Surviving the Red Planet: Living and Working on Mars*

James F. Reilly[1]

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[1]Mach25Management, LLC, Colorado Springs, Colorado (jim@mach25mgmt.com)

Abstract

Compared to the Earth's cradle for humanity, Mars is a unique environment. It has a very low pressure atmosphere composed almost completely of carbon dioxide, about half the incident solar energy seen at Earth, an insignificant magnetic field where a large percentage of solar and cosmic radiation bathes the surface of the planet, and it has no water at the surface. Freezing is a warm day on Mars. Not a very hospitable place for future exploration crews to live for as long as a year and a half. In the face of the obvious list of challenges, the first explorers will need to utilize Martian resources to maintain a habitable environment. With the surface exposed to solar and galactic radiation, some form of protected central facility will be required. Experience from the extended duration missions aboard the International Space Station will provide a portion of the countermeasures technology, but a more fundamental technique will need to be employed by the surface geologists on Mars.

Maintaining a biosphere supporting human life will also be a huge challenge. We take for granted the systems that support us here, and as a result, our knowledge of just how these systems interact to keep our biosphere functioning is incomplete. Martian geologists will need to create and sustain their own biosphere (soil, water, air, and living systems) and fully understand how it works. The presence of subsurface ice in recoverable quantities will supply not only metabolic needs but a source of oxygen for atmospheric conditioning and a potential source for rocket engines and fuel cells. The challenge will be to find minable resources. To do that an exploration system very similar to that commonly used here on Earth in hydrocarbon exploration will need to be developed to find these resources. Will the presence of minable water define the location of the future facility? If so, the resource distribution will need to be assessed prior to sending the teams. This article will present some possible answers to these problems. Though there have been a number of what have been termed Martian analog experiences, none can fully expose the research teams to the true Martian environment. One of the few places that can get close will be on the Moon. For this, and other reasons, an extension of the lunar research program begun in the Apollo heroic phase of exploration needs to be an international space priority.

Presenter's notes: Diverse knowledge base.

BP Energy Outlook 2035 indicates population continuing to grow but more critically GDP is going to grow exponentially. Energy will be required to fuel that growth. Renewables, hydro, nuclear never amount to more than a few percent. Dominant energy sources will be hydrocarbons in the foreseeable future. Have to be creative to get there.

Moon first? DISTANCE EXAMPLE HERE

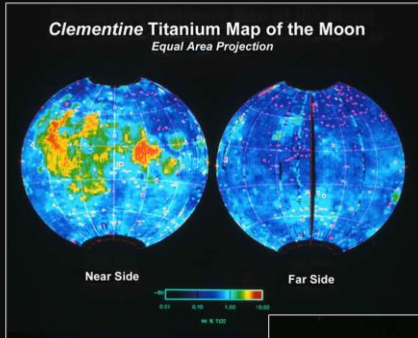
24,000,000 miles
6 months enroute

240,000 miles
3 days enroute

Don't know enough to go straight there…

Lunar prospecting

Resource harvesting for Mars mission support?



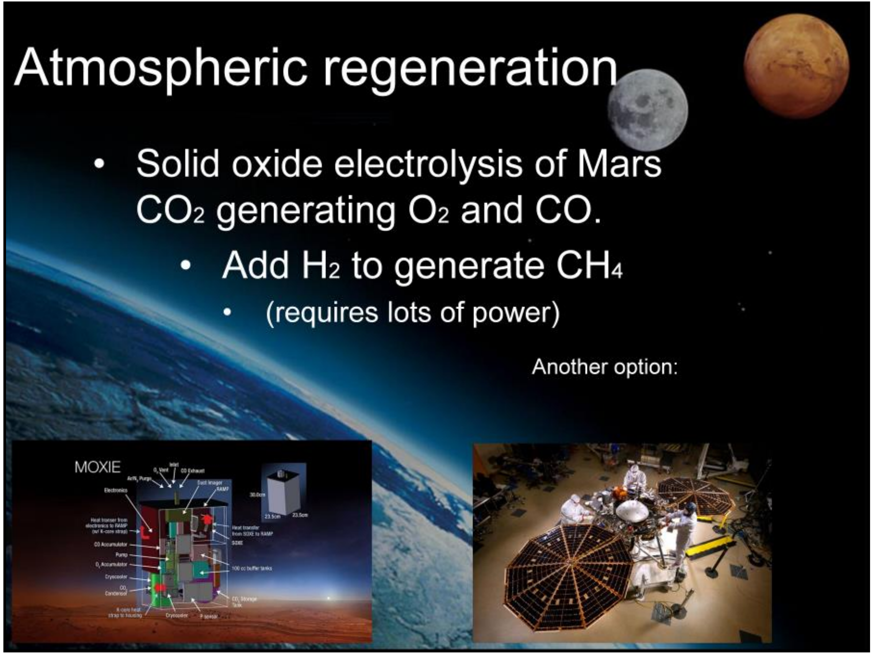

He3 harvesting from the movie "Moon"

Sony Pictures

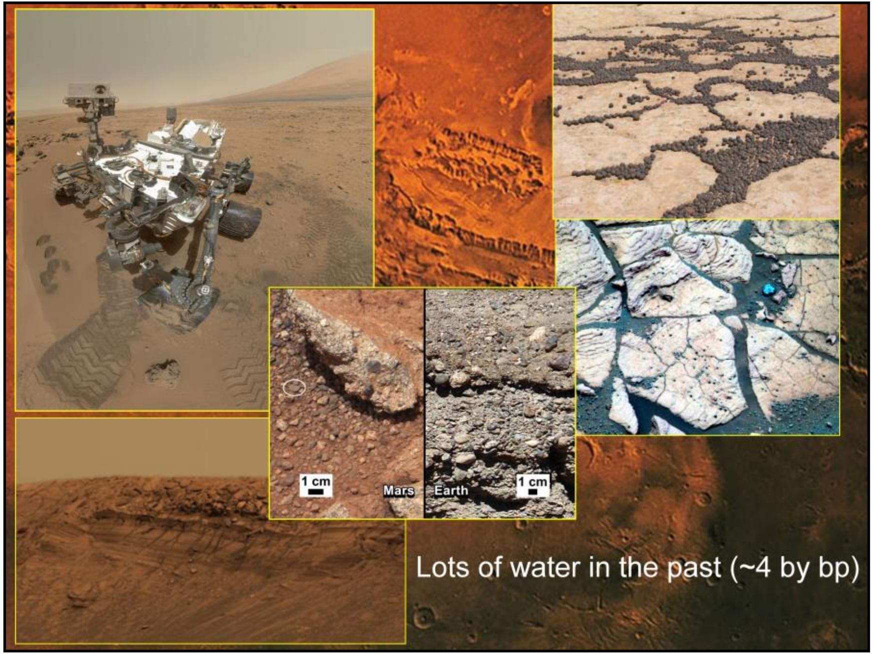
Resources Required for Mars Exploration Teams

- Atmospheric regeneration (add O_2, remove CO_2) for metabolic support (human and protein sources)
- H_2O for metabolic support (ice mining?)
- Energy
- Habitat protection
- Waste management
- Planetary protection

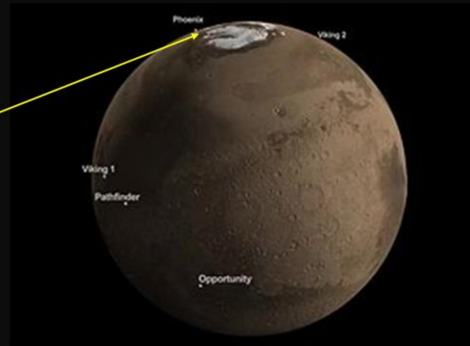
Presenter's notes: Fans of Frank Herbert's "Dune" storyline will instantly recognize the value assigned to water away from Earth.

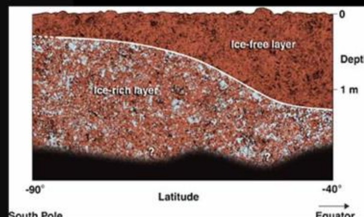


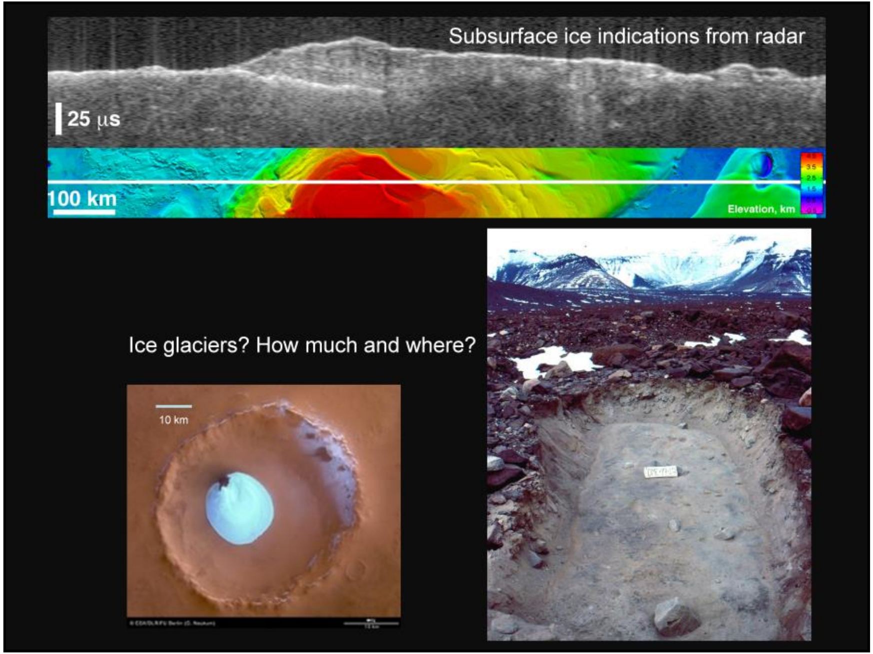
Presenter's notes: Mars Insight lander (2020) will carry the MOXIE experiment to test the ability to conduct solid oxide electrolysis. MOXIE payload on 2020 lander to test O_2 formation from CO_2 utilizing YSZ, yttira-stabilized zirconia, to strip O_2 generating CO (fuel cell in reverse) targeting 2g/hr production [how much power required? Notes from NASA in SpaceNews indicates a RTG or other high-power system to generate the power for a 100x scaled up version of MOXIE]. Solid oxide electrolysis CO byproduct can be combined with H_2 to form methane (propellant or chemosynthetic organism feedstock).


1 cm
Mars
Earth
1 cm
Lots of water in the past (~4 by bp)

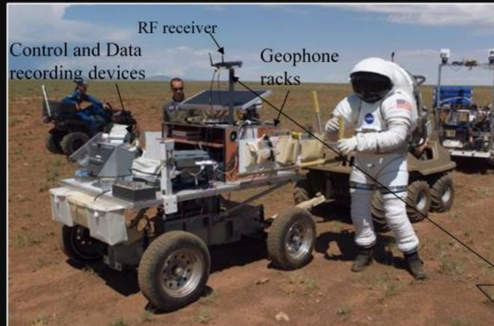
Where is it? In-situ water resources







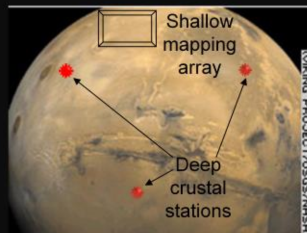
Presenter’s notes: ESA Maars Express MARSIS radar image of south polar layered ice deposits.

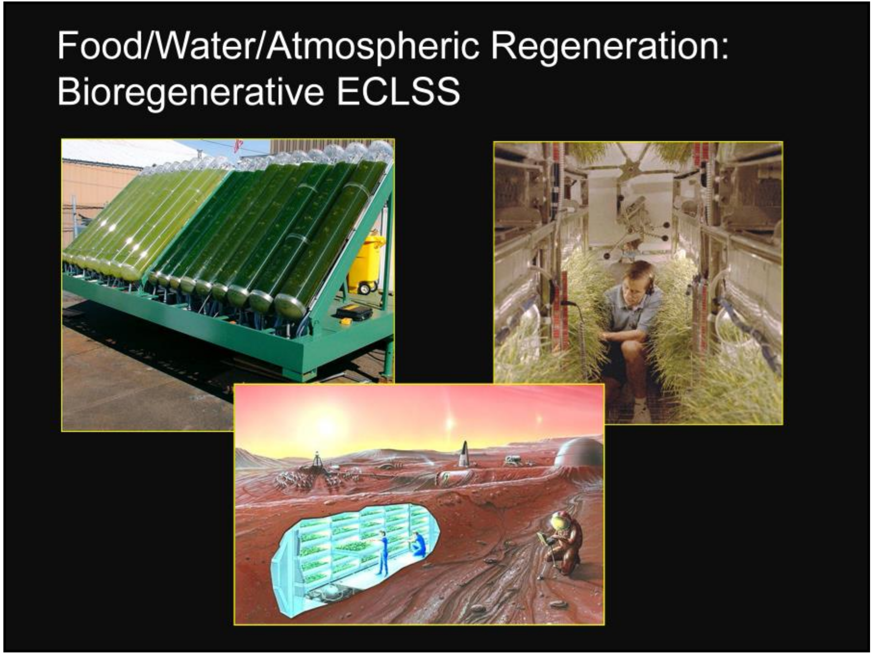


RF geophone and recording devices

Planetary geophysics

1. identify resource concentrations prior to human arrival
2. Planetary research
3. Human-aided systems ("3D") to high-grade prospects





Presenter's notes: Human production of CO_2: 1 kg/person/day.

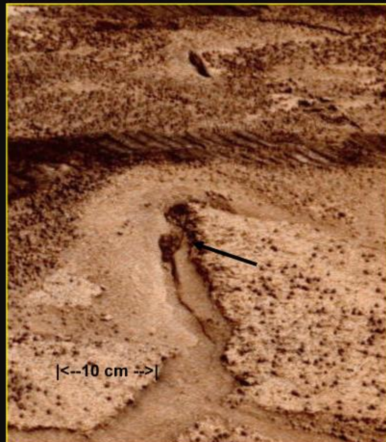
30K wheat plants/person; for a 5 person crew=150K plants, around 0.25 ha soil.

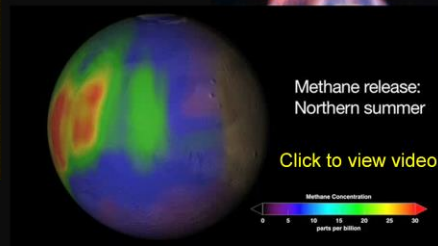
For good yields the fertilizer requirements are up to 150 kg/ha N, 35 to 45 kg/ha P and 25 to 50 kg/ha K.

1 kg algae/person.

A good commercial grain yield is 6 to 9 ton/ha (10 to 13 percent moisture). The water utilization efficiency for harvested yield (Ey) for grain varies then between 0.8 and 1.6 kg/m^3 (equals 4.5-8 kg water/ton).

Methane on Mars? Resource/feedstock?



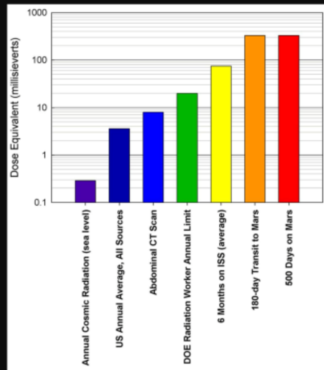


Presenter's notes: At least 8 Saturn V-type missions to deliver this payload to the surface. Does not include consumables. At 10 liters/day/person and assuming a 5 person crew for 544 days (NASA reference mission) this results in 27,200 liters or 27,200 kg for 540 days, this results in another mission just to haul water. Mars One in 2024; 2 then 2 crews in the plan. Not much more than that. Budget has been only enough to support 2 reality TV shows. Funding from the shows is hoped to generate the billions required (unlikely).

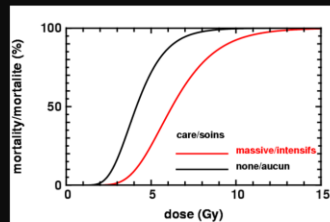
Design team have major technical challenges to overcome before this becomes the ultimate reality show which just might turn public opinion against human exploration of Mars.

One-way trip is not how we have ever done exploration.

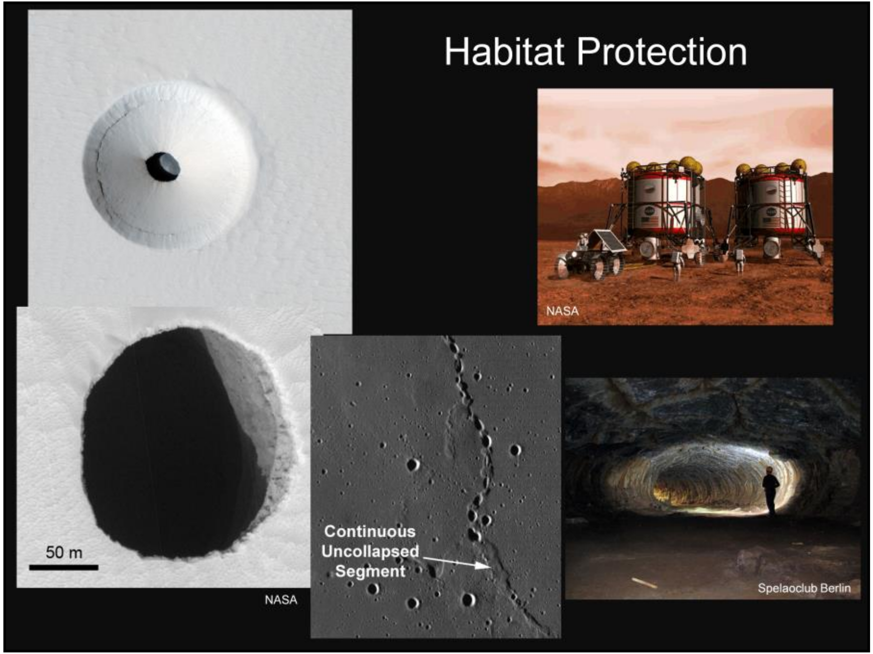
Radiation Exposures Missions to Mars



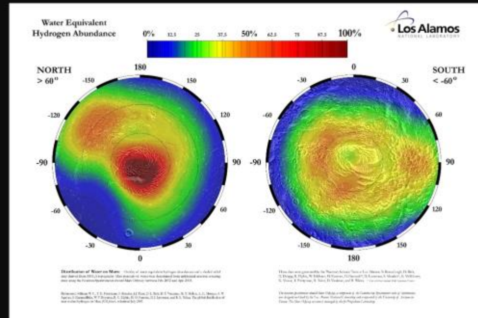
Bottom line: radiation to/from Mars and on the surface will likely be life limiting

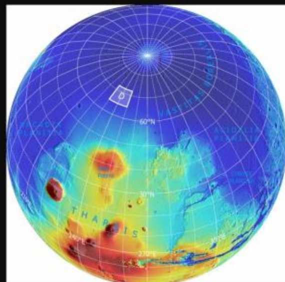


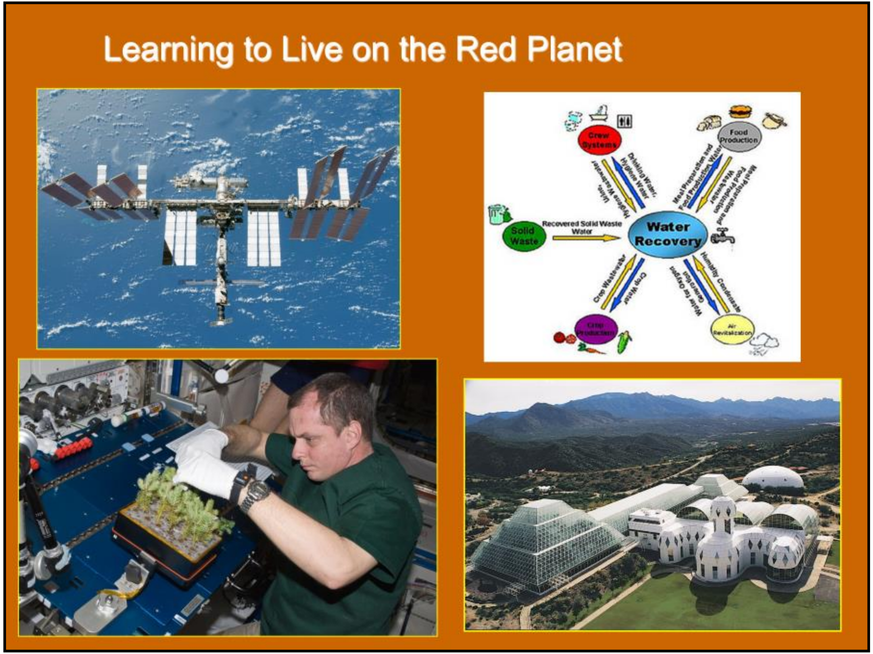
Presenter’s notes: A total mission dose equivalent of ~1.01 Sv for a round trip Mars surface mission with 180 days (each way) cruise, and 500 days on the Martian surface for this current solar cycle.


Habitat Protection
50 m
NASA
Continuous
Uncollapsed
Segment
NASA
Spelaoclub Berlin

Habitat Protection vs Water Resources







Presenter's notes: R&D and testing of techniques already underway on the ISS; Moon is ideal intermediate destination for field lab.

Biosphere 2 was only used twice for its original intended purposes as a closed-system experiment: once from 1991 to 1993, and the second time from March to September 1994. Both attempts, though heavily publicized, ran into problems including low amounts of food and oxygen, die-offs of many animal and plant species, squabbling among the resident scientists and management issues.

Moon as a test bed and potential mining facility

Conclusions

- Atmospheric regeneration
  - Chemical system
  - Bio-Regenerative
    - Supports food production and waste management
- Water may be common
  - Economic deposits prior to crew arrival
  - Meets metabolic, atmospheric makeup, crop and protein support

Conclusions

- Habitats will likely be subsoil for radiation protection.
  - Find suitable locations (e.g., lava tubes)
- Value? Depends…Long or short term ROI?

Human Engineering

“ We should never cease exploring for the end of our exploration
will be to arrive where we began and see it all again for the first time.”

- T. S. Eliot