Abstract #1643

English

Proving and Improving Martian Mining ISRU technology in Hawai`i

The island of Hawai`i has been the stage for the only NASA ISRU field tests in 2008, 2010 and 2012. Focused on lunar ISRU and the RESOLVE/Resource Prospector Mission, much can be learned and developed from these experiences as applied to Martian ISRU. Hawaiian tephra has proven geochemical similarities to Mars, and also is the source of the geotechnical NASAJSC1A Mars Simulant. Hawaii is ideal for long term facilities/equipment testing and operational models needed prior to extended human missions to Mars.

French

No abstract title in French

No French resume

Author(s) and Co-Author(s)

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EPO: Logistics Manager
PISCES - Pacific International Space Center for Exploration Systems

Profile of Mr. John Hamilton

General

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Preferred Language: [Language not defined]

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Home

Biographies

Biography submitted with the abstract

John Hamilton is on faculty with the Department of Physics and Astronomy at the University of Hawaii at Hilo, on the majestic island of Hawaii. As the Research Operations Manager of the newly formed PISCES (the Pacific International Space Center for Exploration Systems) in 2007 at the university, he managed multiple field tests with NASA, CSA, DLR, and ESA with surface technologies and ISRU. PISCES later was spun off as a State Agency, where John serves in the dual role of Education/Public Outreach and Logistics manager. Field tests with various GLXP teams and universities continued.

Biography in the user profile

Collaborators

Author(s) and Presenter(s)

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Presenter(s):

Mr. John C. Hamilton
EPO: Logistics Manager
PISCES - Pacific International Space Center for Exploration Systems

CONGRÈS 2017 ICM CIM CONVENTION

CIM ICM

JOHN HAMILTON

Univ. Hawaii / PISCES

Pepeekeo, Hawaii

Présentateur / Presenter

jch@hawaii.edu


FIRST ALERT: BIG ISLAND
WINTER STORM WARNING THROUGH MONDAY MORNING
HAWAII
NEWS NOW
10:03
KHNL

PTMSS
Planetary & Terrestrial Mining Sciences Symposium

Space Resources Roundtable

CIM2017 CONVENTION
Montreal, QC | April 30 - May 3

Proving and Improving Martian Mining ISRU Technology in Hawai`i

John Hamilton

Dept. of Physics and Astronomy University of Hawai`i

Pacific International Space Center for Exploration Systems (PISCES)

University of Hawai'i Hilo

PISCES
Pacific International Space Center for Exploration Systems

PTMSS
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CIM2017 CONVENTION CIM ICM
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Proving and Improving Lunar Mining ISRU Technology in Hawai`i

John Hamilton

Dept. of Physics and Astronomy University of Hawai`i

Pacific International Space Center for Exploration Systems (PISCES)

University of Hawai'i Hilo

PISCES
Pacific International Space Center for Exploration Systems

In-situ Resource Utilization

- *The collection, processing, storing and use of materials encountered in the course of human or robotic space exploration that replace materials that would otherwise be brought from Earth.*

  - Sacksteder, Kurt R.; Sanders, Gerald B. (January 2007). "In-situ resource utilization for lunar and mars exploration" AIAA 2007-345
- ISRU is for BASICS to support requirements and capabilities of an off-Earth mission
  - Water
  - Oxygen
  - Propellents & Fuel (Methane, H2O2)
  - Native Construction Materials

Planetary Mining

1. “Planetary mining” supports ISRU mission on volatiles extraction from feedstock (“ore”) for direct support of continued human activities.
2. “Planetary mining” also encompasses detection, prospecting, mining and processing of resources/minerals of value economically to Earth. (Including cost of shipping)

I will concentrate on #1

Mars = Hawai`i

- “The rock distribution and soil composition of Hawaii’s volcanic deposits provide an ideal terrain for testing ISRU hardware and operations.” https://www.nasa.gov/analogs/isru
- “Based on infrared spectroscopy, the fine-grained component of Mauna-Kea palagonite is the terrestrial material with the best match to the spectral properties of Martian dust, and is believed to be similar in composition and in origin to dusty component of the surface regolith of Mars” – Wikipedia!

Palagonite

- Much of the cinder and basaltic rocks are alteration products from the interaction of water with volcanic glass of chemical composition similar to basalt.
- Palagonite can result from the interaction between water and basalt melt.
- It can also be formed by a slow weathering of lava, resulting in a thin, yellow-orange rind (palagonite) on the surface of the rock.
  - R.B. Singer, "Mineralogy of High-Albedo Soils and Dust on Mars", (1982)
  - R. B. Singer and T. L. Roush, "Spectral reflectance properties of particulate weathered coatings on rocks: Laboratory modeling and applicability to Mars", (1983)
  - E.A. Guinness,R. E. Arvidson, M. A. Dale-Bannister, R. B. Singer and E. A. Brukenthal, "On the Spectral Reflectance Properties of Materials Exposed at the Viking Landing Sites", (1987)

JSC-Mars-1A Mars Simulant (2005)

Volcanic Ash

Palagonitized Tephra

Chemical match to Viking 1 landing site.

- Hand quarried
- Permitted for 125 tons
    1. Feasibility & Design– 3 tons
    2. Test Production – 8 tons
    3. Awaiting Phase 3 funding

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.

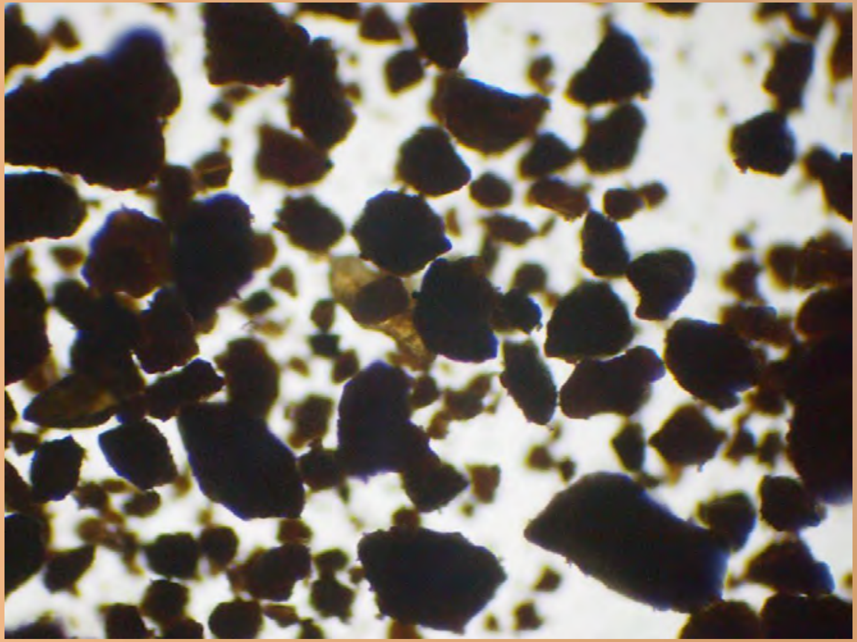
GRAIN SIZE: 1mm & Lower

Item Size: 2 lbs $25.00

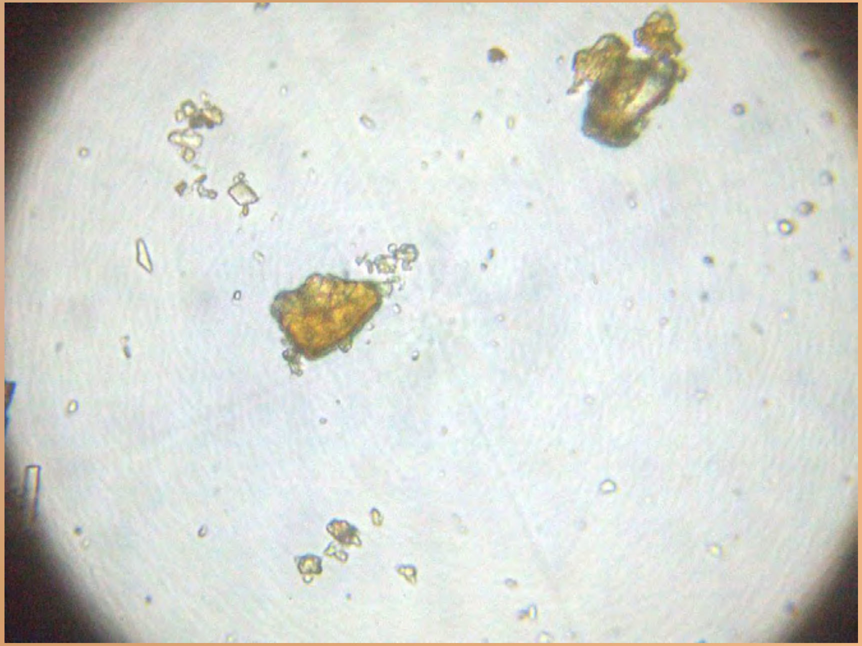
Shipping & Handling: $12.00

A closer look at tephra

100x magnification

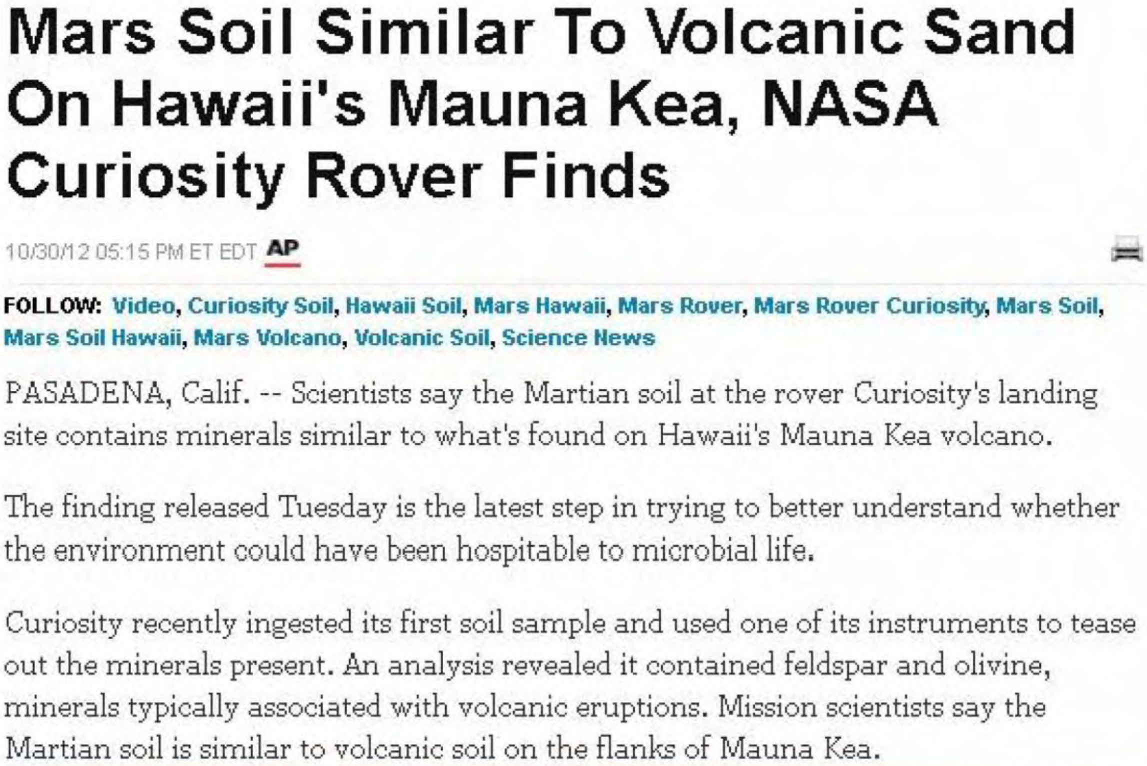


400x magnification



Note the rough and angular edges which help define the bulk properties such as flow, compression and “digability”


Saddle Rd
200
Google



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

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

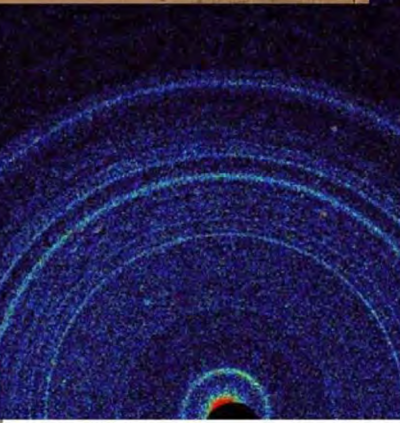
FOLLOW: Video, Curiosity Soil, Hawaii Soil, Mars Hawaii, Mars Rover, Mars Rover Curiosity, Mars Soil, Mars Soil Hawaii, Mars Volcano, Volcanic Soil, Science News

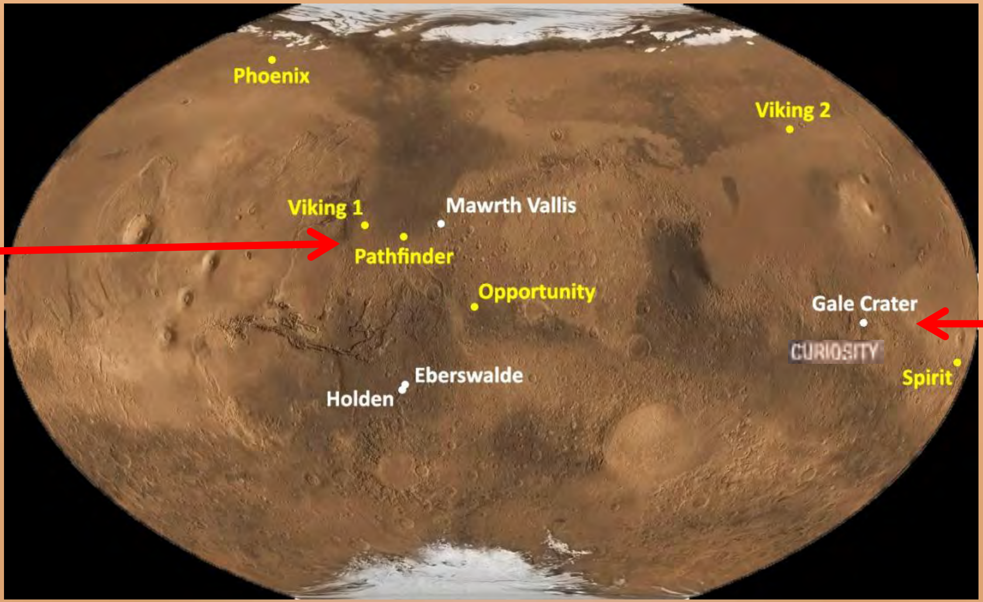
PASADENA, Calif. -- Scientists say the Martian soil at the rover Curiosity's landing site contains minerals similar to what's found on Hawaii's Mauna Kea volcano.

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.

CheMin at PISCES 2008 Test





- JSC Mars1A is based on IR Reflectance data
  - Remote Sensing
- The CHEMIN data is based on XRF data
  - *In-situ* Measurement
- Two different sites on Mars!
  - Viking 1 (1976) 22.5°N 49.97°W Acidalia Planitia
  - Curiosity (2012) 4.6°S 137.4°E Gale Crater

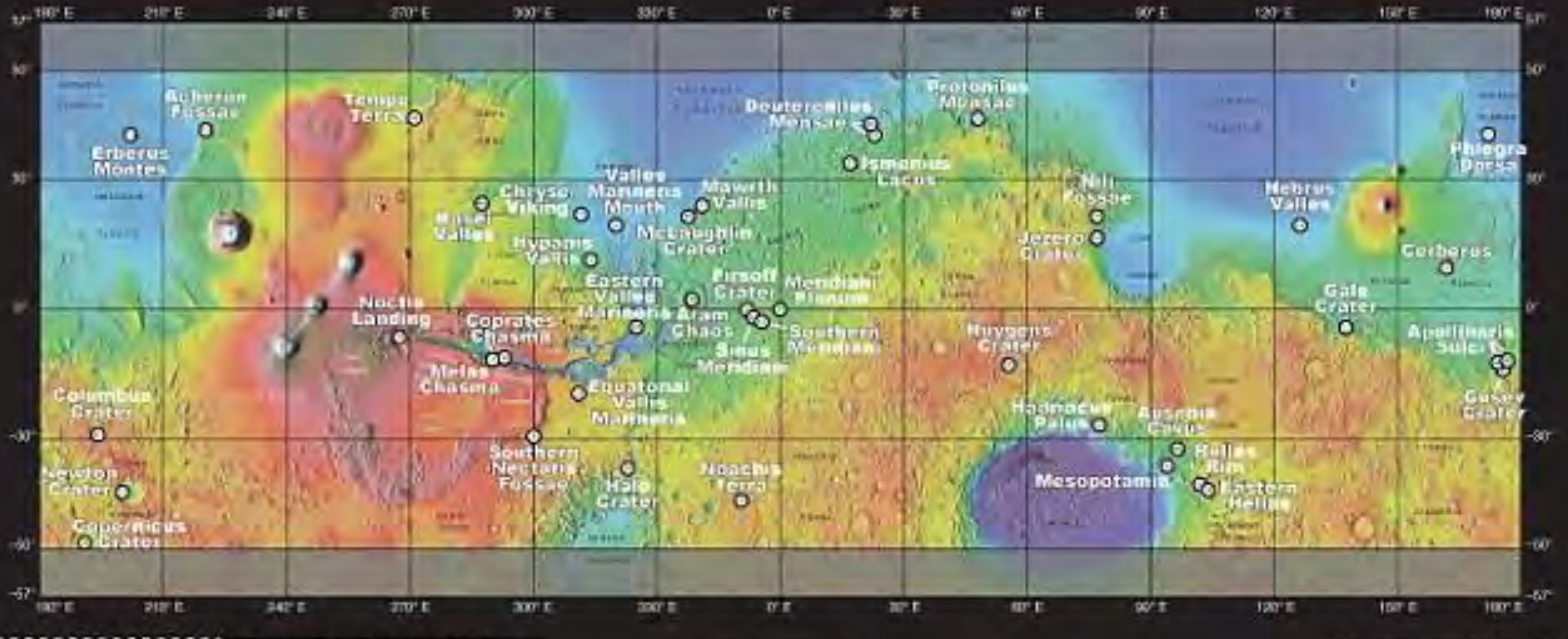
October 2015 @ LPI Houston

MARS

Human Landing Sites Study (HLS²)

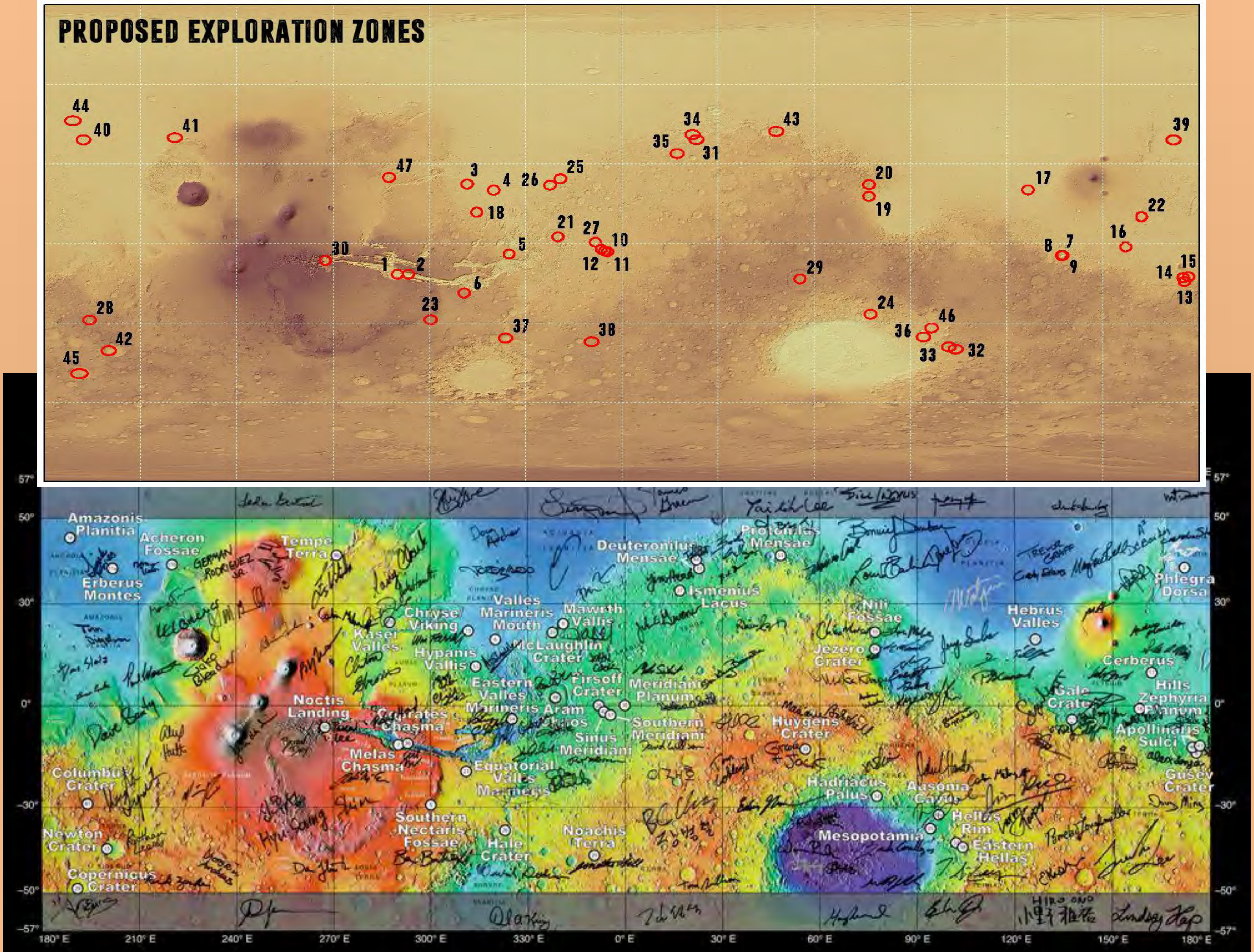
For Human Missions to the Surface of Mars

Potential Exploration Zones for Human Missions to the Surface of Mars



© Lindsay Hays/Mars Program Office

PROPOSED EXPLORATION ZONES



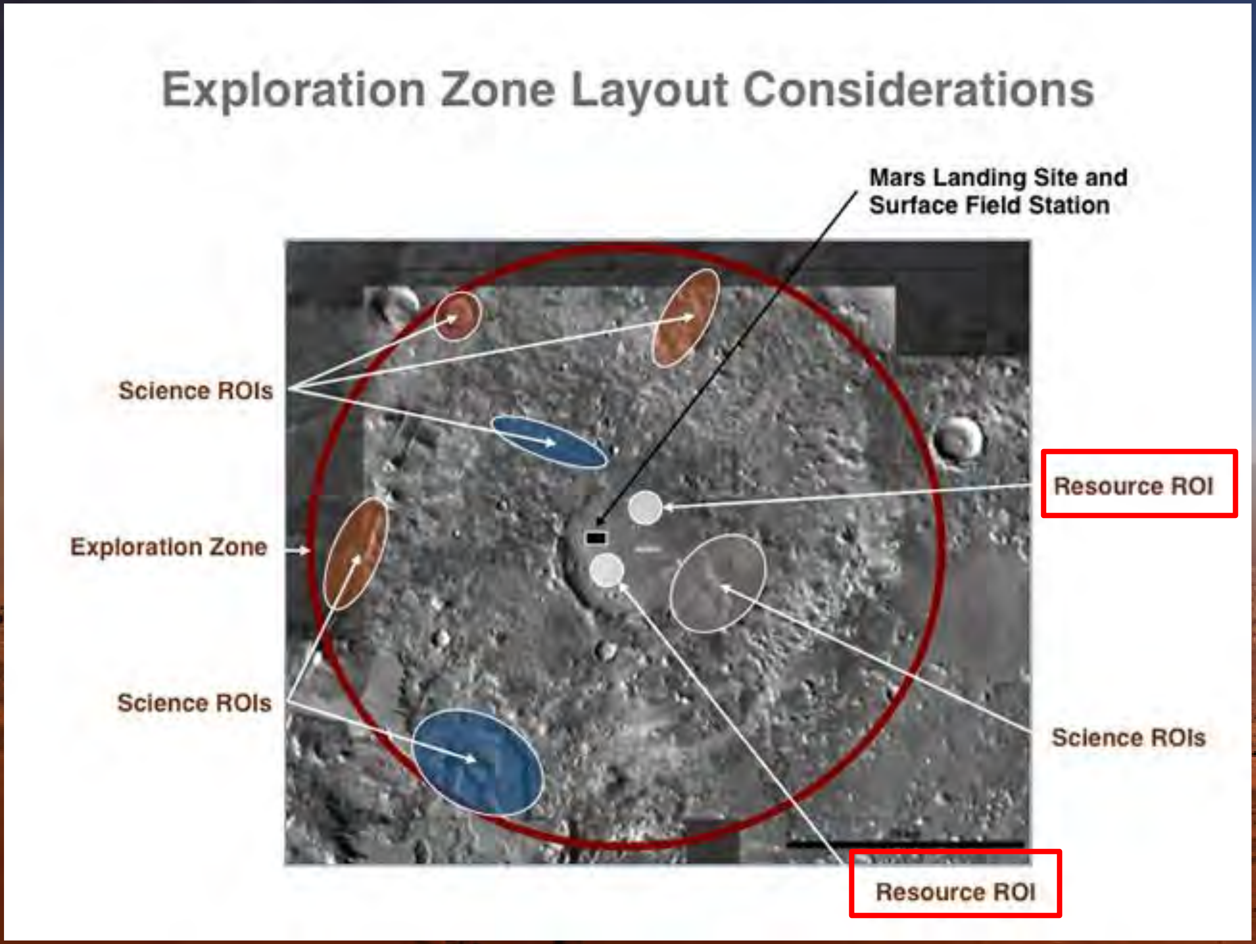
Exploration Zones proposed for humans to Mars.
Numbers correspond to the abstract submission #
At the equator, circles are ~100km radius

version 12 October 16, 2015

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

Exploration Zone Concept

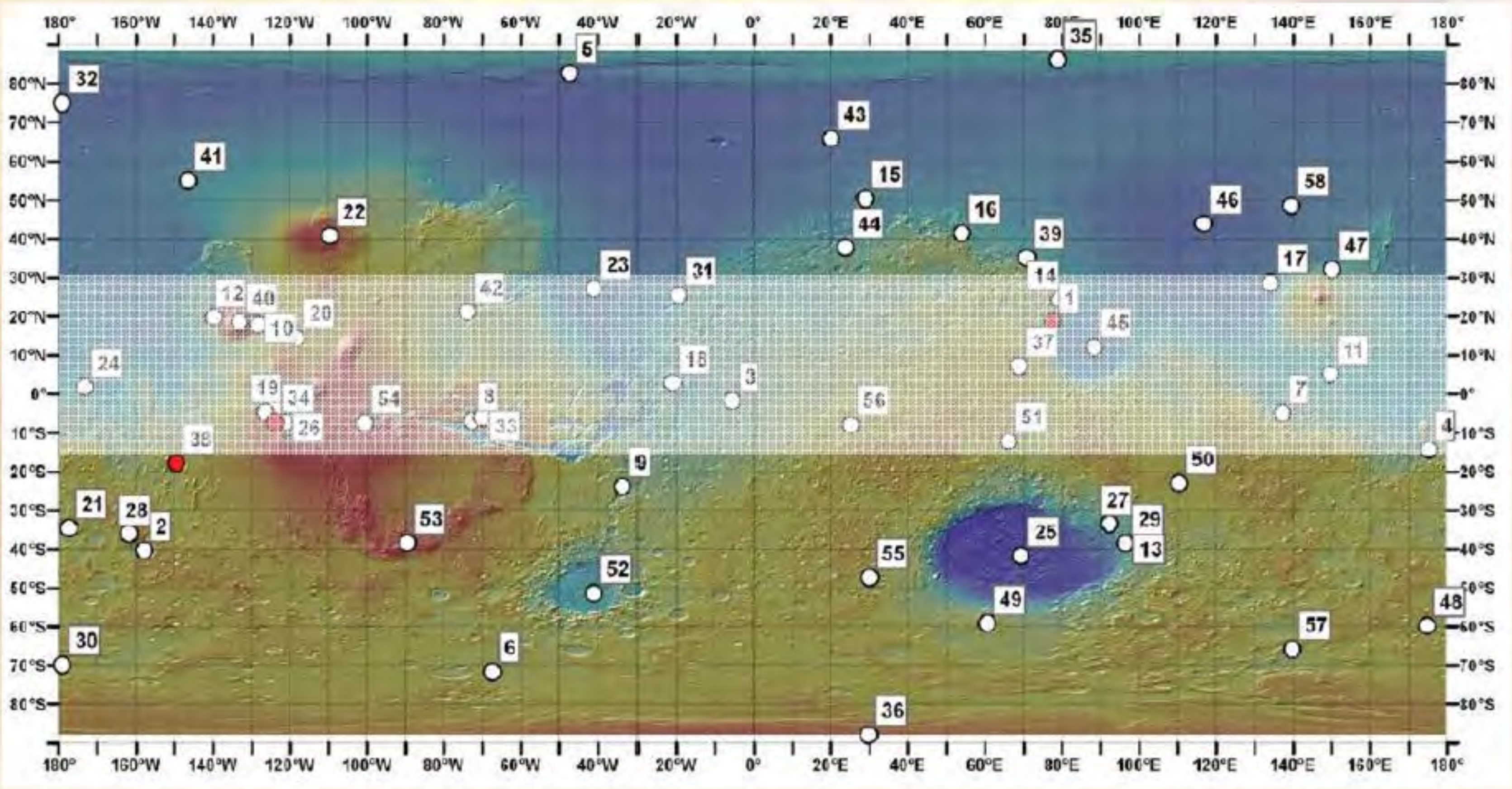
Resources ROI (Regions of Interest)



Exploration Zone Layout Considerations

Special Consideration: Latitude Constraints

- Solar power applicability best between 15°S and 30°N latitudes
  - System efficiency drops quickly beyond outside this band
  - Covers 26-28 of the 58 sites of potential interest identified by HEM-SAG



NASA DRA5 – Less solar availability plus dust accumulation on panels

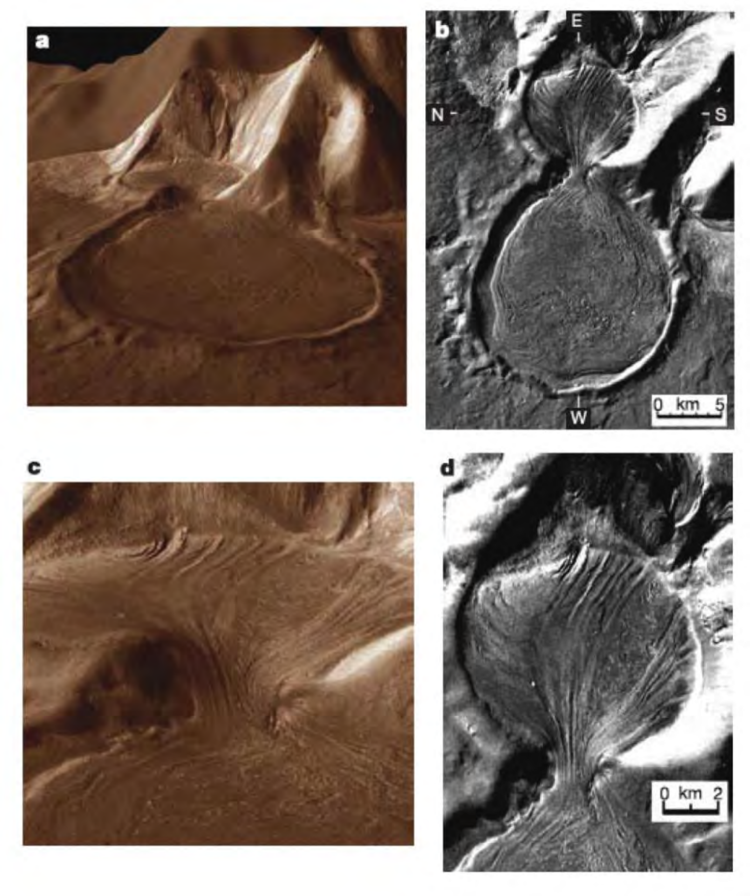
Glaciers!


© ESA/DLR/FU Berlin, G. Neukum

Mars Express: Deuteroniius Menae 39N, 23 E

Orbital Parameters explain mid/low latitude glaciers: Key to ISRU water

- Nutation (Axial Tilt) ~25deg
- Precession
- Eccentricity

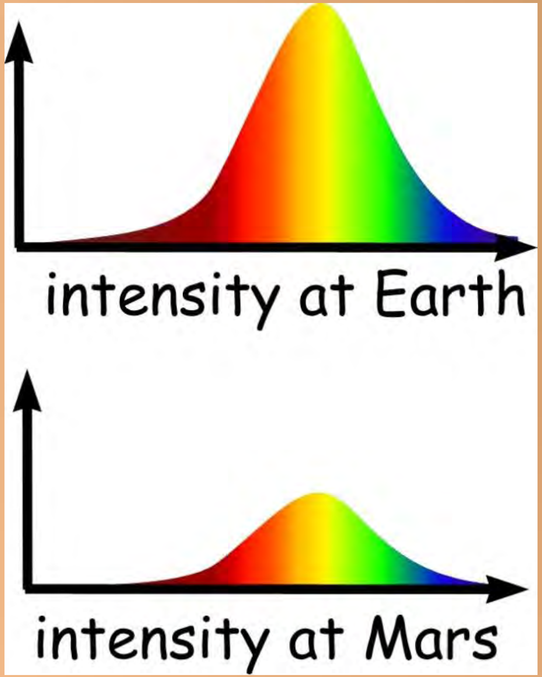


"Mars is a dusty covered frozen sea"
(Permafrost layer pervasive)

  - Laskar et al., 2002;
  - Head et al., 2003

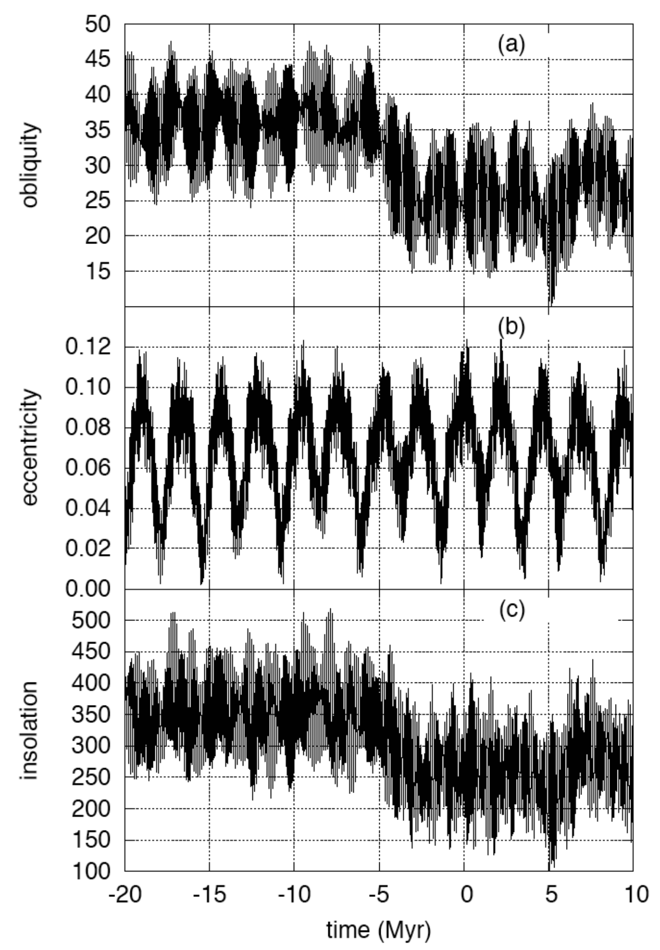
Solar variable insolation

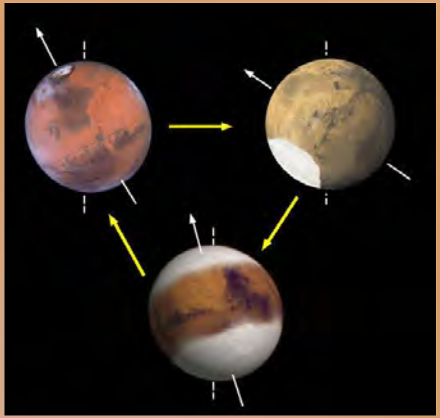
- Intensity less due to distance
- More variable due to eccentricity of orbit
- Affects Solar Power & Agriculture

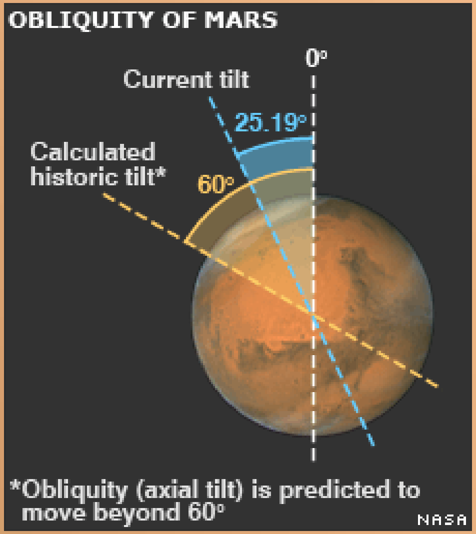


Solar Constant @ Earth
$= 1370\ Wm^{-2} +/- 2\ Wm^{-2}$
$e = 0.0167$ $R = 0.98\text{-}1.02$ AU

Solar Constant @ Mars
$= 586\ Wm^{-2}$
($717\ Wm^{-2}$ to $493\ Wm^{-2}$)
$e = 0.0934$ $R = 1.38\text{-}1.67$ AU



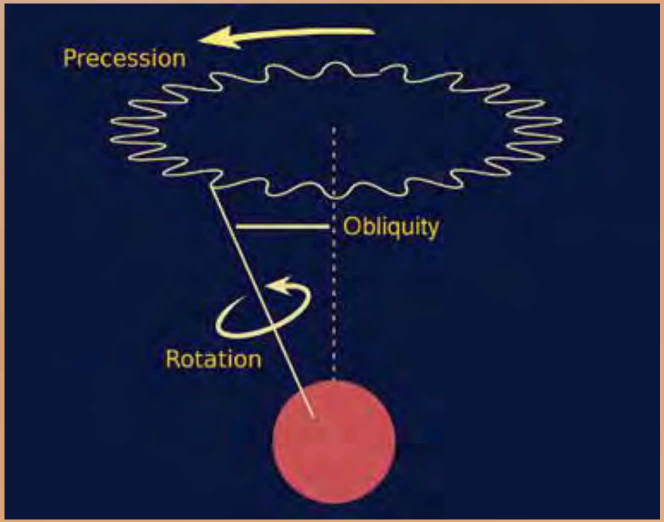




OBLIQUITY OF MARS

*Obliquity (axial tilt) is predicted to move beyond 60°

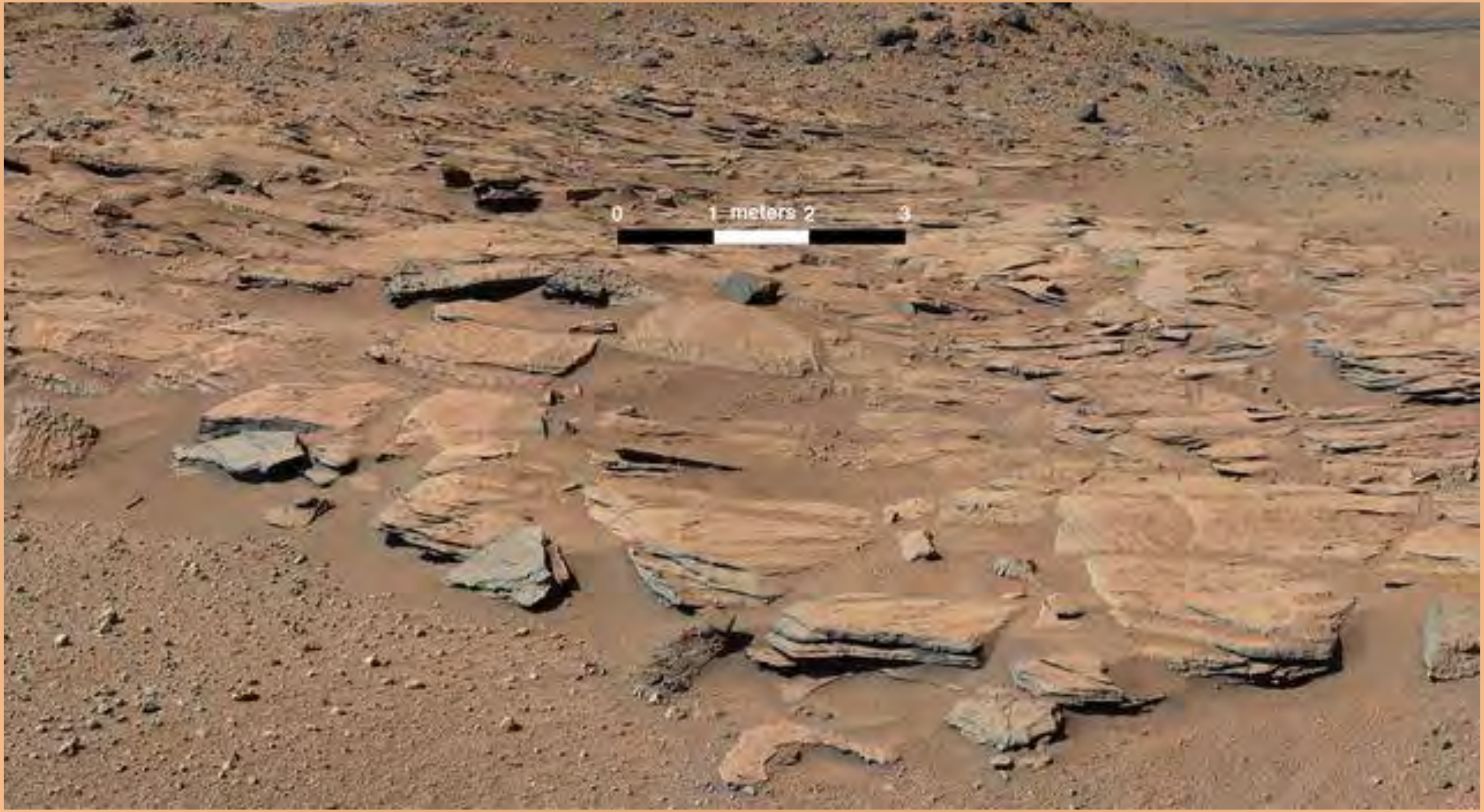
NASA



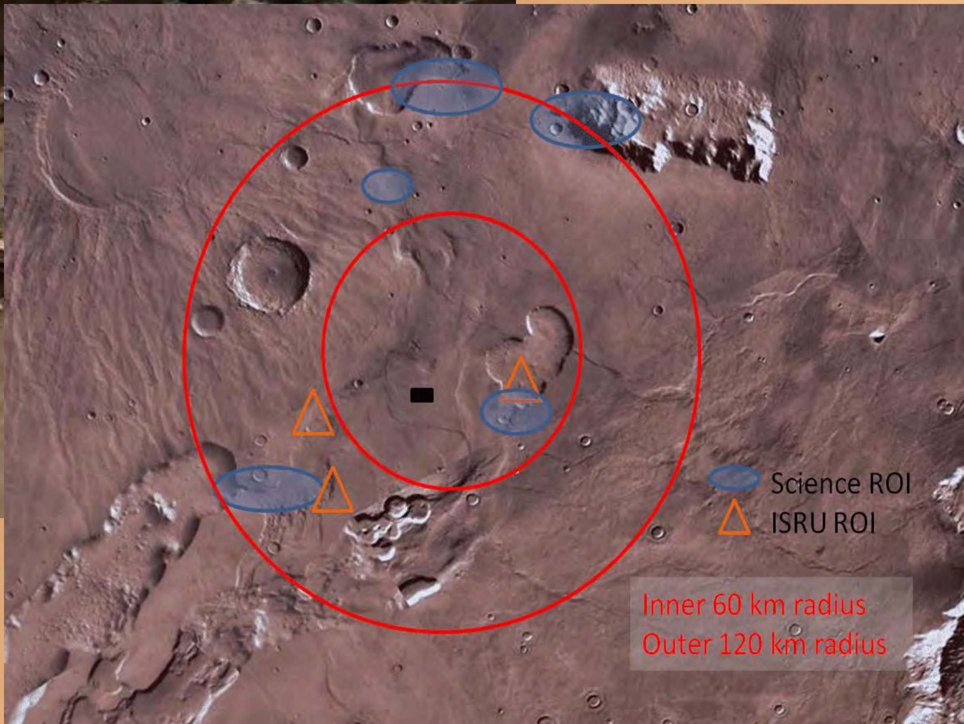
Laskar et al. 2004; Read Milankovitch on Mars 2013

Native regolith scales (centimeters)

Native regolith scales (meters)



Mars is not all flat and smooth



Mobility and traction - tribology

Twin Peaks

Pathfinder landing site

- 19°7′48″N 33°13′12″W
- Ares Vallis, Chryse Planitia
- 4 July 1997
- ~30-35m tall, ~ 1km distant

TWIN PEAKS

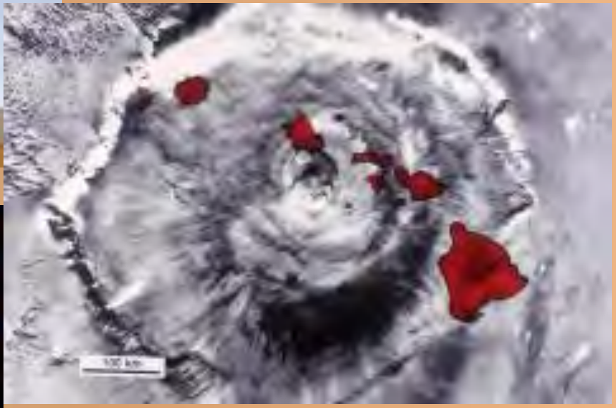
EATS ♦ DRINKS ♦ SCENIC VIEWS

Small mining rover testing

(UH Hilo 2015 RMC entry)
Summer 2015 Pu`u Nene

Grading tests with PISCES Helelani Rover 2015 – Pu`u Nene

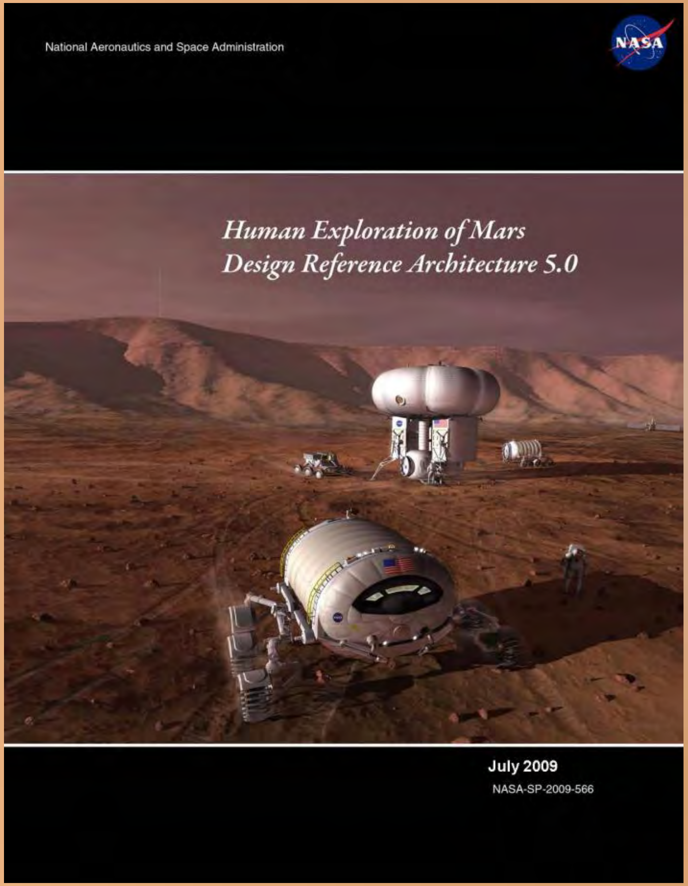
Mauna Loa vs Olympus Mons



Mokuaweoweo

What’s the plan?

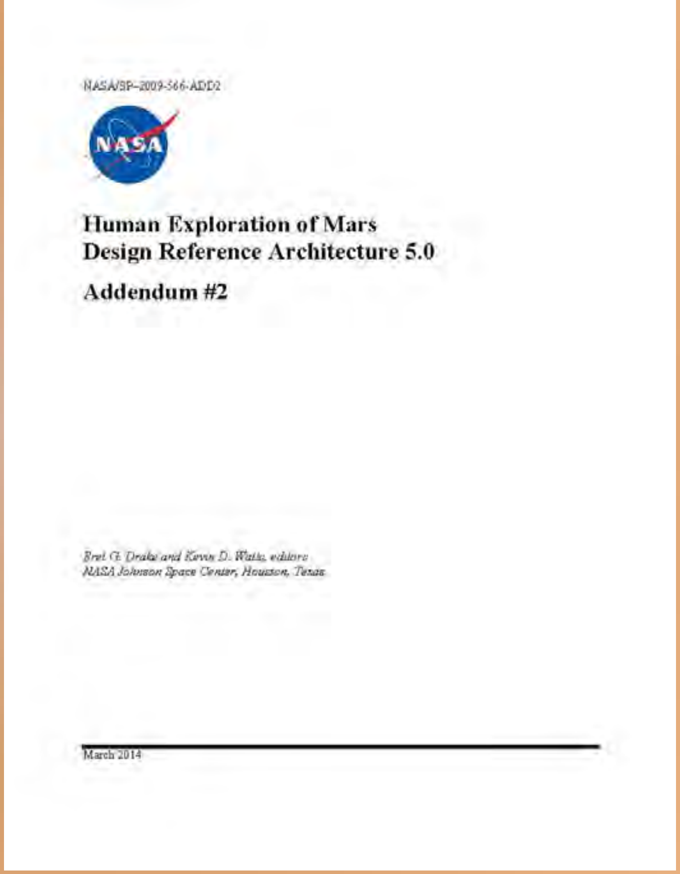
- NASA Design Reference Architecture (July 2009)



National Aeronautics and Space Administration

Human Exploration of Mars
Design Reference Architecture 5.0

July 2009
NASA-SP-2009-566



NASA/SP–2009-566-ADD2

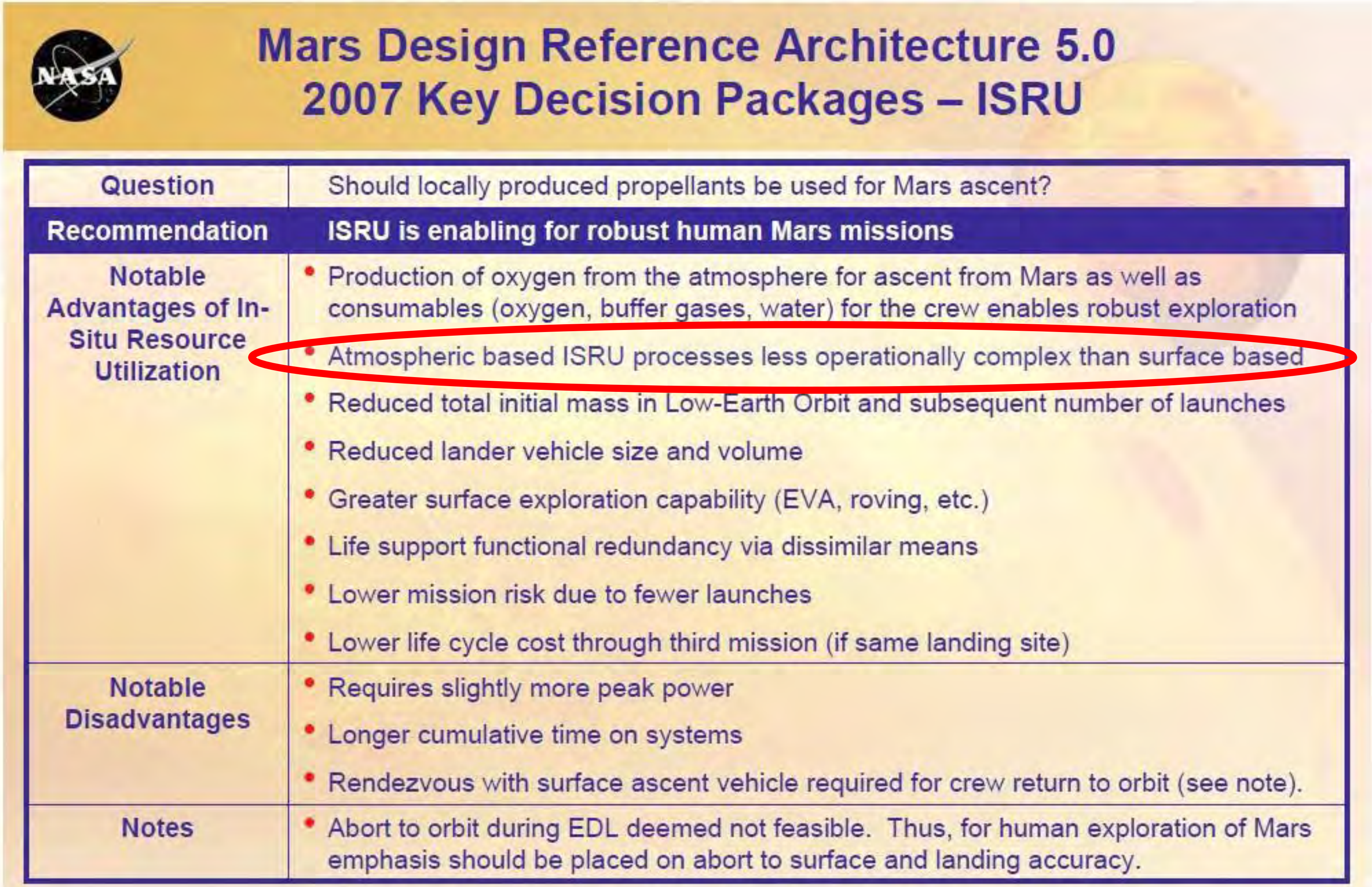
Human Exploration of Mars
Design Reference Architecture 5.0

Addendum #2

Bret G. Drake and Kevin D. Watts, editors
NASA Johnson Space Center, Houston, Texas

March 2014

- Addendum #2 (March 2014)



Mars Design Reference Architecture 5.0
2007 Key Decision Packages – ISRU

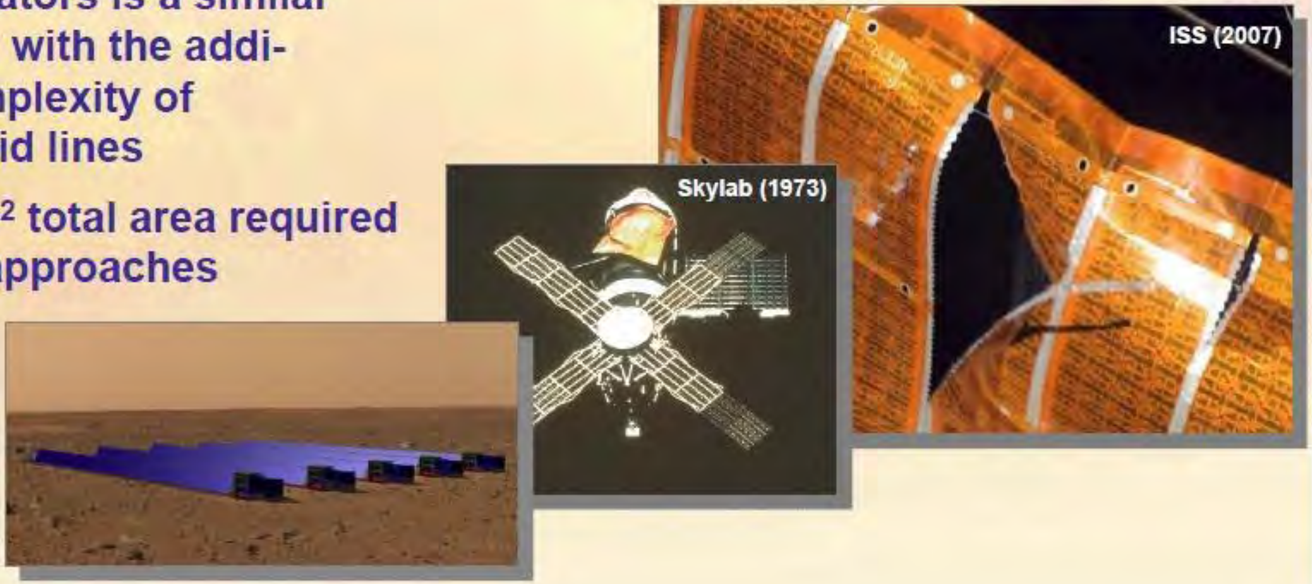
Question	Should locally produced propellants be used for Mars ascent?
Recommendation	**ISRU is enabling for robust human Mars missions**
Notable Advantages of In-Situ Resource Utilization	• Production of oxygen from the atmosphere for ascent from Mars as well as consumables (oxygen, buffer gases, water) for the crew enables robust exploration • Atmospheric based ISRU processes less operationally complex than surface based • Reduced total initial mass in Low-Earth Orbit and subsequent number of launches • Reduced lander vehicle size and volume • Greater surface exploration capability (EVA, roving, etc.) • Life support functional redundancy via dissimilar means • Lower mission risk due to fewer launches • Lower life cycle cost through third mission (if same landing site)
Notable Disadvantages	• Requires slightly more peak power • Longer cumulative time on systems • Rendezvous with surface ascent vehicle required for crew return to orbit (see note).
Notes	• Abort to orbit during EDL deemed not feasible. Thus, for human exploration of Mars emphasis should be placed on abort to surface and landing accuracy.

i.e. Surface / Regolith based ISRU is more complex.

- **More moving parts: propectors, diggers, transporters**
- **Robust Components (durability & longevity).**
- **Need Robot Repair Facility. Not everything can be 3D printed!**

Special Consideration: Deployment

- Autonomous deployment of large structures is inherently complicated, especially in a gravity field
  - Solar array deployment is relatively straightforward, but the sheer size of the arrays makes this task problematic
    - It is of note that Skylab, Mir and Space Station have experienced serious problems with solar array deployment requiring crew intervention
  - Deployment of the large FSPS radiators is a similar operation, with the additional complexity of jointed fluid lines
  - ~5,7500 M² total area required for solar approaches



*Hamilton, *ED-23 UV from Quasars*, NASA Skylab Student Project (1973)

MSFC- SL-73-3

skylab
student project
summary description
march, 1973

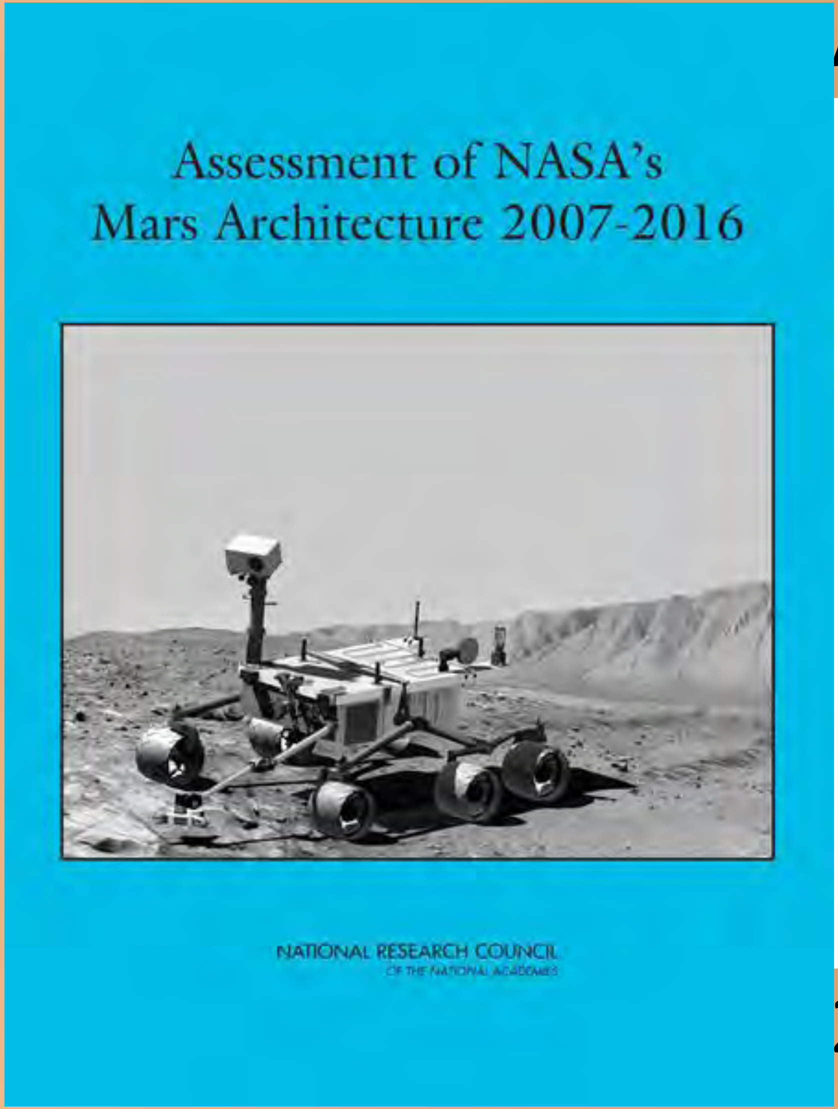
GEORGE C. MARSHALL
SPACE FLIGHT CENTER

MSFC - One-Time Form 21 (March 1972)

Skylab
UNITED STATES OF AMERICA

What’s the plan (and will it work?)

- A



Assessment of NASA’s
Mars Architecture 2007-2016

NATIONAL RESEARCH COUNCIL
OF THE NATIONAL ACADEMIES

- 2

The National Academies of SCIENCES ENGINEERING MEDICINE

MEPAG Goal IV – Prepare for Human Exploration

Objective A. Obtain knowledge of Mars sufficient to design and implement human missions with acceptable cost, risk, & performance.

Objective B. Conduct risk and/or cost reduction technology and infrastructure demonstrations in transit to, at, or on the surface of Mars.

==============================

Conduct long-term component and system demonstrations at terrestrial analog sites, (Hawai`i)

PILOT

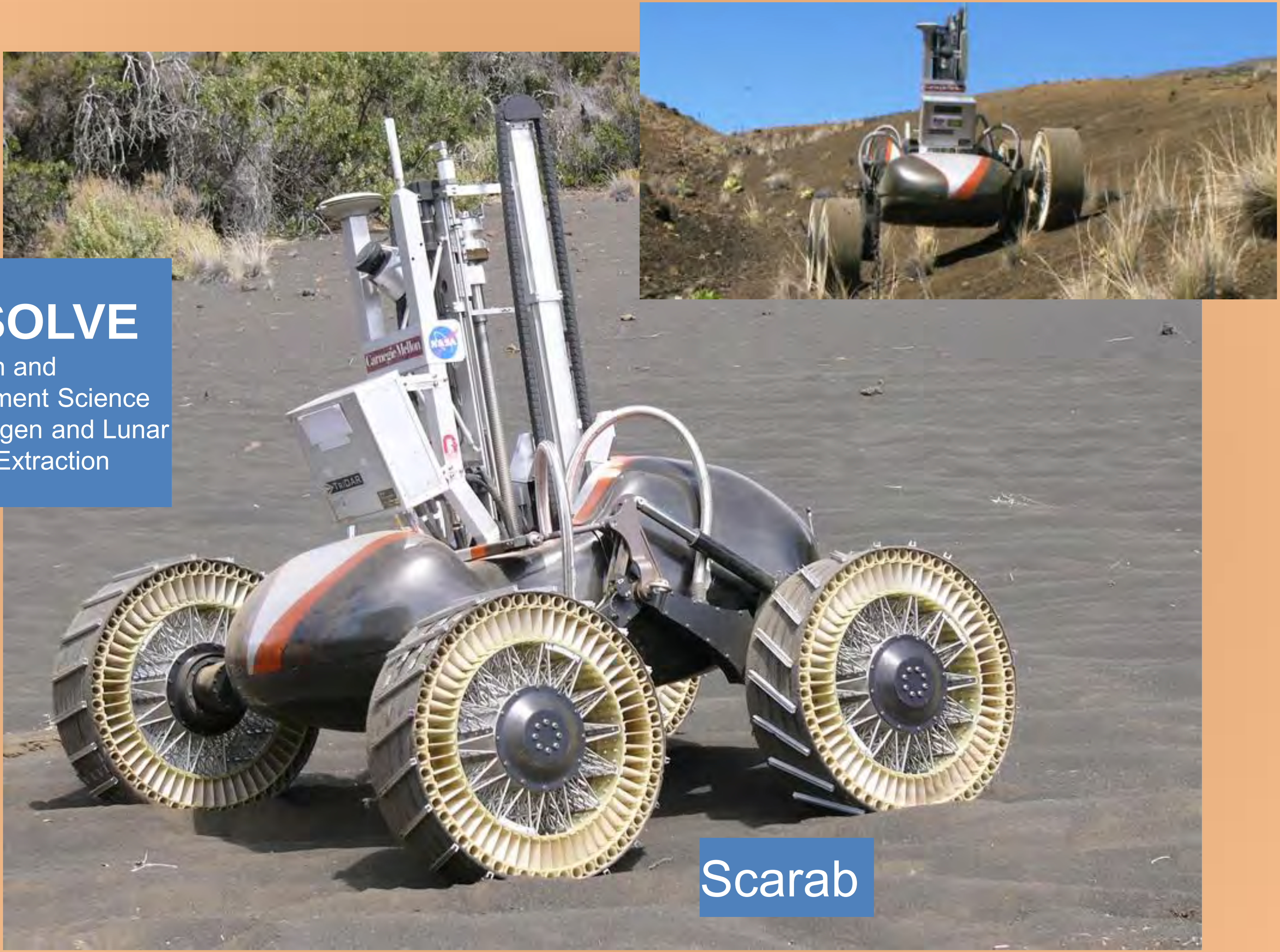
Precursor ISRU Lunar Oxygen Testbed

ROxygen

Cratos

RESOLVE

Regolith and Environment Science and Oxygen and Lunar Volatile Extraction



Scarab


NASA

Civil Engineering
3 rovers landing pad

Integrated Carbothermal Regolith Reduction reactor integrated to a solar energy collection and delivery

Mauna Kea, Hawaii, as an Analog Site for Future Planetary Resource Exploration: Results from the 2010 ILSO-ISRU Field-Testing Campaign

> "It is essential to test these instruments in environments on Earth that bear a close resemblance to planetary conditions. …This site will be used as one of the future standard test sites to calibrate instruments for in situ lunar research. In 2010, a total of eight scientific teams tested instrument capabilities at the test site."

Inge ten Kate; Rob Armstrong; Bodo Bernhardt; Mathias Blumers; Jack Craft;
Dale Boucher; Eric Caillibot; Janine Captain; Gabriele Deleuterio; Jack
D. Farmer; Daniel P. Glavin; Trevor Graff; JohnC. Hamilton; Göstar Klingelhöfer; Richard
V. Morris; Jorge I. Nuñez; Jacqueline W. Quinn; Gerald B. Sanders; R.
Glenn Sellar; Leanne Sigurdson; Ross Taylor; and Kris Zacny

http://ascelibrary.org/doi/full/10.1061/(ASCE)AS.1943 5525.0000200#sthash.C5Zb26Sa.dpuf

Prospecting with GPR

Prospecting with (Canadian) Drill

REGOLITH & ENVIRONMENT SCIENCE & OXYGEN & LUNAR VOLATILE EXTRACTION

RESOLVE

Resource Prospector

NASA

Artemis Jr. on Mission sortie 2012

https://www.youtube.com/watch?v=4jG86-Bnrbs

Google
LUNAR X PRIZE

White Label Space => Hakuto

OFFICIAL TEAM
whitelabelspace
WHITE LABEL SPACE

GOOGLE LUNAR X PRIZE
OFFICIAL TEAM

2012 PISCES conference

Analogue Field Testing

GOOGLE LUNAR XPRIZE
puli
OFFICIAL TEAM

Extreme Terrain Environments

Ongoing analogue operations

Concepts of operation, traverse planning, exploration/prospecting

Geobiology astronaut simulation under 2 time delay and 2 bandwidth scenarios.

Field test of RP NIRVSS

@Hawaii Volcanoes National Park

Habitats, bases and construction

NASA DRA5

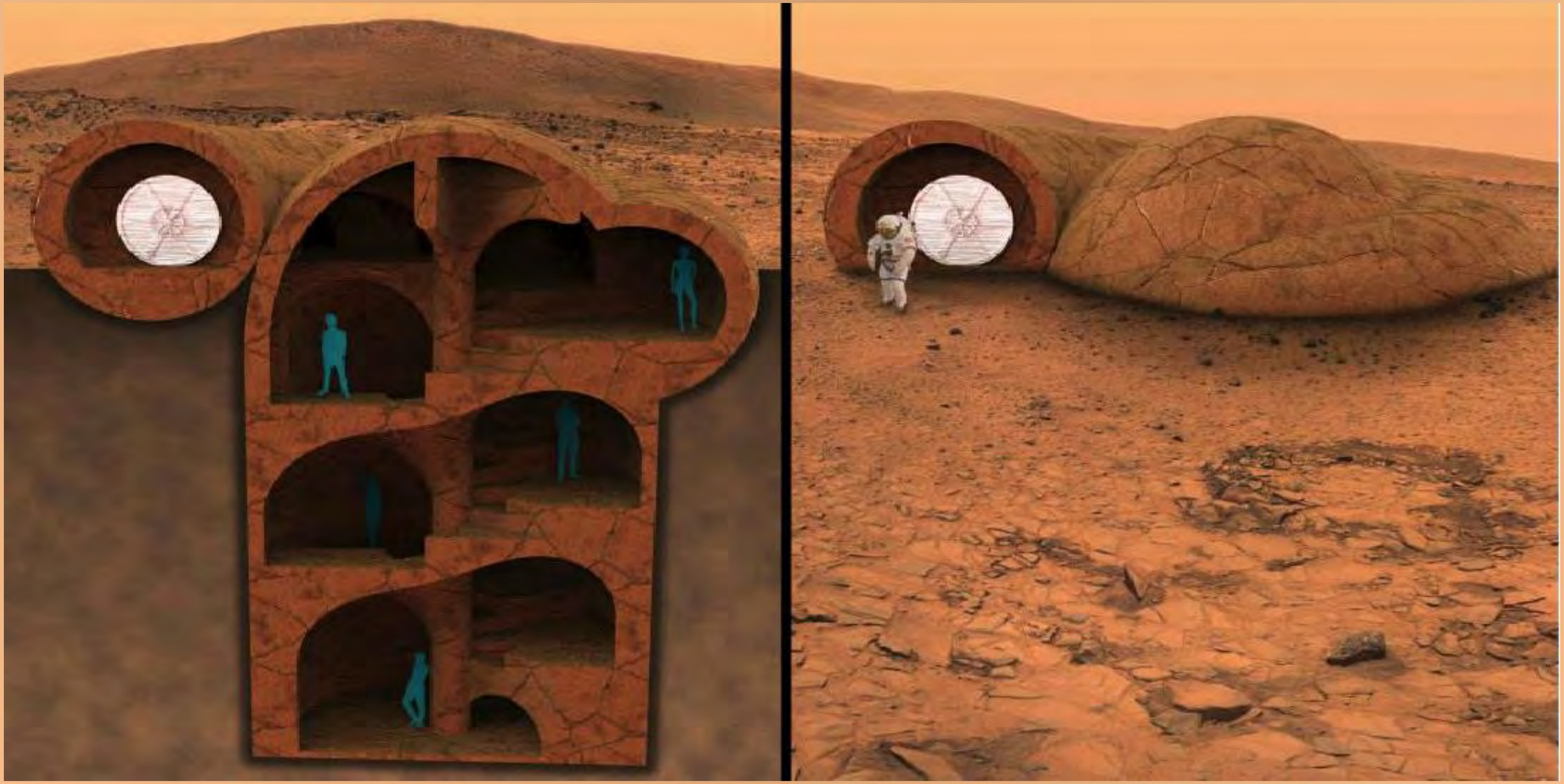
HI-SEAS
HI-SEAS.ORG

NASA Ice House

ISRU Station
from NASA Technology Roadmap

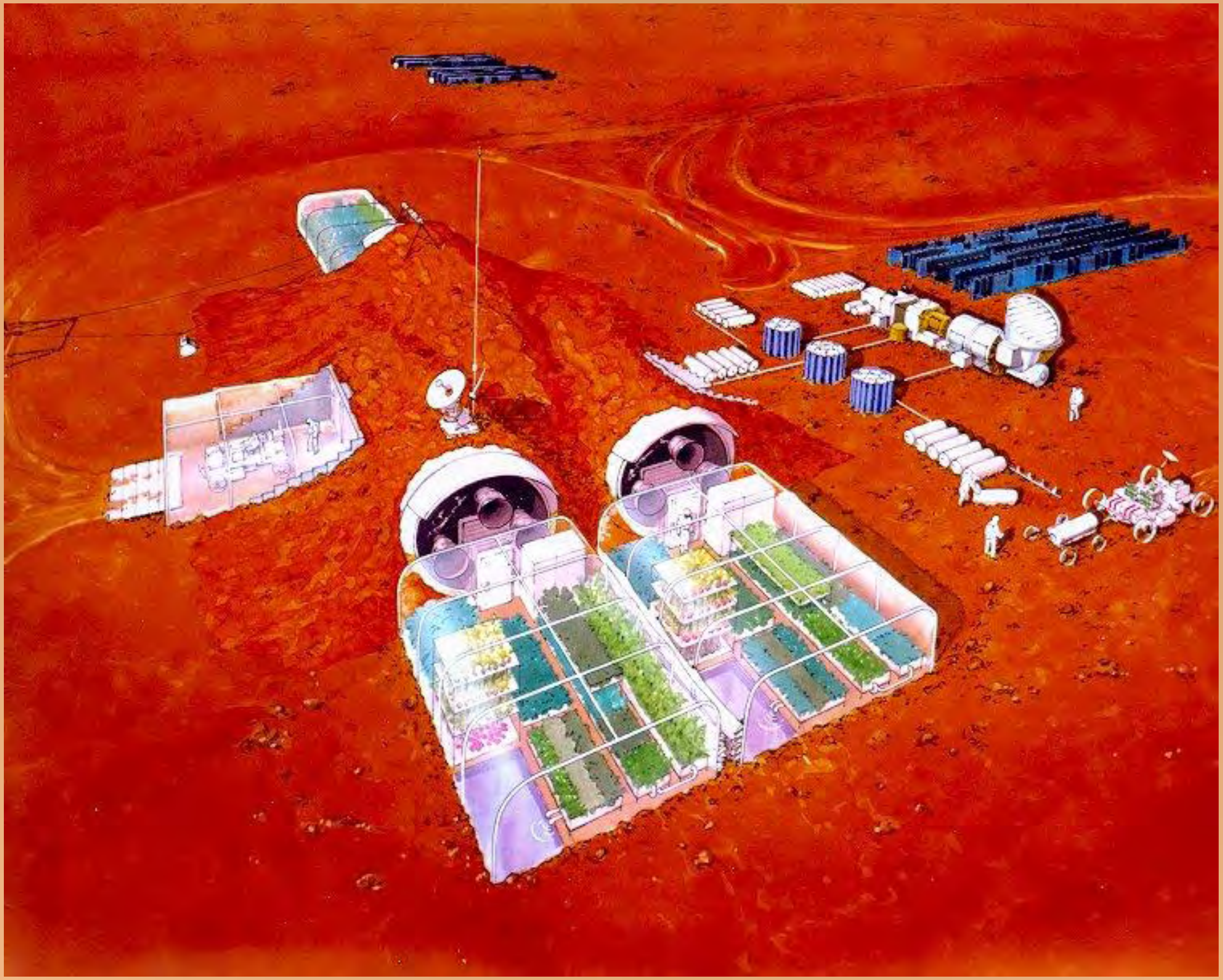
ISRU ground vehicle

3D printed, native material



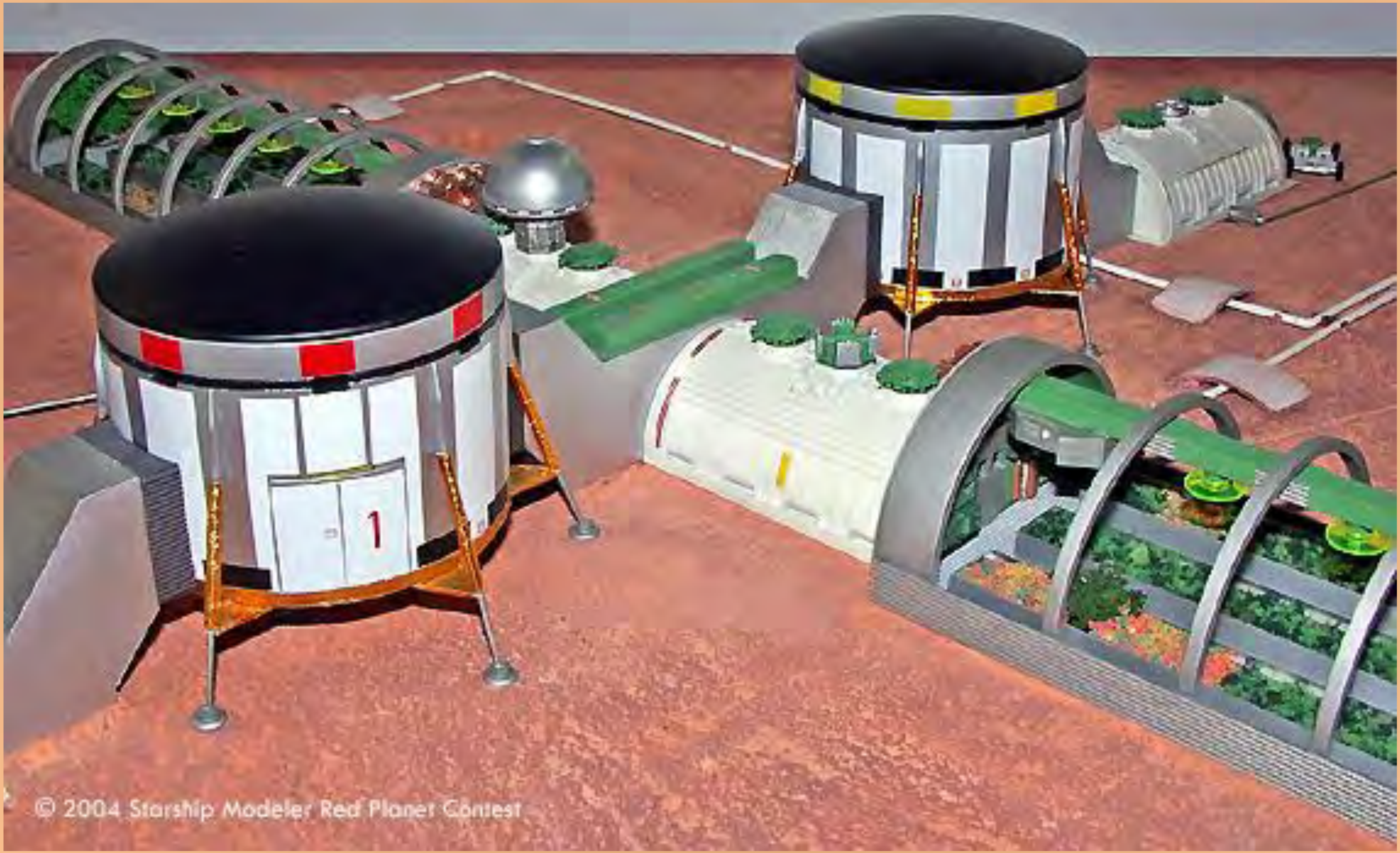
Space Agriculture

- For long term Lunar, Martian or Deep Space



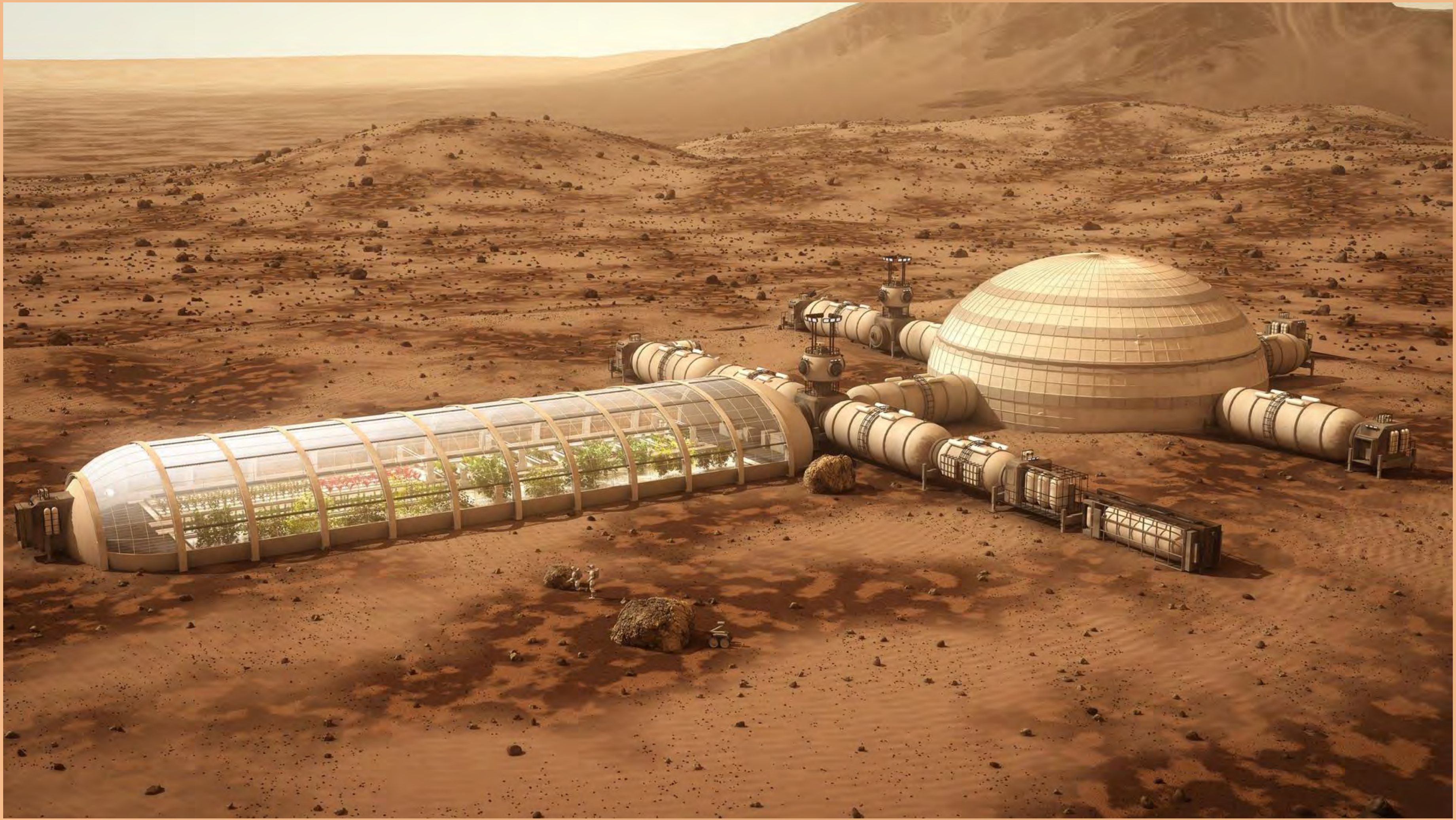
Small

Medium



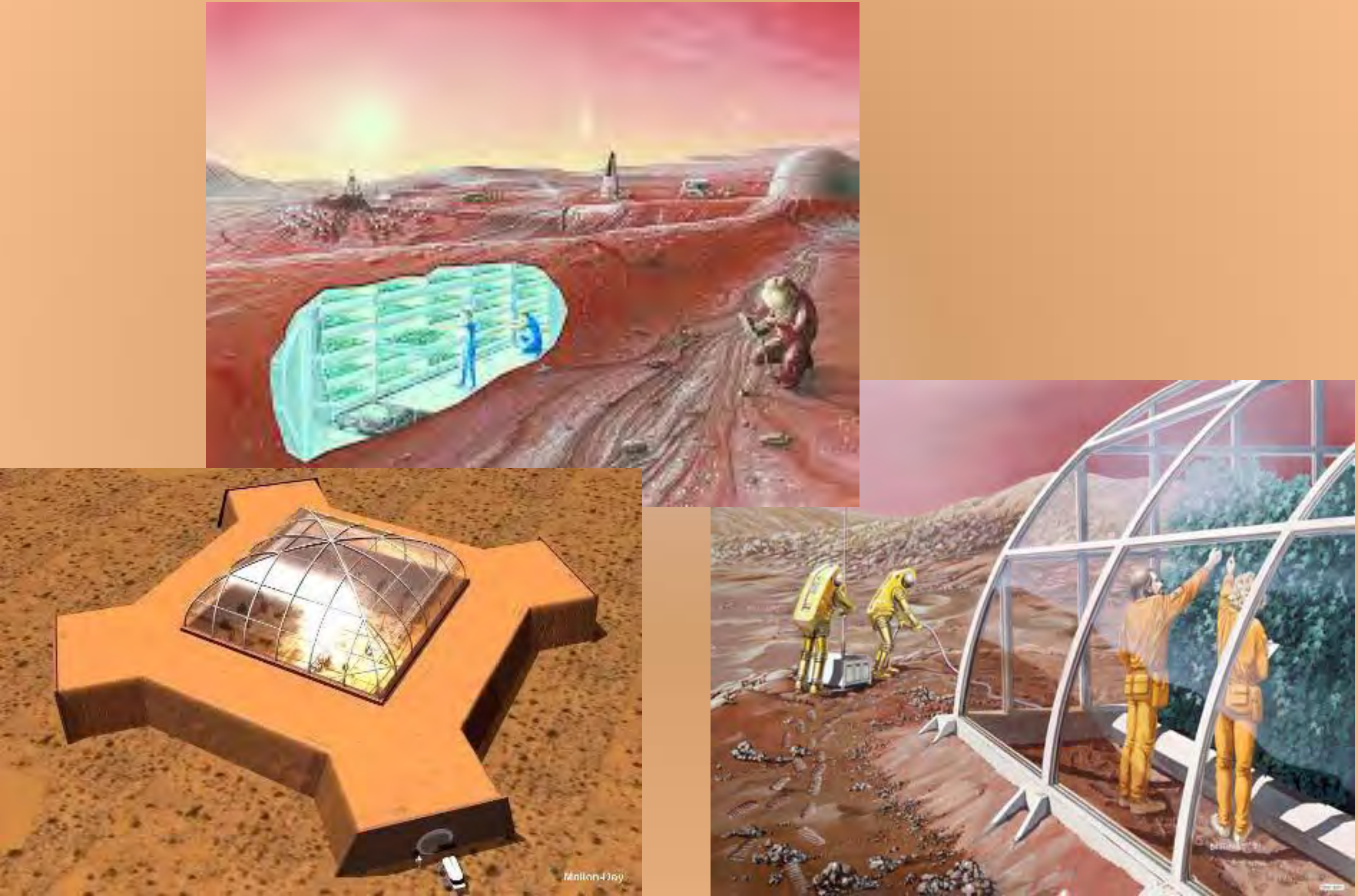
© 2004 Starship Modeler Red Planet Contest

Big

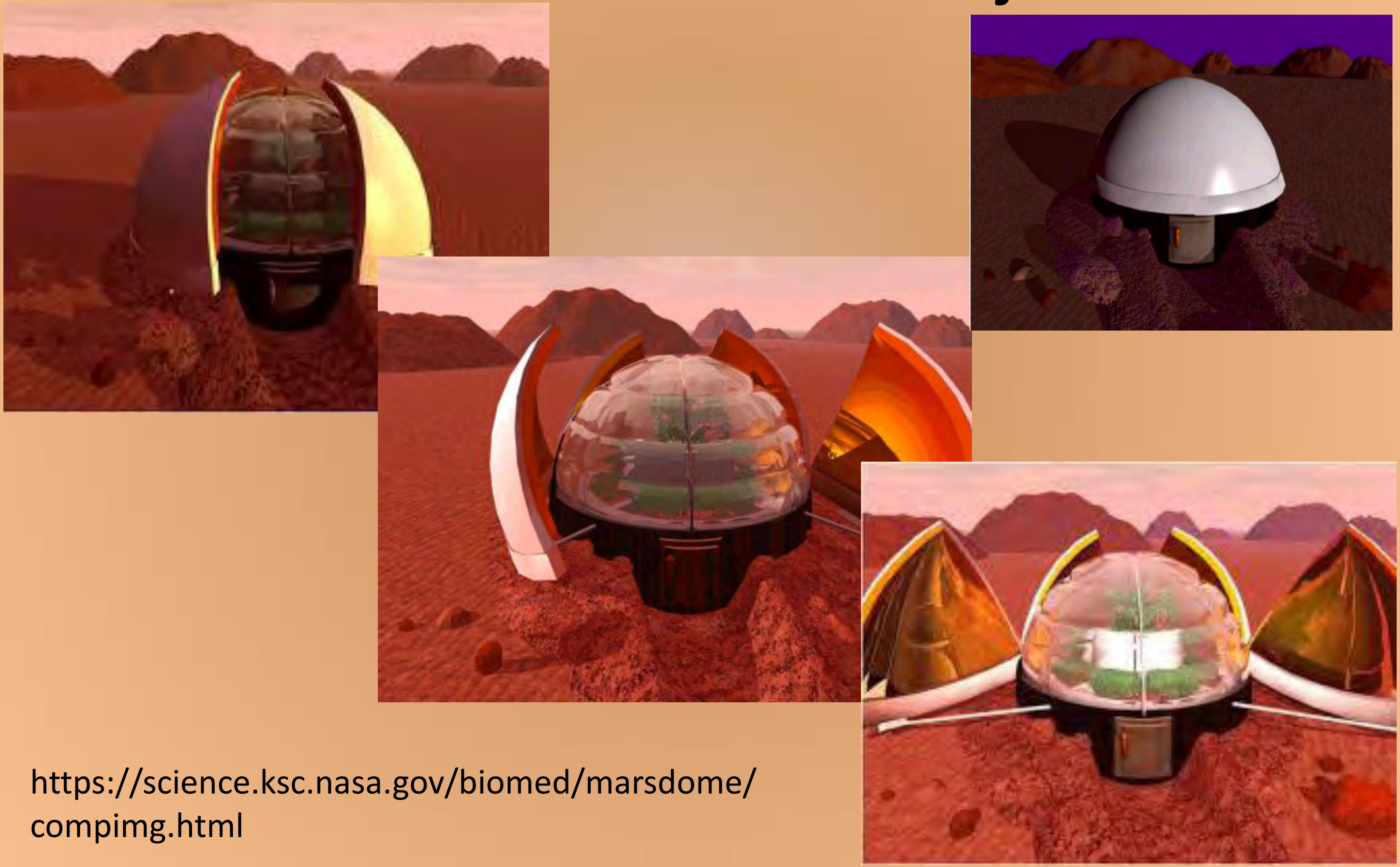


GRAPHIC BY PHIL SMITH, COPYRIGHT (C) 2005 BY MARS FOUNDATION. USED WITH PERMISSION.

Varying Safety Factors

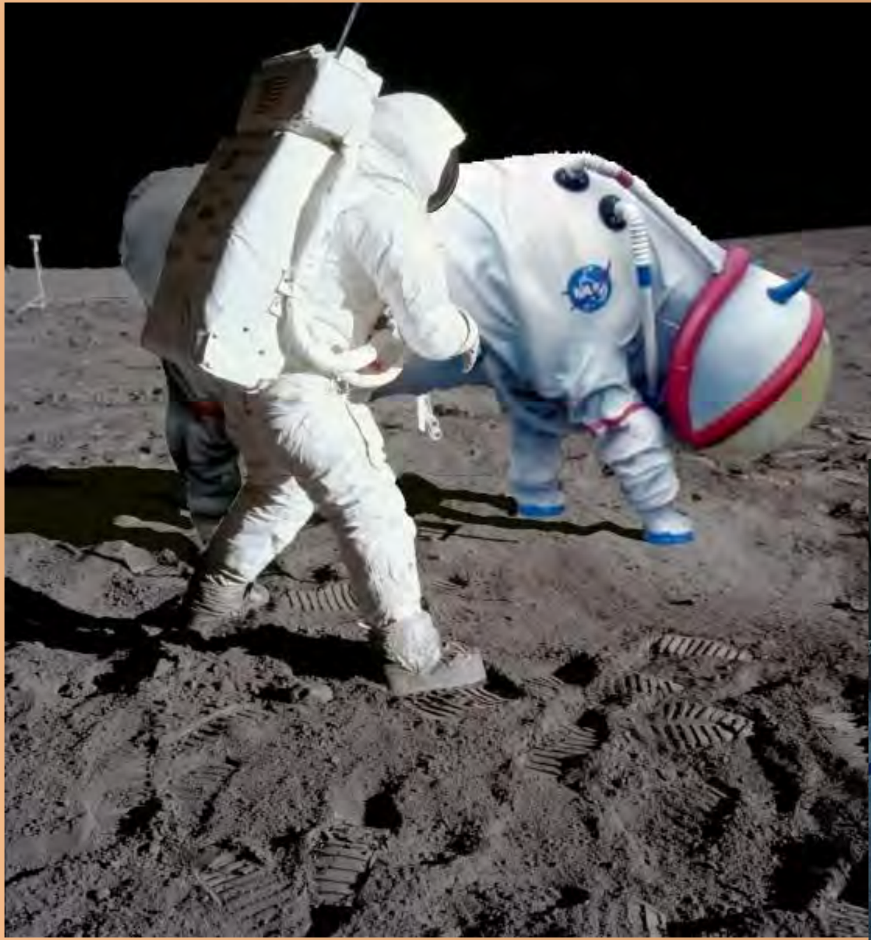


KSC Petal concept
Mars Greenhouse Project



https://science.ksc.nasa.gov/biomed/marsdome/compimg.html

Are astronauts doomed to be vegetarians??



THE UNIVERSITY OF
TEXAS
AT AUSTIN

Lunar Base

Mars Base

Mining Camp

“Modern mining camps are more than a place to sleep.”

- http://www.resourcesroadhouse.com.au/_blog/Resources_Roadhouse/post/Be_it_ever_so_humble%E2%80%A6/

Exploration Camps

a la Antarctica

Halley Base (UK)

Amundsen–Scott South Pole Station

Chinese Zhongshan Station

Benefits of Field Testing in Hawai`i

- 365 day testing
- Accessible by air and ship
- High-fidelity science and technical analog sites
- Abundance of tephra and *realistic* Martian and Lunar simulant. (Abundance of dust!)
- Topography similarities with potential LZ/EZ
- More affordable than arctic/antarctic sites

Prototype Lunar/Martian Base

Premise: There exists a compelling need for a analog facility to perform long-term (months to years) testing of equipment in a high-fidelity (dusty) operating environment.

- Durability, operational life expectancy, repair capability, swap-out methods
- Individual components (mining robots, ISRU processing ovens, transporters, habitats)
- Subsystems, systems and Systems of systems.

- Materials processing/manufacturing
    - (3-D, Sintering, compression, etc.)
- Human/robotic Co-operation (co-robotics)
- International & Commercial, public/private/NGOs
- Interface **Standards** for power, communications, data, fluids, fuel.

Certified and safety tested

A Mars version of an Underwriter’s Laboratory (*in the field*)

Agriculture Expertise

- UH Hilo has College of Agriculture
- UH Manoa has College of Tropical Agriculture and Human Resources (CTAHR)
- Major USDA research facility in Hilo
- Active student driven work, e.g.
  - Metabolic Engineering of Plants for Detoxification of Martian Regolithic Perchlorate – Shintaku, Hamilton, Thomas, Kalbec

Perclorates ($CL0_3$-) accumulate in food plants, some turning into chlorite ($CL0_2$). GMO a microbial chlorite dismutase gene may allow rapid detoxification of clorite eliminating the phytotoxic effects of chlorate and perchlorate.

Not a Biosphere

From this

To this!

THE INTERNATIONAL MOONBASE SUMMIT

ENABLING MULTINATIONAL PARTNERSHIPS
TOWARD A
SUSTAINABLE SPACE ECONOMY

MAUNA LANI BAY RESORT
KOHALA COAST – ISLAND OF HAWAII
OCTOBER 1 - 5, 2017

* * *

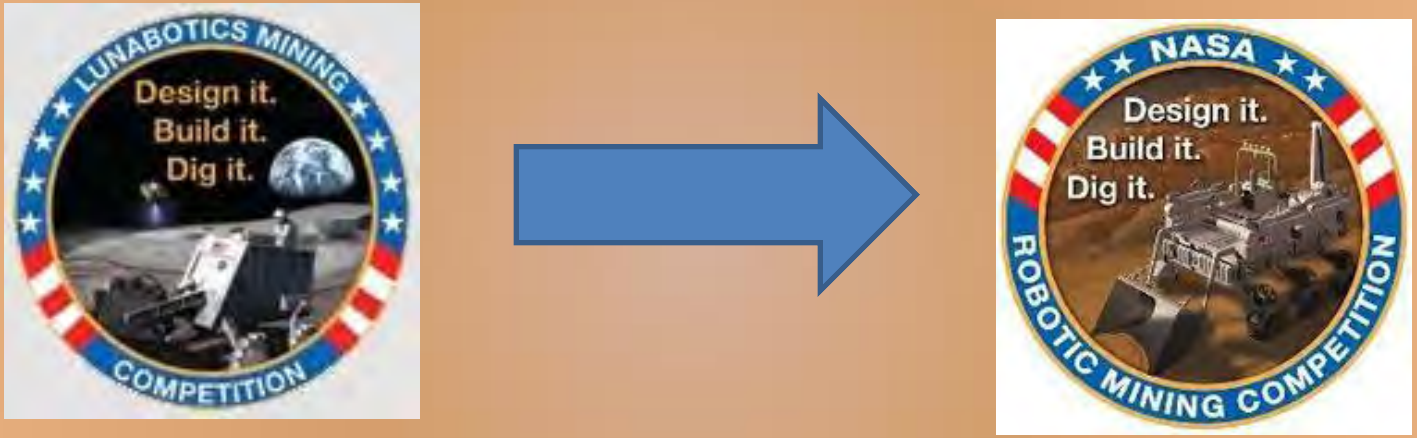
The International MoonBase Summit (IMS) will convene a team of leading scientists, entrepreneurs, and representatives from space agencies and associations worldwide to advance the development and implementation of a multinational base on the Moon.

The goal is to build upon discussions and recommendations from the Lunar Exploration and Analysis Group (LEAG), the European Lunar Symposium, the International Space Development Conference, the NewSpace Symposium, the International Astronautical

moonbasesummit@gmail.com
(808) 586-2388

Lunabotics to RMC

- Be it Moon or Mars, its all regolith!!



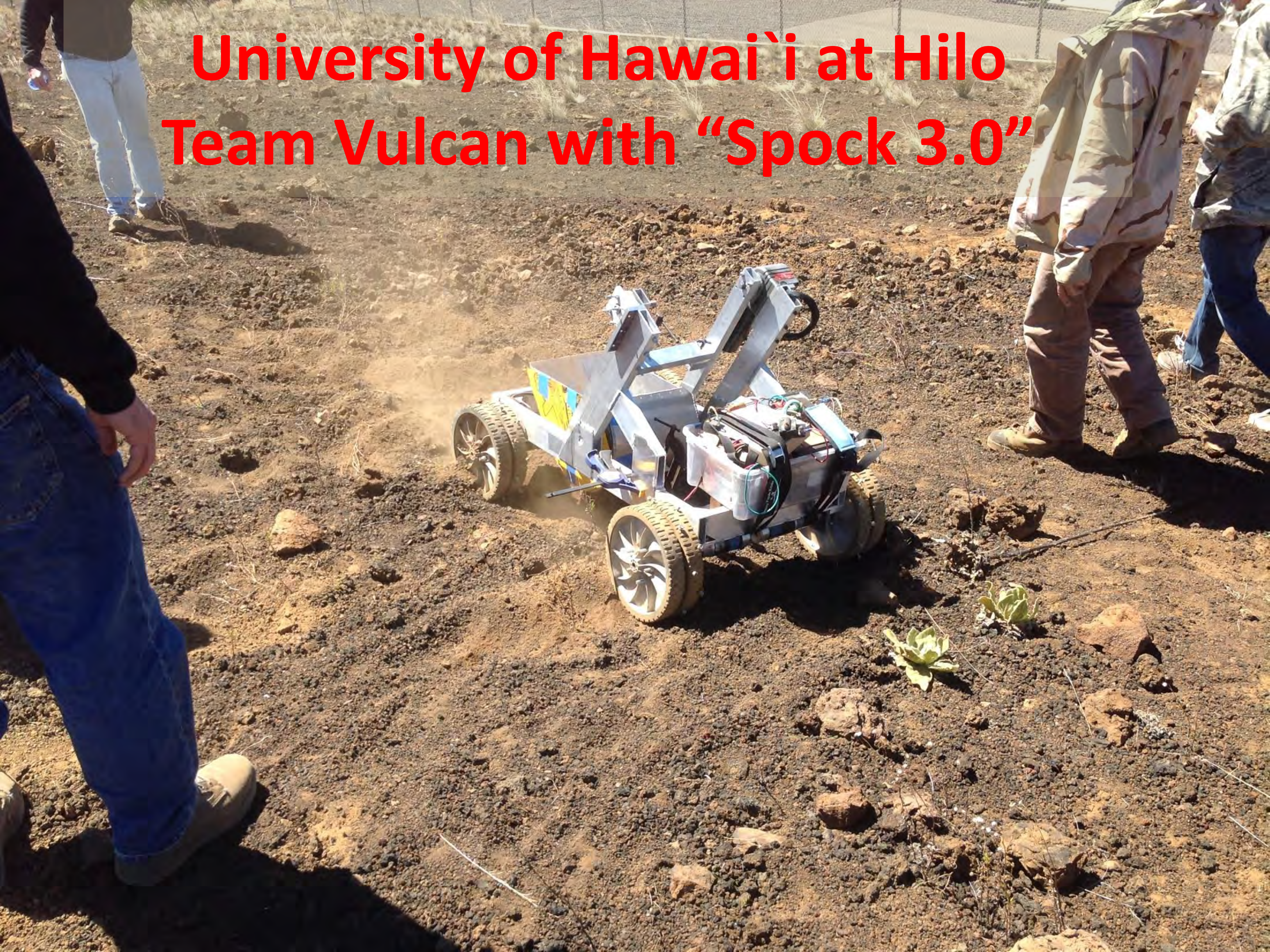
College design competition inside arena bin

Virtual rover college competition stressing autonomy with multiple robots (swarms).

2012 Lunabotics Winner U. Alabama

PRISM – 6 Lunabotics Teams into the Field Environment

University of Hawai`i at Hilo Team Vulcan with "Spock 3.0"



Traction in Tephra

2017 UH Hilo RMC Team Vulcan

VULCAN SPACE ROBOTICS TEAM

2016 - 2017

UNIVERSITY of HAWAI'I
HAWAI'I
COMMUNITY COLLEGE

Vulcans
University of Hawai'i at Hilo

UNIVERSITY of HAWAI'I
HILO


BREAKING
NEWS

2017

THE UNIVERSITY of
NEW MEXICO
Department of Computer Science

May 2, 2017

Dear Swarmathon Competitor:

On behalf of NASA, the University of New Mexico, and all of our partners, we congratulate your team on its participation in the 2017 NASA Swarmathon. We extend a special congratulations to our award-winning Virtual Teams!

1st place – Montgomery College
2nd place – University of Hawaii at Hilo
3rd place – Inter American University of Puerto Rico
Semi-Finalist – University of Houston - Downtown

The competition was fierce, the comradery was inspiring, and these in particular demonstrated algorithms that get us one step closer to swarming robots on Mars!

Questions?

Don’t make me be nice to you!

Fin