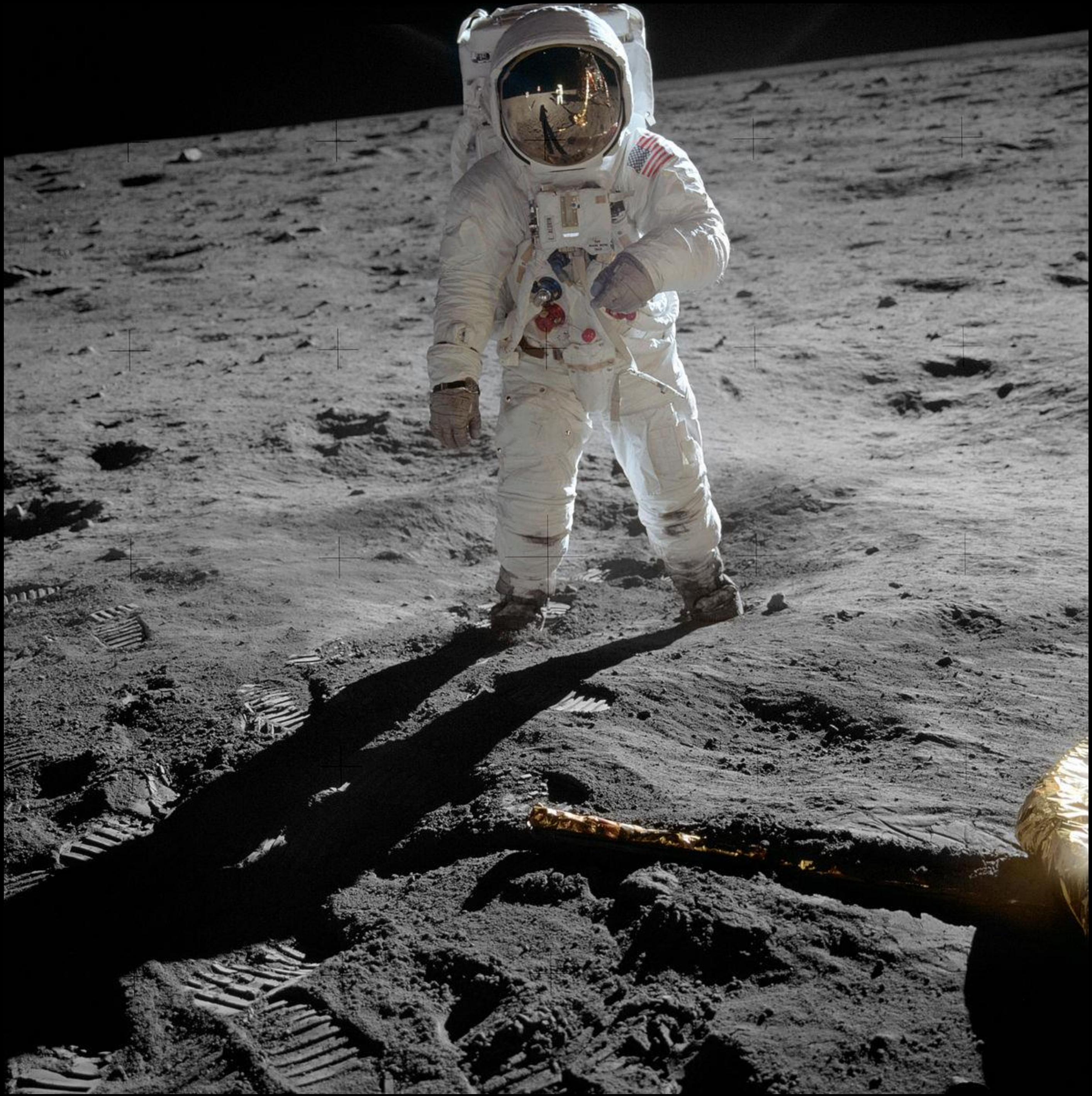
To Mars – and back again!

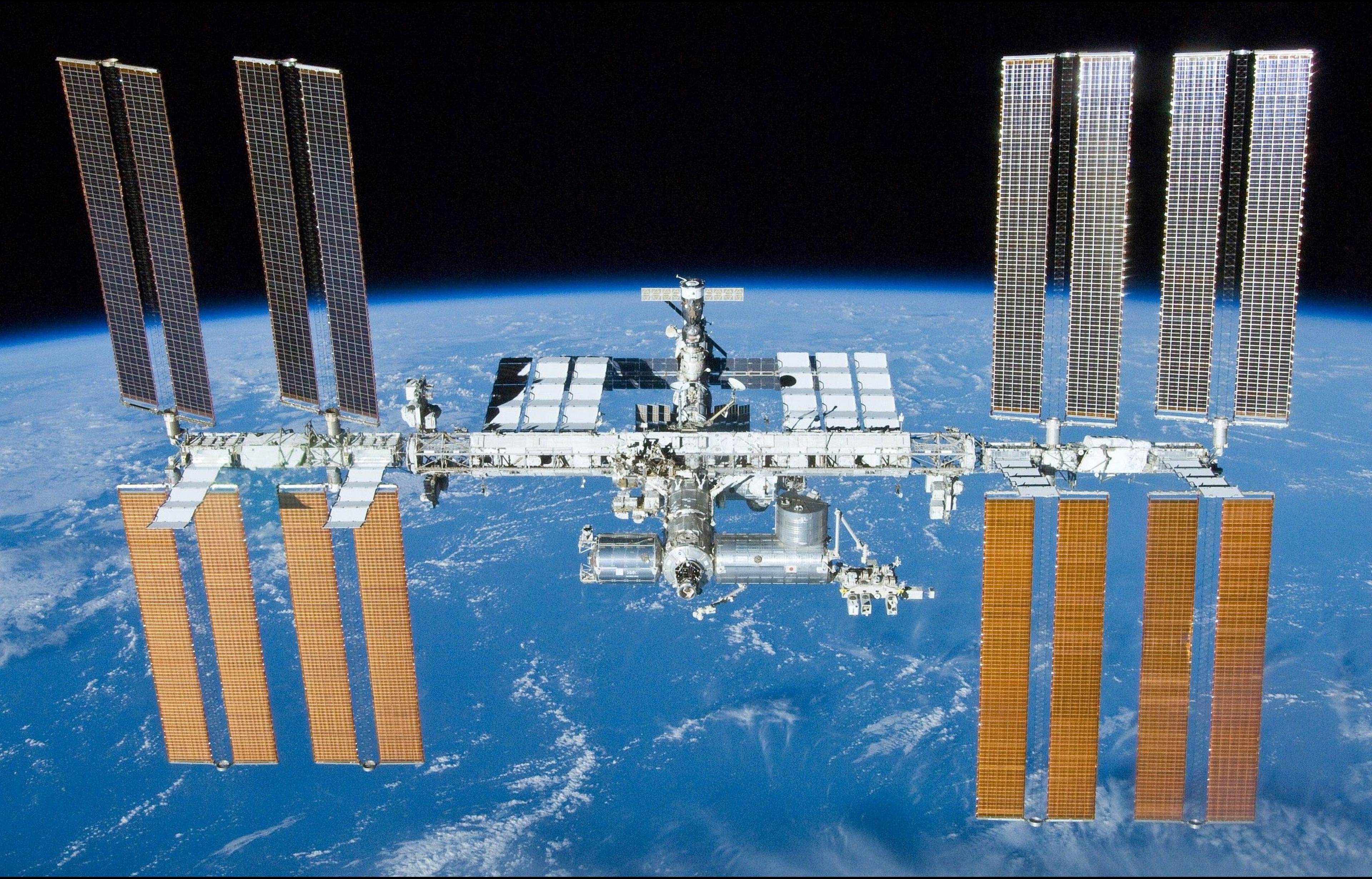
1957

1961

1969



1995



Humans → Mars Challenges

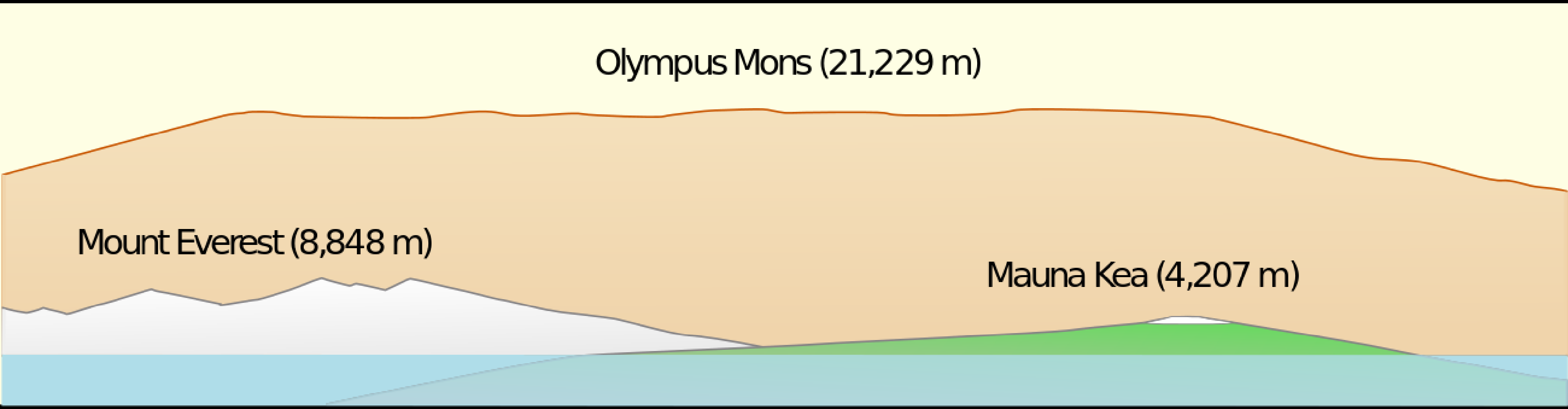
- Getting there
- Radiation
- Low gravity
- Resources
- Distance from Earth
  - Long mission duration
  - Isolation
  - Psychological health
  - Time delay

Credit: NASA

About Mars

- 142 million miles from Sun (average)
- Year: 687 Earth days
- Day: approx. 24hrs and 39 minutes
- Moons: Phobos and Deimos
- Gravity: ~1/3G
- Atmosphere: ~0.6% of Earth's, mostly CO_2
- No magnetosphere (dynamo stopped ~4Gya)

Olympus Mons



https://en.wikipedia.org/wiki/List_of_tallest_mountains_in_the_Solar_System

Lava Tubes

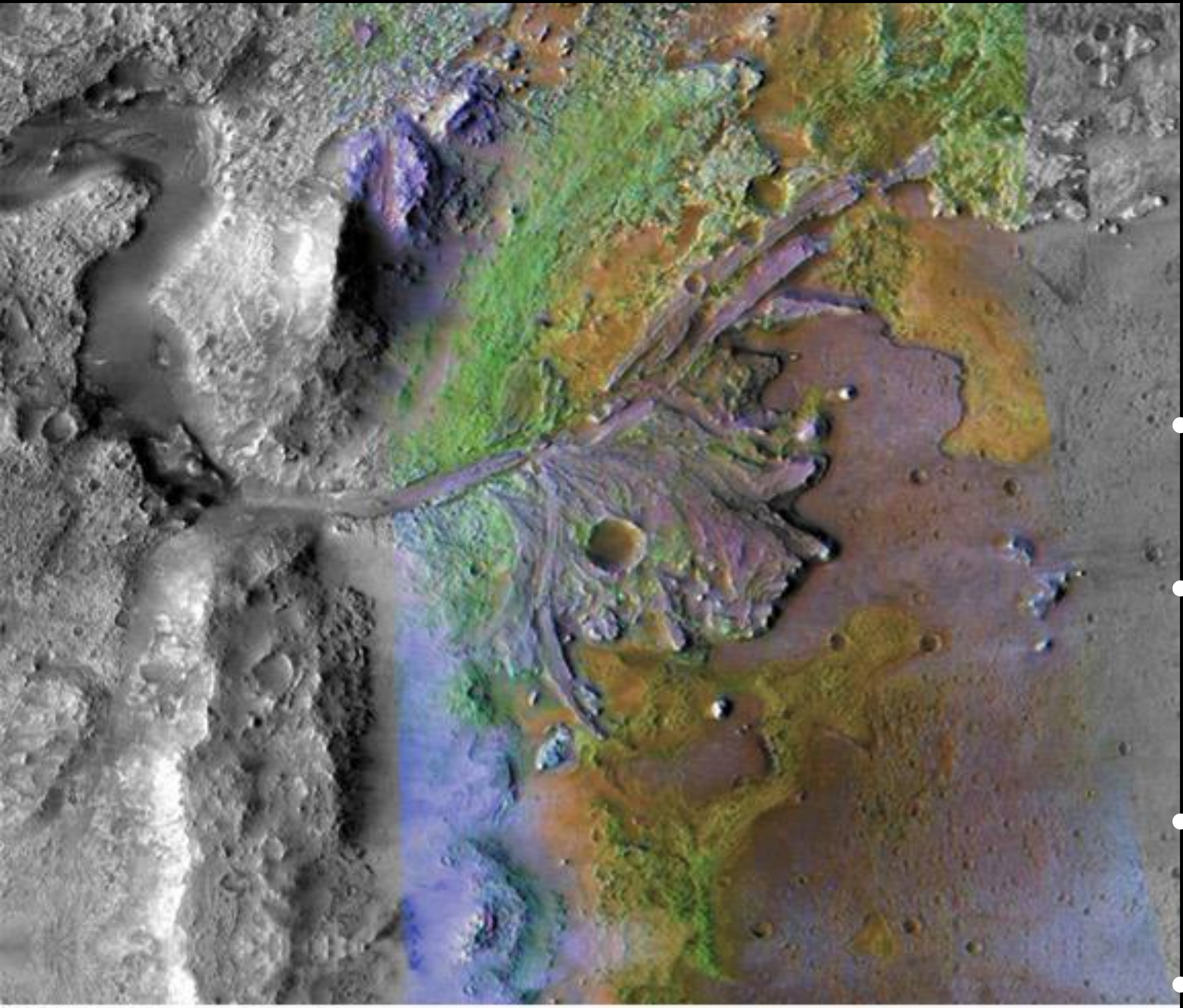
https://www.newscientist.com/article/dn9220-lava-tubes-snapped-snaking-across-mars/

Why lava tubes?

- *Geology:* access to rocks relatively preserved from surface weathering
- *Biology:* stable temperature, radiation protection, conditions may be favorable for stable water ice
- *Exploration:* natural shelters, subsurface volatiles, potential hazards

Credit: HI-SEAS

Early Mars (~3.5Gya ago)

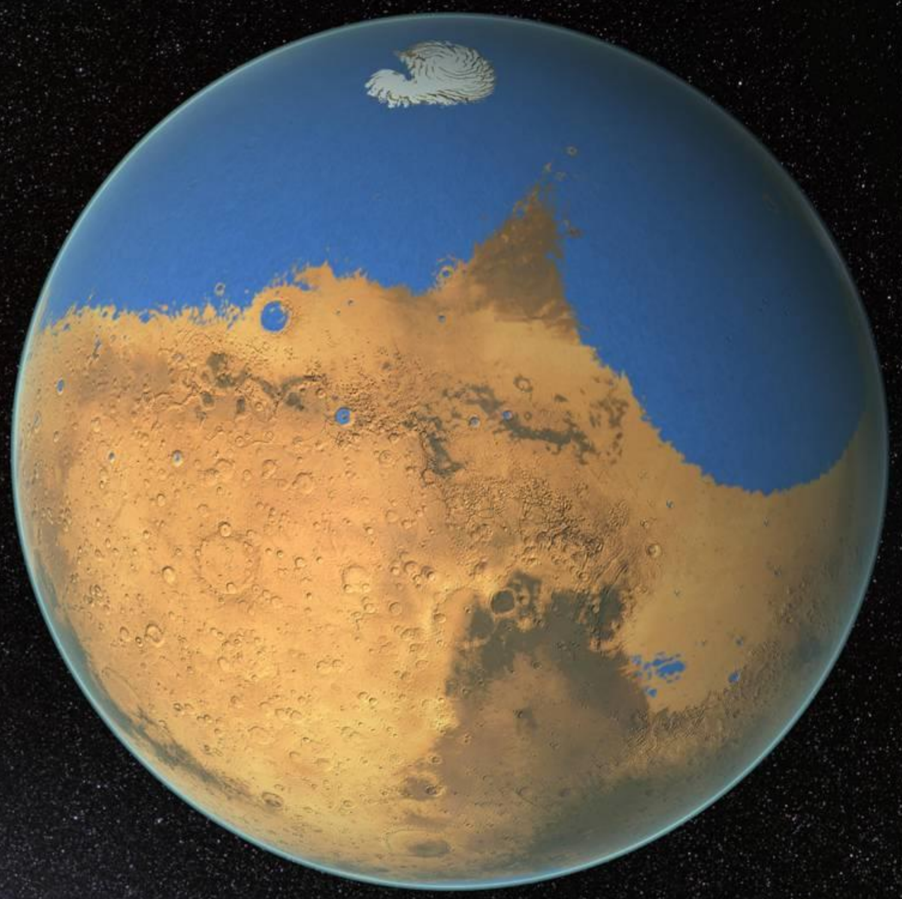


The western fan of the **Jezero delta** is believed to have formed when a lake occupied the crater ealry in Mars' history. Jezero crater is located at 18.9°N and 77.5° East. **Color shading represents minerals mapped by the CRISM instrument on MRO:** phylosilicates are green, olivines are yellow, and pyroxenes are blue/purple (see Ehlmann et al., 2008).

- Thicker atmosphere
- Warmer (greenhouse effect)
- Liquid water on surface
- Life?

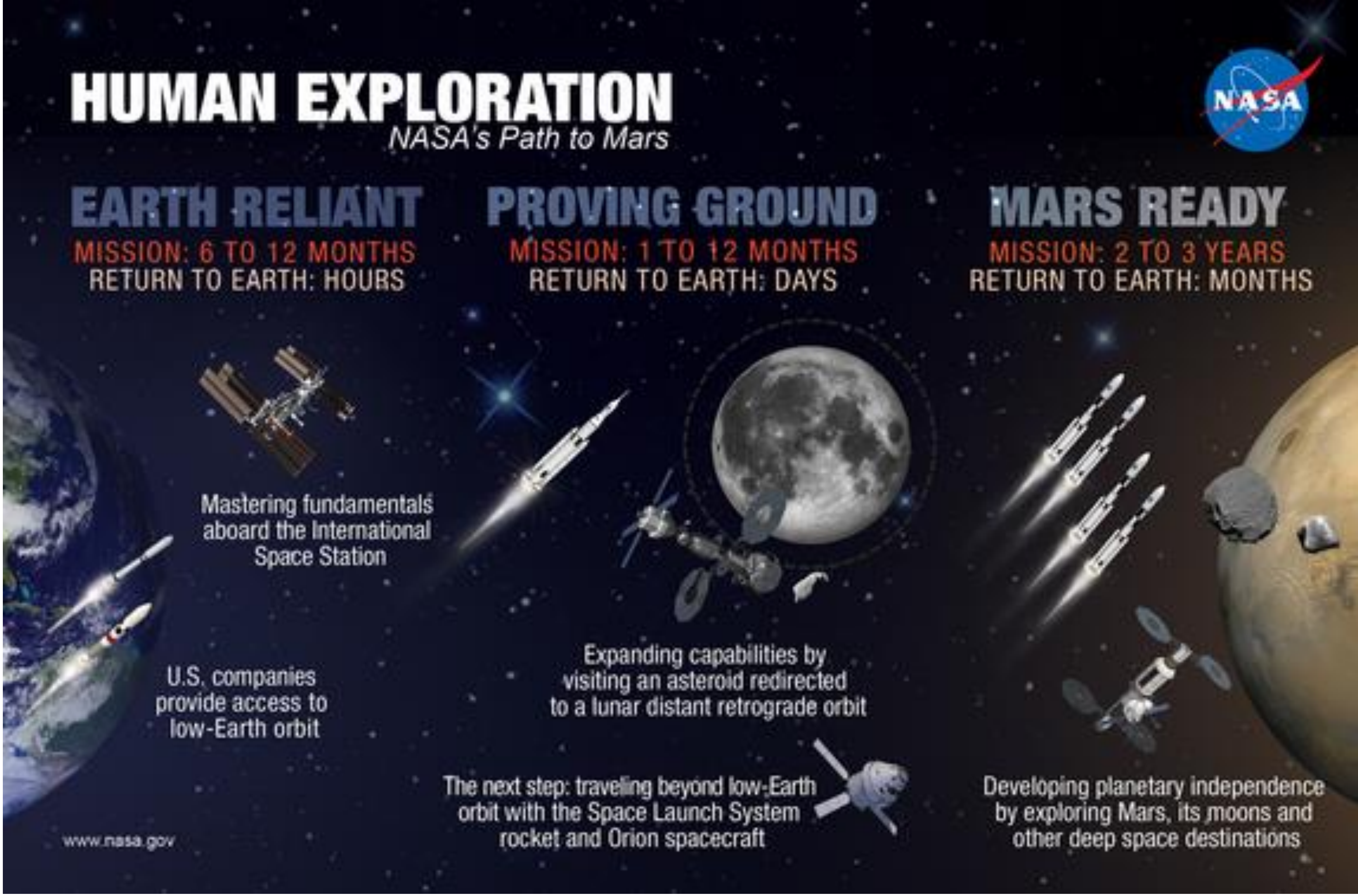
Mars Ocean?

- N hemisphere is lower, flatter and less cratered than S hemisphere
- Ocean was about the same size as Arctic Ocean?
- 87% of water lost to space?
- Or: could be impact feature



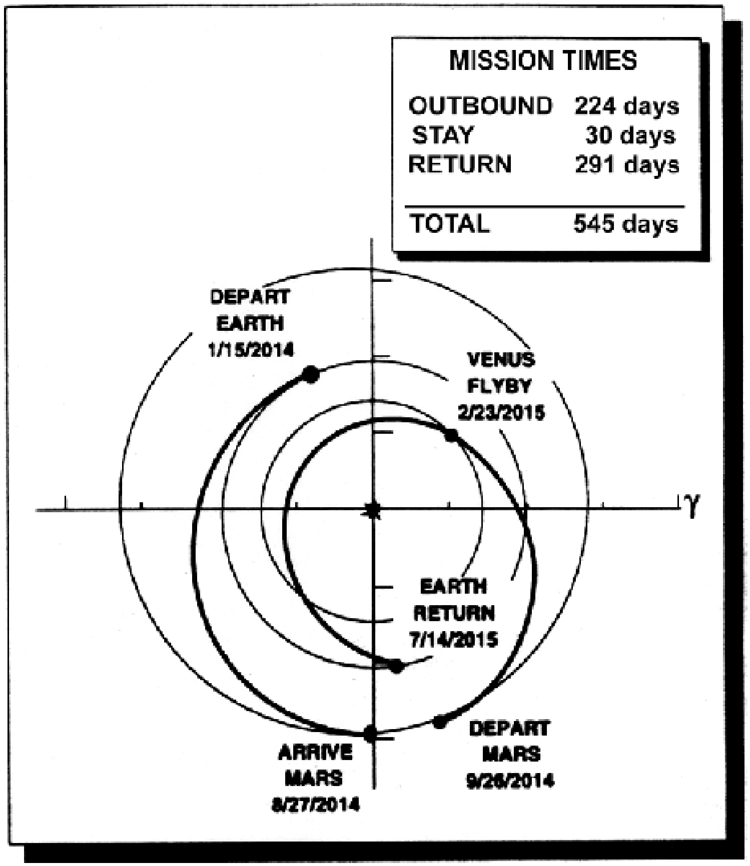
National Aeronautics and Space Administration https://www.nasa.gov/press/2015/march/nasa-research-suggests-mars-once-had-more-water-than-earth-s-arctic-ocean


Human Exploration of Mars
Design Reference Architecture 5.0



National Aeronautics and Space Administration

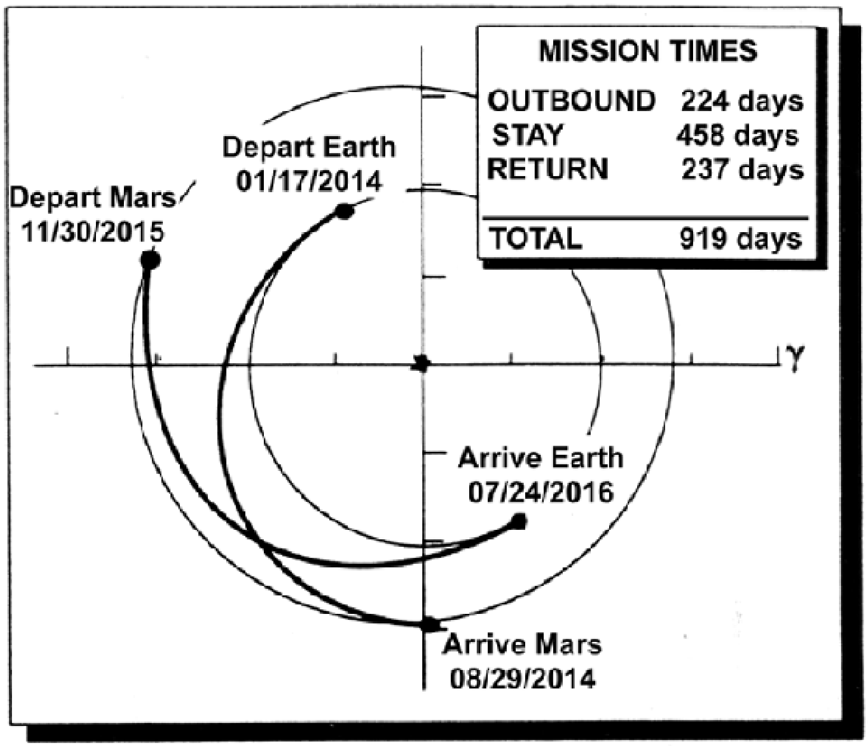
Mission Profile Option 1: Short Stay



- AKA: “Opposition Class” mission
- Pro: shortest overall time
- Con: A lot of time in space (the most dangerous part), little on the surface

http://nssdc.gsfc.nasa.gov/planetary/mars/marsprof.html

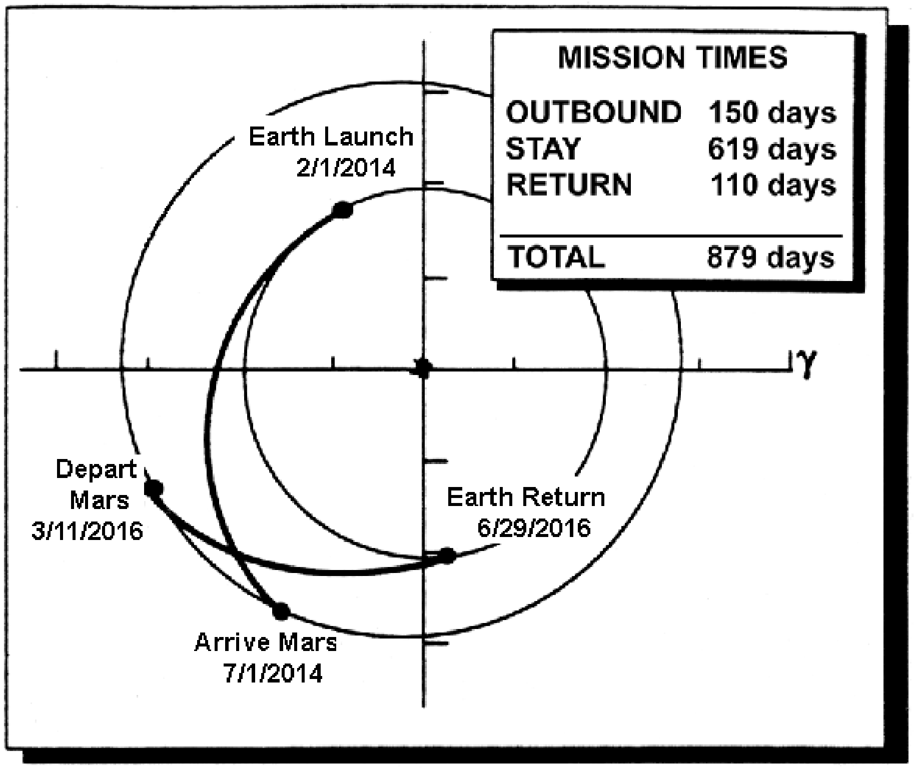
Mission Profile Option 2: Long Stay, Minimum Energy



- AKA "Conjunction Class" mission
- Pro: Less time in space, more on surface, less energy ($$) overall
- Con: Longest total time

http://nssdc.gsfc.nasa.gov/planetary/mars/marsprof.html

Mission Profile Option 3: Long Stay, Faster Transit

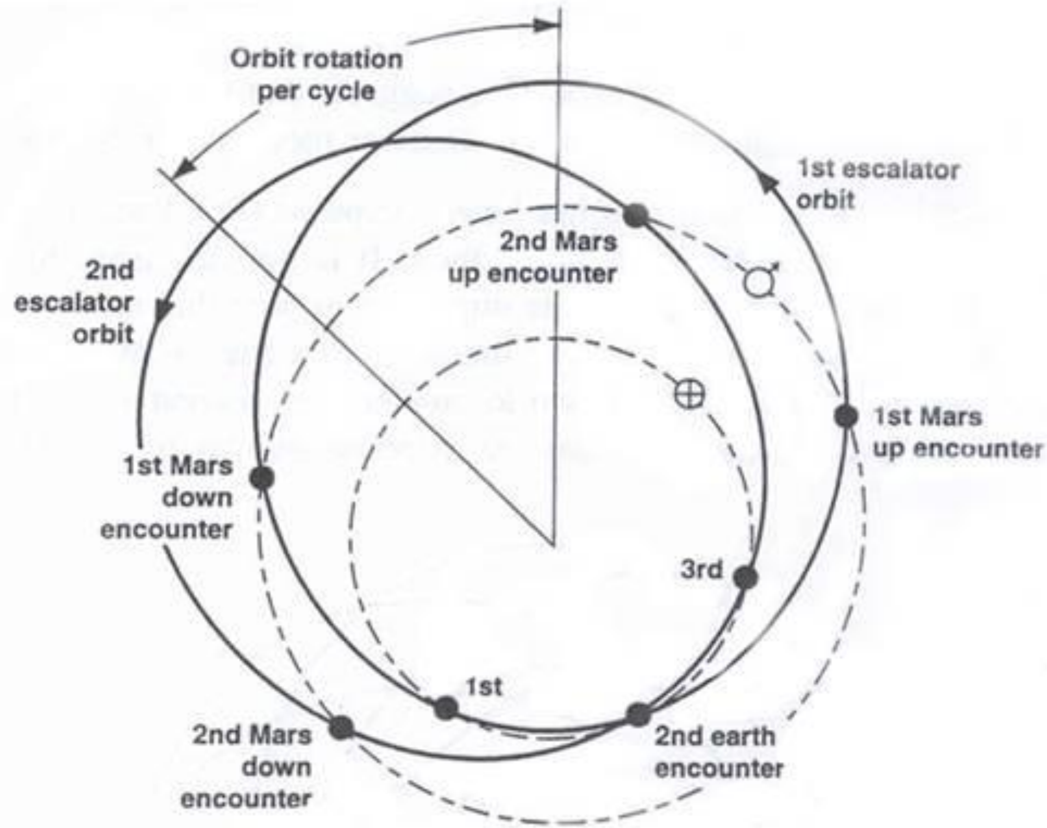


- Similar to 3, but adding propulsion to reduce transit time
- Makes overall mission slightly shorter
- More importantly, reduces time in space by ~100 days each way.
- Preferred option in DRA 5

http://nssdc.gsfc.nasa.gov/planetary/mars/marsprof.html

Another option: The Aldrin Cycler

- https://www.youtube.com/watch?v=qCVfUlFZQ4U
- Pro: once set up, minimizes propellant, transit ship can have heavy shielding
- Still requires heavy lift from planetary surfaces - and they have to be *fast* to catch up with the cycler!
- More upfront expense



Up/Down Escalator Cycler Orbits

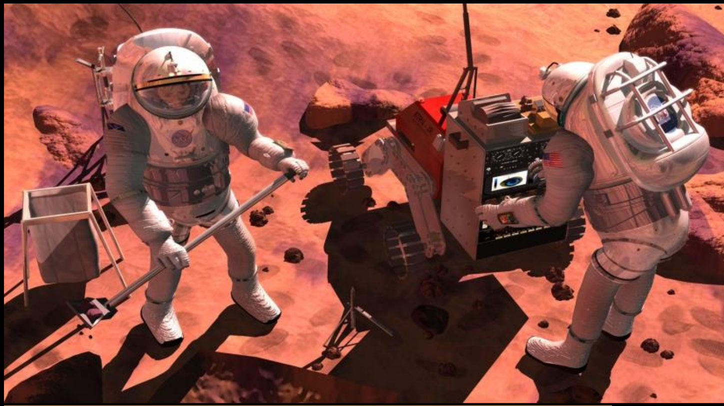
http://courses.ae.utexas.edu/ase333t/past_projects/04spring/Cycler%20Website/cyclers.html

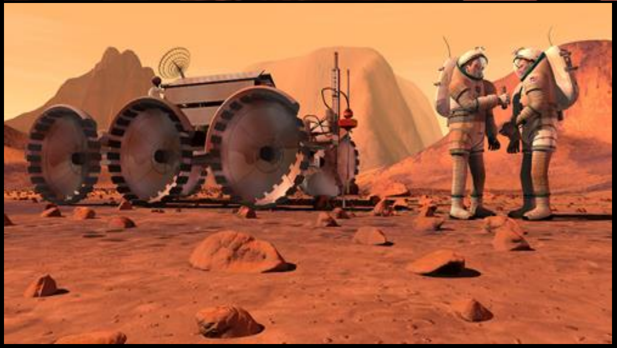
Mars Design Reference Architecture 5.0

- Twenty-six months prior to crew departure from Earth, pre-deploy:
  - Mars surface habitat lander to Mars orbit
  - Mars ascent vehicle and exploration gear to Martian surface
  - Deployment of initial surface exploration assets
  - Production of ascent propellant (oxygen) prior to crew departure from Earth
- Crew travel to Mars on “fast” (six month) trajectory
  - Reduces risks associated with zero-g, radiation
  - Rendezvous with surface habitat lander in Mars orbit
  - Crew lands in surface habitat which becomes part of Mars infrastructure
  - Sufficient habitation and exploration resources for 18 month stay

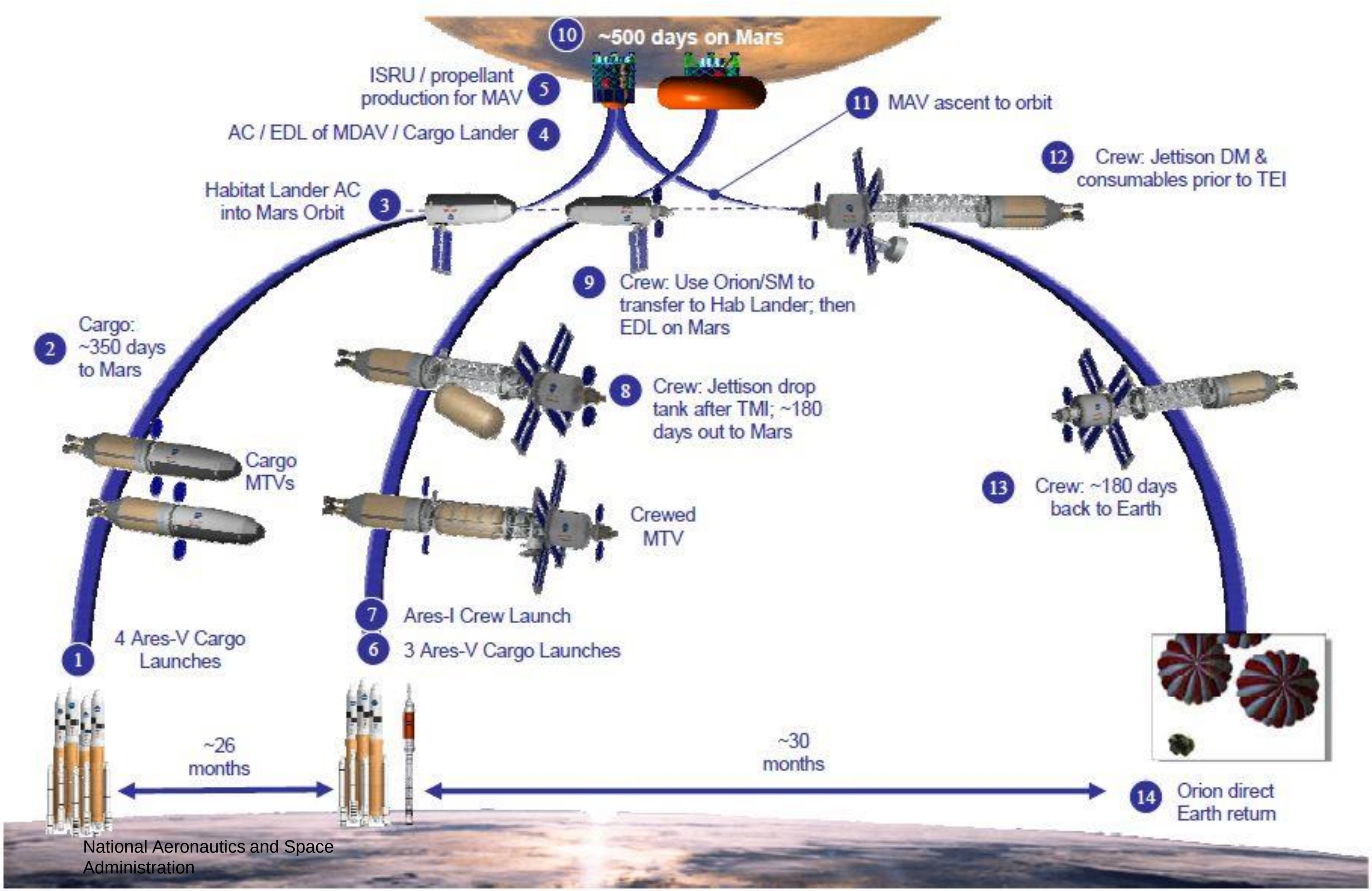
Surface Exploration and Discovery

- Long surface stays with visits to multiple sites provides scientific diversity thus maximizing science return
- Mobility at great distances (100’s km) from the landing site enhances science return (diversity)
- Subsurface access of 100’s m or more highly desired
- Advanced laboratory and sample assessment capabilities necessary for high-grading samples for return



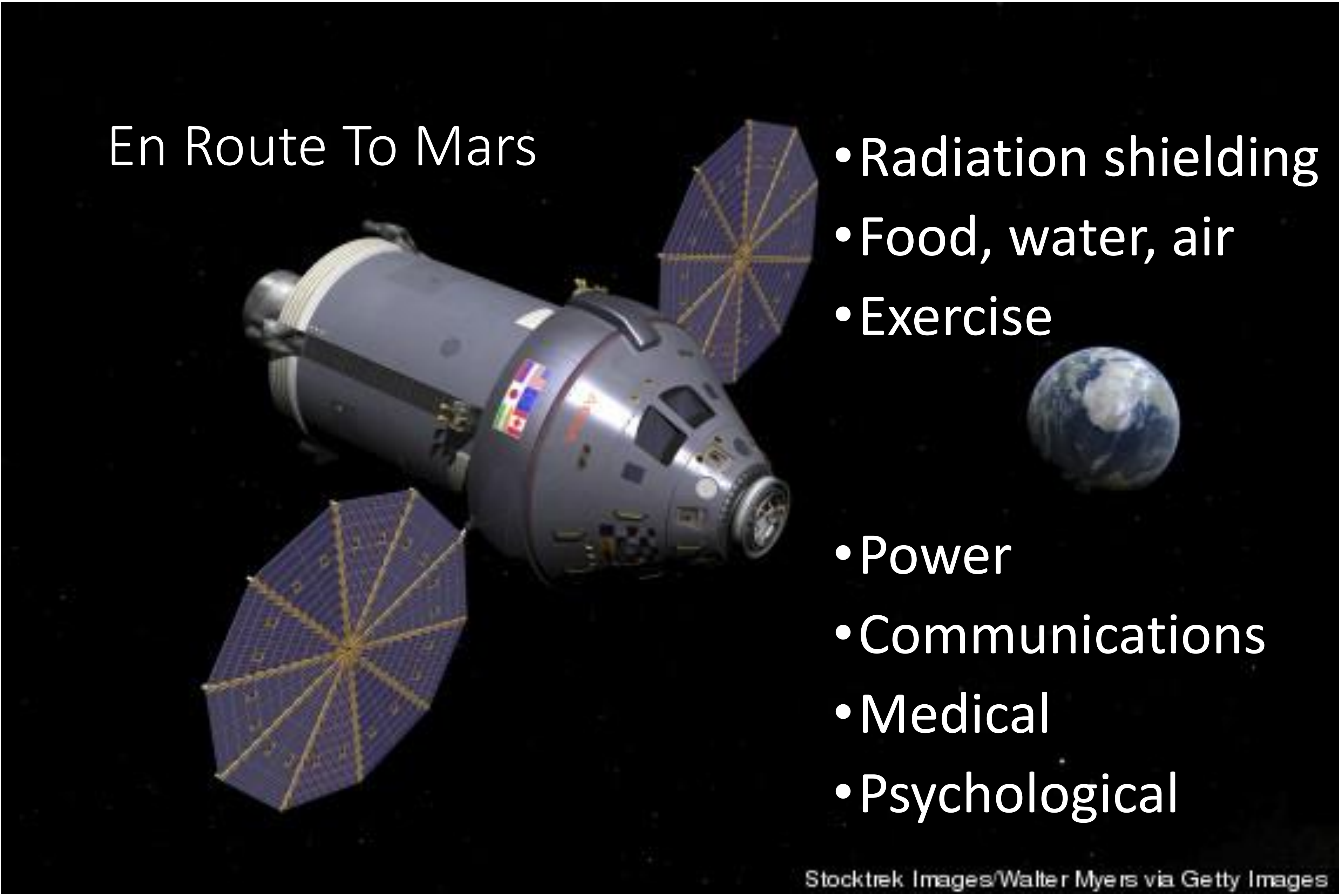


Sequence Summary



National Aeronautics and Space Administration

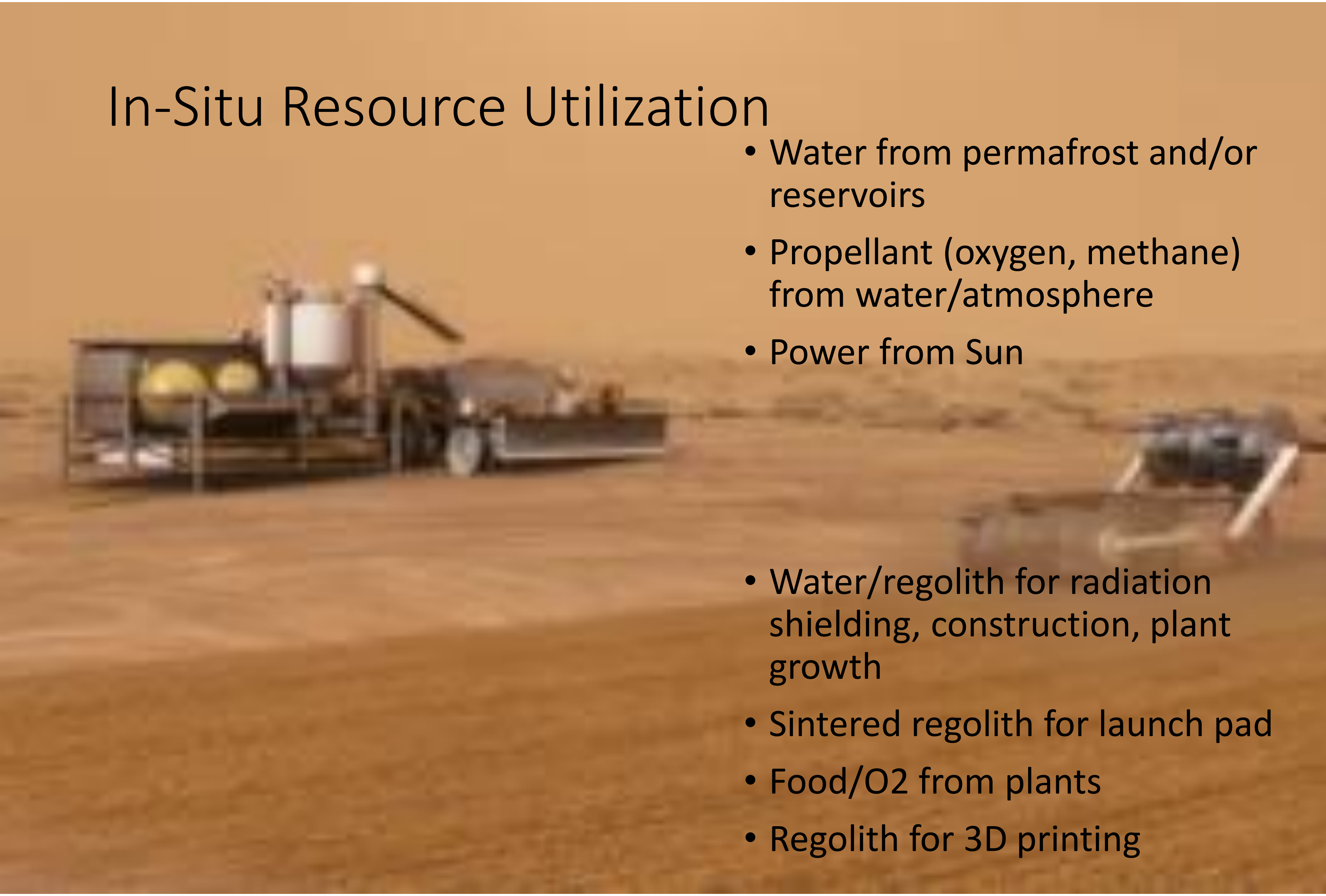
En Route To Mars



- Radiation shielding
- Food, water, air
- Exercise

- Power
- Communications
- Medical
- Psychological

In-Situ Resource Utilization



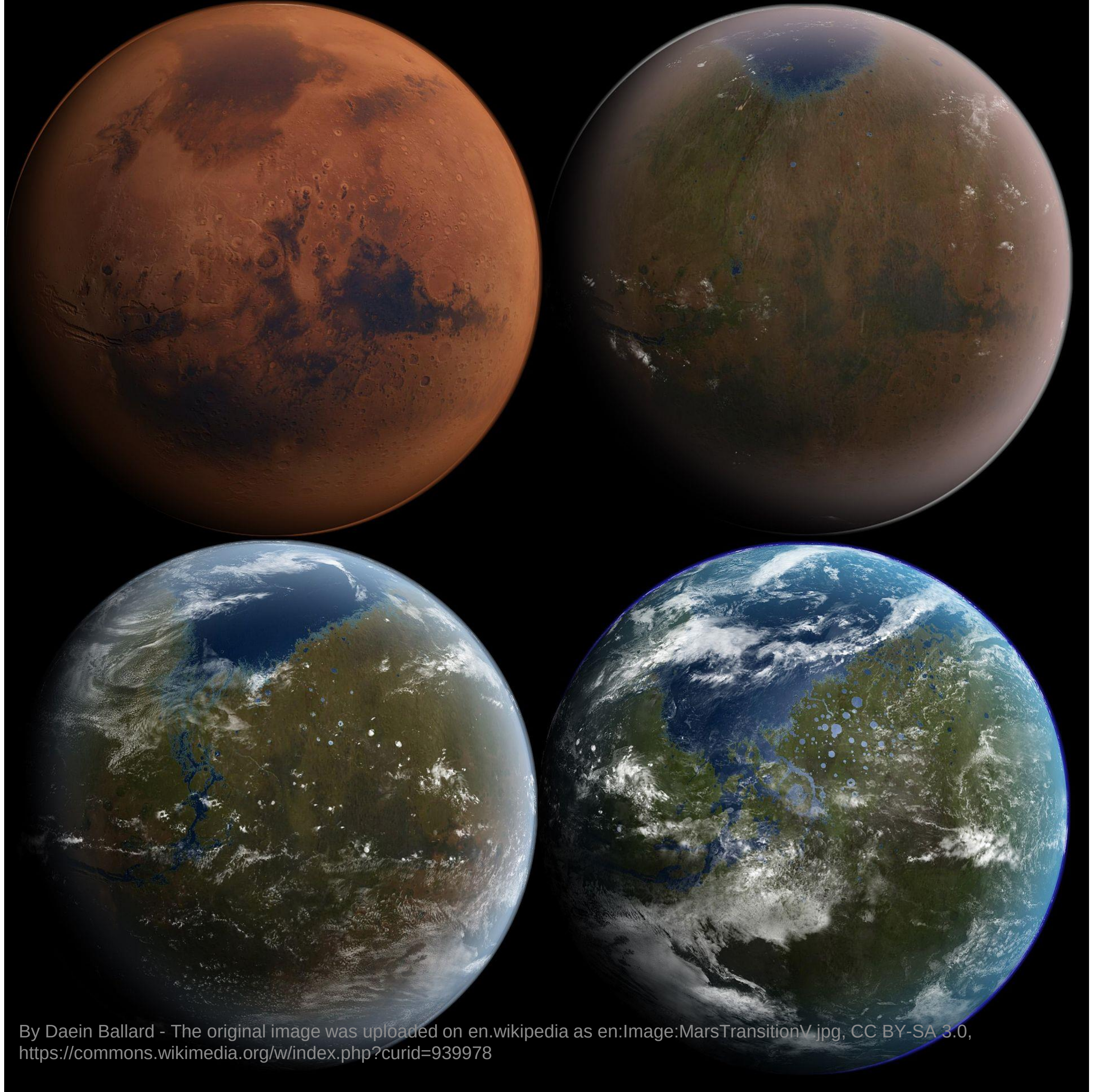
- Water from permafrost and/or reservoirs
- Propellant (oxygen, methane) from water/atmosphere
- Power from Sun

- Water/regolith for radiation shielding, construction, plant growth
- Sintered regolith for launch pad
- Food/O2 from plants
- Regolith for 3D printing

Planetary Protection (both directions!)

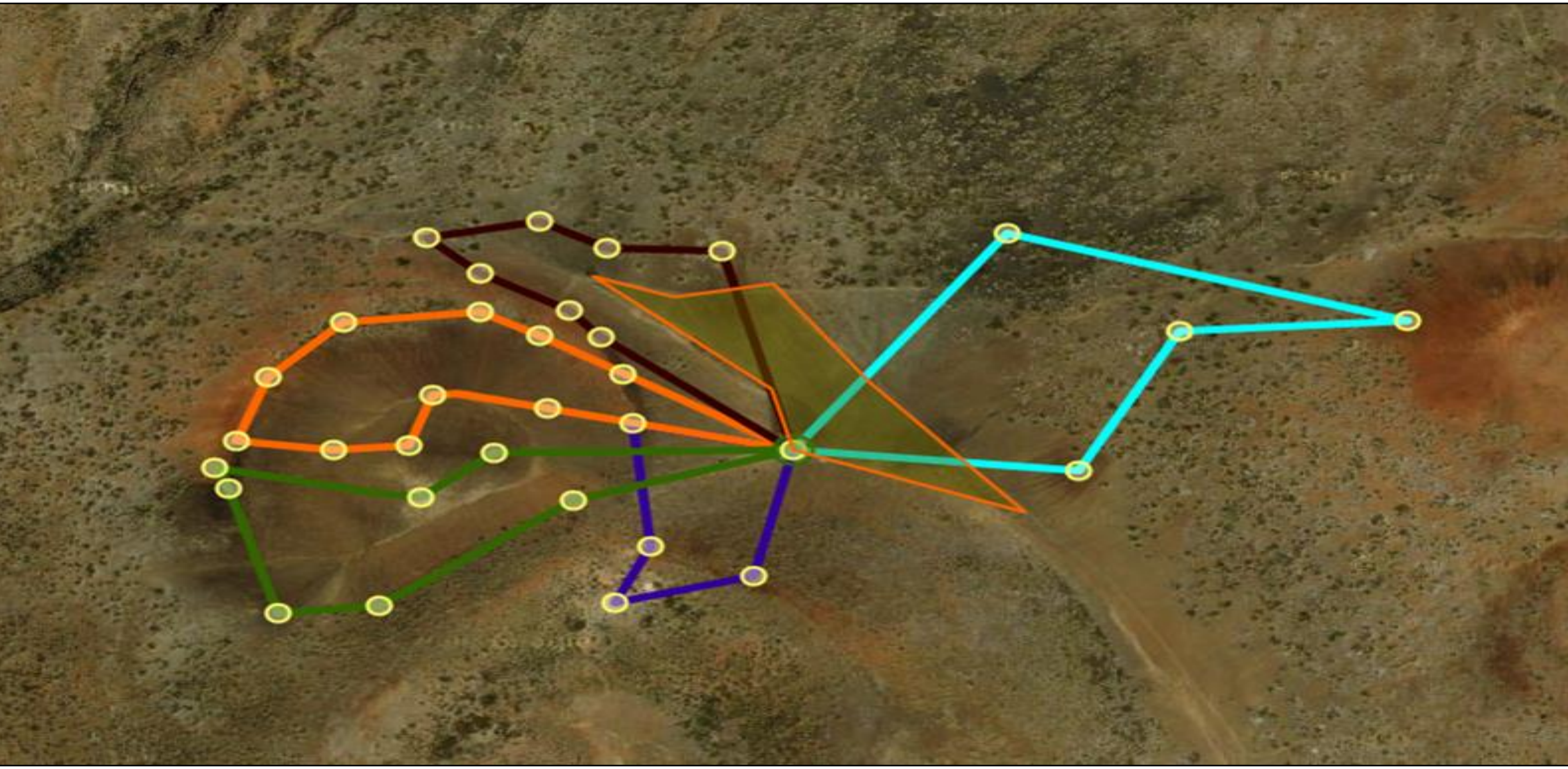
https://what-if.xkcd.com/imgs/a/117/officer.png

Terraforming

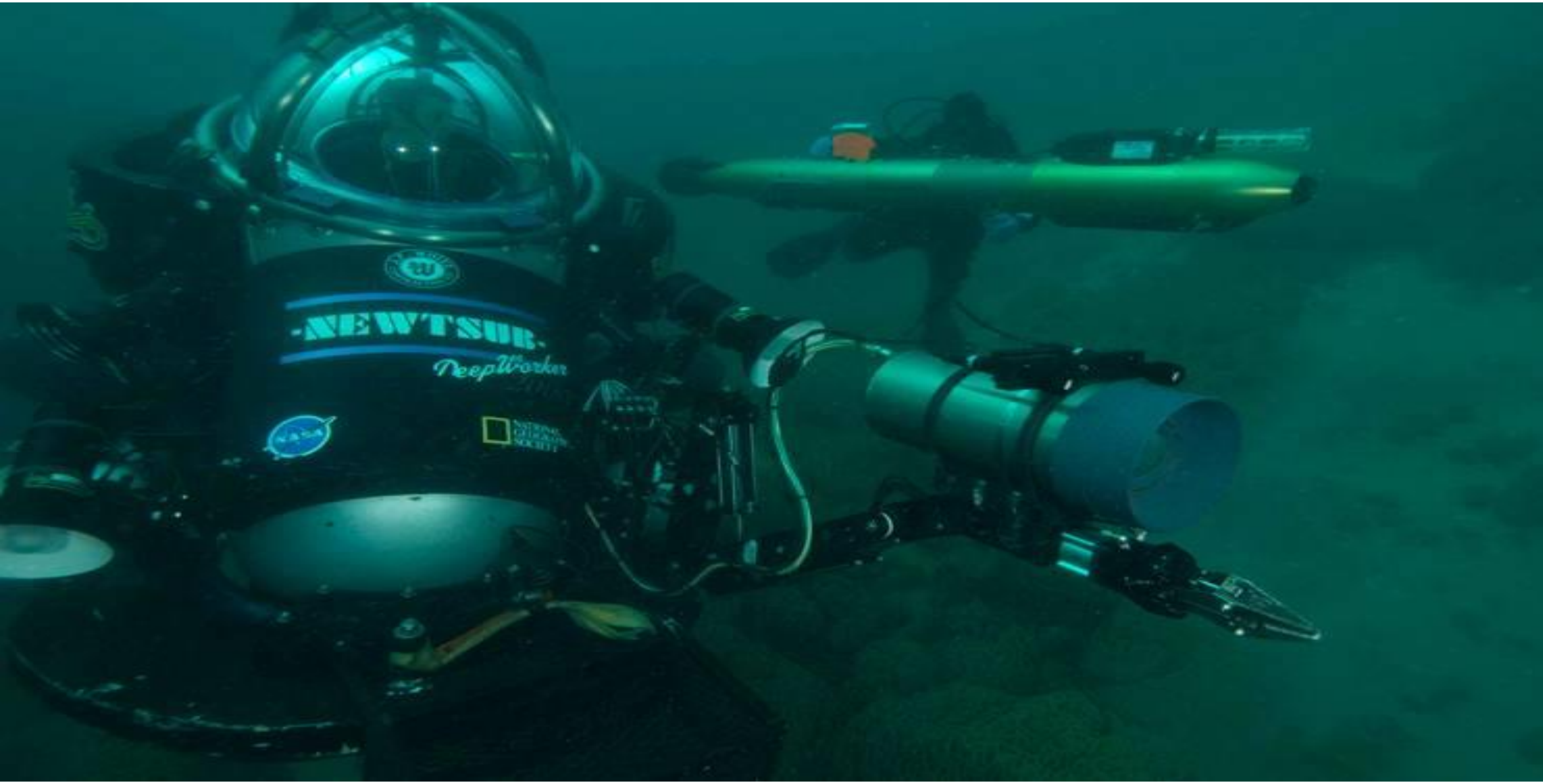


Use analogs to:
discover problems, test solutions

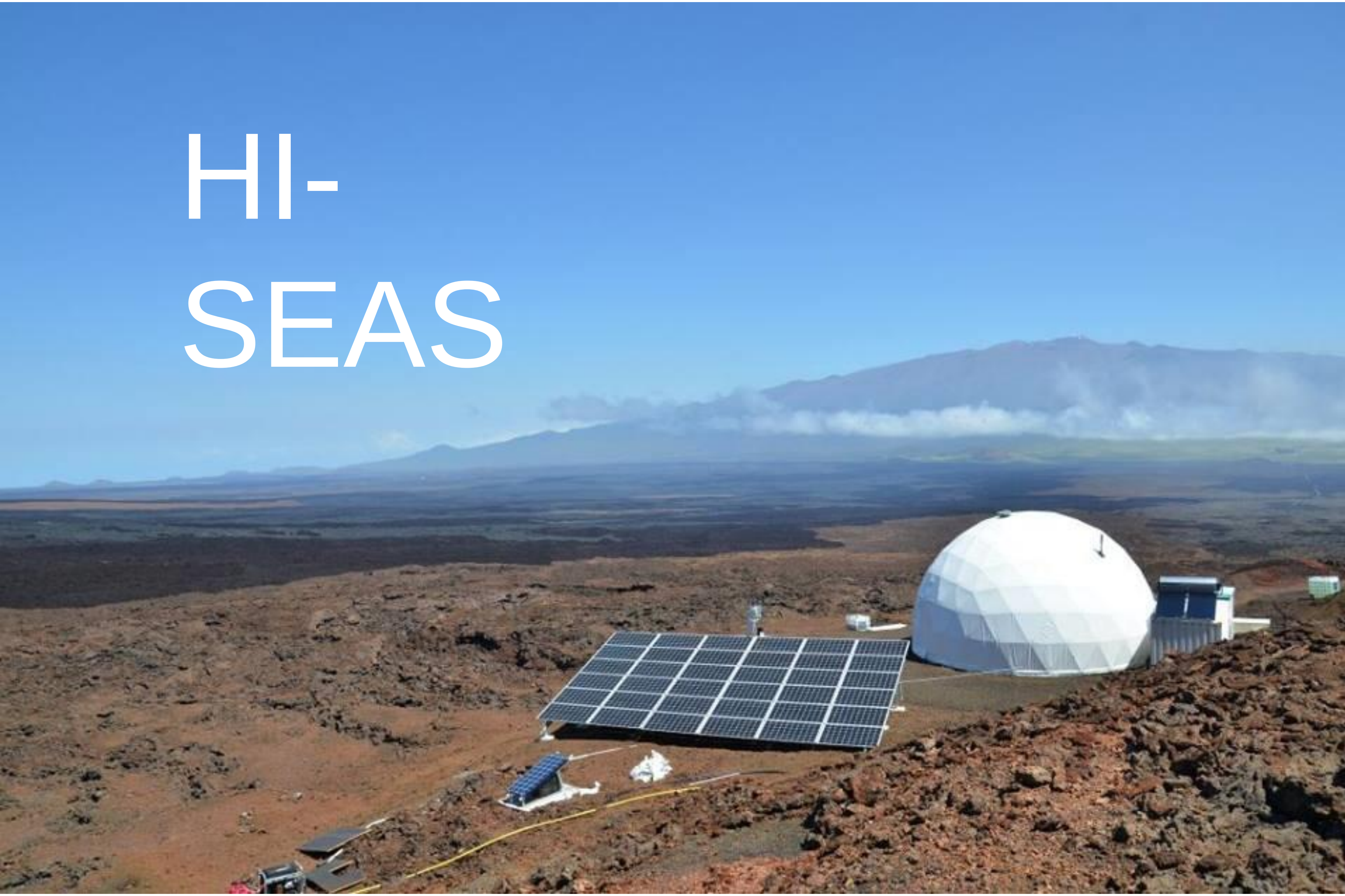
Use analogs to:
design in the context of use



Use analogs to: *integrate* people and systems in realistic scenarios

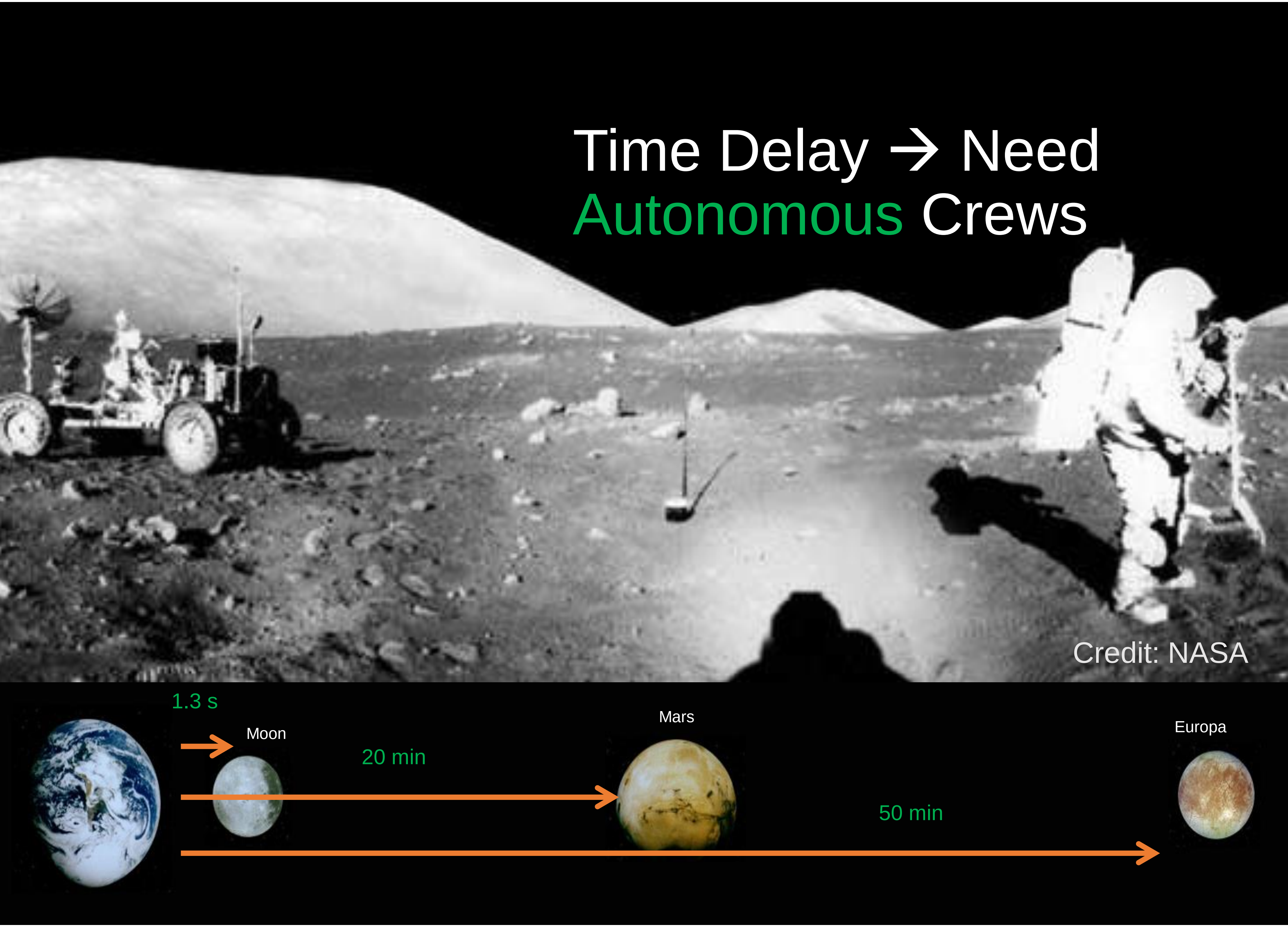


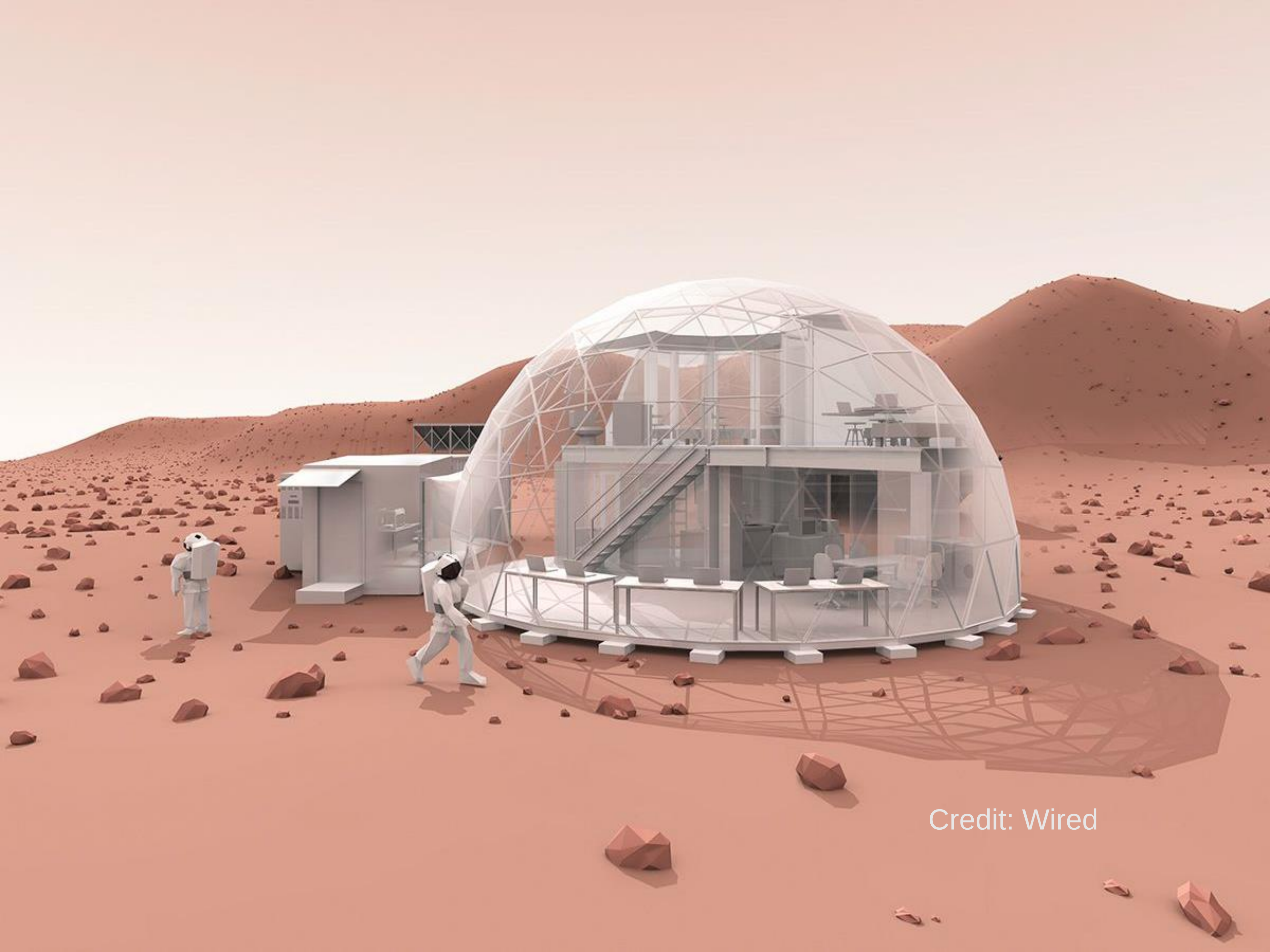
HI-SEAS



Retiring risks for long duration missions

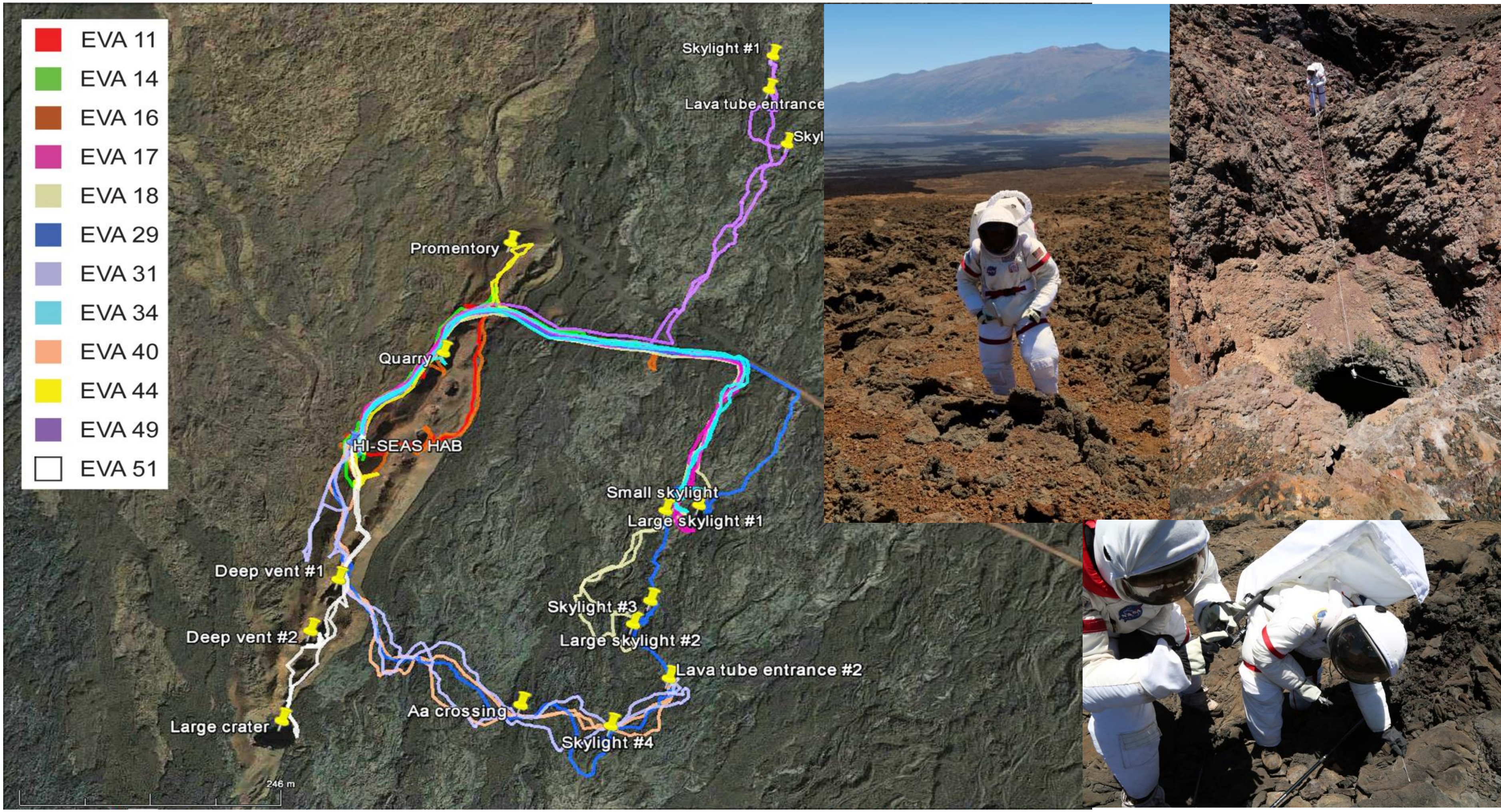
- Astronaut or astronaut-like crew
- High-fidelity mission profile and environment
- Long-duration (4+ months) studies
- Site that allows both crew isolation and easy access by researchers
- High level of control of mission parameters (e.g. communications latency) by researchers


Time Delay → Need
Autonomous Crews
Credit: NASA
1.3 s
Moon
20 min
Mars
50 min
Europa


Credit: Wired


Credit: HI-SEAS

HI-SEAS Mission 1 EVA map



MX spacesuit simulators provided by Space Systems Laboratory, University of Maryland

Crew selection

All happy families are alike; each unhappy family is unhappy in its own way. - **Anna Karenina**, Leo Tolstoy.

- Need certain skillsets
- Prefer international with demographic balance
- There is no “perfect astronaut.”
- Something will always cause conflict – instead select/train for resilience.

Questions?