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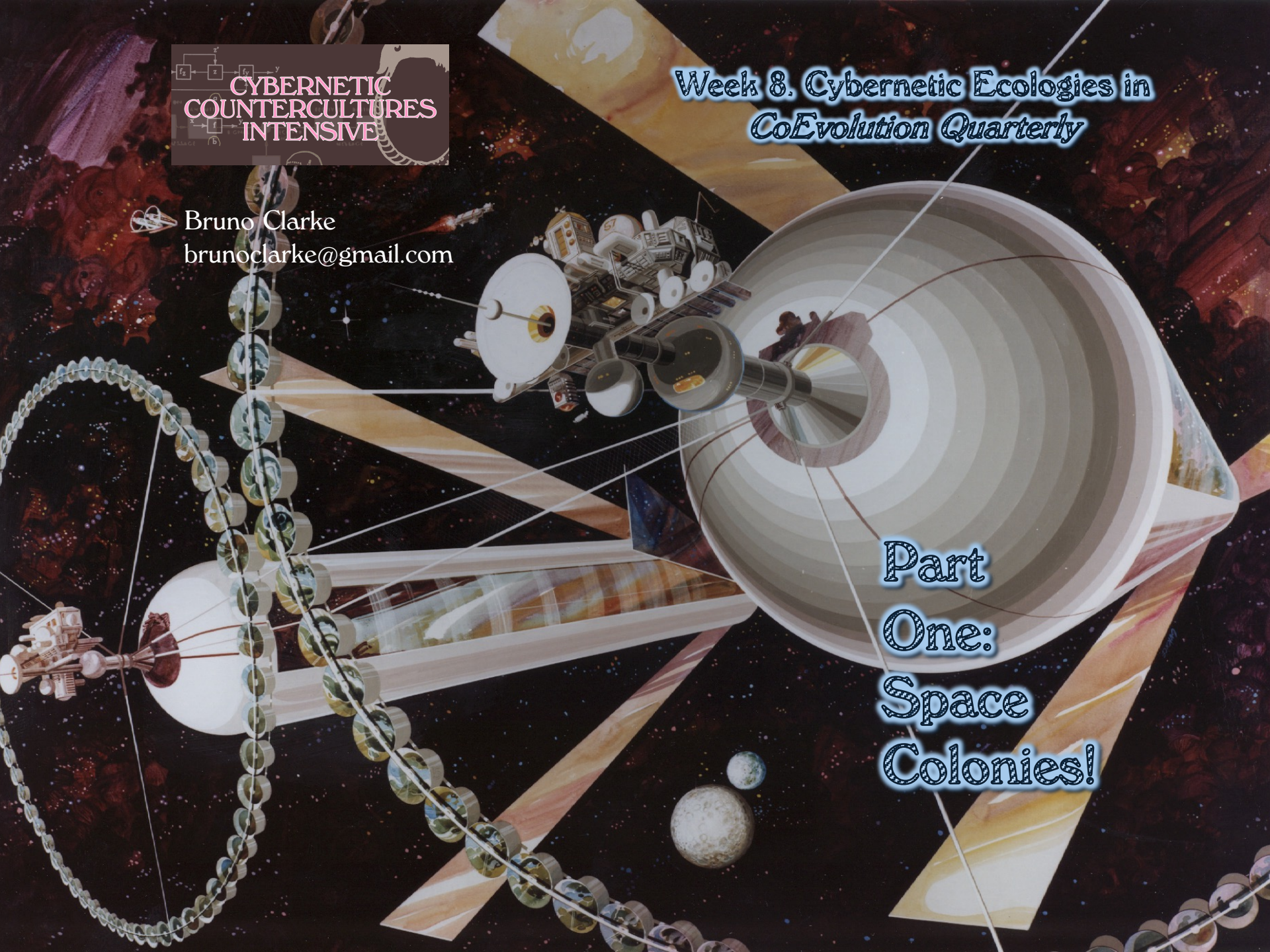
CYBERNETIC COUNTERCULTURES INTENSIVE

Week 8. Cybernetic Ecologies in *CoEvolution Quarterly*


CYBERNETIC COUNTERCULTURES INTENSIVE
Week 8. Cybernetic Ecologies in CoEvolution Quarterly
Bruno Clarke
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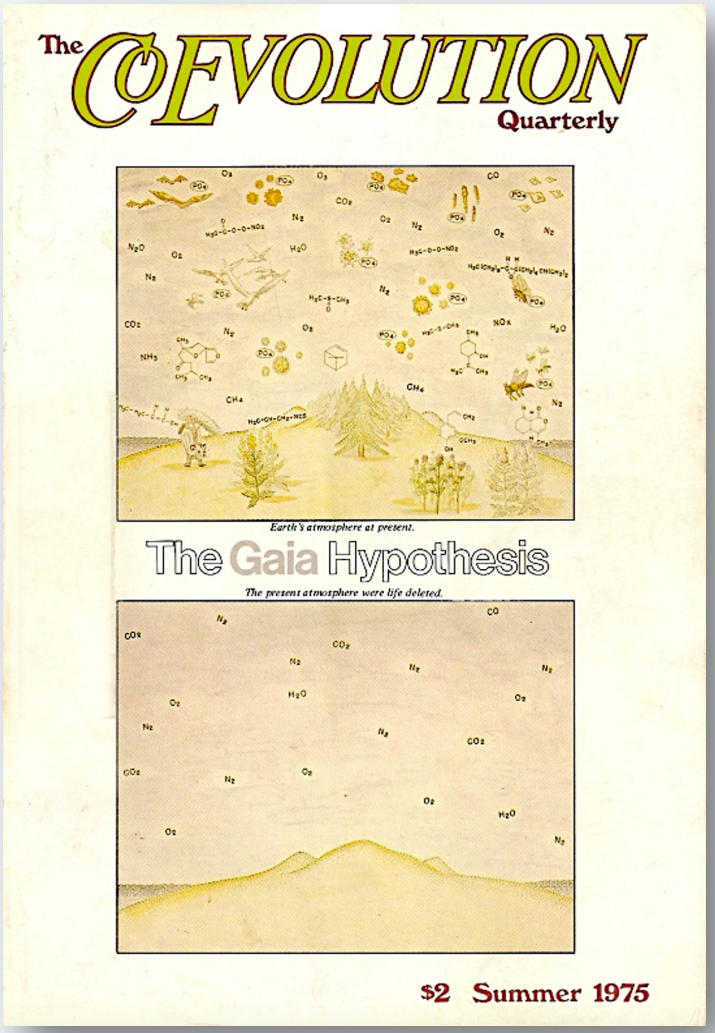
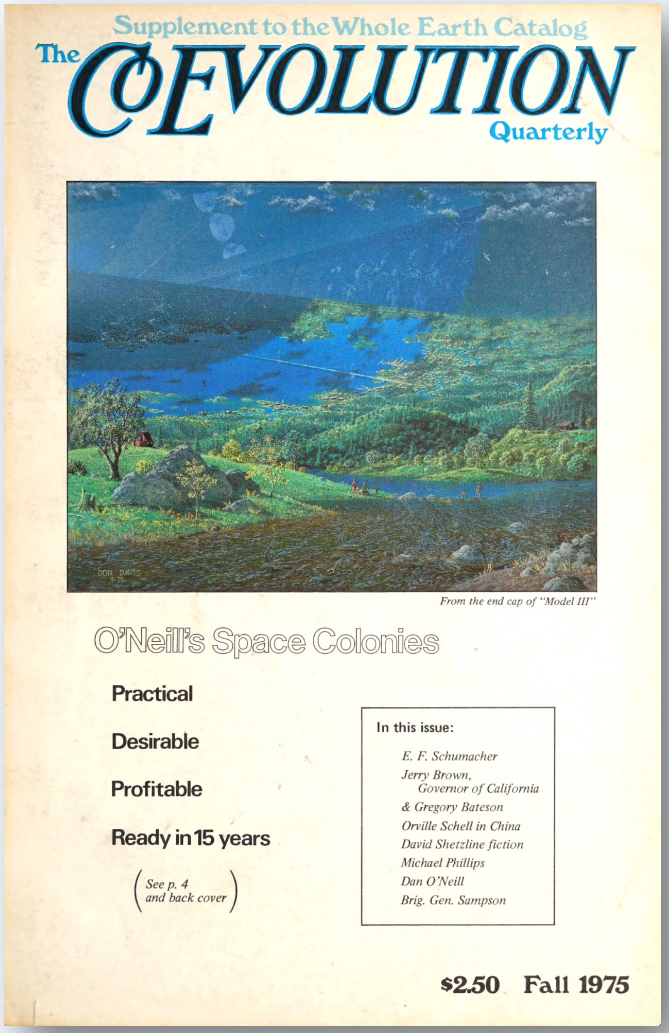
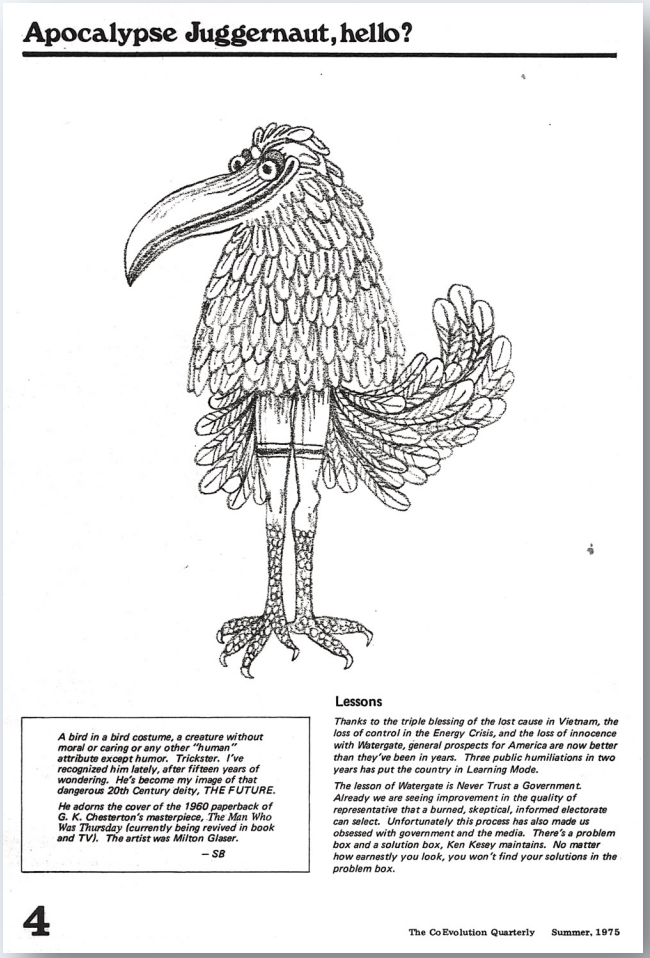
Part One: Space Colonies!



CoEvolution Quarterly's exceptional introduction of Margulis and Lovelock's "The Atmosphere as Circulatory System of the Biosphere: The Gaia Hypothesis" in the summer of 1975 was immediately followed by a fall number devoting the first thirty pages to Princeton physicist Gerard K. O'Neill's proposals and designs for geostationary high-orbital space colonies, along with memorable depictions by NASA artists. O'Neill's technological speculations presented seductive images of environmental duplication that translated Gaia's terrestrial implications into idealized visions of closed ecologies supporting sustainable habitats in space.



Hello?



Apocalypse Juggernaut, hello?

A bird in a bird costume, a creature without moral or caring or any other "human" attribute except humor. Trickster. I've recognized him lately, after fifteen years of wondering. He's become my image of that dangerous 20th Century deity, THE FUTURE.

He adorns the cover of the 1960 paperback of G. K. Chesterton's masterpiece, The Man Who Was Thursday (currently being revived in book and TV). The artist was Milton Glaser.

— SB

Lessons

Thanks to the triple blessing of the lost cause in Vietnam, the loss of control in the Energy Crisis, and the loss of innocence with Watergate, general prospects for America are now better than they've been in years. Three public humiliations in two years has put the country in Learning Mode.

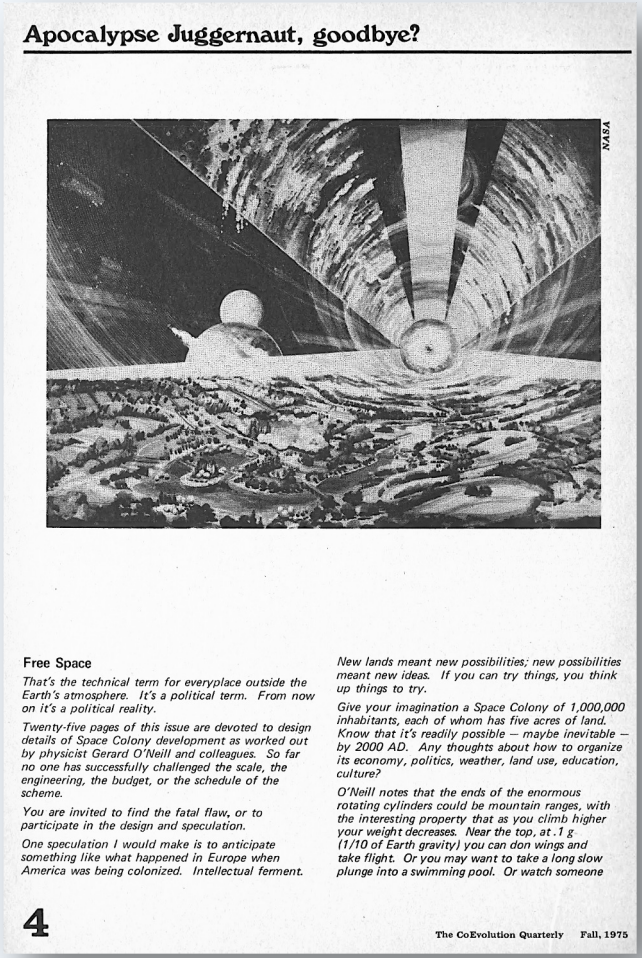
The lesson of Watergate is Never Trust a Government. Already we are seeing improvement in the quality of representative that a burned, skeptical, informed electorate can select. Unfortunately this process has also made us obsessed with government and the media. There's a problem box and a solution box, Ken Kesey maintains. No matter how earnestly you look, you won't find your solutions in the problem box.

4 The CoEvolution Quarterly Summer, 1975

Summer 1975

This moment also appears to mark the beginning of a turn in Brand's conception of the *purpose* of his *Whole Earth* publications. Up to now, the underlying sensibility driving the Catalogs and their various supplements has been the anticipation of some sort of apocalyptic event—nuclear Armageddon, environmental collapse, societal breakdown. Some sort of techno-industrial catastrophe seemed to be just over the horizon, making it that much more imperative and reasonable to depart the cities, head back to the land, join a commune, and be green in all things. Despite the celebrations of space technologies and sundry cybernetic developments, organic and otherwise, the early Whole Earth project had a distinct *survivalist* undercurrent which now bids to turn seriously *escapist*. For what if those same technological developments in relation of control systems could bring about the creation of space colonies with new pioneer environments in "free space" where one could leave all that terrestrial *angst* behind?

Goodbye?



Apocalypse Juggernaut, goodbye?

Free Space

That's the technical term for everyplace outside the Earth's atmosphere. It's a political term. From now on it's a political reality.

Twenty-five pages of this issue are devoted to design details of Space Colony development as worked out by physicist Gerard O'Neill and colleagues. So far no one has successfully challenged the scale, the engineering, the budget, or the schedule of the scheme.

You are invited to find the fatal flaw, or to participate in the design and speculation.

One speculation I would make is to anticipate something like what happened in Europe when America was being colonized. Intellectual ferment. New lands meant new possibilities; new possibilities meant new ideas. If you can try things, you think up things to try.

Give your imagination a Space Colony of 1,000,000 inhabitants, each of whom has five acres of land. Know that it's readily possible — maybe inevitable — by 2000 AD. Any thoughts about how to organize its economy, politics, weather, land use, education, culture?

O'Neill notes that the ends of the enormous rotating cylinders could be mountain ranges, with the interesting property that as you climb higher your weight decreases. Near the top, at .1 g (1/10 of Earth gravity) you can don wings and take flight. Or you may want to take a long slow plunge into a swimming pool. Or watch someone

4 The CoEvolution Quarterly Fall, 1975

Fall 1975

CQ 9 (Spring 1976), inside front cover, detail. Image: "Model I Space Colony as designed by NASA-Ames Summer Study, 1975."

CQ 9 (Spring 1976), p.1. "The Blackfoot couple was photographed by Edward S. Curtis early in this century." —SB

The macro-planetary imaginary of the Gaia concept on the one hand, and the micro-planetary imaginary of a massive space settlement on the other, called out to each other through the contemporary trope of Spaceship Earth. With the Apollo space program now wound down, O'Neill envisioned a "high frontier" beyond JFK's New Frontier. He had already been working at this project for several years with modest preliminary support from NASA (also funding the fabulous artistic conceptions). *CoEvolution Quarterly* published a long transcript of O'Neill's congressional testimony seeking (without success) a major NASA commitment. Six months later still, in its Spring 1976 number, *CoEvolution Quarterly* devoted eighty pages to the controversy that erupted among its readers over its positive presentation of O'Neill's vision as a potential form of outlaw zone or countercultural commune in the heavens.

BC] "Brand worked the space-colony debate for *CoEvolution Quarterly* content by pitting post-psychedelic space-oriented technophiles such as himself against Whole Earth–identifying environmentalists and green technophobes. Numerous supporters and detractors responded, including Buckminster Fuller and Paolo Soleri, novelists Ken Kesey and Wendell Berry, the poets Gary Snyder and Richard Brautigan, astronaut Rusty Schweickart, cultural observer William Irwin Thompson, scientists Lynn Margulis, John Todd, Paul and Anne Ehrlich, and Carl Sagan. A year later, Brand gathered, republished, and expanded these materials as the freestanding paperback volume *Space Colonies*" (*Gaian Systems* 118).

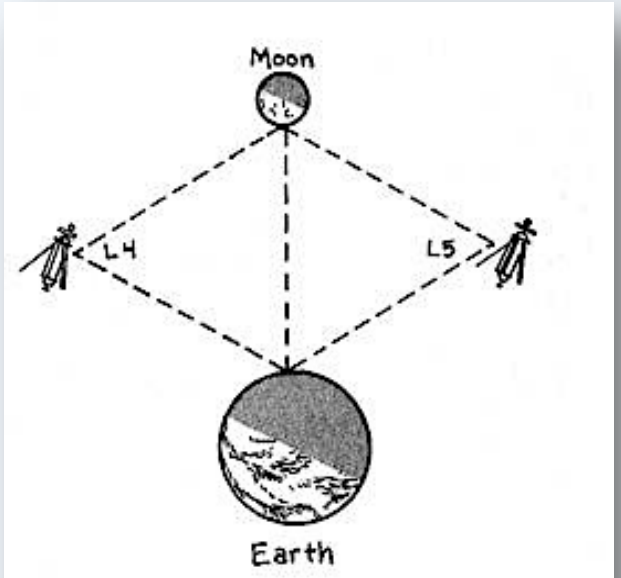
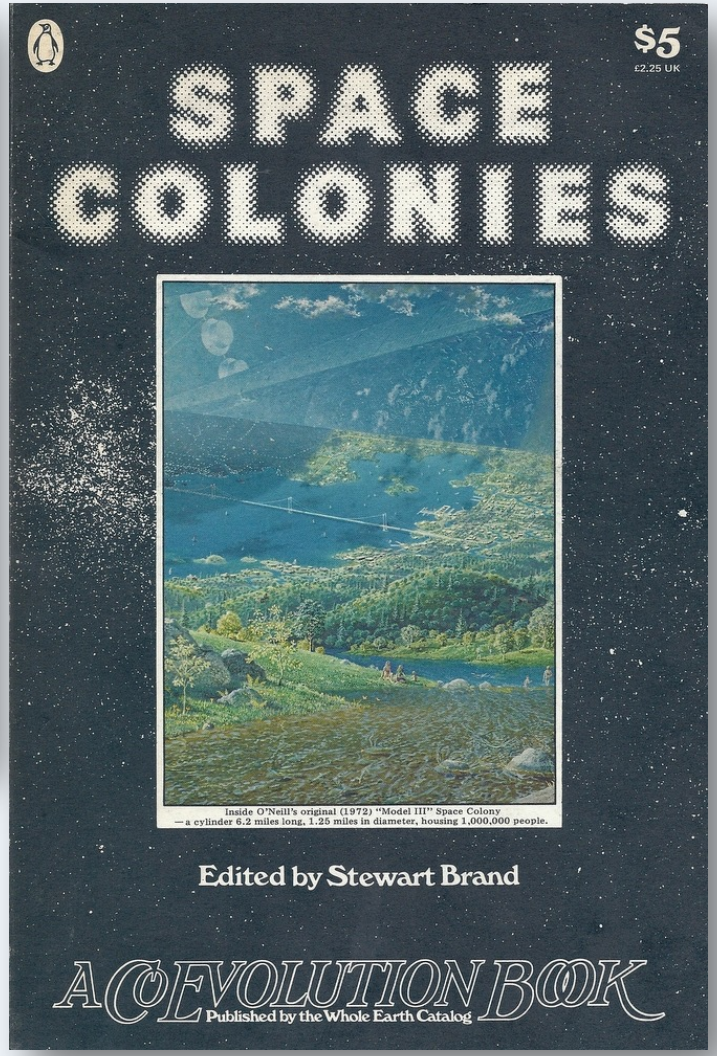


Figure 1. Location of the Lagrange points L4 and L5. Each is on the orbit of the Moon and is the third point of an equilateral triangle, the Earth and Moon being the other two points. Space communities could be located on stable orbits about either L4 or L5.



The High Frontier

BY GERARD O'NEILL

During the past decade a number of premises about the basic problems of the world have become very widely accepted. The more important of these accepted ideas are:

1) That for the forseeable future every significant human activity must be confined to the surface of the earth.

2) That the material and energy resources of the human race are just those of our planet.

3) That any realistic solutions to our problems of food, population, energy and materials must be based on a kind of zero-sum game, in which no resources can be obtained by one nation or group without being taken from another.

Given those premises, logic has driven most observers to the conclusion that long-term peace and stability can only be reached by some kind of systematic global arrangement, with tight constraints to insure the sharing, equable or otherwise, of the limited resources available. I find it personally shocking that many such observers, even those who profess to a deep concern for humankind, accept with equanimity the need for massive starvation, war or disease as necessary precursors to the achievement of such a systematic global arrangement.

Dr. Gerard O'Neill, 48, is a high-energy physicist best known for originating the colliding-beam storage ring, which has been adopted throughout the world. Since 1974 he has become better known to the general public as the designer and promoter of very large scale Space Colonies.

He is a professor at Princeton, a former Navy non-com, and a holder of the International Diamond Badge for soaring (about 1% of glider pilots have one).

This talk was given at the World Future Society convocation in Washington D.C. this spring. It was perhaps the least well-attended of the 100 or so panels and presentations. Futurists are more interested in problems than solutions this year. This talk is what converted me from mild interest in the Space Colonies to obsession.

—SB

In what follows, I will deliberately depart from my usual style. I will not hedge all my statements with cautious limits and buttress them with footnotes, as I would before a scientific audience or as I certainly shall when I testify before a Congressional subcommittee a few weeks from now. Rather, I will be assertive in style, so as to make clear by its shock-value how fundamentally different one new concept is.

If the studies which we have carried out at Princeton University continue to survive technical review, then I must tell you that in my opinion the three basic premises on which most discussions of the future have been based are simply wrong. The human race stands now on the threshold of a new frontier, whose richness surpasses a thousand fold that of the new western world of five hundred years ago.

That frontier can be exploited for all of humanity, and its ultimate extent is a land area many thousands of times that of the entire Earth. As little as ten years ago we lacked the technical capability to exploit that frontier. Now we have that capability, and if we have the willpower to use it we can not only benefit all humankind, but also spare our threatened planet and permit its recovery from the ravages of the industrial revolution.

These statements may sound like empty rhetoric. In the next few minutes I would like to sketch for you how they can be proven to be true. It is not necessary to have a technical background to appreciate these facts. Indeed, one of the most surprising aspects of the new opportunities is that they do not require new technology for their realization.

The high frontier which I will describe is space, but not in the sense of the Apollo program, a massive effort whose main lasting results were scientific. Nor is it space in the sense of the communications and observation satellites, useful as they are. Least

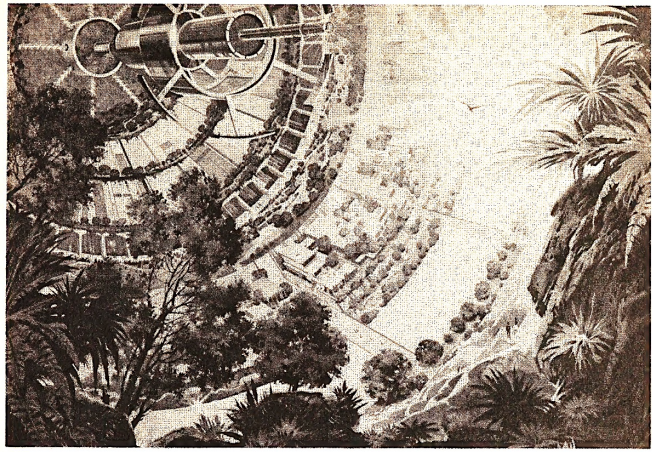


Figure 3. Possible interior design of a first, small-size space community. It could be large enough to provide comfortable apartments, shops, parks, small rivers and lush vegetation.

of all is it space in the sense of science-fiction, in which harsh planetary surfaces were tamed by space-suited daredevils. Rather, it is a frontier of new lands, located only a few days travel time away from the Earth, and built from materials and energy available in space.

These are the facts which force a revolution in our thinking:

1) Solar energy: as everyone knows, the Sun is a virtually inexhaustible source of clean energy. It is difficult to use on Earth as more than a small supplement to other sources, though, for two reasons:

a) Unreliability: though solar energy is available full time in space, on Earth it is cut off by nighttime, by seasonal variation in the day-length, and by clouds.

b) Low average intensity: the cost of any solar power installation is the amortization cost of the equipment, because the source is free. The amount of solar energy which flows unused, in a year, through each square meter of free space is ten times as much as falls on an equal area in even the most cloud-free portions of Arizona or New Mexico.

A given solar-energy installation in space, therefore, is potentially able to operate at a tenth the cost at which it could operate on Earth.

2) Materials: If we build new lands in space, starting from the Earth, we are the "gravitationally disadvantaged." We are at the bottom of a gravitational well 4000 miles deep, from which materials can only be lifted into space at great cost. Our technique must exploit the fact that the Moon has a gravitational well only 1/20 as deep, and as we now know from the Apollo samples is a rich source of metals, glass, oxygen, and soil. In the long run, we can use the fact that the asteroids are also a source of materials: the three largest asteroids alone contain enough materials for the construction of new lands with a total area many thousands of times as large as that of the Earth.

Briefly I will describe for you first the long-term then the immediate possibilities on this new frontier. As I do, remember that everything I describe is well within the limits of present-day, conventional materials, and of present technology. If we were to start now, with determination and drive, in my

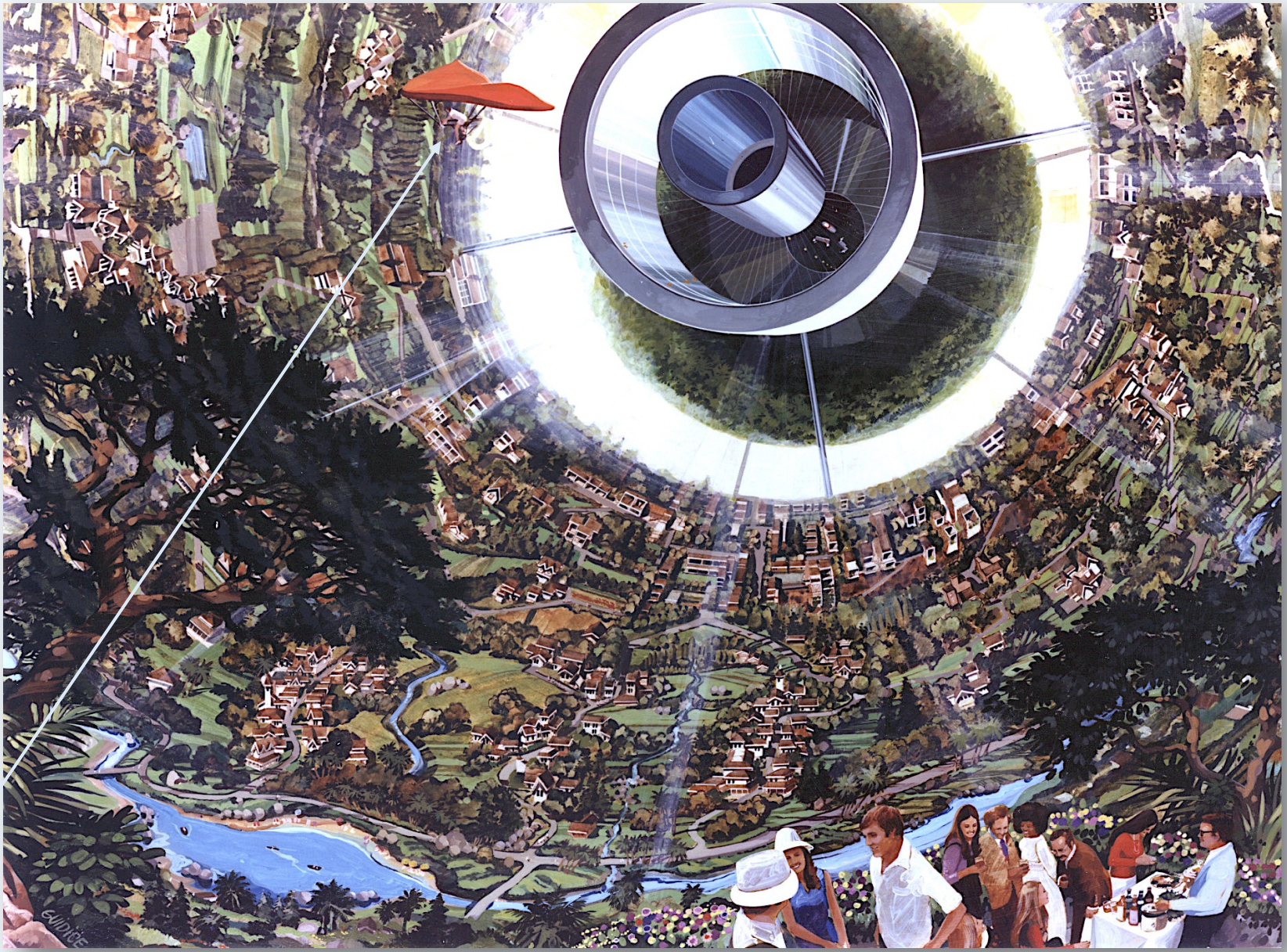
"This talk was given at the World Future Society convocation in Washington D.C. this spring. It was perhaps the least well-attended of the 100 or so panels and presentations. Futurists are more interested in problems than solutions this year. This talk is what converted me from mild interest in the Space Colonies to obsession." —SB

". . . Indeed, one of the most surprising aspects of the new opportunities is that **they do not require new technology for their realization**. . . ."

[BC: This brash assertion indicates the physicist O'Neill's complete lack of understanding of the severe contingencies of closed life-support systems.]

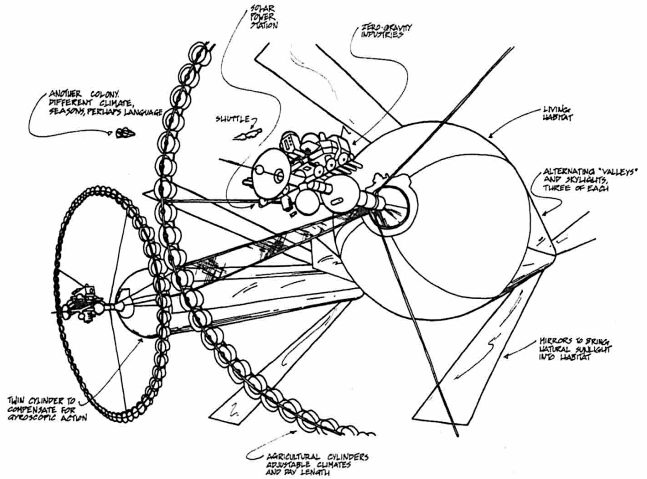
"The high frontier I will describe is space, but not in the sense of the Apollo program, a massive effort whose main lasting results were scientific. Not is it space in the sense of the communications and observation satellites, useful as they are. Least of all is it space in the sense of science-fiction, in which harsh planetary surfaces were tamed by space-suited daredevils. Rather, it is a frontier of new lands, located only a few days travel away from the Earth, and built from materials and energy available in space."

But why let a few pesky biological details get in the way of a fabulous affirmation that our modern Western corporate-industrial lifestyle has got the Right Stuff to be cloned in high orbit!



"Bernal Sphere Interior including human powered airplane"

Space Colonies



Summary

of the 26 pages on Space Colonies in the Fall '75 CQ *to which the following 76 pages of comments respond.*

Gerard O'Neill, 48, is a notable high-energy physicist — he developed the particle storage rings that have become standard on nuclear accelerators. In 1969 he posed a special question to a special seminar of his freshman physics students at Princeton, **"Is the surface of a planet really the right place for an expanding technological civilization?"**

They and he concluded that, no, free space would be better — richer energy domain (sunlight pouring past at ten times the strength of Earth sunlight), fine manufacturing materials available in the Moon and asteroids, many advantages of zero gravity, and lots of room. When they addressed the engineering of building an Earth-like environment, they found that many of the design problems solved each other.

The pinnacle of their vision is the behemoth Space Colony Model III, home of 1,000,000 inhabitants, the result by about 2000 AD of a "bootstrap" sequence of successively larger space manufacturing facilities. The first step, Model I, would cost $100 billion, be ready in 15 years, house 10,000 people, and rapidly start paying for itself by constructing Satellite Solar Power Stations (SSPS) for micro-wave beam-down of energy from low-Earth-orbit — replacing nuclear and fossil fuel use on Earth.

The later colony, Model III, would be 6¼ miles long by 1¼ miles in diameter (across each of the two counter-rotating cylinders). The cylinders would rotate at a rate to provide centrifugal force equivalent to Earth gravity (1 g). Each cylinder would consist of three valleys, interspersed with three enormous windows with huge mirrors to reflect in sunlight. Every inhabitant would have something like five rural acres in this space terrarium. A vessel that big would have blue sky and weather.

98% of the material of the colonies would come from the Moon, taking advantage of the high metal, glass, and oxygen content of lunar "soil." Hydrogen, nitrogen, and other essentials for life would have to be hauled up from Earth. With 1/20 of Earth's gravity on the Moon, and no atmosphere, it would be possible to propel lunar material off the Moon by means of a "mass-driver" — magnetically controlled buckets flinging Moon chunks toward the colony site. The entire construction of Model I would leave a mined hole only 7 yards by 200 yards by 200 yards. O'Neill claims that the whole Space Colony project can be done with present technology.

The site, usually called "L-5," is one of the two stable gravitational points in the Earth-Moon system. The Lagrangian libration points, L-4 and L-5, precede and follow the Moon in Orbit around the Earth (see diagram). They are Sargasso Seas of space, where things accumulate.

As the bootstrap process continues, O'Neill foresees each colony manufacturing more colonies, and each of them making themselves as attractive as possible to draw colonists from Earth. Travel and communications between colonies would be very easy, but O'Neill expects that they would become increasingly diverse, comprising different Earth groups, different ideas, and setting forth on different missions to the asteroids, other planets, and even out of the solar system entirely.

This year, 1975-76, the Space Colonies are beginning to be a public issue. O'Neill has testified before a House Committee and a Senate Committee. NASA (National Aeronautics and Space Administration) has done studies on the scheme and increased their interest. One Presidential runner, Morris Udall, has already expressed interest. Since O'Neill's original article in Physics Today *in 1974, there have been major articles in* The New Scientist, Science, The New York Times Magazine, Saturday Review, Harpers, The Smithsonian, *and others.*

Everything that has appeared in print has been favorable. Till now.

—SB

BC] It is ironic that the only substantial remains of O'Neill's grandiose project—other than the pages of *CoEvolution Quarterly* and other contemporary publications—are works of graphic and literary art: NASA's illustrations of his designs for inhabitable spheres and cylinders, and William Gibson's descriptions of off-world "islands" in his Sprawl trilogy.

▪

Archipelago

The islands. Torus, spindle, cluster. Human DNA spreading out from gravity's steep well like an oilslick.

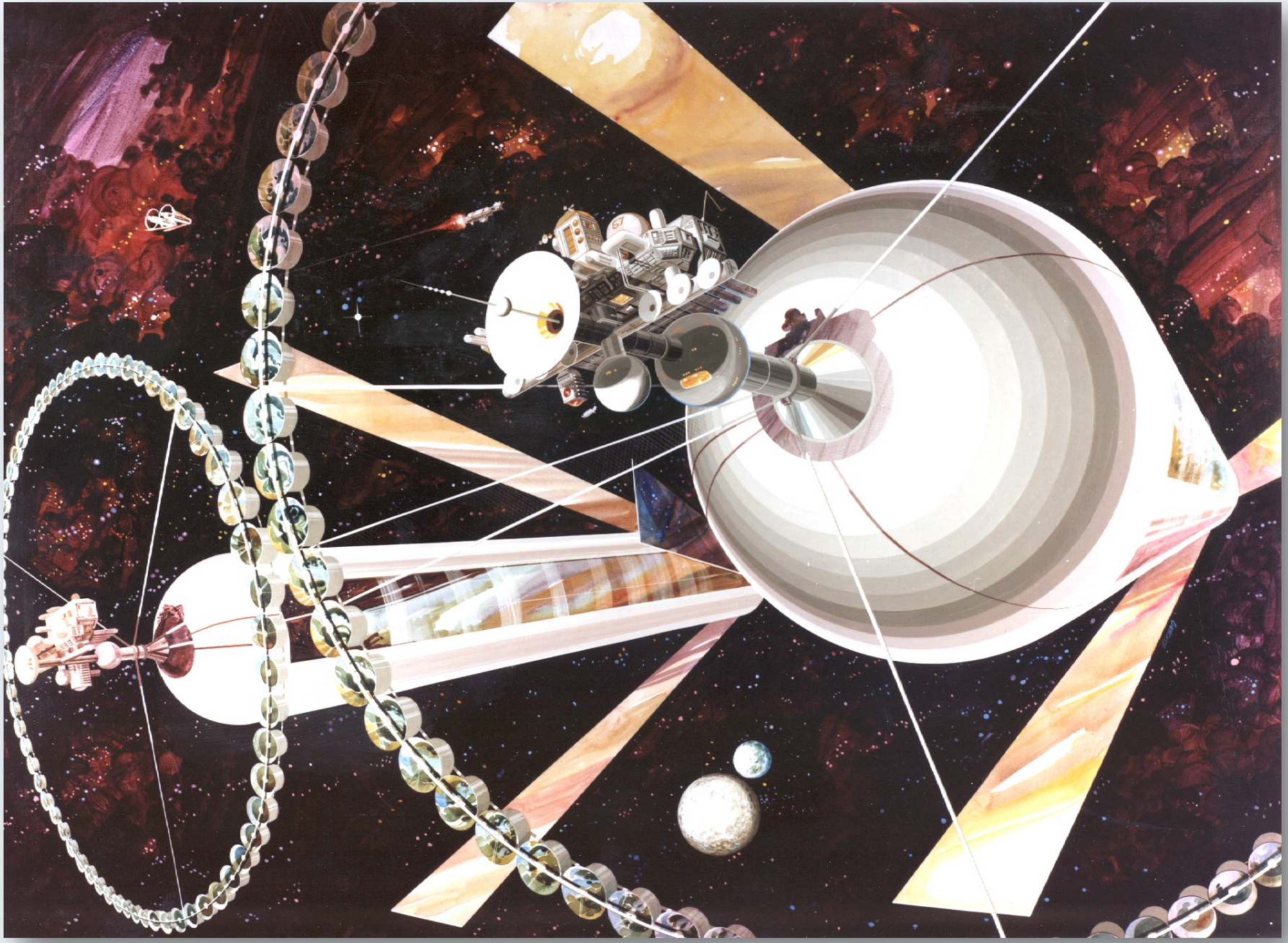
Call up a graphics display that grossly simplifies the exchange of data in the L-5 archipelago. One segment clicks in as red solid, a massive rectangle dominating your screen.

Freeside. . . .

—William Gibson, *Neuromancer* (1984)

▪

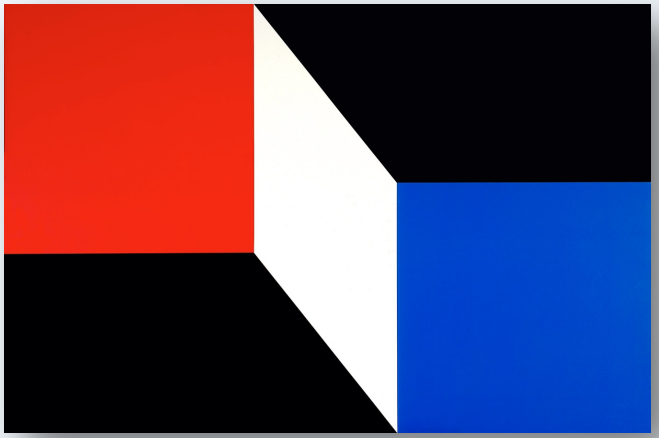
The **Lagrangian points** (also Lagrange point, L-point, or libration point), are the five positions in an orbital configuration where a small object affected only by gravity can theoretically be stationary relative to two larger objects (such as a satellite with respect to the Earth and Moon). The Lagrange points mark positions where the combined gravitational pull of the two large masses provides precisely the centripetal force required to rotate with them. They are analogous to geostationary orbits in that they allow an object to be in a "fixed" position in space rather than an orbit in which its relative position changes continuously. (*Wikipedia*)

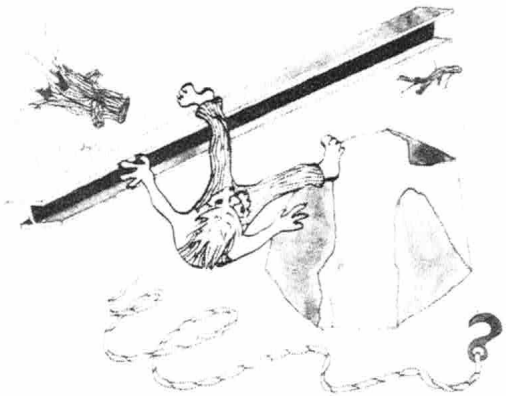


O'Neill Space Colony Model III at the L-5 Lagrangian Point - NASA AC75-1085

Some folks were more than ready to be beamed up.

Dean Fleming, "Snap Roll," 1965





DEAN FLEMING

Artist, co-founder of Libre Commune

Space colonies are potentially the greatest creative focus in human history. If we may assume the highest achievement for humankind is to become totally, fruitfully human; responsible for being conscious of every detail of the living environment, heart and mind used for the mundane manipulation of matter while soul abides receiving continuously from the More then clearly the way now to reach such states is to take on the task of a totally integrated colony in Free Space. Every being so fortunate as to be able to participate will immediately be called upon to come up spiritually and psychically to handle the overload of unbridled forces (which may be ecstatic according to some astronauts) and still live the simple human life watching the vibes of the rock and the pond. Every conceivable act would have to be as the Hopis' dream an act of consciousness and inevitable worship. If being creative without ceasing builds humanness in humans imagine how sprung loose God will feel when relieved of the burden of creating the "skies" and the "waters"!

In May 1970 I attended a NASA symposium on habitability in Venice, CA. During which time I lobbied for an experimental community deliberately living as if in space. (Forget about the Arctic! Maybe on some Caribbean Island!) They thought I was nuts. But now they would have 5 years of solid info at their fingertips. Do you think they could go for it yet? Sign me on! I swear all this time I've been painting for that kind of space!

CoEvolution Quarterly 9 (Spring 1976), 8-9.

Dean Fleming's geodesic domicile at Libre in Colorado, 2010. See https://www.aaa.si.edu/blog/2010/07/archivist-on-the-road-Colorado, the source of this description:

"Libre was founded in 1968 by New York painter Dean Fleming, his wife Linda, and a group of their close friends. Fleming was part of the important Park Place group of artists who fused geometry, sculpture, painting, and sound to create groundbreaking group installations in their cooperative space in SoHo. Fleming was intrigued by the design philosophy of Buckminster Fuller and his geodesic domes as a low cost solution to housing shortages. After visiting Colorado for an exhibition in Denver, Fleming purchased a remote 360 acre tract of land in the mountains southwest of Pueblo, Colorado. With the help of his friends he built the house and studio he lives in to this day."

Others—such as this hero of the founding *Whole Earth* ethos—saw space colonies as following a natural cultural-evolutionary progression, humanity readying itself to leave the terrestrial cradle.

CoEvolution Quarterly 9 (Spring 1976), 29.

R. BUCKMINSTER FULLER

Design scientist, author of **Synergetics; Nine Chains to the Moon; Ideas and Integrities**

Conceptualizing realistically about humans as passengers on board 8,000-mile diameter Spaceship Earth traveling around the Sun at 60,000 miles an hour while flying formation with the Moon, which formation involves the 365 revolutions per each Sun circuit, and recalling that humans have always been born naked, helpless and ignorant though superbly equipped cerebrally, and endowed with hunger, thirst, curiosity and procreative instincts, it has been logical for humans to employ their minds' progressive discoveries of the cosmic principles governing all physical interattractions, interactions, reactions and intertransformings, and to use those principles in progressively organizing, to humanity's increasing advantage, the complex of cosmic principles interacting locally to produce their initial environment which most probably was that of a verdant south seas coral atoll – built by the coral on a volcano risen from ocean bottom ergo unoccupied by any animals, having only fish and birds as well as fruits, nuts and coconut milk. First the humans developed fish catching and carving tools, then rafts, dug-out canoes and paddles and then sailing outrigger canoes.

Buckminster Fuller on Hippie Hill, San Francisco, 1968.

—from the *Last Whole Earth Catalog*

Reaching the greater islands and the mainland they developed animal skin, grass and leafwoven clothing and skin tents. They gradually entered safely into geographical areas where they would previously have perished. Slowly they learned to tame, then breed, cows, bullocks, water buffalo, horses and elephants. Next they developed oxen, then horse-drawn vehicles, then horseless vehicles, then ships of the sky. Then employing rocketry and packaging up the essential life-supporting environmental constituents of the biosphere they made sorties away from their mothership Earth and finally ferried over to their Sun orbiting-companion, the Moon.

Employing principles of optics, chemistry and electromagnetics, humans have now gained celestial information at the range of 11.5 billion light years in all directions around our Spaceship Earth. They have photographed equi-deeply into the microcosm. Macrocosmically they have located and photographed a billion galaxies of hundreds of billions of stars each. They have photophed atoms. Humans are now operating successfully in such vast and minute realms of scenario universe that 99.99% of their realistic activity is "invisible" to humans' limited range of direct sensing.

Clearly, human beings are designed and equipped to operate in both ever larger and more incisive manner in respect to local universe and will for some time base their operations on their Mothership Earth.

I have now traveled around the world 39 times, never as a tourist but only in the course of my work. For the last quarter of a century, I have spent 9/10ths of my time away from my official home. People often say to me, "I do not see how you can stand so much travel." I answer, "You obviously don't know what you are doing. You and all of us are making 60,000 miles an hour around the Sun, which makes my kind of Earthian travel of utterly negligible magnitude." People ask me, "Where do you live?" I answer, "I do not mean to be rude or facetious, but I live on a little planet called Earth. I never leave home. My back yard has become greater and greater until it has proven to be a big sphere, and I can travel in any great circle direction and eventually find myself where I started, ergo: I never leave 'home'." If anyone asks, "How was the trip?" or "Where do you live?" they are not living in cosmic realism – they are "grooved" like an L.P. disc.

To all who are living in cosmic realism, the immediate inauguration of additional Earth-Moon, around-the-Sun flying formations of our team could not be more humanly normal. It is just as normal as a child coming out of its mother's womb, gradually learning to stand, then running around on its own legs.

"Wendell Berry is the Sergeant York charging unnatural odds across our no-man's-land of ecology" wrote Ken Kesey in his review of Berry's book of essays Long-Legged House *(CATALOG, p. 48). Wendell is a prodigious novelist, poet, college teacher, and Kentucky farmer besides. Here he is responding to the 76 pages of comment on O'Neill's Space Colonies in the previous* CQ *(Spring '76).*

—SB

Others still were outraged and felt betrayed.

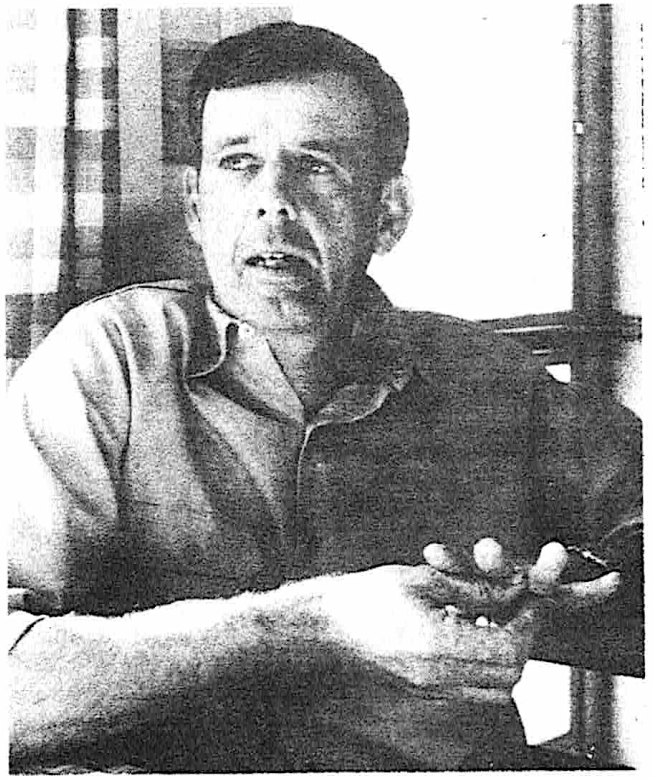
WENDELL BERRY ANGRY

April 27, 1976

Dear Stewart,

Your promotion of the space colony idea is getting more and more irresponsible. Like O'Neill and Vajk, you begin with an air of critical reasonableness, and promptly resort to the glib logic of a salesman. None of you has yet foreseen a problem without at the same time foreseeing a more than adequate answer; indeed, as you represent it, a space colony will be nothing less than a magic machine that will automatically transmute little problems into big solutions. Like utopians before, you envision a clean break with all human precedent: history, heredity, character. Thanks to a grandiose technological scheme, nothing is going to happen from now on that is not going to improve everything; as you say, even if it fails, we will be much better off. You people are operating at about the cultural depth of an oil company public relations expert. All this prophetic-ethical computer-mysticism! What is wrong with it is that it is simply failing to make sense — unless, of course, one is looking at it as a sycophant of science, or from the point of view of a government agency or a corporation. That is exactly what worries me: that your coverage of this issue, whatever you mean it to do, will serve to recruit and train a company of intellectual yahoos to justify the next power-grab by the corporations and the government.

Your dismissal, out of hand, of so many people's objections and doubts — solicited by you — is an alarming display of smugness. It is also insulting. I thought I was being asked to take part in a debate on an issue that you felt to be debatable. I now sense, from the substance and tone of your various remarks in the spring issue, that I was asked to say something that you expected to be inconsiderable in support of what you had already determined would be the losing side.



James Baker Hall

Wendell Berry

the more technological sophistication we have attained, the more destructive we have become. I do not think you recognize any of the doubts that now must surround the argument that still more of such sophistication will make us less destructive. It is not sophistication that makes people behave responsibly, but generous purpose and moral restraint.

LYNN MARGULIS

Microbiologist, author of Origin of Eukaryotic Cells, *co-deviser of the Gaia Hypothesis*

Sorry to be so late to respond to your invitation, but of course things on the surface of the earth, things here and now, always take precedence. That, alas, may also be the fate of the planning for Space Colonies that you ask me to comment on.

Of course Space Colonies are worthy of investigation and investment, in my opinion. (Why do some sun-requiring algae actually live inside carbonate rocks? Why do you find small blind arthopods scurrying at the backs of caves? Why do giant luminescent female fish (carrying their tiny males parasitically) inhabit the abyss? Why do red and green microorganisms cover the newly fallen arctic snows and multiply on its surface? Why do certain funny poorly known fungi (examples in the group Laboulgeniomycetes) live only on the left anterior appendage (read left front toe) of its insect host? The answer is the same as the one to the question why do people like O'Neill and his students imagine Space Colonies and advocate the move out. There are two parts to the answer: (1) the environment exists; and (2) the populations of organisms in question have the capacity to adapt to the environments. No fancy explanations are required. If there is space and if organisms can internally regulate utilizing the sources of energy at hand well enough to insure their replication, organisms will fill the space. This is the evolutionary pattern. It began over 300 million years ago, it still goes on. Steadily more and rougher parts of the earth's surface and near-surface have been colonized. There is no reason to believe the pattern will not continue to go on, at least in the near future.

What is obvious (and you already have said so) is that the John Todds of the World (e.g., holistic biological thinkers and doers) must connect with O'Neill and his crew to help stop the handwaving. Many details are not easily worked out simply because it is said that they are easy. Delivery of all needs, removal of all wastes, transport of the right things to the organisms in the right quantities with the right timing Easy to say but perhaps incredibly complex to realize. I am not qualified to comment on the engineering difficulties except to perceive that they must exist. Furthermore, I think the working out of the details might be frightfully boring.

Others did not question the good faith behind Brand's platforming of O'Neill's proposals while calling for urgent attention to their current infeasibility. Those scientists in a position to understand the biological end of the project realized that the eco-technology needed to pull this off was nowhere in sight.

JOHN TODD

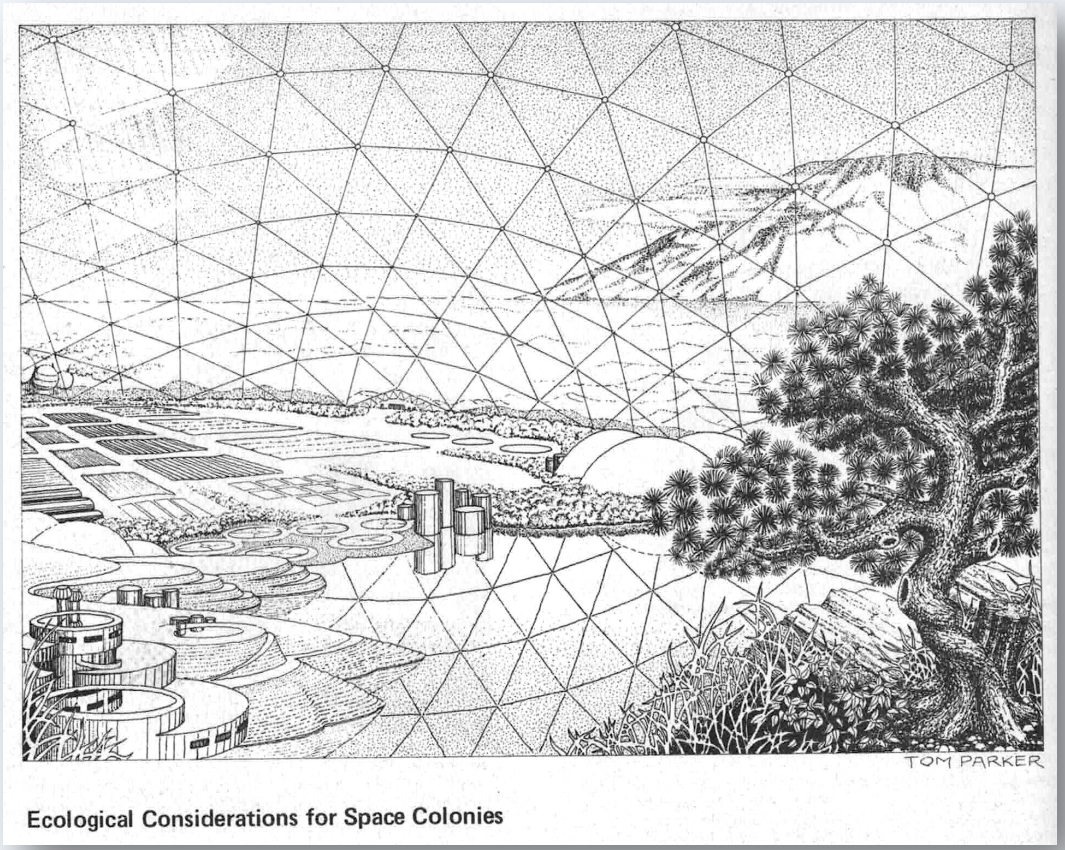
Biologist, co-founder of The New Alchemy Institute.
See also article on p. 54.

I have a perspective on the proposed space colonies that might be of use in the debate. I am a biological designer and for the past decade have been simulating a variety of aquatic and terrestrial ecosystems in contained spaces or "capsules." Some of them, like the tropical marine environment which my friends and I set up in a greenhouse at the Woods Hole Oceanographic Institution, were difficult to design. This "tropical" ecosystem was established to house the blennies and gobies (fishes) Bill McLarney and I were bringing back from Central America. Such a contained environment had to be designed well enough to permit the little marine fishes to breed, which is not an easy task. Fortunately, we were able to raise several generations in the north and learn something about them as I was interested in their sexual and social communication. We also simulated conditions of a local pond and an inshore marine area for studies of the effects of environmental perturbations on the social organization and behavior of a number of fish species.

From all this we learned that the social behavior of fishes and other animals can often be an extremely sensitive indicator of the health of a contained ecosystem and the highly social creatures have an intrinsic ability to bioassay their own environments. We also discovered that artificial environments were often unpredictable even when established as diverse ecosystems. Occasionally under conditions we did not fully comprehend, a particular alga species began to predominate, producing an antibiotic which killed the green and blue-green algae and a toxin which wiped out the molluscs and fishes. Sometimes an ecosystem became sick and we had to link it back up to the ecosystem from which it was derived originally. During my period at the Oceanographic Institution I didn't know too much about designing or using sub-ecosystems for self-regulation and biopurification, and was highly dependent upon technology. If a circulating pump blew or an air system quit, the next morning brought putrid smelling pools filled with dead animals floating belly-up on the surface.

After a decade of living intimately with designed ecosystems I am coming to know that nature is the result of several billion years of evolution, and that our understanding of whole systems is primitive. There are sensitive, unknown and unpredictable ecological regulating mechanisms far beyond the most exotic mathematical formulations of ecologists. When I read of schemes to create living spaces from scratch upon which human lives will be dependent for the air they breathe, for extrinsic protection from pathogens and for biopurification of wastes and food culture, I begin to visualize a titanic-like folly born of an engineering world view. At this point we don't know enough, being totally reliant on knowledge as well as physical subsidies from nature to survive on earth. In space there are no doors to open or neighbouring ecosystems to help correct our mistakes.

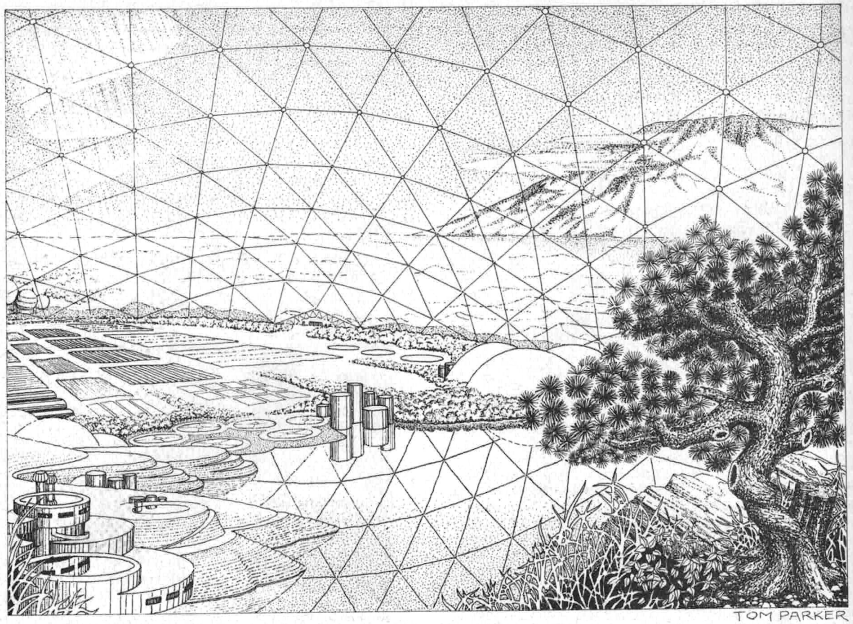
BC] "In the midst of these developments, Margulis gathered with a band of fellow ecologists to take up the issue, and *CoEvolution Quarterly* co-published their two-page multi-authored position statement. Brand's headnote to 'Ecological Considerations for Space Colonies' identified Margulis and two of her colleagues from the Woods Hole Oceanographic Institution on Cape Cod as the prime movers of the piece.... [Their] cautionary sentiments are as cogent now as they were in 1976, but you would hardly know that from the coverage of Jeff Bezos's [Blue Origin, a] revival of O'Neill's colonies as a scheme worthy of serious reconsideration. Both of Gaia's authors were cited in 'Ecological Considerations,' for which text Margulis may have been largely responsible. Although this article never mentions the Gaia concept by name, it purveys a broadly Gaian sensibility applied to vexed issues in the capacity of closed environments to maintain habitability" (*Gaian Systems* 119).



CoEvolution Quarterly 12 (Winter 1976/77), 96-97.

—The difference now, a fourth of the way into the 21st century, is that an egregious development within the cyberculture then in embryo in the Whole Earth network has spawned a "longtermist" philosophy that is willing to sacrifice terrestrial habitability—or at least, a major portion of current humanity and its nonhuman planetmates—in favor the future humans who will have left the Earth behind. For more on this, see "The TESCREAL Bundle" in the Knowledge Base.

"There appears to be growing interest in the possibility of establishing large space colonies capable of supporting hundreds or thousands of people in isolation from the earth for long periods. . . . Such colonies would present extremely difficult biological and ecological problems. These should be addressed at the very outset if any serious effort toward designing satellites or colonies on celestial bodies other than the earth is to proceed."



Ecological Considerations for Space Colonies

by
Antonio Ballester, Barcelona, Spain
E.S. Barghoorn, Cambridge, Massachusetts
Daniel B. Botkin, Woods Hole, Massachusetts
James Lovelock, Bowerchalke, Wilts., U.K.
Ramon Margalef, Barcelona, Spain
Lynn Margulis, Boston, Massachusetts
Juan Oro, Barcelona, Spain
Rusty Schweickart, Washington, D.C.
David Smith, Bristol, U.K.
T. Swain, Boston, Massachusetts
John Todd, Hatchville, Massachusetts
Nancy Todd, Hatchville, Massachusetts
George M. Woodwell, Woods Hole, Massachusetts

There appears to be growing interest in the possibility of establishing large space colonies capable of supporting hundreds or thousands of people in isolation from the earth for long periods (for example, see G. O'Neill, **Co-Evolution Quarterly**, Spring, 1976). Such colonies would present extremeley difficult biological and ecological problems. These should be addressed at the very outset if any serious effort toward designing satellites or colonies on celestial bodies other than the earth is to proceed. This statement is the product of a series of discussions held in Woods Hole on May 14 and subsequently with scientists who have had experience in the study or design of closed ecological systems and who express concern lest the problems of developing congenial livable conditions on artificial or natural satellites be considered engineering problems rather than basic humanistic and biological ones.

The proposal is considered a logical and exciting extension of our space exploration and pioneering. It is to build a new meta-stable ecosystem, complete with biotic resources and closed cycles for other essential resources, and capable of supporting man over long periods. No such system has ever been constructed on earth. The probability that such a system can be built and maintained indefinitely at present seems remote. It seems especially remote when we realize that we have no background in the analysis of the problem and no technical or scientific research programs underway at present to develop the background. One of the current theses of economists and technologists is that economic and industrial growth is necessary for support of contemporary

The product of one large meeting and many individual conversations, this criticism and proposal brings rigorous ecosystem biology into the Space field for the first time. The text and the agreement about the text were carried through largely by Lynn Margulis, George Woodwell, and Dan Botkin. The statement is appearing simultaneously in **The Ecological Bulletin.** *Ecology may slow down Space mega-exploration. Space exploration may expand ecological understanding by at last permitting research on progressively more closed ecological systems.*

–SB

—O'Neill proposed "to build a new meta-stable ecosystem, complete with biotic resources and closed cycles for other essential resources, and capable of supporting man over long periods." However, "No such system has ever been constructed on earth. The probability that such a system can be built and maintained indefinitely at present seems remote. It seems especially remote when we realize that we have no background in the analysis of the problem."

Our experience leads us to believe that the greatest probability of success in establishing a space colony that might remain for as long as 25 years would be derived by adapting a large natural ecosystem on earth to the support of man. By large we mean in addition to surface area, a high diversity and high degree of patchiness. The versatility of forested areas, subtropical savannahs, and coastal environments and the success of man in adapting such ecosystems to human support leads us to the conclusion that the focus should be on such areas. With this background we would advance a very preliminary list of issues as worthy of immediate consideration before further commitments of funds or time are made.

1. Do all space colonizations intrinsically depend on exploitation of earth resources or, at least in principle, can independent and eventually productive ecosystems be established anywhere in the solar system?

2. A viable space station that has the possibility of being stable in its basic biotic structure over a period of 25 years would probably require an area of several square miles. The total amount of primary productivity, its diversity, and its distribution between food and fiber and the stabilization of other resources and potentiality for recycling will obviously determine the upper limit of the number of people that might be sustained. Do we in principle have the technological capabilities to launch or establish such large colonies?

3. Decisions would have to be made as to the minimal volumes required to sustain segments of the ecosystem and minimal volumes to sustain individual populations within it. The knowledge of minimal volumes is in its infancy and the relationship between stability and minimal area has been established only in the most rudimentary ways. In general larger more diverse ecosystems are more stable; if stable and productive closed ecosystems could not be made to function on Earth they certainly would not function in orbit.

4. The distribution of major mineral nutrient elements is a major problem. All organisms on earth require six major elements in abundance: carbon, hydrogen, nitrogen, phosphorus, sulfur and oxygen. There are an additional six to ten that seem to be universally required and there are probably 30 more that are required in special circumstances by certain organisms. Almost any ecosystem would contain these elements, yet their proper delivery and removal, their cycling, is a serious challenge. Elements must be delivered in the optimal quantities and proportions and in appropriate chemical form. Often they are required as gases. We must be concerned with the biological and geological and man-made informational systems that distribute essential elements.

5. Most productive forests, mixed agricultural and coastal ecosystems are attuned to seasonality, which implies appropriate variations in precipitation and temperature. One must recognize at the outset that natural ecosystems will not remain in their initial condition but will change by both succession and evolution. The design of the allowable maximum and minimum ranges of variation of ambient conditions in an orbiting space colony may be a serious problem.

6. Because the major source of energy to drive this basic unit of nature is solar, the question of the spectral distribution of incident energy, the quantity and periodicity of electromagnetic radiation at each wavelength, must be considered and controlled.

7. It will be essential that water be recirculated within the colony, delivered to the vegetation at appropriate intervals, collected, used in irrigation and for other purposes. We recognize the desirability of something similar to a coastal system with both terrestrial and aquatic components.

Biosphere 2, Oracle, AZ, February 2019

"Ecological Considerations" conveys the tight conceptual coupling between ecosystem ecology and the Gaia hypothesis. The basic proposition of such artificial habitats, once their shells are engineered in place, is to expect a viable replication of the Earth's own "ecosystem services" within a materially closed vessel—in other words, the effective production of miniature Gaias. However, "Ecological Considerations" also rang the sobering note of Gaian complexity, the exceedingly recondite dynamics by which viable planetary regimes arose and have maintained operations, the wicked difficulty of achieving working replicas of living ecosystems in artificial form. Sustained research into the Gaia hypothesis would address those very problems, but at that moment such efforts were confined to disparate and inconclusive research projects by ecosystem ecologists at the scale of terrariums and greenhouses. A decade later, Sagan and Margulis would speculate in "Gaia and Philosophy" that "the full scientific exploration of Gaian control mechanisms is probably the surest single road leading to the successful implementation of self-supporting living habitats in space." But in 1975, O'Neill took that implementation for granted. Two decades later, Biosphere 2 scaled up such an experiment, with disappointing results.