Terraforming Mars

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"Thank God for Terraforming Mars!" my friend Kate told me recently. Her gratitude was directed not at the ambitious goal of making Mars human habitable but at the board game that she and I play with our respective spouses. During the pandemic, when we couldn't get together in person, we figured out a way to keep playing via Zoom. The game kept our morale buoyant.

Released in 2016 to prompt acclaim, Terraforming Mars is a game of card drafting, tableau building, and resource management. Players assume the roles of corporations whose investments and actions enable them to vie for supremacy while they work to raise the temperature and oxygen level of the Martian atmosphere and lay down cities, greeneries, and oceans on the Martian surface.

Having played the game many times, I became intrigued: How close is it to the real science of terraforming? And did that science make its way into the game, which was designed by Jacob Fryxelius?

The term "terraforming" was introduced by Jack Williamson in the short story "Collision Orbit," which appeared in the July 1942 issue of *Astounding Science-Fiction*. Scientific papers about terraforming tend to cite as the field's origin Carl Sagan's 1961 review of the atmosphere, surface, and possible biology of Venus.[1] Having concluded that the planet is likely devoid of life, Sagan went on to explore the prospect of making it habitable.

The surface of Venus is hostile to life in part because the thick carbon dioxide–rich atmosphere traps so much outgoing heat that the mean temperature is 471 °C. Sagan proposed reducing the greenhouse effect by seeding the cooler heights of the Venusian atmosphere with photosynthetic bacteria that would convert carbon dioxide into formaldehyde (CH_2O). If the bacteria sank to lower, hotter altitudes, the CH_2O in their bodies would be oxidized to carbon.

In 1965 NASA's *Mariner 4* mission to Mars confirmed that the planet's atmosphere is mostly CO_2 and that it's too thin to exert a strong greenhouse effect. The mean temperature of the Martian surface is −63 °C. Schemes to terraform Mars have tended to propose ways to boost the greenhouse effect by releasing sequestered CO_2.

Prospects seemed good at first. If Mars's polar caps were made mostly of solid CO_2, melting them would release huge, maybe planet-altering amounts of the gas. Sprinkling black dust to raise the caps' albedo was one option. But it turned out that the polar caps are made mostly of water ice. Reducing carbonate regolith or rock became the next best option.

When I searched for research on terraforming Mars, I discovered that most of the highly cited papers were from the 1980s and early 1990s. Perhaps not uncoincidentally, 1992 saw the publication of Kim Stanley Robinson's *Red Mars*, the first of three novels about humans' centuries-long project to terraform Mars. Some of the ideas in the scientific literature made it into Robinson's Mars trilogy and into Fryxelius's board game.

Among the most influential papers of that heyday was Martyn Fogg's "Terraforming: A review for environmentalists."[2] I asked Fogg via email why scientific interest in terraforming Mars had waned. He acknowledged that the broader topic of planetary engineering was, and is, on the fringe. What sustained it briefly, he told me, was the chance conjunction of a small number of keen personalities, like Sagan, who were also capable scholars. "People's interests have moved on, including mine."

In a 2018 paper, Bruce Jakosky and Christopher Edwards marshalled data from four 21st-century spacecraft that orbit Mars to conduct an inventory of all the sources of CO_2 available for terraforming Mars.[3] The pair concluded that there isn't enough. If Mars is to be made habitable, new technologies will be needed.

In his 1993 paper, Fogg advocated using terraforming Mars as an educational tool. It remains an excellent idea. To dispel the notion that terraforming is far-fetched, he demonstrated that human builders, farmers, and miners already displace more of Earth's crust than do the natural processes of erosion and weathering. Humans are already emitting more greenhouse gases than natural processes do. The amount of energy from the Sun, he calculated, is more than enough to power terraforming schemes whose feasibility is readily evaluated with an attractively interdisciplinary mix of biology, chemistry, geology, and physics.

References

1. C. Sagan, *Science* **133**, 849 (1961).
2. M. J. Fogg, *Environmentalist* **13**, 7 (1993).
3. B. M. Jakosky, C. S. Edwards, *Nat. Astron.* **2**, 634 (2018).

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