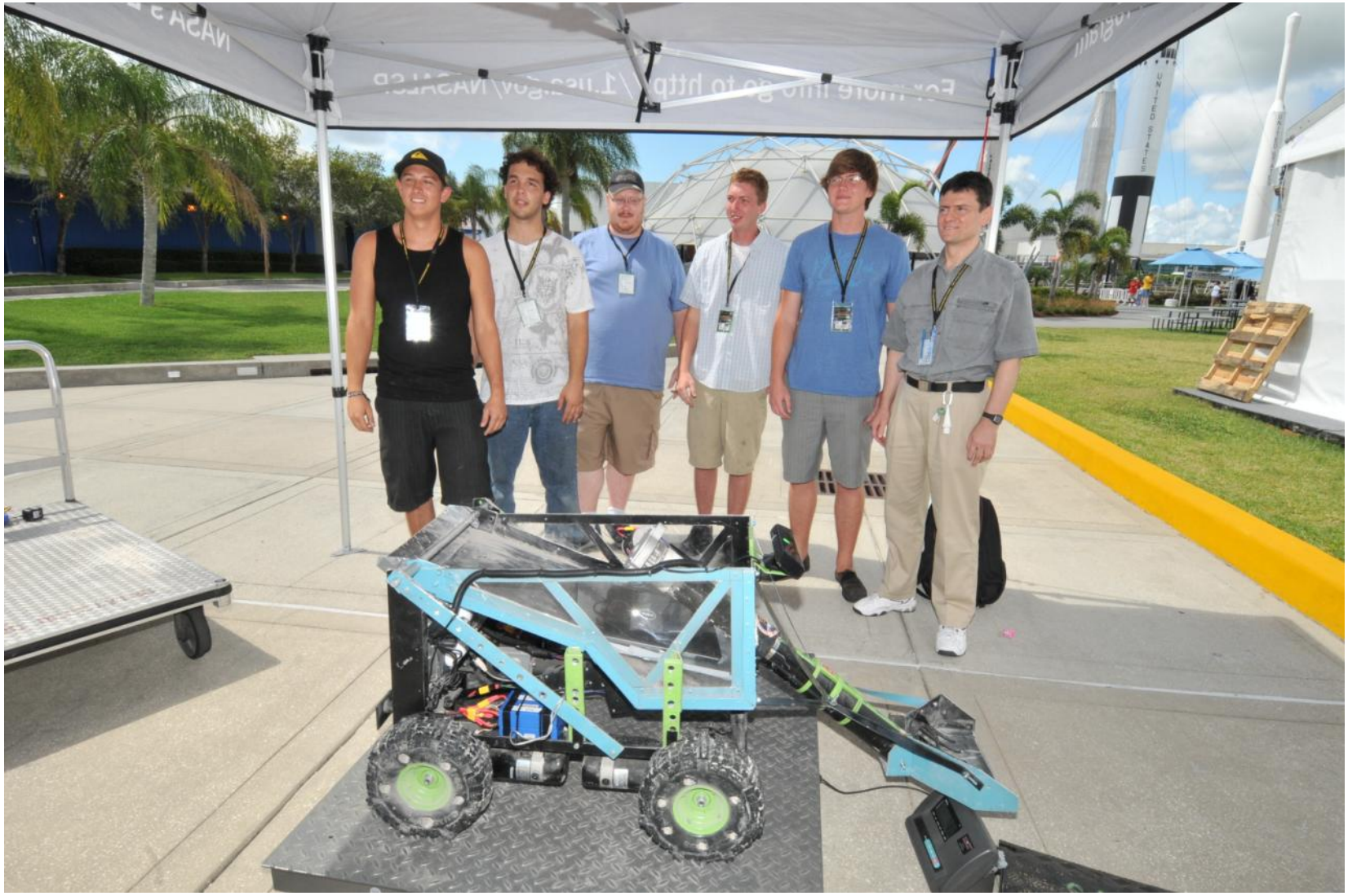
Srinivasan U – Wheels – Scraper - Bucket Chain– Bucket



S Dakota School of Mines – Wheels – Front End Loader

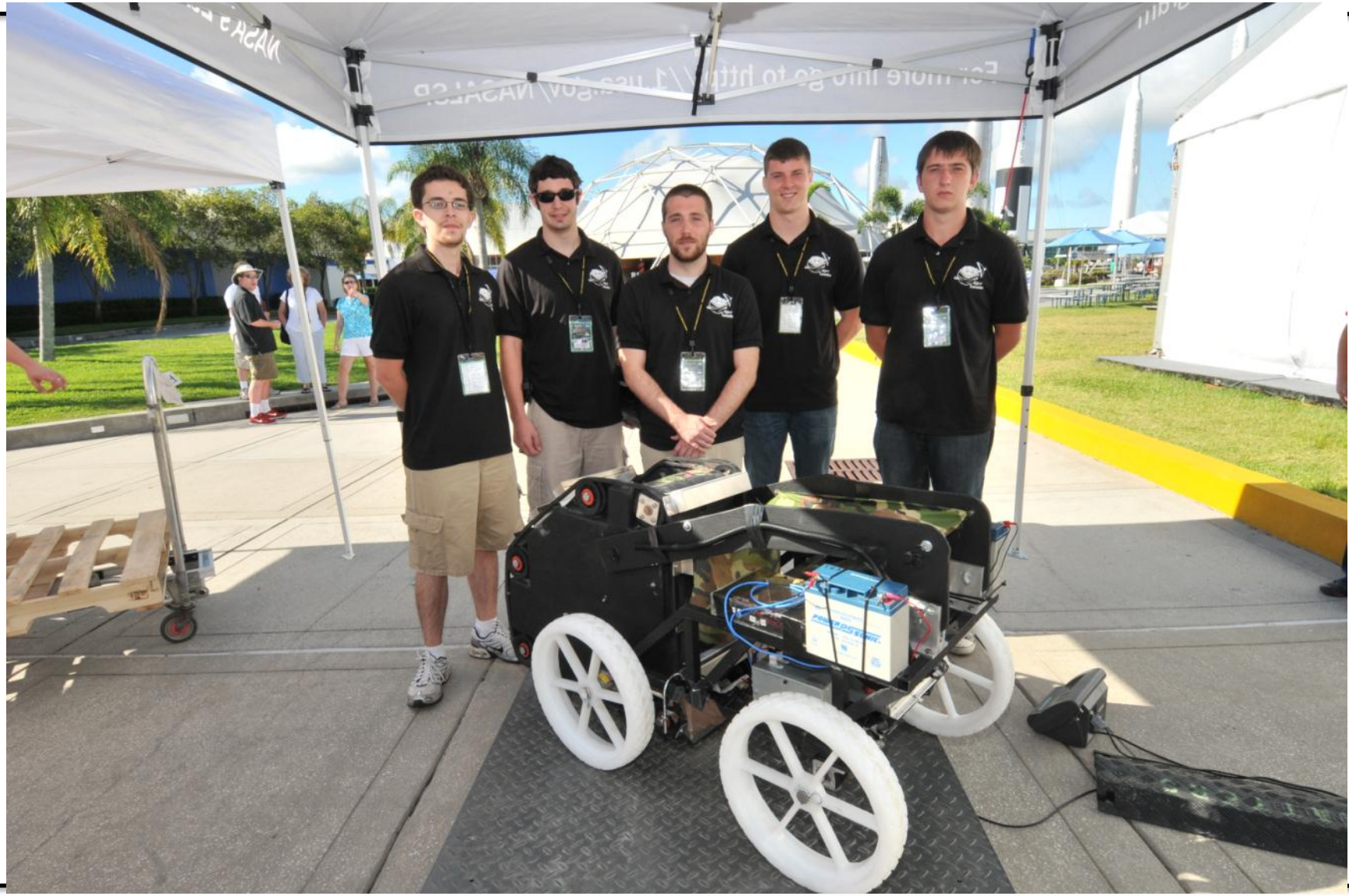
Temple U – Wheels – Front End Loader

TAMU CC– Wheels – Scraper - Auger– Bucket



UA Metropolitana – Wheels –Bucket Chain– Conveyer

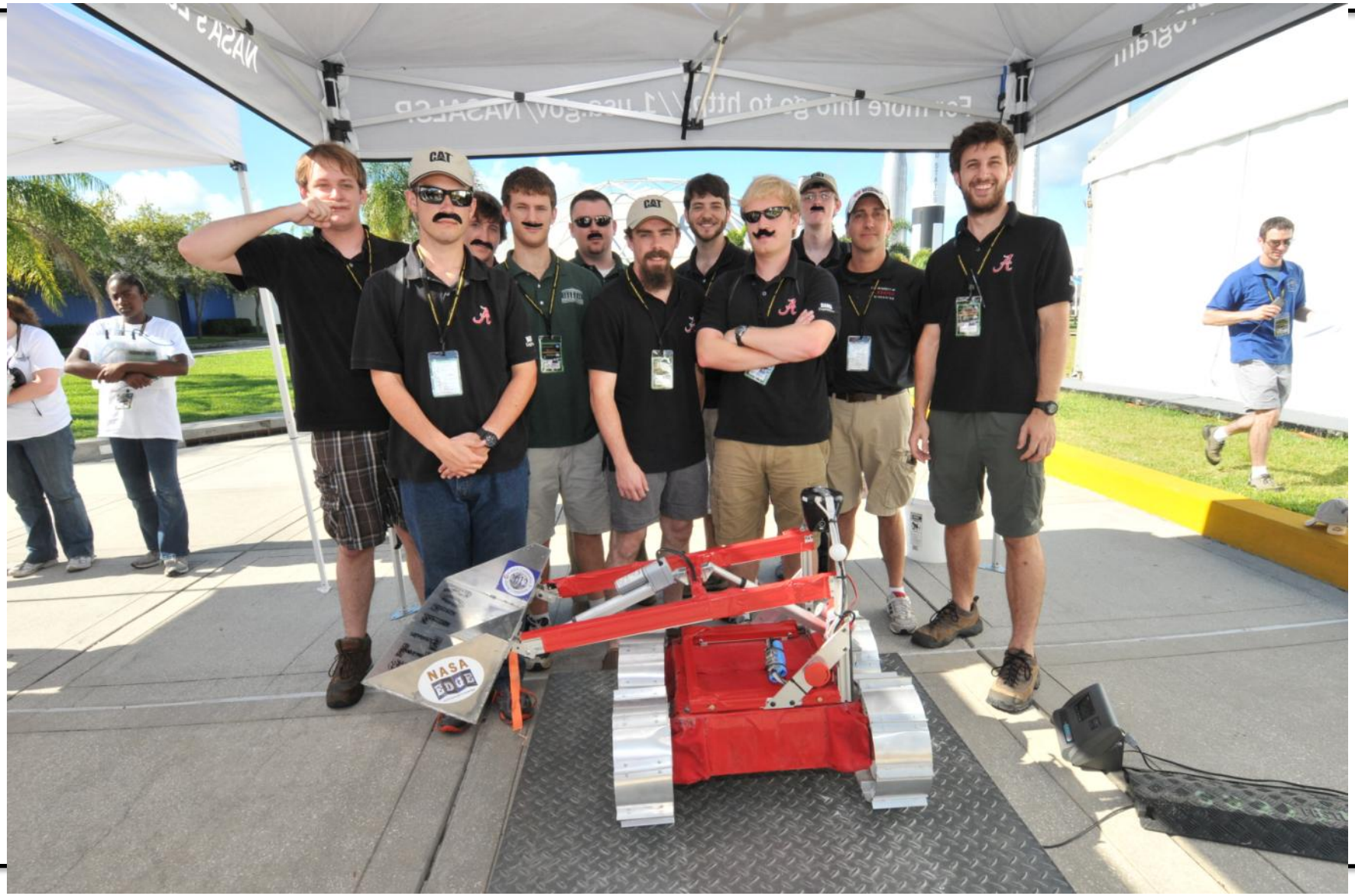
Saveetha U – Wheels –Bucket Belt– Bucket



U of North Florida– Wheels – Front End Loader - Bucket

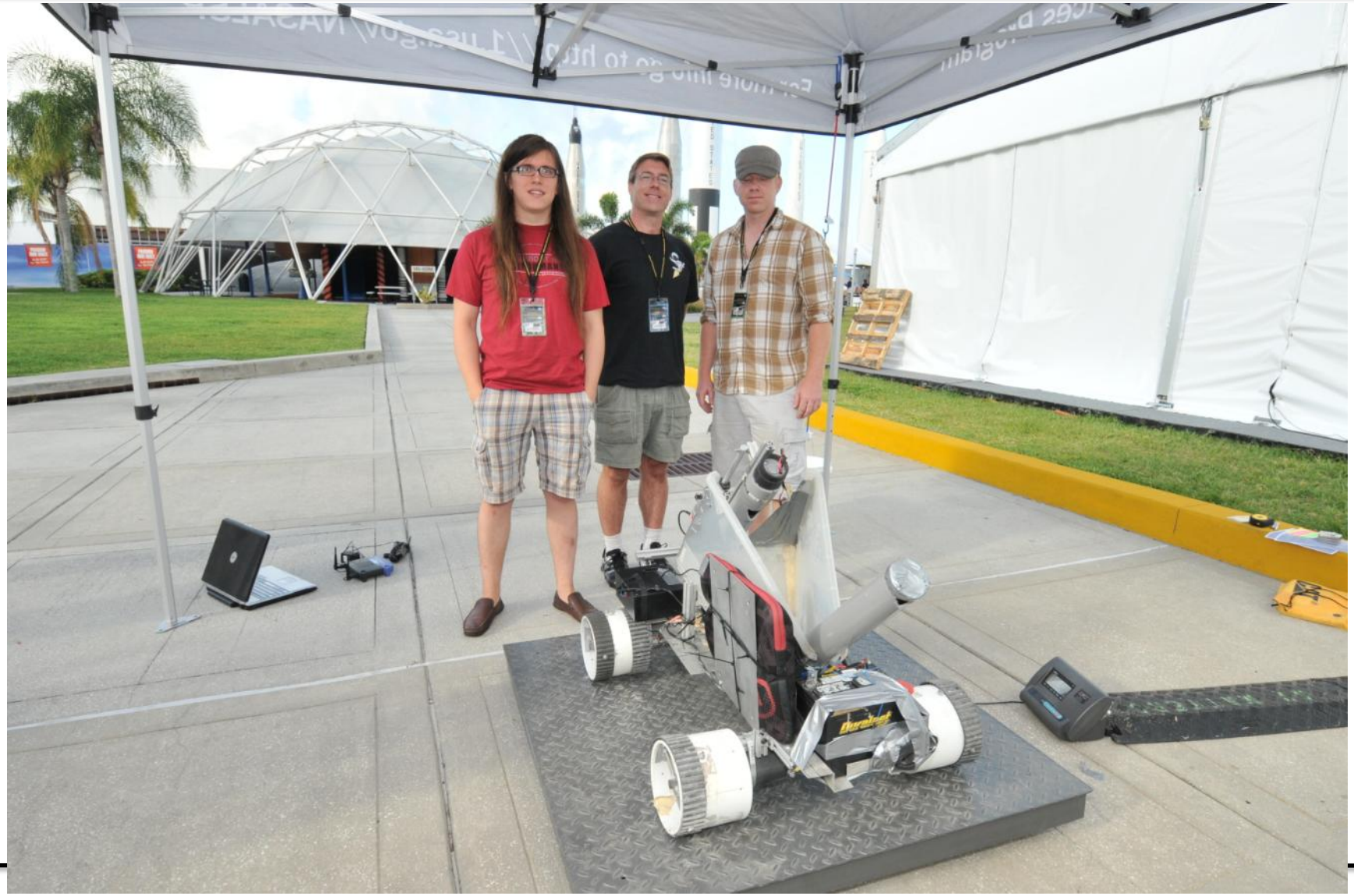
U Akron – Tracks – Overshot Scraper

U Alabama – Wheels – Front End Loader

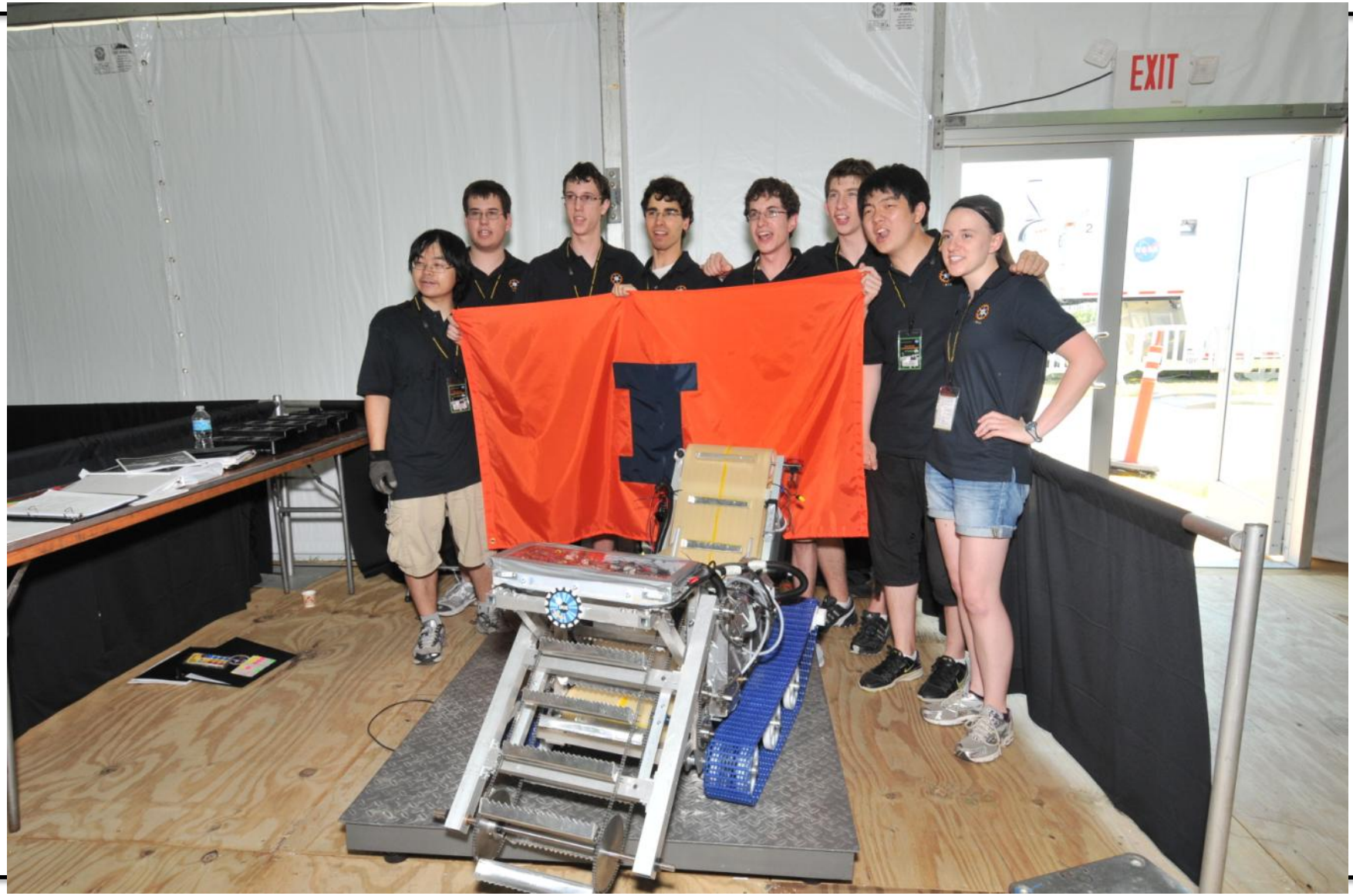


U de Los Andes – Tracks – Bucket Wheel – Dump Bucket

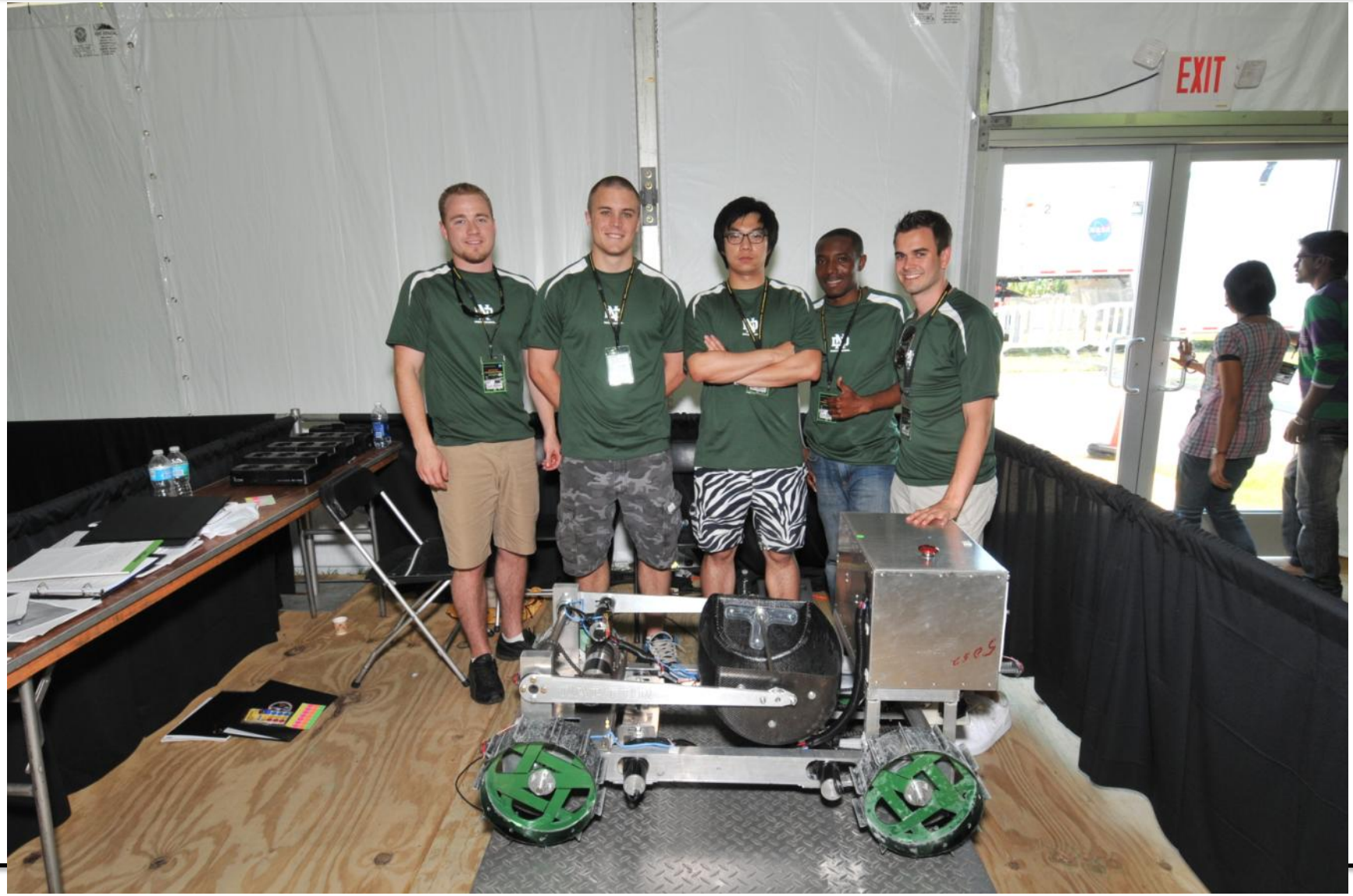
U Arkansas– Wheels – Auger – Dump Auger



U Illinois – Tracks –Bucket Chain – Dump Conveyer



U of N. Dakota – Wheels – Rotating Scoop

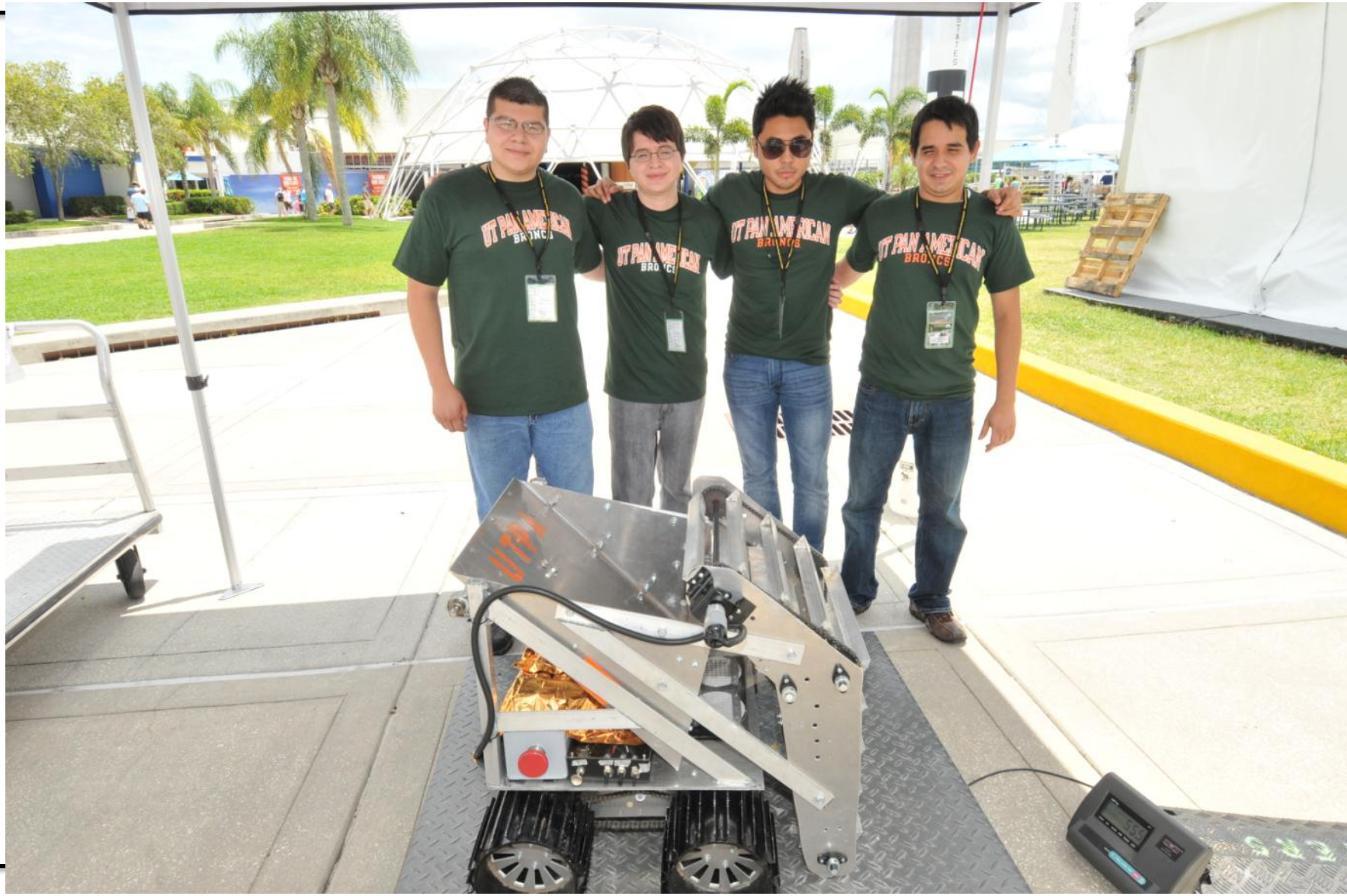


U Nebraska – Tracks – Front End Loader – Dump Bucket

U New Hampshire – Wheels – Front End Loader

U Portland – Wheels – Front End Loader

UTPA– Wheels – Bucket Chain – Dump Bucket



Virginia Tech – Wheels – Front End Loader

West Virginia U – Wheels – Overshot Loader - Conveyer

York U – Wheels – Scraper - Bucket Chain– Bucket

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.

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.

Thank You!!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