Terraforming: An Investigation of the Boundaries Between Science and Hard Science Fiction

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To my parents and Kitten.

Thank you for standing by me through the dark and bright times this project has spanned.

If I amount to anything as a human being, it is because of you.

Abstract

Hard science fiction is a genre of science fiction in which the fictional settings, events, and technology conform to scientific and technological laws and facts. This mixture of science and fiction creates a rich site for the development of new speculative ideas and theories in the twentieth century. One example is the idea of terraforming, wherein a planet's environment is re-engineered to support human life. Early ideas about terraforming emerged from 1930s-1960s hard science fiction. By the early twenty-first century, the idea of terraforming had been the subject of over two-hundred scientific journal articles and six different conferences sponsored by NASA and other agencies. This dissertation examines the history of the idea of terraforming; describes its cultural history; and relates that history to twentieth century American scientific, technological, and cultural developments. It argues that terraforming hard science fiction and terraforming science overlap in ways that challenge perceived boundaries of science and fiction. In doing so, this dissertation illustrates how hard science fiction can be factored into the history of science and technology as a vernacular space outside the perceived dichotomy of science and non-science.

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Introduction

Hard science fiction is a genre of science fiction in which the fictional settings, events, and technology conform to scientific and technological laws and facts. This mixture of science and fiction create a rich site for the development of new speculative ideas and theories in the twentieth century. One example is the idea of terraforming, wherein a planet's environment is re-engineered to support human life.[1] Early ideas about terraforming emerged from 1930s-1960s hard science fiction. By the early twenty-first century, the idea of terraforming had been the subject of over two hundred scientific journal articles and six different conferences sponsored by NASA and other agencies.[2] In this study I examine the history of the idea of terraforming, describe its cultural history and relate it to twentieth century American scientific, technological, and cultural developments. I argue terraforming hard science fiction and terraforming science overlap in ways that challenge perceived boundaries of science and fiction. In doing so, I illustrate how hard science fiction can be factored into the history of science and technology as a vernacular space outside the perceived dichotomy of science and non-science. In this space, authors play out "thought experiments" that can have direct bearing on the questions, answers, and solutions that scientists form.

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[1] The term was first coined in Jack Williamson, "Collision Orbit" *Astounding Science Fiction,* July 1942 though early manifestations of the idea can be found in Olaf Stapledon's novel *Last and First Men* published in 1930.

[2] The first conference on terraforming was held at a special session of the Lunar Planetary society in Houston, Texas March 1979. One of the most recent conferences was held at the NASA Ames Research Center in March of 2004 titled "Science Fiction Meets Science Fact" featuring a debate with scientists and science fiction authors about terraforming.

Hard Science Fiction- Origins and Definitions

Building on the work of authors like H.G. Well, Jules Verne and Edgar Rice Burroughs, the magazine publisher Hugo Gernsback was largely responsible for establishing the genre boundaries of science fiction and its relation to science. With the publication of his groundbreaking magazine *Amazing Stories* in 1926, Gernsback became the first magazine publisher to put out magazines[3] solely dedicated to what he referred to alternately as "scientifiction," "science faction," "scientific fiction," and, ultimately, science fiction. His magazines initially published reprints of stories by H.G. Wells and Jules Verne, but shortly began to publish new stories that fit is criteria for science fiction which he explained was "a charming romance intermingled with scientific fact and prophetic vision."[4] To meet his goals, Gernsback repeatedly called on writers to do research in order to utilize up-to-date scientific knowledge and ideas to include in their stories and build their plots around, suggesting an ideal story would contain seventy-five percent literature and twenty-five percent science.[5] By basing their ideas on scientific fact, Gernsback felt authors could essentially predict future developments, ideas, and technologies, going so far as to suggest authors seek patents for their ideas.

In creating stories based in scientific fact and prophesy Gernsback sought to both entertain his audience and impart scientific knowledge that they might otherwise not obtain. This educational goal was also extended to Gernsback's editorials which were often lectures on new scientific ideas, and to quizzes that he included to test his readers

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[3] Other Gernsback titles dedicated to science fiction stories included *Science Wonder Stories*, *Air Wonder Stories*, and *Science-Fiction Plus*.

[4] Hugo Gernsback, "A New Sort of Magazine," *Amazing Stories*, 1 (April 1926), 3.

[5] Hugo Gerbsmack, "Fiction Versus Fact," *Amazing Stories*, 1 (July 1926), 291.

on the knowledge they learned from his stories. Despite these goals, Gernsback often published stories that stretched the limits of scientific plausibility. Though he repeatedly stated in his editorials that the best science fiction would “stick to science as it is known, or as it may reasonably develop in the future,” he also allowed for some “poetic license.”[6] Economic difficulties pushed Gernsback out of the publishing world by 1933, but his notion that science fiction should be built on scientific foundations and incorporate elements of prophesy influenced authors and publishers throughout the 1930s and 1940s.[7]

However, it became clear that not all science fiction stories met exacting standards of scientific verisimilitude. Publishers, including Gernsback, published a wide array of adventure stories that were often more fantastic than scientific including stories of time travel, intergalactic battles, and showdowns with heinous alien beings; a style latter dubbed “Space Opera.”[8] Science fiction publications also began to target younger audiences, publishing stories that focused more on simple adventure than science. As science fiction magazines proliferated in the 1930s, they often contained a mixture of stories that used science in a variety of ways, from the realistic to the fantastic.

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[6] Hugo Gernsback, “Plausibility in Scientifiction,” *Amazing Stories*, 1 (November 1926), 675.

[7] Gary Westfahl has been greatly influential in outlining the history and evolution of hard science fiction and especially the role that Gernsback played. See Gary Westfahl, *Cosmic Engineers: A Study of Hard Science Fiction* (Westport: Greenwood Press, 1996) and Gary Westfahl, *The Mechanics of Wonder: The Creation of the Idea of Science Fiction* (Liverpool: Liverpool University Press, 1998).

[8] Science fiction fans originally coined this term in the 1940s when it was used to define generally poor or trite science fiction. Since then, the term has been broadened to encompass science fiction stories that focus on adventure over scientific content, often reframing traditional narratives like westerns or military stories in space. For a concise history of the term, its application, and representative stories see David G. Hartwell and Kathryn Cramer, *The Space Opera Renaissance*, (New York: Tor Books, 2006).

In 1937 John W. Campbell became the editor of *Astounding Science Fiction* and sought to bring stricter guidance to the publication of science fiction. Though not eschewing fantastic stories entirely, he focused on recruiting authors with technological and scientific backgrounds to write stories aimed at an intelligent, well-educated audience. The stories he published were based heavily on scientific and physical laws that could draw readers' attention to potential wonders and dangers for future human societies. Having been educated at the Massachusetts Institute of Technology and earned a bachelors' in physics from Duke University, Campbell worked closely with his authors, monitoring their use of science, suggesting new stories based on new discoveries, and pushing for realistic and logical extrapolations. Like Gernsback before him, Campbell also saw his magazine and science fiction as avenues for scientists to examine and speculate upon a wider range of ideas than was allowed by the scientific academy. But unlike Gernsback, he sought to improve the literary quality of the stories by insisting his authors focus on engaging stories that incorporated scientific facts less didactically. Campbell envisioned authors using literary skills and scientific knowledge to create stories that essentially functioned like thought experiments; extrapolating future possibilities that could indicate problems and promises science and technology posed, and the impact these developments would have on humanity.[9]

Even with these guidelines, the scientific veracity of the stories Campbell published varied widely. Like Gernsback, Campbell made exceptions for poetic license,

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[9] An engaging biography of Campbell can be found in Albert Berger, *The Magic That Works: John W. Campbell and the American Response to Technology* (San Bernardino: Borgo Press, 1993). For a concise summary of Campbell's philosophy of hard science fiction see Westfahl, *The Mechanics of Wonder,* 179-202.

and expanded the notion of “science” to include the “soft” sciences like psychology and pseudoscience like telepathy. Nevertheless, Campbell and *Astounding’s* regular book reviewer P. Schuyller Miller considered stories that attained the greatest scientific verisimilitude as the “hard core” of the science fiction genre. This variety of story came to be recognized as a distinguishable sub-genre of science fiction; eventually dubbed “hard science fiction” by Miller in the 1950s.[10]

Boundary Work

By examining how hard science fiction and science interact, I will be focused on the boundaries between science and non-science. The sociologist Thomas Gieryn has suggested that boundaries between science and non-science are drawn out like the outlines of an ever-changing map in response to historic and cultural developments. Scientists use their authority and credibility to establish these boundaries. These “credibility contests” have high stakes, as the winners get the right to declare their vision as “true,” and along with that often comes jobs, fame and further influence.[11]

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[10] For an account of Miller’s role in naming the genre see Gary Westfahl, "The Closely Reasoned Technological Story: The Critical History of Hard Science Fiction," *Science Fiction Studies* 20.2 (1993), 157-175.

[11] Thomas Gieryn, "Boundary Work and the Demarcation of Science from Non-Science: Strains and Interests in Professional Interests of Scientists," *American Sociological Review* 48 (1983), 781-795. Further examples in: Thomas Gieryn, "Distancing Science from Religion in Seventeenth-Century England," *Isis* 79 (1988), 582-593; Thomas Gieryn, "Boundaries of Science," *Handbook of Science and Technology Studies*, ed. Shelia Jasanoff et al (Thousand Oaks: Sage, 1995), 393-443; Thomas Gieryn and Anne Figert, "Scientists Protect Their Cognitive Authority: The Status Degradation Ceremony of Sir Cyril Burt," *The Knowledge Society: The Growing Impact of Scientific Knowledge on Social Relations*, eds. G Bohme and N Stehr (Dordrecht: D. Reidel, 1986), 67-86. On credibility contests see Thomas Gieryn, *Cultural Boundaries of Science; Credibility on the Line* (Chicago: Chicago University Press, 1999), 14-16.

Historians of science have argued scientists and non-scientists use boundary work in complex ways. For example, the cultures of the New Age movement, the parapsychology movement, and skeptic groups contested for authority in America throughout the 20th century.[12] Early ecological science emerged from boundary work done between local practitioners and trained scientists in the Illinois Natural History Survey in the early part of the 20th century.[13] Boundaries existed between scientific communities as "trading zones" where simplified languages, or pidgins, allow for interaction, collaboration, and exchange without expertise.[14] Institutions and organizations can also play roles in establishing or expanding scientific boundaries.[15] Historians have sought to understand popularization by documenting how "legitimate science and nonlegitimate knowledge has been generated and how it is endlessly renegotiated" through the process of "marginalization, exclusion, and disqualification."[16]

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[12] David Hess, *Science in the New Age: The Paranormal Defenders and Debunkers, and American Culture* (Madison: University of Wisconsin Press, 1993).

[13] Daniel Schneider, "Local Knowledge, Environmental Politics, and the Founding of Ecology in the United States," *Isis* 91 (2000), 681-705.

[14] Peter Galison, *Image and Logic: A Material Culture of Microphysics* (Chicago: Chicago University Press, 1997).

[15] David Guston, "Stabilizing the Boundary between U.S. Politics and Science: The Role of the Office of Technology Transfer as a Boundary Organization," *Social Studies of Science* 29 (1999), 87-111; Kelly Moore, "Organizing Integrity: American Science and the Creation of Public Interest Organizations, 1955-1975," *American Journal of Sociology* 101 (1996), 1592-1627; and John Lynch, "'Scriptural Geology', Vestiges of the Natural History of Creation and Contested Authority in Nineteenth-Century British Science " *Repositioning Victorian Sciences: Shifting Centres in Nineteenth-Century Scientific Thinking*, eds. David Clifford, et al. (London: Anthem Press, 2006), 131-142.

[16] Bernadette Bensaude-Vincent, "A Historical Perspective on Science and Its 'Others'," *Isis* 100 (2009), 361, 367.

The boundaries between popular and professional science have been of particular concern to historians of science and technology. Roger Cooter and Stephen Pumfrey have explained that as the discipline of the history of science evolved,

> scholarly focus was rightly aimed at necessarily esoteric and… elite groups of knowledge-makers. On this reading… 'popular' science had to be a diminished simulacrum- simpler, weaker or distorted in proportion to the distance between the learned and lay communities.[17]

With the rise of cultural and social approaches to the history of science and technology, historians began to pay more attention to the role that popular culture and popularization played in knowledge creation and dissemination. Throughout the 1980s, historians published numerous social histories of science that incorporated popular culture with varying degrees of success. For instance, some historians worked to explain how popular groups sought to appropriate the authority of science.[18] Other historians examined how scientists began to bring science to public audiences.[19] Cooter and Pumfrey argue, however, that these histories maintained strict dichotomies between the elite and the

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[17] Roger Cooter and Stephen Pumfrey, "Separate Spheres and Public Places: Reflections on the History of Science Popularization and Science in Popular Culture," *History of Science* 32 (1994), 240.

[18] E.g. Patrick Curry, "Astrology in Early Modern England: The Making of Vulgar Knowledge," *Science, Culture, and Popular Belief in Renaissance Europe*, eds. Stephen Pumfrey, et al. (Manchester: Manchester University Press, 1991), 274-291; and Richard Yeo, "Science and Intellectual Authority in Mid-Nineteenth-Century Britain," *Victorian Studies* 28 (1984), 5-31.

[19] E.g. Simon Schaffer and Steven Shapin, *Leviathan and the Air Pump: Hobbes, Boyle, and the Experimental Life* (Princeton: Princeton University Press, 1985); Jan Golinski, *Science as Public Culture: Chemistry and Enlightenment in Britain, 1760-1820* (Cambrige: Cambridge University Press, 1992); Larry Stewart, *The Rise of Public Science: Rhetoric, Technology, and Natural Philosophy in Newtonian Britain, 1660-1750* (Cambridge: Cambridge University Press, 1992).

popular, and only defined the popular in relation to the elite groups.[20] These histories only focused on individual popularizers, the places they popularize, and their methods while overlooking the audiences themselves and how they assimilated the presented information. Many studies uncritically accepted the "diffusionist" or "deficit" model of knowledge transmission that had been utilized by scientists since the 1960s, wherein an elite group communicates knowledge to a passive and accepting common group.[21] Cooter and Pumfrey insisted this diffusionist model was problematic for a number of reasons. First, it tended to reinforce a static nature of knowledge generation rather than a dynamic one. Second, this model suggested that popular culture did not generate knowledge that differed from, or disagreed with, elite science. Third, this model insisted that popular culture blindly accepted the messages of the elites and did not interpret them in any way other than what was originally intended.[22]

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[20] Also see John C. Burnham, *How Superstition Won and Science Lost: Popularizing Science and Health in the United States* (New Jersey: Rutgers University Press, 1987).

[21] Some representative examples the authors cite include Christopher Hill, "Science and magic in Seventeenth Century England," *Culture, Ideology and Politics*, eds Raphael Samuel and Gareth Stedman Jones (London: Routledge, 1983); Keith Thomas, *Religion and the Decline of Magic* (London: Oxford University Press, 1971); David Vincent, *Literacy and Popular Culture: England 1750-1914* (Cambridge: Cambridge University Press, 1989). The authors also cite the Public Understanding of Science (PUS) movement for relying on "traditional historical and sociological formulations of the 'popular' as passive lay consumptions of learned products." Cooter and Pumfrey, "Separate Spheres," 238.

[22] For additional explanations of this model as a form of science communication, how it has been used, and its inadequacies see Bruce Lewenstein, "From Fax to Facts: Communication in the Cold Fusion Saga," *Social Studies of Science* 25.3 (1995), 403-436; Stephen Hilgartner, "The Dominant View of Popularization: Conceptual Problems, Political Uses," *Social Studies of Science* 20.3 (1990), 519-39; Robert Logan, "Popularization V. Secularization: Media Coverage of Health," *Risky Business: Communicating Issues of Science, Risk and Public Policy*, eds. L. Wilkins and P.

Cooter and Pumfrey suggested refining the history of the relationship between the popular and scientific with more dynamic and interactive models, researching a wider field of popularizers and sites where knowledge is made and disseminated, and utilizing a larger selection of cultural productions including non-scientific texts, popular prose, and non-text based artifacts. Many historians of science have begun to address these issues[23] in ways that illustrate the distinction between popular and professional are no longer meaningful.

For instance, Anne Secord studied artisan botanists of Lancashire to "dispel the notion that 'popular' and 'learned,' or 'high' and 'low' culture are fixed categories

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Patterson (Westport: Greenwood, 1992) 43-60; Jane Gregory and Steve Miller, *Science in Public: Communication, Culture, and Credibility* (New York: Plenum Press, 1998), 81-99.

[23] A few notable examples of scholarship embracing these approaches include: on new models see Katherine Pandora, "Knowledge Held in Common: Tales of Luther Burbank and Science in the American Vernacular," *Isis* 92 (2001), 484-516; Katherine Pandora and Karen Rader, "Science in the Everyday World: Why Perspectives from the History of Science Matter," *Isis* 99 (2008), 350-364; Andreas Daum, "Varieties of Popular Science and the Transformation of Public Knowledge," *Isis* 100 (2009), 319-332; on non-text based sites see: Sally Gregory Kohlstedt, "Parlors, Primers, and Public Schooling: Education for Science in Nineteenth-Century America," *Isis* 81 (1990), 424-445; Sally Gregory Kohlstedt, "'Thoughts in Things': Modernity, History, and North American Museums," *Isis* 96 (2005), 586-601; Samuel J.M.M. Alberti, "Objects and the Museum," *Isis* 96 (2005), 559-571; on broadening conceptualizations of popularizers see: Bernard Lightman, *Victorian Popularizers of Science: Designing Nature for New Audiences* (Chicago: Chicago University Press, 2007); Aileen Fyfe and Bernard Lightman, eds., *Science in the Marketplace: Nineteenth-Century Sites and Experiences* (Chicago: Chicago University Press, 2007); on resistance to "popular" label see: Jonathan Topham, "The *Mirror of Literature, Amusement, and Instruction,* and Cheap Miscellanies in Early Nineteenth-Century Britain," *Reading the Magazine of Nature: Science in the Nineteenth-Century Periodical*, eds. Geoffrey Cantor and et al. (Cambridge: Cambridge University Press, 2004), 37-66; and Anne Secord, "Botany on a Plate: Pleasure and the Power of Pictures in Promoting Early Nineteenth-Century Scientific Knowledge," *Isis* 93 (2002), 28-57.

defined by their content, and see them instead as emergent social constructs."[24] Jane Gregory and Steve Miller argued that the idea of popularized science is blurry at best, and professional journal articles were, to some degree, popularized versions of the science they represent: "There is no clear boundary between what is and is not 'popular' science as opposed to any other science."[25] Bruce Lewenstein has argued that professional and popular communications can inform and refer to each other, creating a complex web of interaction.[26] In his survey of literature on diet and cancer, Stephen Hilgartner concluded that distinctions made between popular and professional science are inconsistent, ambiguous, and arbitrary.[27] Jim Secord implored historians of science to broaden their approach to the discipline by creating a new framework that views science as a form of communication and drop the term "popular science" because there is no one definitive version of popular science and labeling something as popular science "can be seen as tantamount to saying that it is 'not science' or even a kind of pseudoscience" while reaffirming the perceived boundaries "between expert, exoteric knowledge and the exoteric knowledge found in textbooks and simplified redactions."[28]

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[24] Anne Secord, "Science in the Pub: Artisan Botanists in Early Nineteenth-Century Lancashire," *History of Science* 32 (1994), 270-71.

[25] Gregory and Miller, *Science in Public: Communication, Culture, and Credibility*, 245.

[26] Lewenstein, "From Facts to Fax," 425-431; Bruce Lewenstein, "Science and the Media," *Handbook of Science and Technology Studies*, ed. Sheila Jasanoff (London: Sage Publications, 1995), 343-360.

[27] Hilgartner, "The Dominant View of Popularization: Conceptual Problems, Political Uses," 528-529.

[28] James Secord, "Knowledge in Transit," *Isis* 95 (2004), 670-671. One prime example of Secord's own efforts to investigate the boundaries between the popular and scientific and illustrate science as communication came in his widely acclaimed book James

In 2009, the History of Science Society's journal *Isis* dedicated a "Focus" section to the approaches to the study of history of science and popular culture in which many historians supported Secord's conclusions. Jonathan Topham urged historians to "break down the distinction between the making and communicating of knowledge" and insisted "popular science" and its cognates be considered "legitimate objects of historical inquiry, contributing to a common project of understanding how knowledge comes to be constituted and reconstituted within culture."[29] Andreas Daum acknowledged those studies of the history of science and technology that have incorporated popular culture have privileged elite scientific communities and largely focused on Victorian Britain. Daum recasts popular science and science as interacting in a sphere of "public knowledge," a place that is "part of a larger fabric of practices and oral, written, or visual presentations that societies develop to make meaningful statements about themselves and the natural and cultural worlds they find themselves in."[30]

Katherine Pandora illustrated that the early-20th century horticulturalist Luther Burbank did not fit either notion of a professional or popular scientist. Rejecting the distinction between popular and professional, she argued his ideas flourished in a vernacular space that incorporated "language that each of us regularly speaks and

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Secord, *Victorian Sensation: The Extraordinary Publication, Reception, and Secret Authorship of Vestiges of the Natural History of Creation* (London: The University of Chicago Press, 2000).

[29] Jonathan Topham, "Introduction to Focus: Historicizing 'Popular Science'," *Isis* 100 (2009), 317.

[30] Daum, "Varieties of Popular Science and the Transformation of Public Knowledge," 331.

represents the group to which we all belong, no matter what our other specialized membership might be." In this space, vernacular discussions "create memorable images infused with emotion that persist across social space and generational time" and speedily "travel and proliferate across venues." Most importantly, this intellectual commons allows "modes of communication that professional strictures inhibit… providing opportunities to engage in speculation at odds with the rhetorical norms of academic science."[31]

In this dissertation I explore the boundaries of science and non-science by examining how the idea of terraforming was formed in the interaction between hard science fiction authors and scientists. I explain that this interaction fits Pandora's model and argue terraforming inhabited a vernacular space that elided the distinctions between popular science, professional science, and science fiction.

The History of Science and Technology and Science Fiction

Science fiction has generally been neglected or, at best, given cursory treatment in scholarly works on the history of science that focus on popular culture.[32] For example, Dorothy Nelkin, Marcel LaFollette, and James Lee Kauffman have addressed science in

[31] Pandora, "Knowledge Held in Common: Tales of Luther Burbank and Science in the American Vernacular," 492.

[32] Notable exceptions come from studies pertaining to science and film such as Fred Glass, "The 'New Bad Future': *Robocop* and 1980s' Sci-Fi Films," *Science as Culture* 5 (1989), Robert Lambourne, Michael Shallis and Michael Shortland, *Close Encounters? Science and Science Fiction* (New York: Hilger, 1990); Errol Vieth, *Screening Science: Contexts, Texts, and Science in Fifties Science Fiction Film* (Lanham: Scarecrow Press, 2001), Christopher Frayling, *Mad, Bad, and Dangerous? The Scientist and the Cinema* (Chicago: University of Chicago Press, 2005).

popular media but downplay or fail to note the role of science fiction.[33] Cecelia Tichi and Howard Segal have examined how science impacts American and British literature but ignore science fiction preferring to focus on higher culture.[34] When Steven Dick addressed how imaginative ideas in science fiction were affected by developments in the space sciences, the influence of science fiction upon science were neglected. [35] A similar neglect can be found in histories of planetary astronomy and space technology.[36] William Sheehan's attention to the role of science fiction is also cursory, focusing only on big names such as H.G. Wells.[37]

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[33] Dorothy Nelkin, *Selling Science: How the Press Covers Science and Technology* (New York: W.H. Freeman, 1987); Marcel Lafollette, *Making Science Our Own: Public Images of Science, 1910-1955* (Chicago: University of Chicago Press, 1990), Marcel Lafollette, "Eyes on the Stars: Images of Women Scientists in Popular Magazines," *Technology and Human Values* 13.3/4 (1988), 262-275; James Lee Kauffman, *Selling Outer Space: Kennedy, the Media, and Funding for Project Apollo, 1961-1963* (Tuscaloosa: University of Alabama Press, 1994).

[34] Cecelia Tichi, *Shifting Gears: Technology, Literature, Culture in Modernist America* (Chapel Hill: University of North Carolina Press, 1987), Howard P. Segal, *Technological Utopianism in American Culture* (Chicago: University of Chicago Press, 1985).

[35] Steven Dick, *The Biological Universe: The Twentieth Century Extraterrestrial Life Debate and the Limits of Science* (Cambridge: Cambridge University Press, 1996), Steven Dick, *Life on Other Worlds : The 20th-Century Extraterrestrial Life Debate* (New York: Cambridge University Press, 1998), Steven Dick, *America in Space: Nasa's First Fifty Years* (New York: Abrams, 2007).

[36] Joseph Tatarewicz, *Space Technology and Planetary Astronomy* (Bloomington: Indiana University Press, 1990); Ronald Schorn, *Planetary Astronomy : From Ancient Times to the Third Millennium* (College Station: Texas A&M University Press, 1998)

[37] William Sheehan, *Telescopic Views and Interpretations, 1609-1909* (Tucson: University of Arizona Press, 1988); William Sheehan, *William Sheehan, the Planet Mars : A History of Observation & Discovery* (Tucson: University of Tucson Press, 1996); William Sheehan and James O'Meara, *Mars: The Lure of the Red Planet*, (Amherst, N.Y.: Prometheus Books, 2001). A similar treatment is found in Karl Guthke, *The Last*

Yet, there is growing scholarly evidence that science fiction plays an important role in the development of science. Roslynn Haynes has demonstrated how popular fiction and science fiction have reflected public concerns about scientists and shaped the public response to, and support of, science.[38] David Swift has demonstrated that reading science fiction influenced many scientists who later joined the NASA's Search for Extraterrestrial Intelligence (SETI) program.[39] In his 1997 dissertation, John Cheng demonstrated that science fiction played a pivotal role in the history of rocketry in America by providing both imaginative stimulus and a networking forum for rocketry hobbyists, leading to the development of the first American rocketry club.[40] Howard McCurdy and William Bainbridge have both demonstrated that science fiction played an important role in generating public support for the American space program.[41] Audra Wolfe has demonstrated how themes and images from science fiction were problematic

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Frontier: Imagining Other Worlds, from the Copernican Revolution to Science Fiction (Cornell: Cornell University Press, 1990).

[38] Roslynn Haynes, *From Faust to Strangelove: Representations of the Scientist in Western Literature* (Baltimore: Johns Hopkins University Press, 1994).

[39] David Swift, *Seti Pioneers: Scientists Talk About Their Search for Extraterrestrial Intelligence* (Tucson: University of Arizona Press, 1990).

[40] John Cheng, "Amazing, Astounding, Wonder: Popular Science, Culture, and the Emergence of Science Fiction in the United States, 1926-1939," Diss. University of California Berkley, 1997.

[41] Howard McCurdy, *Space and the American Imagination* (Washington: Smithsonian Institution Press, 1997); William Sims Bainbridge, *Dimensions of Science Fiction* (Cambridge: Harvard University Press, 1986).

for the development of exobiology in the 1950s and 1960s.[42] Ernest Yanarella has argued that science fiction's use of cultural symbols makes it a rich resource for political action and thought regarding ecological policy.[43] Perhaps two of the most refined treatments of the relationship that indicate the important relationship between science fiction and science can be seen in the works of Martin Willis and Robert Markley.

Willis' book *Mesmerists, Monsters and Machines* provides an in-depth examination of the 19th century relationship between science fiction and the culture. He takes an interdisciplinary approach that illustrates how "fictions of science reflect the contemporary scientific world [and] they also contribute to the construction of science within nineteenth century culture."[44] Willis establishes that "science fiction is as intellectually complex, as socially significant, and as historically revealing as any other form of fiction."[45] For instance, Willis traces out the history of the perception of mesmerism in stories by Edgar Allen Poe, which reflect the culture's ambivalence of mechanical/materialist science and suspicions of mesmerism. As Poe's critics debated the truth behind some of his more fantastic stories, they replicated the contemporaneous

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42 Audra Wolfe, "Joshua Lederberg, Exobiology, and the Public Imagination, 1958-1964," *Isis* 93 (2002), 183-205.

43 Ernest Yanarella, *The Cross, the Plow, and the Skyline: Contemporary Science Fiction and the Ecological Imagination*, (Parkland: Brown Walker Press, 2001).

44 Martin Willis, *Mesmerists, Monsters, and Machines* (Kent: Kent State University Press, 2006), 235.

45 Ibid, 2.

debate about mechanics and mesmerism and, therefore, his texts mimicked "authentic scientific theses."[46]

Dying Planet by Robert Markley "draws on work in planetary astronomy, the history and cultural study of science, science fiction, literary and cultural criticism, ecology, and astrobiology to offer a cross-disciplinary investigation of changing perceptions of Mars as both a scientific object and a cultural artifact."[47] It reveals the role that analogy between Earth and Mars played in framing the growing information about the planets in both the popular and scientific realms. Markey demonstrated that the history of Mars "is embedded in larger scientific and nonscientific discourses and practices."[48] Chapters on the historical scientific discoveries about Mars alternate with chapters on how popular culture absorbed or created new ideas about Mars. For instance, chapter four looks at the time between Lowell's death and the first Mariner mission-examining how planetary scientists tried to reconcile Lowell's vision of a dying, desert-like Mars riddled by canals with new data that revealed Mars to be much colder and utterly dry. In chapter five, Markley discusses the way Lowell's visions were taken up and perpetuated by a wide range of science fiction authors who used Mars as a backdrop to express their concerns about ecological devastation, foreign invasion, and cultural conformity. Changing scientific views of Mars ultimately impacted popular conceptions of the planet and the role important analogies between Mars and Earth played in understanding and framing the growing amounts of data about both planets.

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[46] Ibid, 132.

[47] Robert Markley, *The Dying Planet* (Durham: Duke University Press, 2005), 2.

[48] Ibid, 13.

While both Markley and Willis build interdisciplinary studies of their topics, they uphold disciplinary distinctions. Willis consistently draws lines between professional and amateur science, and Markley retains a distinct separation between science and science fiction, even separating the content by chapters. I will show that the situation is not so simple and that a considerable overlap exists between science and hard science fiction. I will argue that the terraforming science is a thought experiment with origins in hard science fiction and trace how and why it crossed from science fiction to professional science. But rather than a one-way transmission of ideas, I will show that terraforming continued to develop in the interactions between science and fiction.

It is important to note that, while Markley does discuss the idea of terraforming, his treatment of the idea varies considerably from mine. First, Markley discusses terraforming as a small thread in a much larger tapestry that is his study of the cultural and scientific history of Mars. As such, he only briefly discusses the idea of terraforming and only incorporates a fraction of the texts about it into his work. In particular, his survey of the scientific literature is exceedingly small, tends to pay little attention to the chronological development of the ideas, and, at times, is incorrect. My study provides a more thorough history of the idea by extensively researching the scientific literature, science fiction literature, biographies of authors and scientists, popular reactions to the idea, and the place of the idea within the history of science and technology. Second, throughout his text Markley analyzes science fiction about terraforming through narrow political and economic lenses that fit his argument that Mars, and by extension Earth, was seen a dying planet. My study focuses more on the historical evolution of the idea as a whole and how terraforming challenges boundaries between the scientific and popular.

Third, Markley indiscriminately draws on a wide array of science fiction genres, ignoring the important connections between the goals of the genre and the form and function of the scientific content it engages. My study will focus on the specific genre of hard science fiction, elucidating the genre's goals and ideals and the manner in which specific authors sought to attain those goals in their development of terraforming.

Design and Methods of Research

In the **first chapter** I establish that 20th century industrialism led to a technological culture defined by Junzo Kawada as "a complex of certain technological principles, in connection with a set of value orientations, such as worldview, attitudes towards living things, productivity and labour."[49] By surveying historical works by historians Thomas Hughes, David Nye, Ruth Schwartz Cohen, and Cecilia Tichi, I identify distinct features of the American technological culture: a positive view of technology as a tool of imperialism and a means to create a materially wealthy and modern society, a glorification of engineers, and a consensus that vast technological projects can improve nature and harness resources that would otherwise be wasted. By surveying thirteen science fiction stories and novels about terraforming created from 1930 to 1960, I show how they reflect and perpetuate the technological culture and its central foundation narratives. I also examine how counter-narratives expressing resistance to and skepticism of the technological culture and terraforming emerged at the end of this period. I conclude that hard science fiction provided a unique space for the

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[49] Junzo Kawada, "Technology and Its Value Orientation," *Culture and Technology in Modern Japan*, eds Ian Inkster and Fumihiko Satofuka, (London: Victoria House, 2000), 129.

creation, communication, and development of terraforming that reflected the values and ideals of American technological culture.

In Chapter two, I analyze the relationship between hard science fiction, professional science, and the technological culture. The first treatment of terraforming by a professional scientist came from Carl Sagan, and an examination of Sagan's biography reveals his activities as an avid fan and proponent of science fiction and the impact science fiction had on his thoughts and professional interests. Sagan's speculation inspired further plans for terraforming by hard science fiction author Poul Anderson. A case study of Anderson's activities as an author based on his published writings and archival letters reveals his reliance on scientific research, an emphasis on scientific fact in his hard SF writing, and the influence of the technological cultural values on his work. Yet the negative impacts of further industrialization, including threats of overpopulation, pollution, and resource depletion generated a cultural backlash. These events represented a growing schism of opinion within America culture over the effects of science and technology that impacted both hard science fiction and terraforming. This can be seen in the emergence of the New Wave science fiction genre that maintained a skeptical view of technology and terraforming, as revealed in an analysis of works by Richard McKenna and Roger Zelazny.

Sagan's idea initially sparked little interest within the larger scientific community. However, in 1975, NASA funded extensive research on terraforming Mars. What accounts for this shift? In **Chapter three,** I examine how, throughout the 1970s, concern continued to build over the impact of overpopulation and pollution as revealed in a survey of works by Barry Commoner, the Club of Rome, and the appropriate technology movement. Technological enthusiasts sought to counter these concerns with plans for space colonies and terraforming, as seen in Gerard O'Neill's, *The High Frontier*. Terraforming science was further aided by data from the NASA space probes, and an analysis of Sagan's professional and popular works illustrates how he used that data in conjunction with ideas from James Lovelock to develop a new vision of terraforming that challenged the traditional technological narrative. Technological optimism also continued to thrive within hard science fiction as seen in a case study of the work of Gregory Benford. An analysis based on his essays and interviews with the author reveal that his approach to hard science fiction and terraforming further demonstrate the overlap between science and hard science fiction and the importance of the genre to the continuing evolution of terraforming.

In Chapter four I explain that in the late 1970s, ideas about terraforming split into roughly two narratives. A survey of hard science fiction, professional science, and popular works reveals that the technological terraforming narrative continued to promote the vision of terraforming laid out in hard science fiction as a natural and inevitable extension of human activities; it was a technological process that could be done quickly and efficiently to harness the "wasted" to create a second creation identical to Earth for the needs or whims of humanity. Yet, following Sagan's ideas, a distinctive new narrative emerged, whose ecological terraforming put the process on a millennial timescale. An examination of professional and popular articles, as well as conference papers reveals that while some still viewed this as a way to create a second Earth, others sought to use terraforming in ways that respected natural environments and proliferated life as a whole, not just humanity. Both narratives developed in the overlap between science and hard science fiction. This is made especially clear by case studies of Jerry Pournelle's hard science fiction and popular science writings and James Oberg's popularizations.

In **Chapter five**, I demonstrate that the overlap between terraforming science and hard science fiction greatly expanded in the 1980s. A survey of an array of professional articles and hard science fiction stories and novels reveals that the technological narrative proliferated throughout this period in a wide array of outlets and genres, optimistically envisioning humanity using vast technological schemes to "fix" other environments while disregarding natural spaces. The boundaries between the science and hard science fiction were transcended as terraforming plans of scientists relied heavily on fantastic technology and drew extensively on hard science fiction texts and narrative techniques. A case study of hard science fiction author Pamela Sargent based on interviews and an analysis of her work *Venus of Dreams,* reveals how these scientific plans influenced her ideas about terraforming and her fictional narratives. At the same time, other authors continued to develop narratives focused exclusively on Mars and using ecological methods to "naturally" transform the planet as revealed in a survey of further hard science fiction and professional sources. This narrative was also advanced across boundaries, as revealed in an analysis of interaction of James Lovelock's novel *The Greening of Mars* and the work of scientist Christopher McKay. Further boundary spanning is revealed in an analysis of Frederick Turner's hybrid text *Genesis*, which combined science, hard science fiction, and epic poetry genres to create a foundation narrative for the future Martian society. This chapter concludes that these texts ultimately formed a vernacular conversation on the ethical ramifications of terraforming while struggling to envision the future of humanity and its relationship to nature and technology.

Original Contributions Of This Study

Based on these sources and analysis, I explain how terraforming science and science fiction are directly related to larger values and ideals of the 20th century technological culture and establish that both the science and the fiction are manifestations of larger cultural narratives. I demonstrate how terraforming hard science fiction and science overlap with one another. It is not just a case of one influencing the other in form or content, but rather the texts occupy a middle landscape between science and fiction. It is within this overlap that the study of terraforming challenges various interpretations of boundary work summarized above, which rely on the categories of science and non-science and the claims to epistemological authority about these differences. Rather, the history of terraforming conforms more precisely to Katherine Pandora's ideas about a vernacular conversation wherein a democratic range of voices shared their ideas in a variety of outlets in an effort to envision the future of humanity in relation to nature and technology. I make this case to highlight the importance of hard science fiction to the history of science. First, hard science fiction can be a space that allows for the creation, development, and communication of scientific and technological ideas. Second, the authors of hard science fiction are often scientists and engineers that at times use the genre to play out "thought experiments" that they could otherwise not examine in professional forums. These thought experiments can have direct bearing on the questions, answers, and solutions, scientists form. Third, these stories are a creative outlet for scientists and engineers that can reveal to historians their hopes and fears in compelling and dramatic ways.

Chapter 1: The Science Fiction Origins of Terraforming

"What are we going to make of this planet? We can make it anything we want…its up to us. They say man is endlessly adaptable. I say on the contrary that man doesn't adapt himself as much as he adapts his environment."[1]

A group of pilgrims aboard the *Mayflower* arrive at their destination after a long and harrowing journey to find their new home a hard and unforgiving place. They struggle with the environment, lack of tools and supplies, and their own misgivings as they try to scrape out an existence by creating farms of their own. Many lose their lives to the conditions, and only the strong and self-reliant survive. The ones that continue find both personal freedom and spiritual fulfillment from creating a better life for themselves and their children. But this is not a story about settling the New World, this is a story about settling Ganymede written by science fiction author Robert Heinlein in the 1950s. The pilgrims do not simply settle the land, they transform it to their needs through terraforming. How and why does the story of 17th century settlement of the North America get transposed to a distant time and a distant planet in a novel from the 1950s? How does terraforming become an integral part of the narrative?

In this chapter I will discuss the origins of the idea of terraforming, and establish its relationship with 20th century western technological culture. This technological culture has distinct features: a positive view of technology as a tool of imperialism and a means to create a materially wealthy and modern society, a glorification of engineers, and a consensus that vast technological projects can improve nature and harness resources that would otherwise be wasted. Science fiction stories about terraforming written between 1930 and 1960 both reflected and perpetuated the technological culture and its

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[1] Robert Heinlein, *Farmer in the Sky* (New York: Ballantine, 1985), 194.

central foundation narratives. However, counter-narratives emerged at the end of this period expressing resistance to and skepticism of the technological culture and terraforming. Through this examination it will be established that science fiction provided a unique space for the creation, communication, and development of speculative scientific ideas like terraforming.

Second Creation, a Sense of Identity, and the Technological Foundation Narrative

In his examination of the impact of technology on cultural and values in Japan, Junzo Kawada explains that industrialism inherently impacts human society in ways that result in a technological culture-- which he defines as "a complex of certain technological principles, in connection with a set of value orientations, such as worldview, attitudes towards living things, productivity and labour."[2] This results in the advancement of different cultural values and ideals depending on how a nation incorporates industry. A survey of works on the history of technology in America reveals a key set of ideals and values that demarcate American technological culture.

From early colonization, American settlers viewed the natural landscape as wasted resources that could be harnessed with technology, allowing them to convert it to a Garden of Eden-- a "second creation." As they pressed westward in the 19th century, their machines "tamed" the prairies and turned "wasted" resources into commodities:

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[2] Junzo Kawada, "Technology and Its Value Orientation," *Culture and Technology in Modern Japan*, eds Ian Inkster and Fumihiko Satofuka, (London: Victoria House, 2000), 129.

axes, saws, and mills turned trees into lumber; picks and steam drills turned ores into metals; irrigation and damming technologies turned deserts into farm land.[3]

During the 19th century, the concept of the second creation as a Garden of Eden was rapidly replaced with the vision of an industrialized second creation produced by the widespread development of the "American system of manufacture," which relied on machinery to mass-produce interchangeable parts, and the factory system, which created organized, hierarchical places to work. These approaches, which benefited greatly from the harnessing of America's open spaces and rich resources, resulted in a proliferation of consumer goods, from sewing machines to bicycles.[4] While other industrializing nations lamented the loss of the natural world and it sublime beauty, Americans often viewed industrialization as an improvement of nature that increased its practicality and utility. At times, nature was seen as designed to be harnessed by technology. While many Americans valued unrefined nature for its vaunted ability to awe and elucidate feelings of the sublime, many others viewed technology in the same way.[5]

The American sense of identify was influenced by further technological developments in the later 19th century. The second industrial revolution was seen as the manifestation of some of the brightest minds in human history created for the purpose of taming, controlling, and organizing nature for human ends and themselves as

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[3] Thomas Hughes, *Human Built World: How to Think About Technology and Culture* (Chicago: University of Chicago Press, 2005), 10; Michael Adas, *Dominance by Design: Technological Imperatives and America's Civilizing Mission* (Cambridge: Belknap Press, 2006), 78; Carroll Pursell, *The Machine in America: A Social History of Technology* (Baltimore: Johns Hopkins University Press, 2007), 155-175.
[4] Pursell, *The Machine in America* 87-91; Ruth Schwartz Cowan, *A Social History of American Technology* (Oxford: Oxford University Press, 1997), 78-89.
[5] For more on the role of sublime in American technological history see David Nye, *American Technological Sublime* (Cambridge: The MIT Press, 1994).

exceptionally able to create technology. As industrialization continued, Americans embraced its implicit values: order, rationality, and control. For instance, as conservation movements and scientific management became popular at the turn of the 20th century, efficiency became equated with moral correctness and wastefulness with immorality.[6]

Narratives reinforced this vision. Environmental historian Carolyn Merchant has argued that a shared cultural narrative she refers to as the "recovery narrative" justified the attempts to harness nature. Derived from a combination of Christian theology and Enlightenment philosophy, this narrative had two manifestations. In one, humanity exists in a world that is increasingly being improved by humanity's actions as it seeks to reclaim the Garden of Eden by slowly taming all of Earth. In the other more secular version, humanity exists in a state of ecological decline and corruption, from which it must struggle to return to a more pristine past by restoring Earth's natural systems. More than just providing justifications and motivations, these narratives also encode gender norms. Nature is depicted as the feminine force that must be ruled over or dominated with masculine force.[7]

Similarly, historian of technology David Nye has argued that Americans adopted a "technological foundation narrative" to qualify the relationship between humans and machines in the development of the American nation. This narrative simplified and

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[6] For an in-depth examination of how efficiency became a cultural value in America and abroad see Jennifer Karns Alexander, *The Mantra of Efficiency: From Waterwheel to Social Control* (Baltimore: The Johns Hopkins Press, 2008); also see Adas, *Dominance by Design* 74-75; David Nye, *America as Second Creation: Technology and Narratives of New Beginnings* (Cambridge: MIT Press, 2003), 9-10; Hughes, *Human Built World* 4-5, 29; Pursell, *The Machine in America* 207-213; for specific examples of how the ideas of waste and efficiency influenced American literature see Tichi, *Shifting Gears* , 55-96.

[7] Carolyn Merchant, *Reinventing Eden: The Fate of Nature in Western Culture* (New York: Routledge, 2003), 11-24.

abstracted complex experiences into manageable stories that explained the success of the American society as the result of the application of technology to the natural world; depicted America as a vast and untouched resource; and portrayed technologically rendered transformation as an inevitable and harmonious process. These events were framed in ways that made them consistent with the cultural values of white, middle-class Americans. They asserted that technology was used for egalitarian purposes: the axe was used for independence, the mill created prosperity for all, and the steam engine enhanced republicanism. They took fictional forms at times (e.g. the works of Mark Twain or the tales of Paul Bunyan), and were also manifest in a wide array of sources such as the media (newspaper stories and editorials), the arts (paintings, novels, poems), personal accounts (diaries, letters, speeches) and advertisements. Across all these media, the technological foundation story read the same: "In each case, Americans entered a new region, deployed appropriate technology, reinvented the landscape, and created a prosperous new community."[8]

These values and narratives influenced American imperialism. American imperialists viewed the unique style of American production, organization, and manufacture as crucial to the successful American state. Therefore, it was America's destiny to guide other nations down a similar path. For instance, American efforts to colonize the Philippines were "consistently legitimized by an enduring confidence that a superior aptitude for technological endeavors ensure[d] that American designs for the transformation of non-Euro societies [would] be realized." American colonizers viewed the Philippines as valuable resources squandered by the natives' passive attitude toward

[8] Nye, *America as Second Creation* 2-12; quote 220 .

technology and primitive techniques like slash and burn that were wasteful and destructive. Such perceived wastefulness justified intrusive and disruptive projects to transform indigenous societies.[9]

As the 20th century progressed, optimism about technology grew and generated positive claims about the future. Nature was increasingly marginalized as American engineers, scientists, and managers continued to view it as a source of exploitable resources, and saw industrial laboratories and universities as places to generate substitutes for resources that nature did not readily provide. American progress seemed unstoppable, inspiring many to forecast a future of continued progress. Technological enthusiasts like Robert Thurston, Thomas Edison, and Nicola Tesla foresaw rapid evolutionary progress, improved quality of life, larger and sustainable sources of energy, and an increase in world peace. Others enthusiastically promoted electricity as a force that, combined with scientifically planned government, could restructure nations, manufacturing, society, and potentially emancipate workers from their dreary existences providing them with individual autonomy.[10] We will see that such optimism deeply influenced science fiction throughout the 20th century.

The First World War and ensuing American prosperity further supported these optimistic opinions of technology in America. Americans celebrated technology's role in winning the war. Shortly after the war Americans were flooded with affordable

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[9] Adas, *Dominance by Design* Chapter 3 "Engineer's Imperialism," quote from 31. Carroll Pursell has also noted how engineers held lead positions in other American Imperial endeavors in Japan, Cuba, Nicaragua, and Mexico: Pursell, *The Machine in America* 189-198.

[10] Hughes, *Human Built World* 9, 52; Nye, *America as Second Creation* 261, 270-273; Thomas Hughes, *American Genesis: A Century of Invention and Technological Enthusiasm* (New York: Penguin Books, 1989), 299-302.

technologies from automobiles to radios that promised to make life easier while every aspect of American life was converted by the industrial society including homes, work, communication, food, and their goals.[11] In the immediate Post-war era, with the exception of Dos Passos, "no major [American] writer challenged the assumption that scientific research and technological innovation were fundamentally progressive and beneficent."[12] As American industrial ascendance continued during the 1920s, other nations began to look to America as an example of a distinctly "modern" culture-- what Hughes refers to as the "second discovery of America."[13]

<u>Glorification of Engineers</u>

In this technologically-based society, a cult evolved around engineers. Engineering grew into a profession from the 1870s to the 1940s. Professional ideology cast them as a "vital force" for progress and enlightenment, bias-free thinkers suited to lead and arbitrate causes, and gave them the special responsibilities to undertake projects beneficial to all humanity.[14] Engineers played highly visible and critical roles in the development of key aspects of American industry including transport (railroads, canals, bridges), electrification, cities (sewers, transport lines, stadiums), and military might (weapons research and development, ship construction, logistics). The embodiment of

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[11] Pursell, *The Machine in America* 239-250. For summary of these changes see Cowan, *Social History* Chp 7 "Industrial Society and Technological Systems."
[12] Adas, *Dominance by Design* 200-205 quote from 200.
[13] Hughes, *American Genesis* 295-297.
[14] Edwin Jr. Layton, *The Revolt of the Engineers; Social Responsibility and the American Engineering Profession* (Baltimore: Johns Hopkins University Press, 1986), 56-65. Also see Pursell, *The Machine in America* 101-107; Tichi, *Shifting Gears* 99-100. Layton received criticism for what some saw as overstating the political action of a handful of engineers as a revolt. For recent scholarship that seeks to assemble a more nuanced depiction of the engineering populations and their motivations see Peter Meiksins, "The *Revolt of the Engineers* Reconsidered," *Technology and Culture* 29.2 (1988), 219-246.

industrial ideals like efficiency, organization, and production, engineers became symbols of masculine power within American culture.[15] In the late 1800s, engineering was seen as masculine an occupation as being solider or explorer. Engineers were treated as masculine role models in juvenile fiction and surveys indicated that 31% of American high school-age boys desired to be engineers.[16]

Writing as early as 1844, Ralph Waldo Emerson glorified the role of engineers and their machines for the ability to tame the frontier and "bind" disparate reaches of America together.[17] In 1895, George Morison, the president of the American Society of Civil Engineers, idealized engineers as priests leading the world into a new era free from superstition.[18] Writing in the interwar period, Charles Beard, a Columbia University historian, praised American engineers for their work ethic and God-like ability to shape the natural world to fit human desires.[19] When establishing the colonies in the Philippines, American engineers were portrayed as models of empirical thinking and technical expertise. This was in stark contrast to the native population depicted as primitive, credulous, and impractical. As the colonies were established, the engineers'

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[15] Adas, *Dominance by Design,* 142-144; Tichi, *Shifting Gears,* 104-106.
[16] Hughes, *Human Built World,* 31-32; Adas, *Dominance by Design,* 140-141; Tichi, *Shifting Gears,* 100-102. For a comprehensive study of this topic see Ruth Oldenziel, *Making Technology Masculine: Men, Women, and Modern Machines in America, 1870-1945* (Amsterdam: Amsterdam University Press, 1999).
[17] Quoted in Adas, *Dominance by Design,* 72.
[18] Layton, *The Revolt of the Engineers,* 58-59.
[19] Hughes, *Human Built World,* 68-74.

reputation earned them positions in all levels of the administration, supervision over each province, and lead roles in health initiatives.[20]

Harnessing Nature With Vast Technological Systems

In the late 19th and 20th century American engineers undertook numerous large-scale projects aimed at harnessing and reordering nature through vast technological systems. In 1902, the Roosevelt administration established the Reclamation Service to implement large-scale irrigation plans for arid and semi-arid areas of the West and Mid-West. One of the greatest of these efforts was the Hoover Dam. Planned in the late 1920s and completed in the 1936, the dam was over 700 feet high and consisted of 5 million barrels of cement, making it the largest man-made object on the planet. Spanning the Colorado River at Boulder Canyon, the dam flooded thousands of acres of wilderness area. This created an immense lake, while regulating the notoriously irregular flow of the Colorado River.[21]

In the 1920s, progressive politicians, social scientists, and engineers with the belief that technology could harness wasted resources, redesign landscapes for the betterment of human populations, and provide those populations with cheap and readily available electricity joined to create planning associations like the Tennessee Valley Authority (TVA). Managers promised that a carefully redesigned Tennessee Valley would prevent soil erosion, eradicate disease, control floods, and create a wealth of new

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[20] Adas, *Dominance by Design,* 155, 144-145. American engineers also had key roles in other American Imperialistic endeavors in Japan, Cuba, Nicaragua, Mexico and Panama. See Pursell, *The Machine in America* 189-196.
[21] Hughes, *American Genesis* 353-354; Nye, *America as Second Creation* 236-247. Cowen, *A Social History* 263.

industries run on cheap electrical power.[22] Also inherent in these promises was the autonomy and freedom that cheap resources and an ordered environment would provide to the occupants in the valley. In attempting to realize these promises, numerous dams were built along the Tennessee River to regulate and harness the water flow, rivers were redirected and re-channeled to allow for smoother navigation, and vast tracts of natural and inhabited land were seized and developed for farming and industry.

Such projects inspired many larger plans that reiterated the values of the technological culture. Pierre Gandrillon called for damming of the Jordan River, flooding the entire Jordan River Valley, and constructing canals over thirty miles of hilly terrain to the Mediterranean Sea. The plan would allow for expanded transportation, water resources, and hydroelectric power. As Willy Ley explained in *Engineer's Dream*, "The Jordan Valley was, if you utilized it correctly, the Nature-made 'stage set' for a useful and highly interesting feat of engineering." Though foreigners may mourn the loss of the symbolically significant river, it "would be mourned far less by the people living in its vicinity… It is, in its present shape, no great asset to Palestine, nor is it in any respect a beautiful or impressive river." Damming the Congo River and flooding the Congo Basin would allow humans to "conquer the rainforest" and create a navigable passage across Africa. In this case, one could say with "certainty that every square mile of covered in water would be a gain." The two million Africans that lived there could be easily moved because their property is "mainly portable" and "since the move would certainly better their living conditions, it is unlikely they would object."[23]

[22] Hughes, *American Genesis* 353-367; Adas, *Dominance by Design* 207-210.
[23] Willy Ley, *Engineers' Dreams* (New York: Viking Press, 1966), quotes 105, 134, 135.

Ley's works were a staple amongst science fiction writers and fans. He contributed science articles to *Astounding Science Fiction*, and *Galaxy Science Fiction,* two of the most popular science fiction magazines. *Engineers' Dreams* was enthusiastically reviewed in the November 1954 issue of *Astounding Science Fiction.* The reviewer claimed its importance for "those of you who are designing a future for the race" and reveled in the sublime devastation the plans would cause. Once the Congo were dammed, "it would probably take up to half a century for the Congo Lake to fill, spill over into the Caspian size lake Chad Sea in the middle of the Sahara, and drain out around the end of the Ahaggar and through Algeria and Tunisia into the Mediterranean. It's a big world!"[24]

These developments provide the backdrop against which the stories of terraforming were created. The following sections will illustrate that five novels and eight short stories about terraforming published from 1930 to 1960 recreate the characteristics of technological culture and the technological foundation narratives that surrounded it. By examining how the second creation and the technological foundation story plays out in these terraforming narratives, this section provides a fuller sense of how the technological culture influenced scientific speculation about the future of humanity.

Terraforming Authors

The majority of terraforming authors maintained a direct relationship to the technological culture. Their education, training, and experience working with science

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[24] P. Schuyler Miller, "The Reference Library," *Astounding Science Fiction* Nov 1954, 147.

and technology gave them first hand understanding and appreciation that they brought to their stories. Furthermore their occupations, and training instilled central aspects of the technological culture, such as the celebration of engineers, and the belief that technology could solve any problem. They then used the genre of hard science fiction to explore ideas about terraforming as a means to further proliferate the 20th century technological culture.

Seven of the eleven of the terraforming authors were educated in the sciences. Olaf Stapledon completed his doctoral degree in psychology and philosophy in 1925 at the University of Liverpool.[25] James Blish earned a Bachelors of Science in microbiology from Rutgers University in 1942 and after the war he continued with masters work in zoology at Columbia for two more years, though he eventually took up writing instead of finishing his degree.[26] Arthur C. Clarke enrolled in Kings College in October 1946, where he earned a Bachelor of Science degree.[27] Robert Heinlein retired from the Navy in 1934 and began a graduate degree in physics and mathematics at University of California Los Angeles.[28] Isaac Asimov earned a B.S. and M.S. in

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[25] Leslie Fielder, *Olaf Stapledon; a Man Divided* (New York: Oxford University Press, 1983), 14-16.

[26] David Cowart and Thomas Wymer, eds., *Twentieth-Century American Science Fiction Writers* (Detroit: Gale Research, 1981), 41; John Clute and Peter Nicholls, eds., *The Encyclopedia of Science Fiction* (New York St. Martin's Press, 1993), 135-136; Bryan Stableford, *Science Fact and Science Fiction: An Encyclopedia* (New York: Routledge, 2006), 67.

[27] Neil McAller, *Arthur C. Clarke: The Authorized Biography* (Chicago: Contemporary Books, 1992), 6-22.

[28] H. Bruce Franklin, *Robert Heinlein: American as Science Fiction* (New York: Oxford University Press, 1980), 7-18, 66-74; Virginia Heinlein, *Grumbles from the Grave* (New York: Ballantine Books, 1989), xi-xv.

chemistry from Columbia University and a PhD in biochemistry in 1948.[29] Walter M. Miller was educated in engineering at the University of Texas though he did not complete a degree. Poul Anderson received a physics degree from University of Minnesota in 1948. He never pursued a career in physics, instead publishing his first science fiction story in 1947 while still an undergraduate and continuing as a freelance author after that.[30]

Many were also employed within the technological culture. Jack Williamson enlisted in 1942 and trained as a meteorologist. Walter M. Miller worked as an electrical engineer before publishing his first science fiction story in 1951. After the immense popularity of his 1960 novel *A Canticle for Leibowitz,* he retired from writing, working as an engineer and living as a recluse for the rest of his life.[31] After earning his degree, Clarke worked as assistant editor of the journal of *Physics Abstract*s that exposed him to a wide array of cutting-edge scientific research that he incorporated in his science and science fiction.[32] Isaac Asimov taught at Boston University School of Medicine as his science fiction career developed.

Both Stapledon and Clarke also had first hand experience with imperial aspects of the technological culture, growing up in Britain. Though Stapledon spoke repeatedly against British Imperialism, he simultaneously sought to promulgate British cultural

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[29] Isaac Asimov, *I. Asimov: A Memoir* (New York: Bantam, 1995) 1-3, 43-46, 89-90, 132-135.
[30] Stableford, *Science Fact and Science Fiction* 21-22; Cowart and Wymer, eds., *Twentieth-Century American Science Fiction Writers* 4.
[31] Cowart and Wymer, eds., *Twentieth-Century American Science Fiction Writers* 19-20; Curtis Smith, ed., *Twentieth-Century Science Fiction Writers* (Chicago: St. James Press, 1986), 514.
[32] McAller, *Arthur C. Clarke: The Authorized Biography* 45-61.

values and ideals.[33] Likewise, though Clarke decried racism in a number of his stories, he lived in British Ceylon employing up to fifty indigenous house servants. In an account of Clarke's time in Ceylon he described in disparaging terms his employment of a series of inept, lazy, embezzling house workers.[34]

Vast Terraforming Technologies

Like grander visions of the TVA or the Hoover Dam, in all cases the authors envisioned terraforming projects as complex, organized, technological systems. The stories exhibit no concern for natural spaces or indigenous biology and use massively disruptive processes that reorder the original conditions of the target planet. The narratives exhibit no doubt in the ability of technology to beneficially alter other environments for humanity.

The first manifestation of terraforming comes from *Last and First Men* by Olaf Stapledon. In his novel, the moon's decaying orbit forces the fifth generation of humanity, or Fifth Men, to abandon Earth. The Fifth Men decide they must either "remake man's nature to suit another planet, or to modify conditions upon another planet to suit man's nature." The decision is made to alter Venus. Stapledon explains the fifth men use "great automatic electrolyzing stations," to "split up some of the ocean of the planet into hydrogen and oxygen by a process of vast electrolysis."[35] The oxygen mingles with the atmosphere while the hydrogen is ejected beyond the limits of the

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[33] Robert Crossley, *Olaf Stapledon: Speaking for the Future* (New York: Syracuse University Press, 1994), 261-262.
[34] Arthur C. Clarke, *The View from Serendip* (New York: Random House, 1977) especially chapter 3, "Servant Problem- Oriental Style."
[35] Olaf Stapledon, *Last and First Men* (London: Penguin Books, 1966), 246-247.

atmosphere. Vegetation is introduced to further prepare the atmosphere, and the planet is ready to receive humans in less than a million years.

A similar technology is found in Jack Williams' 1942 serialized story "Collison Orbit," later republished as the novel *Seetee Ship*. Here, asteroids are mined for fissionable ores, which are running out on Earth. Engineers explore harnessing anti-matter (known as contraterrene, abbreviated C.T. and pronounced seetee) to produce energy.[36] In the first instance of the word, "terraforming" machines are used to create Earth-like conditions on the asteroids. The terraforming machines are immensely complex and can only be created with billions of dollars of investment, which only Interplanet (the largest mining corporation) can afford.

In Robert Heinlein's *Farmer in the Sky*, Ganymede has been partly terraformed by "mass converters"- devices that transform any substance into pure energy with perfect efficiency. They are used to melt Ganymede's ice layer and "bust up the water molecule into hydrogen and oxygen. The hydrogen goes up- naturally- and the oxygen sits on the surface where you can breathe it." To replace leaking atmosphere and replenish nitrogen used in farming, the atmosphere project turns to "converting stable isotope oxygen-16 into stable isotope nitrogen-14," a process made possible with the right sort of mass

[36] In his biography Williamson recalls that he pitched a story to Campbell "for a series about the planetary engineers who would 'terraform' new planets to fit them for colonization." Campbell wrote back providing Williamson with a "long letter about CT physics" and outlined a "story about building a CT machine shop on an airless terrenes asteroid" based on the recent discovery of the positron. Jack Williamson, *Wonder's Child: My Life in Science Fiction* (New York: Bluejay Books, 1984), 135.

converter. Last, another technology called a "heat trap" enables colonists to control the temperature of the planet.[37]

In Arthur C. Clarke's 1952 novel *The Sands of Mars*, scientists trigger an atomic reaction called a "meson resonance reaction" on Phobos, turning it into a second sun that will burn for 1,000 years.[38] This warms most of Mars to Earth-like temperatures. Clarke also includes biology in the process, and the scientists re-engineer the native Martian flora so that they will flourish in the higher temperatures and light, releasing large amounts of oxygen.[39] The reviews of Clarke's book highlight how a single work of hard science fiction can traverse the continuum between scientifically real scenarios and speculation. One review cites the book as "one of the most believable trips to Mars you will have seen in a long while." P. Schuyler Miller, book reviewer for *Astounding* and one of the key figures in delineating hard science fiction, agrees that the space flight to Mars is "utterly real," but in regards to the meson resonance chain reaction suggests:

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[37] Heinlein, *Farmer in the Sky* quotes 123, 124.
[38] Mesons are sub-atomic particles that posses masses in between electrons and protons. They were first predicted to exist by Hideki Yukawa in 1935 in "On the Interaction of Elementary Particles" *Proc. Phys.-Math. Soc. Japan*, 17. His predictions were confirmed in 1947 by British researcher Frederick Charles Frank, who at the same time suggested they might be used to create a low-temperature nuclear reaction in "Hypothetical Alternative Energy Sources for the 'Second Meson' Events" *Nature* 160: 525. Yukawa was awarded the Nobel Prize for the discovery in 1949.
[39] Arthur C. Clarke, *The Sands of Mars* (New York: Signet, 1967), 187. Clarke's depiction of Mars was one of the first in science fiction to abandon romantic notions of a canal-laced Earth-like planet, instead basing it on the most up-to-date knowledge. After the *Mariner 9* mission, Clarke would reflect that while much of his depiction still held true, he was embarrassed that the novel did contain the emphatic line that "*There are no mountains on Mars.*" Ray Bradbury, et al., *Mars and the Mind of Man* (New York: Harper and Row, 1973), 85.

"One may perhaps be justified in a slight cringe at the super-scientific way the problems of Mars' cold and its low oxygen are eventually solved."[40]

Poul Anderson was responsible for some of the most detailed terraforming schemes that were the first to combine technological approaches with biological ones. In his 1955 short story "The Big Rain," terraforming is a multi-stage process. First, wind-powered airmakers-- "one of the most complicated machines in existence"-- are installed in which the formaldehyde-laced Venusian atmosphere

> was broken down and yielded its binding water molecules; the formaldehyde, together with that taken directly from the air, reacted with ammonia and methane-- or with itself-- to produce a whole series of hydrocarbons, carbohydrates, and more complex compounds for food, fuel and fertilizer; such carbon dioxide as did not enter other reactions was broken down by sheer brute force in an arc to oxygen and soot. The oxygen was bottled for industrial use; the remaining substances were partly separated by distillation-- again using wind power, this time to refrigerate-- and collected.[41]

With a million airmakers in use, and six million more scheduled for deployment, the Venusian atmosphere will be transformed in twenty years. At the same time, genetically engineered bacteria release oxygen from the surrounding rock by consuming the natural carbon and silicon. Meanwhile, pulverizing machines break down surface rock and mix it with fertilizer to create soil. Once these steps properly prepare the atmosphere, hydrogen bombs will be exploded in the interior of the planet to reactivate volcanoes, venting gases and "unthinkable tons" of water. The result will be a rain that lasts for ten

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[40] Miller, P. Schuyler, "The Reference Library," *Astounding Science Fiction*, October 1952, 168.

[41] Poul Anderson, "The Big Rain," *Astounding Science Fiction* Oct 1954, quote from 21-22. This depiction of a formaldehyde laced atmosphere on Venus was proposed by Rupert Wildt in **"**On the Possible Existence of Formaldehyde in the Atmosphere of Venus," *Astrophysical Journal*, vol. 92 (1940), 247.

years which, combined with the effects of lightning, will wash out the remaining poisons from the air and ground and create hydrological systems on the surface of Venus.[42]

In his 1958 novella, *The Snows of Ganymede*, Anderson simplified the process of terraforming Venus, relying on genetically designed bacteria to consume the poisons from the atmosphere and release oxygen. Once again hydrogen bombs are used to set off volcanoes and additional plants are developed to fit the new conditions. Anderson also advanced the first plan for terraforming Mars. Engineered bacteria create oxygen, water is found by drilling, and carbon dioxide is generated to develop a greenhouse effect. Despite this work, Mars will remain a cold and dry planet so geneticists create modified plant, animals and humans that would be comfortable in the environment. Other technologies are needed for Ganymede, which is warmed by sinking shafts in which controlled atomic explosions, called hydrogen –lithium fires, are ignited that warm the planet and atmosphere. Drilling rigs use “minimal nuclear engines” to bore the holes, atomic burners are used to melt away ice and automated diggers clear away the detritus. Here too Anderson relies on biological engineering to create organisms that can metabolize the poisons in the atmosphere and release oxygen to create a suitable atmosphere for humanity.[43]

In his 1959 short story “Sister Planet,” Anderson hinges his terraforming plan on a theoretical structure of Venus’ core. Here, Venus is a vast, hot, landless ocean, with a

[42] Ibid, quote from 22. Such details are the hallmark of hard science fiction. In a follow-up poll, readers ranked “The Big Rain” second favorite story out of the five in the issue, narrowly missing first. *Astounding Science Fiction* (January 1955), 114.
[43] Poul Anderson, *The Snows of Ganymede* (New York: Ace Books, 1958), 29-31, 57.

carbon dioxide atmosphere, "enough to kill a man in three gulps."[44] Scientists have set up a floating research facility called the Station, where they study the planet and trade with a native species of dolphin-like creatures called cetoids. A geophysicist on the Station discovers that an immense nuclear explosion placed at Venus' core would create continents. The resulting land mass would be similar to Earth's, and genetically engineered photosynthetic life could be sown that would liberate oxygen from the carbon dioxide, forming a protective ozone layer, and eventually striking an atmospheric balance of elements identical to Earth's. Humans could walk safely on the surface in fifty years, or faster if more agriculture is begun early on.

Harnessing the "Wasted" for a Second Creation

Just as American settlers and industrialists saw technology as a means to turn "wasted" natural resources into commodities, the process of implementing these terraforming technologies are depicted as "harnessing" or "taming" extra-terrestrial spaces that are often described as "wild," "wastelands," "desolate," and "barren."

In Henry Kuttner's 1947 novel *Fury*, terraforming is performed by monstrous technology in a war against uncontrollable nature. Humanity has been forced to flee to Venus due to atomic contamination from nuclear war. But on Venus the air is not breathable and the landscape inhospitable- a teeming with flora and fauna "homicidally and fratricidally determined to bud and seed, to mate and breed, in an environment so

[44] Poul Anderson, "Sister Planet," *Satellite* May 1959, quote from 6. This view of Venus was promoted in Donald Menzel and Fred Whipple, "The Case for H2o Clouds on Venus," *Publications of the Astronomical Society of the Pacific* 67.396 (1955), 161-168.

fertile that it made its own extraordinary imbalance."[45] Humans eventually seek to terraform the planet and colonize the surface. Chemical weapons are used to destroy the dangerous flora and fauna. Then a machine called a "crusher" knocks down vegetation drooping from poisonous sprays, creating broad avenues. Finally, a fleet of smaller land craft with specialized killing weapons clears the remaining jungle.[46]

This view of nature as "wasted" continues in other works. In *Seetee Ship*, asteroids are described as "lumps of next-to-worthless nickel-iron."[47] In *The Sands of Mars*, Phobos is only valued after it is transformed into a sun to aid colonization.[48] As in the Westward expansion of America, colonists in *Farmer in the Sky* are entered into a homesteading program to claim and "improve" the "dead" areas on Ganymede.

Harnessing these wasted areas results in a second creation.[49] In *Seetee Ship* the dream of the engineers is that the asteroids could be "tamed" and remade into human homes, creating a "magnificent new world." On visiting a terraformed asteroid,

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[45] Henry Kuttner, *Fury* (New York: Prestige Books, 1980), 109. Due to its cloud cover, the makeup of Venus was debated throughout the first half of the 20th century. The various interpretations are reflected in the terraforming stories about Venus. Here, Kuttner draws on one of the popular visions of Venus put forward by the Swedish chemist and noble laureate Svante Arrhenius in his 1918 book *The Destinies of the Stars* (Putnam: New York) 1918. Arrhenius concludes "The humidity is probably about six times the average of that on the Earth...We must therefore conclude that everything on Venus is dripping wet" (250-251). Therefore "A very great part of the surface of Venus is no doubt covered with swamps," where "Only low forms of life are therefore represented, mostly no doubt belonging to the vegetable kingdom; and the organisms are nearly of the same kind all over the planet. The vegetative processes are greatly accelerated by the high temperature" (252-253).

[46] Ibid, 163.

[47] Jack Williamson, *Seetee Ship* (New York: Bart Books, 1989), 23.

[48] Clarke, *The Sands of Mars* 188.

[49] The use of technology for a second creation is particularly interesting because in all cases authors foresee the need for terraforming as a result of industrial society, atomic war, over population, and the depletion of resources.

characters feel like conquerors: “Once a fragment of dead stone, now it was a man-made island of life. The spatial engineers had triumphed over the cold black eternal enmity of space to claim such bold new outposts for mankind.”[50] In Jack Vance’s 1947 short story “I’ll Build Your Dream Castle,” an engineer builds custom-designed homes for his clients on asteroids along with its atmosphere creating “individual worlds to suit any conceivable whim.” A tree-lined plain and a lake where cranes fish amongst the reeds surround one customized home. Another features a jungle-like estate with flora and fauna from all over Earth. A third world is in perpetual night with floating glass bubbles, trees with fluorescent sap and a lake with luminous fish supplying light. Each is its own unique second creation.[51]

Farmer in the Sky is also redolent with second creation imagery. The Ganymede terraforming project is defended in the following, gendered, terms: “Wherever Man has mass and energy to work with and enough savvy to know how to manipulate them, he can create any environment he needs.”[52] One scientist invokes terraforming as inevitable next step: “What are we going to make of this planet? We can make it anything we want…it’s up to us. They say man is endlessly adaptable. I say on the contrary that man doesn’t adapt himself as much as he adapts his environment.”[53] The Chief Executive of Mars in *The Sands of Mars* echoes this sentiment. He argues deterministically that “Wherever men can live, that will be home to someone, some day,” technology has given

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[50] Williamson, *Seetee Ship* quotes 11, 93.
[51] Jack Vance, "I'll Build Your Dream Castle," *Astounding Science Fiction* Sept 1947, 82.
[52] Heinlein, *Farmer in the Sky* 22.
[53] Ibid, 194.

them “enormously greater powers of control. Given time and material, we can make this a world as good to live on as Earth.”[54]

In Poul Anderson’s “Big Rain,” Venus’s eternal winds, poisonous gray clouds, chemical rains, blinding dust storms, and storm-gnawed crags loom over inhuman landscapes. After terraforming, “men could walk unclothed on this world and they could piece by piece make the desert green.” Within a hundred years Venus would be like Earth, and within five hundred “all of Venus might be a Paradise.”[55] In “Sister Planet” one scientist argues that a terraformed Venus would be a second chance for humanity: “Warmer, of course- a milder climate, nowhere too hot for man… but nevertheless, New Earth!”[56] The planet would provide a bounty of resources and “The first comers would have hope- their grandchildren will have wealth!”[57]

Terraforming Imperialism

Just as Americans relied heavily on technology to accomplish their imperialistic endeavors, and technological values to justify them, terraforming for a second creation often smacks of imperialism. Little regard is allotted for any indigenous flora, fauna, or ecologies as humans seek to impose their life and culture on the target planets.

In Stapledon’s *First and Last Men*, the Fifth Men realize that an underwater species already inhabit Venus, presenting a moral dilemma, “What right had man to interfere in a world already possessed by beings that were obviously intelligent, even though their mental life was incomprehensible to man?” Stapledon solves the problem quite easily. The Venetians, by exhibiting tendencies toward violence and warfare,

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[54] Clarke, *The Sands of Mars* 187.
[55] Anderson, "The Big Rain," 13.
[56] Anderson, "Sister Planet," 121.
[57] Ibid, 122.

convince the Fifth Men that they are inferior though intelligent. The Fifth Men, who had long ago evolved past warfare also discover that the radioactive atoms the Venetians rely on for life would eventually run out, and in fact "…the increasing difficulty of procuring radioactive matter was already the great limiting factor of civilization. Thus, the Venetians were doomed, and man would merely hasten their destruction." The Fifth Men decide to "Put them out of their misery as quickly as possible" and a planetary genocide ensues.[58]

Though Clarke decries racism in a number of his stories, he was no stranger to imperialism, having lived in British Ceylon with up to fifty indigenous house servants. In his *The Sands of Mars*, a race of kangaroo-like native Martians shows signs of intelligence and communication. They are the first example of an extra-terrestrial species ever found by humanity. Despite this, the colonists give no thought to the impact of their plan for Phobos on the creatures or their ecosystem, and enslave them to plant the oxygen rendering plants for the humans: "They needn't know what they're doing, of course. We simply provide them with the shoots… teach them the necessary routine and reward them afterward."[59] While changing the habitat they rely on, they rationalize that the creatures could be moved to the polar regions if it gets too hot, and adapt to the higher levels of oxygen. Mars belongs to the Martians, but "man might shape it for his own purposes."[60]

Depictions of Engineers

Most of these stories center around engineers that are overwhelmingly idealized as strong, masculine, capable, organized, controlled, brave, and disinterested in personal

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[58] Stapledon, *Last and First Men* quotes 251, 252.
[59] Clarke, *The Sands of Mars* 197.
[60] Ibid, 199.

gain. In *Seetee Ship*, Rick, an engineer with a "rawboned frame, big fingers" and "lean fitness… competent for anything."[61] Rick's boss Paul is tall, handsome, and a "man of practical action."[62] They do not care about profit from their inventions, they only seek to improve the world for humanity and prevent a potential war from resource depletion.

Poul Anderson's *Snows of Ganymede* portrays engineers as an elite class-- the Order of Planetary Engineers, who must be well-trained and brave because they constantly work in alien and lethal environments. Extensive "mind training" enable them to think logically in any stressful situation, instantly comprehend and memorize ideas and facts, and control their physiology. They "make space available for all men, regardless of race, creed, or political affiliation." Their rewards are intangible: "prestige, comradeship, a sense of being important to man's highest and finest adventure." These ideals allow them to stay neutral and "to keep the scientific spirit alive. To reform planets, not people."[63]

Autonomy and Fulfillment

Just as the massive technological schemes like the TVA promised and implied a new, better way of life and fulfillment through new jobs and products, terraforming narratives consistently depict terraforming technology as a means to personal autonomy and fulfillment.

In *Fury*, the colony's first dome on the surface of Venus recreates the enclosed existence that was maintained in the seas. Transforming the atmosphere of Venus not only allows the colonists access to open areas, but provides autonomy from the resources needed to sustain life under domes. In *The Sands of Mars*, the Chief Executive of the

[61] Williamson, *Seetee Ship* quotes 15, 11.
[62] Ibid, 90.
[63] Anderson, *Snows of Ganymede* quotes 13, 18, 52.

colony explains the reliance on Earth's resources means: "I'm fighting a campaign at the end of a supply line that's never less than fifty million kilometers long."[64] The scientists rebel by creating the Phobos sun, thereby establishing Mars as a colony of scientists free from reliance on Earth.

In Isaac Asimov's 1952 short story "The Martian Way," a future Earth has colonized the solar system for mining. The colonies are generally unproductive while drawing down Earth's resources-- especially water. This creates tension between Earth and the colonies. Earth rations water to its Martian colonies, limiting their ability to work and farm, and requires that they buy their food from Earth. Ted Long, the main character, insists that taking the water by force is the "Earth way." The colonists need to "cut the umbilical chord that ties Mars to Earth" and deal with the problem the "Martian way" by finding a new source of water.[65] A 19th century foundation narrative is reenacted on Mars. With a specially rigged caravan of ships, the Martians harness an ice asteroid from the rings of Saturn and bring to the surface of Mars to provide enough water for hundreds of years. As with his review of *The Sands of Mars*, Schuyler's review of "The Martian Way" explains that the story "sets up a very logical socio-political situation developing out of the cost of supporting a Martian colony," but describes the terraforming efforts as "a couple of nice gimmicks."[66]

In *The Snows of Ganymede*, it becomes clear to the engineers that the Jovians are not capable of producing the technology required to terraform Ganymede as long as they remain in their current state, living underground "dependent on a complex of machines

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[64] Clarke, *The Sands of Mars* 86.
[65] Isaac Asimov, "The Martian Way," *Galaxy* Nov 1952, 26.
[66] Ibid, "The Reference Library," *Astounding Science Fiction*, December 1955, 147.

and chemicals for the most elementary necessities of life." "Human robots" are used to do jobs that could have been performed by machines; "They didn't count for more than the lathes and furnaces they manned."[67] Ironically, the engineers' solution to this dependence on technology is more technology. In their minds, it is not technology that dehumanizes people, it is the lack of *advanced* technology which causes them to work like robots.

In addition to autonomy, terraforming narratives frame the act as personally fulfilling. In *Fury,* the people in the Keeps are stagnating. They have every available comfort and want for nothing, but it comes at the price of living a purposeless existence. The colony needs to expand into open spaces in order to revive humanity. Though the first stages of colonization fail, they are viewed with nostalgia and longing as a time when men were forced to use all of their capabilities to fight the "ravaging" planet. Ultimately the colonization succeeds at terraforming Venus and changes humanity in the process. As the colonists work to change the planet:

> There was danger in every breath they drew and every move they made. But they were happy. The work was new and absorbing. They were creating. They could see great strides of their progress simply by glancing behind them. This was the proper occupation of mankind- bringing order out of chaos in the sweat of their brows.[68]

In the "Martian Way," terraforming has meaning for similar reasons. The people of Earth live an easy existence, taking what the Earth readily provides. But Mars presents difficulties:

> It is sort of raw and doesn't fit people. People got to make something out of it. They got to build a world, and not take what they find. Mars isn't much yet, but we're

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[67] Anderson, *Snows of Ganymede* quotes 40, 35.
[68] Kuttner, *Fury* 165.

> building, and when we're finished, we're going to have just what we like. It's sort of a great feeling to know you're building a world.[69]

In *The Sands of Mars*, the colony is a group of pilgrims on the frontier fighting in a uniting cause, with "a sense of fulfillment which very few could know on Earth." Gibson realizes he is happier on Mars because he has done something valuable; his friends back home will think, "Mars has made a man out of him."[70]

Counter-Narratives

Narratives do not always bear out, however, and are often contradicted by reality. The Hoover Dam and other state-run irrigation projects did little for the local individual farmers for whom they were purportedly built. Rather than fostering further individual farms, the lion's share of the water tended to go to large and wealthy landowners increasing their monopoly of land. In addition, though the promise had been made to release the systems to private enterprise after their creation, they often remained under governmental control and regulation.[71] The TVA was originally formed with the mandate to improve local ecology and access to electricity. However, the project resulted in deeply invested government interests that forced the sacrifice of these ideals. Demand for electricity rose to the point that the TVA turned to strip mining coal for electricity, jeopardizing the ecological imperatives of the project. In the 1950s the government itself became the primary consumer of the electric power with 50% of it dedicated to Atomic Energy Commission sites. The remaining energy was largely dedicated to agricultural

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[69] Asimov, "The Martian Way," 34.
[70] Clarke, *The Sands of Mars* quotes 118, 164.
[71] Nye, *America as Second Creation* 247.

purposes, not for people's homes. In the process, democratic participation broke down considerably as local populations were discounted, excluded, and displaced.[72]

Both Merchant and Nye have suggested that such events spurn opposition to the dominant stories. For instance, Merchant has argued that 19th century romantic authors and conservationists rejected notions of dominating nature, advancing instead counter-narratives depicting nature as both a powerful force to be revered, and a mothering force to be respected. In the 20th century the counter-narratives focused on the decline and desecration of nature as well as the environmental injustices suffered by minorities and women for the sake of environmental progress.[73]

Nye argued opponents to the technological foundation narrative created counter-narratives whose characteristics include: discounting harmonious relationships between settlement and technology; focusing on ecological devastation and human displacement caused by technology; and ending in tragedy and defeat. For instance, Nye cites the 1941novel *People of the Valley* by Frank Waters as an example of a counter narrative about government backed irrigation efforts. Here, white Americans occupy an active Hispanic community, not an empty wasteland. They use their resources and technology to build a dam that rips apart the natives' world, stripping them of both their resources and the scenery that is a part of their traditional way of life. Rather than bringing freedom and autonomy, the dam brings dislocation and marginalization.[74]

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[72] Hughes, *American Genesis* 379-381.
[73] On the romantics and conservationists see Merchant, *Reinventing Nature* 133- 143, on minority counter-narratives see145-165.
[74] Nye, *America as Second Creation* 251-252.

In the post-World War II era such counter narratives became increasingly more common. Many became disenchanted with the conformity that resulted from the industrial lifestyle and began to question its benefits. As the implications of the use of atomic weapons set in and information about the Manhattan Project was released, concerns over the dangerous and destructive capabilities of technology grew. The rapid expansion of the military industrial complex and the proliferation of nuclear weapons led many to view America as an assembly of "enormous, complex technological systems defying control." Furthermore, despite the fact that Americans were flooded with consumer technology throughout the 1950s, the Soviet's ability to apparently surpass American technological superiority with *Sputnik* was cause for considerable anxiety.[75]

This anxiety was particularly apparent in science fiction where common themes throughout the late 1940s and early 1950s dealt with destruction of the Earth through a variety of technological apocalypses. A testament to increasing numbers of these themes can be found in an editorial column in *Galaxy Science Fiction* from 1952. The editor, H.L. Gold, somewhat tongue-in-cheek, complained that over 90% of the submissions he receives:

> still nag away at atomic, hydrogen and bacteriological war, the post-atomic world, reversion to barbarism, mutant children killed because they have only ten toes and fingers instead of twelve, world dictatorships, problems of survival wearily turned over to women, war, more war, and still more war- between groups, nations, worlds, solar systems.[76]

This fear and mistrust of technology is found within counter-narratives about terraforming as well.

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[75] Adas, *Dominance by Design* 224-225, 237-239; Hughes, *American Genesis* 443-445; Hughes, *Human Built World* quote 12.
[76] H.L. Gold, ""Gloom and Doom"," *Galaxy Science Fiction* Jan 1952, 2-3.

Terraforming Counter-Narratives

In James Blish's short story "A Time to Survive," later a chapter in the novel *The Seedling Stars,* terraforming results in slavery and oppression, not autonomy. On a future Earth, a vast government called the Authority has planned to reduce population pressure by spreading humanity throughout the universe with terraforming. Expensive and complex, terraforming assures control of the colonies. The Authority plans to terraform Mars by moving it closer to the sun, transporting the Indian Ocean to its surface ("only a pittance to Earth, after all"), and transplanting soil to grow plants to alter the atmosphere. The project cost would be recovered through taxes on the colonists that would reap the Authority an immense profit and keep the colonists under its control. Domes that could house fewer people and produce less revenue, "were out; terraforming was in."[77] Opponents develop "pantropy," which adapts the human body to other environments, rather than the other way around. Humans adapted to their environment would have no need of the Authority or its resources, they would maintain their individual autonomy. The Authority outlaws pantropy to maintain control of the colonies. However, pantropic humans adapted to Ganymede escape and proliferate pantropic humans throughout the universe.

Another powerful counter-narrative to terraforming is Walter Miller's 1953 short story "Crucifixus Etiam." Manue Nanti, a worker from Peru, signs a five-year contract with the "Mars Project" to earn enough money to retire at the age of 24 and travel the Earth. Rather than a second creation, Mars is "a nightmare, a grim, womanless, frigid,

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[77] James Blish, *The Seedling Stars* (New York: Signet, 1957), 43.

disinterestedly evil world" and Manue's camp is no solace; "ugly, lonely, and dominated by the gaunt skeleton of a drill rig set up in its midst."[78]

Unlike previous narratives, where technology and humanity exist in harmony, in Miller's world technology consumes humanity. To live on the planet, workers must have oxygenators installed-- machines that fuse with their bodies and automatically remove the need for breathing except to speak, but atrophy the lungs and chest over time. Manue insists on trying to keep his lungs strong by restricting the oxygen the machine supplies, forcing him to constantly gasp for breath. Over time, the machine's tubes become unbearably painful, but if the tubes are removed or come loose a worker will bleed to death within minutes. The lack of oxygen makes sleep a "dread black-robed phantom" resulting in nightmares of falling into bottomless space from which dreamers wake up screaming. The only relief comes from turning the oxygen up, resulting in lung atrophy.

Engineers are not a heroic or selfless group, but elites whose pressurized tents allow them to sleep at night without oxygenators. They embezzle government funds, treat the workers like "children, or enemies, or servants" and refuse to answer workers' questions. Manue and the workers are not brave pioneers. They are slaves trapped on Mars both by contracts and their oxygenators. Their work seems pointless, serving only to enrich the contractors and the engineers. Life for Manue becomes "an endless routine of pain, fear, hard work, anger… what sense was there in this endless scratching at the face of Mars... to build a world so un-earthlike he could not love it?" To Manue, the sky

[78] Walter M. Miller, "Crucifixus Etiam," *Astounding Science Fiction* Feb 1953, quotes 100, 99.

of Mars becomes “a bottomless well into which Earth poured her tools, dollars, manpower, and engineering skill.”[79]

Eventually the men are told that they are helping to give Mars an atmosphere by setting up stations that will set off controlled atomic explosions within the planet, releasing helium and oxygen. But it will take three hundred wells and eight centuries to attain a breathable atmosphere on the Mars. Ultimately, Manue resigns himself to his fate: he is nothing more than a tool. He will never be able to leave Mars or see a hospitable atmosphere on the planet. His life and work are a sacrifice to a future generation that will never know who he was or how he suffered.[80]

Perhaps the most bizarre counter-narrative is the 1959 short story “When the People Fell” by Cordwainer Smith, the pseudonym of Paul Linebarger, born in Milwaukee in 1913. His father was a political and legal advisor for US interests in the Pacific so Linebarger was educated in various Asian cities including Shanghai and Nanking. He earned a M.A. and a PhD from John Hopkins in political philosophy with an emphasis on Asian cultures, served in the US Army Intelligence Corps in China in World War II and supported Chiang Kai-shek against communism.[81] While clearly a

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[79] Ibid, quotes 60, 57, 55.

[80] The readers of *Astounding* seemed to have had a mixed reaction to Miller’s challenging and dark story. In a following poll, the story was ranked third favorite out of the five stories in the issue. *Astounding Science Fiction*, May 1953, 47.

[81] Karen Hellekson, *The Science Fiction of Cordwainer Smith* (Jefferson: McFarland and Company, 2001), 1-8; Cowart and Wymer, eds., *Twentieth-Century American Science Fiction Writers* 127-128.

warning about the growing power of Chinese communist society, his story questions the assumption that only vast technology can create a second creation.[82]

In the time of the story, the only thing preventing the colonization of Venus is the presence of millions of “loudies”- a native species that floats close to the surface eating microbes. The loudies pose no direct threat unless they are killed, in which case they explode and contaminate thousands of acres. Despite advanced technology, humans have found no way to safely remove them. One day, thousands of “Chinesian” ships from Earth arrive and eighty-two million men, women, and children are forced to parachute to surface. A grim scene ensues as thousands die: beheaded by their parachute chords, suffocated when air hoses are ripped from their throats, landing incorrectly or trampled by others. The survivors link arms and form an immense human corral that gently traps the loudies. Unable to move, the loudies eventually starve to death and are safely disposed of. Meanwhile, other survivors begin planting rice for both food and as means to convert the atmosphere. The bodies of the dead are used as fertilizer. Within days the Chinesians assume control of the planet: “Mere human beings did what machines and science would have taken another thousand years to do…”[83]

Poul Anderson’s counter-narrative in “Sister Planet,” questions the morality and inevitability of terraforming. A scientific team on Venus discovers a way to create continents on the ocean-planet by collapsing the core of Venus with a massive nuclear explosion. The only problem is that the planet is inhabited by an intelligent dolphin-like

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[82] Further example of simplistic technological fixes seen elsewhere in Smith’s fiction, including his 1950 story “Scanners Live in Vain” where technologically complex inter-stellar ships and space suits are simply lined with oysters for protection from radiation. “Scanners Live in Vain,” *Fantasy Book Magazine,* 1:6 (January 1950), 23-37.

[83] Smith Cordwainer, "When the People Fell," *Galaxy* 1959, 58.

race called cetoids. The scientists decide to save the cetoids by abandoning the plan by going so far as to destroy all records of the discovery and swear secrecy to never divulge what they have discovered. One scientist believes that it is only a matter of time until someone duplicates the work and places the value of an inhabitable world over that of the native life. He stages a war between the cetoids and humans by personally destroying the Station and all the scientists in it, bombing the cetoid's underwater city, and shooting dozens of them. No one will make a second creation out of Venus.

<u>Conclusion</u>

The terraforming narratives manifest the technological culture which created them: a generally positive view of technology as a means to a materially wealthy and modern society, a consensus that vast technological projects can improve nature and harness resources that would otherwise be wasted, an imbibing of industrial values like efficiency and order, and a glorification of engineers. But counter-narratives to terraforming science fiction manifest resistance to and fear of the larger technological culture including: concerns about the increasing reliance on technology, its invasive abilities, its abilities to corrupt, and its use as a tool of dominance, and questions about the purposes and benefits of its widespread application.

Science fiction allows for the creation, communication, and development of scientific speculation about terraforming. The majority of terraforming authors had direct experience and training with the technological culture that they utilized to create hard science fiction that adhered to the restrictions of known scientific and technological laws and principles. But within these restrictions hard science fiction maintains a continuum of realism from the meticulously created and clearly delineated concepts and devices (like Poul Anderson's terraforming machines) to the use of plausible, though more speculative, technologies.

For instance, Clarke admits that he knew a meson resonance chain reaction was plausible, but likely "nothing more than a science fiction writer's gobbledygook." Far from being ridiculous fantasy, however, gobbledygook allows the author to use the plausible (i.e. the possibility of a meson reaction, or the possibility of a mass converter) to conduct thought experiments like terraforming projects. Thus, gobbledygook, ideas that are plausible though unproven, serve an important function of allowing the authors to free themselves from the absolutely known, and allow their imaginations to explore the plausible unknown. They can create something that seems fantastic but adheres to known laws in order to logically and soundly speculate about ramifications of such a technology. As a testament to the plausibility inherent in gobbledygook, numerous scientists have conducted work on mesons as a source of fusion energy since Clarke first published *Sands of Mars*. This reaffirms that "at least the idea has some tenuous basis in genuine physics," a key element of hard science fiction.[84]

Thus, through the combination of realism and speculation, hard science fiction allows for the creation of new sets of speculative scientific ideas. These ideas, and the scientific knowledge behind them, are then communicated through the stories. For instance, Poul Anderon's stories discuss terraforming plans and the physical features of planets like Mars, Venus, and Ganymede that make them plausible. Readers can then evaluate these details to determine the veracity and plausibility of the idea. Based on that

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[84] Arthur C. Clarke, *The Snows of Olympus Mons* (New York: W.W. Norton Company, 1995), 95.

assessment, future authors can then develop new approaches, new applications, or correct aspects they felt were inadequate or incorrect. For instance, biological elements became common parts of terraforming stories, but were applied in different ways.

Finally, the stories perpetuate and reassert the technological foundation narratives in a way unique to the science fiction genre. Their location in the future allows them to repackage and perpetuate the narratives in a way as to tell to the reader of the story "This is how it was in the past." Heinlein's characters not only replicate the technological frontier narratives of 19^{th} century America, but reassert the reality of those events for the reader of his book. Their location in the future asserts a deterministic view of the future of human technological culture by transplanting those same narratives into the future. In this manner, terraforming narratives firmly frame images of the future of humanity within the technological culture of the 20^{th} century. Terraforming is portrayed merely as a natural continuation of the way humanity (primarily Western White males) used technology in the past to restructure environments. As a result, these authors present terraforming as an inevitable technologically driven process that replicates both the perceived American past and the technological world of the 20^{th} century.

Chapter 2- Carl Sagan, Poul Anderson, and the New Wave

"You'd be surprised how much purely sentimental opposition there was to changing the looks of the dear old moon."[1]

The previous chapter illustrated that the origins of terraforming are found in the 20th century western technological culture. This culture has distinct features: a positive view of technology as a means to create a materially wealthy and modern society, a glorification of engineers, and a consensus that vast technological projects can improve nature and harness resources that would otherwise be wasted. Up until 1960, terraforming was an idea that was developed within hard science fiction publications. Though at times fantastic, the idea was not sheer fantasy. To varying degrees, the authors of hard science fiction tried to place the idea of planetary terraforming and its applications within scientific and technological laws.

In this chapter, I will more closely analyze the relationship between hard science fiction, professional science, and the technological culture. The first extensive discussion of terraforming by a professional scientist came from Carl Sagan, an avid science fiction fan and supporter. The overlap between Sagan's speculations about Venus and terraforming with aspects of hard science fiction led science fiction editor Joseph Campbell to solicit him as a contributor to his magazine. Sagan's work also inspired further plans for terraforming by Poul Anderson, spreading the vernacular conversation about terraforming beyond science fiction and incorporating professional science. Anderson's letters and essays reveal his reliance on scientific research and emphasis on

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[1] Poul Anderson, "To Build a World," *Galaxy Science Fiction* 1964, 25.

scientific fact in his hard science fiction writing, a genre he felt was best suited for the extrapolation of real science and technology. Inspired by Sagan, Anderson's work continued to develop terraforming and proliferate the American technological culture, even as the negative impacts of further industrialization, including threats of climate change, pollution, overpopulation and resource depletion, generated a cultural backlash. A new science fiction genre called the New Wave emerged with a skeptical view of technology. Writing in this style, Richard McKenna and Roger Zelazny created additional terraforming counter-narratives. These events showed a growing schism of opinion within America culture over the effects of science and technology that impacted both hard science fiction and terraforming.

Carl Sagan's Early Life

Born in 1934, Carl Sagan grew up in an American society that believed in technology's ability to build a better tomorrow. Sagan became an active consumer of science fiction from a young age and it had a deep and long lasting influence on his life. Sagan attributed his interest in space to the work of Edgar Rice Burroughs. Burroughs was a popular author of Space Operas throughout the first half of the 20th century. By the age of ten, Sagan was an enthusiastic Burroughs reader. He loved the stories for their new and exciting ideas, alien life, and landscapes. [2] He would later comment that he felt modern science fiction like *Close Encounters of the Third Kind* and *Star Wars* engendered an interest in space and science in children just as Burroughs' works had

[2]Henry S.F. Cooper, "A Resonance with Something Alive," *Conversations with Carl Sagan*, ed. Tom Head (Jackson: University Press of Mississippi, 2006), 27.

done for him.[3] Wishing to be transported to Mars, like Burroughs' hero John Carter, his imagination opened to the potentials of space travel and extraterrestrial encounters.[4] The rash of UFO sightings in the 1940s made perfect sense to a young Sagan.[5] He recalled, "Such ideas, when encountered young, can influence adult behavior. Many scientists deeply involved in the exploration of the solar system (myself among them) were first turned in that direction by science fiction."[6]

However, as he matured, the joy of those stories faded as he became more critical of Burroughs' stories, which held little scientific merit when examined closely. Sagan's interest in science fiction was restored by the burgeoning genre of hard science fiction in Campbell's *Astounding Science Fiction*. These stories appealed to his intellect and introduced him to themes he would explore for the rest of his life. For instance, Raymond F. Jones' "Pete Can Fix It" introduced him to "the social implications of development of nuclear weapons," he recalled."[7] Sagan later aggressively campaigned against nuclear proliferation, notably in his popularizing of the nuclear winter theory.

Nuclear technology gave the young Sagan more to think about than weapons. Science fiction stories that featured intergalactic travel by rocket ships stretched back to

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[3]Art Harris, "Second View: Sagan on *Encounters*," *Conversations with Carl Sagan*, ed. Tom Head (Jackson: University Press of Mississippi, 2006), 50.
[4] He recounts this story in a panel conversation transcribed in Bradbury, *Mars and the Mind of Man* 10. He recalls the same story in Cooper, "Conversations," 27.
[5] Carl Sagan, *The Demon-Haunted World: Science as a Candle in the Dark* (New York: Random House, 1996), 66-67.
[6] Sagan provided a reflection on the impact of science fiction on his life and criticisms of contemporary science fiction in Carl Sagan, *Broca's Brain: Reflections on the Romance of Science* (New York: Random House, 1979), 145. Here Sagan illustrates knowledge of the work of many terraforming authors including Clarke, Heinlein, Anderson, Miller, Asimov and Williamson.
[7]Ibid, 138.

the earliest science fiction stories. They had a significant impact on Sagan, who recalled visiting colleges that engaged his interest in space.[8] While at Princeton, he spoke to astronomer Lyman Spitzer Jr. about the use of rockets to gather data, "another holdover from the fiction I'd been reading."[9] Science fiction played an important role in maintaining his interest in science in this period; "it sustained me in my early years. I got a keen sense of the excitement of science from science fiction."[10]

Sagan's College Life

In 1954, Sagan enrolled in the University of Chicago's interdisciplinary Hutchins Program, which incorporated philosophy, astronomy, and biology. Sagan's college friends recalled his "enormous interest in science fiction." One considered Sagan a "Ray Bradbury freak."[11] Another remembered that after he and his friends had "gotten over" science fiction, Sagan maintained a personal library of science fiction books.[12]

Herman J. Mueller, a Noble Prize winning biologist who established the link between radiation exposure and chromosomal mutations in fruit flies, was Sagan's advisor at Chicago. Their shared fascination with life on other planets and science fiction kept him from "bow[ing] under the weight of conventional opinion" that space travel and

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[8] In addition to fiction, Sagan considers reading Clarke's non-fiction book *Interplanetary Flight* as a turning point in his life which led him into the sciences- "In Praise for Arthur C. Clarke," *The Planetary Report*, May/June 1983, pg 3. Here he also recounts a friendship that blossomed with Clarke around 1964 that continued throughout his life.
[9] Cooper, "Conversations," 29.
[10] Anon, "A Slayer of Demons," *Psychology Today* Jan/Feb 1996, 47. This ability of hard science fiction to elucidate the "excitement" of science will be a theme amongst fans and authors, including Gregory Benford who is covered extensively in chapter 3.
[11] Keay Davidson, *Carl Sagan: A Life* (New York: John Wiley and Sons, 1999), 37.
[12] William Poundstone, *Carl Sagan: A Life in the Cosmos* (New York: Henry Holt and Company, 1999), 16.

extraterrestrial life were "quite disreputable."[13] Sagan earned a B.A. in astronomy, a B.A. in physics, and a M.A. in physics by 1957. That year he was accepted in the University of Chicago's graduate astronomy program at Yerkes Observatory.

Sagan hoped to use spectroscopy to detect organic molecules in the atmosphere of other planets, inspired by William Stinton's use of infrared spectroscopy to search or organic materials on Mars. Sagan suggested that organic molecules could explain features in atmospheres of planets like Uranus and Neptune. Conventional science denied that complex organic molecules existed in the atmosphere of other planets. Sagan's dissertation, "Physical Studies of Planets," covered largely speculative topics including the possibilities of life and organic molecules on the moon and in Jupiter's atmosphere, and the intense radiation from Venus' atmosphere. [14]

In the third section of his dissertation, Sagan, sought to explain the results from a recent study of Venus' surface temperature. In 1940, Yale astrophysicist Rupert Wildt used spectroscopic analysis to determine there was a large presence of carbon dioxide in Venus' atmosphere. He estimated that Venus' carbon dioxide levels would create a greenhouse effect creating a temperature of around 400 degrees Kelvin. Studies by researchers at the Naval Research Laboratory using a radio telescope measured the planets temperature at closer to 600 degrees.[15] In his dissertation, Sagan explained the 600 degree reading by suggesting that the difference was made up by the presence of

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[13] Swift, *Seti Pioneers: Scientists Talk About Their Search for Extraterrestrial Intelligence,* 212-213.

[14]Carl Sagan, "Physical Studies of Planets," University of Chicago, 1960, ii.

[15] Sagan relied on a paper presented by Cornell Mayer et al. at the University of Michigan symposium "The Next Five Years in Radio Astronomy," Ann Arbor , Oct 1959. The findings were later published in Cornell Mayer, "The Temperatures of Planets," *Scientific American*.May (1961), 58.

water vapor in Venus' atmosphere, which would dramatically increase the greenhouse effect on the planet. This would easily allow Venus to generate temperatures comparable to 600 Kelvin.[16]

1961 *Science* Article

In "The Planet Venus" Sagan explained his theory of the Venus greenhouse effect. After describing competing theories of the planet as a swamp, a desert, a planetary oil field, and a "global Seltzer ocean," he examined different optical and microwave temperature readings, arguing the greenhouse effect was responsible for such high temperatures. The piece continues, "Hot, arid, calm, and overcast, the surface of Venus appears inhospitable for human habitation at the present time," however steps could be taken to "prepare Venus for comfortable human habitation."[17]

Sagan argued that both the temperature of the planet and its low pressure of molecular oxygen could be altered by biology. Organisms capable of existing in extreme temperatures and disassociating atmospheric carbon dioxide and water vapor into oxygen and carbon could be seeded into the clouds. There they would break down the water and carbon dioxide through photosynthesis, creating food for themselves and discharging oxygen. As the organisms drifted down towards the surface they would eventually be "roasted," releasing water in to the atmosphere while their bodies fell as carbon onto the planet's surface. This process would remove the abundant carbon dioxide in Venus' atmosphere, thereby dismantling the greenhouse effect and producing surface water. These organisms did not need to be made in a lab or specially engineered for Venus. Instead, an organism already existed that could withstand being submerged in liquid

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[16] Sagan, "Physical Studies of Planets," 50-64.
[17] Carl Sagan, "The Planet Venus," *Science* 133 (1961), 857.

nitrogen and also lived in hot springs on Earth: blue-green algae "primarily of the Nostocaceae family." Sagan concluded "the microbiological re-engineering of Venus will become possible."[18]

Sagan also sought to give scientific legitimacy to his plan. Instead of terraforming, he referred to the process as "microbiological planetary engineering." Instead of relying on massive technologies or highly complex schemes, Sagan's plan was relatively simple, comparatively pragmatic, and based in basic biology. His article also minimized the improbable elements of the plan by avoiding any quantification of how much algae would be needed or how it would be transported to Venus. To further ground the idea in science, he surrounded his theory with a fair amount of scientific caution: it must be known if the algae "can reproduce prior to thermal decomposition; whether a complete aerial existence is possible… whether a strain can be found which will photosynthesize at low temperatures and high ultraviolet fluxes." In addition, more must be known about the Venus' makeup before the scheme can be carried out.[19] Though the implication is that microbiological engineering is for human settlement, Sagan provided no justification for the action. Instead, the article was surprisingly silent on the justifications for the plan, and the whole discussion hinged on the simple speculative statement that the "prospect may exist."[20]

While no documentary evidence has been found illustrating Sagan was directly influenced by terraforming plans in hard science fiction, an overlap clearly exists with hard science fiction treatments. Though Sagan's ideas are more refined and based on

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[18] Ibid, all quotes from 857.
[19] Ibid, 858.
[20] Ibid, 856.

more specialized knowledge, he and Poul Anderson were thinking about the problem in the same way. In particular, both Sagan and Anderson's plans centered on dismantling the planet's greenhouse effect. His speculations on biological organisms to break down carbon dioxide parallel plans found in Poul Anderson's works such as "The Big Rain," "Sister Planet," and *The Snows of Ganymede*. In addition, the final image of Sagan's article in which Venus is engulfed in rain and made ready for habitation is strikingly similar to passages from "The Big Rain."

<u>Scientific Speculation Meets Hard Science Fiction</u>

The publicity from his 1961 article caught the attention of Ukrainian born astrophysicist Iosef Shklovskii, head of the Sternsberg State Astrophysical Institute. In 1959, Shklovskii had published a piece arguing that Mars' moons, Phobos and Deimos, were artificial satellites based on their slightly irregular orbits and calculations of Phobos' density, which was so low that it must be hollow. Unable to explain why, Shklovskii speculated it might be an artificial refuge formed when Mars went dry millions of years ago.

Sagan sent him a manuscript he had written on the possibilities of interstellar space flight. This led to a collaboration between the two scientists: *Intelligent Life in the Universe*, published in 1966. Its fourth chapter "Intelligent Life as a Factor on the Cosmic Scale" revisited Sagan's ideas about the microbiological re-engineering of Venus. After discussing the "exhaustive" research required to find algae that would not fall ineffectually to the planet's surface,[21] they repeated that the planet must be free from

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[21] I. S. Shklovskii and Carl Sagan, *Intelligent Life in the Universe* (San Francisco: Holden-Day, 1966), 468.

any form of indigenous life for terraforming to occur. But if so, terraforming was the next step in space science.

In 1967, Sagan speculated that, while life on the surface of Venus was implausible, its clouds possessed all the prerequisites for photosynthesis and presented an environment more similar to Earth's than any other planet. In an article that bridged the boundaries between scientific speculation and hard science fiction, Sagan imagined what creatures could live in the Venusian atmosphere. He proposed that an "organism constructed of a float bladder" filled with hydrogen would be able to sustain itself in the upper temperate reaches of the clouds and avoid downdraughts into the extreme temperatures below. Sagan blended speculation with meticulous scientific details in the descriptions of ping-pong ball-sized balloon creatures and how they would function within the ecosphere of the clouds. He then built a narrative around these ideas: life emerged on Venus in its more clement periods but immigrated to the clouds as the greenhouse effect increased, awaiting discovery by "the first biological experiments to be performed in the vicinity."[22]

In October 1967, John W. Campbell sent Sagan a letter further illustrating the overlap between Sagan's speculation and hard science fiction. Dupont researcher Paul

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[22] Carl Sagan and Harold Morowitz, "Life in the Clouds of Venus," *Nature* 215.September 16 (1967), 1259-1260. Sagan reiterates these claims in an article published just two months later. The article extends the ramification of Sagan's greenhouse theory of Venus establishing that it renders the surface temperature of the entire planet well above 700 degrees Kelvin, thus ruling out the existence of liquid water or any biological organic molecule. Sagan is prepared to dismantle aspects of the romantic view of Venus as a twin to Earth, but he is not prepared to surrender all hope: while "the overall chances of life on the surface of Venus remain bleak" he refers to his earlier article indicating life may exist in its clouds in the form of ping-pong shaped creatures. Carl Sagan, "Life on the Surface of Venus," *Nature* 215.December 23 (1967), 1198-1999.

Arthur sent Campbell a copy of Sagan's 1967 article. The article had appeared under *Nature*'s heading "Planetary Science," to which Arthur had added the word "fiction" and asked why Sagan was not in Campbell's regular corral of science fiction writers. Whether or not the comment was intended satirically, Campbell agreed, writing to Sagan, "Your article is precisely the sort of thing we want to present, of course- intelligent, careful analysis of non-terrestrial environments which could be life-supporting environments." Campbell solicited an article from Sagan, explaining:

> The present cultural attitude makes professional scientific journals very limiting in an important respect; scientists are not adequately free to speculate on possible systems in public, where scientists of other disciplines can cooperate in refining or expanding the suggested ideas. That is one very real service that science–fiction [*sic*] magazines such as *Analog* can serve, and which I try to make it serve.[23]

Sagan was not the only scientist from this period advancing speculative scientific ideas that overlapped with science fiction. Physicist and mathematician Freeman Dyson was inspired by Olaf Stapledon's novel *Starmaker* to conceptualize ways humanity might find more resources in the future.[24] Similar to *First and Last Men*, *Starmaker* takes the reader on a voyage of chronologically vast proportions. At one point, the narrator describes a time when many stars lacking planets are "surrounded by concentric rings of artificial worlds. In some cases the inner rings contained scores, the outer rings thousands of globes adapted to life at some particular distance from the sun."[25] Dyson argued that any significantly advanced civilization would eventually fall short of energy

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[23] Perry Chapdelaine, Tony Chapdelaine and George Hay, eds., *The John W. Campbell Letters* (Franklin: AC Projects, 1985), 513. Though Sagan did not provide Campbell with such an article, he allowed the reproduction of a section of *Cosmic Connections* as a guest editorial in *Analog* October 1973.

[24] Freeman Dyson, *Disturbing the Universe* (London: Harper and Row Ltd, 1979), 211.

[25] Olaf Stapledon, *Star Maker* (Baltimore: Penguin Books, 1972), 165.

supplies due to basic Malthusian principles. The solution to the problem might be constructing an artificial biosphere that completely surrounded a star and captured all its released energy. For instance, the future human race might choose to disassemble Jupiter whose mass,

> if distributed in a spherical shell revolving around the sun at twice the Earth's distance from it, would have a thickness such that the mass is 200 grams per square centimeter of surface area…a shell of this thickness could be made comfortably habitable, and could contain all the machinery required for exploiting the solar radiation falling onto it from the inside.[26]

Numerous science fiction authors such as Frederick Pohl, Robert Heinlein, and Isaac Asimov, utilized this plan for the so-called Dyson Sphere, further demonstrating the overlap of science and hard science fiction. A similar overlap can also be found in the hard science fiction writing of Poul Anderson.

Poul Anderson

In a writing career that spanned four decades, Anderson became one of hard science fiction's preeminent authors, publishing over 70 novels and well over two hundred short stories.[27] He earned a degree in physics and described himself as a self-proclaimed "hard boiled" logical positivist and technophile. Scientific development was "basically good," he felt, "a necessary if not sufficient condition for the improvement of

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[26] Freeman Dyson, "Search for Artificial Sources of Infrared Radiation," *Science* 131 (1960), 1667.

[27] Letters from Anderson to his editors at Doubleday and Company indicate his level of production throughout the 1960s. He modestly boasts, "I do come up with the wordage equivalent of three or four ordinary length novels annually," and expresses concern that "Nothing would please me more than to have your firm absorb all my book-publishable output. But can you? My rate of production seems approximately twice your stated rate of consumption!" Poul Anderson, letter to Timothy Seldes, April 29th 1964, Papers of Poul Anderson, Huntington Library, San Marino, California.

man's lot, even his mental and spiritual lot."[28] Yet, as his story "Sister Planet" demonstrated, he was wary of unmitigated technological development. He explained:

> We today have learned, the hard way…that in blind expansionism lies doom. The modern technophile says, 'What we need is not less science and technology, but more of the right kinds: a science which sees man in perspective, a technology which will let him treat his world and his fellows with reverence. The gains of moving onward are worth the risks and costs.'[29]

Anderson strove to attain scientific verisimilitude in his works that required research and theoretical application. He was disappointed that much science fiction depicted either worlds just like Earth or "an unbelievable mishmash" of Earth's characteristics with alien ones that showed a lack of research and basic scientific understanding.[30] He insisted that achieving scientific veracity "does not take a degree in physics. It simply takes the basic knowledge of current scientific fact and theory, …imagination and a willingness to work." He recommended authors seek out texts like *Intelligent Life in the Universe* as a resource for story ideas.[31] In a pitch for a non-fiction book on ancient humans he claimed that he had "accumulated a small library on the subject" of paleoanthropology but more library research and review by researchers in the

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[28] Poul Anderson, "1965-1970: The Science," *Nebula Award Stories*, ed. Lloyd Biggle, vol. 7 (Harper & Row, 1973), 269.
[29] Ibid, 270.
[30] Despite his prolific output, Anderson held himself to high standards. In one letter he discusses writer's block and considers shelving a project because, "one could get the job done on sheer technique, but the chore would be miserable and the result not up to standard." Anderson, letter to Lawrence Ashmead, April 21st 1965, Papers of Poul Anderson.
[31] Poul Anderson, "The Creation of Imaginary Worlds: The World Builder's Handbook and Pocket Companion," *Science Fiction Today and Tomorrow*, ed. Reginald Bretnor (Baltimore: Penguin Books, 1974), 107. An example of his research process can be seen in the conclusion of one letter: "A thousand thanks for [anthropologist Edward T. Hall's 1959 book about culture and perception] THE SILENT LANGUAGE. Utterly fascinating, and loaded with story ideas." Anderson, letter to Lawrence Ashmead, January 7th 1965, Papers of Poul Anderson.

field at the University of California in Berkeley would be required.[32] A multi-year collaboration with fellow science fiction writer Hal Clement, produced an "extraordinarily rich" backdrop; research notes alone came to "30,000 words, plus maps and pictures and such!"[33]

Anderson's pieces on hard science fiction writing advised starting with simple parameters-- the size of the planet, its orbit, the kind of sun it has, number of satellites and other details that provided a sense of "the subtlety and interrelatedness of nature and her laws." He advised on determining the type of sun by mass and color, explaining that only a certain range of stars will collect planets, and even fewer may be stable enough to allow for life to develop on the planets. Brighter stars will be too intense and young for photosynthesis to have begun, while older stars will not provide enough energy for a thriving ecology. These decisions must follow the rules of science. For instance, the orbit must be elliptical, but not too eccentric: "If you want to play with an oddball orbit… you had better explain how it got to be that way."[34] Despite his meticulousness, Anderson made scientific errors. For instance, he recalled the shame of having readers point out his characters were attacked by saber-toothed tigers in times and regions where

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[32] Anderson, letter to Lawrence Ashmead, February 19th 1965, Papers of Poul Anderson.
[33] Anderson, letters to Diane Clever, Oct 17th 1973 and Sept 19th 1973, Papers of Poul Anderson. This research must apply to literary realism as well. In one letter to Doubleday, Anderson addressed the editor's concerns about the veracity of a character's German, which Anderson admitted: "is not perfect; but who would expect the character to get it right? He is described as speaking 'with more pride than grammar.' The Yiddish I got from [Jewish science fiction writer] Avram Davidson, who should know. He explained that transliteration is a somewhat arbitrary matter, the more so when there are several different dialects of the language; so what I put down is not necessarily what one of your Yiddish-speaking friends might write." Anderson, letter to Lawrence Ashmead, January 7th 1965
[34] Anderson, "The Creation of Imaginary Worlds," quotes 108, 116.

they were extinct. In regards to these mistakes, he admitted "even though we often fail, the ongoing effort to get things right is of fundamental importance. I really see no excuse for sloppy workmanship."[35]

Accordingly, the author must consider the ramifications of the design of the planet such as the size of the sun in the sky, the color of shadows it would cast, its effect on radio transmissions, power lines, and planetary biology. Each detail offered intriguing details and possible story lines. For instance, if the Earth did not have an axial tilt it would have no natural cycles, "Then what form would agriculture have taken? Society? Religion?"[36] To Anderson, these kinds of details were crucial "nuts and bolts," "ribs and foundations" necessary to create a fully rendered and scientifically true setting.[37]

Anderson defined hard science fiction as stories that use "real, present-day science or technology, and carries these further with a minimum of imaginary forces, materials or laws of nature," providing a "perfect scientific extrapolation, where known facts of physics, chemistry, biology and astronomy go into the construction of

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[35] Poul Anderson, "Nature: Laws and Surprises," *Mindscapes: The Geographies of Imagined Worlds*, eds. George Slusser and Rabkin Rabkin (Carbondale: Southern Illinois University Press, 1989), 7-8. Despite Anderson's penchant for details and research, he rarely wrote non-fiction pieces. His letters indicate this is not for lack of ideas. One letter pitched a nonfiction book of essays "on an important historical figure who failed. …it seems to me that such a set, taken together, would offer food for thought: and at the very least it should be entertaining." Possible topics included Ikhnaton of Egypt, Kleomenes III of Sparta, and Harold III of Norway. The reason for such lack of non-fiction may be evident. At the top of the letter the editor posted a note reading: "Looks very doubtful to me. I can't see anyone buying a book about failure… and there's also the problem of it being a collection…and Poul is not well-known outside of sf field. Reject." From letter to Diane Clever, July 18th 1973, Papers of Poul Anderson.
[36] Anderson, "The Creation of Imaginary Worlds," 128.
[37] Anderson, "Nature: Laws and Surprises," 10.

fascinatingly strange worlds and creatures."[38] This type of extrapolation was necessary to predict which direction the quickly changing fields of science and technology would move and how they would impact humanity.[39] Furthermore, like Campbell, he argued that science fiction should be a place to expand or refine scientific ideas.[40] Ultimately, hard science fiction was like science in that "science fiction, with its elements of pure imagination, is… a child of science, which itself has elements of the same pure imagination."[41]

There is an element of play in this seriousness and Anderson often referred to this process as "fun." It offered a "unique thrill" by providing a chance to open people's eyes to the "astounding" possibilities that science and technology present.[42] Far from being constraining, adhering to the rules of science could be inspiring and lead to surprising results, for both the author and the audience. Anderson in particular seemed to enjoy the challenge of creating plausible environments and explanations for fantastic things, describing the process like solving a puzzle or doing a scientific experiment. For instance, his story *The People of the Wind* resulted from a challenge by Campbell to

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38 Anderson, "1965-1970," 264. In a later piece, he refines this definition to the type of stories that ideally "confines the story assumptions to established facts. The author postulates no laws of nature, as yet undiscovered, which would allow things to happen" and the consequences of the story's propositions are logically concluded. Poul Anderson, "Science Fiction and Science: Part 3," *Destinies: The Paperback Magazine of Science Fiction and Speculative Fact*, ed. James Baen, vol. 1:3 (New York: Ace Books, 1979), 305.

39 Statements to this effect are made: Anderson, "Nature: Laws and Surprises," 9; Poul Anderson, "Science Fiction and Science: Part 1," *Destines: The Paperback Magazine of Science Fiction and Speculative Fact*, ed. James Baen, vol. 1:1 (New York: Ace Books, 1978) 295; Ibid., 1:2, 252; Ibid., 1:4, 320.

40 Anderson, letter to Lawrence Ashmead, March 31st 1970, Papers of Poul Anderson.

41 Anderson, "Science Fiction and Science: Part 3," 320.

42 Anderson, "1965-1970," 264.

determine how winged humanoids could have evolved.[43] Building meticulous extrapolations in turn set up a "game" that was "played between author and readers… the fewer scientific nits readers can pick, the higher the author scores."[44] This game was one of "the special joys" of hard science fiction.[45]

Nevertheless, Anderson was forced to admit that absolute accuracy was almost impossible and gobbledygook sometimes needed. Scientific facts were always changing, spelling the doom of many hard science fiction stories. Authors were also trying to tell good stories, and the creation of a good narrative might require a nonscientific or counter-scientific assumption. However, rules must still be followed. Faster-than-light speed travel is legitimate as long as an explanation is given for what innovation occurred to allow its existence.[46] Such gobbledygook could be used for minor elements, but should not be the focus of the story. This is what separated hard science fiction from what Anderson labeled "imaginary science stories," which hinged on the exploration of "the development of an idea for whose reality we have no evidence, or which the evidence is actually against it [sic]."[47]

"To Build A World"- Communicating, Developing, and Expanding Science

Given these insights, it is no surprise Anderson's next piece of terraforming science fiction reflected the influence of Sagan's ideas. "To Build a World," published in 1964, centers around Sevigny, a new terraforming engineer working on the Moon. After

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[43] Poul Anderson, "Science Fiction and Science: Part 2," *Destinies: The Paperback Magazine of Science Fiction and Speculative Fact*, ed. James Baen, vol. 1:2 (New York: Ace Books, 1979), 259-262; Anderson, "Science Fiction and Science: Part 3," 306.
[44] Anderson, "Nature: Laws and Surprises," 7.
[45] Anderson, "Science Fiction and Science: Part 2," 257.
[46] Anderson, "Nature: Laws and Surprises," 8-9.
[47] Anderson, "1965-1970," 266-267.

an incident of sabotage, Sevigny is sent to Earth to make sure that the damaged equipment is properly examined. Anderson lifts Sagan's plans for Venus and packages it in a conversation between Sevigny and a woman named Maura. Sevigny explains to her that Venus originally had:

> nitrogen, carbon dioxide, and a certain amount of water in the clouds. But the photosynthesizing algae grew exponentially once they'd been seeded in the upper atmosphere. They released oxygen; also, they kept sinking to lower levels where it was so hot they decomposed into carbon and water. The greenhouse effect dropped off until temperatures went below a hundred; and for ten years it rained without pause. Given liquid water, the Urey process operated, raw rock consumed still more CO-two [*sic*] and at last there was air that men could breathe.

Anderson then enhances Sagan's idea, explaining, "Solar protons and ultraviolet radiation helped, too, especially in breaking down hydrogen compounds. In other words, a weak magnetic field is an asset to the terraformer."[48]

In addition to using Sagan's plans for Venus, Anderson advances a plan for the Moon in a passage that illustrates hard science fiction's ability to develop new ideas and communicate science. Maura asks Sevigny how the moon can successfully be terraformed without a protective magnetic field to deflect solar radiation. Sevigny replies:

> "Given enough atmosphere, that doesn't matter. [Venus' atmosphere] amounts to a good bit more than [Earth's]".
>
> "But the Moon's is so small! How can it hold onto the gases?"
>
> "Loss to space isn't that fast. They won't have to worry about it for an estimated half million years. As for atmospheric shielding, the moon actually has an

[48]Anderson, "To Build a World," , 27. Though Anderson borrows largely from Sagan, he still refers to the process as terraforming, not Sagan's "microbiological planetary engineering." The process and the reference to the Urey process are strikingly similar to Sagan's description discussed above, which, in turn, is similar to a passage from Anderson's "The Big Rain."

> advantage over Earth. So low a gravitational field makes a correspondingly lower gradient. A surface pressure equal to three-fourths of earth sea level, which is what's planned, means that there will be a measurable concentration at altitudes which correspond to open space here. Charged particles won't penetrate deep, and actinic rays will be absorbed."
>
> "I've heard, though, that there isn't enough gas to be had."
>
> "The selenologists swear there is. Not as such, naturally. As buried ice; water of crystallization; carbon, nitrogen, and sulfur compounds released when minerals- and other organics left over from the original nebula- break down. What we're doing, actually, is using deep wells and atomic bombs to start vulcanism. The same process that gave all the smaller planets their atmospheres. Only we're going to tickle Luna so much that everything will happen several orders of magnitude faster than it did in nature."
>
> "But suppose your figures are wrong?"
>
> "That's been thought of. It won't be hard to deflect some comets into collision orbits, if necessary, and they're mostly big balls of frozen gas," Sevigny chuckled. "One way or another, the final stages ought to be quite a show..."[49]

Anderson perpetuates many aspects of the technological culture. Sevigny advances justifications for terraforming to demonstrate his "male knowledge" of engineering.[50] Terraforming enhances the natural beauty of Moon, making "the dark part glimmer and the bright part shine as men had never seen before."[51] Sevigny insists that the creation of a whole new world to inhabit is almost priceless and the process itself is invaluable. It will result in scientific and technological breakthroughs that will have wider applications, strengthen unity on Earth, exploit the moon's mineral wealth and provide a refuge for humanity in case of nuclear war.

Opponents of the plan, described as irrational, sentimental, and shortsighted, include religious fundamentalists who lament the spiritual impact of the Moon's altered

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[49] Ibid, 26.
[50] Ibid, 27.
[51] Ibid, 23.

appearance and politicians who believe it is a wasteful utopian dream that will bring no benefit to Earth. Meanwhile, the children of the planet starve "because the soil is exhausted and water tables are emptied and raw materials are too costly for chemosynthesis." Earth, they insist, is the place to begin reclamation. Sevigny explains that the Moon will pay off ten times what similar investment on Earth would produce in the long run, but opponents see that as "Too long a run."[52] As with Anderson's justifications for terraforming, this depiction of opponents to terraforming influenced future terraforming authors, especially Jerry Pournelle, the focus of the next chapter.

Growing Skepticism Toward Technology in the 1960s

Anderson's story and self-proclaimed technophilia are indicators of the continued prevalence of the technological culture and values through the 1960s. Positive attitudes toward technology and the belief in its ability to improve standards of living persisted as Americans. By the late 1960s, however, attitudes to the technological culture and space exploration had shifted. A growing backlash caused by environmental destruction generated some of the greatest criticisms of science and technology. In particular, fears about climate change, pollution, and overpopulation had a deep and lasting impact on the development of terraforming.

One area of concern focused on the impact of industry on the Earth's climate. In 1955 climatologist Hans Seuss and oceanographer Roger Revelle determined that the continued expansion of industry was dramatically increasing the concentration of atmospheric carbon dioxide, which they identified as a green house gas that could directly impact the climate. Their ideas were supported by Dave Keeling who measured

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[52] Ibid, 32.

exponential increases in atmospheric carbon dioxide across the globe from 1957 to 1963.[53] The 1965 Center for Atmospheric Research conference on climate change further established that the Earth's climate could shift rapidly and dramatically. Computer models indicated that small shifts in environment such as an increase in atmospheric carbon dioxide could trigger a series of feedback loops resulting in rapid and dramatic shifts. Researchers calculated that an increase of six degrees Fahrenheit might melt glaciers and cause planet-wide flooding. The Scientific Advisory Committee concluded that climate change resulting from carbon dioxide production was a real concern. The consensus that emerged was that the Earth's climate was dynamic, delicate, and alterable by human actions- a vision that would directly impact terraforming science.[54]

Another area of apprehension pertained to the effects of industrial pollution on humans and natural systems. Fears over the quality of air prompted citizens to lobby for the first Clean Air Act, and concern about the growing amounts of waste produced by the technological culture created an outcry against over-consumption and wasteful practices.[55] Bi-products of nuclear technology brought increased concern about radiation emissions in both the air and water.[56] Atmospheric sampling illustrated that radiation from atomic testing was circulating the globe, infiltrating food and water supplies.[57]

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[53] Spencer Weart, *The Discovery of Global Warming* (Cambridge: Harvard University Press, 2003), 23-32, 34-38.
[54] Ibid, 39-40, 62-63, 43-44.
[55] Samuel P. Hays, *Beauty, Health, and Permanence* (Cambridge: Cambridge University Press, 1987), 73-78, 176, 80-81.
[56] Ibid,177-178.
[57] Weart, *The Discovery of Global Warming* 41-42; Spencer Weart, *Nuclear Fear* (Cambridge: Harvard University Press, 1988), 205-206.

Rachel Carson's book *Silent Spring* further established that fallout and other poisons easily spread within localized natural systems and food chains.[58] Thousands of commonly used chemicals were exposed as potentially hazardous, spreading fears that the chemicals were leading to birth defects and cancer spread throughout the popular culture.[59]

A third concern pertained to the Earth's abilities to deal with the demands of the growing human population. From 1960 to 1969 over 400 popular articles about overpopulation were published in America. These articles largely took an alarming attitude to the overpopulation, arguing it would produce increased pollution, urban congestion, an elimination of open spaces and housing and massive unemployment. Land, water, and fossil fuels would be exhausted. The stability of world political systems would be threatened, potentially resulting in communist revolutions and wars. At its worst, these events would culminate in widespread ecological disasters, famine, disease, and the loss of millions of lives.[60]

Two influential pieces argued that technology could not alleviate these issues. In 1968 biologist Garret Hardin argued only social legislation against population growth would offer a solution to overpopulation because "Freedom to breed will bring ruin to all."[61] Ecologist Paul Ehrlich's 1968 book *The Population Bomb*, also traced pollution and environmental degradation to overpopulation. In his mind,

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[58] Rachel Carson, *Silent Spring* (New York: Mariner Books, 2002), 25-38.
[59] Victor Scheffer, *The Shaping of Environmentalism in America* (Seattle: University of Washington Press, 1991), 92.
[60] John Wilmoth and Patrick Ball, "The Population Debate in American Popular Magazines, 1946-90," *Population and Development Review* Dec (1992), 639-642.
[61] Garrett Hardin, "The Tragedy of the Commons," *Science* 162.3859 (1968), 1248.

> the causal chain of deterioration is easily followed to its source. Too many cars, too many factories, too much detergent, too much pesticide, multiplying contrails, inadequate sewage treatment plants, too little water, too much carbon dioxide- all can be traced easily to too many people.

Beyond these immediate and evident problems, Ehrlich predicted larger devastation including widespread war and disease. Like Hardin, he sought to alleviate the problem through legislation, arguing for a strict adherence to zero population growth (ZPG).[62]

Collectively, the data emerging at this time established that humans and their technology could change the Earth for the worse. For some, these issues would be evidence that the technological culture can only destroy natural systems, and that any terraforming endeavor would only perpetuate that destruction elsewhere. For others, these events would be the primary evidence that humanity can willingly change planet-wide environments and justified terraforming as a long-term necessity to escape a planet the technological culture would inevitably exhaust, overwhelm, or destroy.

The Emergence of the New Wave and Further Terraforming Counter-Narratives

A manifestation of the growing skepticism toward the technological culture emerged in science fiction as the New Wave movement, explicitly rejecting the parameters of hard science fiction and the celebration of the technological culture of the first half of the 20th century. A new group of science fiction authors and editors focused on the impact of science and technology on human experiences, perceptions, and relationships, turned away from the exploration of space, redirecting their energies to stories about the human mind and "inner-space." They experimented with new forms of storytelling and sought to create futures that were not just extrapolations of the present,

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[62] Paul Ehrilich, *The Population Bomb* (Cutchogue: Buccaneer Books, 1971), 1-26, 44 (quote).

but involved radical new settings, scenarios, and forms of life. Rather than strong, triumphant, masculine protagonists steeped in the technological culture, lead characters were often foreigners to it, morally and physically weak, and failed as often as they succeeded. The workings of science and technology often went unexplained. These stories were far more cynical about the promise of complex, rationalized science and technology to create a better world and tended to celebrate simplicity and irrationality. New Wave authors Richard McKenna and Roger Zelazny both contributed counter-narratives that challenged the assumptions and justifications implicit in terraforming.

"Hunter Come Home"

Richard McKenna's 1963 story "Hunter Come Home" takes place on a planet where life has taken the form of one large, symbiotic jungle. The jungle is composed of different organisms called phytos- some that are like trees, some like stems, some like leaves, but all of which are interconnected. The main character, Craig, is part of a terraforming crew from the planet Mordin. The Mordin men work with scientists from another planet who study the planet while developing a poison called Thanasis to kill off the phytos and clear the land.

Nature is depicted as gentle, wholesome, and sympathetic while the terraforming technology is depicted as dark, dangerous, and uncontrollable. The workers drill holes that they fill with explosive pellets that distribute the Thanasis. The explosions cause uprooted phytos to form "terrified, chromatic clouds that marked the rolling shock wave. Behind it the silvery plain darkened with the sheet flow of poisoned water."[63] Though

[63] Richard McKenna, "Hunter Come Home," *The Magazine of Fantasy and Science Fiction* March 1963, 99.

the phytos can feel pain and suffer, they never die. Instead, they are reabsorbed into the system and the planet never decays or experiences death. Their pain is expressed as a piping sound. When the settlers first arrived the planet was silent, but now it is alive with the piping- the sound of "whole continents hurting and crying, day and night for years."[64] Even the crude Mordin men can appreciate the beauty of the planet, but they show little remorse in converting it to their ends, accepting it as inevitable.

But the phyto-planet evolves rapidly and is only susceptible to strains of Thanasis for brief periods before growing back. As the planet becomes a symbol of their failure and impotence, the Mordin men grow impatient, and develop a dangerous strain of Thanasis that rampantly evolves and overruns the planet. But the phyto planet survives. Craig, and his love interest Midori, are killed by the poison, but reconstituted by the planet and given ever-lasting life as a part of the phyto organism. The second creation is in enacted within their bodies, which have now become one with the Eden-like planet. Unlike previous works, they have found fulfillment through oneness with nature, not by conquering it with technology.

"The Keys to December"

Roger Zelazny's 1966 story also challenged both the technological culture and the key aspects and assumptions of terraforming. The main character is Jarry Dark, an engineered human called a "catform," designed to live on a cold world. Jarry and twenty eight thousand other catforms save enough money to buy a planet and "Worldchange" machines to alter it to fit their physical needs within three thousand years. As they

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[64] Ibid, 103.

terraform their target planet, Jarry and the others take turns monitoring the machinery for three months then sleeping in suspended animation for two hundred and fifty years.

But there is no glory in the technological second creation. Here, one species' terraforming is another species' destruction. The pre-terraformed planet is a beautiful place with expansive plains, skies the color of dry sand, and green birds with "wings like parachutes, bills like sickles, feathers like oak leaves."[65] As Jarry and the others come in and out of suspended animation, they witness the planet's slow death by freezing. As in previous narratives, they see the process through a utilitarian lens, but unlike those in other stories, they are deeply distressed to see the impacts of their desires. The animals move to warmer regions, but once they reach their limits they suffocate and die. Jarry is horrified to realize that the native caterpillars have begun wearing the skins of other dead caterpillars to stave off the increasing cold. The planet becomes engulfed in massive windstorms and volcanic eruptions begin to spew ash, darkening the sky. Jarry cannot decide if it is beautiful or horrendous. Yet, he insists the second creation is still paramount:

> "Everything is changing because we want it to change. We're stronger than the world, and we'll squeeze it and paint it and poke holes in it until we've made it exactly the way we want it. Then we'll take it and cover it with cities and children. You want to see God? Go look in the mirror."[66]

Particularly upsetting is the fate of a group of bi-pedal creatures called "redforms." Half-way through the process, the redforms begin using fire, dressing themselves in animal skins, and leaving animal sacrifices at the scientific stations. Jarry realizes that the creatures have human characteristics such as intelligence, opposable

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[65] Reprinted in *World's Best Science Fiction*, (New York: Ace Books, 1967), 43-44.
[66] Ibid 52.

thumbs, religion, and communication. One scientist revels in this discovery explaining: "Perhaps they would have remained stupid-animals- if we had not come along and forced them to get smart in order to go on living. We've accelerated their evolution. They had to adapt or die, and they adapted."[67] But Jarry feels guilt over creating an intelligent species only to extinguish them, and questions the worth of the terraforming project at such a great expense.

Fearful that the creatures will not be able to evolve fast enough to survive, Jarry seeks to slow the terraforming. The other catforms refuse for petty reasons. After a failed coup attempt, Jarry abandons the terraforming project, choosing to live amongst the redforms for the rest of his life. He no longer finds value in selfishly pursuing the project at the expense of the life it has unintentionally created. He realizes in this second creation, "I am their God… In this capacity, I owe them some consideration…. And these things are all that my life is worth now."[68] As in numerous New Wave stories, Jarry is portrayed as a hero for rejecting the technological values in preference of protecting life and nature.

Conclusion

As Sagan continued to build his professional career, he was continually drawn to highly theoretical and fringe ideas. He often openly speculated about propositions grounded in *plausibility* rather than absolute fact, choosing to examine scenarios that scientific fact had not yet documented, but which "the probability of their existence [was] not zero."[69] To many scientists, his approach was simply a way to garner attention and

[67] Ibid 60.
[68] Ibid 63-64.
[69] Shklovskii and Sagan, *Intelligent Life in the Universe* 475.

stay in the limelight- motivations that had no place in serious scientific research. Stanley Miller explained, “It raises questions of whether he is a serious guy” and even fellow fringe scientist and SETI pioneer, Frank Drake, claimed Sagan’s approach “was not good science.”[70] While this refusal to rule out plausible ideas riled his colleagues, his approach overlapped with hard science fiction, and it was within this shared frame of extrapolation that Sagan speculated about terraforming.

Hard science fiction author Poul Anderson shared Sagan’s criteria for exploring plausible ideas. Following his rules for hard science fiction, Anderson continued to explore the idea of terraforming. In doing so, he used the genre to refine Sagan’s ideas, expand the idea with new plans, and communicate these to his readers. In this manner, the vernacular conversation spread beyond hard science fiction to incorporate professional sources. His work also continued to frame terraforming within the values and ideals of 20th century technological culture, portraying it as a masculine activity designed to technologically improve nature and create a glorious second creation resulting in increased material wealth and space for human populations to expand.

But throughout the 1960s, these ideals and values were increasingly challenged by an increase in awareness of the dangers of science and technology and their ability to damage the environment. These events influenced the development of the New Wave and its technological skepticism. Just as these stories rejected hard science fiction formulas and ideals, they too rejected terraforming. Richard McKenna and Roger Zelazny reframed terraforming as a dangerous, dark process. Rather than providing a means to a second creation, technology violently destroys nature and life. Rather than

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[70] Quoted in Davidson, *Carl Sagan: A Life* 132.

providing spiritual fulfillment and autonomy, the process is selfish and pointless and the characters find their fulfillment and autonomy by reacting against terraforming and surrendering to nature.

We will see that as Americans come to understand the dangers inherent in their technological culture, the idea of using those same technologies to terraform and replicate the culture on another planet is viewed with increasing cynicism. The following chapter will examine how these conflicting views establish a dichotomy that will divide terraforming as it continues to be developed throughout the 1970s.

Chapter 3- 1970-1975: Pessimism, Optimism, and Schism

"Given half a century, they'll give us a thick atmosphere and burn away the toxic gases. Another twenty years and there will be Earth-style air and crops and people on Ganymede."[1]

Throughout the 1970s, the skepticism over the benefits of the technological culture continued on a number of fronts. Concerns built over the impact of overpopulation and pollution as expressed in the works of Barry Commoner and the Club of Rome. Ironically, the growing environmental dialogue introduced key ideas, tools, terminology, and arguments that would be capitalized on by those who saw technology and terraforming as humanity's saving grace. The appropriate technology movement marked one response to these events by promoting simple technologies that worked in harmony with nature. John Varley's short story "Retrograde Summer" provided a terraforming counter narrative that reflected this re-envisioned relationship to technology.

Technological enthusiasts sought to counter these concerns with plans for space exploration that ultimately benefited terraforming science. Gerard O'Neill developed and popularized plans for space colonization as a way to solve the limits to growth imposed upon Earth-bound humanity and infinitely extend the technological culture that informed arguments terraformers would later make. Terraforming science was further aided by data provided by NASA space probes that Carl Sagan used in conjunction with ideas from James Lovelock to develop a new vision of terraforming that challenged aspects of the tradition technological narrative. Technological optimism continued to thrive within the genre of hard science fiction, and Gregory Benford emerged as one of the new voices of the genre. An examination of his approach to hard science fiction and terraforming

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[1] Gregory Benford, *Jupiter Project* (New York: Avon Books, 1975), 69.

further illustrates the overlapping between science and hard science fiction and the importance of the genre to the continuing evolution of terraforming.

Environmental Concerns and Counter-Narratives

As the 1970s progressed, the technological culture was targeted and criticized in two influential texts by Barry Commoner and the Club of Rome. In 1971, Barry Commoner reflected on the post-Earth Day world in a book that greatly influenced the direction of the environmental movement and sharply criticized the American technological culture. Unlike Hardin and Ehrlich, discussed in the previous chapter, Commoner did not believe that environmental problems could be traced back to overpopulation. The technological culture was to blame, "with the ways in which society has elected to win, distribute, and use the wealth that has been extracted by human labor from the planet's resources."[2]

Two influential ideas emerged from Commoner's work. First was the ecosphere, defined as "The home that life has built for itself on the planet's outer surface. Any living thing that hopes to live on the earth must fit into the ecosphere or perish."[3] Commoner utilized it to clarify environmental problems and simplify complex interrelationships between man and nature. Second, he argued anything extracted from the ecosphere by human effort must somehow be replaced, something the technological culture, inherently failed to do- and thus produced the modern crises. As a result, science offered few solutions while, technology was the cause of most of the problems. The few

[2] Barry Commoner, *The Closing Circle* (New York: Alfred A. Knopf, 1971), 178.
[3] Ibid, 11.

instances where science and technology were used productively to address environmental problems failed to address wider, systemic problems.[4]

A second influential text published at this time was *The Limits to Growth*, the result of studies done by the Club of Rome. The Club of Rome was founded in 1968, when thirty people from ten different countries and a variety of occupations assembled in Rome to analyze the interconnected global systems and how they contributed to overpopulation, environmental degradation, and poverty. In the following years, the group grew and published works that highlighted the impending nature of these issues and popularized ways they could be averted. *Limits to Growth* was their greatest effort to draw attention to the issues and effect change through global policy shifts.[5]

A key part of their work was the creation of a computer model that extrapolated trends and predicted the time horizons for pressing issues like overpopulation. Many of the calculations relied on feedback loops to compute the impact of exponential growth on available global resources and pollution levels. Though they admitted the model was not perfect, they sought to use the results to inspire decision-making and political action. Their conclusions were dire:

> If the present growth trends in world population, industrialization, pollution, food production, and resource depletion continue unchallenged, the limits to growth on this planet will be reached sometime within the next one hundred years. The most probable result will be a rather sudden and uncontrollable decline in both population and industrial capacity.[6]

[4] Ibid, 140-177.
[5] Donella Meadows, Dennis Meadows, Jorgen Randers and William Behrens, *The Limits to Growth* (New York: Universe Books, 1972), 9-11.
[6] Ibid, 23.

Technology and science would be of little assistance. Even under the most optimistic forecasts, nuclear energy or birth control could not prevent the decline of population and industry resulting from unchecked growth beyond the year 2100. Furthermore, the world was replete with issues technology posed no solution to, including the arms race, racial tensions, and unemployment.[7]

But the situation could be averted if a "global equilibrium" were designed to satisfy the needs of everyone on Earth and enable that "each person has an equal opportunity to realize his individual human potential." But action had to begin immediately. Constraints must be placed on population growth and zero population growth policies implemented. This would be coupled with limits placed on resource consumption and the reorientation of global values onto establishing equilibrium between populations and resources. Only by abandoning the goals, values and ideals of the technological culture could humanity create a "totally new form of human society- one that would be built to last for generations."[8]

One response to these issues was the "appropriate technologies" movement. Rather than abandoning technology, this movement looked to strip down technology to its most simple forms and use it in a manner that would alleviate problems created by the larger technological culture. *The Whole Earth Catalogue* emerged as a guide both to the creation and purchasing of technologies that were simple, easy to operate, affordable and offered autonomy from larger technological systems. For instance, readers could purchase plans for solar cookers, solar water heaters, and kerosene lamps that would

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[7] Ibid, 145-150, quote 145.
[8] Ibid, 163, 173-174, quotes 24, 184

enable the individual to "conduct his own education, find his own inspiration, shape his own environment and share his adventure with whoever is interested," while using technology to maintain elements of their lifestyle.[9] Limited technology could benefit and supported the individual while working in harmony with nature rather than exploiting or polluting it.[10]

These ideals and concerns also found expression in science fiction. For example, John Varley's terraforming counter narrative "Retrograde Summer" reflected the increase in environmental ideals and captured this new desire to use technology harmoniously with nature. In Varley's story, rather than using complex technological systems to adapt the planets to people (terraforming), or people to planets (Blish's pantropy), Earth colonies rely on specialized and localized technology to keep them alive. For instance, on Mercury colonists use force field technology to exist in harmony with nature. Force fields are used to generate structures for humans to live and work in that do not alter the environment in anyway. Personal force fields called "suits" replace the large, technologically complex space suits of previous science fiction. The suit activates any time humans are not under larger protective force fields, automatically oxygenating the blood, venting carbon dioxide, and cooling the body. This technology gives humans the freedom and autonomy to live, work, and play on the surface of the planet.

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[9]Stewart Brand, *Whole Earth Catalogue: Access to Tools*, (New York: Random House, 1971), 3.

[10] For more on appropriate technology see Carroll Pursell, "The Rise and Fall of the Appropriate Technology Movement in the United States, 1965-1985," *Technology and Culture* 34.July (1993), 629-637; Pursell, *The Machine in America* , 302-308; Hughes, *American Genesis* , 453-459.

Humans use the technology to harmoniously interact with their extraterrestrial surroundings. A natural pool of liquid mercury becomes a playground for children who slide on its frictionless surface protected by their suits. This world remains untamed--earthquakes are accepted and technology used to rebuild what has been destroyed. Conservation has become a primary ideal and resource exhaustion and overpopulation primary concerns. The first moral lesson taught to humans is zero population growth: "one person one child." The nuclear family of previous human culture is viewed as a disgusting, antiquated notion that brought with it "Husbands killing wives, wives killing husbands, parents beating children, wars, starvation..."[11]

***The High Frontier* and the Persistence of Positive Attitudes in the 1970s**

In spite of, and in ways because of, the growing understanding in American culture of the environmental expense of the technological culture, a handful of researchers continued to develop ways that technology could be used to create radical new futures free from the effects of overpopulation and pollution. For them, technology, and space exploration in particular, remained a way to preserve and extend the Western technological culture. These ideas would find expression in plans for space colonies, which ultimately proved influential to arguments in favor of terraforming.

One such response came from physicist and Princeton professor Gerard O'Neill who developed and promoted plans for immense, cylindrical, self-sufficient space colonies as the next logical step for the expansion of humankind. In the early 1970s, O'Neill's plans were discussed in a wide range of popular media and in 1976 O'Neill

[11] John Varley, "Retrograde Summer," *The Magazine of Fantasy and Science Fiction* Feb. 1975, quotes from 95, 101.

testified in front of Congress about his plans summarized in his book, *The High Frontier*. Using an approach that would influence later terraformers, O'Neill sought to find ways that all humanity could benefit from technology, "yet prevent the material aspects of that expansion from fouling the worldwide nest in which we live."[12]

In O'Neill's mind, humanity had become a victim of its technological success. The industrial revolution that had increased health, wealth, and standards of living had also "scarred, gutted, and dirtied our planet to a degree many people find intolerable." The technological culture had progressed at unsustainable levels, and humanity was currently faced with devastating limits on food, energy, and other non-renewable resources. A less industrialized world could not sustain the current level of population. In fact, third world nations needed more industrialization to feed the desperate populations in which "parents must watch their children die, and be powerless to save them."[13]

And the future looked worse. Like the Club of Rome, O'Neill cited numbers that indicated the human population doubled every 35 years- with most of the growth occurring in poorer nations. By the year 2000, 88% of the world's population would exist in poor nations. The increase in energy demands could not be addressed through conservation, and expanding current energy resources would only result in further pollution and global warming. These demands would increase political tension across the globe, resulting in an increase in authoritarian governments to maintain control and repress social revolutions. In disagreement with the Club of Rome, he thought it was

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[12] Gerard O'Neill, *The High Frontier: Human Colonies in Space* (New York: William Morrow and Company, 1976), 12.
[13] Ibid, quotes 20, 21.

unlikely that industrialized western nations would be willing to sacrifice in order to prevent these issues. Even if cleaner forms of energy could be found on Earth and shared, O'Neill was worried about the threat of lost frontiers. As the populations expanded, what opportunity would there be "for rare, talented individuals to create their own small worlds of home and family, as was so easy a century ago in our America as it expanded into a new frontier?...the most chilling prospect I see for a planet-bound human race is that many of those dreams would be forever cut off."[14]

Space colonies would provide a way to solve the energy crisis, overpopulation, and "the opportunity for increased human options and diversity of development."[15] Earth and lunar materials could be assembled in space into a habitable colony and accompanying industrial center that would make it self-sufficient. The station would utilize uninterrupted solar energy to drive its industry and agricultural centers. The asteroid belts would be mined to further provide Earth with needed resources. The initial colony could hold up to ten thousand people, and later ones could hold up to ten million. Importantly, the colonies would assemble massive solar satellites that would convert solar energy into microwave energy and beam it to Earth. He estimated the construction of the space colonies could begin within seven to ten years and be completed within 15-25 years. When the space colonies were fully developed they would provide cheap and unlimited energy for all humanity, "living space of higher quality than that now

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[14] Ibid, 43.
[15] Ibid, 19.

possessed by most of the human race," and nearly inexhaustible sources of materials from the moon and asteroids "without stealing or killing, or polluting."[16]

O'Neill admitted to being a science fiction fan, but repeatedly insisted the plan was not at all "science fiction;" colonies could be made with current technology. Yet, O'Neill's book included numerous hard science fiction vignettes, which explained technical details of his plan, and provided a feeling of familiarity and reality to his plans. They promised an Earth-like Eden where the main living areas of the colonies would provide the "ideal" habitat. One vignette explained the station has a "Hawaiian climate, so we lead an indoor-outdoor life all year. Our apartment is about the same size as our old house on Earth, and it has a garden."[17] A second creation would be made in space where "There will be no need to introduce insecticides or other poisons, and industrial wastes, if any, will be borne away by the solar wind."[18] Like the Ark, the colonies could act as preserves for endangered species to thrive and flourish.

O'Neill's plans reflected persistent beliefs in the power of technology to improve humankind's lot and break down the limits on humanity's existence. They also illustrate that, like the appropriate technology movement, the 1970s were not simply a time of backlash against technology but also a time of re-envisioning how technology should and could be used. Furthermore, these plans mark a continuation of the overall vision of technology as presented within the technological foundation narratives discussed in previous chapters. As the 1970s continued, this vision of space exploration as a form of technological salvation also provided support and motivation for terraforming. In

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[16] Ibid, quote 38.
[17] Ibid, 14.
[18] Ibid, 87.

addition, the idea of harnessing unutilized space to benefit all humanity by removing polluting industry, excess populations, and providing free energy resources would prove irresistible targets for future terraformers. Furthermore, future terraforming plans would have to be justified in contrast to plans for space colonies. Another contributing factor to the development of terraforming and its plausibility was the information about the solar planets returned by a number of NASA's space probes.

NASA and the Martian Space Probes

NASA opened in the fall of 1958 to a flood of funding resulting from the successful *Sputnik* mission. From its inception, NASA's attention was split between plans to send a man into space and the need to accumulate data about space. It was further split by calls from different agencies that wanted NASA to work in their interests: for military research (the Department of Defense) or for pure science (Jet Propulsion Laboratory).[19] In 1960, NASA laid out its official ten-year plan establishing planetary missions as one of its key goals. Mars quickly became a target for NASA, not only for its proximity, but also for the promise that it might hold for finding extraterrestrial life. In 1962, NASA headquarters authorized the first series of space probes called the *Mariners* to be launched at the next advantageous orbital path in 1964.[20]

In July of 1965, *Mariner* 4 returned a series of 22 images that shocked the scientific community. The grainy, black and white images revealed a heavily cratered, desert-like terrain that was far more like the Moon than the Earth. This gave the first

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[19] Edward Ezell and Linda Ezell, *On Mars; Exploration of the Red Planet 1958-1978* (Washington DC: NASA, 1984), 15-19, 23.

[20] Clayton Koppes, *JPL and the American Space Program; a History of the Jet Propulsion Laboratory* (New Haven and London: Yale University Press, 1982), 165.

impression of Mars' true topography, and, for many scientists who had expected to see Mars filled with Earth-like features, it was a great shock and disappointment. Especially disheartening was the fact that the numerous impact craters indicated that the surface of Mars was essentially geologically inactive and had remained unchanged for millions of years. The disappointment caused by the photographs was coupled with the tests done with radio signals from *Mariner* 4 that established the atmosphere was significantly thinner than Earth's and composed of about 95% carbon dioxide.[21]

NASA continued its exploration with *Mariners* 6 and 7, launched in February and March of 1969. Circling about 3500 km above the surface of Mars, the two probes increased the close-up photographic coverage of Mars from 1% returned by *Mariner* 4, to 10%. The probes' cameras revealed areas scientists believed to have vegetation or ground cover of some variety to be areas of heavily cratered, geologically dead surface with no evidence of water.[22]

NASA coordinators agreed that Mars still represented the best chance to find evidence of life in our solar system. The *Mariners* 8 and 9 were designed to detect surface temperatures and locate a suitable landing spot for a future probe. After the accidental crash of *Mariner* 8, its duplicate, *Mariner* 9, was launched on May 30th, 1971 and successfully achieved orbit around Mars only to find the planet engulfed in a dust storm. It became clear to scientists that seasonal dust storms, not masses of vegetation, caused occasional darkening of the Martian landscape.[23] *Mariner* 9 captured over 7,000

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[21] Ezell and Ezell, *On Mars; Exploration of the Red Planet 1958-1978* 75-83;William Sheehan, *The Planet Mars* (Tucson: The University of Arizona Press, 1996), 164-167.
[22] Ezell and Ezell, *On Mars* 179-181.
[23] Ibid, 161.

images of massive Earth-like volcanoes that dotted the planet's surface, vast systems of canyons and valleys, and networks of channels emanating from dry lakebeds. Images of the northern polar cap revealed that a large part of it sublimed away during warmer seasons on Mars, leaving behind a massive permanent cap likely consisting of frozen water. All this photographic evidence led to speculations that at some point in its past Mars' climate was less severe, and had a thicker, warmer atmosphere which allowed liquid water to flow.[24] One of the first people to capitalize on this new knowledge was Carl Sagan.

Sagan, Lovelock, and the Foundations of Modern Terraforming

In the early 1970s's Sagan used the data from the Mariners to advance new plans for Mars that challenged aspects of the traditional technological terraforming narrative. He advanced plans that relied primarily on biology, and eschewed gobbledygook, and common justifications for terraforming. Yet, his ideas did not form a complete break from the technological narrative, and he justified terraforming as a natural extension of humanity's spiritual need to conquer and colonize.

In a 1971 article, Sagan argued Mars periodically underwent massive environmental transformations. While the southern polar ice cap had been known to vanish as Mars traveled in its orbit, the northern polar cap (NPC) had never been seen to evaporate. *Mariner* photographs suggested water that once flowed across Mars' surface was trapped in its frozen mass along with various atmospheric gases such as ammonia and methane. Sagan postulated that during Mars' orbital precession, which is completed

[24] Sheehan, *The Planet Mars* 175-176; William Sheehan and Stephen James O'Meara, *Mars: The Lure of the Red Planet* (Amherst: Prometheus Books, 2001), 255-257, 261-263.

every 25,000 years, a large portion of the cap was converted into a dense atmosphere, warming the planet through the greenhouse effect. He concluded:

> "The biological consequences of this hypothesis are straightforward. The bulk of Martian organisms shut up shop for the (processional) winter. Spores, vegetative forms, and- for all we know- hibernators abound, but only for a few or no active organisms."

Aside from arguing for the plausibility of Martian life, Sagan's model indicated "human endeavors could, by volatizing the present remnant of the northern polar cap and taking advantage of the hypothesized instabilities, introduce much more clement conditions on Mars." In essence, humanity could use the greenhouse effect to terraform Mars.[25]

Inspired by Sagan's ideas, in 1973, Cornell University researchers Joseph Burns and Martin Harwit suggested altering Mars' precession would allow a unique opportunity to watch an undeveloped ecosphere evolve. But beyond gaining this scientific knowledge, "man will almost certainly soon need areas for expansion (ZPG or no!)." Burns and Harwit proposed a technological fix: moving Mars' moon, Phobos, or a significant amount of matter from the Kuiper asteroid belt closer to Mars' orbit could permanently force the planet into a "biologically favorable" position. They rely on gobbledygook in the form of a "perfect solar engine" to move the immense amount of mass in reasonable periods of time. Though such technology did not currently exist, they insisted it was certainly something that humans of the future would be capable of crafting and such plans have "undoubtedly" been accomplished by other life forms somewhere in the universe. They admitted, "there is always something a little repugnant about man pushing his own interests and fixing nature" but their plan would avoid "damaging" Mars

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[25] Carl Sagan, "The Long Winter Model of Martian Biology: A Speculation," *Icarus* 15 (1971), quotes 512 and 513.

by keeping foreign matter out of its ecosystem.[26] Reflecting the technological values, the process itself would fix Mars, not damage it.

Sagan reflected on their ideas and expanded the idea of terraforming in his popular science book, *The Cosmic Connection,* which contained some of Sagan's most imaginative speculations to date.[27] For example, like a hard science fiction story in *Analog*, he postulated that some creatures on Mars might have developed ways to protect themselves from the intense ultraviolet radiation that would kill any earth life. He suggested that these might be "organisms walking around with small ultraviolet-opaque shields on their backs: Martian turtles. Or perhaps Martian organisms carry about ultraviolet parasols…"[28] Chapter 22, "Terraforming the Planets," used the word for the first time outside of science fiction.

In explaining how hostile planets can be converted into life-bearing Edens, Sagan drew on a theory postulated by James Lovelock's theory. Lovelock worked for Jet Propulsion Laboratories (JPL) during the 1960s designing sensitive detectors for space missions. Asked by NASA administrators how to detect life on Mars, he devised an

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[26] J. Burns and M. Harwit, "Towards a More Habitable Mars -or- the Coming Martian Spring," *Icarus* 19 (1973), quotes 127 and 130.

[27] One activity that set Sagan apart from many other professional scientists was his dedication to spreading scientific knowledge to the American people. He did this through various popular outlets including books, magazine articles, and, perhaps most famously, his television appearances and specials. *The Cosmic Connection* was simultaneously expansive and comprehensive, written in a language comprehensible to a wide variety of Americans. The main objective of the book was to carry Sagan's enthusiasm for space and space exploration to a larger audience and it was an undeniable success, receiving numerous laudatory reviews. For instance, the journal *Science* proclaimed that the book "ought to be read by high school and college kids, college dropouts, your nephews and nieces, everybody who ever uttered a word against science and technology," William Hartman, *Science*, May 10 (1974), 663.

[28] Carl Sagan, *The Cosmic Connection* (Garden City: Anchor Press, 1973), 59.

entropy detection test that could analyze the chemical composition of Mars' atmosphere. If there was no life on Mars, the Martian atmosphere would be close to chemical equilibrium (low entropy), but if life were present the atmosphere would be in a state of high entropy.[29] His idea attracted the attention of NASA senior scientists. In early 1965 he was made acting chief scientist for physical life-detection experiments for the next Mars probe. In addition to devising biological experiments, Lovelock proposed building an infrared telescope to analyze planetary atmospheres. He explained, "At this time scientists still seemed to think that life flourished on Mars. I recall Carl Sagan enthusing over the wave of darkness that crosses Mars when winter ends [that] he and many others saw as indicative of the growth of vegetation…"[30]

As head of the life detection project, Lovelock worked to detect life through atmospheric analysis. His fundamentally different view of the interaction organisms had with their environment consistently met with resistance. Conventional biology and planetary science of the time held that organisms adapt to their environment. Lovelock argued, "that organisms change their environment," resulting in confrontations between Lovelock and the biologists on the life-detection team. After nine months, Congress withdrew funding for the life-detecting missions and Lovelock lost his managerial position. Though he continued to act as an advisor and even helped to build many of the devices that would be flown on *Viking*, Lovelock recalled, "It vexed me a little to see the

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[29] J. E. Lovelock, *Homage to Gaia: The Life of an Independent Scientist* (Oxford: Oxford University Press, 2000), 241-245.
[30] Ibid, 248.

excellence of the engineers and instrument scientists wasted on what I thought were the wrong experiments…"[31]

Shortly after the program was shut down, Lovelock was shown infrared spectrum charts of Mars and Venus indicating their atmospheres were dominated by carbon dioxide. Mars was close to chemical equilibrium, indicating the absence of life. In contrast, oxygen, methane, and nitrogen dominate Earth's atmosphere. Since oxygen and methane react with one another and nitrogen is most stable as a nitrate dissolved in water, how could these elements remain constant in Earth's atmosphere? Lovelock came to believe that these elements were constantly being replenished by the abundance of life on Earth. He recalled that:

> "It came to me suddenly… that to persist and keep stable, something must be regulating the atmosphere and so keeping it at its constant composition. Moreover, if most of the gases came from living organisms, then life at the surface must be doing the regulation."[32]

Absent the presence of life, the balance of elements in the Earth's atmosphere would shift to a state of entropy similar to Mars. Though skeptical of the idea, his JPL officemate, Carl Sagan, suggested his theory might solve the "cool sun" problem. Theories of planetary formation indicated that the Earth was 25-30% cooler in its earlier history, but the geological record showed Earth had maintained an average global temperature close to today's. Lovelock's notion about the regulatory effect of life might offer a solution to the mystery.[33]

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[31] Ibid, 250.
[32] Ibid, 253.
[33] Lovelock worked to get his idea accepted by the mainstream scientific community with mixed results. In 1967 at the American Astronomical Society engineers who understood the idea of feedback systems and their regulating ability enthusiastically accepted it. In a

In *Cosmic Connections*, Carl Sagan argued that Earth's atmospheric elements like carbon dioxide, nitrogen, and methane were likely the product of micro-organisms and plants. These gases create a feedback cycle that warmed the atmosphere making the planet suitable for more life. Martians looking at Earth with a spectrographic telescope would see the unstable elements like methane, and deduce the existence of life on Earth. He concluded that, "In a way, life on Earth has terraformed Terra"[34]

Sagan speculated that biology and feedback cycles might replicate this process on Venus. Nostocaceae algae released into the upper atmosphere of Venus could add oxygen through photosynthesis and add a foot-high layer of water to the surface --an "example of how human technology and science may, in periods quite short compared to geological time, rework the environment of another planet."[35] In 1973 A. T. Young published new evidence indicating that the clouds of Venus were probably sulfuric acid solutions.[36] Sagan responded that while this "sets some further boundary conditions on the hardiness of the proposed organisms," terraforming might still be used on other planets "to alter their contemporary environments into ones which are for various reasons more appropriate to human activities."[37] The most viable target was Mars and Sagan set about promoting a plan for terraforming the planet in his popular and professional pieces.

Sagan rejected Burns' and Harwit's technological fix for Mars, mathematically demonstrating their schemes ultimately fail to generate enough torque to alter Mars'

1968 meeting on the origins of life at Princeton, Lovelock's ideas were completely ignored. Ibid, 254-255.

[34] Sagan, *The Cosmic Connection* 149-150, quote 150.

[35] Ibid, 152.

[36] A.T. Young, "Are the Clouds of Venus Sulfuric Acid?," *Icarus* 18 (1973), 564-582.

[37] C. Sagan, "Planetary Engineering on Mars," *Icarus* 20 (1973), 513.

orientation and "were-- needless to say-- expensive." Instead, the most reasonable way to effect climatic instability on Mars was to alter the albedo (reflective quality) of the northern polar cap. Decreasing its albedo would trap more solar energy, melt the cap, increase the atmospheric pressure and improve the movement of heat across the planet "which in turns heats the caps still further, and so on."[38] As opposed to previous terraforming plans, Sagan's suggestion was remarkably simple. Covering 6% of the cap with 1mm of energy-absorbing material like carbon black would create a net reduction of the albedo enough to trigger a gradual warming of Mars. Although he admitted there was no easy way to transport such vast amounts of materials (8 to 10 metric tons) such vast distances so his plan was only "slightly less difficult than the celestial mechanical proposals of Burns and Harwit."[39]

To salvage it, he reasserted the potential of biology to effect change and suggested making the albedo-lowering substance out of micro-organisms that could process the atmosphere through photosynthesis. This would simultaneously provide a dense covering of low albedo, significantly increase oxygen on the planet, and lower the overall freightage of needed materials. Though no such creature existed, he echoed Poul Anderson in suggesting it could be genetically engineered to survive conditions on Mars. Such organisms would henceforth play a fundamental role in terraforming. He concluded optimistically that after a:

> "thorough and ecologically responsible program of unmanned planetary exploration has been completed… human technology may well have reached the point where it will be possible, in a short period of time to reengineer Mars into a

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[38] Ibid, 513-514.
[39] Ibid, 515.

> world with much higher pressures and temperatures, and much larger abundances of surface liquid water than are now present on the planet."[40]

But what is the purpose for such projects? In contrast to much hard science fiction and Burns and Harwit's work, Sagan argued terraforming is not a solution to overpopulation; too many people were being born and there was no means to transport hundreds of thousands of people to a different planet. Furthermore, terraforming would not allow development of a thriving mining industry because the costs of returning the materials to Earth would be prohibitive. Yet, even in rejecting these justifications, he couched terraforming within the same technological foundation narratives that hard science fiction authors advanced: terraforming is necessary to provide humanity with much needed places to conquer. "The human spirit is expansive; the urge to colonize new environments lies deep within many of us," he wrote, and terraforming was the best way to carry out this expansion because artificial settlements like domes or space colonies would be far too constrained and difficult to maintain. But as opposed to the "arrogance" that characterized the European colonization of the New World, or of white colonists' occupation of Native American territories, Sagan had a fundamental faith that the colonization of other planets could be done without imperialism by insisting that human expansion be balanced with the environmental ideals of ecological respect and careful stewardship. Thus, he insisted that a planet with an indigenous population should not be terraformed, unless terraforming helped the population thrive. In this way, such colonization can be in line with the "highest aspirations and goals of mankind."[41] Within a few centuries, terraforming would allow humankind to leave its "cradle" and colonize

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[40] Ibid, 514.
[41] Sagan, *The Cosmic Connection* 151.

the entire inner solar system, including the major planets and their satellites. Sagan's idea continued to be influential and inspired further development of terraforming schemes within hard science fiction as found in the works of Gregory Benford. An analysis of his approach to hard science fiction and his work further demonstrate the interconnections between the genre and science.

The Hard Science Fiction of Gregory Benford

As a youth, Benford was an avid consumer of science fiction books and magazines, having been drawn to the field by Robert Heinlein's book *Rocketship Galileo*. As a teenager he would later edit and write stories for his own fanzine. In his junior year of high school he became interested in science after reading *Atoms and the Family* – Laura Fermi's account of life with her husband the physicist Enrico Fermi. Up until that point his knowledge of science had derived almost completely from science fiction. Inspired, he enrolled in calculus and physics classes at the University of Oklahoma and found that they "resonated completely" with him and were "almost effortless."[42] He continued to write science fiction, which he failed to publish and found that science and science fiction had parallel processes of discovery. He saw no contradiction between pursuing both and recalled that "it took a while before I realized that most people thought that a 'science fictional' concept meant it was some how unreal, even absurd."[43] Yet he continued to pursue science fiction because it provided a means of creative expression within the sciences: a "creative well spring that was outside the box."[44]

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[42] Interview with Benford by the author, September 23, 2009.
[43]Gregory Benford, "The Science Fiction Century: A Brief Overview," *The Magazine of Fantasy and Science Fiction* September 1999, 126.
[44] Interview (ref. 41), September 23, 2009.

Benford graduated in three years with a B. S. Physics and completed a PhD in Physics at the University of San Diego in 1967. During his graduate work he placed second in a magazine writing contest. The story began his career as a published writer. He completed a two-year postdoctoral position at Lawrence Radiation Laboratory, where he stayed on as a laboratory assistant. He continued writing as a way to earn extra money for his growing family and his confidence as a writer grew as his stories were nominated for science fiction awards. In 1971 he took a faculty position at the University of California—Irvine where he specialized in plasma and astrophysics and directed the High Energy Density Laboratory for the next thirty years while publishing twenty science fiction novels.[45]

Heinlein and Clarke's influence, and his interest, education, and occupation in physics compelled him to write hard science fiction: "I prefer to stick to the lived experience. What I know. I know how scientists think and work. So many of my best novels are about … confronting all the problems of being a scientist and the mechanisms of science."[46] He felt that stories that adhere to physical facts and the application of well-worked-out details could frame fantastic events and ideas in a convincing manner, revealing surprising, but logical, consequences, and instilling wonder by convincing the reader of the truth of the scenario. This scientific constraint is central to making any larger philosophical investigation: "How seriously will a reader take an author's ruminations or explorations on metaphysics when he's clearly shown that he doesn't feel

[45] Interview (ref. 41), September 23, 2009.
[46] Interview (ref. 41), September 23, 2009.

bound by what we've already learned about the world?"[47] Although fictional imperatives often complicated the adherence to absolute scientific veracity, authors should avoid making errors that are visible under careful scrutiny. For instance, he recalled being "mortified" when Heinlein caught an error he made about the freezing point of methane in *Jupiter Project*. Like Anderson, he allowed for some gobbledygook like time travel and faster than light speed, placing them "marginally within the hard SF boundary" since science may yet find some way to accomplish them.[48]

Unlike previous authors, he emphasizes that hard science fiction should also be scrupulous about how scientific thinking is done. The genre provides a "golden opportunity" to communicate what science as a lived experience is like, something conventional literature mostly ignores.[49] While authors like John Updike have captured elements of American culture, few authors have written about scientific culture, and "certainly nobody writes about [scientists'] dreams."[50] Through hard science fiction, authors can capture the importance and grandeur of the modern technological culture in ways that other genres cannot. As a result, hard science fiction "speaks for science more than any other fiction (and often more tellingly than nonfiction)."[51]

Benford also insists that hard science fiction allows for the exploration of the workings of science and its inherent drama, mystery, and awe. Much literature about

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[47] Gregory Benford, "Journey to the Genre's Core: A Reply to Damon Knight," *Science Fiction Review* August 1984, 32.
[48] Gregory Benford, "Is There a Technological Fix for the Human Condition?," *Hard Science Fiction*, eds. George Slusser and Eric Rabkin (Carbondale: Southern Illinois University Press, 1986), 83-84; Gregory Benford, "Imagining the Real," *The Magazine of Fantasy and Science Fiction* January 1993, 50.
[49] Benford, "Imagining the Real," 56.
[50] Interview (ref. 41), September 23, 2009.
[51] Benford, "The Science Fiction Century," 127.

science provides after-the-fact explanations of how ideas came to be, like a mystery novel that begins by explaining how the crime was committed. But Benford believes that science is best understood as the pursuit of the unknown. Well-crafted hard science fiction conveys "the official experience of discovering things… the thrill of it… the whole game is not revealed except by talking about things that could be true but aren't necessarily true because there is an open question involved."[52] Thus, rather than up-to-the-minute expertise of science, authors are better served by maintaining a fundamental understanding of science and its worldview, focusing on science as a process, not a collection of facts.[53] This portrayal is important, Benford argues, because hard science fiction readers are not simply technophiles interested in the nut and bolt descriptions of technology. They are people, most often scientists and engineers, which appreciate the inherent strangeness of the universe and understand that science is a process, not an authoritarian voice. They understand that, because hard science fiction plays "with the net up," it can provide intriguing new ways of looking at our accepted interpretations of nature.[54] They view the genre as a way to comprehend the vast new perspectives and information that science garners and communicate the joy and awe of scientific discovery. As both a writer and a fan of hard science fiction, Benford argues, "Most

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[52] Interview (ref. 41), September 23, 2009.

[53] Gregory Benford, "The Awe and the Aweful," *Analog Yearbook*, ed. Ben Bova (New York Ace, 1978), 15.

[54] Benford, "Technological Fix," 97. Benford repeatedly estimates that half the scientists he knows are fans of hard science fiction fans. While working at Livermore, he repeatedly heard "physicists quote sf works as arguments for or against the utility of hypothetical inventions, especially weapons." Benford, "The Science Fiction Century," 134.

readers hope that somewhere in the course of reading a good novel or short story, they will be surprised, intrigued, and-- if it is quite good-- awed."[55]

He also believes hard science fiction provides a valuable venue for scientific speculation because, "There is a Puritan impulse in science to eschew speculation. But you don't get new ideas without speculation… There needs to be more of a sense of play in science, I have always thought, because it is play."[56] His own scientific career has demonstrated that imaginative speculation is necessary and, ultimately, leads to further development of new ideas. This speculation can also both frame visions of the future and provide ways to deal with the challenges science creates to our human-centered worldview.[57] In his personal research he saw a direct overlap between "the science I practice, and the fiction I deploy in order to think about the larger implications of the discipline."[58]

With these parameters in place, Benford ultimately sees very little difference between speculative science and well-made hard science fiction. A line can be drawn, "but there is frequently illegal immigration in both directions."[59] Like scientists, authors build their ideas on accumulated facts and develop theories that can be derived from them. While these authors romanticize and dramatize science, they share the essential core of science: the desire to know and to explore the unknown. As with professional journals and conferences, hard science fiction forms an ongoing discussion where authors strive to create plausible scenarios that they can defend with "hard" science and

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[55] Benford, "The Awe and the Aweful," 20
[56] Interview (ref. 41), September 23, 2009.
[57] Benford, "Imagining the Real," 48; Benford, "The Awe and the Aweful," 20.
[58] Benford, "The Science Fiction Century," 134.
[59] Interview (ref. 42), September 23, 2009.

calculations. Through their books and magazines, the authors and audience form a community where they analyze and debate aspects of science and technology, forming "a kind of 'virtual club,' which inspires real feelings of companionship and loyalty."[60]

Jupiter Project

Benford applied these ideas and practices in his terraforming novel *Jupiter Project*. The first time he came across the idea of terraforming was in Heinlein's *Farmer in the Sky*, the first novel he ever bought in hard cover. The novel had a deep impact on him, and he wrote *Jupiter Project* as a way to try to imagine how the process started. In doing research on the topic he "read up about Ganymede and worked out all the usual stuff" about the planet's makeup, rotation, and climate, relying heavily on Steven Dole's *Habitable Planets for Man*, which he first read it in graduate school. Carl Sagan, whom he had met while in graduate school, also influenced him. He had read *Intelligent Life in the Universe* and "paid a lot of attention to what he said."[61]

The story follows the life of a teenage boy named Matt Bohles living in a scientific space station in orbit around Jupiter. The workers on the station monitor the space around Jupiter while maintaining the machinery that is slowly terraforming Jupiter's moon, Ganymede.

Like previous stories, Benford's account depicted Earth as verging on disaster due to depleted natural resources, overpopulation, and pollution creating "a dog-eat-dog

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[60] Benford, "Technological Fix," 92; quote from Benford, "Imagining the Real," 57.
[61] Interview (ref. 41), September 23, 2009. In an homage, he named one of the space ships *The Sagan*, and would later model one of the main character in his novel *Timescape* after him.

world … a zoo with all the animals out of their cages."[62] He explored these issues in a number of his works and still feels they pose a considerable threat to humanity. As the population continues to grow, "I think we are going to see a hell of a lot of disasters," and human "diebacks," something he expanded upon in his award-winning novel *Timescape*. Benford maintains a positive attitude toward technology and technological development as a means to alleviate these potential problems. Technology is "the best idea" humanity ever had. The problems are more the cause of inherent human flaws rather than technology itself. Modern pollution problems exist because, "Restraint is not what we are good at." Foresight is not a strong point for either. Drawing on Hardin's ideas, he argues the modern technological culture views the atmosphere as commons, and while "everybody suffers globally for your excretions, the payback is so far down stream that you simply can't get people to pay attention to it."[63] Though Benford acknowledges terraforming is "hubris with a capital H," he maintains a belief that terraforming other planets or the Earth may provide a solution to these issues.

In *Jupiter Project*, Benford presents a new plan for terraforming Ganymede that blends industrial processes with Sagan's biological approach. He recalls that he worked on this plan for some years, describing it as an "interesting experiment." Fusion seemed the easiest answer because it provided an efficient way to transform the icy planet.[64] The protagonist, Matt, describes Ganymede as a "big snowball" with "an ice crust about seventy kilometers thick… Below that crust Ganymede is slush, a milkshake of water and ammonia and pebbles." Giant computer-controlled fusion plants slowly wander across

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[62] Benford, *Jupiter Project* , 19.
[63] Interview (ref. 41), September 23, 2009.
[64] Interview (ref. 41), September 23, 2009.

the planet, taking in ice, spraying out a mixture of ammonia-water, heating surrounding areas, and thickening the atmosphere to create a green house effect. Echoing Sagan and Anderson, scientists also plant micro-organisms, “tailored in the Lab to live under Ganymede conditions [that] start producing oxygen, using sunlight and ice and a wisp of the atmosphere.”[65] In a half-century the process would create a thick atmosphere free of toxic gases. In another twenty years the second creation would be realized and a carefully balanced “ecosphere” created with “Earth-style air and crops and people on Ganymede.”[66]

As with previous works, the terraforming not only provides the promise of a new Earth, but a sense of meaningful work. Many people on Earth are given government jobs to reduce unemployment that makes “you feel pretty useless.” Others maintain manufacturing jobs that are largely automated meaning people only push buttons. Their lives seem meaningless because “People like to see their work doing something, they want to see a final product.”[67] As a result, the people of Earth turn to eccentric fashions in order to give themselves worth. But the work on the laboratory and on Ganymede creates “a different culture” that values hard work and sacrifice. This frontier work provides meaning and the scientists fight to keep their jobs as much as for their own spiritual benefit as for the pure pursuit of science.

<u>Conclusion</u>

Attitudes toward technology were clearly divided in the 1970s. Criticism continued to grow over pollution and population concerns but, ironically, the criticisms of

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[65] Benford, *Jupiter Project* 72.
[66] Ibid, 68-69.
[67] Ibid, 49.

the technological culture were incorporated into plans to spread the technological culture through terraforming. For instance, the concern for overpopulation and the institutionalization of ZPG advocated in *The Limits to Growth* rallied many terraformers such as Burns and Harwit and later Jerry Pournelle, as discussed in the next chapter. Barry Commoner's ideas of the ecosphere and laws governing impacts on natural resources provided concepts, models, and justifications for terraformers seeking to create new Earths. Finally, the growing understanding of feedback cycles and their impact on the atmosphere became crucial tools for terraforming plans.

Yet the growing environmental movement caused a split within the terraforming community. The approaches Sagan advocated mark the first challenge to the technological plans and ideals that have guided terraforming up to this point, what I will refer to as the "technological terraforming narrative." Sagan insisted on using simple schemes based in biology, as opposed to complex technological ones. He redoubled his insistence that indigenous species should prevent terraforming. Sagan also tried to weed out the gobbledygook and affirm the plausibility of the idea, striving to advance the most pragmatic and simple approaches. He also challenged traditional justifications, arguing terraforming did not promise a way to solve overpopulation or resource depletion, as hard science fiction authors had argued since its inception. Yet, vestiges of the technological narrative remained. He agreed with the preponderance of hard science fiction that humanity was spiritually driven to conquer and colonize frontiers, and terraforming would be essential to fulfilling that need. But he insisted it must be done with environmental ideals and stewardship of natural spaces as a primary goal. The following chapters will illustrate how these ideas continue to diverge, ultimately forming two separate terraforming narratives: the ecological and the technological.

But others maintained a focus on technological schemes as the key to humanity's salvation. Just as O'Neill relied on technology to create a new human frontier in space, Burns and Harwit relied on technology to create a new frontier on Mars. In contrast to Sagan's ethic, Burns and Harwit continued to promote the terraforming as a technological fix, a portrayal common to the previous hard science fiction. Like hard science fiction authors, they promoted gobbledygook to carry out a complex technological scheme. They expressed little concern for indigenous life, asserting that human needs for resources and space were preeminent. The proliferation of this technological terraforming narrative will continue to be promoted in the work of Jerry Pournelle illustrated in the next chapter.

In this same period, Benford's work continued to transcend boundaries between science and fiction. By his own recounting, his terraforming plan was carefully drafted after a considerable amount of research. Like much scientific work, it was a theory developed out of the work of previous researchers, in this case Robert Heinlein and Carl Sagan. He discusses the novel itself as though it is a scientific experiment. The results of his experiment then take the form of the published work, which is then critiqued (and corrected) by a cohort of other specialists such as Robert Heinlein. This overlapping of boundaries will continue throughout the 1970s and reach its apex in the work of James Lovelock, discussed at length in Chapter 5. Hard science fiction continued to allow a place for the development of terraforming; a space that elides clear distinctions between science and non-science.

Chapter 4- 1975-1980; Professionalization and Proliferation

"There are millions of Earths out there, and if we use up this one, we'll just have to go find another, that's all."[1]

The previous chapter demonstrated that in the first half of the 1970s environmental concerns became increasingly prevalent in American culture, challenging the values and ideals of the technological culture and the narratives that supported it. Responding to these events, Carl Sagan advanced biological schemes over technological plans and insisted terraforming adhere to a form of environmental stewardship.

During the late 1970s, ideas about terraforming continued to develop into roughly two narratives. What I will call the "technological terraforming narrative" promoted the vision of terraforming laid out in hard science fiction as a natural and inevitable extension of the technological foundation narrative. These plans continued to cast terraforming in the mold established by the earliest literature: it was a technological process that could be done quickly and efficiently to harness the "wasted" or conquer the natural to create a second creation identical to Earth designed to meet the needs or whims of humanity.

But in the later 1970s a new group of researchers began to challenge this narrative. Responding to burgeoning environmental values and continued suspicion of technology and the technological culture, they tended to prefer to use biology to establish ecological systems to that would allow for terraforming. While some still viewed this as a way to create a second Earth, others like Christopher McKay and Penelope Boston

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[1] Jerry Pournelle, "That Buck Rogers Stuff," *Galaxy* December 1976, 47.

sought to use terraforming in ways that respected natural environments and proliferated life as a whole, not just humanity. Their efforts will embody what I refer to as the "ecological terraforming narrative."[2]

Both narratives continued to grow in the overlap between science and hard science fiction. This is especially clear in Jerry Pournelle's hard science fiction and popular science writings as well as James Oberg's popularizations.

The Proliferation of the Technological Terraforming Narrative

Throughout the late 1970s, the technological narrative was developed in an array of sources. Jerry Pournelle resisted the values of the environmental movement by developing and promoting terraforming schemes in popular science articles and hard science fiction. David Bergamini also used terraforming hard science fiction to promote the values of the technological culture. Their plans had similar analogues in the scientific work of Richard Vondrak. James Oberg became a primary proponent for terraforming, publishing numerous popular science articles that framed terraforming as a relatively easy and quick technological fix that would turn planets into beautifully rendered second creations.

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[2] Martyn Fogg's comprehensive textbook on terraforming, *Terraforming: Engineering Planetary Environments* (Warrendale: Society of Automotive Engineers, 1995) also divides terraforming schemes into somewhat similar groups, which he refers to as technocentric and ecocentric. However, while Fogg advocates the difference in these approaches, I argue that the two approaches ultimately vary little from one another. Further, while Fogg uses "eco" in the sense that it is the opposite of "techno," I use the term ecological to identify that these authors see ecological systems, not just biological organisms, as the primary means for terraforming. The next chapter will establish that Fogg and his work generally embrace the technological terraforming narrative.

Jerry Pournelle

Pournelle was born and raised in Louisiana in 1936. He attained an eclectic variety of degrees from the University of Washington, including Bachelor's degrees in history and engineering, a Master's in experimental statistics, and doctoral degrees in psychology and political science. During the 1950s, Pournelle worked as a research scientist, and headed the experimental stress program at Bowing's Human Factor Laboratories. After a stint as a history instructor at Pepperdine University in the late 1960s, Pournelle began to support himself as a writer starting with his non-fiction book *The Strategy of Technology: Winning the Decisive War* in 1970, a treatise on cold war technology that argued technological progress was an unstoppable and impersonal force. Pournelle concluded that success in the cold war required unlimited funding for technological development, particularly development focused on innovative defensive technologies that would assure (at least partial) survival from nuclear war. Pournelle would go on to become an active and vocal advocate for the Star Wars Defense Initiative (SDI) in the 1980s. Pournelle also began publishing science fiction with his 1972 novel, *A Spaceship for the King*, and became an active science writer for science fiction magazines like *Galaxy*.[3]

[3] Jeffrey Elliot, *Science Fiction Voices III: Interviews with Science Fiction Writers* (San Bernadino: Borgo Press, 1980), 51-55; Charles Platt, *Dream Makers Volume II: The Uncommon Men and Women Who Write Science Fiction* (New York, NY: Berkley Publishing, 1983), 93-95; On Pournelle and SDI see Samuel Spence, "Strategic Fictions and 'Star Wars': Science Fiction's Formative Influence on SDI," Midwest Junto for the History of Science (University of Minnesota: 2008).

In essays and articles published in science fiction magazines, Pournelle fought the rising distrust of technology, presenting an undiminished optimism in technology's capability to solve crises and improve the quality of life worldwide. He blamed *Limits to Growth* and Paul Ehrlich's *Population Bomb* for presenting inaccurate and overly pessimistic arguments against the technological culture and encouraging the intelligentsia and young generation to abandon hope in technology. Pournelle argued that zero population growth would bring unemployment, stunt technological development, and lower standards of living. He dismissed the Club of Rome as "naïve"; insisting the West would never share its resources with developing countries. Even with zero population growth, Earth's non-renewable resources would be exhausted within 400 years.[4]

To Pournelle, the movement for "soft" and "appropriate" technologies was even worse. These "doomsayers" might be right; technology might have damaged the Earth. But rather than abandon faith in progress or technology, science and technology must be tapped, not hampered. It is not evil to have things like disposable flashlights, heated swimming pools, and large, fast automobiles. Humanity might have to give up on some of these, but adopting the "anti-technology" movement was akin to setting (American) society back a century. By defending against the possibility of collapse by emphasizing simpler technologies, the appropriate technologists will *cause* the collapse by cutting research and development and creating "a world slowly settling into satisfaction with less," no longer capable of advancements in things like space exploration.[5] Pournelle

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[4] Jerry Pournelle, "Survival with Style," *Galaxy* March 1976, 76-77; Jerry Pournelle, "How Long to Doomsday," *Galaxy* June 1974, 110-111; Jerry Pournelle, "Blueprint for Survival," *Galaxy* 1976, 60.
[5] Jerry Pournelle, *A Step Farther Out* (New York: Ace Books, 1979), 378.

refused to accept this: "I want Western civilization… not only to survive, but to survive with style" by maintaining or increasing its current quality of life. Doing so will provide that "everyone on Earth shall have hope of access to most of the benefits of technology and industry." Technology could solve the issues that the pessimists insisted were impending crises.[6]

Developing new sources of energy could solve all famine, pollution and overpopulation. Pournelle asserted nations made enough food to support themselves, but the food often spoiled or was damaged before it could be used. Spreading Western industrial technology and chemicals to developing nations would allow them to even out their food supply, distribution, and production. All that was needed was the energy to drive the production. Given enough energy, any pollution problem can be solved by technology as well. Climate change is a non-issue because humanity will exhaust its fossil fuels before significant damage is done. If a change did occur, technology could solve it, "provided we don't loose faith in ourselves."[7] Overpopulation fears were based on faulty logic and "mindlessly" manipulating exponential curves and formulas. Furthermore, Pournelle refused to believe humanity would continue reproducing to the point of exhausting all resources.[8] The only reliable counter to population increase was wealth and the key to wealth was energy. Where would the energy come from to solve these issues? Any numbers of revolutionary systems are available, provided the investments were forth coming. Fusion energy, ocean thermal systems, and O'Neill's solar powered satellites could all do the task.

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[6] Pournelle, "Survival with Style," 77.
[7] Pournelle, *A Step Farther Out* 12-14, 55 (quote).
[8] Pournelle, "Survival with Style," 78.

Resource depletion was the result of narrow vision and scope: "If we like, we live in a system of nine planets, 36 moons, a million asteroids, a billion comets and a very large thermonuclear reactor/radiation source," all of which can be harnessed for human use.[9] Asteroid mining could produce a wealth of resources to give Earth "real" freedom. Pournelle calculated that a spherical asteroid four miles in diameter would provide enough metal for every person on Earth to live by American standards. Asteroid mining would also remove the industrial process to outer space, eliminating one of humanity's most polluting activities from the Earth. The energy to move the asteroid into Earth's orbit could be generated with hydrogen bombs or fusion energy.[10] Pournelle insisted this could be accomplished with current technologies and such steps would solve the problems of pollution, dwindling resources, the promotion of industry in third world nations and the food production crisis.[11]

Another option was to get off of Earth entirely. O'Neill's Space stations could reduce Earth's population and provide electricity by harnessing solar energy, converting it to electricity, and beaming it down to Earth via microwaves. This crucial source of energy would forestall strip mining of billions of tons of coal. It would be very expensive, but not as expensive as the long-term effects of zero population growth. And the costs were affordable with manageable sacrifices: for less than Americans spent on alcohol or cosmetics, they "could break out of Earth's prison and send men to space."[12] After humanity had spread out across the solar system, we could dismantle some of the

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[9] Pournelle, *A Step Farther Out* 32.
[10] Pournelle, "That Buck Rogers Stuff," 47.
[11] Pournelle, "Survival with Style," 84.
[12] Pournelle, "Blueprint for Survival," 66.

more "useless" planets and use the mass to form great flying cities in space fed by solar energy from the sun. Then humanity could move out to nearby systems, looking for a place to live with "elbow room." This movement to space was consistent with human history. America was not settled by a large government program, but rather by brave individuals looking for opportunity and freedom. The same would hold of space as soon as there was an affordable and safe form of transport off the planet. The asteroid belts in particular will be like "the wild west," complete with boomtowns and traveling entertainment caravans.[13]

The idea of terraforming fit directly into Pournelle's technological visions and environmental agenda. In 1975, he celebrated terraforming and Sagan's plans for Venus in *Galaxy Science Fiction Magazine*, framing it within the familiar technological foundation narrative:

> Mankind needs frontiers. We need new worlds to conquer, impossible odds to overcome, a place of escape from bureaucracy and government; a place where life is hard but the problems are simple, requiring no more than courage, determination, and hard work to win great rewards… For the warriors and dreamers among us a frontier is so vital that if there isn't a physical one, we'll create an internal problem to fight.[14]

The only frontiers left were the planets, and terraforming was the key to making them habitable and exploitable modern versions of the "New World," to absorb the adventurous and discontented populations that would otherwise stagnate on Earth.

Pournelle calculated Sagan's plan would take about one hundred rockets at a total cost of ten billion dollars. Even a hundred billion dollars would be less than the cost of a war and a reasonable price for a whole new world. Nor would there be any natural costs.

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[13] Pournelle, "That Buck Rogers Stuff," 53, 49, 50.
[14] Jerry Pournelle, "The Big Rain," *Galaxy Science Fiction* September 1975, 65.

Venus -- “a more useless planet is hard to imagine--” is a “lump” of desert where the surface temperature are high enough to melt lead, the atmosphere is too thick, the winds scour the desolate surface with sand.[15] If it cannot be terraformed it is only suitable as a nuclear waste dump.

Pournelle insisted terraforming can be implemented easily, and within twenty years of its initiation, Venus would be habitable. He blended Sagan’s and Anderson’s ideas, explaining that microbes would cause rain to convert craters into lakes, depressions into shallow seas, and carve channels for water. Snow would form on the mountains and the desert would turn to mud, ready for biological organisms tailored to the long winters and harsh climate. Many would see terraforming as “monstrous” and “obscene.” But, Pournelle wrote, those attitudes were based on the notion that something like “nature” exists. Those who realized that terraforming represented “the most glorious opportunity that has yet faced man” will out maneuver them.[16] Pournelle optimistically insisted that all of these schemes were “not crazy dreams… Its only basic engineering, and some economics, and a bit of hope.”[17] They could all be accomplished in less than one hundred years, if the will was found on Earth to commit to the plans. But this future required humanity to expect more from technology and themselves, not less, as ZPG and appropriate technologies would require.

Pournelle’s ideas found purchase within the science fiction community. A collection of his essays was published as *A Step Farther Out*, which received enthusiastic reviews. One saw it as an invaluable “source of ideas for SF stories…as background for

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[15] Ibid, 68.
[16] Ibid, 70.
[17] Pournelle, "That Buck Rogers Stuff," 52.

stories whose ideas you want to know more about, and as a convincer for anyone you know who doesn't believe in the value of space." His "imperialist spirit of Manifest Destiny" is a necessary counter to NASA's pragmatic, unimaginative thinking and readers should mobilize to buy copies for their governmental representatives, family, and friends. [18] Another review went further, insisting it was "your patriotic duty (patriotism to your species)" to buy and read Pournelle's book. It celebrated that Pournelle "demolishes *all* the idiots" and "antitechnology Luddites" that opposed technological developments or advocated ZPG. The world is filled with people that seek to dismantle the modern society and bring about the downfall of civilization because they are confused, afraid, and misinformed, "If you don't want yourself and your loved ones to die untimely, see that this book is read by as many citizens as possible."[19]

Pournelle also harnessed the hard science fiction format to promulgate his ideas. He insisted hard science fiction authors follow scientific standards and rules in creating their fiction, relying on "formula and tables for getting the orbits right, selecting suns of proper brightness, determining temperatures and climates, building a plausible ecology." But this restriction could cause problems for hard science fiction seeking to imagine human expansion into the universe. For instance, one must come to terms with how to move people around the galaxy. Denying light speed travel makes it difficult to write stories about interstellar civilizations. A writer could choose to ignore general and special relativity, which readers will not generally accept because "It's a cop-out." Or a

[18] Tom Easton, "The Reference Library," *Analog Science Fiction/Science Fact* April 1980, 172.
[19] Spider Robinson, "The Reference Library," *Analog Science Fiction/Science Fact* March 2 1981, 169, 170 (quote).

writer could invoke “double talk about hyperspace,” but such contrivances remove the limits from the genre that create its feeling of authenticity. Good hard science fiction results from authors encountering problems and finding ways to solve them, not work around them.[20]

Like previous authors, Pournelle seemed indifferent to any distinction between science and hard science fiction. At times he equated scientists’ work to his, both being “far out speculation about the future.” At other times, he held hard science fiction as superior to the unimaginative and conservative ideas of professional science. For instance, he reported on a panel at the 1978 American Association for the Advancement of Science meeting for *Galaxy* magazine. The panel included papers from Dyson, Sagan, Dr. Gale (of *The Limits to Growth*), and astronaut Brian O’Leary. He described the attendants as “amateurs at my business… scientists playing science fiction writer with no more spectacular success than most SF writers.” Sagan presented various reasons for the lack of evidence for alien life, including the possibility that aliens might not wish to interfere with human existence, an idea Pournelle pointed out was common to science fiction and only notable in that it “could be presented to a bunch of scientists without getting a laugh.” Pournelle griped the panelists’ ideas were “old hat” compared to what had been going on in science fiction for decades and complained about scientists

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[20] Jerry Pournelle, "Building *the Mote in God's Eye*," *Galaxy* January 1976, quotes 101 and 102. In his stories, Pournelle relied on form of gobbledygook called an Alderson drive based on collaborative work with Dan Alderson at JPL. Alderson’s theory was that certain points in the space might provide places to jump between vast distances. It is consistent with known laws of physics, though it postulates that additional discoveries will be made in the future.

congratulating themselves over having allowed "some elementary speculations of the kind that have gone on in SF convention panels for decades."[21]

Birth of Fire

Pournelle brought together his views about technological expansion and terraforming in a hard science fiction novel *Birth of Fire*. Facing jail on Earth, the protagonist, Garret, takes the option to be permanently exiled to a colony on Mars run by the Earth Federation. Like previous terraforming stories, Mars is a frontier where "You can start over. You can be anything you want to be. Anything you're good enough to be and will work hard enough for." It is a masculine world inhabited by ex-convicts, "failures," "broken men," and a few who are self-reliant enough to become "Marsmen," "good men, tough and proud." There is no help for those that cannot help themselves. Women are either relegated to the outskirts where they take jobs at brothels or live on the farms where they become tough as men and take on the same duties.[22]

As in previous stories, terraforming offers a chance for autonomy. The Federation's regulations and taxes keep farmers in subordinate positions living in man-made domes. The farmers are developing "The Project" as a way to terraform Mars and free themselves from the domes. Echoing numerous plans from Poul Anderson, the farmers plan to use atomic bombs to re-ignite Mars' volcanoes because "There's a lot more air and water inside the planet if we can get them out. Then it'll come alive." The explosion will release a vast amount of gases and water vapor. This will create an atmosphere close to Earth's, warming the planet and allowing life outside the domes.

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[21] Jerry Pournelle, "The Tools of Trade," *Galaxy* June 1978, 65, 68-69 (quote).
[22] Jerry Pournelle, *Birth of Fire* (New York: Baen Publishing Enterprises 1987 edition, 1976), 33, 30.

However, the Federation blocks The Project, claiming it would damage the Martian ecology, insisting a habitable atmosphere on Mars equates to pollution of the natural environment. A handful of scientists help with the plan. One glorifies it as "Magnificent. Making over a whole world. We can all be proud to have been a part of it." In addition to aiding the design of the bomb, the scientists offer help with a plan to melt the polar caps to speed the project along.[23]

The novel climaxes with a life-and-death shoot out between Garret and Federation troops in which Garret is forced to set off the bomb while he is still on the volcano. Pournelle dramatically impresses upon the reader the sublime magnificence of the first terraforming event as Garret relates,

> Streaks of fire shot upward and the entire mountain shook. The white vapor climbed higher and higher into the sky, then condensed. Snowflakes and hail began to fall around us, mixed with red-hot rock that flew out of the rim in a much lower arc… A new world born in fire and ice.[24]

This signals both the start of the terraforming project, but also the revolution that destroys the Federation forces and frees the colonists.

As is the case with hard science fiction terraforming narratives discussed in previous chapters, *Birth of Fire* failed to envision terraforming in any other terms than those of the classic technological foundation narrative. At a time of increasing environmentalism, Pournelle used his novel to perpetuate the values and ideals of the technological culture. His transparent and simplistic vision of the future earned his book poor reviews. One reviewer felt that Pournelle's book was a forced meditation on freedom and his focus was simply to "get some shots off at the justice system, affirmative

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[23] Ibid, 207, 206.
[24] Ibid, 226.

action and certain university types who think that preserving the ecology intact is more important than making life bearable for people."[25] Another reviewer discerned that the setting is "simply projected conservative fears a few years into the future—too much government stifling individual free enterprise, etc… an ideological demonstration."[26] These themes and visions also occur in another piece of terraforming hard science fiction written by David Beramini.

Venus Development

David Bergamini was a contributing editor to *Life* magazine, the author of popular science books and a book on the Japanese Imperial household. His novel, *Venus Development*, is a convoluted tale following interchangeable, infallible "scientists" who get caught up in a fantastic scheme to terraform Venus that one reviewer explained, "I do not believe for a moment, but which I admire for its pure audacity."[27]

While working for the American government, the scientists discover a secret plan to terraform and colonize Venus, originally designed to improve conditions on Earth, but co-opted by a cabal of super-rich elites that want to inhabit the planet Venus themselves. Rivaling the speculations of Burns and Harwit discussed in the previous chapter, the plan involves hitting Venus with one million hydrogen warhead missiles simultaneously. They detonate after piercing the planet's crust and "penetrating to various depths in the liquid magma underneath [and] start a chain reaction with all the hydrogen in the hydrocarbons" in the core of the planet. As a result,

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[25] Lynne Holdom, "Birth of Fire," *Science Fiction Review* August 1976, 22.
[26] Joe Sanders, "Birth of Fire," *Delap's F&SF Review* June 1976, 19.
[27] Robert Chilson, "Venus Development," *Delap's F&SF Review* March 1977, 34.

> "The hydrogen turns to helium but so hot that then there's a helium bomb in Venus. And when it goes of, helium turns to oxygen. Then there's an oxygen bomb… By the time oxygen begins to transmute, Venus'll have a tail of stuff thousands of miles long which she's hurtling off into space. That's what'll start her moving."[28]

Eventually the reaction will end, leaving the planet in a new orbit and with a layer of oxygen in its atmosphere. Radiation will dissipate as the planet moves, and be further cleansed from the atmosphere by rains created by the combination of hydrogen and oxygen released after the explosion. Within a month the planet would be ready for a second batch of rockets that will deliver biological packages to the planet filled with specialized plants that have been bred specifically for the transformed Venus. Another scientist concludes, "Within six months or a year, around the biggest lakes, we should have a going ecology, a broad-spectrum flora and fauna, altogether hospitable to man."[29]

Despite the fact that there is a risk of blowing Venus up entirely or shooting it out of the solar system altogether ("under one percent"), the scientists willingly initiate the plan, not only for the sake of pure science, but also because Earth, with its increasing bureaucracies, government control, corruption, wars, overpopulation, and pollution has become insufferable. The plan is a necessary continuation of the ideas of "Dozens of Enlightenment writers [who] recognized the need and possibility for mankind to extend itself to extraterrestrial frontiers." In addition, the terraformed planet would provide a launching pad for further space exploration, allowing humanity to survive "as long as there's light anywhere in the galaxy." Furthermore, like the *The Sands of Mars*, terraforming offers scientists the opportunity to create a civilization run by the best and

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[28] David Bergamini, *Venus Development* (New York: Popular Library, 1976), 103-104.
[29] Ibid, 107.

brightest who are free from the meddling of any government. This, combined with the fact that the scientists face the threat of being eliminated by the government for knowing too much, inspires them to initiate the plan and launch themselves into orbit around Venus to await the second creation on the planet. [30]

Overall, this narrative epitomized the familiar technological narrative in which technology is used to reinvent the landscape and create a prosperous new community. Yet, the gobbledygook overwhelms the "truth" of the narrative. One review claimed that it was an unsatisfying read for the "experienced sf [sic] reader." The complexity, wordiness, and unrealism (ear plugs alone protect the scientists from the noise of a thousand rockets launching that causes nearby mountains to collapse) make it appropriate only for the general reader. That the plan would require America to use its entire arsenal for the Project was as "incredible" as the idea that "the exploitation of Venus will ease the energy crisis."[31]

Yet, Bergamini's fantastic plans had their counter parts within the scientific literature of the time that promoted similarly "explosive" terraforming programs that placed human expansion over any environmental values. For instance, Stanford lunar scientist Richard Vondrak examined ways to create a breathable atmosphere on the moon. He argued it was possible, but the greatest challenge was to create an atmosphere dense enough that it would not be swept away by plasma streams emanating from the sun (solar winds). If this could be accomplished, there existed a strong possibility for a long lasting atmosphere and humans could then easily colonize the moon.

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[30] Ibid, 90, 78.
[31] Chilson, "Venus Development," 34.

The gases required for a thick lunar atmosphere could be obtained through the vaporization of the lunar soil by "subsurface mining with nuclear explosives."[32] Krafft Ehricke previously established that a one-kiloton nuclear weapon exploded on the moon would form a forty-meter diameter cavern and enough gas to create a long-lived atmosphere. This however, would not provide enough oxygen for a breathable atmosphere. Vondrak estimated to achieve an oxygen rich atmosphere, 2×10^{11} kilotons of TNT must be detonated, equaling the power of 10^4 times the total US stockpile of nuclear weapons. If this massive nuclear arsenal could not be used, then Vondrak suggests that gas would have to be imported by capturing an 80-kilometer wide comet and smashing it into the moon.[33]

Vondrak questioned the benefits of actually creating an atmosphere in this fashion, not because of the risks involved, the moral implications of decimating the Moon, or the questionable usage of such an atmosphere after that much nuclear material was utilized to create it. Instead, he argued the benefits of a lunar colony would be to do experiments in the lunar vacuum, which would be destroyed. Nevertheless, Vondrak concluded, "artificial generation of an atmosphere can be considered as another potential method for modification of planetary environments."[34]

James Oberg

At the same time as these works, James Oberg, a NASA researcher at the Johnson Space Center, began publishing popular articles on terraforming. He continued to frame

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[32] R.R. Vondrak, "Creation of an Artificial Atmosphere on the Moon," *Advances in Engineering Science*, vol. Vol 3 NASA CP-2001 (1976), 1217.
[33] Ibid, 1217.
[34] Ibid, 1218.

terraforming as a natural extension of human abilities and traditions: “We have already demonstrated our ability to change local, even global, environments on Earth.” This prepared humanity to evaporate the clouds of Venus, make it rain on Mars, inhabit the Moon, and dismantle elements of our solar system like asteroids, comets, and planets to create the materials and locals for billions of human descendants.[35] Humans will move to other planets and it can happen in just a “few centuries of deliberate human manipulation.”[36]

Oberg agreed with Pournelle that terraforming was a technological fix that could be performed with relative ease. With enough energy and the right technology humans could harness the universe’s resources to alter feedback cycles that govern the environment of any planet. Hydrogen bombs might seem “abhorrent and destructive” to some, but a well-placed device could propel massive asteroids or comets to terraforming targets across the solar system. Solar-powered mass drivers could send tons of moon rock into space to be processed into useful materials for mirrors or shades to alternately warm or cool planets.[37]

Oberg’s work also elaborated on previous plans for Mars and continued to frame terraforming as a way to quickly create a technological second creation. With technological aides, a few hundred pounds of algae would alter Mars in a few decades, transforming it into a “garden of unearthly Earthliness.” Oceans to remove carbon dioxide and add humidity to the air could be created by smashing Mars with 10-mile-wide hunks of frozen taken from Saturn’s belts. One day in the future, humans may be

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[35] James Oberg, "Terraforming," *Astronomy* May 1978, 7.
[36] James Oberg, "Farming the Planets," *Omni* February 1979, 58.
[37] Ibid, 110.

able to stand unprotected "under the blue Martian sky, and poke a hole into the ground to begin planting a field of pine tree seedlings. With a clean slate, mankind would open a new world."[38] Within two or three hundred years humans could walk on the surface.[39]

Oberg embraced science fiction in these discussions including Pournelle's ideas from *Birth of Fire*, Clarke's plans in *Sands of Mars*, and Asimov's from "The Martian Way." His speculations matched hard science fiction, imagining a world created out of solely water: "Would the surface stay calm from the intense compression heat deep within it? What would be the dynamics of its spin, as the equator completed one revolution faster than the polar regions?"[40] Furthermore, much like hard science fiction, he described his terraforming scenarios as "existence proofs," demonstrating the feasibility of the idea.[41]

<u>The Emergence of the Ecological Narrative and a New Group of Researchers</u>

At the same time, other researchers were developing terraforming schemes that proposed altogether different methods and goals for terraforming. While at times still perpetuating values from the technological culture, these researchers, inspired by 1970s environmental movements, developed more holistic approaches to terraforming influenced by James Lovelock and wary of the use of extensive technological systems. As opposed to the technological approaches, which portrayed terraforming as an easily implemented, technological fix that could be completed in a matter of years, these

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[38] Oberg, "Terraforming," 18, 23 (quote).
[39] Ibid, 28; Oberg, "Farming the Planets," 108.
[40] Oberg, "Terraforming," 8, 25 (quote).
[41] Oberg, "Farming the Planets," 108.

authors tended to underscore the difficulty of the process, the complexity of establishing a permanently inhabitable environment, and put their plans on millennial time scales.

One of the first pieces to embody this new narrative came when Maurice Averner and Robert MacElroy published the first comprehensive scientific study of terraforming Mars that simultaneously evaluated the practicality of the idea, advanced a plan for Mars, and elevated the legitimacy of the idea within the scientific community. They conducted their study under the umbrella of the Planetary Biology Division of Ames Research Center, with financial support from the Stanford-Ames Faculty Fellowship Program and NASA. The authors acknowledged that they were "particularly indebted to Carl Sagan, whose published work has previously examined several of the ideas incorporated in this study."[42] Contributors included members from departments of earth sciences, atmospheric and oceanic science, chemistry, and biological sciences. This diversity illustrated the cross-disciplinary nature of the topic and the growing interest within academic and scientific circles. Averner and MacElroy's formal research report was published in 1976 as *On the Habitability of Mars, An Approach to Planetary Ecosynthesis*. In November of 1976, they gathered with their contributors and other interested scientists and presented further ideas about ecosynthesis at a special session of the 13th Annual Meeting of the Society of Engineering Science. The session was

[42] M.M. Averner and R.D. MacElroy, *On the Habitability of Mars: An Approach to Planetary Ecosynthesis* (Washington, D.C.: NASA, 1976), v.

originally named “Planetary Engineering,” but the title was deemed too speculative and changed to “Planetary Modifications.”[43]

In their works, the authors explained that the prospects for life on the Red Planet were grim. Lack of oxygen in the atmosphere prevented growth of even the simplest single-celled organisms. Ultraviolet radiation passed unfiltered through the Martian atmosphere. Temperatures barely rose above freezing in the warmest latitudes even during the warmest periods. Liquid water was not found anywhere on the planet’s surface, though might be present in the polar caps or underground. The authors conceded, “Even a most optimistic appraisal suggests that the kinds of terrestrial organisms able to survive in the present Martian environment are quite limited, and the growth of even these forms would be quite restricted in vigor and extent.”[44]

Despite these conditions, the authors foresaw that technological values and ideals would inevitably justify the colonization of Mars, and framed terraforming as an essential element in that expansion. If indigenous life was found in this process, Mars should be left alone. But they allowed that “overwhelming reasons” could be “marshaled to justify the disruption of the native population.”[45] If no life was present, the decision to colonize the planet would depend on the usefulness of the planet to human ends, including the “assessment of mineral deposits, industrial possibilities, and perhaps even room for population expansion.”[46] If colonization was desirable, terraforming was a necessary

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[43] James. Oberg, *New Earths; Restructuring Earth and Other Planets* (New York: The New American Library, 1981), 28.
[44] Averner and MacElroy, *Habitability* 35
[45] M. M. Averner and R. D. MacElroy, "Atmospheric Engineering of Mars," *Advances in Engineering Science*, vol. Vol 3, NASA CP-2001 (1976), 1207.
[46] Ibid, 1203.

step, providing the most "efficient" way to "exploit Mars"[47] because it would allow freedom and unencumbered habitation. To do so, humans must find ways to warm the planet and increase the mass of the atmosphere, especially increasing the concentration of oxygen and water.[48]

The authors argued biology provided the most pragmatic and viable way to alter the planet in a long term fashion. James Lovelock's research suggested this is what took place on Earth millions of years ago. In principle, the same elements necessary for terrestrial photosynthesis (light, carbon dioxide, and water) exist on Mars. *Mariner* 9 indicated that certain bacteria could grow on Mars if essential nutrients were provided. Terrestrial microorganisms could be found thriving in Mars-like conditions in the dry Artic valleys of Earth. Could these organisms and photosynthesis alone alter the atmosphere enough to make Mars habitable?[49]

Of the viable terrestrial organisms, the authors found cyanophytes (algae) were most likely to survive and best suited to transform the atmosphere. They were highly tolerant to diverse environments, promoted conditions that were beneficial for the growth of other soil-based organisms, could survive desiccation, and used carbon dioxide either exclusively or almost exclusively. Computer models used to simulate the organism's reaction to Mars found that if one-fourth of Mars was covered by blue-green algae capable of photosynthesis for half of a Martian year, then in 7,000 years "an amount of

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[47] Averner and MacElroy, *Habitability* 11.
[48] Averner and MacElroy, "Atmospheric Engineering of Mars," 1204.
[49] Averner and MacElroy, *Habitability* 5, 36-37.

oxygen would have been produced equivalent to the present amount of carbon dioxide in the Martian atmosphere."[50]

The authors also examined other ways of altering the Martian atmosphere to speed the process along. They agreed with Sagan that the only reasonable way to alter the atmosphere would be to increase solar energy at the cap.[51] If the caps consisted of water, melting them would trigger a greenhouse effect that would warm the planet significantly. If the total pressure increased by 10%, the temperature would increase by 10° K creating a feedback loop resulting in a permanent climate change. "A relatively small" mixture of sand or dust could reduce the cap's albedo enough to cause sublimation and achieve a stable and higher planetary temperature in about one hundred years-verifying Sagan's earlier speculation. The atmosphere could then be made hospitable by microorganisms.[52]

These two elements (the warming of the planet and the growth of organisms) functioning under ideal conditions might provide Mars with a breathable atmosphere after 100 years, but it could take up to several million years. Their most realistic assessment put the timescale in the thousand of years. Though their ideas were fantastic and "will probably not be considered in a serious way for at least a century," they

[50] Ibid, 38, 43-45, 57, 59 (quote).
[51] Citing work by Vondrak and Ehricke on the use of nuclear devices to free oxygen from the crust of the moon, the authors calculated that the same process used on Mars would require ten million megaton bombs but the fallout from such devices would render the planet scientifically useless.
[52] Averner and MacElroy, *Habitability* 65-73.

concluded terraforming was fundamentally possible.[53] However, this assessment changed dramatically when the results form the *Viking* landers were returned.

The *Viking* landers were stocked with miniature laboratories with which to gather information about Mars' atmosphere, geology, and any evidence of life. *Viking* 1 was inserted into orbit around Mars on June 19th, 1976 and the lander touched down on July 20th. The second *Viking* lander touched down successfully on September 3rd, 1976. The *Viking* team put together three different experiments with three slightly different approaches to life detection. When the results were examined, the lack of organic compounds suggested that no life existed on Mars.

A short time after the *Viking* experiments, Averner and MacElroy revised their views about the prospects of terraforming Mars in a report titled "A Post-*Viking* Assessment; The Habitability of Mars." The authors explained the new data showed similarities between Earth and Martian soil and a sufficient amount of underground water, but revealed issues that made their terraforming plan unlikely for a number of reasons. When the landers wetted the samples of Martian soil it gave off great amounts of oxygen. This might have provided terraformers with hope for an oxygen rich atmosphere, but even if soil could be wetted to a depth of a meter it would only add one or two percent more oxygen to the atmosphere. The new data about the strength of the UV rays also raised doubts that even the most successful engineering project could curtail them enough to allow biology to survive.

The direst predictions dealt with the nitrogen cycle. Their vision of transforming the planet with ecology relied on the establishment of a nitrogen cycle between the soil

[53] Averner and MacElroy, "Atmospheric Engineering of Mars," 1208.

and the atmosphere. Mars' lack of this cycle resulted in the equilibrium of nitrogen, sulfur, oxygen, and carbon as Lovelock had predicted. Averner and MacElroy's initial report suggested genetically modified terrestrial plants functioning anaerobically, releasing carbon dioxide and hydrogen without using oxygen, would work in concert with the blue-green algae to create the cycle. But the scant nitrogen the *Vikings* detected in the soil and the atmosphere was inadequate to the establishment of any nitrogen cycle. Even if there were nitrogen below the surface, "it would remain inaccessible to life, even after a major engineering effort." The authors were forced to conclude, "It is not a strong possibility that even a massive engineering project could trigger the conversion of all Mars into a more hospitable environmental state."[54]

Though NASA's stance on the ability to transform this planet was grim, the *Viking* data about the polar caps inspired new thinkers to explore how Mars could be altered. The orbiters established that after seasonal portions of the northern polar cap sublimate during Martian "spring," the residual cap is mostly frozen water. Enough frozen water was trapped in the northern polar cap to cover all of Mars with a centimeter of water.[55] This information gave credence to the idea that water once flowed across the surface of the planet. A handful of University of Colorado students were intrigued by these results. Two of them, Penny Boston and Christopher McKay met at Florida Atlantic University while working on undergraduate degrees in biology and mechanical engineering, respectively. Coincidentally, both attended University of Colorado for their graduate degrees. Fascinated with the results from the *Viking* landers, they tracked down

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[54] Averner and MacElroy unpublished report quoted in Oberg, *New Earths* 181-182.
[55] Sheehan, *The Planet Mars*, 195-196.

and evaluated the ramifications of the *Viking* reports to the prospects of bringing Mars alive. “Motivated by Sagan’s original suggestion some years earlier of terraforming Venus, two other graduate students and I started talking about the possibility of terraforming Mars,” McKay recalled, “I suggested we do a class project on terraforming Mars.”[56] Students from a variety of disciplines joined the Mars Study Group and the group drafted a report about settling and terraforming Mars that they delivered to NASA and conferences on Mars and space exploration. One pivotal conference took place in Houston in 1979, which gave the Mars Study Group a platform to advance further ecological methods and goals for terraforming, which directly challenged the technological foundation narrative.[57]

In 1979 James Oberg arranged a special session on terraforming at the Lunar and Planetary Science Conference in Houston. It was not given official status because terraforming was considered “highly speculative,” despite the work by Sagan and the NASA Ames report.[58] Papers from the Mars Study Group showed continued interest in the idea of terraforming, its plausibility, and passion and innovative thinking about Mars. At the same time, these papers directly challenged framing terraforming within traditional technological foundation narratives. This new group of researchers, headed by Boston and McKay, continued to challenge the dominant technological narrative by further advancing the ecological narrative. They challenged the Earth-centric nature of

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[56] “Meet the Scientist: Dr. Chris Mckay," access date 7-20-2008 2000, http://chapters.marssociety.org/youth/mc/issue5/mts.php3.

[57] R. M. Zubrin, *The Case for Mars* (New York: Free Press, 1996), 70-71; Oliver Morton, *Mapping Mars; Science, Imagination, and the Birth of a World* (New York: Picador, 2002), 244.

[58] Oberg, *New Earths* 29. Though the papers were never published, Oberg summarized and quoted from them at length in *New Earths*.

terraforming, argued for an expansion of life in terraforming plans, reaffirmed the plausibility of terraforming Mars, and rejected previous technological plans while advocating less invasive methods. Together these elements will embody what I will call the ecological terraforming narrative.

One challenge to the dominant narrative came from Penelope Boston. In the introduction to the session, she argued a key flaw in the previous approaches was:

> the tendency to unconsciously take an Earth-centric view of Mars and to conceive of the ultimate fruits of our planetary engineering as merely a carbon-copy Earth. Mars can never be a facsimile of Earth, but in a significant sense it can be made habitable.
>
> For example, the question of oceans on Mars lends itself to this kind of critical analysis. Despite the fact the Earth's surface is three quarters water, oceans are not an essential feature of biotic systems in general. On Earth, the oceans are essential because the ecosystem has evolved under these specific conditions, and a good case can be made for oceans as a necessity for the spontaneous formation of life. But on Mars we have the option of introducing life at the optimal level of adaptive organization to meet prevailing conditions. The absence of large bodies of water will cause the biosystem to be significantly different from that of Earth, and herein lies the trap.[59]

Boston continued to argue for ecological methods of terraforming, broadening the array of natural and engineered life that could be useful for terraformers. Oxygen-producing lichen could easily be genetically modified to produce the optimal amounts of oxygen and to endure the cold conditions of Mars. But mites and red algae were also candidates for genetic engineering that might help improve the Martian environment. Characteristics in terrestrial plants like anhydrobiosis (waterless life) and cryptoprotection (the ability to produce anti-freezing substances) could be engineered into Mars-ready flora. Recent research in Antarctica had indicated that endolithic microbial life (life that exists under thin layers of rock) was also an intriguing option for

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[59] Ibid, 189.

terraforming. She concluded that terraforming research was crucial because it increased knowledge and understanding of our terrestrial world, but also had "potential benefit to any scientific colonies using some of the Mars-adapted organisms in their life support efforts…"[60]

Christopher McKay used data from the Viking missions to refute arguments by MacElroy and Averner. They had predicted it would take energy comparable to three years worth of Martian sunshine to volatilize the frozen carbon dioxide on Mars. McKay corrected that number to 50 years based on more accurate *Vikings* data. While Averner and MacElroy argued that the lack of detection of nitrogen by the *Viking* landers was a death knell for any attempts to grow life there, McKay insisted that such a find should not be surprising. Instead, McKay, influenced by James Lovelock's Gaia hypothesis, claimed that biological activity was what largely created and freed nitrogen from soil, so we should not expect to see nitrogen on an apparently lifeless planet. Nevertheless, data from *Viking* indicated that the nitrogen was there, but located in other places than the landers explored. If nitrogen was lacking it could be imported from the surrounding moons, comets, and asteroids.

McKay also turned his attention to ways to thicken the atmosphere. He dismissed previous plans to use bombs as "preposterous," not only because of the environmental impact, but because it would require ten million atomic bombs just to initiate them. A more feasible, less invasive plan would be to use mirrors that could help speed along the process. That, in combination with a plan like Sagan's to lower the albedo of the caps, could complete the process in less than a thousand years. If these processes resulted in

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[60] Ibid, 188.

the increase of one-bar atmosphere, the atmosphere would then be thick enough so that no further energy inputs beyond normal sunlight would be needed. As a result, it would be stable without any further artificial support.

Dr. Jeffrey Warner of NASA's planetary science office presented one of the earliest pieces on the ethical implications of terraforming that continued to justify terraforming as the next inevitable step in human progress. Warner explained that at first he was opposed to terraforming because he could not see what right humanity had "screw up other planets, especially elegant ones like Mars, Venus, Io and Titan." He eventually came to view terraforming as a nuanced issue, and concluded that it might even be the right thing to do in some cases. The history of humankind's exploration of the terrestrial world indicated that expansion into the solar system is the next logical step. Once that step has been taken, he concluded, it would be a "trigger for the episodic acceleration in evolution to Homo Sapien Prime" and play a part in the "grand future for our progeny."[61]

Conclusion

The late 1970s provided for the proliferation and professionalization of terraforming. At the same time, the schism between the ecological and technological approach persisted as the boundaries continued to blur between hard science fiction and science.

Researchers continued to depart from the technological terraforming narrative. Averner and MacElroy moved terraforming in the ecological direction, relying on microorganisms, not technology, to establish an Earth-like ecology. Yet, their allowance that terraforming may be "economically feasible or socially desirable" continued to frame

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[61] Ibid, 256.

terraforming as a possible solution to the issues of overpopulation or resource depletion. They also left the door to exploitation open, arguing that in the face of indigenous life, the project should not be initiated unless there was "overwhelming need." McKay and Boston rejected framing terraforming within the technological foundation story. Mars should not simply become a replica of Earth designed to further human needs and ends, but rather it should become something capable of bearing life, but inherently still Mars-like. Furthermore, their plans continued to focus on restrained and pragmatic efforts to terraform, rejecting technologically complex schemes or ones involving destructive technologies like nuclear weapons.

Nevertheless, others continued to frame terraforming as an extension of the technological culture. Pournelle, Bergamini, and Oberg all saw terraforming as a way to perpetuate humanity and the values and ideals of the technological culture. Their plans showed no concern for any indigenous life or respect for natural spaces. The solar system was nothing more than materials to be utilized. Pournelle in particular looked disparagingly on the notion of "natural" spaces, and clearly envisioned the cosmos as a place deigned for the expansion of humanity, if humanity simply took the steps to harness it. Oberg echoed such sentiments, delighting in the possibilities of altering or dismantling other planets for human ends. Across the board, all of these authors envisioned technology as the key to all these plans- a force to save humanity and propel it to greater and further ends. With terraforming and technology, there would be no limits to growth.

Furthermore, despite the treatments by Sagan and the NASA Ames report that sought to distance their treatments from hard science fiction, the boundaries between hard science fiction and science continued to overlap. Averner and MacElroy's description of the stages of colonization was strikingly similar to Clarke's *Sands of Mars,* and they continued to pursue the use of biology in ways similar to Anderson. Pournelle's essays and articles offered the same evidence and justifications that his hard science fiction advanced. He drew little distinction between the work of scientists and hard science fiction authors, going so far as to disparage scientists for their inability to visualize the applications and processes that science fiction authors embraced. Oberg freely drew on hard science in his discussions of terraforming, treating Pournelle and Clarke's ideas in the same manner as those of Sagan, Averner, and MacElroy. Hard science fiction, like existence proofs, drew on all the available scientific facts to speculate on whether terraforming was possible, and both found that it was and provided potential plans.

Chapter 5: Science Disguised as Fiction

The previous chapter explained how two different terraforming narratives evolved in the 1970s. The familiar technological terraforming narrative persisted, steeped in the ideals and values of the technological culture, holding little regard for natural spaces: it framed terraforming as a technological process to restructure other planets exclusively for the needs or whims of humanity. Meanwhile, a second narrative emerged, relying primarily on ecological methods to restructure Mars, and not insisting a terraformed Mars replicate Earth.

Throughout the 1980s the technological narrative proliferated in a wide array of outlets optimistically envisioning humanity using vast technological schemes to “fix” other planets. Scientists’ terraforming ideas relied heavily on gobbledygook and drew extensively on hard science fiction texts and narrative techniques. Likewise, hard science fiction like Pamela Sargent’s *Venus of Dreams* incorporated these scientific plans into their fictional narratives.

Other authors further developed narratives focused exclusively on Mars and using ecological methods to “naturally” transform the planet. This narrative was also developed in the overlap between science and hard science fiction as in James Lovelock’s novel *The Greening of Mars*. In turn, scientist Christopher McKay popularized Lovelock’s ideas in professional and science fiction outlets. Frederick Turner’s hybrid text *Genesis* combined science, hard science fiction, and epic poetry genres to create a foundation narrative for the future Martian society. Yet even as these authors attempted to chart a new course, they continued to perpetuate the values of the technological culture. This chapter will conclude with an examination of the vernacular conversation that these authors engaged in, resulting in a synthesis that found ethical justifications in spreading life to other planets through terraforming.

Technological Narrative

Throughout the 1980s, authors of the technological narrative maintained an unbending sense of optimism about the ability of technology to “fix” both Venus and Mars, insisting terraforming was an inevitable extension of common human activities. The narrative transcended both science and hard science fiction. Both hard science fiction authors and scientists developed similar plans and visions of terraformed planets. Hard science fiction authors like Pamela Sargent directly incorporated scientific plans into their narratives. At the same time, terraforming scientists relied on gobbledygook technologies and utilized science fiction vignettes to communicate their plans.

Optimism, Plausibility, and Inevitability

In 1981, NASA scientist James Oberg published the first book-length treatise on terraforming. This comprehensive summary of terraforming science, techniques, and plans sought to inspire readers with awe about the potential ways humanity could alter the universe. An *Analog* review highlighted the grandeur of Oberg’s plans and underscored its relation to science fiction, describing the book as a “catalogue of possibility” that was “thought-provoking, inspiring, and awing. Writers must find it a mine of story ideas…SF fans must be delighted, for here indeed are the wonders of the next few centuries.”[1]

[1] Tom Easton, “Reference Library” *Analog* 1984 (6) June, 170.

Like Jerry Pournelle before him, Oberg displayed an abiding optimistic belief in humanity's ability to use technology to fix problems and depicted planets as frontiers of possibility, awaiting the hand of humankind to recast them into more prosperous molds. In a section on terraforming Venus, Oberg's optimism asserted itself in a justification of the gobbledygook his book utilized:

> It is safe to say that the difficulties in terraforming Venus have been far greater than earlier theorists have liked to admit. However, we have also discovered that human ingenuity is probably far more powerful than we might have hoped. However mind-boggling the preceding suggestions may be, they must certainly be judged unimaginative in light of expected (but unpredictable) technologies for planetary engineering a century or two from now. [By highlighting the difficulties] we can unleash the powers of human imagination against them. Facing such an unstoppable force, not even the hell-planet Venus can long endure.[2]

Jack Williamson's introduction to Oberg's work argued American culture was mired in social and environmental crises, and overwhelmed by fear of technology. Oberg's book was the antidote to these problems, illustrating "we can make our own great destiny, that we can save ourselves." *New Earths* provided insight into the powerful things humans could do if they simply choose to. He finished by warning that terraforming might seem fantastic, but that many commonplace things seemed fantastic fifty years ago.

Other's agreed with Williamson's assessment. Saul Adelman, an astronomer and physics instructor at the Military College of South Carolina, insisted terraforming was not "idle fantasy" as evidenced by the NASA Ames study. Its fruition will simply be a

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[2] Oberg, *New Earths* , 219.

matter of how "vigorously fundamental is research is pursued."[3] Science writer Arthur E. Smith argued terraforming was "not a matter of blind faith," science and technology were "both moving inexorably towards a level at which such a movement will seem both desirable and inevitable."[4]

To further assure the plausibility of terraforming, Oberg and others depicted terraforming as analogous to common human activities like deforestation, the domestication of animals and agriculture that all lowered levels of atmospheric oxygen, humidity levels, and albedo. Thus, other world's ecospheres might be intentionally altered. Likewise, Saul Adelman argued:

> We affect our local climate by changing the amount of dust and pollutants in the atmosphere, and the worldwide climate by raising the carbon dioxide levels of the atmosphere. If such inadvertent activities can cause these effects, then deliberate acts might be able to substantially change the atmosphere of other major bodies.[5]

This analogical thinking led these authors to see terraforming as inevitable. Oberg insisted humanity had been changing the environment since ancient humans lived in caves, and "environmental modification for human gain is bound to continue, on Earth and off."[6] Terraforming is no different than endeavors like swamp draining, forest clearing, and buffalo killing-- "all situations in which the natural order of the universe have been intentionally destroyed in order to provide living space for people."[7] Smith agreed. Just as new ship building techniques propelled people across the ocean, humanity will spread out into the solar system. Although it may take centuries to

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3 Saul Adelman, *Bound for the Stars* (Englewood Cliffs: Prentice-Hall, 1981), 148; S.J. Adelman, "Terraforming Venus," *Spaceflight* 24 (1982), 53.
4 A.E. Smith, *Mars: The Next Step* (Taylor and Francis, 1989), 137.
5 Adelman, "Terraforming Venus," 50.
6 Oberg, *New Earths* 33.
7 Ibid, 244.

complete the process, he noted that humanity (Europeans) settled North America in a similar time span.

In sum, these authors saw no limits to their technological plans to redesign the universe for humanity's purposes. They manifested no doubt that human ability's could conquer other planets and make productive use of otherwise wasted elements. Their narrative insisted not only was it possible, it was inevitable.

Gobbledygook Plans to Create an Earth-like Venus

The bulk of the technological plans these authors created relied on fantastic, though theoretically plausible, pieces of technology (gobbledygook) to redesign Venus. Adelman suggested anti-matter engines propel asteroids into Venus to speed up its rotation and alter its atmosphere. This would make it possible to further increase the speed of rotation by attaching at the equator two enormous anti-matter engines "capable of powering a rather large starship to a substantial fraction of the speed of light"[8] that would run non-stop for twelve years. NASA Ames research fellow and science writer, Robert Freitas, introduced the idea of using self-replicating systems (SRS) for terraforming. Freitas insisted that SRS schemes were superior to ecological ones because, once a SRS system was designed, it could be used for any application, entail less freightage than any biological scheme, produce reliable and consistent results, and ultimately produce the same terraformed planet in the same time frame. He suggested that an SRS programmed to build space engines be sent to a massive asteroid near Venus.

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[8] S.J. Adelman, "Can Venus Be Transformed into an Earth-Like Planet?," *Journal of the British Interplanetary Society* 35 (1982), 4-6; Adelman, "Terraforming Venus," 53 (quote).

There it would use the asteroid's materials to assemble the engines and use them to collide the asteroid with Venus, propelling large portions of Venus' thick atmosphere into space. Meanwhile, a moon-based SRS unit would create factories to manufacture sun shields and hurl them into orbit around Venus to cool the planet. A third SRS unit would be sent to Venus to cover the surface in factories designed to create a breathable atmosphere. An inhabitable, fully industrialized planet would be created in 500-600 years.[9]

Astronomer and researcher Christian Marchal suggested using atomic blasts to move asteroids into orbit and pulverize them into a dust cloud, shielding Venus from the Sun's energy. Alternately the asteroids could be smashed into each other or Venus. The cloud would lower the temperature by one to three degrees a week, creating an acceptable temperature in a few years. As the temperature lowered, the atmospheric carbon dioxide would be absorbed into the regolith.[10] A similar plan is found in Andrew Weiner's novel *Station Gehenna*. Gehenna is a fictional planet that bears many similarities to Venus, including extreme surface temperatures and a thick carbon dioxide atmosphere. The first stages of terraforming involved using "clean" nuclear explosions with "minimal radioactive fallout" to create massive dust clouds that block the sun and cool the planet down. One character explains "That was what they were going to do to Venus, you know, when I was a boy; nuke the hell out of Venus." To speed the process, a string of

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[9] Robert Jr Freitas, "Terraforming Mars and Venus Using Machine Self-Replicating Systems," *Journal of the British Interplanetary Society* 36 (1983), 140-141.
[10] Christian Marchal, "The Venus-New-World Project," *Acta Astronautica* 10(5-6) (1983), 272-274.

terraforming stations are setup with complex machinery that break down carbon dioxide.[11]

Oberg argued such single-pronged approaches to Venus were too simplistic, Venus required a complete “physical assault” by terraformers.[12] He dismissed any plans to “spin up” Venus by impacting it with asteroids because the force would not increase the planet’s momentum enough and would generate excess heat. He suggested creating a heat shield between Venus and the Sun with fabric squares or pulverized asteroids. As the planet cooled, Sagan’s blue-green algae could be introduced to separate carbon and oxygen. Excess oxygen would be bound with hydrogen imported from Saturn, creating rain and oceans, while further cooling the planet and eroding the regolith into soil. Machines would further prepare the soil by crushing rock, digging canals and planting forests. Meanwhile, colonists could occupy giant aerostats that would float high above the surface, held aloft by thermal waves from the planet. As the planet cooled, the aerostat would lower, eventually landing on the ground after the surface has been prepared for life. Oberg concluded, “at last a twin of Earth, will become the new home for humanity.”[13]

Regardless of their approach, these plans illustrate the fundamental belief that turning Venus into a second creation only required the right forms of technology. The technology may be fantastic and massively destructive, but it could be created and used to harness even the most extreme environment for humanity’s needs.

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[11] Andrew Weiner, *Station Gehenna* (New York: Worldwide, 1987), 226.
[12] James Oberg, "Terraforming," *Extraterrestrials: Where Are They?*, eds. M.H. Hart and B. Zuckerman (New York: Pergamon Press, 1982), 63.
[13] Oberg, *New Earths* 218.

Pamela Sargent's Venus of Dreams

A fully rendered fictional version of these plans is found in Pamela Sargent's 1986 hard science fiction novel, *Venus of Dreams*. Sargent, born in 1948 in Ithaca, New York, became interested in science fiction at as a teenager, especially drawn to the New Wave works of J.G. Ballard, and the hard science fiction of Arthur C. Clarke, and H.G. Wells—about whom she wrote her high school senior paper. She attended the State University of New York, Binghamton attaining Bachelors and Masters degrees in philosophy, completing her Masters thesis on the theories of Plato and Aristotle.[14]

She began writing and publishing science fiction while in college, inspired by the efforts of two close friends to become science fiction authors. She maintained a preference for realistic fiction, and was therefore drawn to the hard science fiction style that she defines as "Anything that doesn't violate what we know of science and in which the science is essential to the story." In addition to satisfying her realistic aesthetic, Sargent found that she enjoyed working in the genre because "It has exposed me, through the research I had to do, to a number of ideas and fascinating discoveries that I otherwise might not have known about."[15]

Sargent became aware of terraforming through a mix of the popular writings by Carl Sagan, Jerry Pournelle, and James Oberg as well as the hard science fiction of Heinlein, Clarke, and Benford. Inspired by Thomas Mann's 1901 novel *Buddenbrooks*, an epic novel that follows the decline of a wealthy German family, she sought to write a similar story but in a science fiction setting. The epic and long-term nature of a

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[14] Pamela Sargent. "Twenty Questions," 22 Nov 2009. Personal email.
[15] Ibid.

terraforming scheme seemed an appropriate backdrop. Furthermore, terraforming seemed relevant to the issues of the day,

> especially to the issues raised by global climate change. There are many passages in the novels where I connect the geology of Venus, the fact of global warming on Earth (which I assumed as part of my future history for the novels), and the terraforming project… This isn't always the case with science fiction, but my Venus novels, at least to me, seem even more relevant now than they did when I was writing them.[16]

In her nearly 500-page novel, Earth has been ravaged by wars caused by a lack of resources, and large portions of humanity have abandoned Earth to live in O'Neill–like space habitats. The survivors on Earth are unified under one Islamic nation and begin to terraform Venus. The leader begins the project as a way to give humanity a dream "a goal that might lift them to greater endeavors" and as an outlet to prevent more war from breaking out.

As we have seen with previous hard science fiction authors, Sargent did extensive research on the topic to create the highest amount of scientific verisimilitude possible. She recalls,

> I pretty much read everything I could get my hands on. It was my good fortune that the 1970s and 1980s were times when a lot was being discovered about Venus; there were the Venera missions, the Pioneer Venus missions – there was enough going on that I had to change and rework certain details in my novels from draft to draft.[17]

Echoing Oberg's plan, an immense "parasol" blocks the sun from Venus, cooling the planet. The clouds are seeded with an "altered, hardy strain of algae" that feed on the sulfuric acid in the clouds, breaking it into iron and copper sulfides. As the planet cools it is hit with giant tanks of hydrogen siphoned off from Saturn, binding excess oxygen to

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[16] Ibid.
[17] Ibid.

form water, "while traces of ammonia in the Saturnian elements would also produce needed nitrogen." Oceans form, cooling the surface and activating tectonic plates. Excess oxygen is removed by stations on the surface that separate it from the atmosphere, compress it, and send it to orbiting space stations.[18]

Gobbledygook similar to the work of Adelman and Freitas is used to speed up the planet's rotational period. The main character, Iris, explains that some researchers thought to smash an asteroid into the planet to speed it up, but computer models showed that would not produce enough energy to speed up the rotation and would generate unwanted side effects. So installations are designed that use "gravitational pulse engines" to produce "a large enough anti-gravitational pulse to speed up the rotation." When the engines ignite they rip the world apart: "Mountains were sliding and crumbling. Movements along the ocean bottoms were creating tidal waves. The atmosphere was stirring into violent patterns." To Iris this destruction is a "catastrophic christening,"[19] that slowly begins to speed up the rotation of the planet.

Like the terraforming hard science fiction before her, Sargent's work further communicated the science of terraforming and knowledge about Venus' planetary makeup. Long didactic passages cribbed information from her scientific sources like Oberg and Sagan and her narrative contributed new visions of how terraforming might look and work and the effects the project would have on humanity. In particular she revealed that terraforming, though an attainable goal, would require vast amounts of societal dedication and sacrifice, the likes of which did not exist in modern culture.

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[18] Pamela Sargent, *Venus of Dreams* (e-reads, 1986), 25-26 (quotes).
[19] Ibid, 117, 327 (quotes).

Balancing Pragmatism with Gobbledygook: Steven Gillett and Martyn Fogg

While Oberg and Sargent's projections illustrate the complex and demanding aspects of terraforming, their reliance on gobbledygook irked some terraformers. Geologist and science writer Stephen Gillett sought to inject pragmatism into the technological plans for Venus in a series of articles he published in *Analog Science Fiction*. He railed against "quick fixes," insisting that terraforming was "pointless" unless the final product was stable for millions of years and maintained an Earth-like atmosphere and oceans. His articles scrupulously analyzed Venus' known conditions, insisting "far more is involved than simply squirting some algae into the atmosphere and waiting to set up land offices."[20] Previous solutions were unrealistic or flawed: separating all the carbon from all the oxygen created a massive combustible mixture, the regolith was not substantial enough to simply absorb all the carbon dioxide if the planet were cooled off, introducing any water could cause the greenhouse effect to run away again, and any plans to "spin up" Venus were simply unrealistic.

Yet, Gillett himself was unable to imagine a terraforming plan that was free of gobbledygook. He too suggested seeding the atmosphere with algae. The freed oxygen could be bound up with hydrogen imported from Saturn or Pluto. Importing 10^{14} kilograms of hydrogen (three million tons every 3 seconds for 100 years) would create 800-meter-deep oceans on the surface. Alternately, three to five percent of Mercury's mass could be mined by solar powered SRS robots and flung with mass drivers at Venus,

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[20] Stephen Gillett, "Second Planet, Second Earth," *Analog* 12 (1984), 65.

its metals binding with oxygen as it entered the atmosphere.[21] As water condensed it would mix with the natural sulfates creating briny seas that would help to reduce evaporation and limit the greenhouse effect: "Shallow, salty oceans are the image of the 'new-born seas of Venus!'"[22] The rest of the freed oxygen (2.5 x 10^{20} kg) could be mixed with iron shavings to create oxides that would fall to the surface.

Continuing the cross-boundary discourse, Gillett's articles resulted in a strong response from *Analog* readers. Some ideas were deemed impractical, such as one reader's suggestion that Venus' atmosphere could be thinned by blowing it into space with hydrogen bombs, to which Gillett riposted that such bombs would likely heat and vaporize surrounding rock, rather than expelling the atmosphere. Others were more useful such as one reader who explained that bacteria from the mid-ocean rifts on Earth live in an environment similar to conditions in Venus' clouds and also metabolize sulfur. Gillett acknowledged these could be tailored to bind the carbon from the carbon dioxide atmosphere with sulfur in order to create stable polymers.[23]

British researcher and science writer Martyn Fogg also sought pragmatic plans for terraforming, arguing that Sagan's simple plan had "led to a number of gung-ho, nonsensical, speculations concerning the ease with which terraforming could be performed" like Pournelle's in *A Step Farther Out.* This created a misleading impression

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[21] Stephen Gillett, "Inward Ho!," *Analog* 13 (1989), 70-71.
[22] Gillett, "Second Planet, Second Earth," 72.
[23] "Brass Tacks," *Analog*, Nov 1985, 188-189

that he sought to correct by describing terraforming as difficult, complex, and requiring millennial timescales.[24]

In Fogg's assessment, Sagan's plan would produce too much carbon and an intense oxygen atmosphere whose equilibrium might prevent precipitation. The lack of appropriately sized asteroids and "enough antimatter for even one of [antimatter rocket meant] Adelman's scenarios may be unrealistic." Freitas' SRS plan, though theoretically possible, was implausible and should not be further pursued. Gillette's unacceptably slow rotational period would promote extremely inclement conditions that would destroy the seas and all but the most primitive organisms.[25]

Yet, Fogg too relied on gobbledygook in his own Venus plans. Specially engineered organisms--capable of "ultra efficient photosynthesis; rapid growth and reproduction; nitrogen fixation; tolerance of a wide range of temperatures" and ultraviolet flux--would be seeded into the atmosphere and periodically fed with minerals dispersed into the clouds through atomic explosions on the surface or material from pulverized asteroids. The organisms would transform the bulk of the atmosphere in 15,000 years. The excess free oxygen produced by these creatures would be fixed by importing hydrogen from Uranus in a vast industrial effort requiring advanced futuristic technologies.[26] But without increasing the rotational rate, moving humans to a terraformed Venus would be like moving a "damned soul in Dante's *Inferno* from the

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[24] Quotes Martyn Fogg, "The Terraforming of Venus," *Journal of the British Interplanetary Society* 40 (1987), 552.
[25] Ibid, 553.
[26] Ibid, 554-555.

'seventh circle' to the 'second circle.''"[27] The orbital rotation could be increased by developing a "Dyson engine" created by lining the planet with electrified cables that would work with the rotation of the planet to create a magnetic field. Orbiting generators would then "push" against the field and increase the rotation. Though technically difficult to achieve, like any gobbledygook it was theoretically plausible and "the technological advances that are hoped for in the next few centuries may turn the Dyson motor into a practical proposition."[28] Once an appropriate atmosphere was formed, a sunscreen would be put in place between Venus and the Sun to stabilize the environment and protect against further runaway greenhouse effects. Finally, per Lovelock's ideas, a carefully designed biosphere would have to be put in place to further stabilize the environment and perpetuate life-bearing conditions. Though the process would be complex, he optimistically concluded it is something that our descendants, with thousands of years more of ecological knowledge, could reasonably handle.

Both Gillette and Fogg demonstrated extensive knowledge of the conditions of Venus, knowledge they used to dismantle the less effective or practical plans of other terraformers. Yet, despite their calls to make terraforming plans more realistic and accurate, both Gillette and Fogg could not conceptualize ways to terraform that were simple and did not rely on fantastic technologies. For them, fantastic technology remained the key to fixing Venus.

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[27] Martynn Fogg, "Correspondence," *Journal of the British Interplanetary Society* 42 (1989), 593.
[28] Fogg, "Terraforming of Venus," 557.

Technological Plans for Mars

These authors also advanced similarly technologically-oriented plans for Mars. Though the authors often cited the inherent complexity of the task, a technological fix could always be found. For instance, Adelman suggested nuclear reactors to heat up the polar ice, thus speeding up McElroy and Averner's plans and "fixing" the planet's aridity. Instead of using unreliable microorganisms, A.E. Smith suggested using molecular-sized machines programmed to fertilize the soil with organic compounds. Other nano-machines could mine oxygen and water from the regolith, raising air pressure and humidity. Martyn Fogg suggested Mars could be "fixed" with ten million thermonuclear detonations used to free a vast amount of carbon dioxide and simultaneously excavate large areas of the planet.[29] The scheme's impracticality and reliance on goobledygook led McKay to call the idea "preposterous," but Fogg insisted it was a better alternative to ecological schemes that may not work at all.

Here, too, these narratives were often strikingly similar to terraforming hard science fiction. Echoing ideas in "The Martian Way" (see chapter 1), Oberg suggested using engines to propel asteroids into Mars, releasing water and gases. A similar plan for Mars played out in Charles Sheffield's hard science fiction story "Out of Copyright." Here, terraforming is turned into a technological competition between corporations to see which one can most accurately and efficiently smash massive asteroids into Mars. Highlighting the complexity of such a task, the corporations clone great male scientists,

[29] Martyn Fogg, "The Creation of an Artificial, Dense Martian Atmosphere: A Major Obstacle to the Terraforming of Mars," *Journal of the British Interplanetary Society* 42 (1989), 580.

engineers, and inventors from history like Enrico Fermi, Henry Ford, and Edward Teller to help with the planning and calculations.[30]

Freitas suggested sending one SRS unit to Mars where it would replicate until the entire surface of the planet was covered with factories, requiring about twenty-four years. Then the factories would switch to oxygen creation, fabricating a breathable atmosphere in 100-350 years. The surface of the planet would then be fully prepared and industrialized. The SRS factories could even be used to "fix" Mars by redistributing the material of the massive Tharsis volcano, thereby adjusting the planet's axial precession. These plans were far superior to biological plans that would only produce "planet wide green plant cover." The SRS plan would result in a fully industrialized, "well-ordered" physical habitat for man.[31]

Ian McDonald's short story "Catherine Wheel" depicts a similar process wherein an Earth-based team remotely terraforms Mars. Giant orbiting mirrors are used in the first stages of terraforming to melt the polar ice caps, alter weather and keep storms away from settlements and airships. Computerized gliders seed tailor-made bacteria across the planet. Automated greenhouses raise plants and distribute them across the planet. Remote controlled channel cutters dig canals for irrigation projects. Other machines dig for thermal pockets to use for wells. The world is united by railroads building "a new

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[30] Charles Sheffield, "Out of Copyright," *The Magazine of Fantasy and Science Fiction* May 1989, 95.
[31] Freitas, "Self-Replicating Systems," 140.

world as it ought to be built; as a thing of spirit, pure and untainted by human lusts and ambitions."[32]

Such technological plans continued to demonstrate a reckless disregard for nature that stretched back to the earliest terraforming stories. Bruce Sterling's "Sunken Gardens," uses war-like machinery to compete in terraforming Mars to create dominant ecosystems by blasting immense streams of bacteria, setting fire to vegetation, and shooting packets of eggs and seeds. As these terraformers work, indigenous life forms are fatally overcome.[33] Gregory Benford's *Against Infinity*, a sequel to *Jupiter Project,* takes place on partially-terraformed Ganymede 80 years later. Fusion plants still roll across the surface of the planet now aided by specially designed creatures "beyond the time-locked dictates of Darwin" created, "fresh and sometimes badly in a test tube, engineering miracles" designed to consume surface rock, ice, and methane to produce an Earth-like atmosphere. Ultimately, these creatures will all die as the new oxygen-rich atmosphere evolves, wiping "the entire bio-slate clean, leaving room for a new species."[34] Indicating the way such narratives transcended boundaries, Fogg claimed that Benford's story presented a "well thought-out scheme for terraforming Ganymede," "disguised" as fiction.[35] The plasticity of these boundaries can further be seen in the way scientists incorporated science fiction in to their work.

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[32] Ian McDonald, "The Catherine Wheel," *Isaac Asimov's Science Fiction Magazine* January 1984, 125.
[33] Bruce Sterling, "Sunken Gardens," *OMNI* June 1984, 75.
[34] Gregory Benford, *Against Infinity* (New York: Ultramarine Publishing Company, 1983) quotes 12, 32, 45.
[35] Martyn Fogg, "Stellifying Jupiter: A First Step to Terraforming the Galilean Satellites," *Journal of the British Interplanetary Society* 42 (1989), 77.

Fiction in Science

In addition to the liberal use of gobbledygook, terraforming scientists also incorporated hard science fiction genre elements into their scientific discussions. They used these vignettes to elaborate plans for terraforming, instill awe and wonder into the reader, and make the project seem real and attainable. For instance, Oberg explained how a pilot would scout an area for an asteroid collision:

> His target for today's reconnaissance appeared ahead of him: a large river delta criss-crossed by small streams and littered with boulders carried downstream by last year's floods. That was what the water was needed for, even if it was still far too hot for terrestrial organisms. It had billions of years' worth of erosion to accomplish in less than a century, in order to make the planet useful.[36]

Stephen Gillette used imaginative vignettes focused on the sublime conditions of a terraformed Venus in his articles.[37] Adelman used the same technique to describe the first stages of colonization on Mars.[38] The ability of these vignettes to allow the works to transcend boundaries can be seen in *Analog's* review that exclaimed Oberg's scientific plans "boggle the mind like fiction and have more sweep and scope and grandeur than many stories!"[39]

Perhaps the most remarkable instance of terraforming science articles using genre elements of hard science fiction came with an article published in *JBIS* by A.G. Smith. He used future tense rhetoric that placed terraforming in a fictional future frame, essentially creating a scientific article in the form of one long hard science fiction vignette. For instance he predicted:

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[36] Oberg, *New Earths* 197
[37] Stephen Gillett, "The Postdiluvian World," *Analog* 11 (1985), 40.
[38] Adelman, *Bound for the Stars* 145-148.
[39] Tom Easton, "Reference Library" *Analog* 6 (1984), 170.

> Before Venus can be converted to an Earth-like state, permanent settlements will exist on the Moon, and smaller bodies of the Solar System. Mars will have been changed to make it Earth-like, or preserved as a museum of the early history of the Solar System. A large population will live in space in artificial habitats, spacecraft and power stations.[40]

Smith centered his terraforming plan on his vision that planetary mining would result in vast amounts of "slag"- industrial waste. He suggested adopting Adelman's plan of spinning up Venus with collisions, but substituting the ships full of slag for asteroids. The impacts would speed up Venus' rotation to something akin to Earth's while expelling large portions of the atmosphere.[41] The remainder of his plan reads like a condensed form of Sargent's novel. A massive sunshield would cool the planet, condensing water vapor into rain, washing out much of the carbon dioxide and depositing it in the regolith. The cooling and the numerous impacts would trigger volcanic and plate-tectonic activity, leaving Venus in a permanently volcanic state necessary to form atmospheric cycles and combat erosion. Once this has occurred, the planet will be seeded with life, starting with ecosystems of algae, eventually advancing to forest systems.

Taken as a whole, the technological narrative varied little from the earliest terraforming stories and further perpetuated the technological values of the early 20th century. Whether in hard science fiction or professional scientific journal, the narrative remained the same: humanity uses advanced technology to harness "wasted" resources and reorder the natural environment of other worlds. This reordering is widely destructive, often taking the form of full-blown warfare against nature. Though difficult and demanding sacrifice, these authors evinced complete optimism that the plans would

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[40] A.G. Smith, "Transforming Venus by Induced Overturn," *Journal of the British Interplanetary Society* 42 (1989), 571.
[41] Ibid, 573.

work, and were likely inevitable. Just as humanity had used technology to tame the frontier on Earth, humanity would use fantastic technologies to conquer other worlds and remake them in the ecological and industrial image of Earth. However, not all terraformers accepted this technologically centered narrative. At the same time, other authors sought to advance an alterative vision that relied on biology to create ecological systems that would terraform other planets. Yet, despite their desire to provide an alternative approach to terraforming, ultimately the plans continued to advance the values and visions of the technological culture.

The Development and Failure of the Ecological Narrative

Like the technological narrative, the ecological narrative is perpetuated in a variety of hybrid texts that combine the science of terraforming into fictional narratives. This ecological narrative sought to mitigate the technological, human-centered nature of terraforming by implementing less invasive and more "natural" transformation. Most authors using this narrative concentrated on Mars to explain how humanity would deploy technology to prepare the planet, but then use ecological systems to develop the landscape and create prosperous new communities.

Despite some differences, the ecological narrative continues to perpetuate the values of the technological culture. The ecological narrative imagined Mars would not be a clone of Earth, though the processes relied entirely on Earthly biology to set up Earth-like ecosystems. The process is depicted as "natural," despite the fact that it still incorporates technology and genetically engineered organisms that imperialistically takeover Mars. This narrative also continued to frame terraforming as an inevitable and natural extension of humanity's historic activities of harnessing otherwise "wasted" resources.

The Greening of Mars

James Lovelock's novel *The Greening of Mars* takes the form of a diary/instruction manual that explains how Mars was colonized and terraformed to explain the steps that would need to be taken to terraform Mars, the potential results, and its meaning to the humanity while framing terraforming as a part of human tradition. The settlers coming to Mars are the "true historical descendants of the waves of ambitious, romantic, impoverished, oppressed, frustrated voyagers who crossed the oceans of Earth centuries ago to build new lives in new places." The pilgrims are all young, "adventurers in their own ways… seeking their new world inspired by the highlight of romantic ideals." Like previous settlers, they move to Mars "because of their dreams, for the challenge perhaps, for the opportunities their new world afforded." Unlike them, they are selected for absence of genetic disorders and health and develop orderly settlement rather than a Wild West.[42]

Instead of fantastic technologies, Lovelock uses ballistic missiles loaded with chlorofluorocarbons (CFCs) to collide with Mars. These "super-greenhouse" gases rapidly sublimed the polar ice. Antarctic algae disbursed with the CFCs fertilize soil and maintain the atmosphere after the CFCs dissipated and liquid water began to flow. As the

[42] J. E. Lovelock, *The Greening of Mars* (New York: Warner Books, 1984) quotes 9, 56, 106. Lovelock's piece also maintains an interesting continuity within hard science fiction. Just as Aeneas replicated the journey of Odysseus, and Dante replicated both after that, Lovelock's space travelers mimic the trip that characters from *The Sands of Mars* and *Farmer in the Sky* underwent.

planet evolved, terraformers debated how best to transform Mars. Should it simply become a replica of Earth, or should it be seeded with life and allowed to develop in its own unique way? The narrator explains, "The idea of 'greening' Mars, rather than 'industrializing' it was inherently attractive. It seemed gentler, more 'natural,' and it was more natural too, in that the transformation was to be achieved by the activities of living organisms, left to their own devices."[43] Furthermore, industrializing Mars would bind it to Earth technologically, economically, and politically--limiting Martian autonomy.

To alter the atmosphere "naturally" they sowed genetically engineered micro-organisms and plants to create a Martian ecosphere and colonized the planet quickly by sowing more plants into the Martian soil:

> This was perfectly possible, with a few simple modifications of standard terran agricultural and horticultural techniques. [Colonists] brought with them the sewage sludge accumulated during their voyage, dried and compressed organic soil conditioners, fertilizers and seeds. Once the organic materials were mixed with martian soil, a martian version of agriculture could begin.[44]

The organisms in the mixture provide enough topsoil for plants to take root. With water, the plants proliferate in Martian conditions due to the abundance of photosynthetic materials. The narrator ironically explains this "natural" process in terms of ecological imperialism, in which "micro-organisms, plants and small invertebrate animals are capable of 'taking over' an entire planet and altering it to suit themselves."[45]

In addition to explaining Lovelock's ideas about terraforming, large selections of the book provide explanations of scientific knowledge such as: summaries of modern understandings of the origins of life, arguments about the existence of intelligent life in

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[43] Ibid, 142.
[44] Ibid, 129.
[45] Ibid, 130.

the universe, explanations of the evolution of Earth's atmosphere, the workings of the green house effect, summaries of the up-to-date knowledge about conditions on Mars and explanations of how its atmosphere functions. The Gaia Hypothesis also receives extended explanations in a twenty-page segment that cribs information from Lovelock's previous publications. Lovelock also used the hard science fiction novel to address arguments that the Gaia hypothesis did not conform to Darwinian evolution, wherein organisms evolve in reaction to their surroundings, not the other way around. Using a computer model, he illustrated how black and white daisies reacting to changes in planetary temperature would affect the albedo of a planet, regulating its temperature to perpetuate their growth.

The overlapping aspects of Lovelock's text made it difficult to classify. Lovelock himself explained the book as a way to communicate his ideas about the Gaia hypothesis, insisting, "fiction always seems more credible that fact. If you want to learn about social conditions in Victorian England, you have a choice: you can read Marx or Dickens. Now which would you read?"[46] A.E. Smith described Lovelock's book as "faction," that "deserves to be considered as a serious contribution to the debate on how Mars could be colonized."[47] Carl Sagan reviewed the book in the *New York Times*, calling it "a work of popular science attractively disguised as science fiction, "[48] while another reviewer admitted "It's hard to tell if science or science fiction predominates in this book."[49]

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[46] Tom Ferrel, "A Planetary Air Conditioner," *New York Times* January 6 1985, A1.
[47] Smith, *Mars: The Next Step* 125, 128.
[48] Carl Sagan, "The Terraformers Are Coming," *The New York Times Book Review* January 6 1985, 6.
[49] Margery Coombs, "Review of the Greening of Mars," *Library Journal* (1984), 1764.

These readers questioned Lovelock's terraforming design, though not his Gaia hypothesis. Smith opined the science was "impeccable," but the technology "seriously flawed." He doubted that a thousand tons of CFCs would substantially change the atmosphere, that ballistic missiles would be powerful enough to reach Mars, that it would be as cheap as estimated, and he argued the exhaust from the launches would pollute Earth's atmosphere irredeemably. Sagan also thought the technological side of Lovelock's scheme was "unworkable," requiring the equivalent of a billion Viking spacecraft loaded with CFCs to effect any change.

Sagan also engaged in the hard science fiction "game;" nit-picking details that Lovelock overlooked: existing outer space treaties, the role of the sun in generating tides on Earth, or used incorrectly: misconstruing the heating effects of Martian dust storms, incorrectly questioning the effectiveness of parachutes on Mars, and describing a view of Saturn from Titan which could not be seen from the cloud-covered planet. Because of these errors, Sagan insisted that, while providing an inspiring depiction of a Martian society, the work could not be "recommended as a source book on the relevant science."[50] Despite these criticisms, Lovelock's work and CFC plan greatly influenced terraforming science, especially the ideas of Christopher McKay.

Christopher McKay

Writing in the peer-reviewed scientific journals, a science fiction journal, and science fiction magazines, Christopher McKay redefined terraforming as "alter[ing] the environment of another planet so as to improve the chances of survival of an indigenous

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[50]Smith, *Mars: The Next Step* 125-126; Sagan, "The Terraformers Are Coming," 6.

biology OR to allow habitation by most, if not all, terrestrial life forms."[51] A terraformed environment must ultimately be a stable, long-term alteration requiring little or no maintenance- not a quick technological fix. Only terraforming "techniques consistent with current or foreseeable engineering" should be proposed to alter planets. The target planet need not duplicate Earth: "it is conceivable that a terraformed Mars would not have anything analogous to Earth's oceans, either in size or ecological importance."[52]

McKay limited terraforming to Mars, the only reasonable target as long as the planet possessed enough water, nitrogen, and carbon dioxide.[53] Terraformers could not alter a planet's rotational period, eccentricity, and obliquity. However, excessive UV rays, temperature range and variation, and humidity could be altered by changing the planet's atmosphere. Such changes had been made on Earth and "It is becoming increasingly clear that humanity can be, and is, a factor capable of changing environments on a planetary scale. Collectively mankind is engaged in both deliberate and inadvertent global modifications of Earth."[54]

Vestiges of the technological culture remain in McKay's work. Using rhetoric similar to Oberg, he explains that Mars is "custom-made" for terraforming. One-third of the Earth's gravity requires an atmosphere three times as dense as Earth's to create equivalent atmospheric pressure, compensating for the lower temperatures on Mars by

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[51] Christopher McKay, "Terraforming Mars," *Journal of the British Interplanetary Society* 35 (1982), 427; Christopher McKay, "On Terraforming Mars," *Extrapolation* 23(4) (1982), 310; Christopher McKay, "Terraforming: Making an Earth of Mars," *The Planetary Report* VII(6) (1987), 26.
[52] McKay, "Terraforming Mars," 428.
[53] McKay, "Terraforming: Making an Earth of Mars," 26.
[54] McKay, "Terraforming Mars," 427.

trapping more heat. Its rotational and axial tilt were within five percent of Earth's making Mars "ripe" for a "restoration project," recreating Earth ecosystems by seeding "hardy species of grasses and shrubs" followed by "flowering plants, trees, and food crops" followed by invertebrates, insects, reptiles bids and mammals. Furthermore, terraforming knowledge could be used to "reclaim" vast areas of uninhabitable land on Earth.[55]

Although he initially supported Sagan's plan of triggering the greenhouse effect by lowering the polar caps' albedo, McKay became a staunch advocate of Lovelock's CFC plan from *The Greening of Mars*. He calculated that between nine million and 1.4 billion tons of CFCs would be required to warm the planet to 40 degrees Celsius-- far too much to ship, but easy enough to produce in factories on the surface. Massive orbiting solar mirrors could also be used to warm the polar caps. Using these steps, in 200 years McKay projected Mars is, "warm with a thick carbon dioxide atmosphere and extensive vegetation. There are no large animals, but humans can survive with scuba gear alone."[56]

Once the planet was warmed, a stable, breathable atmosphere could be created with life. Lovelock's Gaia hypothesis indicated technology could be used to start the changes; the ultimate stability of the system would rely on planetary biology.[57] Research showed that the bacteria Beijerinckia-lacticogenes was capable of thriving under Mars-like levels of atmospheric nitrogen, assuming there were sufficient amounts of water and nitrogenous compounds. Genetically modified microorganisms might be more

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[55] All quotes McKay, "Terraforming: Making an Earth of Mars," 26-27.
[56] McKay, "On Terraforming Mars," 312-313.
[57] Ibid, 312; McKay, "Terraforming Mars," 430-431.

effective.[58] Biological systems would require up to 100,000 years to fully convert the atmosphere. This "passive terraforming" allowed for observation, increased chances of success and provided a wealth of knowledge about planetary atmospheric evolution.[59]

McKay's work continued to evince an overlap between science and hard science fiction. He incorporated Lovelock's plans and cited the hard science fiction novel in his scientific publications. His articles credited other science fiction authors for advancing the idea and indicated the important role science fiction had in further development of the idea: "As science now approaches the 'how' of terraforming, science fiction must continue to explore the 'why.'"[60] Like Clarke, Heinlein, and Pournell, took the position that any Martian colony would have to be self-sufficient if it were to survive, so the benefits of terraforming to the Martians "would be quite tangible- the long term survival of their civilization."[61]

Genesis

In addition to influencing McKay, Lovelock's theory was also greatly influential in other hard science fiction. Frederick Turner's *Genesis* incorporated science in 10,000 lines of epic poetry. Turner blended ecological with technological elements, promoting terraforming as a way to subvert the constraints of environmentalism, yet insisting on more "natural" methods. The poem is set in the mid-twenty first century when Earth has become a unified theocracy that promulgates Ecotheism- a religion dedicated to

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[58] McKay, "Terraforming Mars," 431; McKay, "Terraforming: Making an Earth of Mars," 27.
[59] McKay, "Terraforming Mars," 428.
[60] McKay, "On Terraforming Mars," 309.
[61] McKay, "Terraforming: Making an Earth of Mars," 27.

protecting nature and natural environments at all costs. To ecotheists, nature is holy "And the chief evil that afflicts her is/ Technology, its blight and vicious pride."[62] Yet, the ecotheists have not abandoned technology entirely, they kept it exactly as it was when ecotheism began- not allowing advancement, not allowing it to disappear lest humanity forget the dangers it can reap. Without advancing technology, however, Earth societies are slowly decaying and dying. In essence, Taylor depicts Earth as Jerry Pournelle's nightmare and uses terraforming as a way to subvert those that would limit technological growth and, by extension, humanity's expansion and survival.

In the story, Chance Van Riebeck is an entrepreneur conducting scientific research on Mars. He and his followers are opposed to ecotheism and secretly initiate a terraforming scheme on Mars. The plan begins with computer models of living organisms that are placed within a model of the Martian atmosphere and allowed to evolve. The evolved models are then used as blueprints for synthetic organisms that are implanted on Mars. After the bacteria have flourished on Mars, the thirty-mile-diameter Saturian asteroid S26 is smashed into the planet. The asteroid's impact is described as a moment of miraculous destruction and recreation that incinerates the first bacteria, preparing the surface for agriculture. The asteroid's impact and gases provides heat and oceans, activates the tectonic plates, and ignites volcanoes that pump nitrogen into the atmosphere. Within days the atmosphere begins to warm as the caps begin to sublimate. Massive thunderstorms are created. The volatiles in the upper atmosphere are oxidized and split, falling as rain. Subsequently, the terraformers rely exclusively on biology to

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[62] Fredrick Turner, *Genesis: An Epic Poem* (San Francisco: Saybrook, 1988), 36.

complete the transformation. For instance, to create a greenhouse effect they alter the albedo of the planet with more bacteria:

> The first bacteria just darkened up
> The surface- and especially the caps-
> To stop enough re-radiation out
> Of the planet to get the cycle going.
> …
> Then we got oxygen-excreting algae
> And sowed them in the mulch the first bugs made
> By dying of the heat they generated[63]

As time passes, genetically engineered life forms fill every ecological niche on the planet.

Turner depicts this process as conforming to historical continuity; framing it as a part of human experience stretching back through the American, Roman, and Greek civilizations. The settlers are equated with the Hebrews finding their paradise through the desert. They also reject the oppression and control of Earth governments, mimicking the American Revolution, including flying the "Don't Tread on Me" flag. In addition, despite Turner's implicit argument that terraforming would allow Mars to become a living, unique planet, Mars is reconstructed into a clone of Earth, a process political theorist and cultural critic Ernest Yanarella refers to as "a technocratic/modernist planetary conquest veiled in pastoral garb… an imperialistic or colonial pastoralism."[64] The finished settlements resembled South Florida: airports, monorails, and suspension bridges connect human settlements together that resemble Earth-like seaside resorts including pools, art deco architecture, and pink flamingos.

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[63] Ibid, 165-166.
[64] Ernest Yanarella, *The Cross, the Plow, and the Skyline: Contemporary Science Fiction and the Ecological Imagination* (Parkland: Brown Walker Press, 2001), 235.

Negotiating Differences

Despite their different approaches, these narratives share a number of commonalities that reveal a struggle to envision the future of humanity and its relation to technology and nature. Each narrative listed benefits to humanity and envisioned terraforming as revitalizing activity that created utopian societies. Some critics rejected these optimistic visions, and challenged unchecked expansion of human culture to other planets. While both ecological and technological narratives agreed that Earth had been damaged by human activities, they viewed terraforming as the essential key to saving life on Earth and spreading it to the larger universe. Ultimately, a synthesis developed that relied on the moral justification of spreading life and turning "dead" useless planets into "live" useful ones, a vision of terraforming as providing knowledge to save Earth, prepare another home for life, and express human ability.

Terraforming Creates a Utopia and Revitalizes Earth

Both narratives justified terraforming with visions of a utopian world that varied little from the very first visions of terraforming science fiction found in Chapter 1. In *Genesis*, the terraformed Mars becomes a bastion of freedom and autonomy. Not only is it separated from any ties to Earth, but new levels of freedom accompany the discovery that the reduced gravity on Mars allows for individual human flight. The Martians literally know no bounds, and their notion of personal boundaries break down, resulting in a communal society where personal property holds little meaning. The freedom they are afforded increases cultural values on loyalty, constancy, truthfulness, and dedication to family.

On Lovelock's Mars, all notions of race, creed, class, and nationality are abandoned. There is no war. Instead, the Martians become reliant on each other for survival, "because without help a human being in difficulties is very likely to die. Altruism is the most sensible behavior and its benefits are clearly apparent. It is a case of 'do as you would be done by- or die.'"[65] Humans group together in a wide array of tribes that feature a vast amount of diversity. When diversity leads to conflict, the groups simply move off and begin a new settlement. This diversity also makes it difficult to rule with any one set of rules.

But advocates also envision terraforming revitalizing Earth-bound culture too. Turner argued humanity suffered from a "widespread sense of loss of value, dignity, and grandeur in our vision of ourselves and our cosmos." The cold war had provided global focus, but now a new goal was required:

> How are we to employ the beautiful and terrible heroic spirit of humankind, ready for suffering and sacrifice, when we no longer have war and nationalist myth to spend it on? How are we to use those billions of dollars and rubles, which employ millions of workers and serve as a fiscal and technological flywheel, to keep the economy going? Garden Mars.[66]

Much like the great pyramids had created the "most contented society in the world," terraforming would provide unified actions and goals and raise morale world-wide. Sargent, too, sees terraforming as a revitalizing force. Her character Iris explains terraforming will provide a new culture that "can revitalize Earth, the way younger, newer cultures changed old one in the past. Differences move history forward… [terraforming] will both make us stronger and give us a sense of our true place in the

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[65] Lovelock, *The Greening of Mars* 182.
[66] Frederick Turner, "Life on Mars- Cultivating a Planet and Ourselves," *Harper's Magazine* 279 (1990), 35.

universe."[67] Adelman also argued terraforming would have a profound effect on the constitution of Earth's population. The scope of the project would:

> help breakdown barriers between sciences. With a broad training in science, individuals would be readily able to perform interdisciplinary research. Scientifically trained people would number in the hundreds of millions. For the first time in human history, a scientific based world society would emerge.[68]

Oberg foresaw terraforming as the cure to Earth-bound "syndromes" conjured up by the technological foundation narrative. For instance, his "Mayflower Syndrome" held that terraformed worlds would provide the perfect place for social deviants to migrate to in order to create their own diverse, profitable, and unique culture. The "Wild West Syndrome" held that terraformed worlds offered a place of escape for those who felt hemmed in physically, socially, or psychologically. Not just an 'escape hatch,' a terraformed planet offered the vicarious experience of adventure and opportunity for those that stay-at home. This would be an important gain for America, which "has not reconciled itself to the demise of the Western frontier." These historical "syndromes" would compel future individuals to risk their lives to terraform. Given this history, he concluded it would be far more astonishing "if nobody ever wanted to terraform a planet."[69]

Skepticism and Criticism

But other authors were not convinced by such optimism and were worried by such determinism. A letter in *JBIS* argued that humanity had done poorly with the Earth. The

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[67] Sargent, *Dreams* 185.
[68] B Adelman and S.J. Adelman, "Some Research Requirements of Planetary Engineering," *Journal of the British Interplanetary Society* 42 (1989), 557.
[69] Oberg, *New Earths* 250, 251.

imperatives of the technological culture and its emphasis on dominating nature had led to global warming, devastation of natural habitats, widespread pollution, and expansive growth. "Are we, therefore, to give up on our own world, and instead export out into the Universe" the Western ideology that caused all the problems in the first place? Humanity had not yet developed the wisdom to effectively deal with the pollution it creates, nor did it seem capable of realizing the ramifications of exporting such a "throw-away" culture to places like the Moon and beyond. The letter concluded, "A terraformed world would be essentially a controlled environment in which all that was wild, exotic, hostile, and dangerous, would have been eliminated. We would only create an impoverished world."[70]

Similar criticisms were leveled in Andrew Weiner's hard science fiction novel *Station Gehenna*. This terraforming counter-narrative questions the purposes of terraforming and criticizes the justifications of humanity's need to dominate nature as a specifically masculine one. Rather than being a heroic act achieved by brave pioneers, the novel depicts the activity as a repetitive and isolating task conducted by workers that struggle to maintain their sanity in their day-to-day routines. Rather than creating glorified utopias that provide autonomy, terraforming is conducted exclusively by corporations that seek simply to harness planets for their resources.

In one passage, a female scientist questions the tacit technological values and ideals imbedded in terraforming, including the masculine need to dominate nature. The male protagonist insists that the goals of terraforming are to create new habitats for

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[70] Enrico Coffey, "Correspondence," *Journal of the British Interplanetary Society* 42 (1989), 596.

humanity while achieving a profit. The female scientist presses the point, insisting many researchers argued the pointlessness of trying to change the planet and the implicit folly in the project. The male protagonist replies:

> "But don't you see that we could hardly let a place like this defeat us? Its very existence is an affront to our conquest of nature. How could we pass it by? We could not permit such a failure of nerve, we have come much too far for that. We can only go forward…Otherwise the whole thing would be meaningless…Don't you see that?"

She responds:

> "What nonsense… The kind of nonsense only a certain sort of man would talk… so eager to participate in our glorious conquest of the universe…. Certainly, a woman would never say such a thing… I believe that women, at least, know that many things are meaningful, beyond our war with this hapless planet, this vast inexhaustible adversary of a universe... [Things like] living. Loving. Taking care of one another. Building a better world for our descendants."

He continues:

> "Yet surely more basic still is our urge to control nature. To achieve some predictability in lives once at the mercy of arbitrary and inhuman forces. Should we not build houses against storms, or plant seeds to ensure food supply?...And yet we are doing precisely what you would have us do. Building a better world."

She concludes: "We're destroying it… to build… what? Open pit mines. High rise warrens for the miners. Shopping malls, perhaps."[71]

As the story proceeds, it is revealed that Gehenna is inhabited by a planet-wide blanket of moss, which the terraforming is killing. Personifying a female form of nature,

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[71] Weiner, *Station Gehenna* 120-123. This dialogue is representative of the thoughts of a number of feminist authors developing from the 1970s and 1980s. As Carolyn Merchant explains, authors such as Françoise d'Eaubonne, Chellis Glendinning, and Linda Nicholson sought to challenge the recovery narrative by rejecting the patriarchal and rationalist elements that marginalized women's participation and limited the value of their reasoning. For more see Merchant, *Reinventing Nature*, 195-199. Merchant herself seeks to create a new narrative that sidesteps the dominant recovery narrative by also looking to Lovelock's Gaia model as a way to conceptualize humanity working in partnership with nature. For more see 217-220.

the moss is able to communicate psychically with the scientists and lure the male members to their death. The rest of the workers shut down the machinery and abandon the terraforming plan.

Researcher Martin Heath was also critical of terraforming. He maintained that the devastating effects that human engineering had wrought on the Earth, including global warming, should give pause to any idea of transforming the atmosphere of some other planet. Humanity needed to gain a full understanding of its weather systems and biospheres. Otherwise, the chances of survival were slim, and terraforming plans pointless.[72]

Preserving Earth and Spreading Life

Both the ecological and technological narratives agreed with Heath's dark assessment of the future of the Earth. Hard science fiction authors consistently depicted future Earth as an ecologically devastated husk of its former self where humanity struggled for existence. Researchers repeatedly warned of impending environmental crises in their terraforming articles. Undaunted by the environmental damage that technology has rendered; they optimistically predicted terraforming would be essential to saving life on Earth and spreading it throughout the galaxy.

Fogg argued Earth's ecological crisis is not the result of technology, but rather part of a pattern of exploitation that haunts all human history. Abandoning technology and adopting a "sack cloth and ashes" approach would be of little use, and developing

[72] Martin Heath, "Earth: A Problem in Planetary Management," *Journal of the British Interplanetary Society* 42 (1989), 559-566.

terraforming technology may be the only key to our survival.[73] McKay insisted data rendered from terraforming work could also be essential in saving humanity from the "de-terraforming" processes occurring on Earth.[74] In *Venus of Dreams*, one character explains Venus might have been Earth-like, but "took a different path. Now our world is also changing. We may need to transform it in the future."[75] Sargent herself explains that she does not believe terraforming is a way to technologically fix another planet, but that "playing with the idea imaginatively, or doing the kinds of studies and experiments that any actual terraforming project would have to undertake, might yield knowledge and technologies that could be helpful in dealing with environmental crises."[76] Likewise, biologist Robert Haynes argued humanity would never fully understand Earth's biosphere without trying to replicate it elsewhere. Any research into the feasibility of changing other planets would be great value to maintaining Earth's biosphere and avoiding environmental devastation.[77]

Beyond preserving life on Earth, terraformers argued that terraforming was justifiable as a way to proliferate life throughout the universe. Adelman saw that learning to terraform would mean "Our galaxy would be opened to the spread of humanity outward from the Earth and the solar system."[78] Gillett exclaimed that in terraforming Venus, "We are not 'just' making a planet suitable for human habitation, we are making

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[73] Fogg, "Correspondence," 596.
[74] McKay, "On Terraforming Mars," 313.
[75] Sargent, *Dreams* 13.
[76] Pamela Sargent. "Twenty Questions," 22 Nov 2009. Personal email.
[77] R.H. Haynes, "Ecce Ecopoiesis: Playing God on Mars," *Moral Expertise*, ed. D. MacNiven (New York: Routledge, 1990), 180.
[78] Adelman and Adelman, "Some Research Requirements of Planetary Engineering," 557.

it suitable for entire diverse, disparate ecologies of terrestrial life!" The seeded ecologies will develop into a Gaia-like system, independent of humanity and its technology, and will have a stable platform to support evolution for millions of years. Regardless of humanity's future, terrestrial life would have "an opportunity to work out an alternate destiny."[79] Fogg insisted the "sublime" justification to proliferate both human and non-human life would trump more "common" motivations like finding new resources.[80] McKay saw terraformed Mars as the solution to the "so called 'Heinlein egg-basket': Mars could insure the survival of terrestrial life-forms if or when we destroy the Earth- a sort of cosmic Noah's ark."[81]

The importance of spreading life ultimately led Lovelock to a new way of thinking about planetary engineering. Four years after *The Greening of Mars*, he introduced a new term suggested to him by Robert Haynes: ecopoiesis. The term referred to the process of altering a lifeless planet to create "a new arena in which biological evolution ultimately can proceed independently of that on Earth." Rather than terraforming a planet completely, Lovelock now argued that the greater goal was to enable life to flourish and begin to "control" Mars. Plans should not focus on creating a planet specifically for human life, but "making of a planetary home for life then leaving it to evolve so that the climate and chemical composition are regulated automatically at

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[79] Gillett, "The Postdiluvian World," 57; Gillett, "Second Planet, Second Earth," 78 (quote).
[80] Fogg, "Terraforming of Venus," 560.
[81] McKay, "On Terraforming Mars," 313.

what is desired."[82] The issue of the importance of spreading life ultimately underpinned the ethical discussions that began to develop around terraforming in the 1980s.

Synthesis

The issue of spreading life was key to forming a synthesis between the ecological and technological narratives. The opposing sides of this debate were illustrated in *Genesis* in a trial held to prosecute terraformers that examines terraforming in relation to ideas of "natural." Opponents argue that terraforming violates natural law and the natural destiny of Mars to be the planet that it was. The clays of Mars were a "rich heritage" which belonged to all humanity and have been destroyed. Terraforming is no different than the "ecological disasters" humanity had perpetrated before, and the biological creations used in the process were unnatural monsters. Such arrogance went against the will of the people, the laws of nature, and the "clear decree of God."

Terraforming proponents question the very meaning of "nature" and the moral assumptions it implies. If humans had no rights over nature, then is it wrong to save a baby from the mouth of a crocodile? Proponents argue terraforming is a moral act; reactivating Mars provided the clays of Mars with the chance to evolve; the clays would "thank us, if they could." The organisms used to terraform were 'natural' in that they created themselves within the computer matrix- the terraformers simply gave them organic life. Ultimately terraforming was, in fact, the greatest "natural" act of freedom: "That freedom is not choosing but creation,/ The making of a new alternative/ where

[82] J.E. Lovelock, "The Ecopoiesis of Daisy World," *Journal of the British Interplanetary Society* 42 (1989), 583, 586.

none existed, and its rough/ Insertion in the bland ensembles of/ Existence futures lined up for our choice." If anything, this act of creation was as "natural" as parents creating a child.[83]

James Oberg sought to bridge the natural/unnatural divide by uniting each side under their desire to live in "natural" conditions. For Oberg, "natural" meant a pristine Earth-like environment, and he envisioned terraforming as park management on a massive scale. Terraforming would monitor environments, ensure they are pollution free, and regulate the human presence within. This regulation would further assure that the people who colonized terraformed planets would not duplicate the urban systems they had fled.

Robert Haynes sought to apply modern ethical systems to resolve this divide, but found they would inevitably block terraforming. The ethical caveats that Mars must be proven totally sterile and fully catalogued in its natural state prior to transformation would require a massive amount of resources and may never completely satisfy critics. This could indefinitely suspend the program. Establishing a terraforming ecosystem created its own issues. It would not be allowed to evolve "naturally", rather it would have to be tended and pushed in directions to ultimately create the desired end result. Furthermore, as in Zelazny's "Keys to December" and Benford's *Against Infinity*, ecological systems that evolved along the way may need to be destroyed in order to achieve the proper end result, compromising any sense of "freedom" to natural systems. In light of these issues, Haynes is forced to create a new code of ethics that would allow for terraforming, a new "cosmocentric" ethical system. Such a system would blend

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[83] Turner, *Genesis: An Epic Poem* 106, 107 (quotes).

ecological values and technological progress, allowing for the extension of science and technology throughout the solar system, while simultaneously acknowledging humanity's dependence on the Earth's biosphere. It would strip questions of the "natural," placing human artifacts on the same level as elements of the biosphere like animals and plants.[84]

McKay tried to apply modern environmental ethics to terraforming plans, but received mixed results. Principles of "anti-humanism" demanded that all technologies associated with developing or improving Mars be dismantled. Principles of "wise stewardship" would allow for the development of Mars provided there was no indigenous life. If there was life, the potential of that life would have to be weighed against the potential gains of terraforming. Principles of "intrinsic worth" provided two radically different results. If inanimate objects are believed to have intrinsic value, then Mars could never be developed. If only life had intrinsic value, there would be an implied directive to encourage the development of life everywhere. Thus, it could be argued that "planets without life are unfulfilled and humans have the moral obligation to allow Mars to realize its potential as a biotic planet." Notably, this need not be human life, and Mars may be entitled to its own form of "natural life" that can exist under Martian conditions. McKay concluded it was ethical to encourage ecopoiesis on Mars, allowing the development of natural life. If no natural life was found, then it would be ethical to

[84] Haynes, "Ecce Ecopoiesis," 177-178.

implant life on Mars so that "the maximum diversity of Earth life can be accommodated there…"[85]

In a co-authored article published in 1990, Haynes and McKay simplified their ethical rational, ultimately framing it within the values of the technological culture. The choice of terraforming came down to having a "dead" useless planet, or a "live" useful one: "It is illogical to argue that a dead planet ought to remain as it is, simply because it is." Ultimately this became the guiding ethical principle for terraformers into the 21st century. Highlighting the importance of the narratives this study has examined, they concluded that one of the strongest justifications for terraforming would be its consistency with the technological narratives, "the Promethean myths of many human cultures."[86] The same narrative that led to the creation of terraforming, will ultimately drive humanity to perform it.

Green Mars

Taken as a whole, this discourse reveals that terraforming advocates reached a consensus that, under the influence of technological values and myths, the process will inevitably occur, perhaps despite moral objections or reluctance. But the benefits for humanity from terraforming will be found in the journey, as much as in reaching the final goal- whether that be a completely Earth-like planet, or one simply capable of bearing life. Kim Stanley Robinson's hard science fiction novella "Green Mars" provided a

[85] Christopher McKay, "Does Mars Have Rights? An Approach to the Environmental Ethics of Planetary Engineering," *Moral Expertise*, ed. D. MacNiven (New York: Routledge, 1990), 193-194 (quotes).
[86] Christopher McKay and Robert Haynes, "Should We Implant Life on Mars?," *Scientific American* 263(6) (1990), 144.

prescient interpretation of this view that would guide terraforming discourse throughout the rest of the 20th century.[87]

The story is set on a terraformed Mars on which a plethora of life exists and humans can exist outside with warm clothes. The plot follows a group of people climbing Olympus Mons, the enormous Martian volcano. Robison uses the setting of the characters tackling this dangerous, difficult, and seemingly pointless task of climbing the mountain as a metaphor for the task of terraforming a planet.

Mars society has recently reunited after a fractious period between the Reds and Greens. The Reds sought to preserve the natural Mars, or at least strike a balance between its development and preservation. The Greens put value on the human world and sought to convert the planet into an Earth-like environment. Recently the Red party has been dissolved and the terraforming undertaken to its fullest leading to an abundance of transplanted flora and fauna. In addition, the planet is alive with a host of chimerical creatures genetically engineered for the planet. ‘Dune dogs’ blend wolverine genes with those from marmots and seals. A ‘killer rabbit’ is a cross of a lemming, pika, and lynx. The designers that create the most successful creatures become famous and are celebrated like great artists. No empty natural spaces are left, and the climbers find life in even the most remote parts of their climb.

Rodger was a leader of the Red party, and represents the counter arguments to terraforming. He fought the terraforming development at every step, first as a wilderness advocate and then as a representative of the Red government. He does not celebrate the

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[87] “Green Mars” reprinted in Kim Stanley Robinson, *The Martians* (New York: Spectra, 1999), 112.

Martian ecosphere. For him, this second creation has actually obliterated the 'natural' world of Mars. Long passages are given to descriptions of how Mars used to be, highlighting its sublime and untouched beauty. To him, terraforming is a manifestation of human colonialism- "the visible sign of a history of exploitation…"[88] Worse, it does not seem to serve any purpose. Humans could have lived on Mars as it was: "we didn't need another Terra up here. And everything they did eroded the planet we came to. They destroyed it! And now we've got- whatever. Some kind of park. A laboratory to test out new plants and animals and all."[89] He theorizes that the 'heartless immensity' of the original Mars was too much for humanity, who sought to protect their sanity by converting it to something familiar and safe. But the 'nature' that terraformers have filled Mars with is nothing more than the manifestation of human mind- life that has been carefully designed and created by humans.

As Rodger participates in the climb, it mirrors the vision of the terraforming process that both narratives envisioned. As with terraforming, the act is a dangerous and complex feat that demands the group's attention, leading them to experience nature with new vigor and respect. The climb tests their limits, forcing them to push their capabilities. The climbers are both men and women, both equally capable of the tasks at hand. Their technology aide them and in turn they rely on it for their safety, their existence. As they climb, they model the scientific process in their discovery of natural features of the volcano and debate their theories about their origins and evolution. Their exploration also reveals unexpected surprises that simultaneously increase their

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[88] Kim Stanley Robinson, *The Martians* (New York: Spectra, 1999) 163.
[89] Ibid, 127.

understanding and sense of wonder. Roger at first resists these wonders, but becomes more engaged and invigorated as he climbs. At first morose, moody, and without direction, Roger transforms into a virile, focused and upbeat participant.

Ultimately the climbers reach the top of the volcano where they are left in a lifeless wasteland. One character appreciates the sublime beauty of the scene, but notes "it seems to me that you don't need the whole planet this way. This will always be here. The atmosphere will never rise this high, so you'll always have this. And the world down below, with all that life growing everywhere- it's beautiful."[90] It is possible to have the beauty of life and the sublime of the untouched in the same place. Roger, having completed the climb and experiencing the thrill of conquering nature, realizes the climb has changed him for the better and finally accepts that it is human nature to alter and change environments. Solace can be found in the beauty of this new world and wisdom in its creation.

[90] Ibid, 175.

Conclusion

This study demonstrates how terraforming science and science fiction relate to larger values and ideals of the 20th century technological culture and establish that both are manifestations of larger cultural narratives. In his examination of the impact of technology on culture and values, Junzo Kawada explains that industrialism impacts human society in ways that result in a technological culture, which he defines as "a complex of certain technological principles, in connection with a set of value orientations, such as worldview, attitudes towards living things, productivity and labour."[1] This results in the advancement of cultural values which relate directly to the ways a nation incorporates industry. A survey of works on the history of technology in America reveals a key set of values that demarcate American technological culture including a view of technology as a means to create a materially wealthy and modern society, a glorification of engineers and a consensus that vast technological projects can conquer and improve nature, thereby utilizing resources that would otherwise be wasted. The earliest hard science fiction treatments of terraforming emerging from 1930-1960 manifested these values.

These values were perpetuated throughout the 1960s in both the science and hard science fiction. Carl Sagan was the first scientist to propose a terraforming scheme designed to allow human expansion into the solar system. Though it is unclear if Sagan's ideas were directly influenced by hard science fiction, his approach to the problem and final solution paralleled the work of Poul Anderson. His scientific plans for terraforming

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[1] Junzo Kawada, "Technology and Its Value Orientation," *Culture and Technology in Modern Japan*, eds. Ian Inkster and Fumihiko Satofuka (London: Victoria House, 2000), 129.

inspired further plans for terraforming by Anderson. Anderson's work further connected terraforming to the technological culture, depicting it as a technological feat would provide humanity with a wealth of knowledge, strengthen unity on Earth, and provide a refuge from potential natural or nuclear devastation.

Counter-narratives questioned the justifications, methods, and morality of terraforming. Beginning in the 1950s, authors like Walter M. Miller challenged the visions of terraforming proposed by previous authors. His vision of terraforming was one of great pain, sacrifice, and emptiness. James Blish depicted terraforming as the tool of the hegemonic powers, used to oppress human freedoms and perpetuate servitude. Freedom would only come by altering individuals, not altering worlds. Poul Anderson questioned humanity's ability to resist planetary imperialism, especially when profit motives came into conflict with natural environments and indigenous life.

Throughout the 1960s and 1970s, growing awareness of pollution, fears of exponential population growth, and concerns about climate change resulted in further criticism of technological culture and values. Barry Commoner and the appropriate technology movement argued science and technology could not alleviate the world's problems. Others like Paul Ehrlich, Garret Hardin and the Club of Rome argued that only legislation against further population growth, limits to further technological expansion, and a wholesale rejection of the technological values in preference for a global equilibrium could reestablish the balance that the world desperately needed and allow humanity to live within its means.

The negative impacts of technology generated a cultural backlash and the New Wave science fiction genre emerged with a skeptical view of technology that challenged the forms, narratives, and themes of hard science fiction. Richard McKenna portrayed terraforming as a destructive and dark force that corrupts the wholesomeness of nature. Attempts to “tame” nature ultimately fail, and salvation is found in uniting with nature, not fighting or taming it. Roger Zelazny showed the epic costs of terraforming, depicting it as a selfish act that inherently prefers one life form to another. For him, humans have a responsibility to act as stewards of nature, not destroyers.

But technological enthusiasts rejected such pessimism, clinging to the technological culture and foundation narratives that supported it, while offering new solutions. They argued resource depletion and overpopulation were precisely the things that technology would be able to solve. Gerard O’Neill offered plans for space colonies that would remove humanity’s worst polluting industries and excess population from Earth, while providing abundant free energy and fantastic new second creations floating in space. Burns and Harwit, Jerry Pournelle, and James Oberg envisioned terraforming as a way to harness other world’s resources to break free of the restrictions imposed by Earth’s limited resources. Just as pioneers used technology to tame the frontier, the solar planets could quickly and efficiently be converted into second creations by colliding asteroids, building fantastic technologies or initiating nuclear explosions. Concerns for perpetuating humanity and promoting expansion overwhelmed worry about impacts of their plans on natural landscapes, indigenous life, or the environmental.

But not all scientific researchers agreed with this technological terraforming narrative, and by the end of the 1970s, a separate ecological terraforming narrative evolved. Responding to the growing environmental activism, Carl Sagan drew on Lovelock’s Gaia hypothesis and envisioned terraforming primarily as a biological process to use on sterile planets. Contrary to previous stories and scientific plans, terraforming would not provide a source of commodities or a refuge for excess human populations and it would only be done with environmental values in mind. NASA researchers Averner and MacElroy also pushed for simpler terraforming techniques, insisting that biological transformations offered the most efficient path to convert Mars.

Yet, neither Sagan nor Averner and MacElroy could envision terraforming outside the technological foundation narrative. Their plans were reliant on technological processes like biological engineering and inherently required complex technological systems to be carried out. Sagan argued terraforming was a way to satisfy humanity's spiritual need to conquer and colonize new frontiers, a notion that stretched back to the earliest terraforming science fiction. Averner and MacElroy viewed terraforming as a way to create a "useful" planet that could provide further resources or space for humanity.

Chapter five demonstrated these two narratives proliferated widely throughout the 1980s. The technological terraforming narrative propagated in hard science fiction, scientific articles, and popular science alike optimistically predicted a time when fantastic technologies would allow humanity to harness wasted spaces and fix nature to suit human needs or whims. Based in the traditional technological foundation narrative, this narrative insisted terraforming would occur in the same ways and for the same reasons that humanity has always expanded into and conquered new territories. Humans would inevitably terraform other planets just as humans had first started using agriculture, built canals, and conquered the New World.

By contrast, the ecological narrative limited the vision of terraforming, insisting that Mars was the only viable target, and the only way to practically transform it was by establishing ecological systems. Researchers Penelope Boston and Christopher McKay insisted that terraforming should only be performed by biological processes that allowed life to take hold on another planet and flourish in its own unique way in its own timeline. This narrative sought to ameliorate environmental values by ostensibly eschewing technology and industrialism, allowing Mars to evolve in a "natural" way that would not duplicate Earth.

Yet, this narrative still relied on artificially created, genetically engineered organisms that imperialistically dominated a foreign space and duplicated Earth-like ecosystems. In this way, the ecological terraforming narrative ultimately conformed to the values and visions of the technological culture. As terraformers struggled to find ethical justifications for their plans, a synthesis was formed between the two narratives: terraforming is justified because it uses life, not technology, to turn a dead useless planet into a live useful one. This middle landscape found poignant expression in Kim Stanley Robinson's novella *Green Mars*, embodying a narrative terraformers would use well into the 21st century.

Both terraforming science fiction and science conform to the values promoted in the technological foundation narrative. They followed the basic premise of the established narrative, were constrained by it, and conformed to the values in it. This interaction reveals the impact of cultural narratives on how members of a culture both construe their reality with science and view their future with fiction.

Secondly, I have sought to demonstrate that terraforming hard science fiction and science overlap, negotiate with and inform one another. It is not just a case of one influencing the other in form or content. The boundaries between the two overlap as they share form and content.

This crossover began in hard science fiction that was based on rigorous extrapolation from known scientific rules and laws. Authors of the first terraforming stories, such as Arthur C. Clarke and Robert Heinlein, were often trained in the sciences or engineering, and used their expertise to craft hard science fiction stories that advanced ideas based on scientific laws. Poul Anderson and Gregory Benford based their ideas on extensive scientific research. Anderson amassed libraries on research topics and Benford spent years doing research for his terraforming plans. They used this research to create realistic worlds in which to base their scientific extrapolations. Pamela Sargent extensively researched terraforming Venus in the work of Carl Sagan and James Oberg. When known scientific law did not conform to the needs of plot, these authors would utilize gobbledygook, namely theoretically plausible, though scientifically unverified, ideas. Like Arthur C. Clarke's meson reaction in *The Sands of Mars*, these ideas were still founded on scientific law.

Such scientific verisimilitude communicated scientific information to readers. These texts were essentially popular science. For instance, Lovelock's *The Greening of Mars* extensively details the origins of life, the existence of intelligent life in the universe, the evolution of Earth's atmosphere, the greenhouse effect, conditions on Mars and its atmospheric functions. The authors in this study felt such research and methodology lent their work scientific legitimacy. Like the practicing scientists, authors based their ideas on facts, published them, and discussed them in open forums. For instance *Analog*'s letters column acted as a place both for criticisms of old ideas and advancements of new ones. Authors were held to standards of truth and legitimacy in these forums, as readers, reviewers and other authors engaged in digging out logical fallacies or incorrect scientific information in stories. Such standards and open communication led authors like Pournelle, Benford, and Anderson to question the difference between well-crafted hard science fiction and speculative science, going so far as to argue that, in some ways, hard science fiction forums were superior to scientific ones. Statements by John W. Campbell, Jerry Pournelle, Gregory Benford and others indicate the authors' beliefs that hard science fiction venues allowed for open, unbounded speculation; something they believed was critical to scientific progress, but rarely afforded within the sphere of professional science.

Just as there was science in terraforming hard science fiction, professional and popular texts on terraforming manifest genre elements of hard science fiction. Like hard science fiction, they invoked gobbledygook. From Dyson engines to self-replicating systems and anti-matter engines, these researchers relied on plausible scientific and technological developments to advance their terraforming plans, just as hard science fiction authors used them in their stories. Oberg, Adelman, and Smith often used hard science fiction vignettes within their professional publications to lend plausibility and explain elements that might other wise be difficult to grasp. These vignettes also communicated emotionally laden depictions of sublime landscapes that terraforming would create. Researchers like James Oberg and Martyn Fogg both described their work in terms similar to hard science fiction authors as efforts to extrapolate from scientific laws what would be possible in the future. They insisted that their ideas were not to be taken as literal plans for the future, but “existence proofs” demonstrating that terraforming was something future civilizations would be able to accomplish. Finally, terraforming researchers like Sagan, Oberg, and McKay drew liberally from hard science fiction authors, citing and explaining their ideas in professional and popular works alike, alternately criticizing, praising, or emending them as they did ideas of professional scientists. They then published their ideas in scientific and science fiction venues.

My third goal has been to show that within this cross-boundary interaction between hard science fiction and scientific research the study of terraforming engages with the studies of epistemological boundaries. Clearly hard science fiction, and terraforming in particular, challenge interpretations of boundary work that rely on the categories of science and non-science and their claims to epistemological authority. Gieryn depicts boundary contests in which scientists jockey to assert their authority and interpretations over other scientists and non-scientists alike, ultimately “claiming” an area of knowledge for themselves, essentially removing it from influence or development of non-professionals. While it could be argued that scientists used their credibility to establish terraforming as a legitimate area of scientific inquiry, they never laid “claim” to terraforming in any significant way. The idea of terraforming persisted regardless of scientific disapproval and the term “terraforming” persisted despite attempts by scientists to re-brand it as microbiological engineering, biological ecosynthesis, or atmospheric engineering. Furthermore, the topic was never exclusively relegated to scientists, and hard science fiction authors continued to develop the idea in concert with scientists. If the categories science and science fiction must be used in regards to terraforming, then it might be best to describe them as partners rather than dominator and dominated or claimer and claimed.

In addition, my history of the interaction between science and fiction in the creation of terraforming resonates with imbalances that Roger Cooter, Stephen Pumpfrey and Andreas Daum argue need addressing. Clearly the history of terraforming does not conform to the diffussionist model of scientific transmission that Topham, Secord, Lewensein and others cited in the introduction seek to dismantle. Instead the interaction is a dynamic one that responds to ideas advanced by scientists and non-scientists alike; it is not simply a case of elite knowledge being passed down to a passive popular audience. This study also responds to Cooter's and Pumphrey's calls to investigate broader arrays of texts and locations into the history of science including non-scientific texts and popular prose. Daum argued that three imbalances persisted in the history of popular science and culture: a general lack of studies pertaining to the larger humanities, excessive attention to Victorian popularizations, and an "astonishingly" small number of studies set in the 20th century. This study with its focus on 20th century American science and hard science fiction addresses these imbalances. This study, with its emphasis on cultural narratives and their impact on both science and fiction also satisfies Daum's call for historians to seek to understand how public knowledge "becomes part of the larger fabric of practices and oral, written, or visual presentations that societies develop to make meaningful statements about themselves and the natural and cultural worlds they find themselves in."[2]

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[2] Daum, "Varieties of Popular Science and the Transformation of Public Knowledge," , 323-326, quote 331.

I feel the history of terraforming also responds to Katherine Pandora's ideas about a vernacular conversation where a democratic range of voices shared their ideas in a variety of outlets in an effort to envision the future of humanity in relation to nature and technology. Hard science fiction authors embedded in the technological culture were the first to imagine the idea as an immense engineering activity involving fantastic technologies, some based on pragmatic ideas, others on gobbledygook. Poul Anderson advanced the most detailed terraforming plan, relying on both technology and genetically modified organisms to recreate Mars, Venus, and the Moon into wondrous worlds. Carl Sagan grew up an avid consumer of hard science fiction stories, and their ideas and visions influenced his professional life throughout his career. Perhaps unsurprisingly, he was the first professional scientist to advance terraforming plans and, though it is not documented, it likely that he read Anderson's stories. While he sought to downplay science fiction elements of the idea in his 1961 *Nature* article, his techniques and final vision of a terraformed Venus illustrated he was thinking about the problem in the same way as Anderson and developed similar solutions. Anderson, in turn, popularized and further developed Sagan's plans in his 1964 story "To Build a World." Anderson's and Sagan's ideas inspired both Jerry Pournelle and Gregory Benford, who wrote up their versions of terraforming in both popular science and science fiction works. Their ideas further inspired James Oberg, who published a popular summary of terraforming science in the early 1980s. The work contained Oberg's own plans for Venus, which in turn inspired Pamela Sargent and her hard science fiction epic *Venus of Dreams*. Many of these plans drew heavily on the Gaia hypothesis by James Lovelock, who, in turn, created the boundary-blurring novel *The Greening of Mars* that contained his own carefully extrapolated plans for terraforming Mars. His ideas went on to greatly influence researchers, including Christopher McKay who adapted Lovelock's plans into his scientific publications on terraforming. In this vernacular conversation, it is clear that the notions of "popular," "scientific," and "science fiction" were largely irrelevant as the idea evolved in a space where ideas circulated "without regard for scientific propriety…providing opportunities to engage in speculation at odds with the rhetorical norms of academic science." In particular the role of hard science fiction in the proliferation of terraforming further illustrates Pandora's ideas that the vernacular conversations, despite not being sanctioned by elite authority, proliferate across diverse venues creating "memorable images infused with emotion that persist across social space and generational time."[3]

This pattern of interaction continued throughout the 1990s and into the 21st century. In June of 1991, NASA hosted a conference at the Ames Research center on terraforming Mars. Over two days, the participants discussed potential ways Mars could be altered through the green-house effect.[4] Three participants from the conference, Chris McKay, Owen Toon, and James Kasting, published the conclusions of the meeting in a 1991 article in *Nature,* one of the most prestigious science journals, in which they proposed a plan similar to the one outlined by Lovelock using CFCs to warm the planet and then introducing plants would likely produce a human-breathable atmosphere within 100,000 years. This publication received world-wide attention in the popular press, prompting the publication of a special edition magazine on the topic by the Japanese

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[3] Pandora, "Knowledge Held in Common: Tales of Luther Burbank and Science in the American Vernacular," , 492.

[4] NASA Workshop on Terraforming Mars, Ames Research Center, June 1991.

Yazawa Science Office.[5] McKay, at NASA Ames, arranged two separate terraforming conferences. "The Physics and Biology of Making Mars Habitable," was held at the NASA Ames in October 2000. It dealt exclusively with altering Mars' environment so that it could support life, possibly including human life. The second conference was held in March 2004, and cosponsored by the Science Fiction Museum and Hall of Fame. Titled "Science Fiction Meets Science Fact," it included a debate about terraforming between scientists Chris McKay and James Kasting, and science fiction authors Arthur C. Clarke and Kim Stanly Robinson. Over 40 different researchers published more than 100 professional and popular articles on terraforming between 1990 and 2001. In 1993, the verb "terraform" was added to the *Oxford English Dictionary*.[6]

Terraforming Science or Science Fiction?

Where in the continuum between professional science and hard science fiction does terraforming ultimately lie? To some degree terraforming maintains the trappings of a science. It has been examined and developed by a community of professional scientists from Carl Sagan to the ongoing work by Christopher McKay and Robert Haynes. Ideas about terraforming have been published in a wide array of peer-reviewed and professional journals, ranging from the speculative-leaning *Journal of the British Interplanetary Society* to the more conservative *Nature* and *Science*. The idea has also been discussed in an array of scientific conferences. Finally, in recent years the idea has been developed to the point where it has moved from feasibility studies done with "back

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[5] *The Terraforming of Planets, Man-made Biospheres and The Future Civilization*, Yazawa Science Office, Tokyo (1992).
[6] L. Brown (Ed.), *The New Shorter Oxford English Dictionary*, Vol. 2 (1993).

of the envelope" calculations and guesses, to comprehensive assessments in recent work by authors such as Martyn Fogg. Based on these developments the boosters of terraforming such as Oberg, Pournelle, and Fogg certainly assert its veracity as a science. But is it science?

Many elements of the idea suggest it is not. First, it is an act that cannot currently be verified in any meaningful way. No simple experiment can be set up to determine if terraforming can be done in a manner that will achieve the desired goals. Nor is there a way to determine if a terraformed result could be repeated under other circumstances. In fact, the more that is learned about ecological and environmental systems, the more distant the idea of altering them to conform to our needs seems. For instance, Mars is the best target for terraformers, but only a fraction of Mars' natural systems have been explored and much more must be understood before it is known if a terraforming plan is even possible, let alone feasible. Second, the technologies that terraforming schemes rely upon are either vastly extrapolated versions of current technology or speculative forms based on postulated future developments. In both cases the practical development and functioning of such technologies are considerable unknowns. Third, most estimates put the process of terraforming on a millennial timescale requiring an investment of resources that seems untenable and the likelihood of achieving a desired outcome over such a span minute.

Where does that leave the epistemological statue of terraforming? Again, I feel Pandora's idea of a vernacular conversation is useful. In this sense, the terraforming conversation can be seen as a broad and interdisciplinary public inquiry of the future of humanity and its relation to nature and technology. In the case of terraforming, this conversation takes on a particular style, or genre, which could be referred to as "speculative science" which maintains its own set of conventions. It allows fictional, non-fictional, and hybrid forms, generally written by authors from diverse scientific backgrounds. The ideas they posit adhere to known scientific and technological laws, but gobbledygook is permissible provided it also adheres to known laws or explains how such laws are circumvented. Settings for these texts are in future or near-future times, and generally limited to locals within our own solar system. Finally, science and technology are generally used as tools to achieve human-centric goals. In this manner terraforming can be placed somewhere between a scientific and cultural phenomenon, in a middle landscape between science and hard science fiction.

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