

the ecological COLONIZATION OF SPACE

“IMAGINE THAT MARS is a Utopia in which there is complete trust, total harmony, no selfishness and no deceit,” Richard Dawkins encouraged readers of *The Extended Phenotype*, published in 1982. “Now imagine a scientist from Mars trying to make sense of human life and technology [on Earth].” Dawkins attributed this Martian outlook to the “pop-ecology literature” of James Lovelock and to the followers of Lovelock’s Gaia thesis. The image of an ideal community on Mars was not accidental; leading ecologists in the 1970s were investigating how to construct colonies on Mars and how this research was relevant to understanding ecosystems on Earth. In 1975, Edward O. Wilson, for one, advised readers of his *Sociobiology* to view life on Earth as “a perceptive Martian zoologist.”¹

This article investigates what ecologists sought to do on Mars and what the Martian perspective meant for their understanding of life on Earth. It is a history that originated in military research into constructing self-sufficient closed ecological systems within submarines and underground shelters. In the U.S. space program of the 1960s, this know-how was used by leading ecologists to suggest construction of closed ecological systems within space capsules, ships, and colonies. Their research into the ecological “carrying capacity” for a given number of astronauts within a spaceship subsequently was used to analyze carrying capacity onboard Spaceship Earth. In the 1970s, environmental ethics became an issue of trying to live like astronauts by adapting space technologies such as bio-toilets, solar cells, recycling, and energy-saving devices to general use. Technology, terminology, and methodology developed for ecological colonization of space became tools for solving environmental problems on Earth.

Space colonization caused hardly any controversy until 1975, when royalties from the counterculture sourcebook, *The Whole Earth Catalog*, were used to

finance space-colonization research. In the debate that followed, the overwhelming majority thought space colonies could provide well-functioning environments for astronauts seeking to push human evolutionary expansion into new territories, while also saving a Noah's Ark of earthly species from industrial destruction and possible atomic apocalypse on Earth. To supporters, space colonies came to represent rational, orderly, and wise management, in contrast to the irrational, disorderly, and ill-managed Earth. Some of them built Biosphere 2 in Arizona to prepare for colonization of Mars and to create a model for how life on Earth should be organized. The skeptical minority argued that space colonization was unrealizable or unethical, yet nevertheless adopted terminology, technology, and methodology from space research in their efforts to reshape the social and ecological matrix onboard Spaceship Earth.

The use of colonial terminology was deliberate and in line with the imperial tradition from which ecology as a science emerged. According to Stewart Brand, a leading defender of space colonization, the term "space colony" (instead of "space settlement") was unproblematic since "no Space natives [were] being colonized."² Yet, as this article argues, when space colonies became the model for Spaceship Earth, all human beings became "Space natives" colonized by ecological reasoning: Social, political, moral, and historical space were invaded by ecological science aimed at reordering ill-treated human environments according to the managerial ideals of the astronaut's life in the space colony.

The colonialist agenda of space research invites the use of postcolonial theory. Though hardly novel in other areas of historical research, postcolonial analysis has yet to be applied to the history of ecology. The connection between ecological colonization of outer and earthly space has largely been ignored.³ The few historical analyses of space ecology that do exist have hardly paid attention to its importance to ecologists' understanding of Earth.⁴ Scholars have rightly emphasized the significance of modeling closed ecosystems, but have not placed this methodology in the context of ecological colonization of space.⁵ This article holds that advocates of the Martian ecological perspective sought to create on Earth what one proponent described as a "neo-biological civilization" at the expense of the humanist legacy, which holds that every human being has intrinsic and unique capacities, dignity, and worth.⁶

THE MILITARY PATRONAGE OF CABIN ECOLOGY

"CABIN ECOLOGY" was the term scholars in astronautics used in the late 1950s to describe the environment inside a space vehicle. The best way to build space cabins, they believed, was to make their environment as close as possible "to the environment found on the surface of the earth."⁷ About one hundred engineers and scientists worked on the development of such systems for circulation of air, water, and food. This cabin-ecology research was sponsored by the military, which considered this topic to be vital to the construction of submarines, atomic shelters, and environmental planning.

In 1958, submarine development was the focus of about two hundred scientists sponsored by the American Institute of Biological Sciences working on different

cabin-ecology designs. One of them, the biologist Jack Myers at the University of Texas, had for years studied “the use of plants to regenerate air in a closed ecological system, such as that of a space cabin.” This research was used, according to a report published in the journal *Missiles and Rockets*, by submarine engineers to improve the “space flight under sea.” The use of “ecological systems for underwater vehicles” later became the norm in spaceship engineering.⁸

Construction of shelters was also tied to cabin-ecology designs. In the fall of 1961, President John F. Kennedy outlined his program for a nationwide civil defense effort, which threw the country into a shelter building mania. All over America people built shelters according to design handbooks made available by the Office of Civil Defense. A 1965 technical manual, *Shelter Design and Analysis*, typically stated that “[p]roblems of habitability in closed ecological systems have been solved in the past with excellent results. Notable examples of such systems are submarines and space capsules.”⁹ The manual simply applied the principles of closed ecological systems developed for space cabins to large and small underground shelter designs. Inside these underground cabin ecologies, people were to survive for years, months, or weeks (depending on their military importance).

Military environmental planners also took interest in cabin ecology. “A good decentralization program would ... reduce the target attractiveness” in atomic warfare, one typical military analyst wrote.¹⁰ Effective atomic defense required dispersion of the population to the countryside, where people ideally would live in self-sufficient small farms while also nurturing the ability to survive in wilderness. The ultimate program of decentralization would be to place humans in space to secure the survival of the species in case Earth was destroyed in atomic apocalypse.

Though the word “ecology” was widely used in military research, few professional ecologists were actually engaged. This changed in 1962, when the Ecological Society of America arranged a session to discuss the emerging science of space ecology at the annual meeting of the American Institute of Biological Sciences.

HUMAN ECOLOGY IN SPACEFLIGHT

IN MAY 1961, Kennedy announced that the United States should commit itself to sending a spaceship to the moon and to return it safely to Earth. With this ambitious program, and the research money that followed it, the time was ripe for ecologists to get involved. By organizing a session on space ecology, the Ecological Society hoped to establish a closer liaison between space researchers, military engineers, and natural ecologists. Three conferences were held at Princeton University in 1963, 1964, and 1965 about “Human Ecology in Space Flight,” arranged in collaboration with the Office of Naval Research and the National Aeronautics and Space Administration (NASA).¹¹

The brothers Eugene P. Odum and Howard T. Odum were two leading ecologists who jumped on the opportunity to put ecology in service to space exploration. Historians have discussed how in the 1950s and 1960s the Odum brothers, thanks

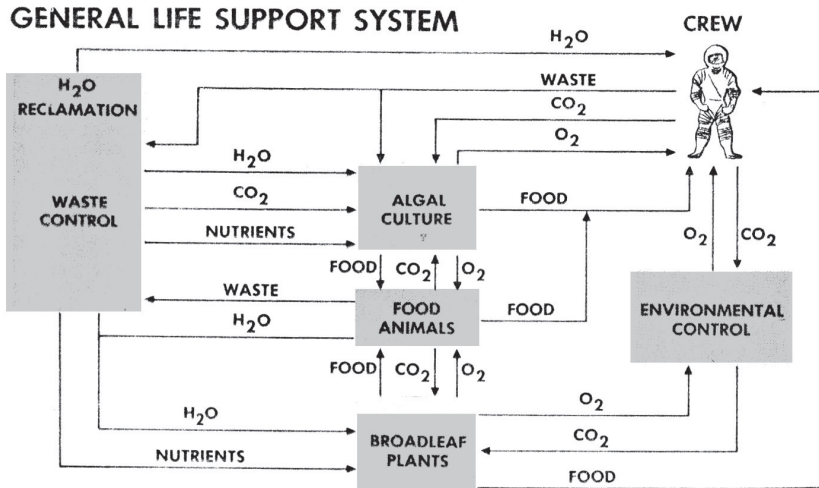
to patronage from the Atomic Energy Commission, came to the forefront of the field by bringing energetic systems theory to ecology.¹² By diagramming the flow of energy in the natural world as input and output circuits in a cybernetic ecosystem, they provided ecologists with new theories and research techniques. Their social program was to bring human activities into balance with the ecosystem through natural, social, and technological engineering. They would throughout their lives be firm supporters of ecological colonization of space.

Eugene Odum thought that to build space cabins, one simply needed to take “a little piece of this biosphere ... and try to build a wall around it so that it would be materially closed but not closed to energy flux.” Howard Odum agreed. It was possible to support humans in space by constructing “a *climax (steady state) ecosystem of many species*” within the space cabin with a “carrying capacity” for a few astronauts. The term “carrying capacity,” it is worth recalling, was first used by Mark Twain in 1883 to describe maximum loads of people and goods on a steamboat, and it had since then mainly been used as a technical expression in shipping. The Odum brothers used the term correspondingly to articulate a spaceship’s ability to support a given number of astronauts.¹³ Close management of the population dynamics of species onboard would be of paramount importance for the ship’s survival. The astronauts would have to live in harmony with the spaceship, something that became equally important when the “carrying capacity” concept became an ethic for humans onboard Spaceship Earth.

The chief professional challenge for the ecologists was how to engineer a viable ecosystem in space. According to Eugene Odum, the solution was to “combine natural components with mechanical shortcuts” in designing the cabin’s dependence on solar energy, recirculation of sewage, air, and water, and production of the crew’s food such as algae or slugs. Other ecologists suggested that microorganisms grown in human urine could be a source of nutrition. They regarded the astronaut as being an integral part of the closed ecosystem, or as Myers pointed out; “the human goes into space, not as a passenger, but as an essential part of the instrumentation needed for a particular mission.”¹⁴ This instrumentalist view of human agency as serving a higher mission of the spaceship was later projected into ecologists’ writings about the ethics of carrying capacity for humans onboard Spaceship Earth.

The space cabin was to be a self-sufficient and stable ecosystem. “Complexity lends stability,” argued the Marine biologist Bernard C. Patten, who saw a “connection between information theory and ecological theory” with respect to the “self-organizing capabilities” of both systems.¹⁵ The idea of using plankton and algae as food was justified by the possibility of synchronizing computer design of the spaceship with the statistical behavior of plankton communities. The robustness of both systems would depend on the complexity of information circuits and number of species. Different species within an ecosystem would feed on each other and thus maintain the stability of the system. The space cabin therefore needed to be equipped with high-tech computer-driven air-conditioning, composting, bio-toilets, algae-sewage rinsing, and solar cellars. These biotechnologies were meant to secure human evolutionary expansion and

Figure 1. A “Life Support System” for Astronauts Living in Space.



From S. P. Johnson and J. C. Finn, "Ecological Considerations of a Permanent Lunar Base," *American Biology Teacher* (1963): 530.

adaptability in space, and would later be regarded as soft-tech eco-friendly solutions necessary of human survival on Earth.

Ecologists also made designs for a lunar base. To be situated forty feet under lunar ground, the base was imagined as a 250,000-cubic-foot closed ecosystem with carrying capacity for twenty-five astronauts. The proposal was supported by a "general life support system" complete with charts for the circulation of oxygen, carbon dioxide, nutrients, waste, plants, animals, and astronauts (see Fig. 1). Eugene Odum's work on climax ecology served as the methodological foundation for constructing a steady-state biotic community on the moon. A larger ecosystem was better than a small one, he argued, since a "diverse system is safer" due to its robust biotic complexity.¹⁶ The moon base was to circulate all its material resources, an aim which later became the architectural ideal for earth-based ecological buildings.

The moon base was imaginative, though NASA was looking for simpler designs for the first space flights. A general agreement emerged from the Princeton conferences that it was unnecessary to build the self-maintaining ecosystem the ecologists imagined for a flight of only a couple of weeks. It would be simpler to rely on food storage and chemical rinsing of air and water than to incorporate biological systems within the spacecraft. For this reason, ecologists did not take part in the engineering of the first space cabins, the space shuttle, or the space station that eventually orbited around the earth.¹⁷ At the same time scientists generally agreed that functioning ecosystems would be necessary for voyages into deep space and for permanent bases on the moon or Mars, since it would be too expensive and complicated to supply such projects from Earth.

Though the ecologists failed to offer NASA a workable short-term proposal for a cabin-ecology system, they did provide an outlook that shaped future

projects. Their ideas consequently would capture the imagination of science fiction and futurist writers. The founder of the British Interplanetary Society, Arthur C. Clarke, for example, used ecological arguments as the scientific basis for the screenplay to Stanley Kubrick's 1968 film *2001: A Space Odyssey*. "The [Moon] Base imagined in the movie," Clarke explained, "was a closed system, like a tiny working model of Earth itself, recycling all the chemicals of life."¹⁸ As science fiction, such fantasies were intriguing, especially to the larger public.

The idea of closed ecological systems was also easy to communicate to students. If the complexity of Earth's nature could be replicated in a small space cabin, one could also replicate it in textbooks. Some of the cabin ecology papers were published in *American Biology Teacher*, for example, because the editors believed that the idea that cabin ecology was an ideal way of bringing the complexity of nature into classrooms. Dennis Cooke, a graduate student of Eugene Odum, emphasized this in his chapter in the third edition of Odum's classic textbook *Fundamentals of Ecology*. He claimed that space exploration was "one of the most exciting new areas in science" generating necessary "lebensraum" for human evolutionary expansion. By evoking the old justification of imperialism, he sought to inspire new students of ecology to devote their research to space exploration. Odum agreed. He believed ecological colonization of space needed help from the scientific community, "and a little financial support from NASA." As Ramón Margalef noted, space ecology was "likely to draw more attention (and surely more money!) than biology."¹⁹

LIVING ONBOARD SPACESHIP EARTH

THE IMAGE OF the earth as a giant space cabin sailing through space with human astronauts onboard came to dominate ecological debates in the late 1960s and 1970s. The use of the space cabin, or the astronaut's *oikos*, as the model for nature's household continued a long tradition in ecology of modeling nature on human homes.²⁰ The framing of nature in terms of life in space cabins enabled an ecological ethic for humans on Earth modeled on the scientifically manageable astronaut.

Buckminster Fuller was probably the first non-specialist to notice human ecology in space research. As the designer of a series of domes and maps used for military purposes and a keen admirer of the Navy, he knew firsthand what was going on in military research. As early as 1963, he noted that "billions of research dollars" had "been applied to a closed chemical circuit of ecologic ... living of moon-rounding men." Around the same time Fuller started using cabin ecology in his lectures as a model for understanding life on Earth. "We are all astronauts," he explained in 1969 in his *Operating Manual for Spaceship Earth*, a book that postulated using cabin-ecology engineering manuals to solve environmental problems on Earth.²¹

Fuller's lectures inspired the economist Kenneth Boulding to write his influential article "The Economics of the Coming Spaceship Earth" in 1966. It was the first attempt to apply cabin ecology to macroeconomics. Boulding juxtaposed an unruly "Cowboy economy" with an "open" and exploitative ethic

and a virtuous “closed” economic system with an ethic of responsible management of the earth as a grand spaceship. The article soon became a standard reference for eco-friendly economic theorists.²²

Another of those who became inspired by the new ecology was Barbara Ward, an international economist at Columbia University who, in 1966, wrote about using the movement of energy within the space cabin to understand life on *Spaceship Earth*. Like Boulding, Ward was no space enthusiast and believed money would be better spent solving environmental problems on Earth. For this purpose she adopted the managerial ethics developed for space exploration. “Most of the energies of our society tend towards unity” of people, Ward argued. She thought that the United Nations was a promising organization for directing the unity of the planet’s carrying capacity. Science-based politics was the way forward, and she organized conferences where scientists and politicians met to push Spaceship Earth toward an orderly future. This reasoning inspired Adlai Stevenson, the U.S. Ambassador to the United Nations and 1952 Democratic presidential candidate, to note that “we travel together [as] passengers on a little spaceship.”²³

“Spaceship Earth” soon became a key term in United Nations vocabulary, especially after Secretary General U Thant used it in connection with Earth Day in 1970. “Spaceship earth is left without central guidance and stewardship,” he complained in a speech critiquing the world’s lack of commitment to United Nations leadership. The Undersecretary-General of Economic and Social Affairs, Philippe de Seynes, also argued that the concept of Spaceship Earth signaled a new commitment to “globalism,” which, unlike “internationalism,” sought to analyze the world in view of “the degradation of the environment, the destruction of ecological balances, the limited capacity of the biosphere, the possible depletion of natural resources, the population explosion, the finiteness of the planet, and perhaps even the finiteness of knowledge.”²⁴

Concerned environmentalists could not agree more. In the 1970s, Spaceship Earth often was a term used to address ecological issues and the urgent need for global leadership. Future “helmsmen on the spaceship Earth,” one environmentalist argued, should base the political realm on a secure scientific footing.²⁵

Cabin ecologists also used the spacecraft as a model for the earth. When the American Astronautical Society met in 1968 to discuss bioengineering and cabin ecology, for example, the opening lecture was all about the future well-being of Spaceship Earth. The “close analogy between the ecology of a space cabin and the ecology of the planet Earth” served as a point of departure to reflect on the state of the world’s environmental and social conditions.²⁶ Thanks to technologies for managing waste, air, food, and energy, the space cabin came to represent the rational and scientific way to achieve ecological living. Humans on Earth, by comparison, were polluting their cabin with carbon dioxide, were hardly recycling their waste, and did not generate enough energy from the sun. It was consequently urgent to transfer technology from the space capsule to Earth. This, at least, was the view of a representative from the Lockheed Missiles and Space Company who believed technologies developed for the lunar base would be the ideal way of solving many of the ecological imbalances on Earth.²⁷

Viewing Earth as a giant space cabin required a panoramic perspective which came when the Apollo spaceship sent images of the planet back from the moon.²⁸ The view inspired many ecologists who also used the imagined communities of future space colonies to analyze the earth. In *Environment, Power and Society* (1971), Howard Odum made a book-length case for understanding the earthly environment and human activity in terms of astronauts' life in outer space. "The biosphere is really an overgrown space capsule, and the questions about carrying capacity [for humans] are similar," he argued. He did not use the space capsule as a vague analogy or metaphor, but as an ontological claim about the world. His methodological reductionism of all biological life (including human behavior) to charts of energy circuits became the justification for proposals to manage human society scientifically. To live in harmony with the earth's ecosystem was to him a question of adopting space technologies, analytical tools, and ways of living. In 1976, with his wife Elisabeth, Odum pointed in *Energy Basis for Man and Nature* to the importance of a "steady state economy" and an understanding of "our life-support system" on Earth in terms of astronauts' life support systems in a steady-state spaceship. Likewise, as late as 1992, Eugene Odum structured his ecology textbook about "life support systems" in accordance with the life-support systems of the Apollo space flights.²⁹

A similar line of reasoning was promoted by James Lovelock. In the mid-1960s, he suggested a method for detecting life on Mars based on what life on Earth looked like from outer space. He developed and patented a series of detection devices that NASA bought for planetary exploration. These inventions provided him with a small fortune. He was not only financially dependent on space exploration, but had also taken part in the technical development of human ecology in space research. The space cabin was designed as a self-regulating cybernetic system with the ability to maintain the chemical components of the atmosphere through negative and positive ecological feedback loops that provided comfortable living conditions for the astronauts. The Gaia hypothesis Lovelock proposed in 1974 with Lynn Margulis basically postulated Earth as a giant space cabin, complete with a self-regulating system that maintained climate and chemical compositions comfortable for living organisms.³⁰

Some people came to understand Earth in terms of a spaceship even though they did not support space colonization. The population biologists Paul Ehrlich and Richard L. Harriman, for example, fashioned every aspect of life on Earth in accordance with life on a spaceship. The biologist Garrett Hardin also explored the ethical relevance of seeing Earth as a spaceship. In the early 1970s, he developed a special "lifeboat ethics" in which he framed environmental ethics for the planet in terms of naval martial codes. His point was that the human population made Earth like an overcrowded, sinking lifeboat. A suspension of humanist ethics was necessary to keep the boat afloat, he argued, just as Naval military codes might require sacrificing marines to save a ship in trouble. Lovelock agreed. Humans were to him "pollution" spreading "like a disease" threatening to kill Gaia.³¹

THE ECOLOGICAL CYBORG

THE ECOLOGICAL COLONIZATION of moral space came in the form of mundane practices like saving energy, recycling, composting, and (for the most conscientious ones) family planning. This ecological ethic had its bearing in the imagined lifestyle of the astronaut. Understanding the earth in terms of a spaceship implied a new set of technological, ethical, and social tools to guide humans toward the astronaut's way of life. The cyborg became the model for living in ecological harmony with the natural world.

The future was to be organized according to human biological needs, at least if one were to believe the professor in biomedicine René Dubos, who in 1972 argued that "space ecology" implied "entirely new technologies" for living on Earth. Numerous designs for such technologies can be found in the *Whole Earth Catalog*, edited by Stewart Brand, and published in various incarnations since 1968. According to a recent study, the catalog represented a bold attempt to "reconcile nature and the machine."³²

The research of John McHale is an example of the type of technological solutions *The Whole Earth Catalog* promoted. McHale was one of the chief proponents of building a new future in tune with Spaceship Earth, a keen follower of Buckminster Fuller, and the director of the Center for Integrative Studies at the State University of New York. Fuller believed that the presupposition of "a non-flying-man ecology" was mistaken and that humans were destined to a healthy ecological future in space.³³ McHale agreed. A dramatic revolution in ecological design was about to change human evolutionary history, he believed. Humans had previously "spread out horizontally into every corner of the planet," he argued in 1969 in *The Future of the Future*, but were now entering a radically new phase of spreading "into space and down to the bottom of the oceans." That spread signified "another evolutionary form" and the coming of the age of ecology. The fusion of ecology and cybernetics in space and submarine technology was, for McHale, the latest and most important shift in human history. He thought that "the organic fusion of the human organism with active cybernetic components" would create a bionic "cyborg" in ecological harmony with the new space or submarine environments. Images of astronauts in space suits, people engaged with robots, and the uses of various bionic devices were examples of future ecological living. This vision was built upon the "closed ecology" of the space cabin or what he also called "the microearth capsule."³⁴ His point was not that everybody in the future would live their lives in spacesuits (though some would do that too), but that if life on Earth was to be in ecological harmony, one would have to learn to live as ecological cyborgs. Just like astronauts, humans on Earth would have to adjust their lives to a host of computer-driven, cybernetic monitoring control systems in order to steer Spaceship Earth into ecological harmony. Humans of the future would have to let technologies for renewable energy, solar cells, recycling of air and water, waste-processing, sewage management, material reuse, and other health-related technologies developed for space stations be part of their daily lives. The task of the ecologists (with the help of a giant computer) would be to monitor and control all these devices in

view of the earth's overall cybernetic system. Images of the Mission Control Center at the North American Aerospace Defense Command (NORAD) were to McHale images of what the control room for scientific ecological steering of Spaceship Earth eventually would look like.

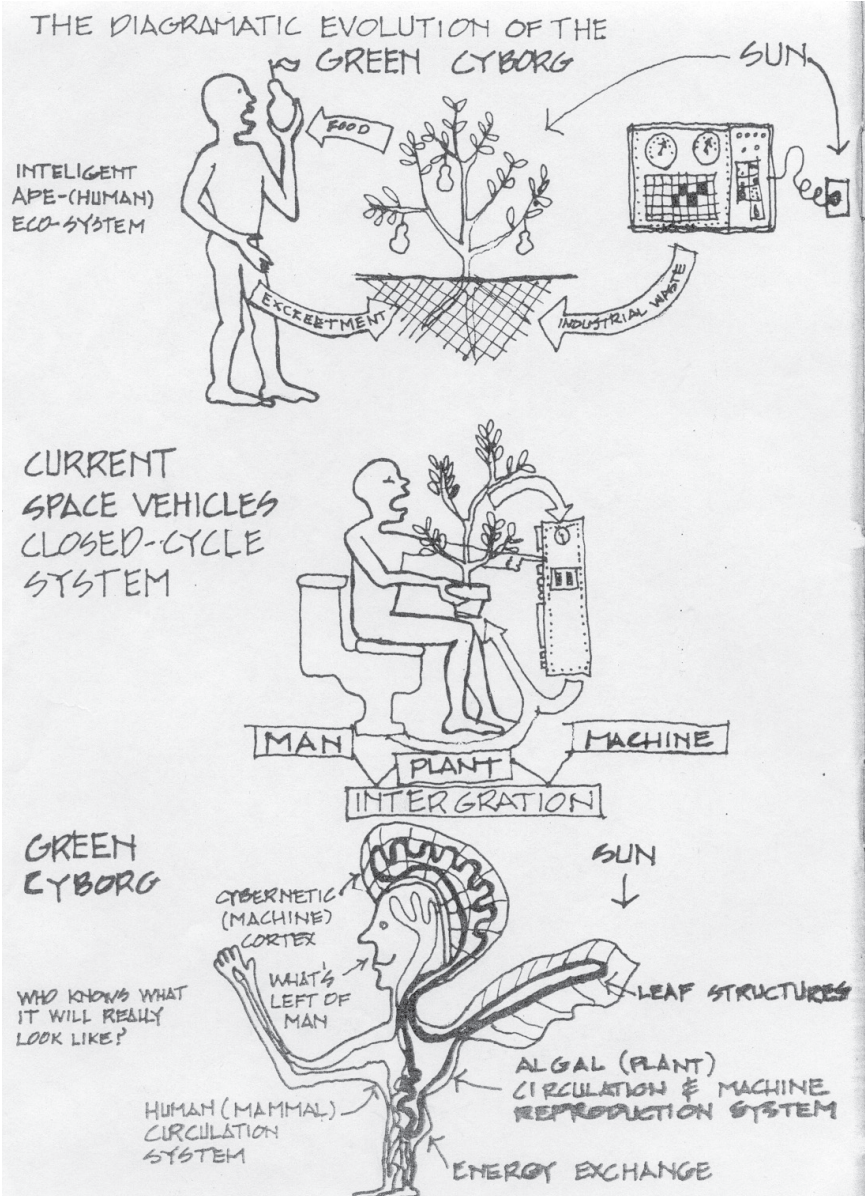
The Future of the Future was well received by reviewers who understood it as an interpretation of Buckminster Fuller's thinking and as an important book in its own right.³⁵ This success encouraged McHale to publish a follow up in 1970, *The Ecological Context*, in which he elaborated on the life-support system of Spaceship Earth. The book was an attempt to monitor the use (or more often abuse) of the earth's energy and material resources. It was crucial, according to McHale, that humans view themselves through the "ecological context" of "planetary housekeeping" and not through "traditional political and economic viewpoints which have guided and measured his large-scale actions before." Using the space cabin as an explicit model, he outlined the ecosystem of the world with cycles of population, food, energy, and various materials. McHale defined the human being as "an energy-converting organism" malfunctioning within the closed ecological system of the earth and thus causing a series of environmental ills. This led him to conclude that Spaceship Earth was out of balance in comparison with the ideal ecosystem within the space cabin. What was needed was an "ecological redesign" of the household of nature through new "ecological housekeeping rules" overseen by specialists at the United Nations.³⁶ In short, the earth should be modeled on space-cabin ecology, and people would have to behave like astronauts in order to live in harmony within its system. As a major organizer of future studies, McHale would promote such ideas for years.³⁷

The systems designer Mike Waters was one of those inspired by McHale. His caricature of "the diagrammatic evolution of the green cyborg" captured how space vehicles would change human relationships with nature (see Fig. 2.) The drawing shows how humans would gradually evolve into green cyborgs thanks to space-cabin technology. The caricature was an ecological elaboration of other cyborg studies imagining "incorporating artificial organs, drugs and/or hypothermia [in astronauts] as integral parts of the life support systems" of spaceships. These ecologically construed cyborgs later became a key source of inspiration for Donna Haraway's thinking about the reconciliation of human relationships with the natural world. The historian of science Michel Serres was equally enthusiastic. To him, the life of astronauts promised a renewal of "the natural contract" the French romantic philosopher Jean-Jacques Rousseau once imagined. "All humanity is flying like spacewalking astronauts," Serres argued in a plea for making peace with "[t]he fastest shuttle. The most gigantic rocket. The greatest space ship [Earth]."³⁸

THE NEXT ECOLOGICAL FRONTIER

THE ECOLOGICAL COLONIZATION of space was a technically and economically viable idea, at least if one were to believe Gerard K. O'Neill, the ex-astronaut candidate and physics professor at Princeton University. His bold visions for space colonization caught the imagination of ecological minded thinkers of the 1970s.

Figure 2. The Green Cyborg.

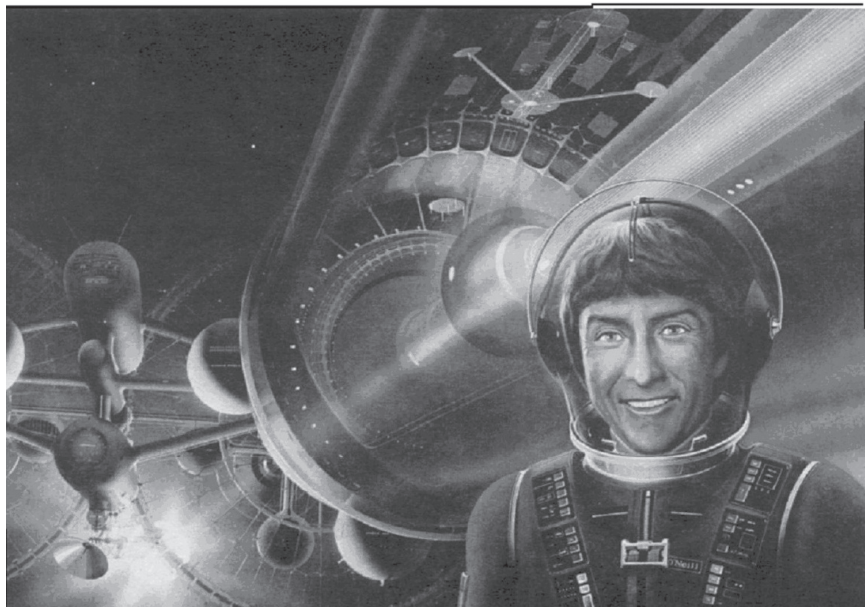


Mike Waters in *Kidstuff* (Berkeley: Department of Architecture, University of California, 1969), 48.

This diagram depicts the imagined historical evolution of green cyborgs as inspired by cabin ecology research.

In 1969, O'Neill's students confronted him with his profession's entanglement with the military-industrial complex, atomic weaponry, and environmental destruction. In response O'Neill designed a course—"Physics 103"—that aimed at studying physics that could produce peaceful solutions to the world's problems. Soon the students were engaged in calculating what it would take to build a colony

Figure 3. Gerard O'Neill.



Penthouse, 1976, Illustration by Shusei Nagaoka.

Gerard O'Neill portrayed as astronaut with the space colony in the background.

in space. This colony was supposed to be free of military purpose, in ecological harmony, without atomic pollution or other suspicious industrial activities, and helpful to the well-being of the earth (including the needs of the inner cities). This assignment resulted in two articles that appeared in *Nature* and *Physics Today* in 1974. "Careful engineering and cost analysis shows we can build pleasant, self-sufficient dwelling places in space within the next two decades, solving many of Earth's problems," O'Neill argued. The idea was to use material resources on the moon to fabricate a grand space station located at one of the points of gravitational equilibrium between the moon and the earth. The station was to be complete with mountains, lakes, and small-town communities. Moving heavy manufacturing to the moon could relieve the earth from polluting industries, and a grand space station could ease population pressure. Such a space station, O'Neill argued, was "likely to encourage self-sufficiency, small-scale governmental units, cultural diversity and high degree of independence." It was to be an Arcadian ecological community rooted in managerial principles.³⁹

The articles raised eyebrows among physicists. According to O'Neill, however, the space colony was not a far-fetched idea in view of the Spacelab program NASA successfully carried out in three missions between 1973 and 1974. Thanks to a series of public appearances, O'Neill soon became a physics celebrity, receiving "thousands of letters" from the broader public about the space colony. The fact that he was interviewed in *Penthouse* may indicate that men were especially fascinated (see Fig. 3)⁴⁰

Former students and environmentally concerned hippies became O'Neill's most loyal supporters. They saw him as a brave professor who was willing to break

Figure 4. Space Colony Landscape with River.

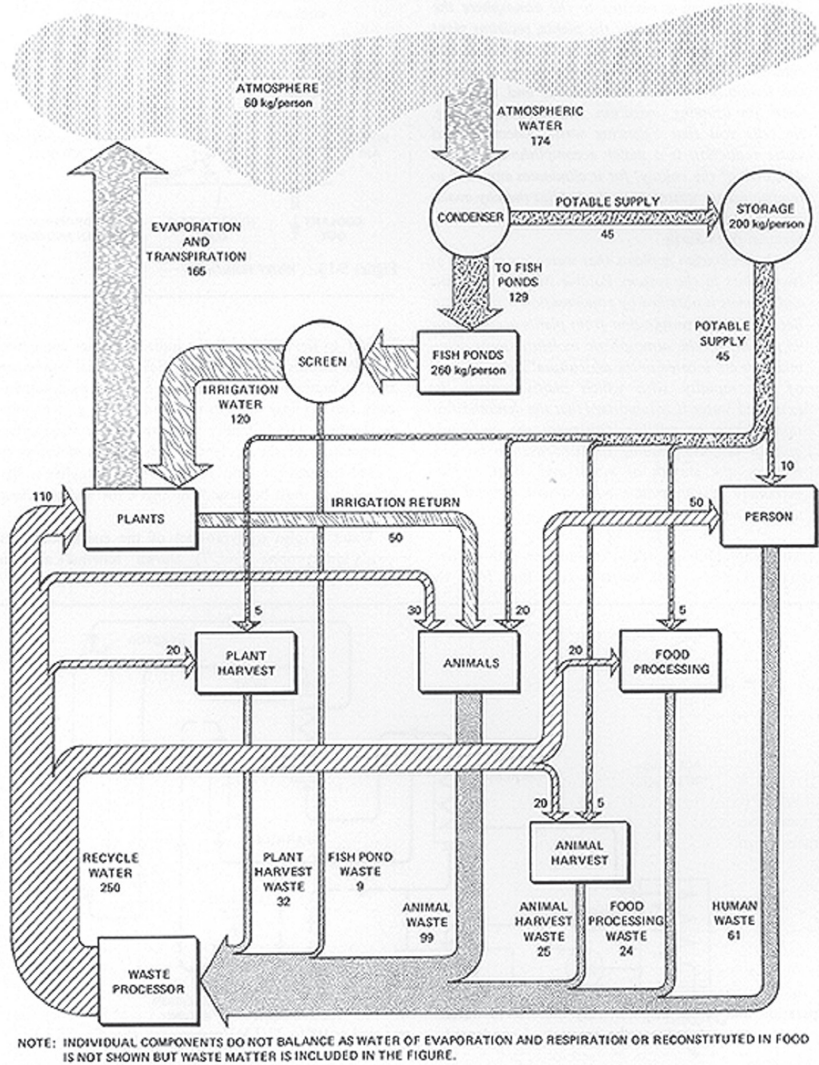


From the NASA report *Space Settlements* (1977). Drawing by Don Davis, courtesy of NASA.

with suspect atomic research to pursue eco-friendly physics. One supporter was Stewart Brand, the editor of *The Whole Earth Catalog*, who used the royalties from this highly successful guide for unorthodox living to generate a research fund, the Point Foundation. He became O'Neill's patron, covering the expenses for the First Conference on Space Colonization at Princeton University in 1975. The conference was a fairly technical showcase of the seriousness of space colonization. One paper published in *Science* argued that O'Neill's suggestion for mining on the moon was feasible and should be pursued. The system analysts Keith Henson and Carolyn Henson contributed another paper, "Closed Ecosystems of High Agricultural Yield," in which they argued that the space ecosystem could provide, among other things, meat from alfalfa-fed rabbits and dairy products from goats. Energized by the conference they went home and started a support group which for a decade came to promote O'Neill's ecological space station. Inspired by systems engineer Wayne Wymore at the University of Arizona, the Hensons calculated the human carrying capacity of future space farms.⁴¹

John Fletcher at NASA was equally excited. He organized a study group at Stanford University "to design a system for the colonization of space" in response to the "finite resources and ominous pollution" on "spacecraft Earth." The result was one of the more imaginative reports from NASA, with colored illustrations of the space colony supported by a diagram of the circulation of water within the capsule (See Figs. 4 and 5). The study group concluded that "Space colonization"

Figure 5. An Ecological Chart for the Circulation of Water Supply in a Space Station.



From the NASA report *Space Settlements* (1977).

was desirable because it offered hope to humanity living in a limited world where “the delicate ecological balance of the planet” was in trouble. Space offered literally “a way out, with new possibilities of growth and new resources.”⁴² It would be, according to one follower, “a pollution-free world.”⁴³

While the group was still working, O’Neill testified before the House Subcommittee on Space Science and Applications that an investment of \$178 billion for a space community of ten thousand people would be paid back in twenty-four years through the sale of environmentally clean energy beamed back to the earth. Given the limits to growth on earth (as described by the Club of Rome’s alarming

report of 1972), O'Neill explained, it was of paramount importance to expand into space. However, Senator William Proxmire, a Democrat opposed to wasteful government spending, declared "Not a penny for this nutty fantasy!"⁴⁴ He did not sway the sub-committee, which recommended a 25 percent increase in NASA's budget to prepare for space colonization.

Intrigued by O'Neill's vision, NASA provided him with money to write a book about his ideas—*The High Frontier* (1977). A space station could solve most of the earth's environmental ills, he argued. The station could be built as a "steady state" economy in harmony with its ecologically engineered system, and clean energy could be sent back to Earth from solar-power satellites in space—a technology proposed by Peter Glaser. Not only could space stations benefit Earth "by relieving Earth of industry and of its burden of population," but "species of animals, birds and fish in danger on Earth will have a better chance of survival" in space. The space station was touted as a Noah's Ark taking an intact ecosystem into space and away from polluting industrialism on Earth. "Noah's passenger list" of species traveling to the space station included only those that were of "pleasure to us" and were necessary for "a complete ecological chain," while "annoying scavengers" such as wasps and hornets were to stay on Earth.⁴⁵

The theory behind O'Neill's ideas derived from Daniel Simberloff and Edward Wilson's ecological methodology for understanding colonization of empty islands. O'Neill's ecological "islands in space" were not, he insisted, science fiction, but "depended on present-day technology, on machines which we are sure we can build within the limits of our present knowledge."⁴⁶ He emphasized this assertion again and again, and backed it up with calculations, tables, and footnotes. His work also carried the authority of his professorship at the prestigious Department of Physics at Princeton, once the home of Albert Einstein.

One who was clearly impressed was the popular science writer Tom Heppenheimer. In 1977 he published *Colonies in Space*, which was widely distributed through Book-of-the-Month Club, Natural History Book Club, Quality Paperback Club, Playboy Book Club, and Macmillan Natural Science and Explorers Book clubs. For popular-science readers, Heppenheimer's work thus became the standard overview on the subject. The book was sold as a remedy to the Malthusian problem of human population growth on Earth, described by the Club of Rome in its 1972 report, *The Limits to Growth*. The technological solutions that came with space colonization, Heppenheimer argued, would solve the earth's energy problem as well as finding new space for an overpopulated planet. "The space colony" would "be a closed-cycle ecology *par excellence*," since all living things would have to live in harmony within the artificially built ecosystem in order for the colony to survive. Solar energy would support farming of vegetables, fruit, fish, birds, and various mammals. The Edenic vision of the space colony as "a land of milk and honey" in balance as "a completely closed ecosystem" served as a contrast to the polluted, ill-managed, and ecologically unbalanced environment on Earth.⁴⁷

The support for the high frontier of ecological space stations grew rapidly. The Governor of California, Jerry Brown, claimed that "ecology and technology find a unity in Space" in his speech on "Space Day" (by analogy to "Earth Day") in

1977. He was a firm supporter of cabin-ecology research, which from 1978 was carried out at NASA under the heading "Controlled Ecological Life Support Systems."⁴⁸ Supporters saw space colonies not as science fiction, but as workable proposals worthy of scientific research. From the point of view of human geography, space stations were an intriguing new environment to analyze.⁴⁹ In the early 1980s, both O'Neill and Heppenheimer restated their arguments by drawing up visions for eco-friendly space stations as well as bases designed for the moon and Mars. A steady group of followers pursued their ideas for ecological colonization of the moon, Mars, and beyond.⁵⁰ One of them was the ecologist and historian Frank Golley, who believed that the ethic of colonization was an inherent quality of western culture. The environmental ethics of "the space colony," he predicted, would set the standard for ecological living "over the entire Earth."⁵¹

THE DEBATE AMONG CO-EVOLUTIONISTS

THE FINANCIAL SUPPORT of O'Neill's space colony from funds generated by *The Whole Earth Catalog* created fierce debates among the journal's readers, many of whom subscribed and contributed to its sister publication, the *Co-Evolution Quarterly*. Stewart Brand, the editor of both publications, devoted much room to the topic which he later collected in the anthology *Space Colonies* (1977). It is worth reviewing this debate in some detail, since it represents possibly the first critical reaction to colonization of space among ecologists and environmentalists.

O'Neill's articles about ecological colonization of space were presented in the fall 1975 issue of *Co-Evolution Quarterly*, with a lengthy interview and a favorable introduction by Brand. Readers were encouraged to voice their opinions about space colonies through a questionnaire and written statements. "Nothing we've run in *The CQ* has brought so much response," Brand noted. Out of 214 replies, 139 (65 percent) thought colonization of space was a "good idea," 49 (23 percent) thought it was a "bad idea," and 26 (12 percent) were "not sure."⁵² Readers of a journal known to be a vanguard for the counterculture, the New Left, and environmentalism thus overwhelmingly supported O'Neill's program.

The large majority saw colonization of space as worthy of investigation and investment. A leading defender was Buckminster Fuller, who believed space colonies were his own original idea, a claim which was not without merit given that he had published a popular article about ecological cities in outer space in *Playboy* in 1968.⁵³ Though the exobiologist Carl Sagan preferred "Space Cities" to "Space Colonies," he too was a supporter of O'Neill, since cities in space would "permit the next evolutionary advance in human society."⁵⁴ Heppenheimer argued that engineering agricultural ecological systems in space was not only possible but desirable, since they promised a remedy to environmental ills hammering Spaceship Earth.⁵⁵ A NASA engineer argued that space colonization would "confound" the "limits to growth" thesis advocated by some environmentalists.⁵⁶ Environmentalists and ecologists such as David Steindl-Rast, Alan Scrivener, and Carolyn Henson also voiced their support. The statement "we have only one Earth," was seen as a questionable assumption for sound environmental reasoning.⁵⁷ A serious space program, the French oceanographer Jacques Cousteau argued,

would provide new technologies for submarine explorations as well as badly needed satellite technology for monitoring the earth.⁵⁸ Lynn Margulis, the microbiologist and co-deviser of the Gaia hypothesis, also favored the idea: "Of course Space Colonies are worthy of investigation and investment," she argued, since human evolution inclined toward expanding into new realms.⁵⁹

The idea of constructing large ecosystems in space met with head-on resistance, however, among the minority of the journal's subscribers. This opposition had hardly been vocal until Brand's support of O'Neill. It addressed the viability, practicality, and sustainability of building moon bases and exploring deep space with the help of ecological science. Lewis Mumford, for example, saw space colonies through the spectacles of *The Pentagon of Power* as "technological disguises for infantile fantasies."⁶⁰ Ken Kesey, the author of *One Flew Over the Cuckoo's Nest*, also thought such a "James Bond" project had "lost its appeal."⁶¹ Likewise, Gary Snyder, the author of *Turtle Island*, thought space colonies were "frivolous."⁶² Ernst F. Schumacher, whose *Small Is Beautiful* had reached a large audience, argued sarcastically that he was "all for it" because space colonies would allow large-scale technocrats to emigrate "out of the way."⁶³ The solar energy advocate Wilson Clark did not see a reason to generate solar energy in space when this could be done more easily on Earth. Dennis Meadows, co-author of *The Limits to Growth* report, also thought one should focus on solving problems on Earth instead of trying to solve them in outer space. Likewise, Garrett Hardin argued that emigration into space was not a solution for human population growth.⁶⁴ The population biologists Paul and Anne Ehrlich recognized that O'Neill's vision shared "many elements with that of most environmentalists: a high quality of life environment for all peoples, a relatively depopulated Earth in which a vast diversity of other organisms thrive in a non-polluted environment with much wilderness, [and] a wide range of options for individuals." Yet they argued that space colonization was not a solution to population growth, and that biologists "simply have no idea how to create a large stable artificial ecosystem."⁶⁵ Environmentalists and ecologists such as Stephanie Mills, Eric Alden Smith, David Brower, Hazel Henderson, and Peter Warshall also voiced criticism. The biologist and Nobel laureate George Wald viewed space colonies "with horror" as the logical extension "of dehumanization and depersonalization that have already gone much too far on Earth."⁶⁶ Most furious perhaps was the poet and environmentalist Wendell Berry, who accused Brand of supporting big government, capitalism, militarism, and "the cult of progress" by devoting *Co-Evolution Quarterly* to space-colony research.⁶⁷

A third group gave conditional support or criticism of O'Neill's proposals. The ecological solar architect Paolo Soleri, for example, thought the design of the space colonies failed to address human spiritual needs.⁶⁸ The environmentalist William Irwin Thompson pointed out "that the apocalypse that we seek to escape [was] inside us" and that although there was nothing wrong in setting up a space colony it failed to nurture "our Buddha-nature."⁶⁹ The ecological architect John Todd recognized that his own buildings had "many of the attributes of a space colony," but "consider[ed] it unsafe to attempt to simulate livable environments [in space] from our present biological knowledge."⁷⁰

The result of these statements was a key consensus paper signed by a series of scholars, including Ramón Margalef, James Lovelock, Lynn Margulis, and John and Nancy Todd. “[T]he question of space colonization should be explored,” they argued, but they thought colonization of space might cause unjustifiable exploitation of resources on Earth, and they were unsure about the technological feasibility the project. What should be done, they argued, was to build a closed ecosystem on Earth before trying to build one in space. After all, “if stable and productive closed ecosystems could not be made to function on Earth they certainly would not function in orbit,” and definitely not on the moon or on Mars.⁷¹ This suggestion became the cornerstone of one of the most expensive ecological experiments ever—the Biosphere 2 project in Arizona.

“NOAH’S ARMY” AT BIOSPHERE 2

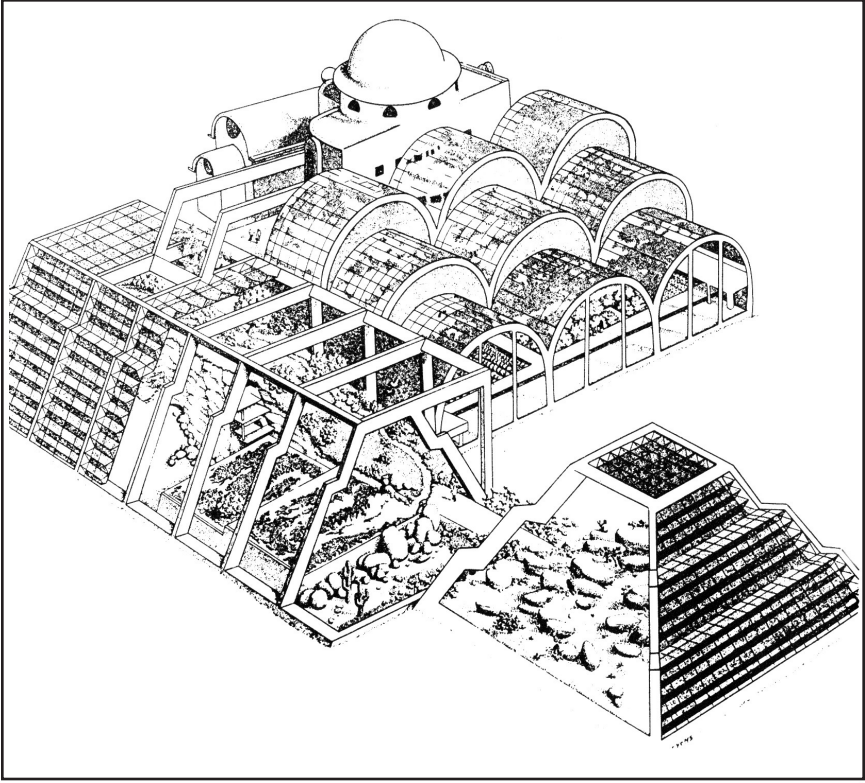
THE RATIONALE FOR the privately financed Biosphere 2 project was to make a profit, to prepare for ecological colonization of space, and to build a shelter in which its owners could hide in case a serious ecological disaster struck. Most important, Biosphere 2 was to provide a model for how humans should live within Biosphere 1—the earth.

The Biosphere 2 idea grew out of discussions at the Synergia Ranch, a commune near Santa Fe, New Mexico. Every hippie commune was different: Synergia was based on “discipline and hard work” to carry out projects that could solve the social and ecological crisis on Earth.⁷² The workers included the union organizer John Allen, the architect Phil Hawes, the philosopher-activist Mark Nelson, and the oil-magnate Edward P. Bass. Inspired by futurists such as McHale and O’Neill, they believed space technology would play a key role in solving the world’s ecological and social problems. Allen and Nelson were cofounders of the Institute of Ecotechnics, which aimed at creating synergy between ecological reasoning and technological know-how. They joined Space Biosphere Ventures Inc., which proposed to build Biosphere 2.

Bass was the major shareholder of the venture, with an investment of \$150 million, while his friends from the Synergia Ranch held only symbolic stakes. In view of later criticisms, it is notable Bass had sought advice from the Harvard biologist Edward Wilson, the Smithsonian biologist Thomas Lovejoy, and Buckminster Fuller. His aim, he explained to *The New York Times*, was to profit from the wide public interest in ecology and space colonization. He calculated that Biosphere 2 would turn into a popular ecological “Disneyland” and become a viable tourist attraction. His partners, including Allen, Nelson, and Margret Augustine, also regarded Biosphere 2 as a for-profit business project. Their goal was to develop cabin-ecology technology for energy-efficiency, recycling, waste processing, sewage management, microbial composting, and other emerging solutions to environmental problems on Earth. The development and patenting of such technologies were to provide Space Biosphere Ventures with a solid profit.⁷³

The scientific rationale for Biosphere 2 was to prove that ecological colonization of space was viable. “Closed ecology systems can free us from Malthusian limitations by making the Solar System our extended home,” one

Figure 6. Biosphere 2.



Biosphere from Earth to Space (1989).

Biosphere 2 as the building was imagined by Dorion Sagan and Lynn Margulis.

proponent argued.⁷⁴ Dorion Sagan and Lynn Margulis described the scientific aims in *Biospheres from Earth to Space*. Their 1989 book applied the Gaia hypothesis to the construction proposal for Biosphere 2 (see Fig. 6). “Imagine for a moment you are building a large ship that will travel through space,” they encouraged readers, before plunging into a detailed analysis of how the science of ecology could enable people to “live in space indefinitely without the cost of importing supplies.” Scientifically the challenge was to determine the “carrying capacity” of a closed ecosystem by determining how large a crew of astronauts could be supported in an artificial biosphere. “Successfully running a new biosphere would show people what it takes to make it in our beloved old one,” they argued, pointing to the relevance of such ecological research to “astronauts” onboard “Spaceship Earth.” Moreover, “to settle Mars” with new populated biospheres could provide “protection in case of nuclear war” and “curb global population growth” on Earth.⁷⁵ Other ecologists, such as Robert Beyers and Howard Odum, agreed. To them, Biosphere 2 was a laboratory and “a prelude to life in space and a means to understand carrying capacity of the earth for humans.” Odum, Ramon Margalef, and Walter Orr Roberts, the founding president of the University Corporation of Atmospheric Research, would serve as scientific advisers, making sure Biosphere 2 was built according to cabin-ecology design.⁷⁶

The aim of Biosphere 2 also was to build a shelter in which ecologists and venture partners could survive in coevolution with thousands of other species in case an eco-crisis turned Biosphere 1 into a dead planet like Mars. This sense of a coming doom for the earth prevailed in the early literature about the project, which was fashioned in line with the story of Noah: "There is an ancient story told in the Bible about a great flood that covered the world long ago," explained a booklet aimed at pupils visiting Biosphere 2. "All of the people and animals were threatened with destruction. But there was one good man named Noah whose family God wanted to save. So He warned Noah that the great flood was coming and told him to build a huge ark." Scientists and designers of Biosphere 2—"The Glass Ark"—fashioned themselves in the image of the Biblical Noah, and they believed the new biosphere could secure their personal survival while at the same time saving some of the world's biodiversity. What was needed was a "Noah's army" of environmentalists to protect Spaceship Earth.⁷⁷

Biosphere 2 was completed and sealed in September 1991, after eight "biospherians" dressed in space suits had marched through the air-lock. They promised to stay there for two years. "The project's participants say it can show how to colonize other planets or survive ecological catastrophe on this one," a journalist reported from the widely publicized event. The sense of community among old friends from the Synergia Ranch was not appreciated by outside journalists, who wrote about the biospherians as a secretive clique. Soon rumors circulated about mechanical (as opposed to organic) carbon dioxide rinsing of the ecosystem, a smuggled bag of supplies to hungry biospherians, and fresh air being pumped into the building.⁷⁸ As a result, a team of scientists lead by Lovejoy and Eugene Odum came to scrutinize the scientific validity of the project. With crew members suffering from lack of oxygen, scientists decided to pump more into the building, though that effectively ruined the value of the experiment, since the building was supposed to be sealed. Nature did not easily conform to the ecologists' cabin concept, later reviews of the project claimed.⁷⁹ It was apparently a relief to the crew when they—in space suits—marched out of the air-lock in September 1993. "The welcoming ceremony, accompanied by a flute solo and a gush of utopian New Age oratory, was in keeping with the odd mix of science and showmanship," *The New York Times* reported on its front page.⁸⁰ All of this was not welcome news to the scientific patrons of the project, such as the Smithsonian Institution's Marine Systems Laboratory, the New York Botanical Garden's Institute of Economic Botany, and the University of Arizona's Environmental Research Laboratory.

Despite the trouble, the ecologists and former biospherians defended Biosphere 2 and the importance of space colonization for years to come.⁸¹ Scientific experiments, they claimed, were all about learning from mistakes. The project inspired numerous cabin ecologists working on different schemes for planetary engineering to make the Mars environment livable.⁸² For architects, the Biosphere 2 building became a model for ecological construction setting the standard for a growing field.⁸³ In a scholarly publication, Eugene Odum defended Biosphere 2 as a vindication of the Gaia thesis.⁸⁴ To Beyers and Howard Odum, it proved the viability of the "carrying capacity" concept for ecological management

of “spaceship Earth.” Further testing of closed ecosystems in outer space was “long overdue,” they argued.⁸⁵ In the final scientific report on Biosphere 2, Howard Odum argued that the experiment had successfully stimulated “the minds of those who have the vision to think beyond the veil of tradition.”⁸⁶ In fact, however, Biosphere 2 represented the culmination of a tradition of research into ecological colonization of both outer and earthly space.

IT’S TIME TO LEAVE THE CAPSULE

THE COLONIZATION OF SPACE was of key importance for ecological debate, methodology, and practice. This endeavor grew out of military efforts to improve submarines and shelters, and make humans less vulnerable to atomic attack through the dispersion of populations. With the space program of the 1960s, ecologists aimed at building cabin-ecology systems for astronauts that later served as models for ecological remodeling of life on Earth. When humans were seen as astronauts, environmental ethics became an issue of trying to adopt the lifestyle of space travelers recirculating their material resources within a closed ecosystem.

Measured in terms of influence, space ecology was a successful endeavor. Space-cabin technologies, such as computer-simulation programs, sewage systems, air-rinsing methodologies, energy-saving devices, and solar-cell panels have become regular ecological tools for biological survival. The rationalist and managerial ideals for measuring a spaceship’s “carrying capacity” of astronauts also became a standard for organizing practical as well as moral life onboard Spaceship Earth. The ecological colonization of human space seems nearly complete.

This turn toward space ecology as a beacon of hope for an environmentally friendly future also had liabilities. For one, it contributed to a managerial culture of scientific technocracy among environmentalists. Moreover, a theoretical *noli me tangere* syndrome came to mark non-anthropocentric thinkers willing to question space exploration but not the value of ecological methodology. As a result, ecological analysis has become synonymous with environmental analysis. This ecological colonization of outer and earthly space empowered the managerial ecologist at the expense of humanism. One can only hope that environmentally concerned humanists of today will abandon the intellectual space capsule ecologists have created for them. In the lyrics of David Bowie’s “Space Oddity,” “Now it’s time to leave the capsule if you dare.”⁸⁷

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NOTES

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