



Credit: NASA

Your Next Home, Your Next Planet - Mars

Glenn Holliday
Rappahannock Astronomy Club
April 19 2017

Going to Mars is hard

Partly because of what Mars is like.

Each of these differences between Earth and Mars makes a big difference to arriving on Mars and living on Mars.



Radius: half of Earth's.

Credit: Wikimedia Commons

Mass: 1/10 of Earth's.

Volume: 1/5 of Earth's.

Gravity: 1/3 of Earth's (surface gravity depends on both mass and radius).

Total area: About the same as Earth's dry land area.

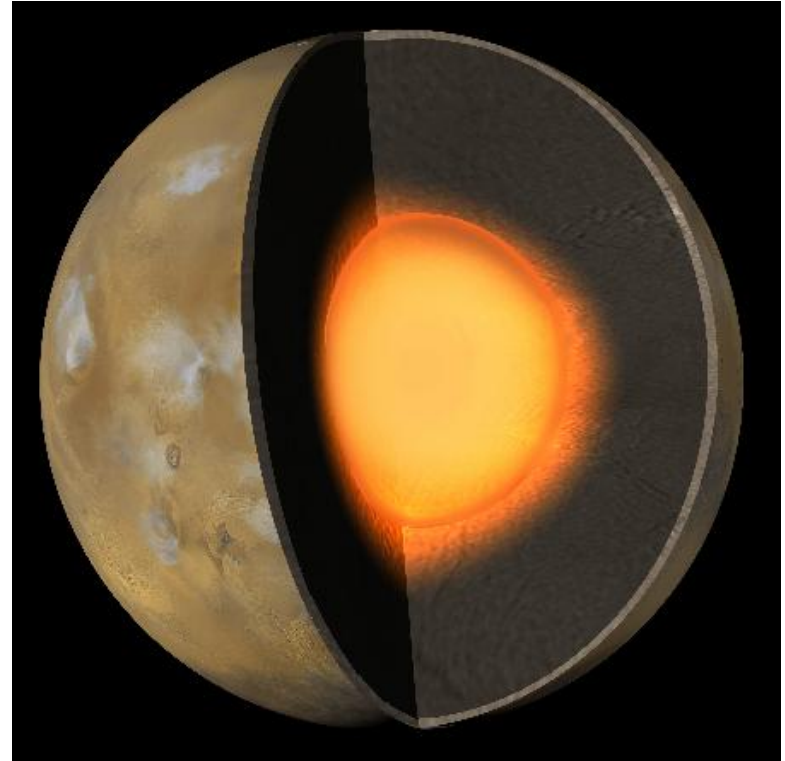
Temperature: Ranges from -200 to +100 F, mostly on the cold end.

Olympus Mons is highest volcano and second-highest mountain in Solar System.

Source: NASA 2004

Mars is like Earth, only different

Like all planets, it started out hot.
Like Earth, Mars differentiated with heaviest metals in its core, lighter rocks forming mantle and crust.
Because it is smaller than Earth it cooled faster.
Its crust is therefore thicker than Earth's.
We have good evidence Mars' core is at least part liquid.

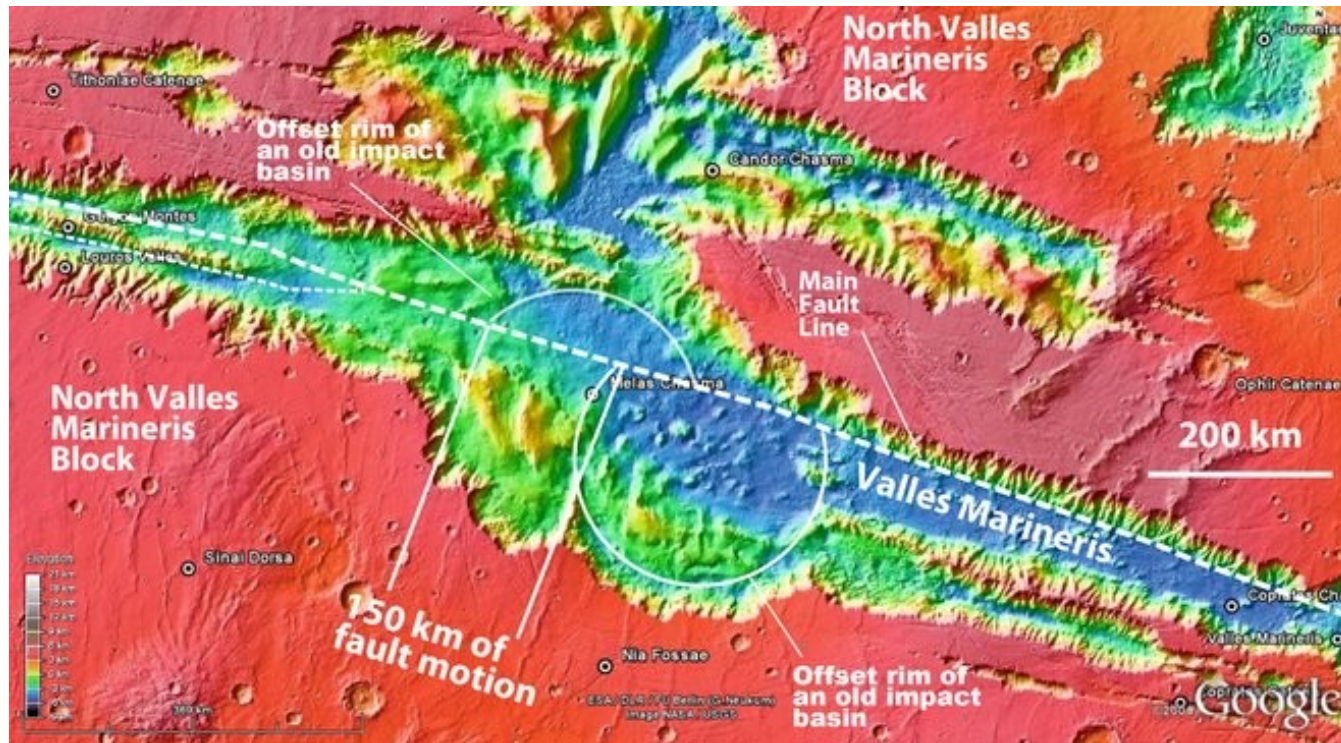


Credit: NASA

This matters to its magnetic field.

Source: space.com 2004

Mars' Geology is Alive, Maybe



Credit: Google Mars

The largest valley on Mars has a length $\frac{1}{5}$ the circumference of the planet.

It might be a boundary between two tectonic plates.

There is evidence (e.g. straight lines of volcanoes) these plates have moved past each other on a fault line.

Mars' crust has a simple structure of 2 plates (Earth has 7).

Mars has smaller scale activity like landslides and spring meltwater flows.

Source: space.com 2004

Mars has twice the moons of Earth



Credit: NASA

This is not an animation but a real time video by Curiosity.

Phobos: Larger, closer, orbits 3 times per day. Moves 47° /hour, 3 times as fast as our sky moves. This makes it rise in the west.

Deimos: Smaller, farther away.

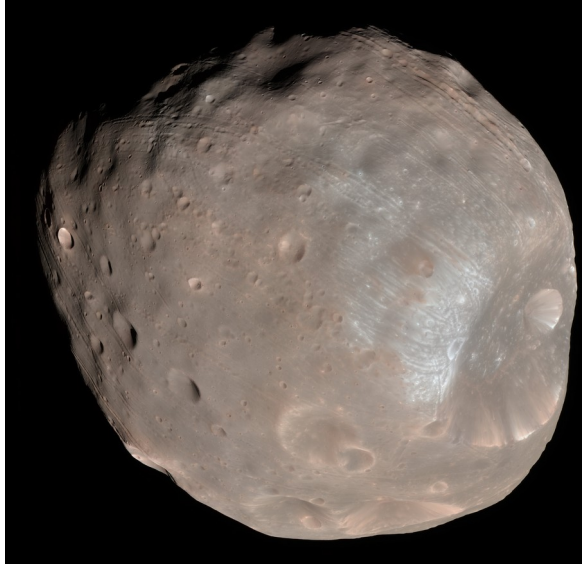
Named for the children of Ares, Fear and Dread.

Phobos is too close to Mars: its orbit decays 2 cm per year.

Recent study suggests Phobos' predecessors have broken up into a ring around Mars, and then the fragments re-formed into a new moon, several times.

Phobos is a big rubble pile, which is consistent with this theory.

Phobos and Deimos are both odd



Credit: Wikimedia Commons



Credit: Wikimedia Commons

Neither is big enough to be round

Phobos radius: 11 km

Deimos radius: 6.2 km

Both have tiny gravity (from our perspective)

Multiple competing theories about their origin

- Part of primordial protoplanetary disk?
- Captured asteroids?
- Debris from a large impact on Mars?

Why is there no air in here?

When ground water reaches the surface, it quickly evaporates.

This is because Mar's air pressure is 6 mbar. Earth's is 1013 mbar.

Yet we have lots of evidence that ancient Mars had flowing rivers, lakes, and small seas. These can not exist with the present atmosphere.

Mars once must have had a thick atmosphere Where did it go?

Rocks we find on Mars say the atmosphere when they were formed had more oxygen, less carbon dioxide. But Mars' atmosphere today is mostly carbon dioxide. What happened?

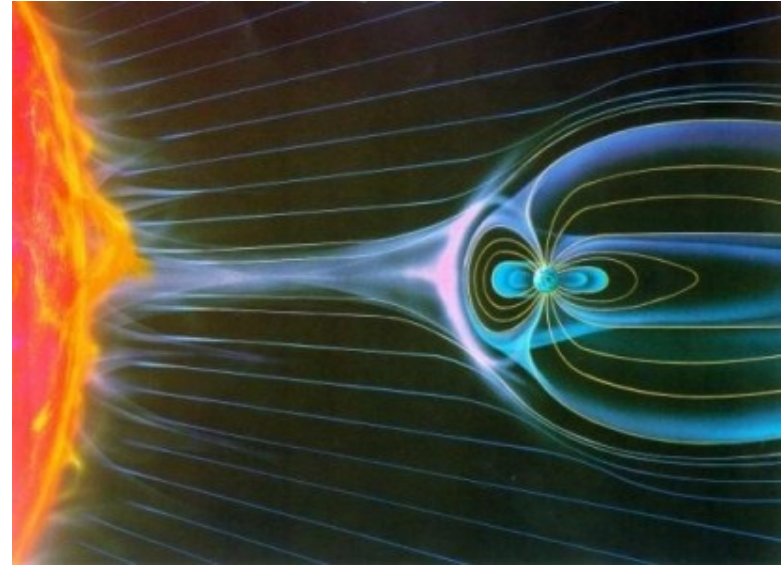
A thicker atmosphere is warmer. Mars was once warm enough for liquid water. Today, each winter, 16% of the atmosphere falls as carbon dioxide snow on the poles and evaporates again in the summer. This causes a planet-wide seasonal circulation of carbon dioxide.

An ancient Mars that was warmer, with a thick atmosphere and more oxygen, would have been habitable for humans. Why do we need spacesuits there today?

Blame it on Magnetism. Or not.

Earth's magnetic field deflects the solar wind.

This definitely protects us from radiation. It also may protect our atmosphere.



Credit: NASA

Air molecules need only a little energy input to reach escape velocity.

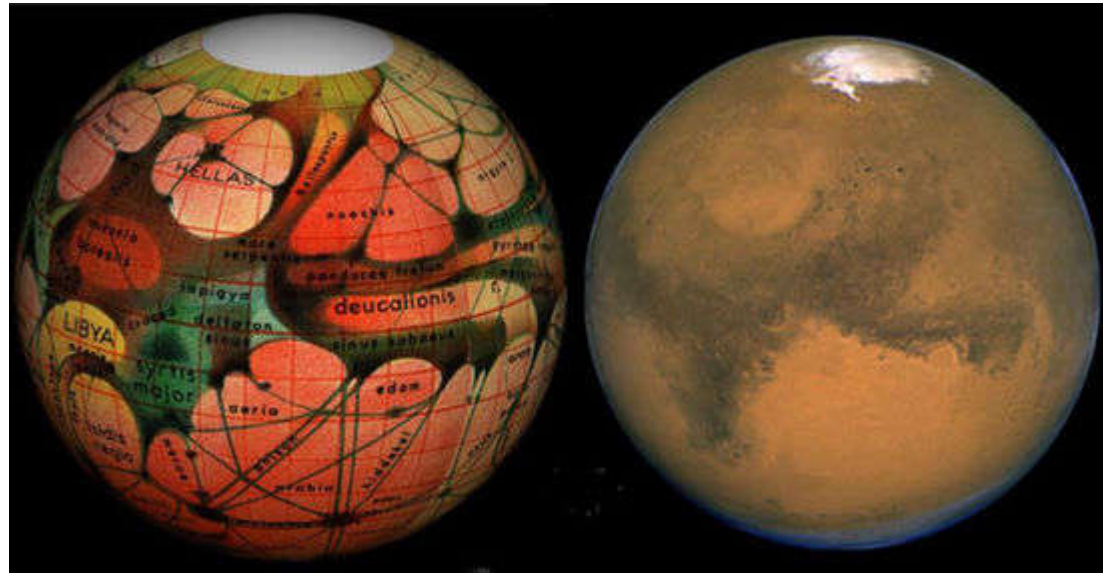
The solar wind can provide that energy. A magnetic field should mean fewer air molecules leak away to space.

We have good evidence ancient Mars had a magnetic field like Earth's. The geological dynamo driving it stopped billions of years ago. Earth and Mars both started with thick atmospheres. Mars lost its magnetic field and its atmosphere.

Some scientists question the importance of this mechanism. But if the loss of its magnetic field does not explain the loss of Mars' atmosphere, something else happened that we don't understand.

Source: Strangeway 2011

Is Mars Alive?



Credit: space.com

1877 Giovanni Schiaparelli drew lines he saw on Mars.
He called them canali, Italian for channels.
The popular imagination has included Martians ever since.
Is there really life on Mars?

Maybe.

Mars was much more similar to Earth when life started on Earth.
Maybe it started on Mars at the same time.
Do we have any evidence?

Evidence for Life on Mars



Credit: NASA

Viking lander 1976 looked for chemistry that life could cause.

Found something. But cause ambiguous.

A recent experiment applied the Viking test to soil from Antarctica and deserts that definitely does contain life. The Viking test failed to find it.

Source: Navarro-González



Credit: Wikimedia Commons

NASA scientists reported in 1996 finding features in a meteorite from Mars that could be fossils of Martian bacteria.

There are other explanations for those features, so most scientists do not accept this as remains of life.

Source: McKay 1996

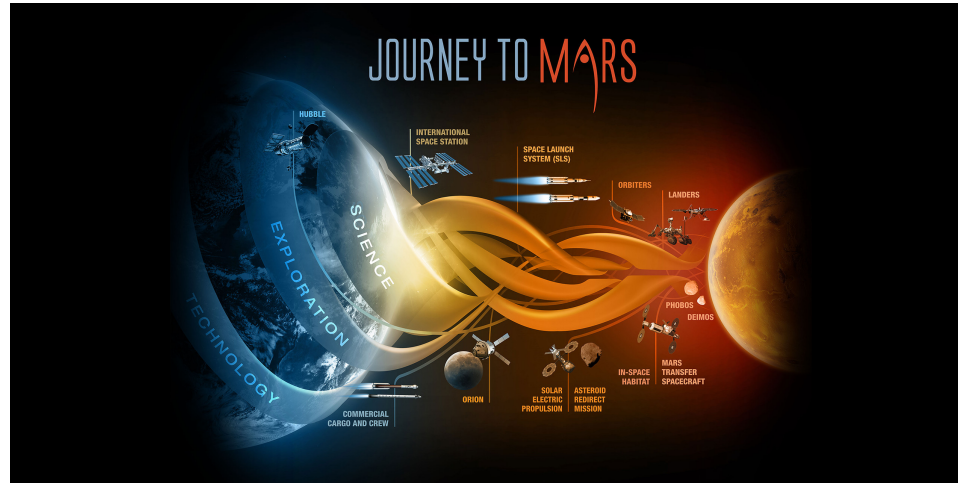
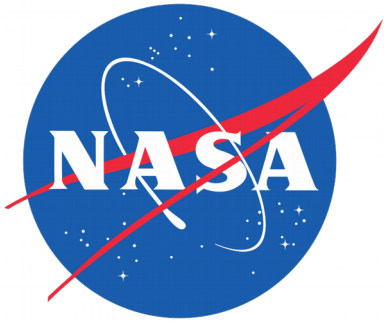


Credit: Warner

Mars satellites and rovers have found periodic spikes of methane and formaldehyde. On Earth, both are most commonly caused by life. But both might also have non-living chemical causes.

Everybody Wants to Go to Mars

There are more competitors that you might think. Each of them has a different plan to get there.



Credit: NASA

NASA's plan has suffered changing political winds.

Early 2000s NASA planned to return to the Moon on the way to Mars.

A budget of \$500 B ended that plan.

Late 2000s NASA planned to go to Mars.

Congress required it to use big Apollo-style rockets.

Boeing CEO Dennis Muilenberg: "the first person to step foot on Mars will arrive there riding a Boeing rocket."

Current budget: \$450 B.

First arrival: 2030s



Credit: NASA



Credit: SpaceX

Elon Musk: Would you rather spend months in their spaceship or in ours?

SpaceX goal: colonize Mars. Be more than a single-planet species.

Budget: a low, low \$10 B.

First arrival: 2025

Then carry a million colonists to live on Mars.

Spaceship carries 100 passengers per flight.

Ticket price: \$100,000



BLUE ORIGIN

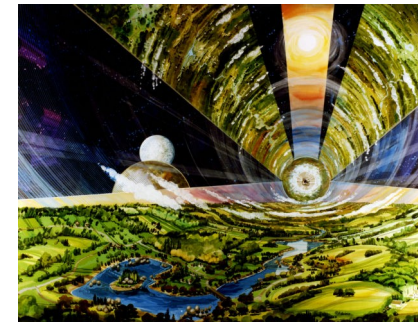
Plans to build a rocket that could reach the Moon or beyond.
Commercialization of space for industry.

Jeff Bezos: "I predict that in the next few hundred years, all heavy industry will move off planet... Earth will end up zoned residential and light industry."

Budget: \$1 B per year.

Interested in Mars "and everywhere else."

Including, maybe, O'Neill cylinder habitats.



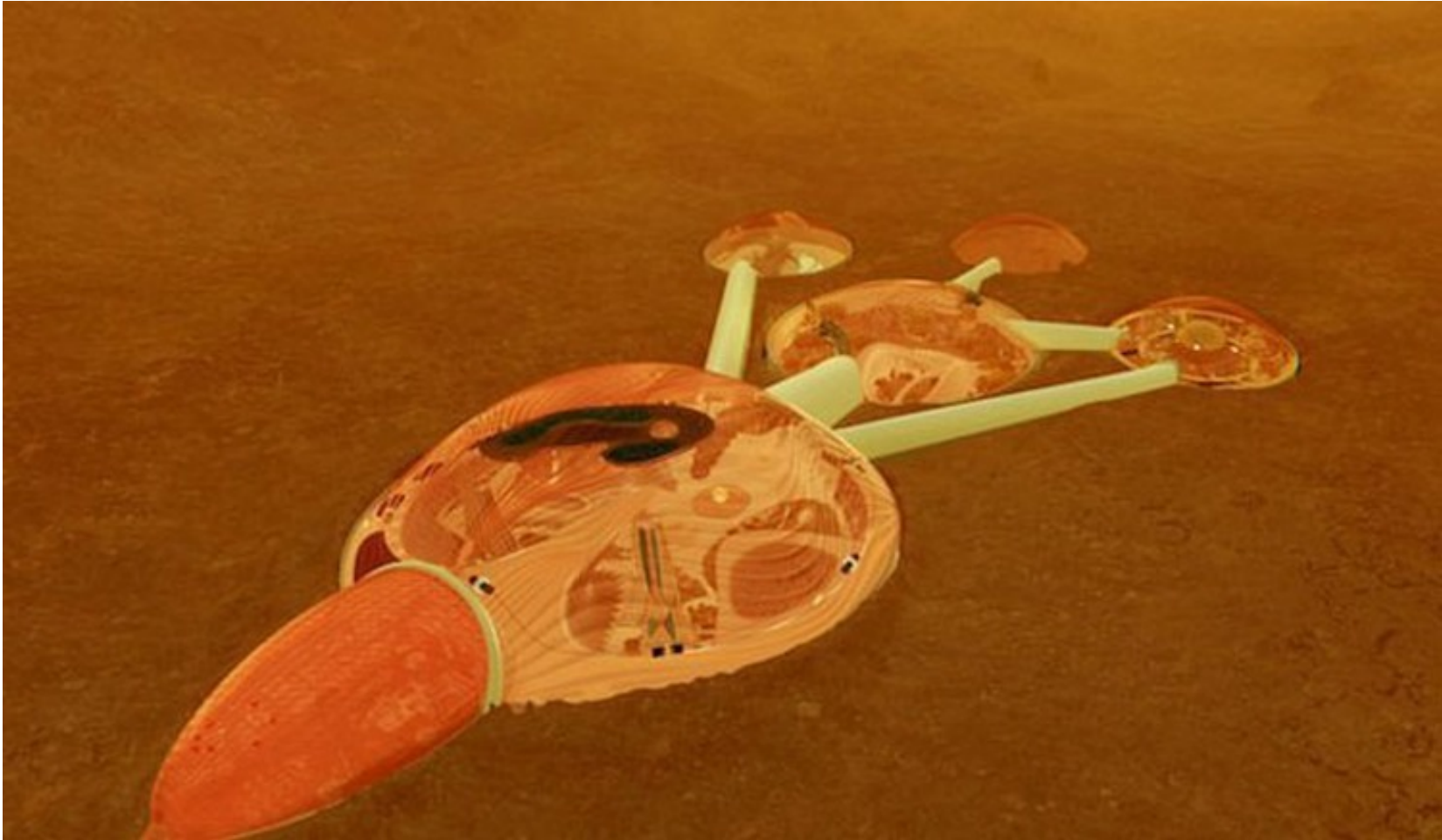
Credit: Wikimedia Commons

But in the short term, space tourism.



Credit: Blue Origin

United Arab Emirates



Credit: Dubai Media Office

SpaceX's 10-year plan and NASA's 20-year plan may both be optimistic.

UAE has a more realistic plan to establish a colony on Mars in 100 years.

Mars One



Credit: Mars One

Got lots of attention by accepting applicants worldwide to be one-way colonists to Mars.

First arrival: 2032.

Planned to finance the effort with a reality TV show.

The TV sponsorship has ended.

Mars One recently letting applicants buy better chance of being chosen.

Announcement of final crews and crew training has not happened on schedule.

Challenges of Living on Mars

Sustainable life support

Building a home that can make its own air, water, and food and not need a maintenance call.

Radiation protection

NASA astronaut twin study (Mark and Scott Kelly) showed unexpected changes in the brain and DNA.

All the colony proposals will build living space underground.

Living with 1/3 gravity

We know living long term in microgravity causes big trouble for human bodies

We know much less about living long term in Mars' gravity.

If there is a colony, somebody will be the first human born on Mars. We don't know if human pregnancy and childbirth will work out in Martian gravity.



Credit: NASA

Maybe Potatoes Would Work

After the success of the movie *The Martian*, the International Potato Center sponsored an experiment planting potatoes in Mars-like soil, temperature, and atmospheric conditions.

Results: the plants successfully sprouted and formed new tubers underground.

Potatoes have not yet successfully put leaves above ground. Other efforts looking for ways to support life using local resources.

Source phys.org 2017

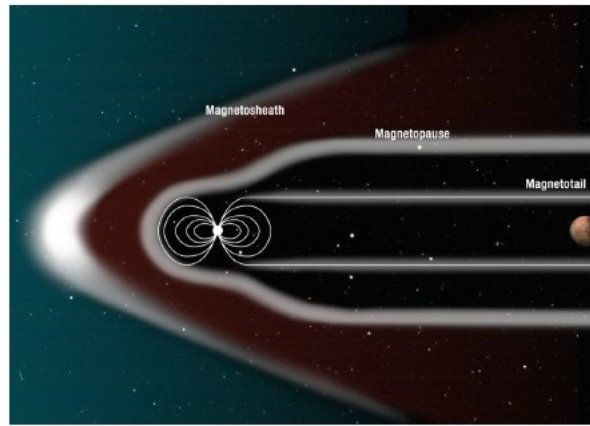
Terraforming



Credit: NASA

NASA suggestion of what Mars might look like with atmosphere, water, and vegetation.

Can we restore Mars' magnetic field?



Credit: NASA

It's possible natural geological processes will one day restart it. If we don't want to wait for that to happen, NASA has a suggestion to provide an artificial magnetic field for Mars. Place a 2 Tesla generator at Mars' L1 point. This would solve the radiation problem. If Mars can hold its atmosphere when the solar wind is no longer eroding it, then the atmosphere would become thick enough (mostly from oxygen venting from the crust) and warm enough in 40 years to melt the carbon dioxide ice. Once the polar caps are added to the atmosphere, global warming would continue to raise the Martian temperature.

Melt the Poles



Credit: NASA

Elon Musk has separately proposed melting the carbon dioxide ice caps at Mars' North Pole and South Pole.

This would greatly increase the amount of carbon dioxide in the atmosphere, starting a greenhouse cycle to warm the planet.

But if the planetary temperature had not already been increased above the freezing point of carbon dioxide, then the newly released gas will freeze out of the atmosphere again as it does every winter, before it has time to trap enough solar energy to start real climate change.

Colonize Mars with Microbes

A small habitat is not big enough to duplicate our native ecosystem.

We live with thousands of other life forms.

One NASA project proposes building Earth's complete biome on Mars from the ground up.

Currently researching what microorganisms could survive if we introduce them to Mars now.

Ethics of Terraforming

Radical changes to make Mars more like Earth could destroy any native Martian life.

People almost universally agree that would be unethical.

Apart from any intrinsic value of native life, we would destroy the feature we are most interested in.

Some make a separate argument that terraforming Mars would be like destroying our National Parks.

On the other hand, one reason to go to Mars is as a Plan B if Earth should be destroyed. If that happens, the desire to preserve ourselves gets a bigger place in the ethical argument.

Why go?

Adventure

Exploration

New knowledge

Earth 2

Because we can

Commercialization of Martian resources

Add your reasons here ...

Bibliography

- Arkai-Hamed, Jafar. Consequences of Giant Impacts on the Martian Dynamo. 2015-12-16 Journal of Geophysical Research. sites.agu.org agu.confex.com/agu/fm15/webprogram/Paper55920.html
- Berger, Eric.
Make Mars great again: Can the 2016 election save NASA's Journey to Mars? 2016-04-12.
<https://arstechnica.com/science/2016/04/make-mars-great-again-can-the-2016-election-save-nasas-journey-to-mars/>
Musk's Mars moment: Audacity, madness, brilliance — or maybe all three. 2016-09-28.
<https://arstechnica.com/science/2016/09/musks-mars-moment-audacity-madness-brilliance-or-maybe-all-three/>
NASA's next stop—Mars or the Moon? 2016-12-22.
<https://arstechnica.com/science/2016/12/time-to-choose-between-the-moon-and-mars-or-nasa-isnt-going-anywhere/>
A bolder, risk-taking NASA? Agency looking at Orion crew launch in 2019. 2017-02-15.
arstechnica.com/science/2017/02/nasa-looking-to-accelerate-first-crewed-orion-launch-to-as-early-as-2019/
Finally, someone has a realistic timeline for Mars colonization—the UAE. 2017-02-15.
<https://arstechnica.com/science/2017/02/finally-someone-has-a-realistic-timeline-for-mars-colonization-the-uae/>
Bristow, Thomas F. et al. Low Hesperian P CO₂ constrained from in situ mineralogical analysis at Gale Crater, Mars. Proceedings of the National Academy of Sciences of the United States.
<http://www.pnas.org/content/early/2017/01/31/1616649114>
- Britt, Robert Roy. Mars: A History of False Impressions. 2005-09-26. space.com/1583-mars-history-false-impressions.html
- Choi, Charles Q.
What Warned Ancient Mars? <https://www.scientificamerican.com/article/what-warned-ancient-mars/>
7 Biggest Mysteries of Mars. <http://www.space.com/13681-mars-biggest-mysteries-water-life.html>
- Garver, Lori. Quoted by Berger, Eric. Former NASA official: NASA must shed "socialist" approach to space exploration. <https://arstechnica.com/science/2015/11/former-nasa-official-nasa-must-shed-socialist-approach-to-space-exploration/>
- Green, J. L. et al. A Future Mars Environment for Science and Exploration. Planetary Science Vision 2050 Workshop 2017 (LPI Contrib. No. 1989).
- Hesselbrock, Andrew J. et al. An ongoing satellite–ring cycle of Mars and the origins of Phobos and Deimos Nature Geoscience. (2017) doi:10.1038/ngeo2916
- Limoli, Charles L. Could Radiation Be a Deal Breaker for Mars Missions? Scientific American February 2017 Issue
- Mars One. <http://www.mars-one.com/>
- Matter. Mars One Insider Quits Dangerously Flawed Project. 2015-03-16.
<https://medium.com/matter/mars-one-insider-quits-dangerously-flawed-project-2dfef95217d3>
- McKay, David S. et al. Search for Past Life on Mars: Possible Relic Biogenic Activity in Martian Meteorite ALH84001. Science. 273 (5277): 924–930. 1996. Bibcode:1996Sci...273..924M. doi:10.1126/science.273.5277.924. PMID 8688069
- Merrill, Ronald T.; McElhinny, Michael W.; McFadden, Phillip L. (1996). The magnetic field of the earth: paleomagnetism, the core, and the deep mantle. Academic Press. ISBN 978-0-12-491246-5.
- Musk, Elon. Quoted by Berger, Eric. Elon Musk provides more details about how first Mars colonists will live. <https://arstechnica.com/science/2016/10/geodesic-domes-and-tunneling-droids-musk-opens-up-about-mars-life/>
- NASA.
Twins Study. <https://www.nasa.gov/twins-study>
Williams, David R. "Mars Fact Sheet". National Space Science Data Center. 2014-09-01.
Acting Administrator Lightfoot Memo: Agency Update. 2017-02-15.
<http://spaceref.com/news/viewsr.html?pid=49863>
Siding Spring comet image from Mars
<http://mars.nasa.gov/multimedia/images/?!ImageID=6725>
- phys.org
Year-long Mars isolation experiment in Hawaii ends. 2016-08-29.
<https://phys.org/news/2016-08-year-long-mars-isolation-hawaii.html>
Indicators show potatoes can grow on Mars. 2017-03-08.
<https://phys.org/news/2017-03-indicators-potatoes-mars.html>
- Proceedings of The National Academy of Sciences of the USA
The limitations on organic detection in Mars-like soils by thermal volatilization–gas chromatography–MS and their implications for the Viking results. Rafael Navarro-González et al. vol. 103 no. 44. 16089–16094
<http://www.pnas.org/content/103/44/16089.abstract>
- space.com
Mars Surface Made of Shifting Plates Like Earth, Study Suggests
<http://www.space.com/17087-mars-surface-marsquakes-plate-tectonics.html> 2012-08-04.
- Stewart, Andrew. Mars: A New Core[C]rystalization Regime. Science vol 316 Issue 5829. 2007-06-01.
- Stone, Maddie. NASA Just Sealed Six People In a Dome For a Year to Practice Mars.
<http://gizmodo.com/nasa-just-sealed-six-people-in-a-dome-for-a-year-to-pra-1727399163>
- Strangeway, Robert
The importance of being magnetized. Earth, Mars, Venus lose ions to space at same rate. 2011-03-21.
<https://phys.org/news/2011-03-importance-magnetized.html>
- Thomas-Keppta, K. L. et al. (2009). Origins of magnetite nanocrystals in Martian meteorite ALH84001. Geochimica et Cosmochimica Acta. 73 (21): 6631–6677. Bibcode:2009GeCoA..73.6631T. doi:10.1016/j.gca.2009.05.064. 2014-05-07.
- Timmer, John. Going to Mars is (relatively) easy; coming back is where it gets tricky. <https://arstechnica.com/science/2016/09/going-to-mars-is-relatively-easy-coming-back-is-where-it-gets-tricky/> 2016-09-26.
- Wikipedia
Allan Hills 84001. https://en.wikipedia.org/wiki/Allan_Hills_84001/
Curiosity (rover). [https://en.wikipedia.org/wiki/Curiosity_\(rover\)](https://en.wikipedia.org/wiki/Curiosity_(rover))
Earth's magnetic field. https://en.wikipedia.org/wiki/Earth's_magnetic_field
Mars Reconnaissance Orbiter https://en.wikipedia.org/wiki/Mars_Reconnaissance_Orbiter
- Wired. Multiple Asteroid Strikes May Have Killed Mars's Magnetic Field. 2011-01-20. <http://www.wired.com/2011/01/mars-dynamo-death/>
- Wood, Anthony. High-resolution gravity map confirms Mars' molten core. 2016-03-23. <http://newatlas.com/mars-gravity-map/42430/>