



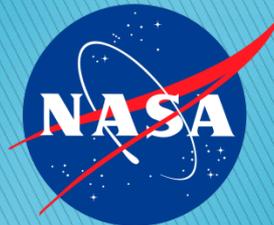
Pacific International
Space Center for
Exploration Systems

PTMSS CSM
2014

PRISM: PISCES Robotic International Space Mining

The “World Cup” of Off-World Robotic Mining

John Hamilton, Rob Kelso



Moon, Mars & Beyond



Why PRISM?

- ▶ **Political/Humanitarian:**
 - To encourage international collaborative effort in space exploration and development
- ▶ **Technical:**
 - To build upon and extend the successful NASA Robotic Mining Competition (nee Lunabotics)
- ▶ **Educational & Workforce Development:**
 - To provide meaningful engineering skills & experience to students and deliver useful concepts to the ISRU community at large
- ▶ **Community Development:**
 - To spur the growth of collegiate level robotics at University of Hawai`i – Hilo, Hawai`i Community College and other similar educational institutions in Hawai`i nei.

Building Blocks. . .

- ▶ *In-Situ* Resource Utilization
 - (ISRU)
 - ▶ PISCES Planetary Analog Test Site
 - (PATS)
 - ▶ NASA Robotic Mining Competition
 - (RMC)

 - ▶ Putting them all together = PRISM
- 



In-Situ Resource Utilization (ISRU)



- ▶ Key to affordable exploration of rocky surface planets and moons.
- ▶ Critical for *development* and habitation.
- ▶ Essential for resource usage on site.
- ▶ Vital for commercial development and use on site and export back to Earth.
- ▶ Consists of 3 main components:
Prospecting, Mining and Processing

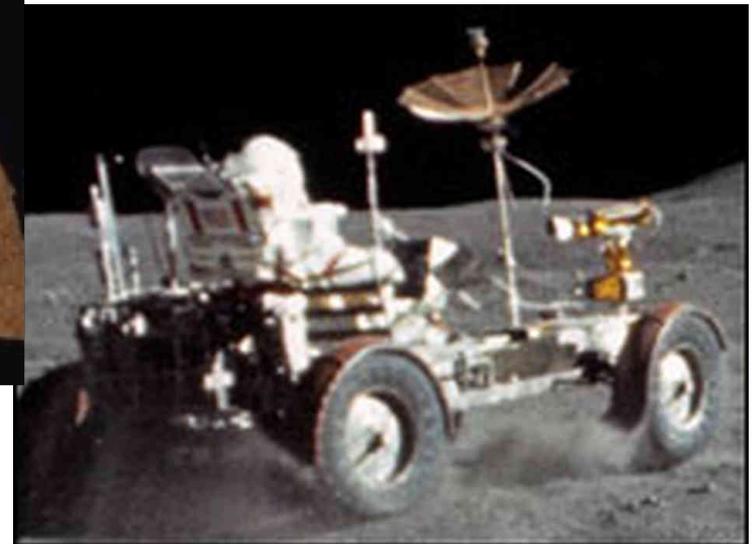
Regolith – “Dusty rocks”

- ▶ Most surfaces consist of regolith a layer of loose, heterogeneous material covering solid rock. It includes dust, soil, broken rock, and other related materials.
- ▶ Found on rocky planets, moons and asteroids

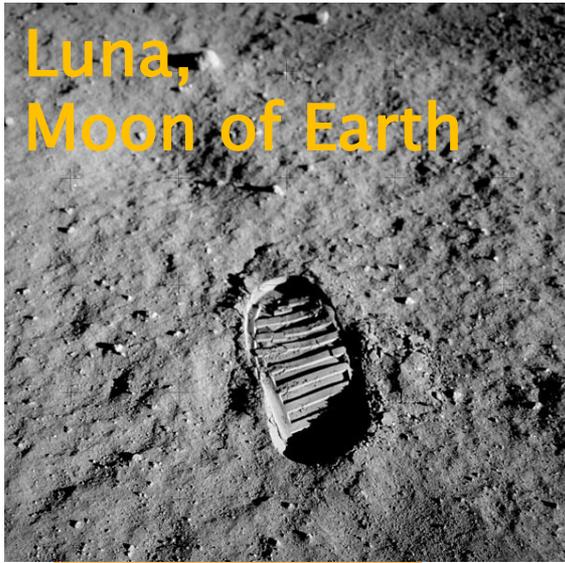


Clean

Dusty

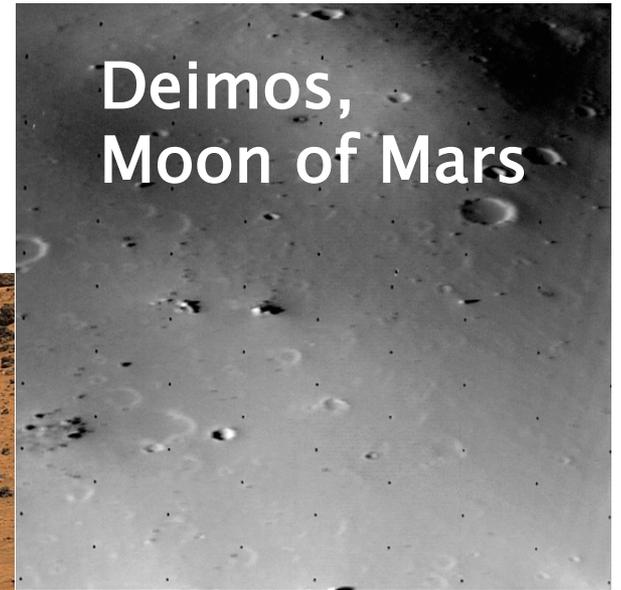


Luna,
Moon of Earth

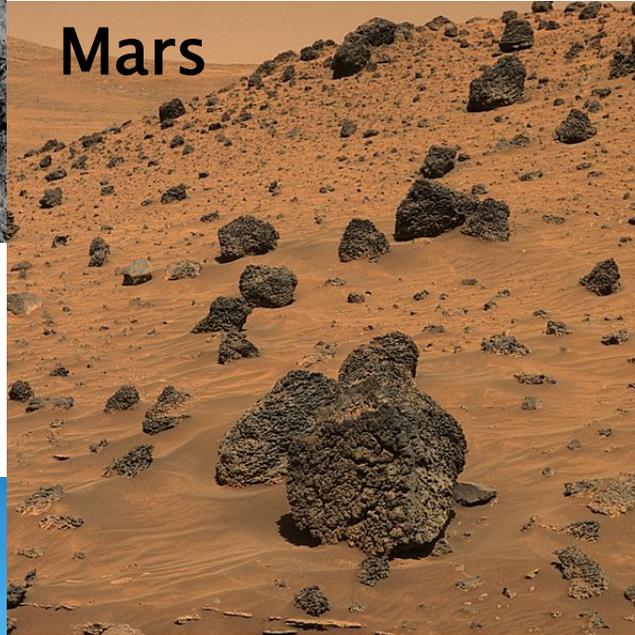


Regolith Sources

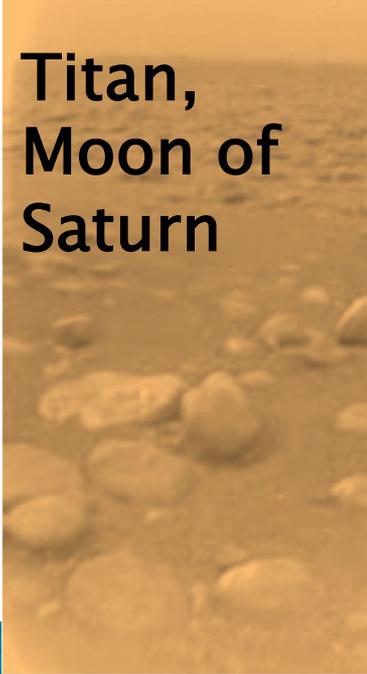
Deimos,
Moon of Mars



Mars



Titan,
Moon of Saturn



Asteroid
Eros

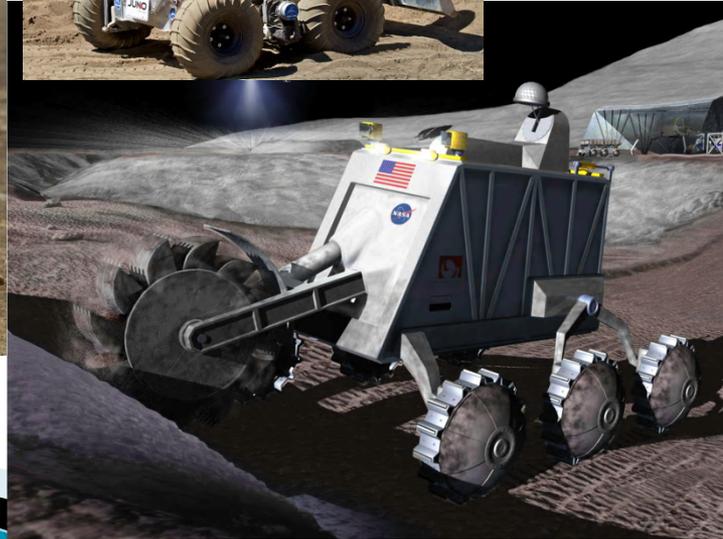
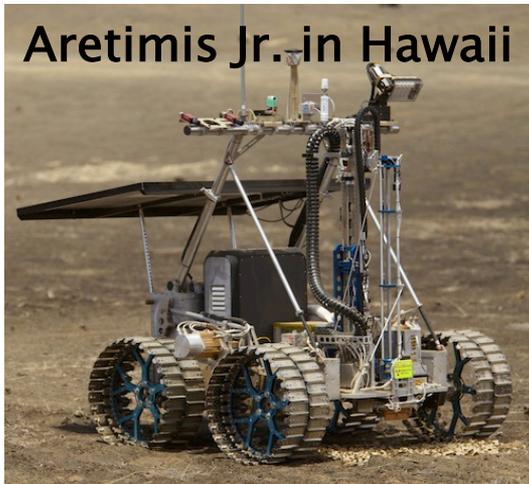


Earth



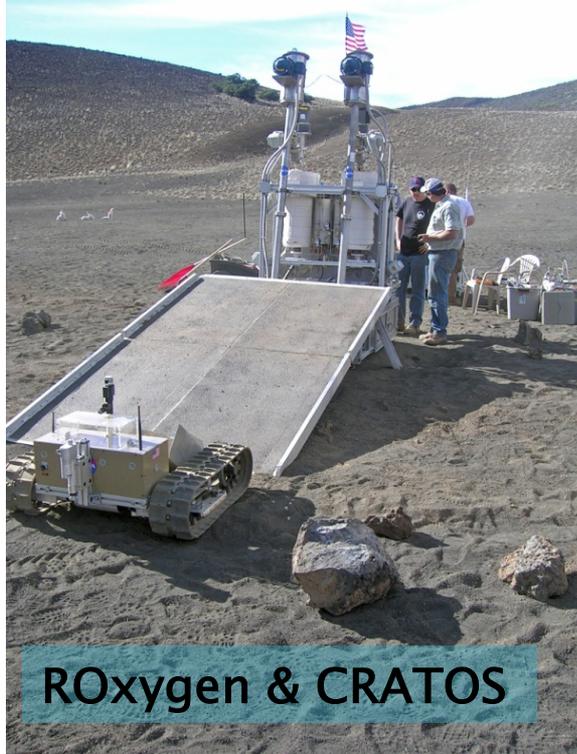
Mining

- ▶ So in most instances, mining on these rocky planetary surfaces consists of scooping and transporting the loose regolith material.
- ▶ Space Mining is the collection of regolith.

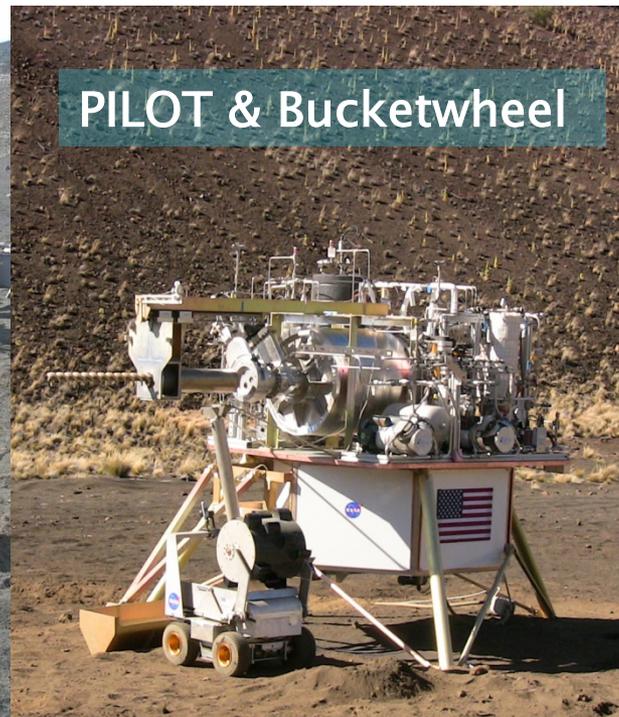


Processing

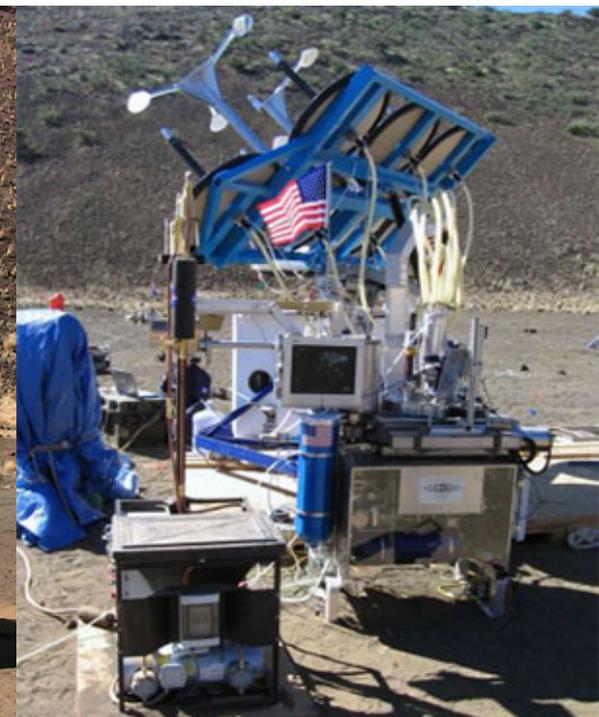
- ▶ Robotic Mining unit deliver the regolith to these plants for resource extraction



ROxygen & CRATOS



PILOT & Bucketwheel

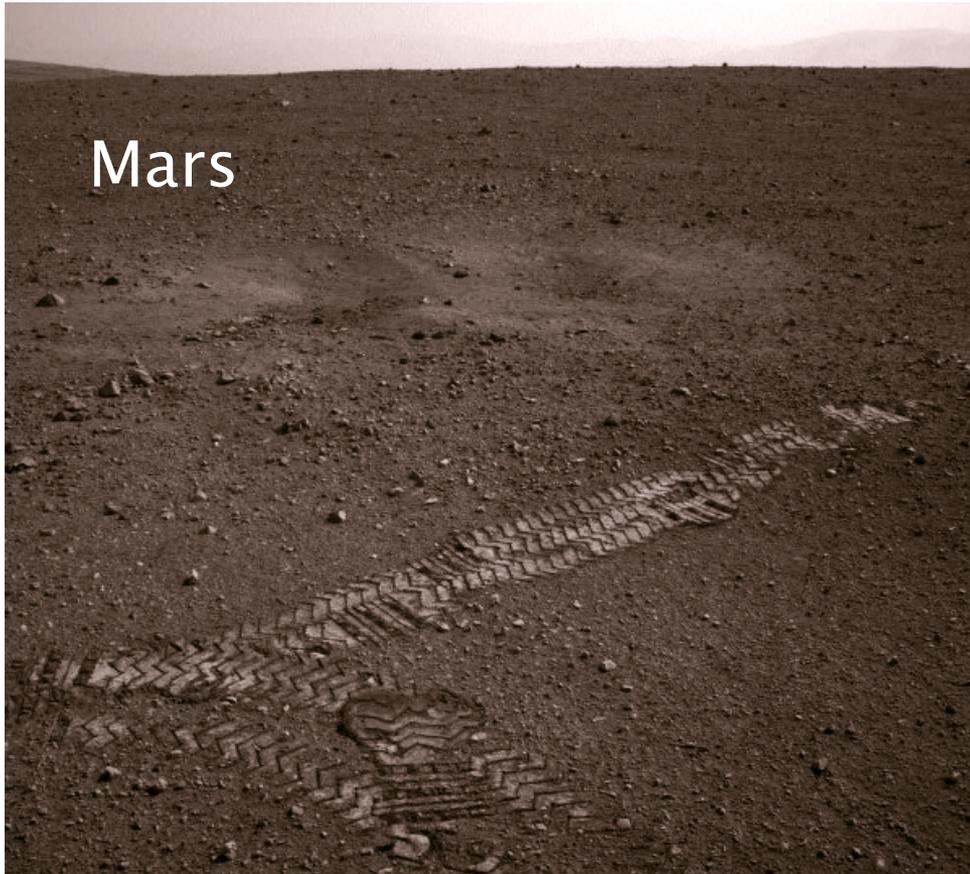


Carbothermal
Reduction

ISRU Equipment field tested in Hawaii

PISCES Planetary Analog Test Site

High Fidelity Lunar & Martian Analog



Mars Soil Similar To Volcanic Sand On Hawaii's Mauna Kea, NASA Curiosity Rover Finds

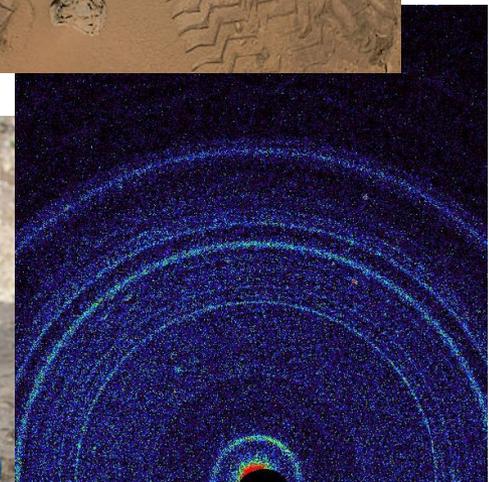
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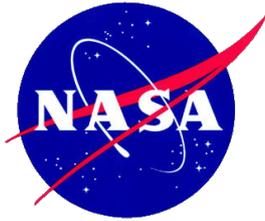
FOLLOW: [Video](#), [Curiosity Soil](#), [Hawaii Soil](#), [Mars Hawaii](#), [Mars Rover](#), [Mars Rover Curiosity](#), [Mars Soil](#), [Mars Soil Hawaii](#), [Mars Volcano](#), [Volcanic Soil](#), [Science News](#)

PASADENA, Calif. -- Scientists say the Martian soil at the rover Curiosity's landing site contains minerals similar to what's found on Hawaii's Mauna Kea volcano.

The finding released Tuesday is the latest step in trying to better understand whether the environment could have been hospitable to microbial life.

Curiosity recently ingested its first soil sample and used one of its instruments to tease out the minerals present. An analysis revealed it contained feldspar and olivine, minerals typically associated with volcanic eruptions. Mission scientists say the Martian soil is similar to volcanic soil on the flanks of Mauna Kea.

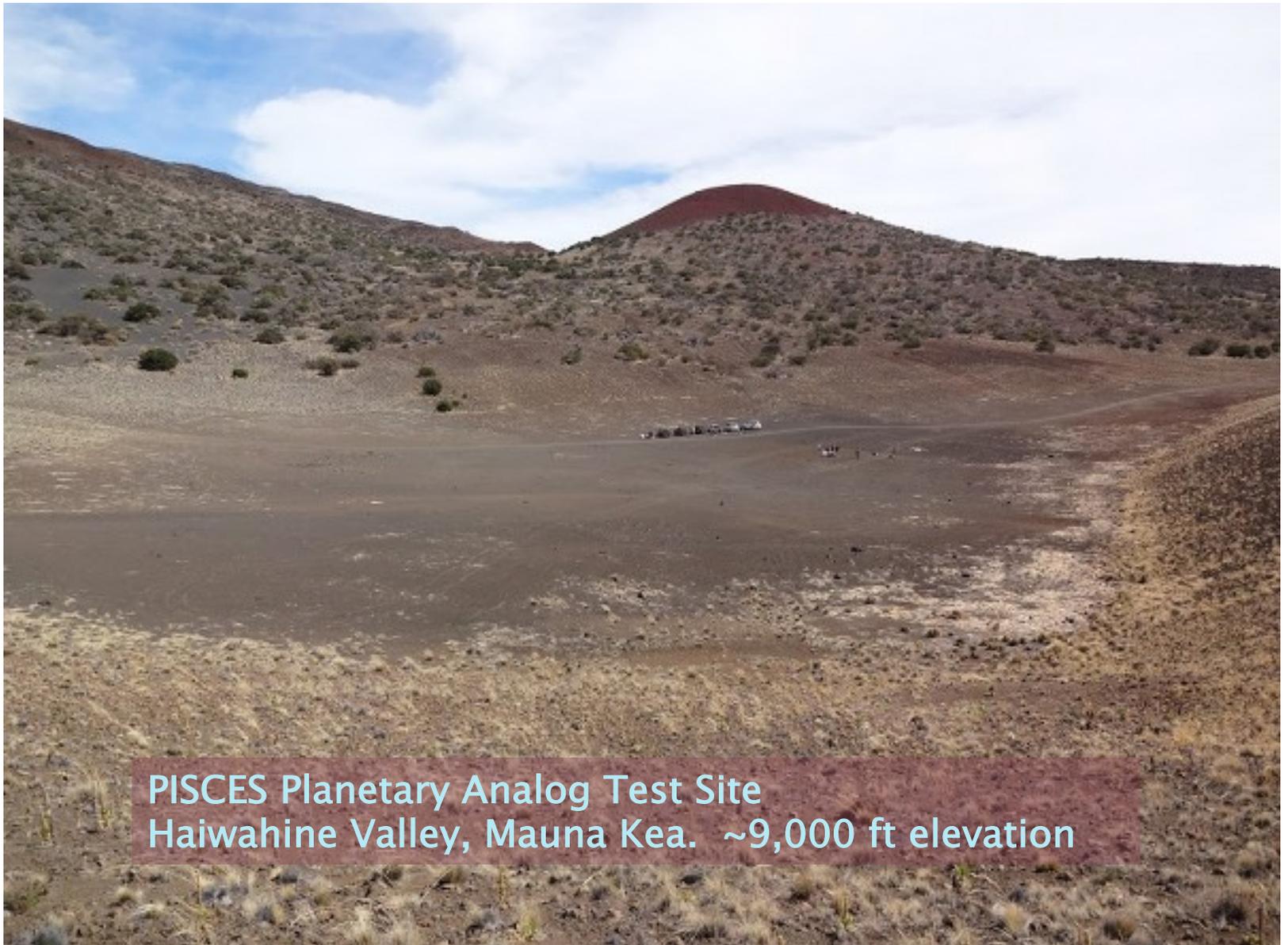




Proven Test Site by NASA & CSA



- ▶ **1st ISRU Surface Operations Analog Field Test**
 - Participation: 5 NASA centers, 2 International Space Agencies (CSA, DLR), 7 companies, 2 Universities.
 - Field Dates: October 30 – November 15, 2008
- ▶ **2nd International Joint ISRU Analog Field Test**
 - Participation: US – 6 NASA Centers, 6 Small Businesses, 5 Universities. Canada – 3 Canadian Government Agencies, 8 Small Businesses, 2 Universities. 20 resource utilization instruments and systems.
 - Field Dates: January 24 – February 14, 2010
- ▶ **3rd International Joint ISRU Analog Field Test**
 - Participation: NASA KSC, ARC / CSA.
 - Resource Prospector Mission operations rehearsal.
 - Field Dates: July 5–18, 2012



PISCES Planetary Analog Test Site
Haiwahine Valley, Mauna Kea. ~9,000 ft elevation



2012 Lunabot Trials

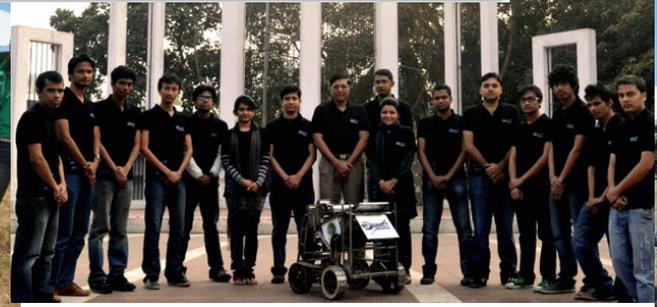
Modeled on NASA Lunabotics Competition 2010–2013

Regolith Arena

- ▶ Black Point, AZ basalt for lunar regolith simulant
- ▶ Very fine dust = EPA/OSHA safety precautions



2013 Lunabot examples



NASA RMC Operation



Rover Checkout
(LunaPits)



Practice Pits



Suit-up



Mission
Control



LAN connection

~50 yards

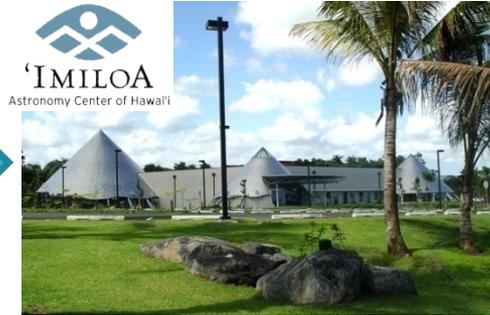
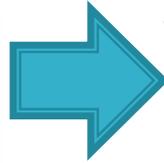


Regolith Arena
(Lunarena)

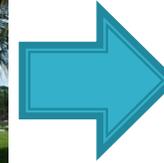
PRISM Operation



Rover Checkout
(U. Hawaii - Hilo)



Practice Area
(`Imiloa)



“Launch”
Transport to
Mauna Kea Test Site

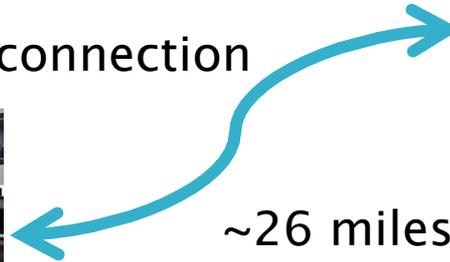


LAN connection

~26 miles



Regolith Arena
Analog Test
Site (9,000 ft)



Mission Control

Gemini Obs., Hilo Base Facility

Modeled on past Analog Tests

- ▶ Luna pits replaced by team tent
 - 10x20 feet with AC generator
- ▶ Lunarena replaced by open field
- ▶ Longer traverse
- ▶ More obstacles (craters/rocks)
- ▶ Larger field allows for multiple competition lanes
- ▶ Robust communications to MC
- ▶ Control Rooms located off site at mission control facility in Hilo

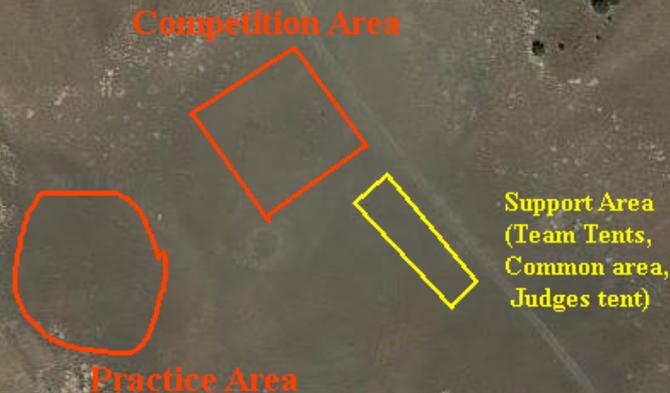


2012 Lunabot Winner, Alabama
at PISCES Analog Test Site

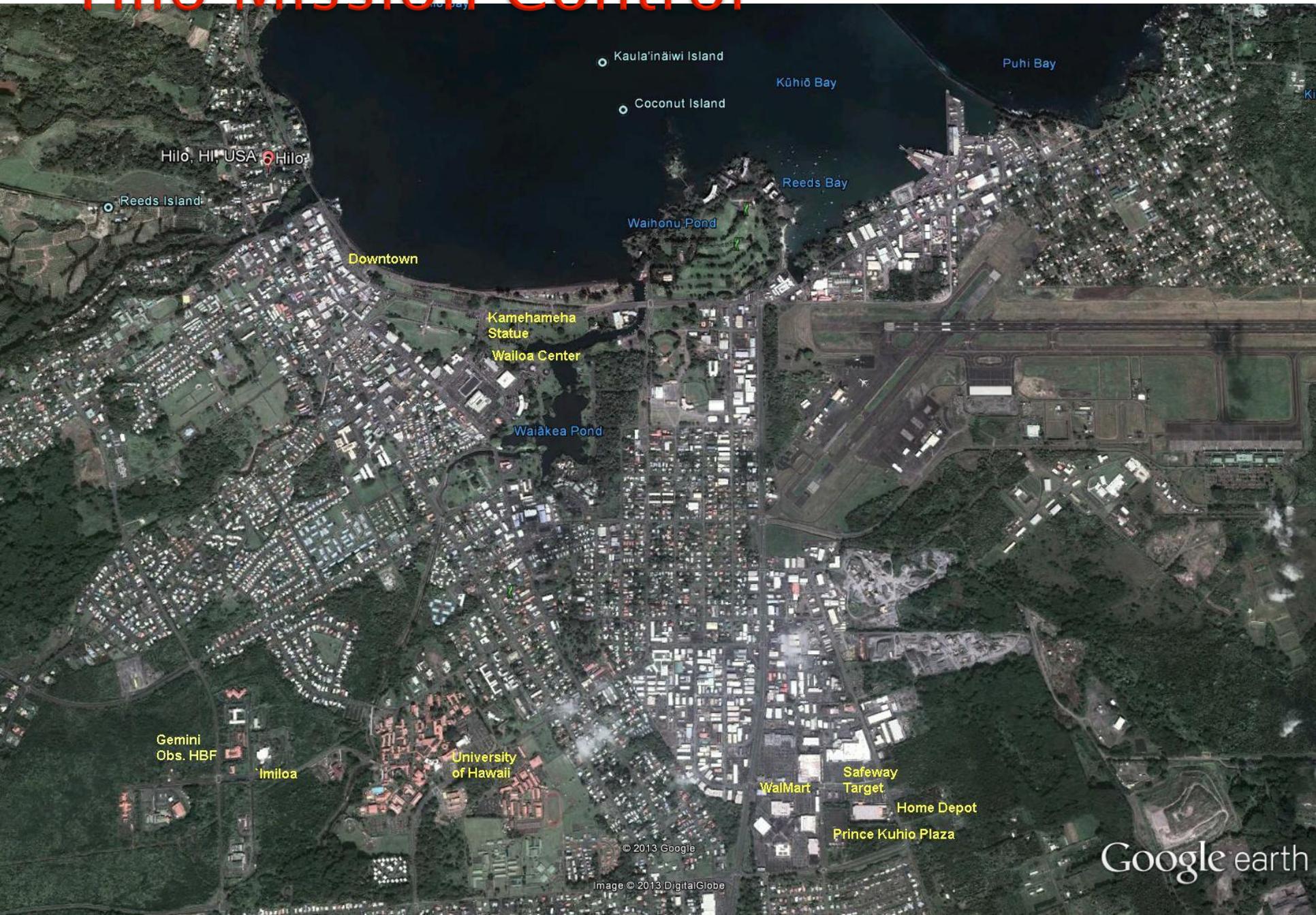


Venue – PISCES Analog Site

- ▶ Mars and Lunar simulated regolith
 - Hawaiian basaltic tephra and ash – Primo #1



Hilo Mission Control



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Image © 2013 DigitalGlobe

Google earth

Schedule of Events

July 21–25

- ▶ Monday – Arrival and checkout
 - University of Hawai`i – Hilo (Technical Check)
- ▶ Tuesday – Rover checkout and practice
 - `Imiloa Astronomy Center field (Coms Check)
- ▶ Wednesday
 - Morning: Launch to site (9,000 ft)
 - Afternoon: Competition begins
- ▶ Thursday
 - Competition Continues
- ▶ Friday
 - Conclusion
 - Awards Banquet

Contemporary Events

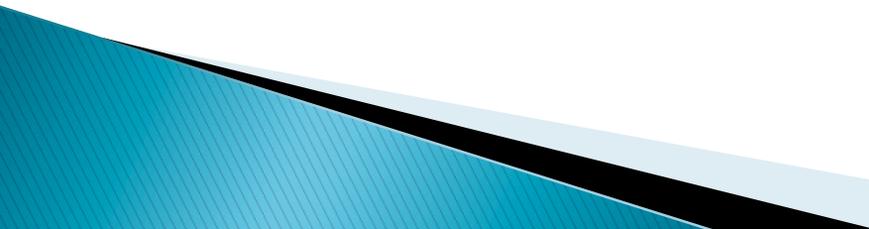
- ▶ 2nd Annual Pacific Astronomy & Engineering Summit (July 21–25)



Pacific
Astronomy & Engineering
Summit

- International High Schools
 - Joint EPO activities (Wed & Thurs)
 - <http://www.paes.hawaii-conference.com/>
- ▶ Optional (pre-/post- event activities)
 - Tour of Mauna Kea
 - Tour of Hawaii Volcanoes National Park

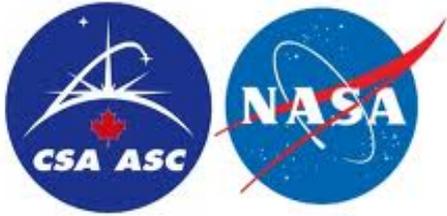
Benefits of PRISM

- ▶ Value to the Local Community
 - Promotes unique College–Level robotic competition
 - Leverages on island High School talent
 - Establishes student robotics capability at UH
 - ▶ Value to the Country
 - Increases the technical challenge to RMC winner
 - Provides a step up into analog conditions
 - ▶ Value to the Global Community
 - Re–establishes an international arena of University space robotics competition (*a la* Lunabotics)
 - Promotes global space culture and good will.
- 

The long term plan

- ▶ 2014 – Invitational
 - Begin development of regional competitions
 - (4–5 Teams)
 - Mirrored on NASA Lunabotic/RMC
- ▶ 2015 – Global Solicitations
 - Expansion to more teams (12–15 Teams)
 - Preference to winners of mini-regionals
 - Promotion with Space Agencies on sponsoring continental regionals (ESA, CSA, JAXA, ISRO, RKA, CNSA)
- ▶ 2016 – Global Regionals feed winners to PRISM
 - Invitational for regions without a competition

Leading Space Agencies

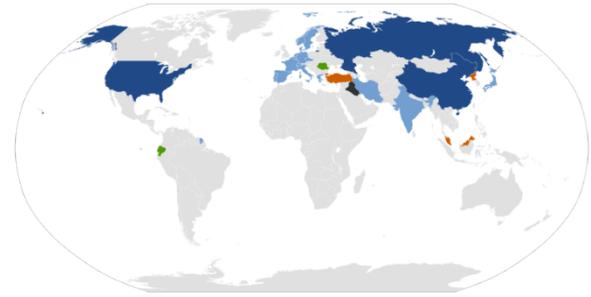


ROSCOSMOS

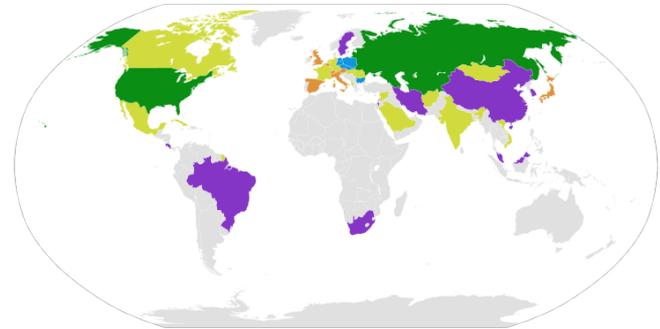


Space is a global effort

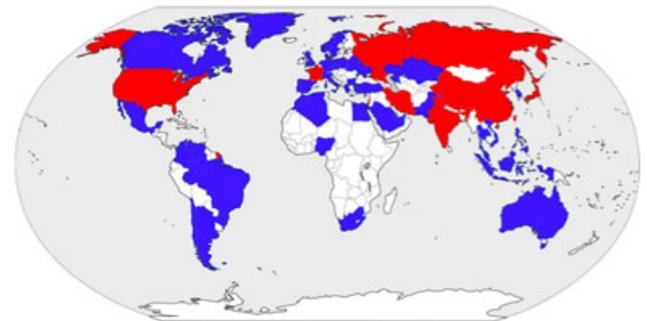
- Human Spaceflight nations



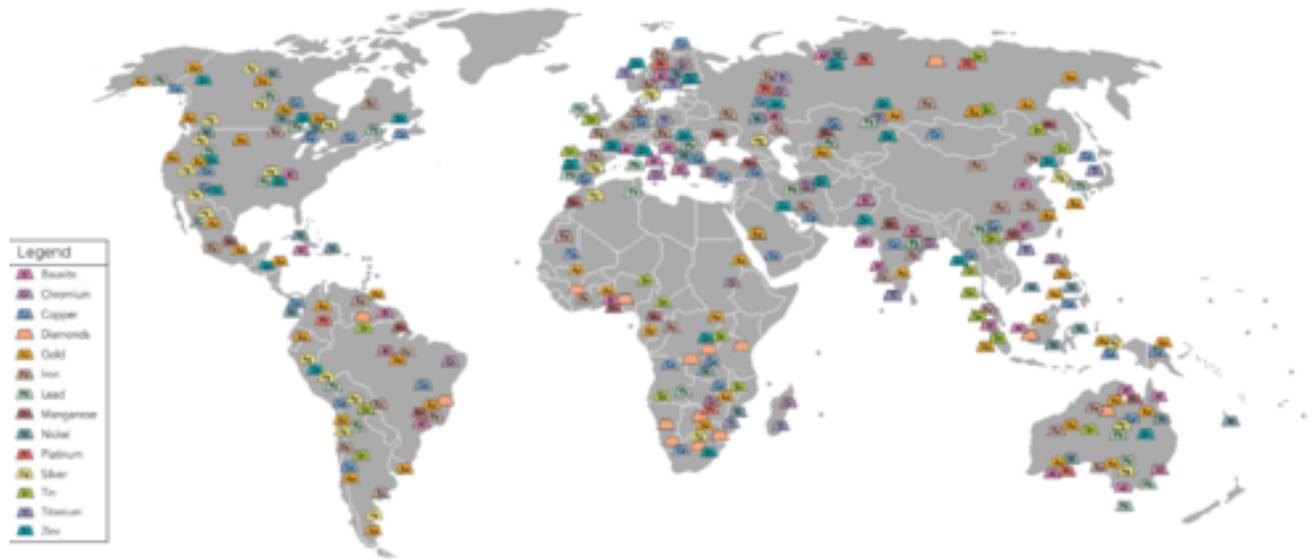
- Astronaut distribution



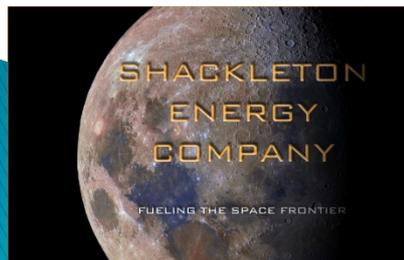
- All Space activities



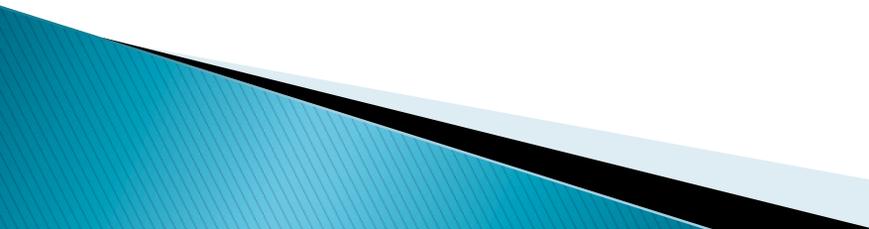
Mining is global effort



Now there is Space Mining....



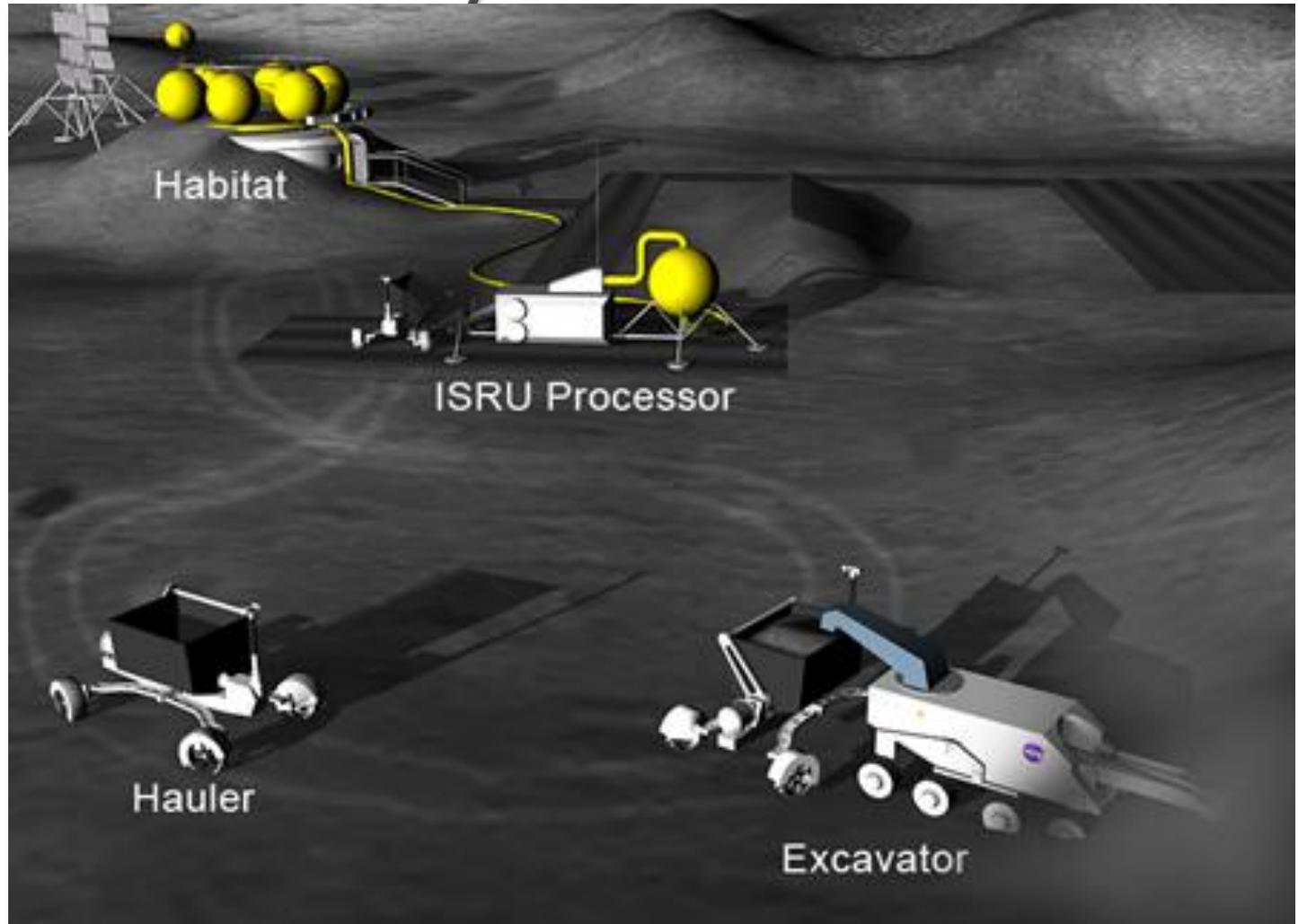
Lunabotics International Teams 2011, 2012 & 2013

- ▶ 1 Australia
 - ▶ 6 Bangla Desh (3 teams multiple repeats)
 - ▶ 10 India (5 teams multiple repeats)
 - ▶ 5 Canada (1 team multiple repeats)
 - ▶ 2 Colombia (2 teams multiple repeats)
 - ▶ 1 Mexico
 - ▶ 1 Poland
 - ▶ 1 Romania
 - ▶ 1 South Korea
- 

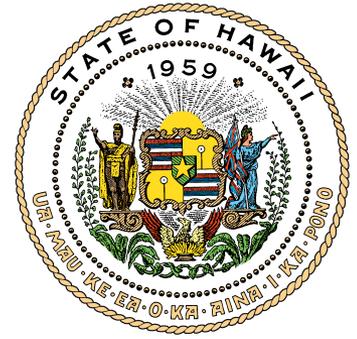
Possible Regional Sites and Sponsors

- ▶ U.S.A. – NASA KSC – existing
- ▶ Canada – CSA sponsor?
- ▶ India – ISRO sponsor?–
- ▶ South Africa – SASRA
- ▶ Asia I
 - South Korea – Hanyang
 - Japan? – Tohoku?/JAXXA
- ▶ Asia II – China – CNSA sponsor?
- ▶ Europe I – Germany (ISTVS/ESA)
- ▶ Europe II – Russia (Roscosmos?)
- ▶ South America – Columbia/Chile

The Future is yours to build



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