Space Resources Roundtable

PTMSS
Planetary & Terrestrial Mining Sciences Symposium

The Journey to Mars with ISRU Pathway

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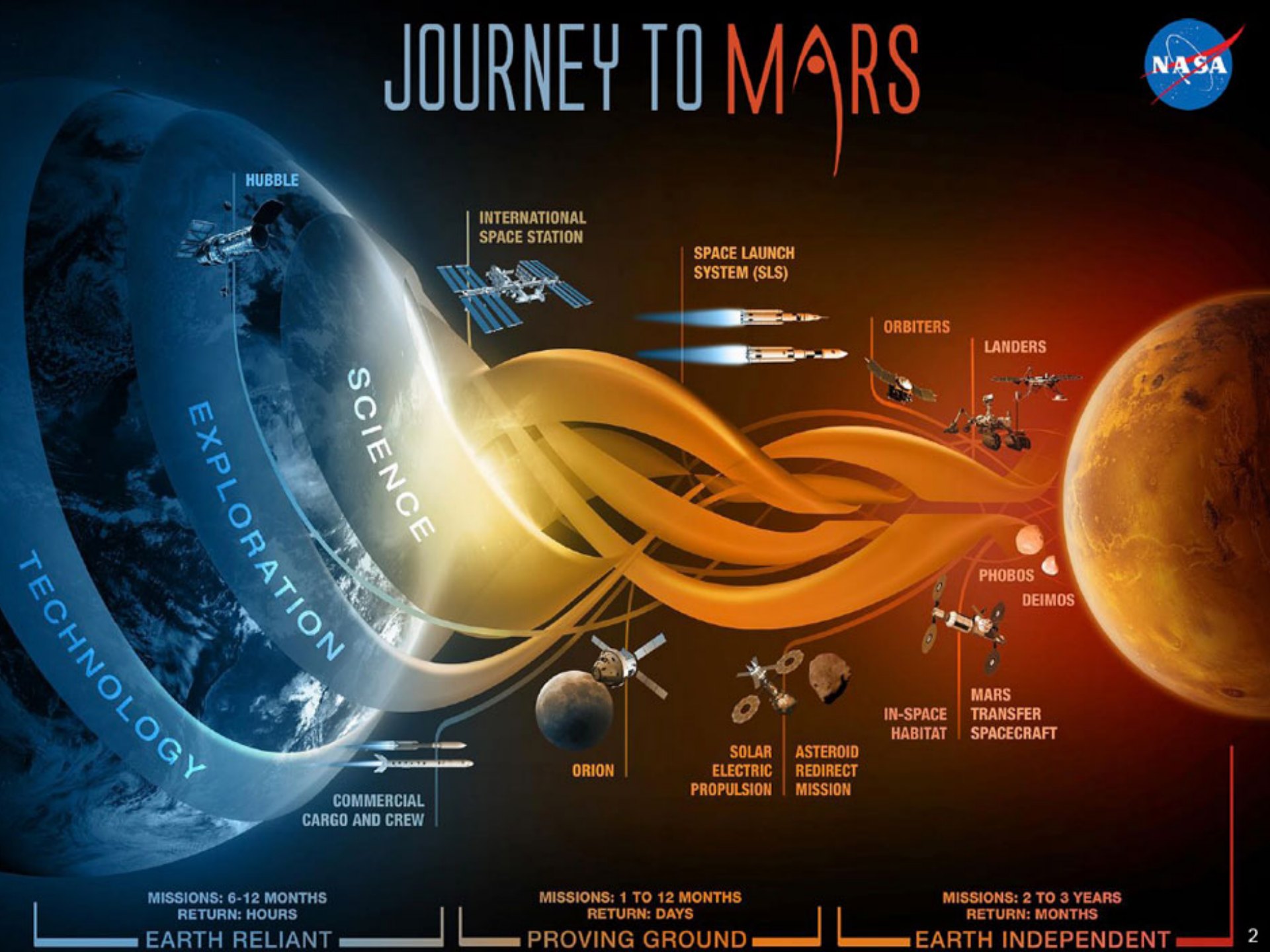
PISCES
Pacific International Space Center for Exploration Systems

University of Hawai'i Hilo


PISCES

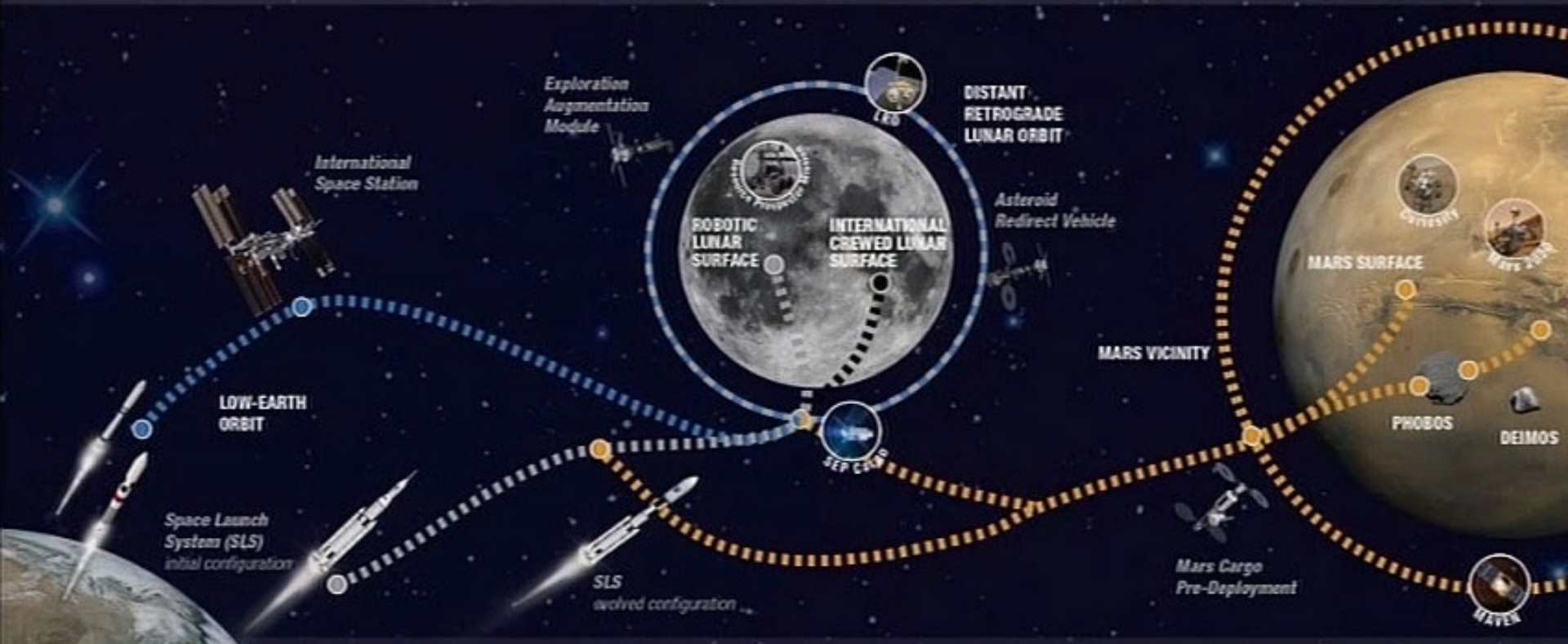

JOURNEY TO MARS
NASA
HUBBLE
INTERNATIONAL SPACE STATION
SPACE LAUNCH SYSTEM (SLS)
ORBITERS
LANDERS
SCIENCE
EXPLORATION
TECHNOLOGY
PHOBOS
DEIMOS
IN-SPACE HABITAT
MARS TRANSFER SPACECRAFT
ORION
SOLAR ELECTRIC PROPULSION
ASTEROID REDIRECT MISSION
COMMERCIAL CARGO AND CREW
MISSIONS: 6-12 MONTHS
RETURN: HOURS
EARTH RELIANT
MISSIONS: 1 TO 12 MONTHS
RETURN: DAYS
PROVING GROUND
MISSIONS: 2 TO 3 YEARS
RETURN: MONTHS
EARTH INDEPENDENT

EVOLVABLE MARS CAMPAIGN

A Pathways Approach to Exploration

NASA

EARTH DEPENDENT | **PROVING GROUND** | **EARTH INDEPENDENT**



THE TRADE SPACE

Across the Board | Solar Electric Propulsion • In-Situ Resource Utilization (ISRU) • Robotic Precursors • Human/Robotic Interactions • Partnership Coordination • Exploration and Science Activities

Cis-lunar Trades

- Deep-space testing and autonomous operations
- Extensibility to Mars
- Mars system staging/refurbishment point and trajectory analyses

Mars Vicinity Trades

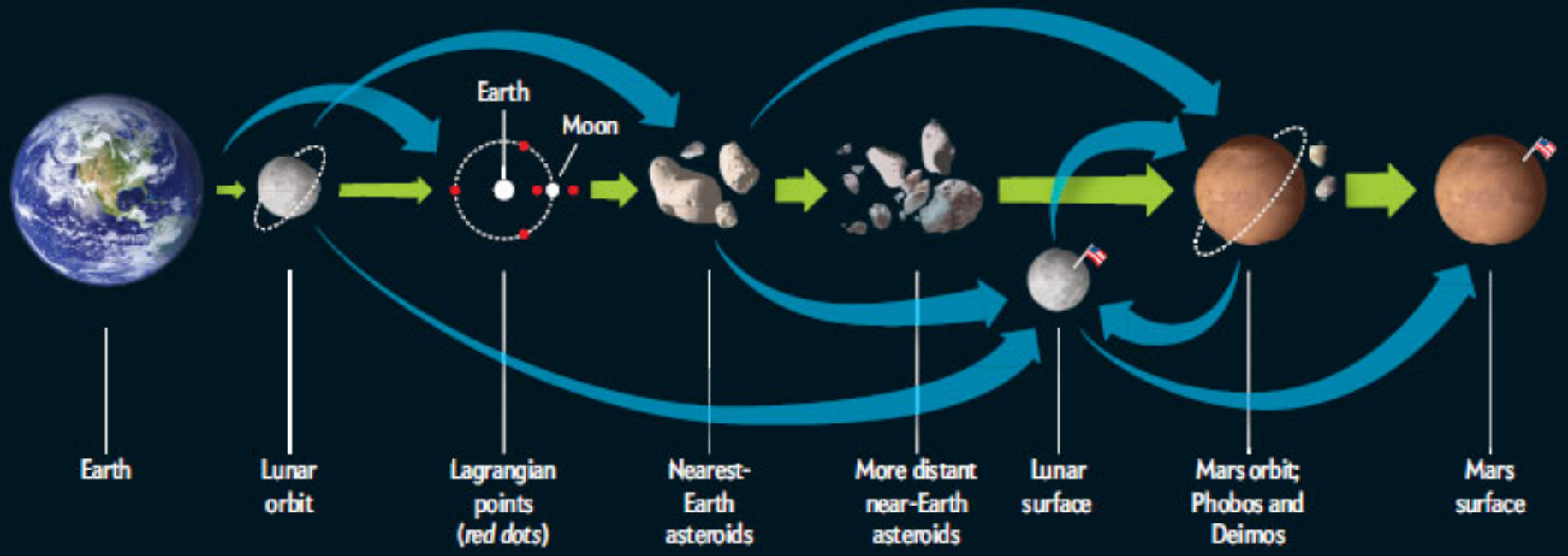
- Split versus monolithic habitat
- Cargo pre-deployment
- Mars Phobos/Deimos activities
- Entry descent and landing concepts
- Transportation technologies/trajectory analyses

Flexible Path

FLEXIBLE PATH

More Than One Way to Reach into Space

In the past the U.S. human space program took an all-eggs-in-one-basket approach: it focused on a specific target and a single system to get there. As of last year, it does things differently. It now has the broad goal of venturing into interplanetary space in progressively more complicated missions, such as the authors' proposed program (*green arrows*) and variants (*blue arrows*). The destinations are listed here in rough order of difficulty. Vehicles can be repurposed to reach different destinations, follow different sequences or use different technologies if technical problems arise or politicians fail to come through with the required funding.



The Cult of ISRU

- ***According to expert Craig Ferguson***

A cult becomes a religion when it:

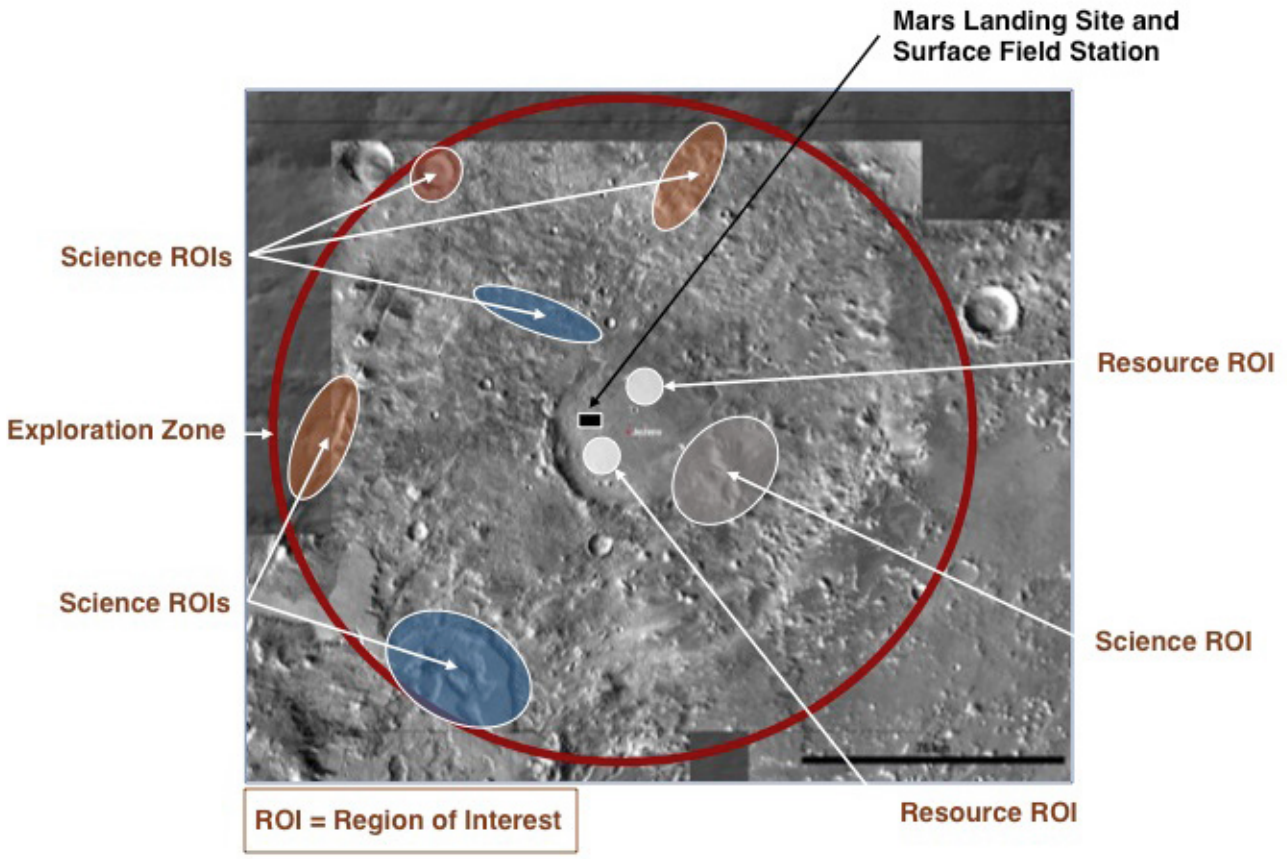
1. has been around long enough.
2. has enough followers.
3. has mysterious symbols.
4. has a few Hollywood Celebrities.

3 down, 1 to go!

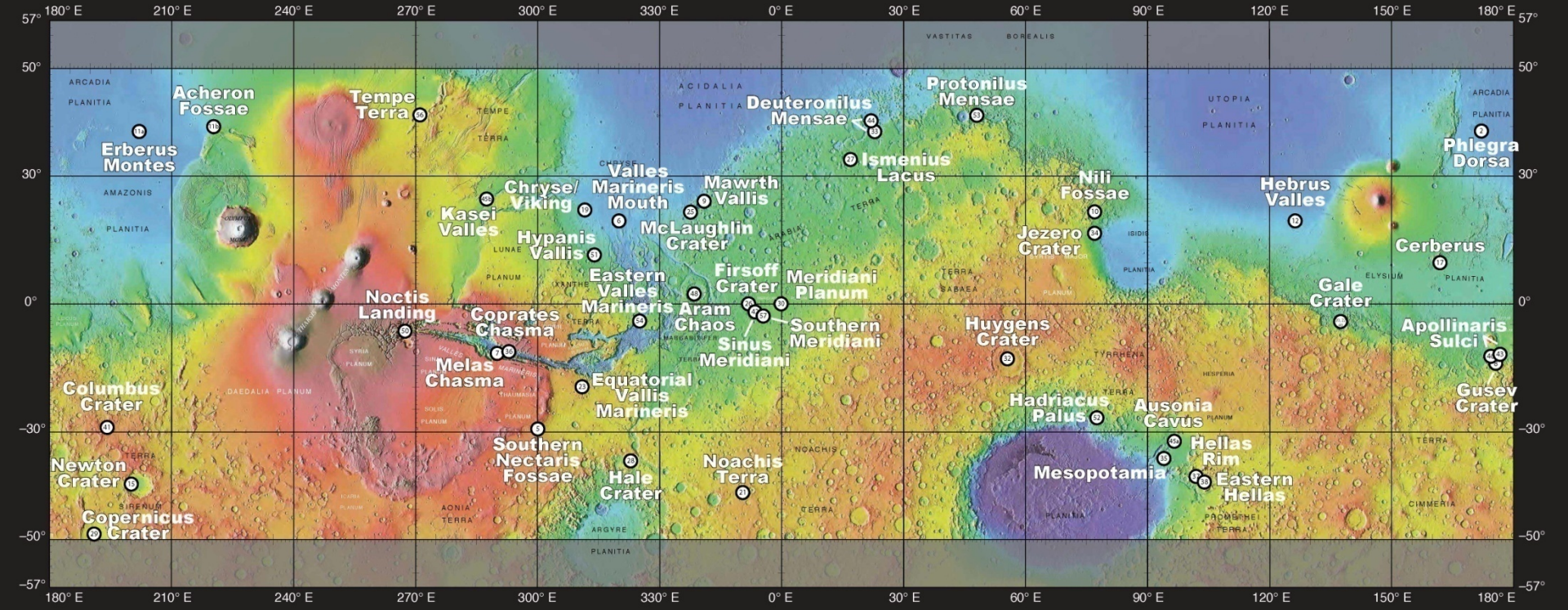
MARS

First Landing Site/Exploration Zone Workshop for Human Missions to the Surface of Mars

Exploration Zone Layout Considerations



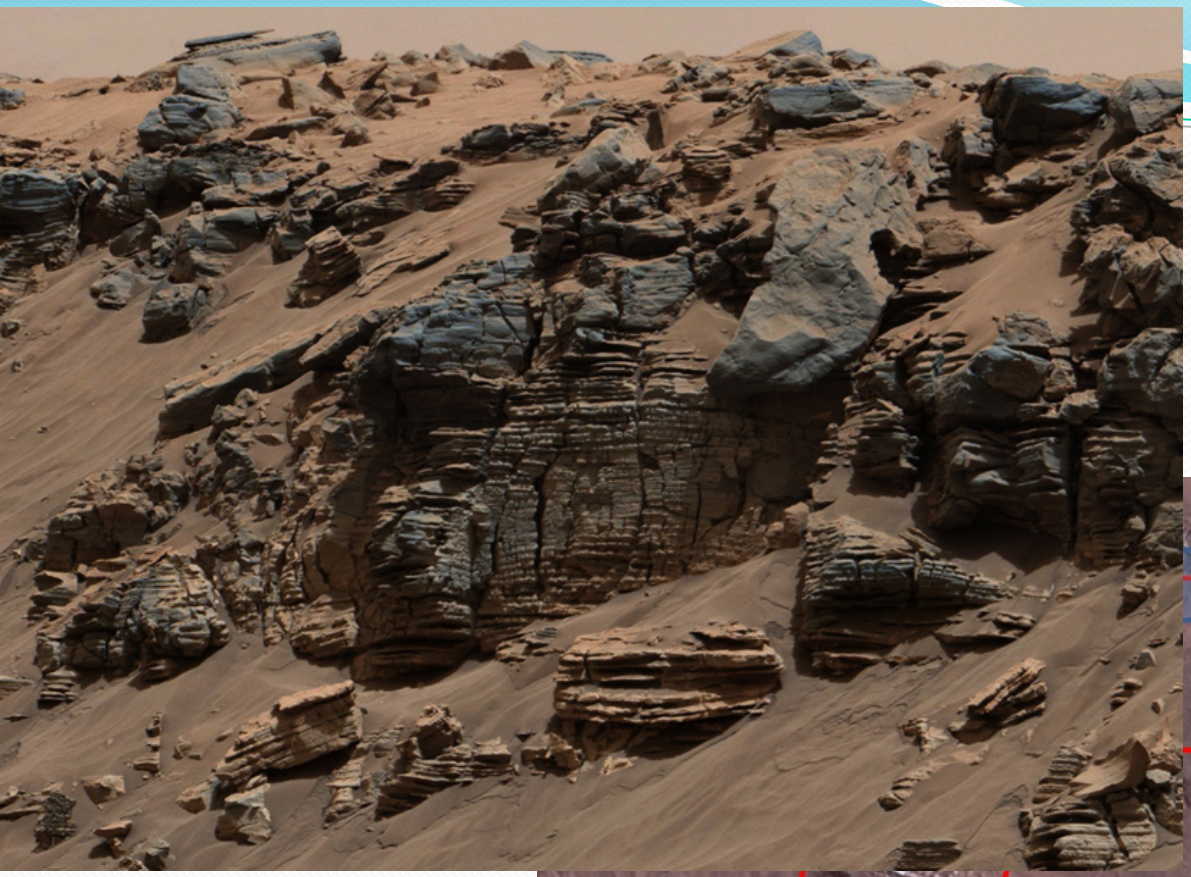
Potential Exploration Zones for Human Missions to the Surface of Mars



Exploration Zones proposed for humans to Mars.
Numbers correspond to the abstract submission #
At the equator, circles are ~100km radius

version 10.0 October 1, 2015

Prepared By: Lindsay Hays, Mars Program Office
lhays@jpl.nasa.gov




Science ROI
ISRU ROI
Inner 60 km radius
Outer 120 km radius

Takeaways from workshop

- A lot of interesting science in most places
  - Geology – everywhere
  - Biology – areas with past history of water
- LZ/EZ choice will be determined by the ISRU Resources
- Will be in sight of Phobos and Deimos as free orbital assets. (Comms, navigation, space station-like role)
- Not solar powered. ISRU requires constant POWER

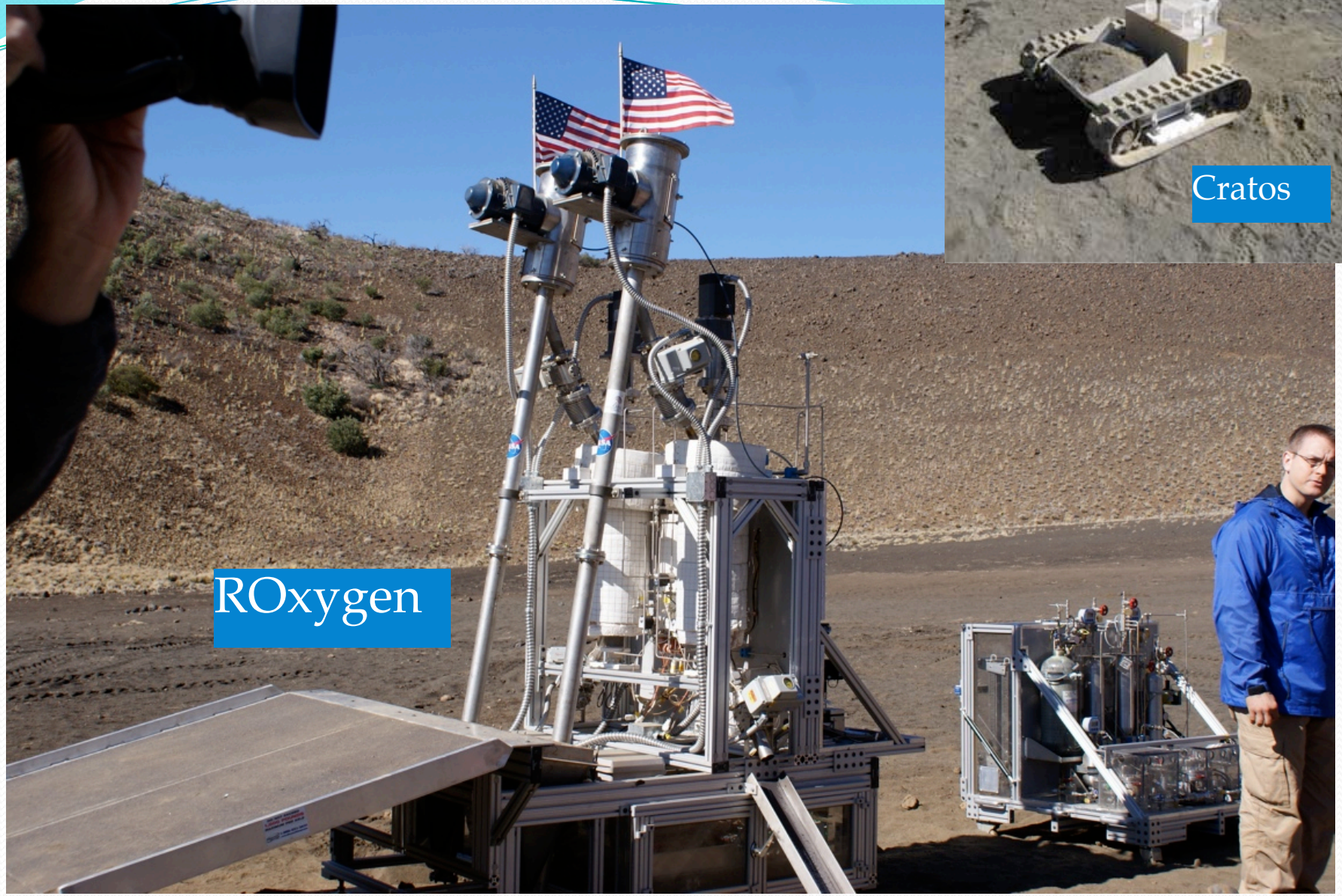
ISRU Terran History

RESOLVE

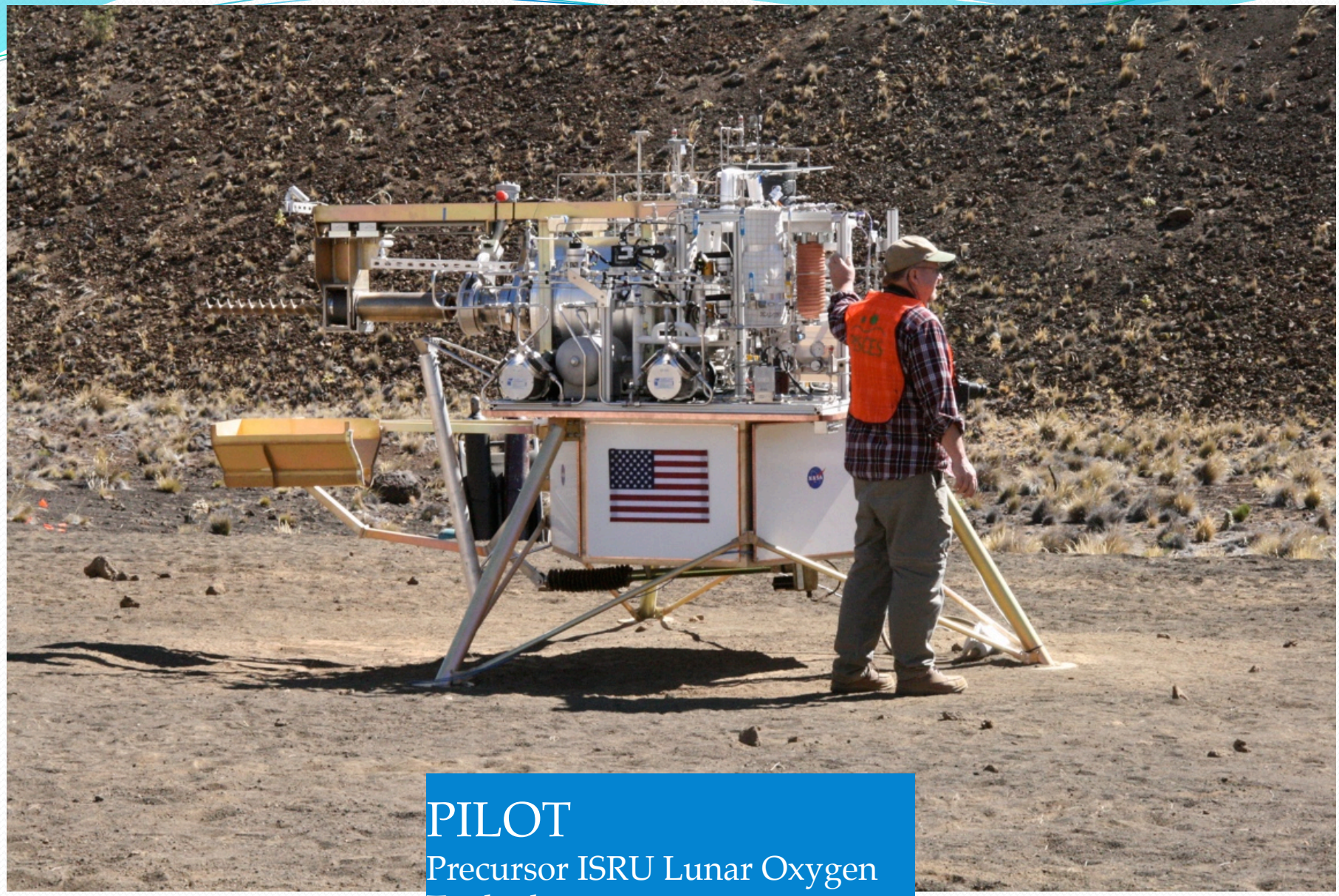
Regolith and Environment Science and Oxygen and Lunar Volatile Extraction

Scarab

Artemis Jr. on Mission sortie 2012


ROxygen

Cratos



PILOT

Precursor ISRU Lunar Oxygen Testbed

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

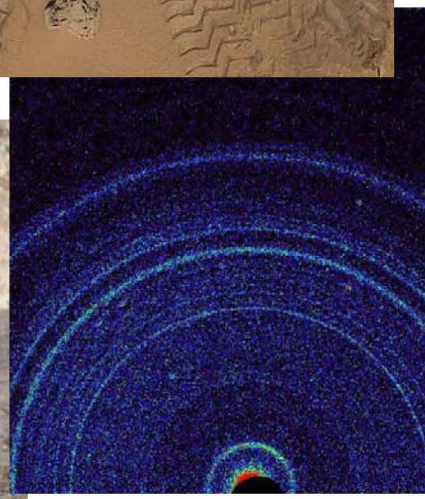
10/30/12 05:15 PM ET EDT AP

FOLLOW: Video, Curiosity Soil, Hawaii Soil, Mars Hawaii, Mars Rover, Mars Rover Curiosity, Mars Soil, Mars Soil Hawaii, Mars Volcano, Volcanic Soil, Science News

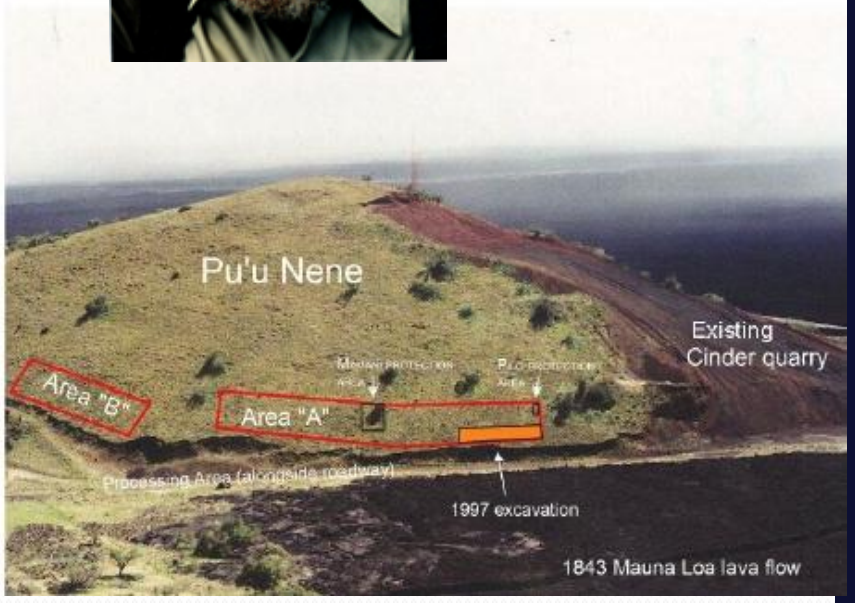
PASADENA, Calif. -- Scientists say the Martian soil at the rover Curiosity's landing site contains minerals similar to what's found on Hawaii's Mauna Kea volcano.

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.



JSC-Mars-1A Mars Simulant (2005)



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MARS SOIL SIMULANT

NASA's exploration plans for Mars and beyond created an immediate need for materials science a human travel and work on future planetary exploration and long-duration missions. Part of the re simulants for materials experiments, prototype testing and dust mitigation of transportation equipme situ resource processing.

Researchers, educators, students and interested commercial parties may purchase simulant from e simulant that approximates the spectral reflectance of the bright areas on Mars.

For more technical information about these simulants:

[Technical Paper on JSC Mars-1]
[Material Safety Data Sheet of JSC Mars-1A]

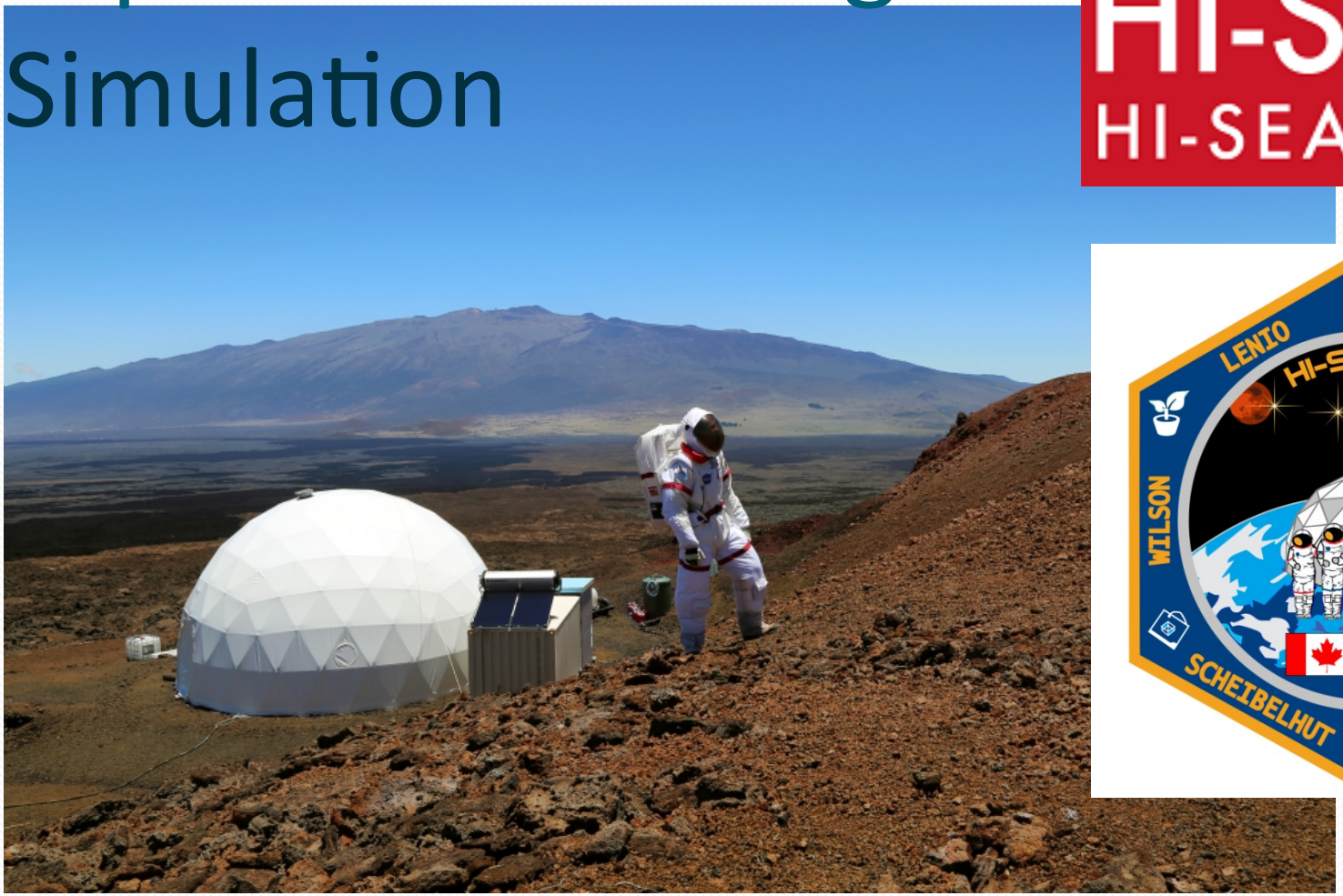
JSC MARS-1A SIMULANT

JSC Mars-1A is a palagonite tephra collected from the slopes of the Pu'u Nene cinder cone on the Island of Hawaii. Palagonitic tephra from this cone has been repeatedly cited as a close spectral analog to the bright regions of Mars. The chemical composition is compared to that of a typical Mars surface sample analyzed at the Viking lander 1 site.

GRAIN SIZE: 1mm & Lower

Item Size: 2 lbs $25.00
Shipping & Handling: $12.00

HI-SEAS: Hawaii Space Exploration Analog & Simulation

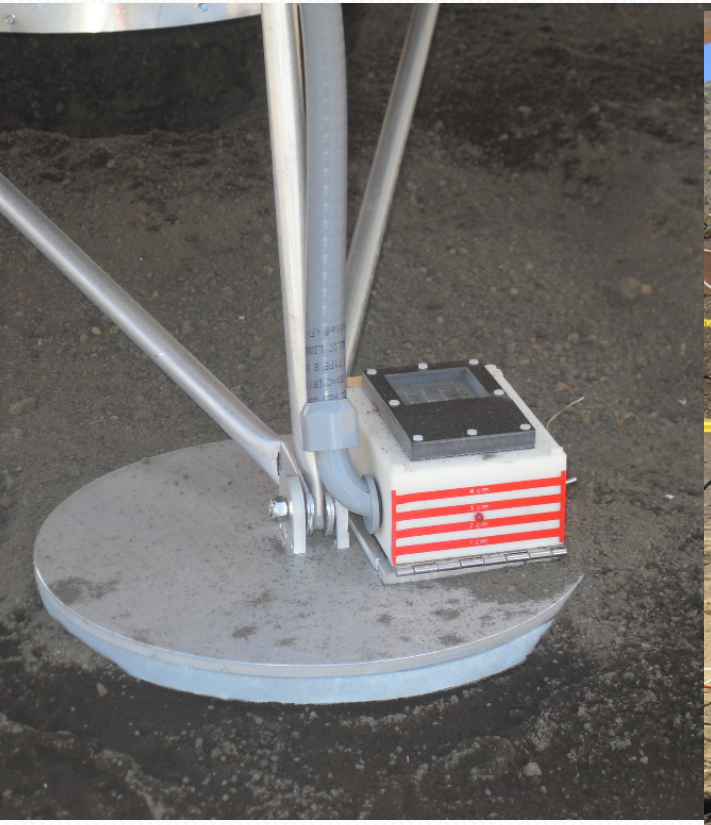


HI-SEAS
HI-SEAS.ORG

HIS

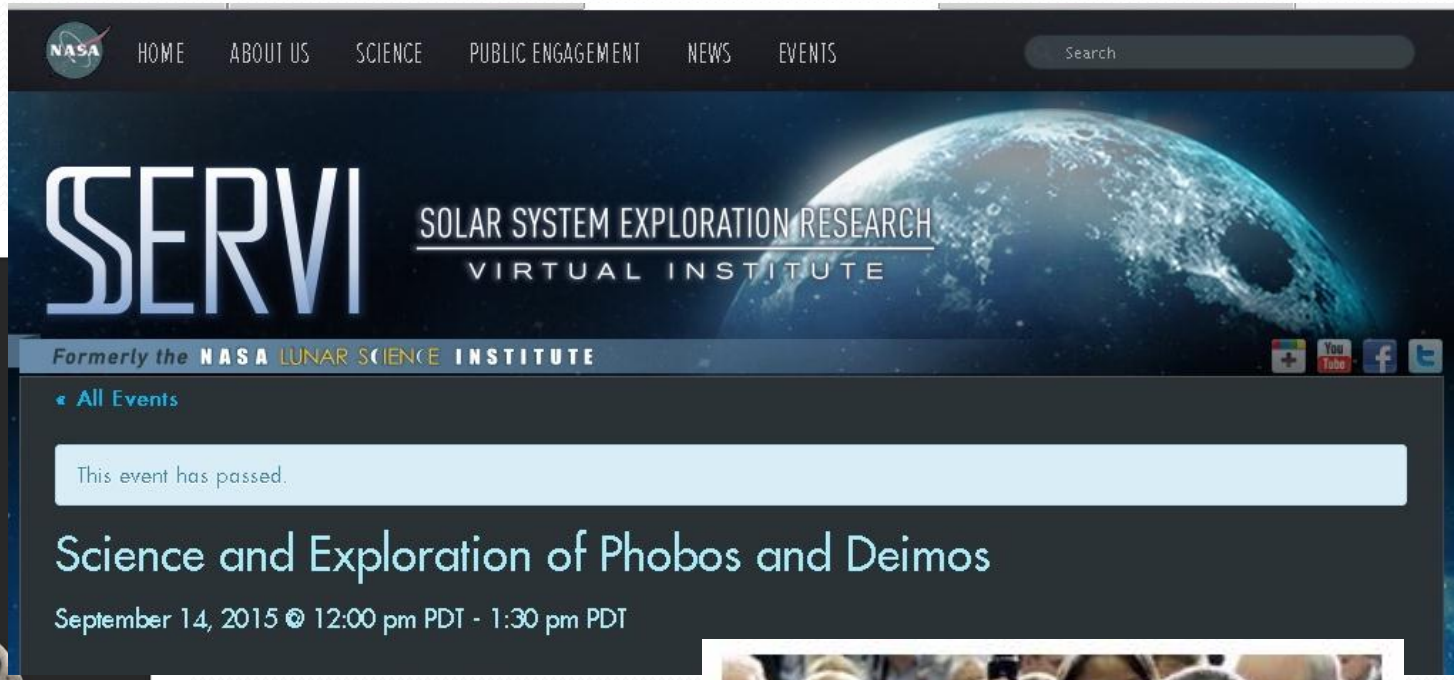
ISRU Construction: Lunar Sidewalk

ISRU – Dust Mitigation
EDS system – KSC Swampworks



Field staff and volunteers

SSERVI course



Need a similar semester course devoted to ISRU

President Barack Obama examines a model of Phobos presented to him by Apollo 11 astronaut Buzz Aldrin.

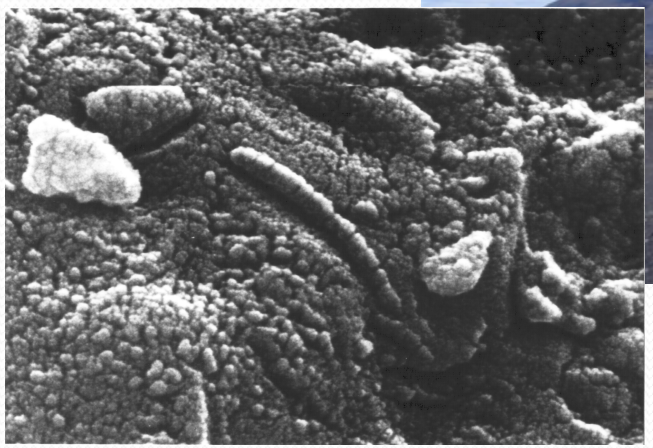
Why are we going to Mars?

- Something for NASA to do?
- Test technology?
- Interesting Geology?
- Human colony backup?

LIFE !

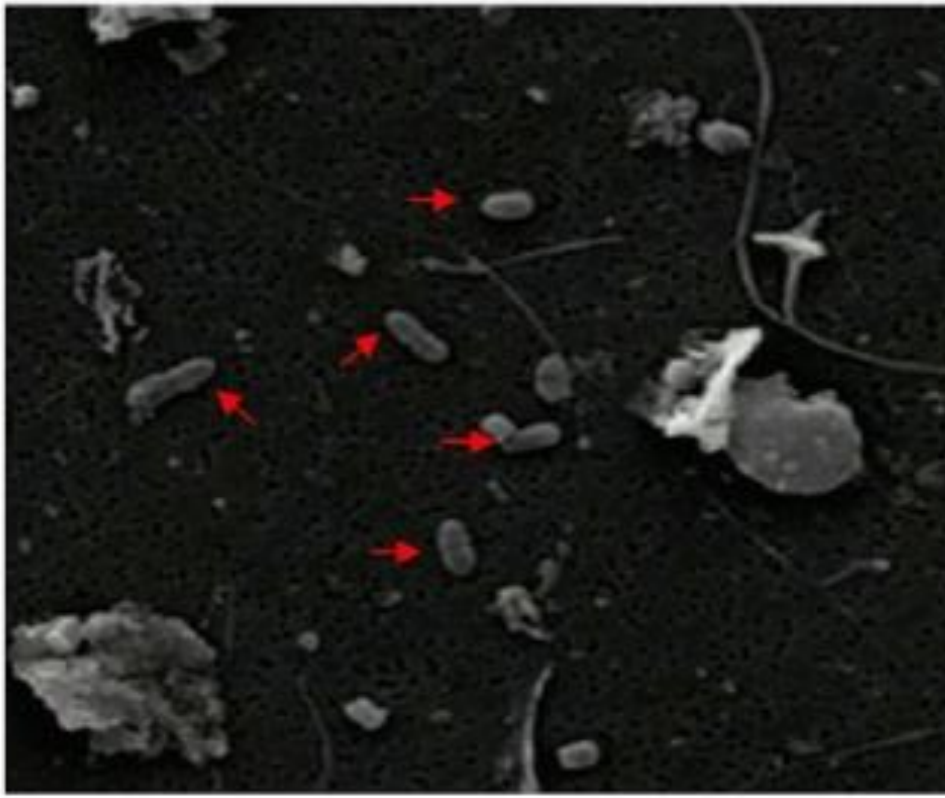

Biosignature
Preservation and Detection in Mars Analog Environments
May 16-18, 2016
Lake Tahoe, Nevada


Summer school
Biosignatures and the Search for Life on Mars
Iceland, 4 - 16 July 2016

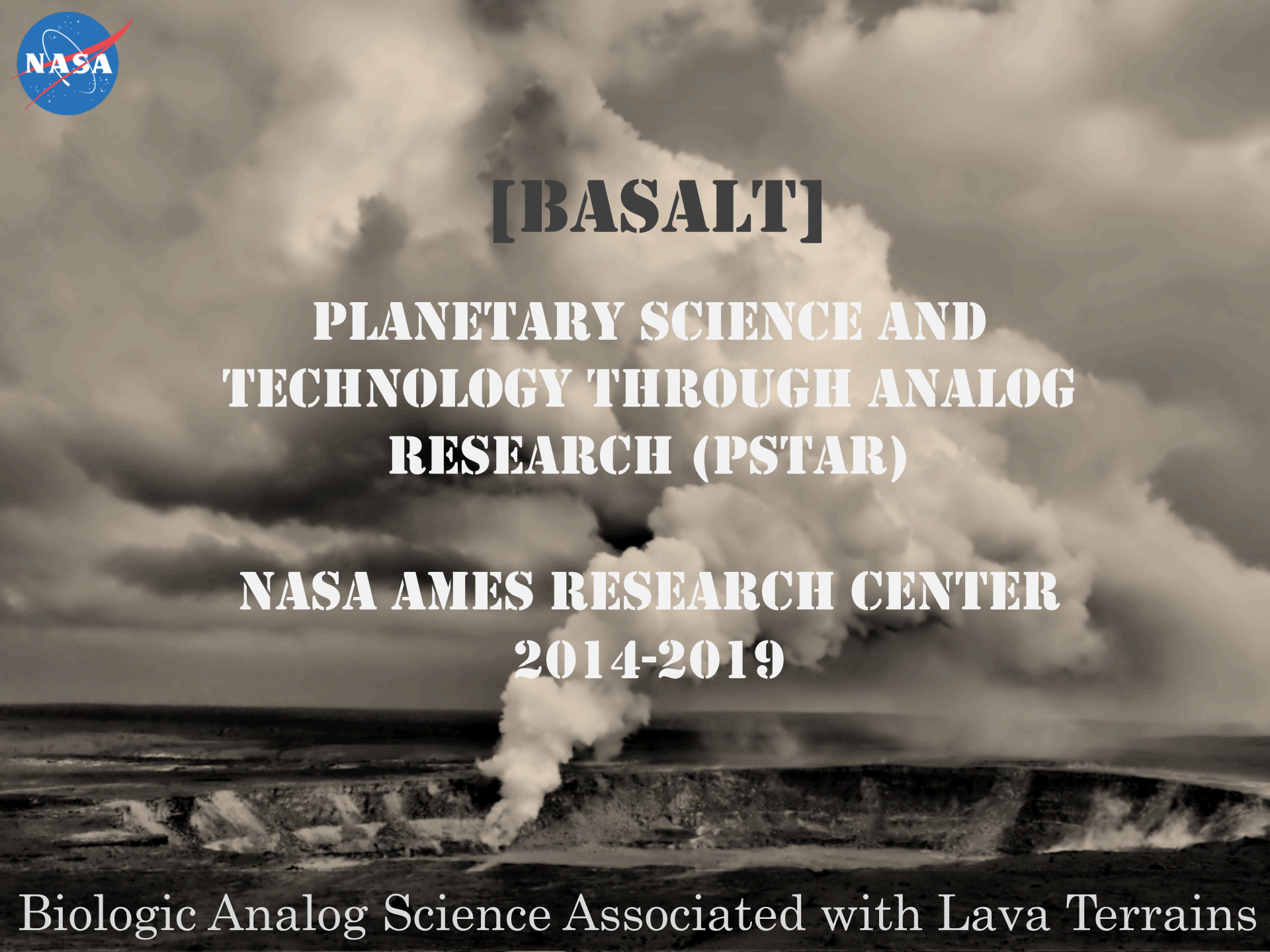


ISRU Processing of Glacier Ice?

- Scanning electron microscopy of samples reveals the presence of distinct bacillary particles in an Antarctic glacier (red arrows), suggestive of intact microbes interspersed with mineral granules.



Mass Spectrometry for direct identification of biosignatures and microorganisms in Earth analogs of Mars, Garcia-Descalzo et al, Planetary and Space Science Nov 2012


[BASALT]
PLANETARY SCIENCE AND TECHNOLOGY THROUGH ANALOG RESEARCH (PSTAR)
NASA AMES RESEARCH CENTER
2014-2019
Biologic Analog Science Associated with Lava Terrains

BASALT

- 4 year grant
- Two Analog Sites
  - Craters of the Moon, Idaho (late Mars)
  - Hawaii Volcanoes National Park, Hawaii (early Mars)
- Develop astronaut sampling protocols for Geology & Biology. Sometimes orthogonal.

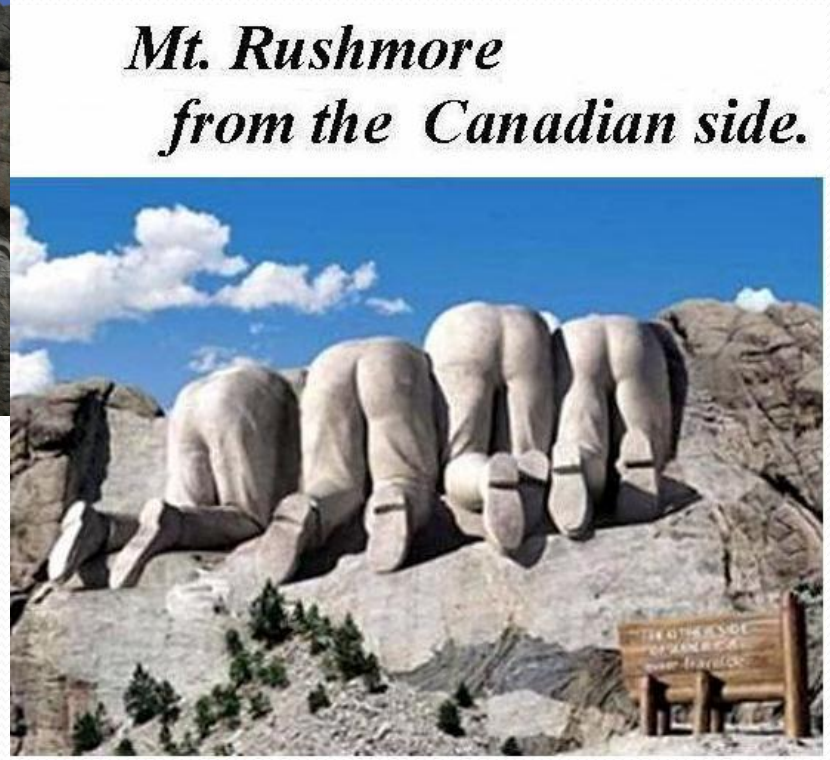
- http://spacescience.arc.nasa.gov/basalt/

Similar to DRATS

Sampling vs Prospecting

- Is a scientific sample useful for ISRU?
- Will prospecting destroy science samples?
  - Particularly in (ex) water areas (fossil destruction)
- Can one prospect from orbit?
  - Resolution
  - Spectral characteristics
  - Overburden

Perspective

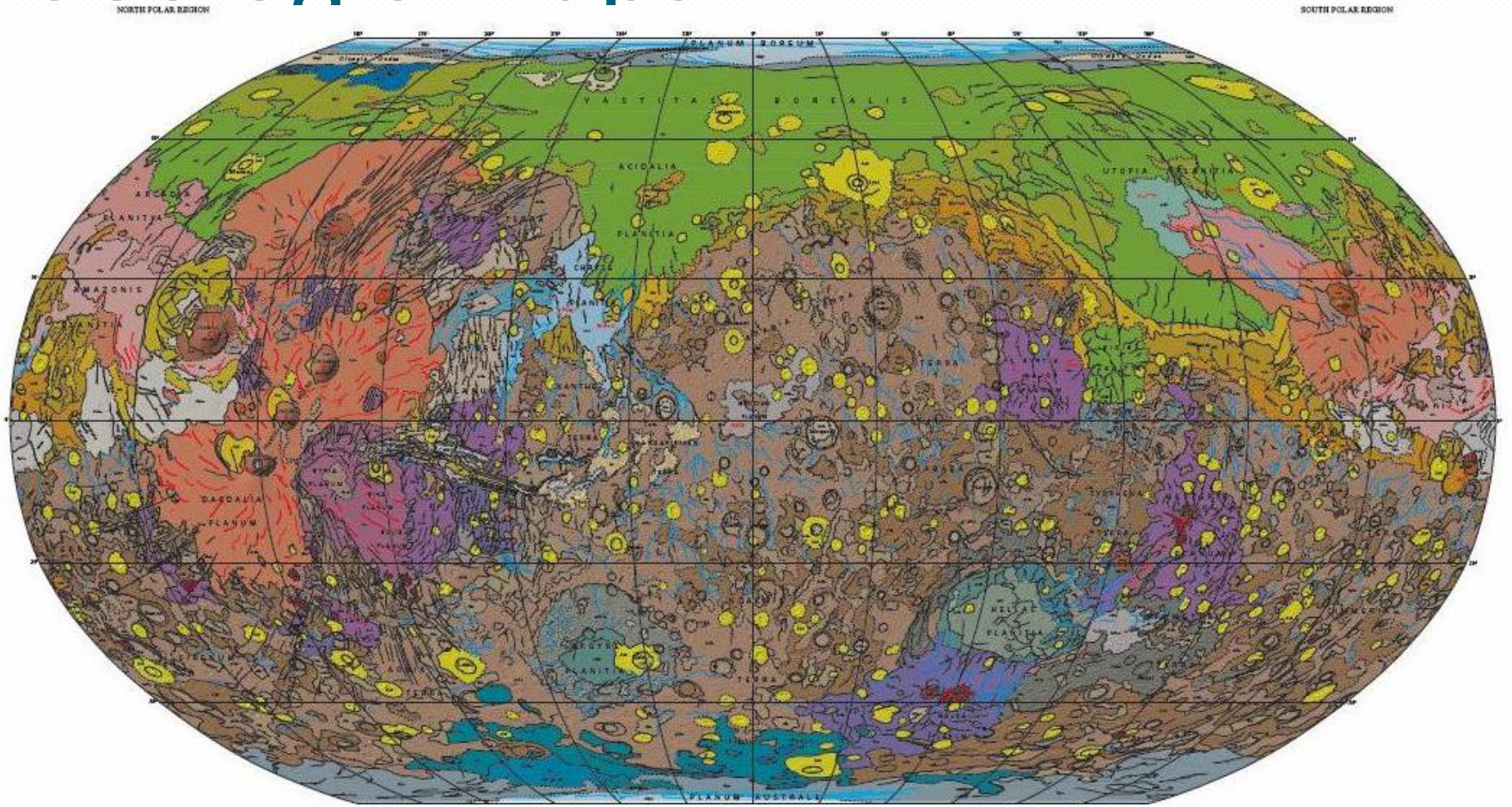


Remote Sensing vs Prospecting

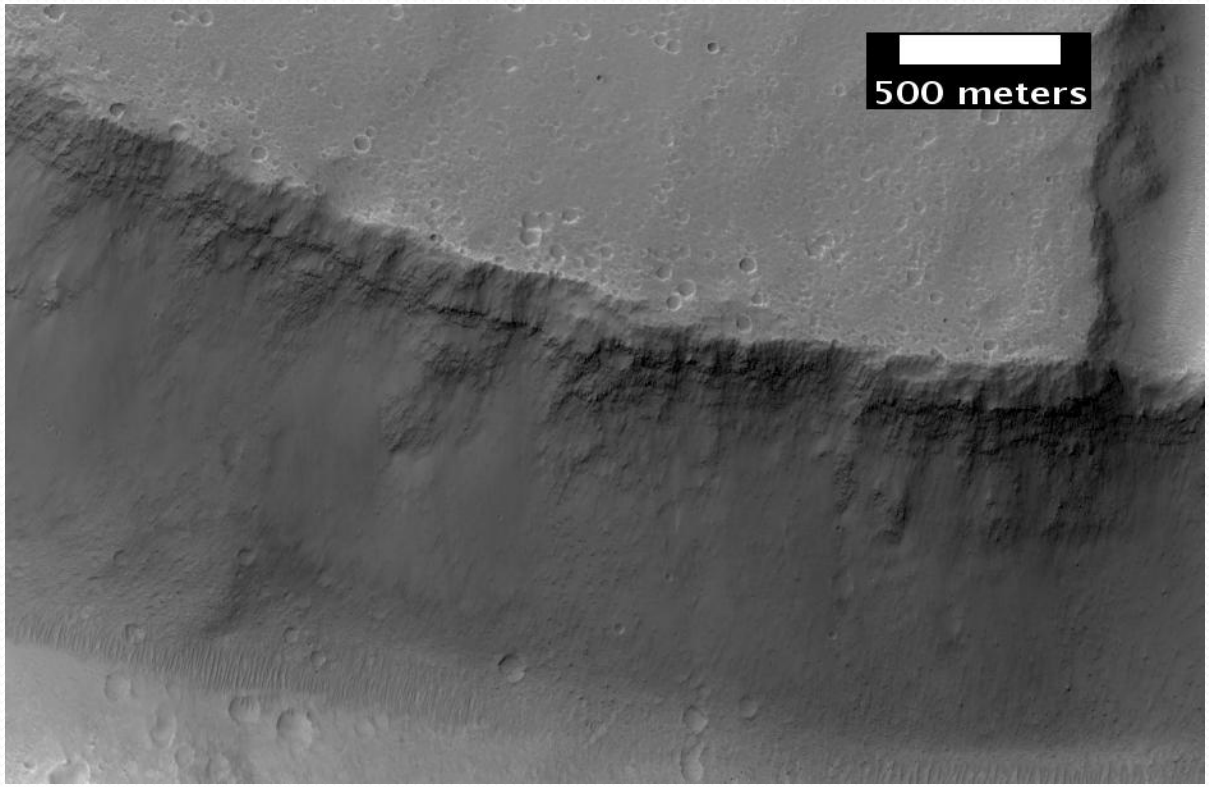
- Remote sensing utilizes a variety of sophisticated technology to record the interaction between matter and electromagnetic energy.
- Remote sensing images are used for mineral exploration in two applications:
  - (1) map geology and the faults and fractures that localize ore deposits
  - (2) recognize hydrothermally altered rocks by their spectral signatures.

New meaning to a new slogan

Geologic Maps



- MRO HISRISE resolution 0.3 meter per pixel at a height of 300 km
- CRISM 18m/pixel



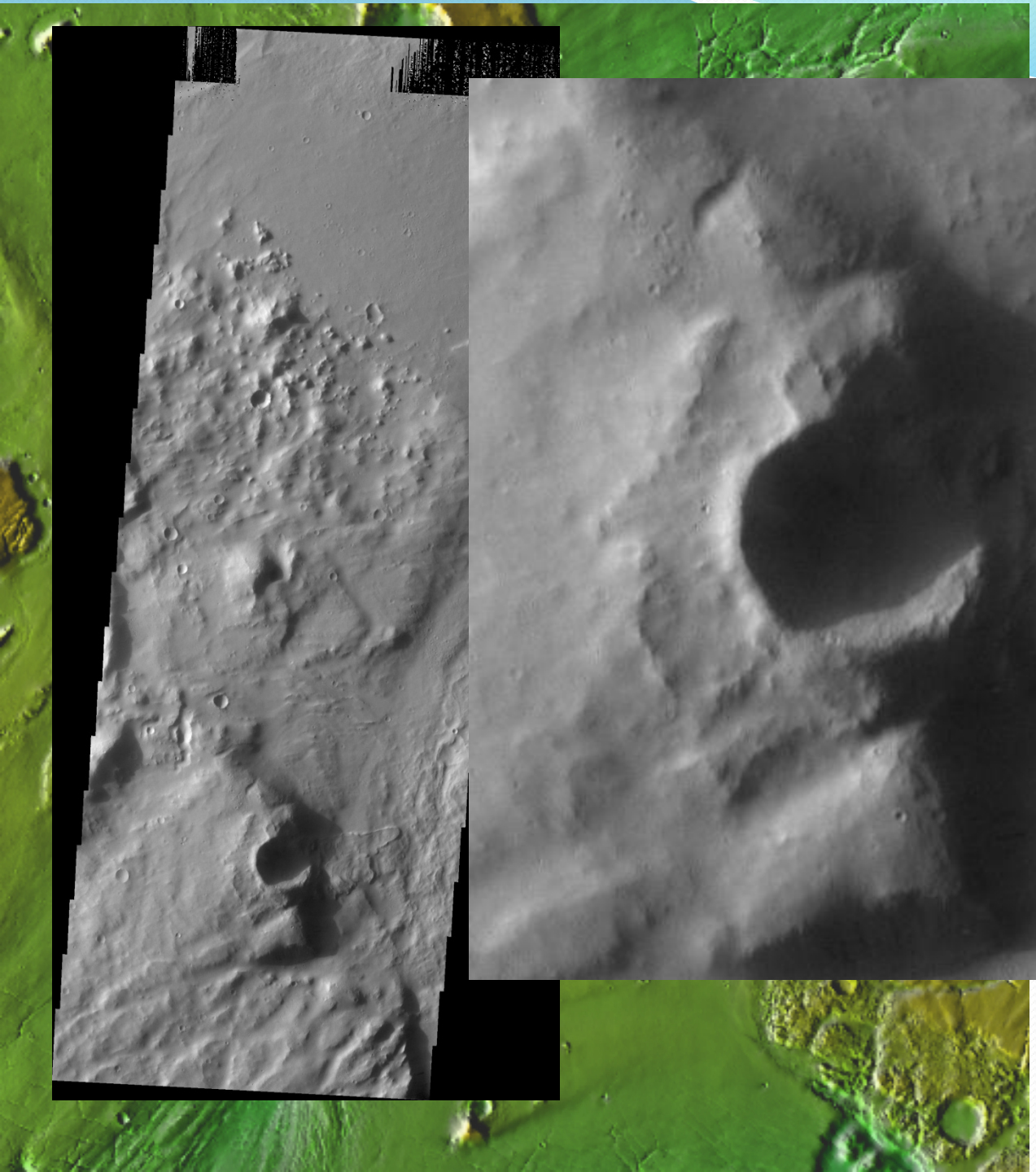
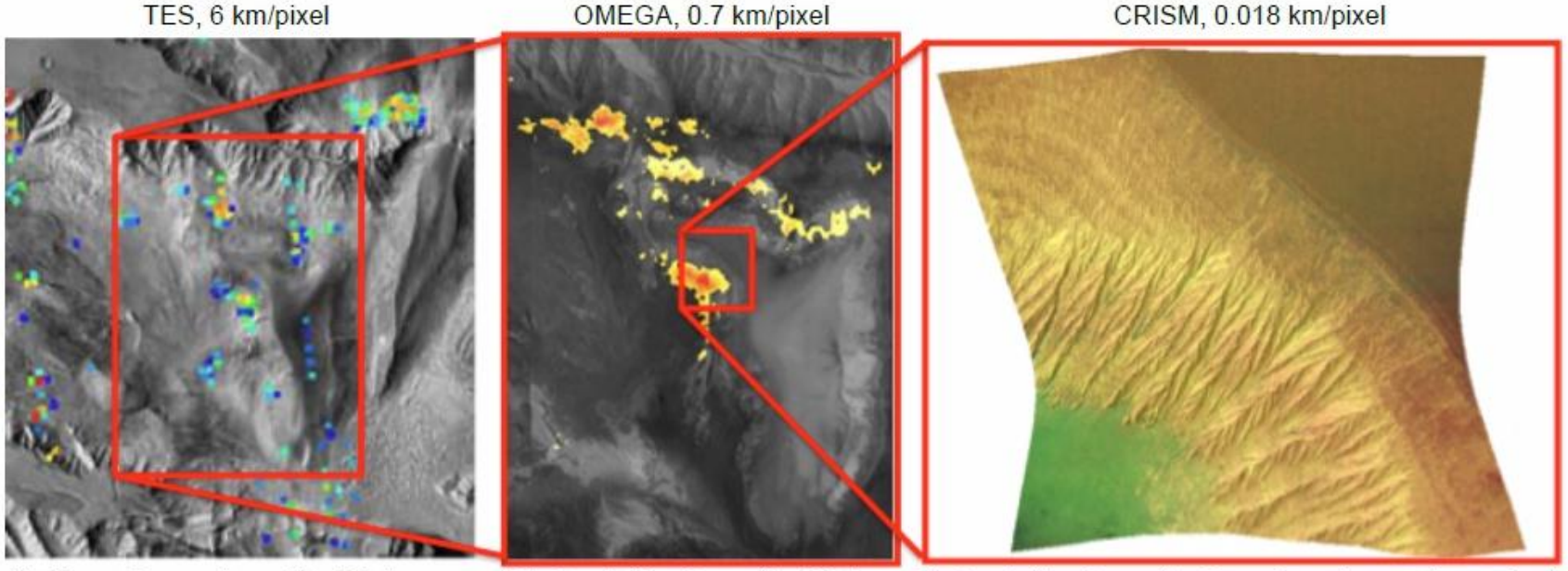


Table 1. Brief timeline of compositional mapping investigations of Mars, showing how improvements in spatial resolution have led to an almost exponential increase in the number of phases identified.

	λ, μm	Sampling, km/pixel	Minerals Reported [6,7]
TES	6-50	3-6	Olivine, pyroxene, feldspar, hematite
THEMIS	7-15	0.1	Same as TES (+quartz, chloride)
OMEGA	0.4-5.1	0.3-1	Same as TES –feldspar (+poly-, monohydrated sulfates, gypsum, 3 types phyllosilicate)
CRISM	0.4-3.9	0.018	Same as OMEGA (+4 more sulfates, 2 types carbonate, opal, zeolite, 5 more phyllosilicates)



(a) Map of gray hematite [8] low on slopes of layered deposits in Candor Chasma.

(b) Crystalline hematite [9] is now resolved as accumulations at the base of slopes.

(c) Crystalline hematite [green] and nanophase ferric oxide (red) (10) are traceable to yellow layers, and accumulate in the green braided channel fill and fan.

BEYOND MRO/CRISM: A HIGH RESOLUTION COMPOSITIONAL IMAGER FOR MARS, Murchie et al International Workshop on Instrumentation for Planetary Missions (2012)

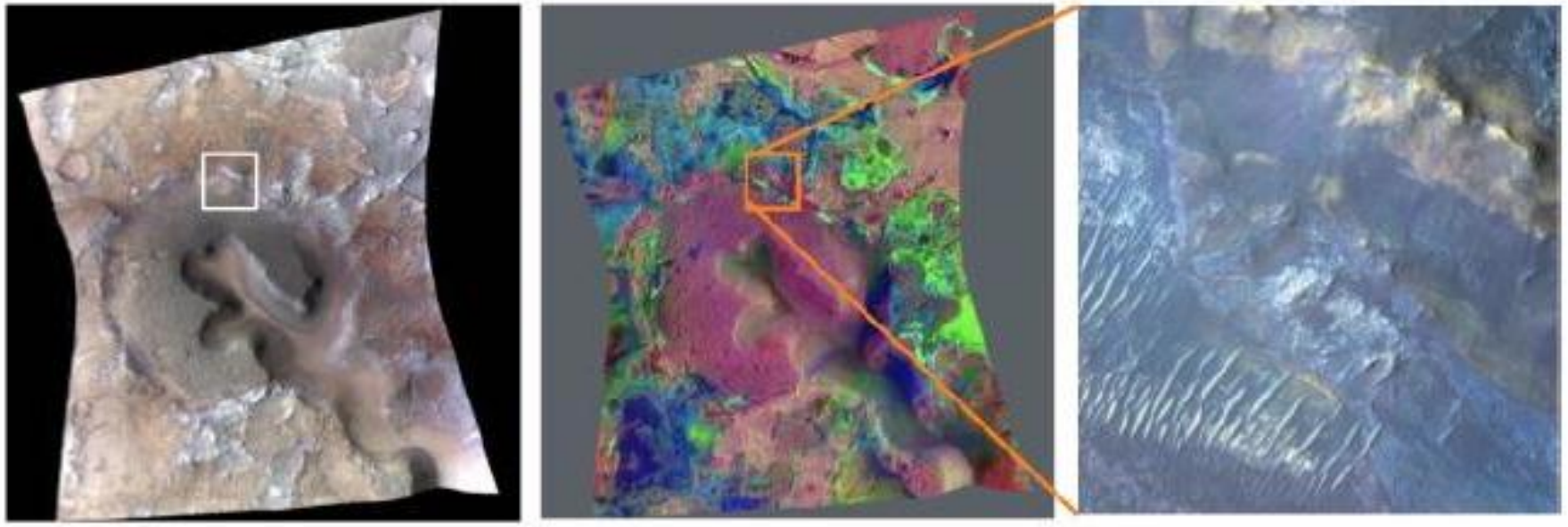


Figure 5. (a) CRISM visible wavelengths show variations in Fe mineralogy (image FTR00003E12). (b) 12 50-nm multispectral bands convolved from CRISM data distinguish key minerals (clay – pink, carbonate – green, olivine – blue, basalt – red). (c) A HiRISE color image approximates spatial resolution of the HRC (HiRISE image PSP_002888_2025).

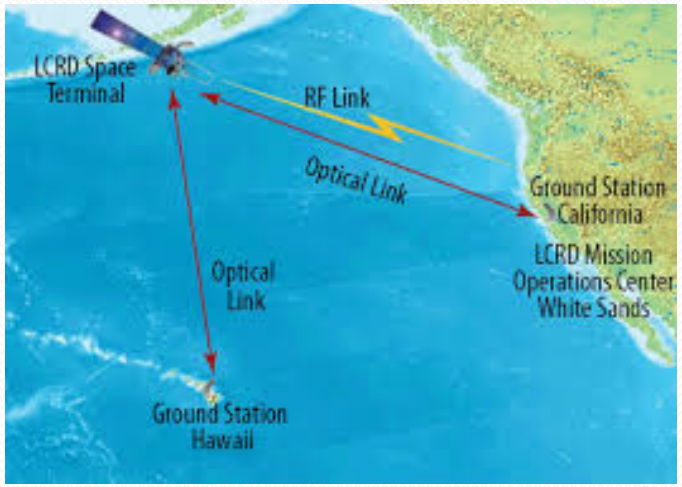
BEYOND MRO/CRISM: A HIGH RESOLUTION COMPOSITIONAL IMAGER FOR MARS, Murchie et al International Workshop on Instrumentation for Planetary Missions (2012)

Future needs

- More orbital assets with ultra high resolution
- Aerial or balloon borne instruments
- A swarm of small, cheap ground robots
  - Von Nueman machines?

Soon and Cheap

Laser Comm



INDUSTRY NEWS TECHNOLOGY

NASA selects Hawaii to develop world's first laser communications site

Duane Shimogawa
Reporter
Pacific Business News

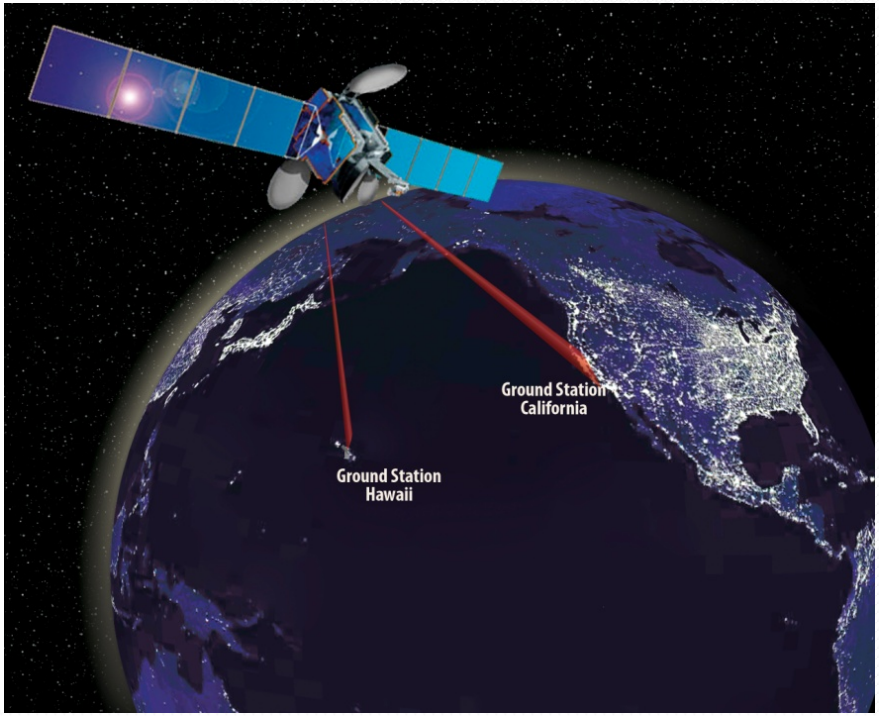
NASA has selected Hawaii as the preferred site to establish the world's first laser communications ground terminal, which could spur major economic activity in the state, translating to job creation and revenues, according to public documents obtained by PBN.

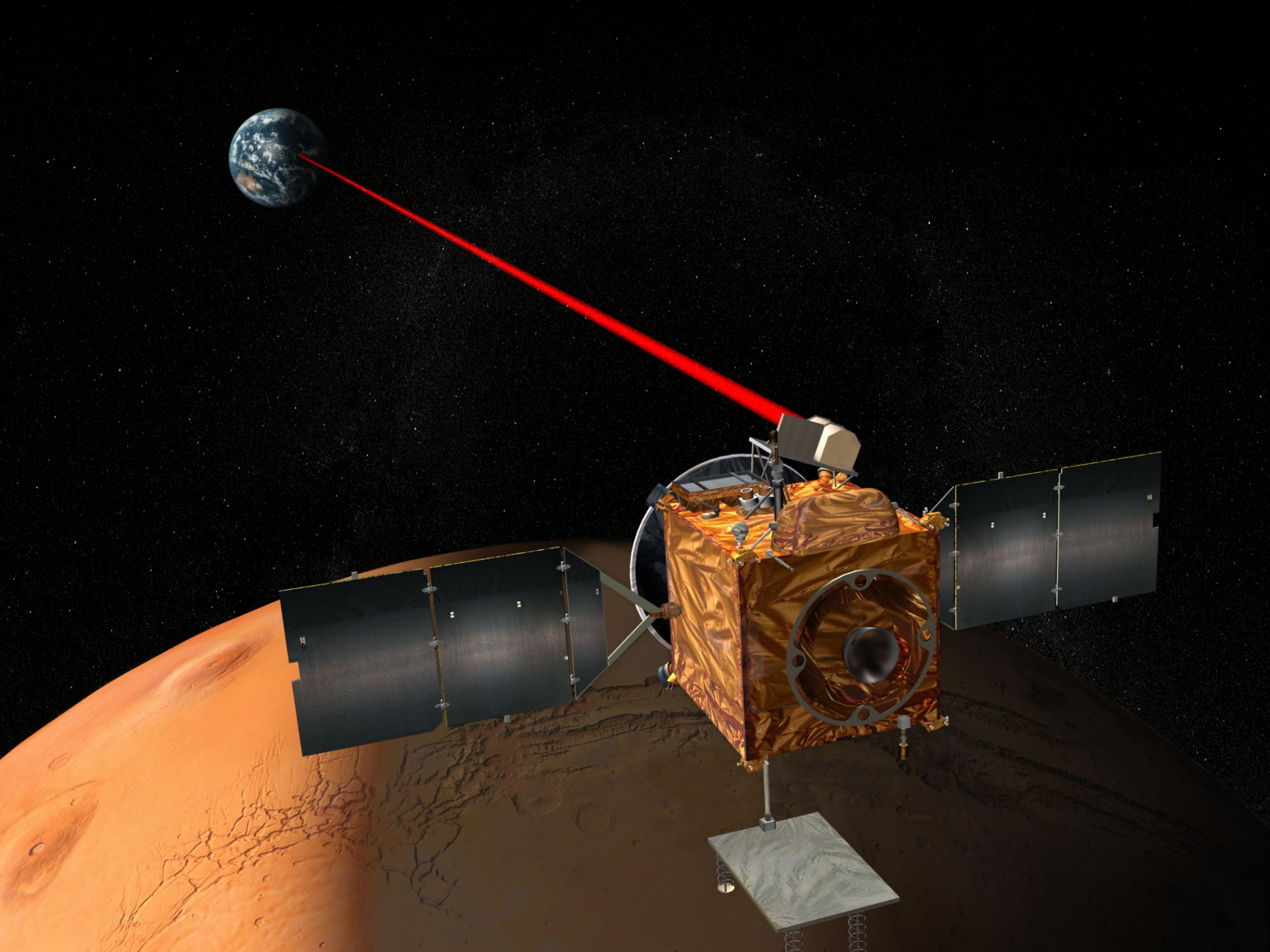
Plans have yet to be finalized, although the terminal, which will communicate with next-generation Earth-orbiting satellites and interplanetary probes, may likely be temporarily sited atop dormant Haleakala volcano on Maui, the documents say.

SPONSOR CONTENT
Make the Most of Corporate Cash

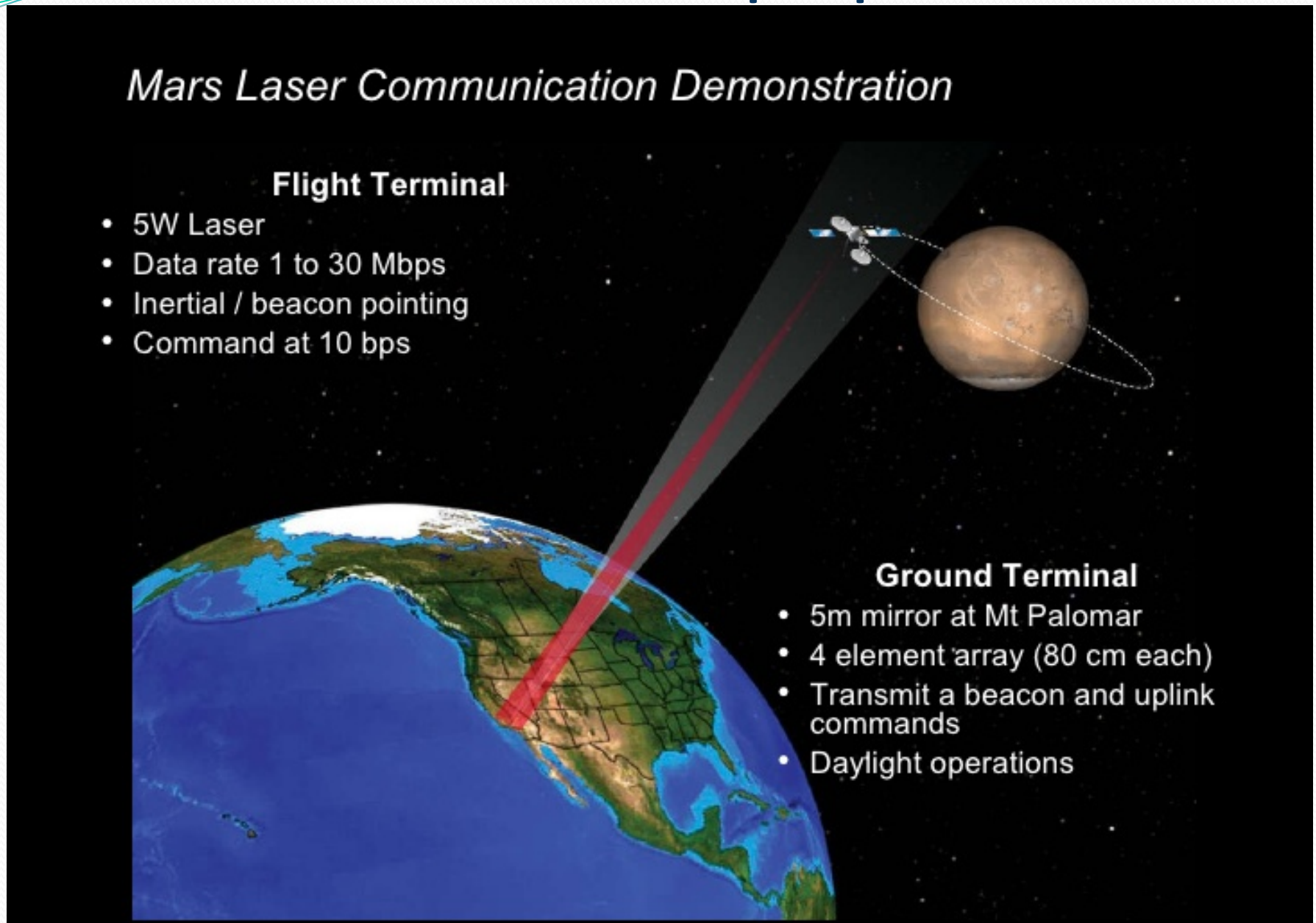
NASA/PR NEWSWIRE

The Hawaii Office of Aerospace Development, which promotes the growth and diversification of the state's aerospace industry, is working with the Pacific International Space Center for Exploration Systems (PISCES) at the University of Hawaii Hilo and NASA to coordinate the





Current NASA Deep Space Demo



Future Deep Space Ground Terminal

Geotechnical Reconnaissance Report
Proposed 4-Acre Site for Development of Future Scientific Facilities
Pacific International Space Center for Exploration Systems (PISCES)
Free-Space Laser Communications Ground Terminal
Near the Summit of Mauna Loa, Island of Hawai'i
TMK: Portion of (3) 4-4-016: 001
Project No. 0006772

for

The Research Corporation of the University of Hawai'i
c/o Pacific International Space Center for Exploration Systems (PISCES)
99 Aupuni Street, Suite 212-213
Hilo, Hawai'I, 96720

COMSPEC ENGINEERING

Final Report

PISCES: FREE-SPACE LASER COMMUNICATIONS GROUND TERMINAL ELECTRICAL POWER AND TELECOMMUNICATIONS ASSESSMENT ON MAUNA LOA, COUNTY OF HAWAI'I, RFP No. 1002

May 31, 2016

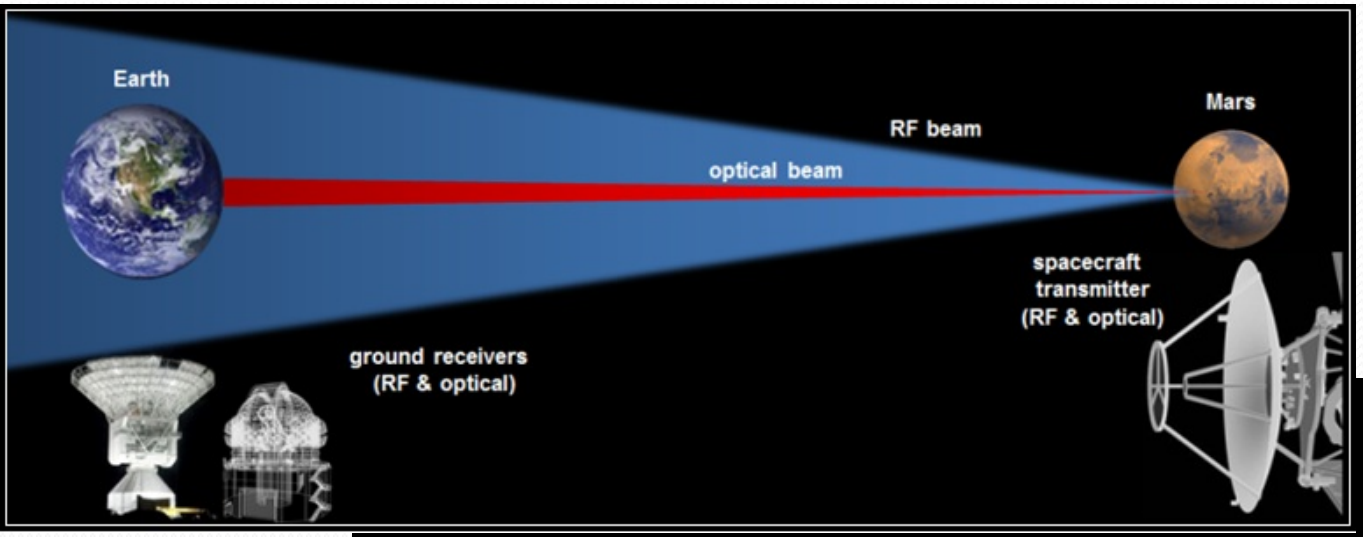
Prepared for **John Hamilton**

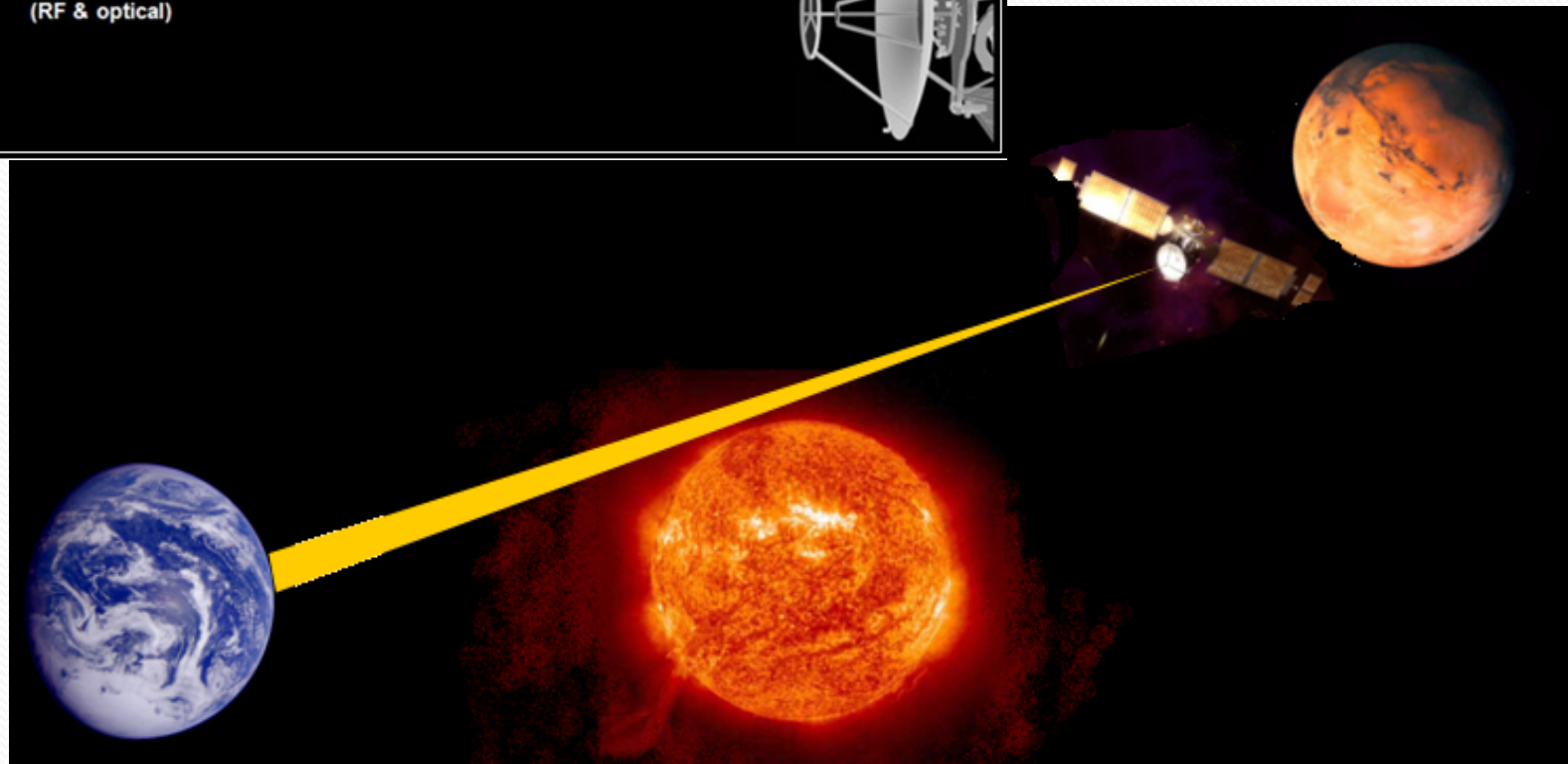
Prepared by **Bruce Yamashita**

Edited by **Greg Matsui**

President
(808)536-1330, x102
gmatsui@comspec-hi.com

Benefits beyond bandwidth





SCAN press

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OPTICS & PHOTONICS NEWS

News Careers Books

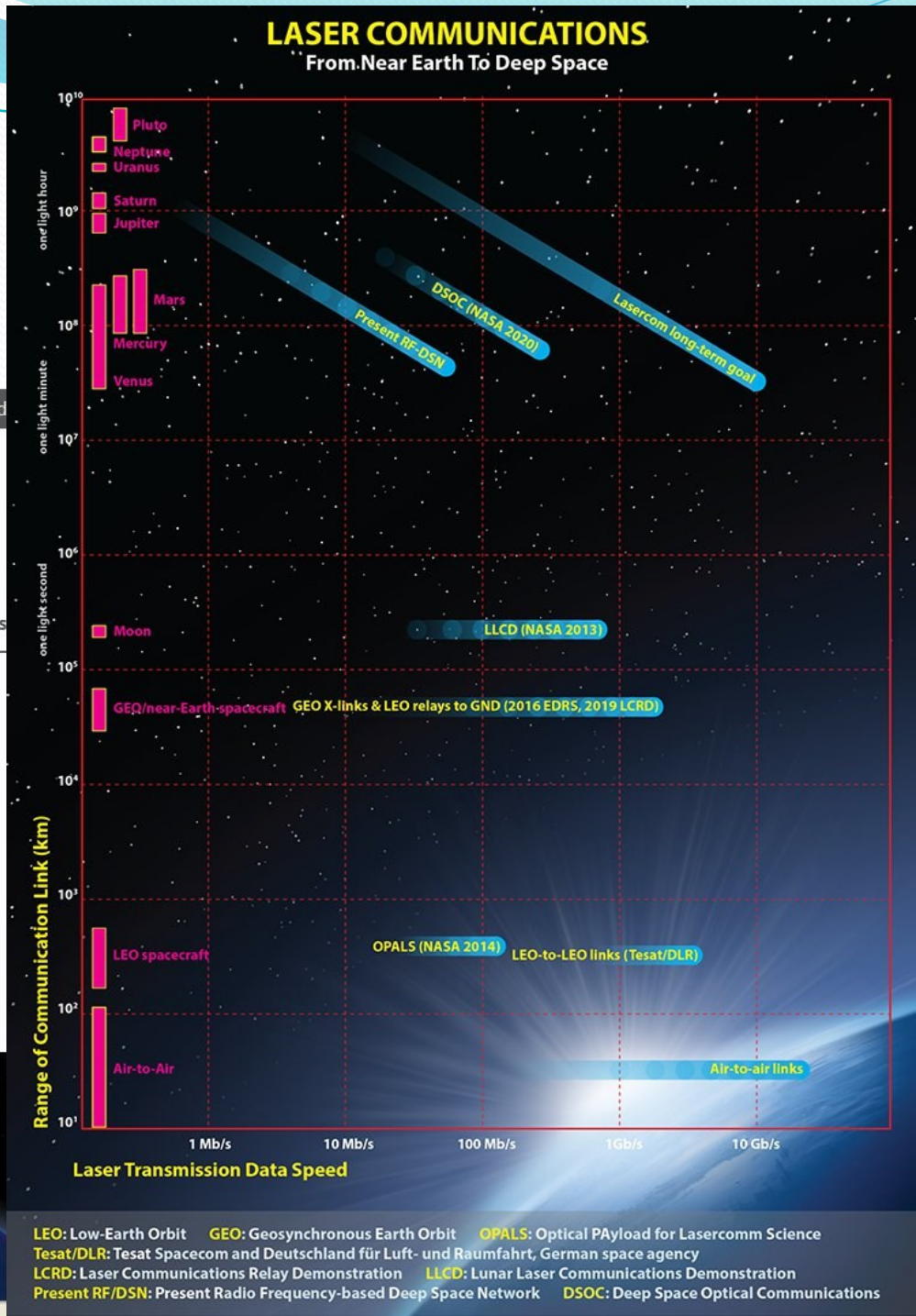
Issues / 2016 / May 2016 / Space-Based Laser Communications Break Threshold

FEATURE OPEN

Space-Based Laser Communications Break Threshold

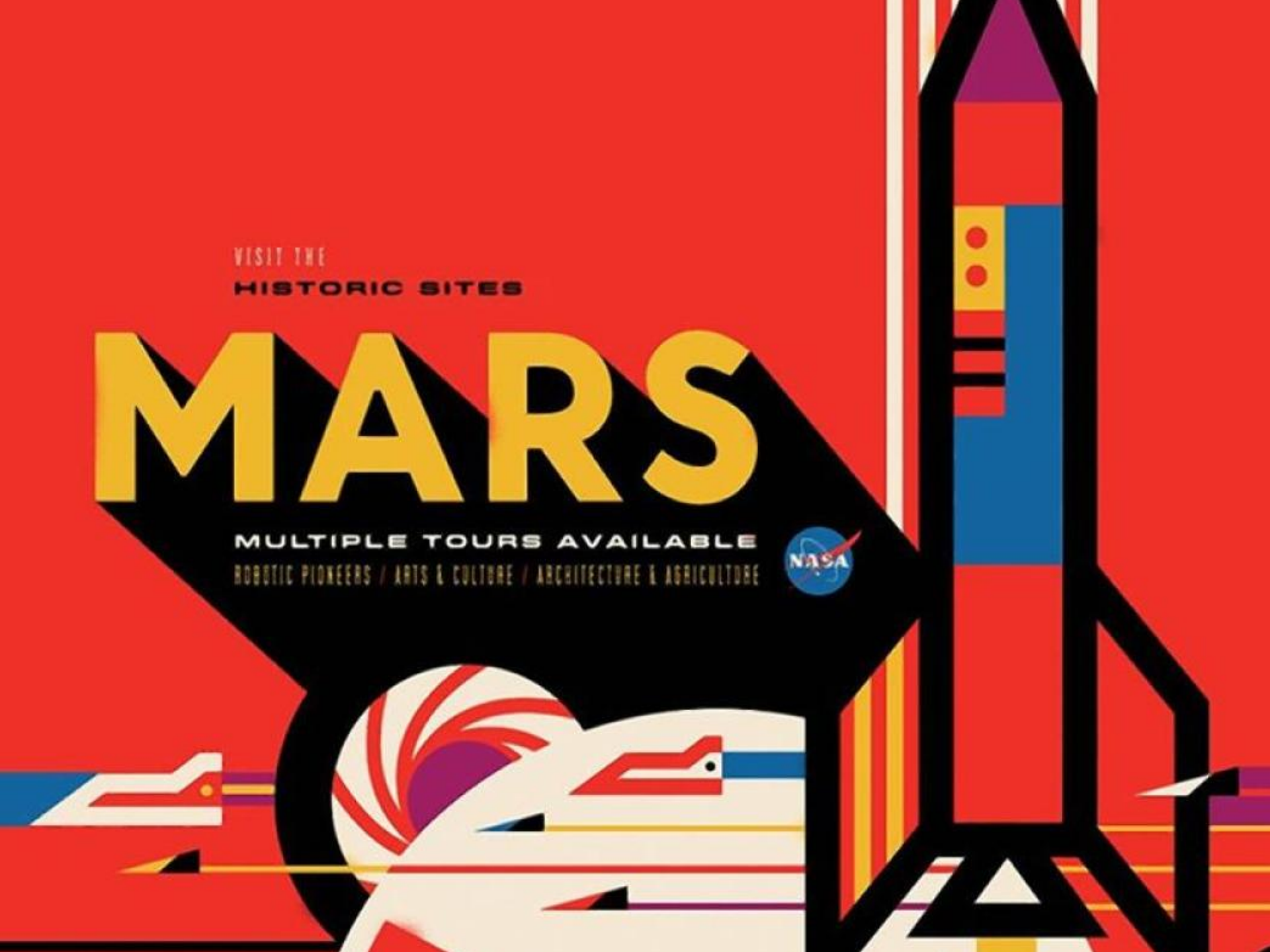
Donald Cornwell

Recent and upcoming deployments of satellite laser communication systems are bringing Internet-like speeds for data transmission in space. The result could be a revolution in communication, both on Earth and across the solar system.



LASERS everywhere!

I wish I had studied ISRU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NASA