SAMPLE

Worlds Beyond Earth: Terraforming

Building a Second Earth

Aira Astralis

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Conclusion

This free sample contains the Introduction and Chapter 1. The complete book contains the full contents above.

Introduction

Terraforming or Earth-shaping is the hypothetical process of deliberately modifying the atmosphere, temperature, surface topography or ecology of a planet, moon, or other astronomical body to be similar to the environment of Earth, with the goal of making it habitable for humans. The concept of terraforming developed from both science fiction and actual science. The term was coined by Jack Williamson in the science-fiction short story "Collision Orbit" in Astounding Science Fiction in 1942.

American astronomer Carl Sagan later gave one of the first scientific propositions of terraforming with the planetary engineering of Venus in 1961.

Even if the environment of a planet could be altered deliberately, the feasibility of creating an unconstrained planetary environment that mimics Earth on another planet has yet to be verified. While Venus and the Moon have been studied in the subject of terraforming, Mars is usually considered to be the most likely candidate for terraforming.

Much study has been done concerning the possibility of heating the planet and altering its atmosphere, and NASA has even hosted debates on the subject. Several potential methods for the terraforming of Mars may be within humanity's technological capabilities, but according to Martin Beech, the economic attitude of preferring short-term profits over long-term investments will not support a terraforming project. The long timescales and practicality of terraforming are also the subject of debate.

As the subject has gained traction, research has expanded to other possibilities including biological terraforming, para-terraforming, and modifying humans to better suit the environments of planets and moons. Despite this, questions still remain in areas relating to the ethics, logistics, economics, politics, and methodology of altering the environment of an extraterrestrial world, presenting issues to the implementation of the concept.

The term "terraforming" was coined by Jack Williamson in "Collision Orbit" in 1942, as a term for making the environment around people habitable.

Chapter 01: The Discovery of Terraforming

The word was added to the fourth edition of the Shorter Oxford English Dictionary in 1993. The concept is contrasted by pantropy, the adaptation of humans to an alien environment rather than an environment to humans. Pantropy has also been envisioned as a substitute when terraforming is not complete. The astronomer Carl Sagan proposed the planetary engineering of Venus in an article published in the journal Science in 1961.

Sagan imagined seeding the atmosphere of Venus with algae, which would convert water, nitrogen and carbon dioxide into organic compounds. As this process removed carbon dioxide from the atmosphere, the greenhouse effect would be reduced until surface temperatures dropped to "comfortable" levels. The resulting plant matter, Sagan proposed, would be pyrolyzed by the high surface temperatures of Venus, and thus be sequestered in the form of "graphite or some involatile form of carbon" on the planet's surface.

However, later discoveries about the conditions on Venus made this particular approach impossible. One problem is that the clouds of Venus are composed of a highly concentrated sulfuric acid solution. Even if atmospheric algae could thrive in the hostile environment of Venus's upper atmosphere, an even more insurmountable problem is that its atmosphere is simply far too thick: the high atmospheric pressure would result in a "atmosphere of nearly pure molecular oxygen" at high pressure.

This volatile combination could not be sustained through time.

Any carbon that had been reduced by photosynthesis would be quickly oxidized in this atmosphere through combustion, "short-circuiting" the terraforming process. Sagan also visualized making Mars habitable for human life in an article published in the journal Icarus, "Planetary Engineering on Mars" (1973). Three years later, NASA addressed the issue of planetary engineering officially in a study, but used the term "planetary ecosynthesis" instead.

The study concluded that it was possible for Mars to support life and be made into a habitable planet.

The first conference session on terraforming, then referred to as "Planetary Modeling", was organized that same year. In March 1979, NASA engineer and author James Oberg organized the First Terraforming Colloquium, a special session at the Lunar and Planetary Science Conference in Houston. Oberg popularized the terraforming concepts discussed at the colloquium to the general public in his book New Earths (1981). Not until 1982 was the word

terraforming used in the title of a published journal article.

Planetologist Christopher McKay wrote "Terraforming Mars", a paper for the Journal of the British Interplanetary Society. The paper discussed the prospects of a self-regulating Martian biosphere, and the word "terraforming" has since become the preferred term. In 1984, James Lovelock and Michael Allaby published The Greening of Mars. Lovelock's book was one of the first to describe a novel method of warming Mars, where chlorofluorocarbons (CFCs) are added to the atmosphere to produce a strong greenhouse effect.

Motivated by Lovelock's book, biophysicist Robert Haynes worked behind the scenes to promote terraforming, and contributed the neologism Ecopoiesis, built from Greek roots meaning "house" and "making". Ecopoiesis refers to the origin of an ecosystem. In the context of space exploration, Haynes describes ecopoiesis as the "fabrication of a sustainable ecosystem on a currently lifeless, sterile planet". Fogg defines ecopoiesis as a type of planetary engineering and is one of the first stages of terraformation.

This primary stage of ecosystem creation is usually restricted to the initial seeding of microbial life. A 2019 opinion piece by Lopez, Peixoto and Rosado has reintroduced microbiology as a necessary component of any possible colonization strategy based on the principles of microbial symbiosis and their beneficial ecosystem services. As conditions approach those of Earth, plant life could be brought in, and this will accelerate the production of oxygen, theoretically making the planet eventually able to support animal life.

Ecopoiesis potentially allows a form of co-evolution of terraforming with the target environment. In 1985, Martyn Fogg started publishing several articles on terraforming. He also served as editor for a full issue on terraforming for the Journal of the British Interplanetary Society in 1992. In his book Terraforming: Engineering Planetary Environments (1995), Fogg proposed the following definitions for different aspects related to terraforming: Planetary engineering: the application of technology for the purpose of influencing the global properties of a planet.

Geoengineering: planetary engineering applied specifically to Earth. It includes only those macro engineering concepts that deal with the alteration of some global parameter, such as the greenhouse effect, atmospheric composition, insolation or impact flux. Terraforming: a process of planetary engineering, specifically directed at enhancing the capacity of an extraterrestrial planetary environment to support life as we know it.

The ultimate achievement in terraforming would be to create an open planetary ecosystem emulating all the functions of the biosphere of Earth, one

that would be fully habitable for human beings. Fogg also devised definitions for candidate planets of varying degrees of human compatibility: Habitable planet (HP): A world with an environment sufficiently similar to Earth's as to allow comfortable and free human habitation. Biocompatible planet (BP): A planet possessing the necessary physical parameters for life to flourish on its surface.

If initially lifeless, then such a world could host a biosphere of considerable complexity without the need for terraforming. Easily-terraformable planet (ETP): A planet that might be rendered biocompatible, or possibly habitable, and maintained so by modest planetary engineering techniques and with the limited resources of a starship or robot precursor mission.

Fogg suggests that Mars was a biologically compatible planet in its youth, but is not now in any of these three categories, because it can only be terraformed with greater difficulty.

The idea is older than the word. Nineteenth-century astronomers watching Mars's seasonal darkening wondered openly about vegetation and even irrigation, and those speculations, wrong as they were, trained a generation to imagine other worlds as adjustable places. When the telescopic Mars of canals faded, the habit of thinking about planets as potential projects survived, waiting for a name.

End of free sample. The full book is available at putrabooks.github.io

ABOUT THE AUTHOR

Aira Astralis is a science writer specializing in astronomy and space exploration. Her work spans the full breadth of humanity's relationship with the cosmos -- from the earliest naked-eye observations to the engineering marvels of modern space missions.

Her books are built on a foundation of primary sources: peer-reviewed research, mission archives, and direct engagement with the scientific community. She writes for readers who want to understand not just what we know about the universe, but how we came to know it.

She believes that the most important frontier is not out there but in the gap between what scientists discover and what the public understands. Her books exist to close that gap.