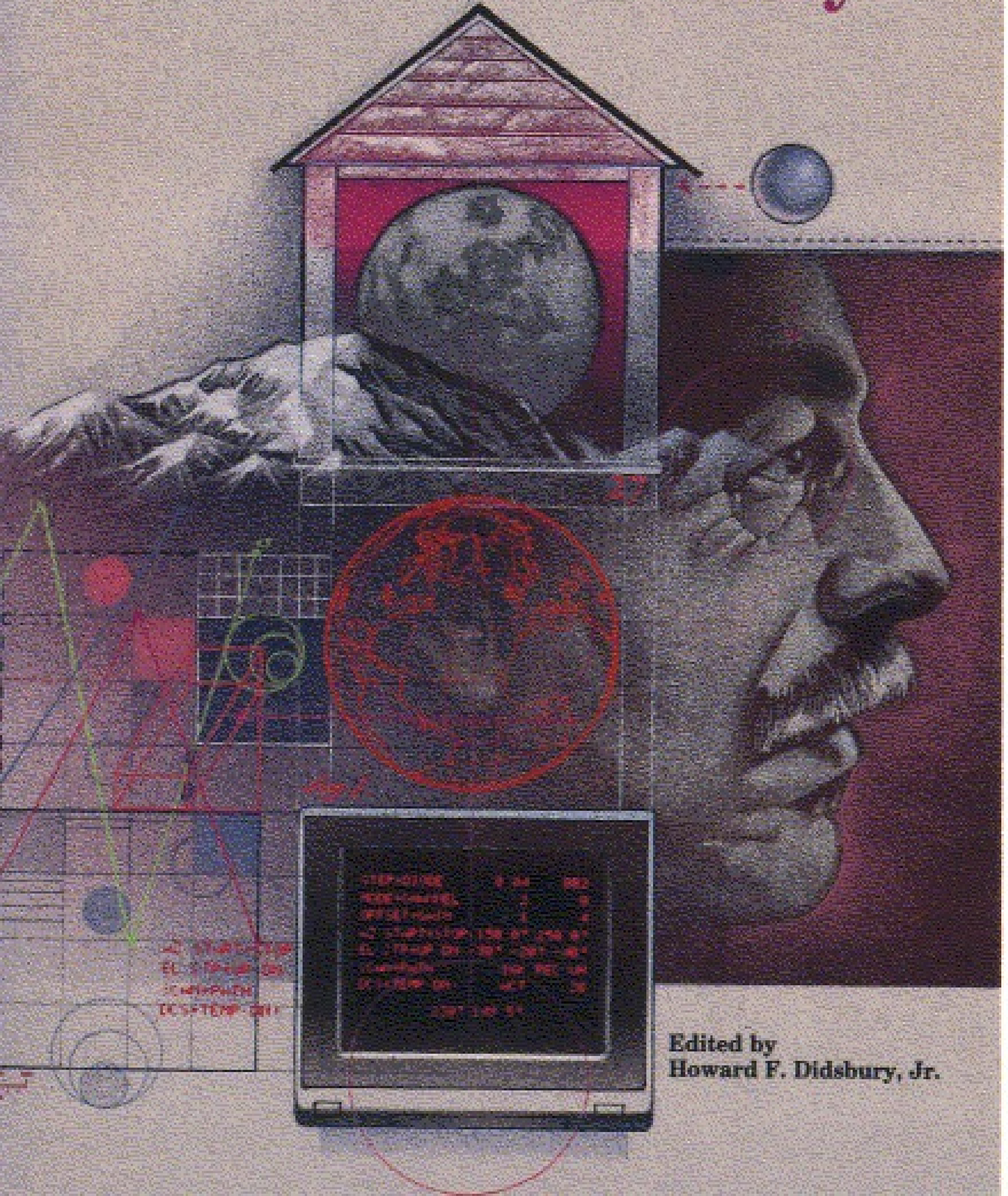
The Future: Opportunity Not Destiny



Edited by
Howard F. Didsbury, Jr.

The Future: Opportunity Not Destiny

Edited by
Howard F. Didsbury, Jr.

World Future Society
Bethesda, Maryland
U.S.A.

Editor: Howard F. Didsbury, Jr.

Editorial Review Committee: Deirdre H. Banks, James J. Crider, Howard F. Didsbury, Jr. (Chairman), Charles H. Little, Theodore J. Maziarski, Andrew A. Spekke

Staff Editor: Edward Cornish

Administrative Coordinator: Susan Echard

Editorial Consultants: Sally Cornish, James J. Crider, Frances Segraves

Editorial Assistant: Patty McNally

Production Manager: Jefferson Cornish

Cover: Michael Hill

Published by: World Future Society
4916 Saint Elmo Avenue
Bethesda, Maryland 20814
USA

© 1989 World Future Society

All rights reserved. No part of this book may be reproduced by any means, nor transmitted, nor translated into machine language without the written permission of the copyright holder.

Library of Congress Catalog Card Number: 89-051059

International Standard Book Number: 0-930242-36-X

Printed in the United States of America

Contents

NOTE

The Future: Opportunity Not Destiny was prepared in conjunction with the World Future Society's Sixth General Assembly, "Future View: The 1990s & Beyond," held in Washington, DC, July 16-20, 1989. The Chairman of the Conference was Kenneth W. Hunter. Susan Echard served as staff director. Robert M. Schley was program coordinator and Tracy L. Nathan served as assistant program coordinator.

The papers presented here were selected from a very large number submitted to the Editorial Review Committee. A number of distinguished papers whose subject matter did not lie within the limits of the volume could not be included.

Footnotes and other academic paraphernalia have been minimized to avoid disrupting the flow of the author's ideas and insights.

OFFWORLD DIVERSITY: THE BRANCHING OF LIFE IN SPACE

by

Brent Sherwood

Introduction

A pivotal accomplishment in the history of Earth life would be, through the agency of technological intelligence, its establishing ecologically independent extraterrestrial beachheads. Should this happen, Earth-based life would achieve an insurance, well beyond its evident tenacity, against periodic or unique planetary cataclysms. Distributed throughout the solar system, in fact, the special self-ordering, reproducing, growing phenomenon which is life could be safe from all but persistently willful disasters, or stellar or extrasolar catastrophes of an irrecoverable scale. Apart from simply insuring its survival, however, moving out into space will allow life to blossom in further variety as it adapts to the ecological niches available there.

We live in the age which, almost certainly, will bridge life's exclusively planetary past to a future of offworld opportunity. As executors of the spaceflight technology required to liberate life from the gravitational prison of its isolated birthplace, humans will determine the manner in which life expands off Earth. Primary in the human agenda, naturally, will be human life itself; other life will accompany and follow, and in some cases pave the way. In an effort to discern better how humans will inoculate space, this paper examines three linked issues: first, the reasons why free-space colonies will be an important component of human offworld expansion; second, some unavoidable conditions that will characterize life in such colonies; third, how those conditions will affect, and effect, offworld evolution.

Why Space Colonies?

The concept of large, manufactured colonies in free space, brought to public attention by Gerard K. O'Neill in 1974, immediately displaced older ideas and standards of space colonization. Since then however, despite a decade and a half of wide exposure in a rapidly changing technological society, despite the growth of dedicated advocacy groups, and despite stimulating and productive scientific and engineering work to develop tools to en-

Brent Sherwood *is senior engineer, future studies office, advanced civil space systems, Boeing.*

able space colonies, our collective image of such colonies and the civilization they embody has, like the older ideas before it, not changed much. But memes (ideas which replicate in human populations) must evolve in response to changing intellectual environments, or perish; it is time once again for the conceived image to mature.

That our image should change is important. As recent tragic US space history has demonstrated perfectly, long-term projects whose goals fail to evolve in step with their changing climate risk at best obsolescence and at worst parochial failure. Unfocused, nonadaptive or dusty images of goals make poor beacons to guide us into the future. While good work may emerge along wandering paths, great and inspiring collective work cannot, except in rare accident. Isolated technological discoveries, after all, often occur serendipitously, but real progress in ability and understanding requires a plan.

Large public works—be they wars or cathedrals or cities—certainly reflect, and may in turn inspire, the ethos of an age. For a society as steeped in the costly blessing of technology as ours is, space represents unequivocably the richest arena for exercising visible, public projects to reflect and inspire our values. Apropos to a media culture however, the space arena is for almost everyone only vicariously participatory. For everyone except the people directly involved in planning and mounting missions, it is not the detailed work itself but rather the *images* and *idea* of the work which can inspire. Ironically then, public perception (as distinct from real knowledge) both holds the financial key to progress in a democracy, and derives from information released by experts. Thus the images carrying that information, to portray the idea, must be critical.

We cannot avoid having some image of space society; the history of that image is eclectic but mainly dichotomous, and mirrors directly the American popular sensibilities of recent decades. In the 1950s and 60s, colonies in space were conceived to be complex planetary bases, where an endless bounty of scientific discovery sustained exuberant exploratory optimism. This limited utopia, populated somehow only by those able to challenge the secrets of Nature at the very edge of the abyss, grew naturally out of an expansionary America for which technology could answer anything. The population infected directly by this meme was, of course, those people who, albeit Earthbound, identified with the fortunate heroes. For them, there was much magic in the whole idea.

As the application of technology failed to solve society's problems at the end of the impatient 1960s, however, and as American popular interest shifted inward toward a more self-centered, materialistic social reconsolidation, the meme of space colonies donned a new, more accessible cloak. O'Neill's conceptual breakthrough was to realize that space industry could with extraterrestrial resources provide the means, in a technically foreseeable future, to house vast numbers of people in free space. Not tied gravitationally to planets, such societies would be free to live as they chose. That central conclusion remains as valid today as in 1974, and appears to represent unassailable logic.

A failure of foresight arose, though, in attempts to define details of the societies that would result, largely because no one understands well the economic setting of space civilization. Dispatching that context by inventing dependent connections to terrestrial economies (solar power satellites, for instance) is suspiciously circular and fragile logic, which fails to penetrate our ignorance of the motives of space dwellers. Laying out the architecture of space colony society is an enterprise far more involved than just outlining its feasibility. Vast voids in the concept have been filled with simple projections of the familiar. The lifestyle "choice" in published images of space colonies thus continues to reflect the dreams of bourgeois, suburban American culture. Jogging through Californian parks in space admittedly appeals to a wider (and incidentally more legislatively influential) popular base than the older "science hero" image, but is no less a utopian artifact of the time that produced it.

The "Island" colony concepts express directly an American 1970s and '80s longing for an Earth made new and clean, a society made prosperous and homogeneous. Its mannered extremes (a colony where Pennsylvania Dutch descendants regain the simple beauties of the rural 19th century replete with covered wooden bridges and horse-drawn carriages, according to one example published by a Sunday supplement in 1985) wax as romantically quaint—and impractical—to a modern view as did those of the "science hero" age. The "middle class in space" image risks foundering partly by leaving the world wondering just what the purpose of it all is supposed to be, and just what the enormous cost is supposed to be purchasing. Veneering space life with such a parochial slice of Earth culture, or even merely imagining that the veneer could be applied without being changed in the process, loses all the magic of new edges and new challenges, and all the potential of new growth, indeed of new life.

Another step in space colony concept evolution is needed now. As we prepare in the 1990s for increased human presence in space, a more careful joining between our knowledge of hard technical realities and of the irrepressible tendency of life to diversify can yield a fresh incarnation of the colony concept, and one with yet wider appeal. Lurking around the fringes of common colony images during their heydays has been a wealth of vignetted alternatives, framed primarily by the literature of speculative fiction. And from another quarter entirely have come such visionary urban planners as Paolo Soleri, with space colony designs as large as and no less sound technically than the island concepts, but yet utterly different in social sensibility. Some concepts nurture the delicacy of solitude; others glorify the darker, denser urban hive of the metropolis.

Apprehending the true range of possible geometries, populations, activities, and goals for free-space colonies—each as "feasible" as any other—can leave us numb. At the same time, the physical environment of space imposes a common set of constraints which cannot be avoided (although the "middle class in space" images tend to skirt them). Combining the real potential of unavoidably coarse—grained diversity with the real restrictions of equally unavoidable physical facts can be the theme of a new, more "open-hearted and tough-minded" generation of colony concepts. By exploring that theme, we can encourage a more mature dialog about space colonies, brightening and sharpening this important beacon to our future.

The Space Colony Environment

Space is necessarily a target-oriented place, where comparatively rare (if sometimes huge) mass concentrations move very quickly, separated by vast distances in a lethal void. That basic, if overly simplistic, structure characterizes all the scales of space, from planetary satellite systems to solar systems to stellar groups to galaxies to galactic clusters. The mass concentrations are where "all the action" is, and spaceflight is the essentially tedious activity of getting from one to another of them. The technical literature has proposed a range of interstellar travel concepts, which depending on their true feasibility and the advent of unpredictable breakthroughs might become possible even in futures beginning just generations from now. Before such time though, the targets available to us are those in our own solar system. And we have in hand some technologies (not the widest range, nor perhaps the best options yet) for reaching those places in our own time.

The attainable targets of our solar system are already essentially characterized. The planets are few, and mostly inimical to colonization. Earth's Moon and Mars present the most likely candidates for surface colonization, because they have natural environments apparently no worse than space itself. Fortunately they are both energetically close to Earth compared to other major solar system bodies, so an entire phase of planetary colonization will no doubt be focused on them. Self-sufficiency (essential for large-scale colonization) and modern technologies would allow a traditionally high "colonization" rate of population growth to be maintained, however. With a combined surface area of the same order as Earth's land, those two worlds would soon be rendered "finite" by even today's (non-colonizing) terrestrial population growth rate. Humans could occupy both of them completely and quickly, should they choose to. The number of generations that occupation might

take is irrelevant to the familiar and invariant result: fully occupied worlds.

The many other moons and planetesimals distributed around the solar system are multifarious, providing at once a diverse range of settings and sources of retrievable raw materials for industry. Particularly with these bodies as catalysts, humans could create their own new places in space by manufacturing and populating them. O'Neill rationally pointed out that for a spacefaring industrial culture, planetary bases are an energetically expensive proposition. Operating transportation systems, as the basis of a material interplanetary economy, in planetary gravity wells incurs high propulsive costs beyond those of just moving from place to place in solar space. Basing operations instead at facilities in high planetary or heliocentric orbits avoids this additional penalty.

Rotation can approximately simulate normal gravity if needed, particularly for large colonies. Shielded from hard space radiation but admitting sunlight, such colonies could proffer the microcosmically earthlike environments common in the popular images—or intriguing settings weirdly unlike anything yet built by humans. Such worlds would close on themselves, generating their own universe of life within, while without would extend the void of space in all directions. We might expect many people, for deep resons, always to favor living environments on planetary surfaces, with solid ground below them and endless sky above. Still, the virtually unlimited and variegated living space available through manufacture just might make free-space colonies dominate a long-term space future featuring human species growth. Indeed, should Earth life eventually become able to consume the resources of our solar system, a Dyson sphere of swarmed free-space colonies could change, from a galactic viewpoint, the visage of our sun.

In the target-oriented expanse of our solar system, the cost of *physical* transportation is measured by both energy and time, which trade off inversely, in large numbers. For example, a carload of people can make a road trip on Earth of several hundred kilometers using chemical, airbreathing propulsion which consumes roughly 50 kg of fuel, taking as long as they like. But to send that same carload of people to Mars and back at an energetically favorable opportunity, using the most advanced technology we have, would take an order 500 metric tonnes of propellant and supplies, and two and a half years. That assumes they start from Earth orbit. A more costly opportunity would need twice as much mass, and take half as long from start to finish (ironically though, it would only let them stay at Mars one tenth as long). Even if Mars becomes a sustaining and refueling stop, the time required to make the trip remains the same, and the magnitude of the effort required is huge. Space is empty, and the targets in it worth catching up to move quite fast.

If high-leverage technologies like electric propulsion and autonomus maintenance are applied, the proper infrastructure could be emplaced to supply steady cargo streams to almost any heliocentric orbit. Interplanetary commerce could become as regular and reliable as intercontinental shipping on Earth. Moving people throughout interplanetary space could in principle occur as regularly, but it is more difficult. Long trip times will always require multifunction life-support mechanisms that dominate populated-mission payloads. Thus no matter what the available interplanetary transportation capacity becomes at any time in our development, human transportation will be less efficient and more expensive than cargo shipping, and therefore limited by vessel manifesting.

Furthermore, human tolerance of extended spaceflight conspires with the cost of life-support to swing the energy-time tradeoff in favor of shorter, more propulsively expensive trips for populated flights. Even apart from the as-yet unresolved question of the need for artificial gravity, flights lasting many months and intended for large numbers of "business" or "leisure" travelers (rather than explorers) would require amenities yet more elaborate than those of modern cruise ships. Shortening the time allows simplifying the necessary "luxury." More advanced propulsion methods (such as nuclear thermal rockets) or truly breakthrough technologies (like mirror-matter-annihilation propulsion) would dramatically reduce interplanetary trip times, by releasing tremendous quantities of energy and converting it into useful work. For instance, constant acceleration equal to that of gravity at Earth's surface, applied to a space vehicle, could get it to Mars in several days (while supplying it with artificial gravity), but at an energy cost that would make sense only in the context of elaborate interplanetary commerce. Any way the problem is taken apart, and in almost any conceivable context, moving lots of people across the solar system is expensive.

The cost of *informational* transfer across space is measured by both link capacity and signal delay. The amount of information that can be transmitted is strikingly limited. Using the most advanced technology available, an optical device smaller than a backyard satellite dish could transmit a few stereo, color, realtime video channels from Earth to Mars. But lasers are not as widely tunable in frequency as radio signals; getting more than those few channels means using larger and much more complex equipment, and the limits for practical large systems are not yet known. However, physics dictates that moving the same equipment twice as far away reduces its link capacity fourfold, so high rates of information exchange across interplanetary space come at a high price.

A firmer boundary is that electromagnetic carriers (optical, microwave, radio) are limited to the speed of light, the finiteness of which becomes appreciable over interplanetary distances. A signal sent from Earth to Mars, for instance, takes between a few and several minutes to get there, depending on the time of year (except for about 1% of the time when it cannot get there at all because the sun is in the way). Immediately reciprocal conversation is therefore impossible between widely separated places in space. The timescale of the message-response cycle, enforced by physical reality, is across space as it was on Earth for all of history before electrical technology: not immediate.

Because of these restrictive transportation and communication costs, free-space colonies will, unless clustered together intentionally, be extraordinarily isolated. Given adequate resources (and no true colony would be located without steady sources of energy and materials) it will always be cheaper for people to make more people where they are, than to move them around for the sake of repopulation. Interplanetary excursion travel will most likely be much less popular and available than is jet travel today. And the kind of world-spanning communications we presume today cannot exist when the "world" is the whole solar system. Thus in a future of many free-space colonies, a social isolation more characteristic of earlier centuries will return. This inescapable fact nevertheless also restores local freedom from "global" homogeneity. Depending on how a colony manages its access to the resources that sustain it, its economic independence from other colonies may be assurable; but its privacy and social autonomy almost certainly are. Long-lasting remote influence over colony affairs is unlikely, and even remote espionage impractical.

A colony in deep space is much more vulnerable to environmental disruption than is a planet. Its buffers of breathable air, drinkable water, comestible food, and finally available help, are all vanishingly small compared to those provided by an established planetary ecosystem like Earth's. The margins are thinner, and the balance finer; fluctuations even mildly outside the design range for a free-space colony could be irrecoverable. Colonies could never allow the kind of environmental degradation Earth has suffered in the last century, for instance. This situation is not surprising to farmers, aquarists or others who use technology to culture life where it otherwise would perish. Successfully culturing colonies in space will require the same type of empirical knowledge, careful monitoring, and exquisite control.

Heavily loaded life-support systems, such as those sustaining the urban population densities driven by spaceflight economics to be most prevalent in free-space colonies, run close to the hazardous edge of failure. Many sources of environmental catastrophe would be possible in space colonies: uncontrolled and devastating biological plague, physical destruction through technical accident, cosmic violence such as an obliterating impact, warfare arriving from outside or erupting from within, or willful, terrorist sabotage. Among these, the last seems the most realistic threat. Rigid control over critical environmental conditions, and of the potential for disruptive outside influences, would be literally vital to the entire colony. When death awaits forever just through the hull, attention to proper protocol can be no less imperative for enormous vessels than for our current tiny space ships. This hard fact of conformity is independent of the size, social complexity, or any individual motives among the vessel's population. But the strict need for such tight control over the total environment also makes every detail of every aspect of that environment a design variable.

The inhabitants of a free-space colony would get to, in fact would *have* to, choose *everything* about the way they lived. Isolated by the scale of space, they would have neither unwanted interference from, nor the opportunity for limitless exchange with, the rest of humanity. Focused connections to other colonies could be arranged if desired, however. Large colonies established in"cycler" orbits, or itinerant colonies equipped with efficient, low-thrust propulsion, could enjoy repeating or touring encounters with others. Such periodic meetings or revisitations could occur at frequencies spanning months to generations, supporting unique trade and cultural exchange rhythms at a grand scale unknown since the last century.

Thus within the constraints of comparative isolation, hazard, and time just outlined, life in space colonies could fulfill practically any agenda desired. The appeal of human expression freed from Earthly precedent can be as broad as the horizon of human imagination and aspiration. Therein lies the potency of space colonies as a beacon for human futures. The possibilities include, but clearly reach far beyond, colorless tableaux of science heroes and bourgeois parks. And the feasibility of free-space colonies then obligates us to attempt scoping the true range of possible futures they could usher in.

Spaceborne Evolution

It is fruitless to predict in detail what free-space colony societies will be like. We have, however, already outlined enough to discern some boundaries, and to see what they can *not* be like. Colony society will in general be nothing like middle America, partly because colonists' aspirations, freedoms and activities will be so different, and partly because their incontrovertible rules of conduct will generate a social milieu utterly foreign to us. Fierce independence and central self-interest will be no one's fundamental right in an isolated colony; the unforgiving hazards of space preclude it. A level of communality, with mutual respect, physical civility and civic duty for which no historical model exists (and which our modern Western sensibility can barely fathom) would seem strictly necessary. Truly dangerous behavior—that which could physically endanger the entire colony—would elicit stern prevention. Earlier, weaker versions of these features have recurred in most frontier

societies; but the rigor imposed by the space frontier is the most severe that humans have ever encountered (the closest analog continues to be ships at sea). Furthermore, the rigor imposed by space will never abate for those who live there, because like the sea and unlike new shores, space will always be intrinsically hostile to *Homo sapiens*. Forever on the frontier, space colony life could enforce the development of exemplary urban order: freedom of opportunity within the boundaries of duty and interdependence.

Out of the internal consistency thus required of colony societies, focused by their limited outside contact and guided by their communal goals, will arise particular customs of civilization unique to each. In a future of far-flung free-space colonies, the paradox will inevitably develop that any single colony society must be homgeneous for the sake of its own survival, but that the sum of all colonies will display a range of diversity far exceeding any ethnic or nationalistic plurality we have yet seen. That is, fierce independence and central self-interest *can* be expected to characterize the motivations of whole colonies. Contemporary concepts have hinted at the potential for willful social diversity among separate colonies, but have stopped short either of recognizing its inevitability or of pursuing its evolutionary ramifications. If we take this extra step, some important conclusions are startling enough to recast reasonable projections about what human space colonization will lead us to.

About the most mild possible future is analogous to a social history like that of pre-European native North Americans living on the central plains. Nomadic by nature, these people achieved a stable social structure which, civilized by ritual behavior, lasted balanced in its natural environment for centuries. Bands of up to several hundred people grew and lived together, moving across the landscape according to its seasonal rhythms. Different bands were linked loosely by limited communication and genetic exchange through marriage, thus each developed its own customs and dialects. The regions overlapped by bands were crossed by their scouts, and periodically enormous festival gatherings of many bands would close and rejuvenate great cycles of social exchange.

Space colonies too can be expected to follow their own local rhythms and rituals, developing their own customs and characters in comparative isolation. Free-space colonies should be viable in virtually any size, from dozens to maybe millions of inhabitants. And the resources available in space, together with high procreative rates, will allow a virtually unlimited number of such colonies to orbit the sun. Choked communication channels, and occasional exchanges of small numbers of people, could link colonies culturally (and biologically) enough for them to feel some real allegiances to extended "nations." Their emissaries—scientists, athletes, and even tourists—would encounter each other when necessary or desirable, perhaps in locations remote to each home colony. And purposely itinerant colonies could periodically rendezvous for a time, fostering rich exchanges that would culminate heliocentric cycles taking perhaps generations to repeat.

A more adventurous future, not at all mutually exclusive with the "itinerant clan" scenario just outlined, would include renegade space colonies as well. Following their own agendas, some might choose complete isolation, giving them the freedom necessary to experiment with nature and with themselves, but without interference, exploring human futures as they wished. The result could go far beyond mere governmental self-determination. Gone would be media spyglasses trained upon their triumphs and traumas, motives and methods by the rest of humanity. The technological history of our species indicates that people do even potentially dangerous things, as soon as (and in fact because) they can, despite any proscription. The true freedom made possible by small directed groups in a large solar system would permit unprecedented expression of human ingenuity of all kinds, and incredible variety would result. In particular, a deeply technological species blowing wide the doors of opportunity in this way directly invites real, physical evolution.

Genetic evolution proceeds variously in species populations according to the frequency of mutations and the frequency of new niches opening up. In a large domain rich with opportunity, a starter species will diversify to fill all available niches, spawning distinct species which share the same environment but capitalize on different resources. The incredible branching of Cichlidae into hundreds of species over the last half million years in Lake Malawi exemplifies this sympatric speciation. And independent, isolated islands of life define the precondition for punctuated-equilibrium evolution. Given unique environments, abruptly isolated populations cannot avoid selective variation from their original mean as they optimize for different conditions. These processes of change will be every bit as valid in space as they have been on Earth. In time, biota descended from the life accompanying humans out into space will adapt to the spectrum of conditions there. Earth organisms have been found thriving in polar ice and scalding mineral springs; some forms can survive dessicated and encysted for decades, some metabolize sulphur around spreading vents under the crushing pressure of kilometers of overlying ocean, while others feed by corroding metals anaerobically inside reactor cooling systems. This tenaciousness leaves no doubt that the energy-rich vacuum of space itself would eventually stimulate variation among, and sustain, life forms once humans provided the substrate and the germ.

Within human populations, neither the subtlety of sympatric speciation nor the luxury of gradual adaptation over eons will most likely characterize evolution. If not already accepted and widely-

applied by the time of space colonies, molecular engineering will certainly be a candidate exploratory activity for humans seeking to escape regulation of their curiosity. The isolation possible with free-space colonies would let those who wish to experiment do so. Humans with the nanotechnological ability to control individual atomic bonds, regardless of however or whenever they acquire that skill, will be able to design life to suit their goals. That includes tailoring organisms to work for them, to entertain them, and to inspire them, but it also includes remaking themselves. Humans will be able to apply their technology recursively, either to suppress the imperceptibly gradual biological changes brought naturally by isolation, or to accelerate their own evolution in directions they choose. Mere social variation among space colonies seems trivial by comparison.

Self-wrought genetic or somatic changes could signal the subtle beginning of true human adaptation to space. For example, black bears are the only hibernating mammals whose bone metabolism remains the same year-round, and which thus avoid excretion of calcium during the winter. The unique protection from osteoporosis thus conferred is thought to be regulated by specialized blood chemicals. Humans engineered to produce an analogous substance might be made naturally and permanently immune to one of the most debilitating, and limiting, effects of weightlessness. With this and other biochemical changes, humans could begin to make themselves into creatures native to space.

Or, changes in what defines humanness might be accomplished more drastically and with other ends in mind. The point is that once indpendent colonies are available, each benefitting from the accumulated knowledge of human history and technology, people intent upon setting their own course could not realistically be stopped. Given biological nanotechnology in an interplanetary future then, social variation in human goals may lead naturally to biological variation in human expression. The genus *Homo*, and other Earth life with it, would branch irrevocably into new species determined by the ingenuity of human will. A diaspora of proportions unknown since life first appeared on Earth, and proceeding at a rate never even approached before, could truly colonize space.

Far from just a means to transplant parochial, privileged pieces of modern Western culture intact to a capitalist "high frontier" of utopian opportunity, free-space colonies represent a powerful tool for determining the future of Earth life. Colonies will establish technologically habitable environments throughout the solar system. Through them and the freedoms they allow, humans will choose and apply a spectrum of conditions, methods and intentions unimaginable, impossible or impermissible heretofore. Restricting their inquiry will become unfeasible. By using advancing technology, life can evolve away from its old terrestrial limitations, expanding through diversity its presence in an infinite universe, as it branches to fill the new ecologies humans will find and make. An agent of change peerless in Earth's history then, free-space colonies may well guarantee that the boundless variety of inventive speciation defines both human destiny and the ultimate future of Earth-based life.