Whole System, Whole Earth: The Convergence of Technology and Ecology in Twentieth Century American Culture

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IN REMAKING THE WORLD, 1960-2000

This study argues that the global network of information technologies, defining so much of late twentieth and early twenty-first century life, has been framed and legitimated by a countercultural discourse first forged in the nineteen-sixties, constructed around a rejection of modern technological civilization and an embrace of deeply ecological values. At the core of this discourse is Stewart Brand, whose publications, including *The Whole Earth Catalog*, sought to equip creative, independent-minded individuals with tools and ideas that they might use to build new relations among people, nature, and machines. In response to a widespread belief that modern technological civilization was fundamentally in conflict with the ecological well-being of the planet, Brand identified an emerging order of technology that was compatible, even co-evolutionary, with the natural systems of the planet because based on the same organizing principles. Whereas some of the most powerful technologies of the modern era – nuclear weapons, chemical pesticides, advanced industrial processes – seemed destined to destroy the natural environment, cybernetic "whole-systems" technologies appeared to Brand and others as a source of hope for salvaging both technological progress and ecological survival. Chief among these technologies was the computer, which appealed to Brand, even as early as the nineteen-sixties, as a tool that enlightened, adventurous individuals might use to remake the world. In the Whole Earth "whole systems" discourse, information technologies became tools for a new *ecological* era. In the nineteen-eighties, as networked personal computers became widely available, the *Whole Earth Review*, the *Whole Earth Software Catalog*, the Whole Earth online community, and other Brand-inspired creations played a central role in shaping how these new tools were understood and received among their first and most influential enthusiasts: hackers, deadheads, ex-hippies, and ultimately the libertarian entrepreneurial class of Silicon Valley.

As it describes and analyzes this Whole Earth whole systems discourse – this quasi-scientific-quasi-countercultural way of representing the relationship between nature and technology – my study focuses on key developments in twentieth-century science, especially the central role played by cybernetics in molding post-World War II conceptualizations of both nature and technology. Studies of post-war technoscience generally address the impact of cybernetics on *biology*. Cybernetic organisms – "cyborgs" – have been the representative figure for scholars identifying the many ways in which organic bodies have been interpenetrated by and have merged with post-war technologies and technoscientific practices.[1] My focus, however, is on the confluence of cybernetics and *ecology*. I argue that the concept of the cybernetic ecosystem has played a crucial role in the development of a discourse in which nature and certain technologies are represented as parallel instantiations of universal laws governing all complex, self-organizing, self-regulating whole systems. The intersection of nature and technology in this ecological domain raises some of the same questions and has resulted in some of the same consequences as the coupling of body and machine: the global reach of technoscience extends into forests and watersheds, ponds and meadows, oceans and atmosphere, just as into the blood and genes of individual organisms. But the intertwining of technology and ecology also generates its own material, conceptual, and cultural effects. An analysis of these techno-ecological effects can contribute to a more complete understanding of the complex interactions among people, nature and technology since the middle of the twentieth century.

My study is also distinguished from other scholarly works on post-war nature/culture relations in its emphasis on the traffic between technoscience and popular culture. Scholars such as N. Katherine Hayles and Mark Seltzer have explored science and technology through popular literature, but other cultural forms by and large have escaped notice.[2] Environmentalism, as a social movement, perhaps has been responsible for the greater variety of connections between ecology and popular culture than one is likely to find in regard to many other post-war sciences. My study demonstrates how cultural forms, such as *The Whole Earth Catalog* and countercultural experiments in alternative living, played key roles in molding broadly-held understandings of nature and technology in the later part of the twentieth century. In fact, I argue, the cultural acceptance of information technologies has depended upon the endorsement of these alternative, ecologically-oriented cultural elements; the cultural reception of information technologies has relied upon a perception of them as a radical alternative to the lumbering, inflexible, resource-depleting, environmentally destructive technologies associated with the waning industrial era.

The Whole Earth whole systems discourse hinged on the convergence of a cybernetic “whole systems” model of nature and a cybernetic “whole systems” model of technology. The product of this convergence is what I call the “techno-ecological system.” I examine a number of such systems, most of which bear the imprint of Stewart Brand: the image of the whole Earth from space, the metaphor “spaceship Earth,” the idea of building colonies in space, cyberspace, and others. Brand hoped that such systems might provide a way past the conflict between the technosphere of modern civilization and the biosphere of planet Earth. He envisioned the space inside these techno-ecological systems as "outlaw areas," where pioneering individuals might forge new, healthier relations with one another, with their environment, and with their own inventions. As we shall see by the end of this study, this whole-systems techno-ecological discourse would eventually come unmoored from Brand's human-centered values. By the nineteen-nineties, instead of empowering individuals to improve their lives and the health of their environment, the convergence of ecology and technology within a whole systems discourse would serve the purpose of perpetuating a self-justifying doctrine of complex whole-systemness. The discourse of the techno-ecological system would become a means for legitimating the global information economy and unrestrained technoscience.

Review of Chapters

The first chapter of my dissertation locates the whole system model within the post-Newtonian science of the early twentieth century. Following the quantum revolution, the thermodynamic whole system model was employed in a variety of life and human sciences – physiology, sociology, ecology, and others – as a means for vaulting over the old mechanism-versus-vitalism problematic. The thermodynamic system model provided a way to address complex wholes without either compromising their complexity through crude mechanistic reductionism or resorting to untestable, unempirical vitalist explanations. This chapter looks at the Russian geologist Vladimir Vernadsky's use of the whole system model in conceiving of the "biosphere," in the 1920s. It also examines the British ecologist Alfred Tansley's formulation of the "ecosystem," in the 1930s. Both the biosphere and ecosystem represented radical reconceptualizations of the relationship between living and non-living things. Whereas in an older ecological paradigm plants and animals were situated within an environment that prompted from them certain physical and behavioral responses, in the whole system model "living matter" and non-living matter were mutually formative components of a larger, encompassing entity called *system*. This system could be studied as a thing in itself; energy flowed through it, materials circulated within it, and through its pattern of organization the system maintained itself in dynamic equilibrium. In this chapter I make the key claim that the whole system model of nature problematizes the place of people. The model locates humans as ecological components *inside* the system. At the same time, however, it positions them as agents *outside* the system, responsible for reshaping the face of the planet to suit their interests, in the case of Vernadsky, and for conceiving of the necessarily artificial ecosystem concept in the first place, in the case of Tansley. This ambiguity in the location of people relative to the system remained a central feature of the system model as it came to encompass both nature and technology in the ensuing decades.

In the 1950s, the ecosystem model combined with one of the most influential conceptual developments of the post-war era: cybernetics, or "the science of control and communication in animals and machines" (Wiener 1961). Based on the same whole-system principles as the ecosystem and the biosphere, cybernetics described the mechanism – the negative feedback of information – through which complex, self-regulating entities organize themselves and become capable of purposive behavior. Part of what made cybernetics such a groundbreaking set of ideas was that the entities it described could be organic, social, or even technological: the principles of self-organization and self-direction it delineated were universal. These ideas were central to the post-war fusion of science and technology, influencing not just the development of complex information machines, but nearly every life and human science as well. Chapter 2 tracks the relationship between cybernetics and ecology in the nineteen-fifties, tracing the development of the cybernetic ecosystem through the work of ecologists Eugene and Howard Odum.

The cybernetic ecosystem was a powerful new conceptual tool for understanding the global environment and assessing the stresses and strains placed upon it by late-twentieth century civilization. Ecology met cybernetics during a time of mounting environmental crisis. The pervasive presence of radioactive isotopes such as strontium-90 and hazardous chemicals such as DDT, along with growing concern about overpopulation, resource depletion, and world-wide pollution, created a widespread belief that the planet could be headed for ecological disaster.

For some people – including a good number of scientists and policy-makers – the cybernetic, whole-system model of nature suggested that the ill effects of technological civilization could be controlled by proper management. Knowing the limits of an ecosystem, for example, scientists could measure and monitor its stressors and keep them within acceptable ranges so as not to overload the system beyond its ability to correct itself. Thus, better ecological management could help ensure that the modern industrial world would not derail itself by destroying the natural systems upon which it depended.

For others, however – again including many scientists and policy-makers – the new model of nature provided scientific validation for the thought that modern civilization itself must be turned in a different direction entirely, before it self-destructed.

The drive for perpetual economic expansion and technological control was pushing the planet to its limits; the Earth's delicately balanced systems were so complex that they could not be fully understood, let alone managed. In this call for re-evaluation and self-restraint, cybernetic ecology was exceptional among post-war technosciences, for it provided the footing for a sustained and powerful critique of modern technological civilization.[3] Many people by the 1970s believed that to avoid world-wide ecological collapse modern civilization would need to scale back its population, achieve a steady-state economy, and curb the proliferation of dangerous global technologies. The Club of Rome's famous prescription for the world's ills, *The Limits to Growth* (1972), formalized the conflict as "technosphere versus biosphere."

But there was also, beginning in the nineteen-sixties, a third position, which sought an alternative to this either/or choice between technosphere and biosphere. We can see this discourse begin to take shape in Stewart Brand's *Whole Earth Catalog*. The diminished prospects of a restrictive, impoverished, technologically-timid-though-ecologically-survivable world were no more appealing to Brand than was the dangerous, pollution-choked, over-populated future modern technological civilization seemed to promise. Instead, Brand believed in the possibility of salvaging both technological progress and ecological sustainability through a whole-systems vision of nature and technology.

Chapter 3 examines the beginnings of the Whole Earth whole-systems discourse in the context of the U.S. manned mission to the moon. The trip to the moon crystallized the dilemma of the era: on the one hand landing people on the moon and bringing them safely back left little doubt about the astounding capabilities of modern technological civilization; but just as astounding was the look back at the whole planet from distant space. The view of Earth as a solitary entity floating in blackness was profoundly sobering for a watching world; it revealed the planet's undeniable singularity, the absolute limits of its size and resources, its heartbreaking rarity and solitude. For progressives, the view of Earth in space suggested that humankind had perhaps outgrown its small planet and was ready to find new homes in the universe beyond. For romantics, the picture urged humankind to reconcile itself to nature on the only home world it would ever know; it made a strong case for living more carefully and cautiously on Earth, with the understanding that there was no recourse if this small island of life were destroyed.

But for Stewart Brand, Buckminster Fuller, astronaut Russell Schweickart, biologist Lynn Margulis, her husband, astronomer Carl Sagan, and others in the Whole Earth community, the picture validated the perspective afforded by cybernetics: the Earth was a whole system, and people could build a prosperous and adventuresome future for themselves by adapting their technologies and ways of life to the universal laws of whole systemness. It was a mistake to imagine that we might simply consume the planet and trust our technologies to carry us to some fresher world. But at the same time, it was much too late and impractical to believe that we might at this stage revert back to pre-modern ways in order to prevent our self-extinction. In the Whole Earth whole systems discourse, hope for adapting civilization to the ecological realities of the planet lay in discovering "outlaw areas," as Buckminster Fuller called them, beyond the constraints of hidebound mainstream society, where creative, self-directed individuals armed with whole systems concepts and tools might experiment with new modes of being and new kinds of relations among people, nature and machines.

In the late sixties and seventies, space seemed just such an outlaw area. Chapter 4 examines three techno-ecological systems constructed around the idea that nature and technology might be reconciled beyond the confines of the planet: the metaphor "Spaceship Earth," the idea of colonizing space, and the Biosphere 2 project, which was envisioned as a first step toward creating a self-organizing, self-regulating environment that could sustain space travelers for long periods of time. In the Whole Earth whole system discourse, space promised a vast new opportunity for cultural experimentation, a venue for creating new worlds in which people could invent fresh modes of social and ecological life, in which humankind could effectively start over and, as Brand said, "get it right this time." The prospect of the unpredictably new emerging from outlaw cultural areas was central to the Whole Earth discourse from the time Brand first imagined that his *Catalog* might inspire legions to turn their backs on modern technological civilization, build their own dwellings, generate their own power, grow their own food, and create a new civilization.

Though nature/culture relations had thus far been botched on Earth, seeing the planet as a spaceship provided a perspective that both inspired dreams of space colonization and suggested that humans still might be able to learn how to live on the home world. First coined by Buckminster Fuller, "Spaceship Earth" summarized, as Brand and Fuller used it, the whole-systems perspective afforded by the view of the whole Earth from space. Humans were not just another species along for the ride; nor were they remote operators capable of directing and manipulating the planet with complete detachment and control. Rather, they were agents within a planetary techno-ecological system that sustained them but which they were also shaping. Equipped with whole systems thinking and design, humans might find a way out of the technosphere-versus-biosphere standoff and re-build their world in such a way that technological civilization and the planet itself might co-evolve. Such a perspective depended upon a whole system model of both nature and technology, and the self-contradictory location of people both inside and outside the techno-ecological system of Spaceship Earth. In this metaphor we can begin to see how the undecidable location of people relative to the system functions as a means for moving past the stalemated inside-nature-versus-outside-nature, technosphere-versus-biosphere problematic, and begins to suggest a future in which both technological progress and ecological survival are possible.

The idea of space colonies was a further step toward that future. On the heels of the successful mission to the moon, Brand was captivated by the prospect of colonizing space, inspired by the vision of a Princeton physicist named Gerard O'Neill. The idea was to build self-contained communities orbiting between the moon and Earth with materials mined from the moon and asteroids. In each colony, up to a million people might live indefinitely amid an enclosed system of manufactured mountains, forests, animals, streams and lakes. Space colonies, O'Neill believed, could relieve Earth of its worst environmental ailments, including overpopulation, pollution, and energy depletion. He received funding from NASA to develop his ideas, and testified before Congress as to the project's merits. Brand published O'Neill's ideas in his magazine, the *CoEvolution Quarterly*, and opened up a dialogue among readers as to whether colonizing space was a good idea or not. Brand was interested in finding out whether space colonies might provide just the kind of outlaw area needed for realizing the Whole Earth whole systems ideal.

O'Neill's space colony dreams remained unfulfilled, but in the nineteen-nineties a group of scientists, financiers, and whole systems visionaries began to build a replica of the biosphere under a dome in the Arizona desert, which was to be a first step towards constructing the kind of self-sustaining habitat that would be necessary to support humans and other life for long periods of time in space. Six "biospherians" struggled to live in Biosphere 2 for two years, but encountered multiple problems which eventually showed the experiment to be unfeasible. I argue that Biosphere 2 failed because of a central conflict in its underlying conceptualization: to function as envisioned, as a true self-organizing, self-regulating whole-system environment, Biosphere 2 would need the self-sovereignty to find its own equilibrium and its own mix of living and non-living constituents; however, the human beings inside needed a very particular environment, namely, the one that had evolved in Biosphere 1, the Earth itself, over hundreds of millions of years. The people conducting the Biosphere 2 experiment could not completely forfeit their control and responsibility to the system and permit the human biospherians merely to go "extinct" while the system organized and regulated itself toward some dynamic equilibrium. In other words, the techno-ecological system located people both inside the system, subject to its control, and outside the system, necessarily exerting their own control. This contradiction, which I contend is embedded in the techno-ecological system discourse, proved untenable when it became instantiated in a manufactured techno-ecological entity encompassing actual human beings.

With the failure of Biosphere 2, space seemed a less and less feasible venue for re-making civilization within techno-ecological systems. By that time, however, a new technological revolution had already taken hold, one Stewart Brand identified as exactly the kind of technology his Whole Earth ideal had been pushing toward all along. Personal computers, especially when networked together, seemed to Brand to place the most sophisticated tools of modern civilization in the hands of myriad individuals, empowering them to build new kinds of relations with one another and with the planet. Networks of information technologies, Brand argued, were best understood as ecosystems: complex, self-organizing entities under no central command, but endlessly adaptive, innovative, and robust. Chapter 5 argues that the Whole Earth whole system discourse framed and legitimated cyberspace as an outlaw area, a techno-ecological space for experimenting with alternative modes of being. Like communes and space colonies before it, cyberspace appeared in the Whole Earth discourse as a venue for new relations among people, nature, and machines. Unlike Biosphere 2, however, the human presence within cyberspace was not physical and therefore not subject to the same material risks that came with relinquishing control to the system. As with all techno-ecological systems, however, the location of people, inside or outside, and the question of system control versus human control, were fundamentally undecidable.

The techno-ecological discourse Brand and others forged from the whole systems model blossomed in the nineteen-eighties and –nineties as the information economy and high-tech culture supplanted the wheezing, post-industrial world of the late-seventies and early eighties. Brand and others understood information technologies, and indeed the global information economy itself, to function according to the same whole systems principles as the complex entities of the natural world. Author Michael Rothschild argued that “the economy is an ecosystem.” His “bionomics” became a guiding economic philosophy among the entrepreneurial set in Silicon Valley during the nineteen-nineties

(Rothschild 1990). Brand protégé Kevin Kelly wrote in his book, *Out of Control*, of the emerging "neo-biological civilization," in which the whole systems "biologic" of nature was migrating into machines, social systems and the world economy (Kelly 1994). Chapter 6 examines these late manifestations of the whole-systems discourse, along with a theory – the Gaia hypothesis – of the planet itself as a single, complex living organism, and the idea that the globe-encompassing technologies of the late modern era represented a new planetary evolutionary stage, called the *noösphere*. All of these developments depended upon a perspective in which information was the currency flowing through the complex interrelationships of techno-ecological whole systems.

The techno-ecological discourse Brand was so instrumental in constructing worked to define the technological and cultural changes that took place as a result of the boom in information technologies in the nineteen-eighties and –nineties. But as the discourse spread it also lost sight of Brand's originating values, which kept human agency and welfare at the center. Rothschild's bionomics and Kelly's neo-biological civilization were elaborate rationalizations for an expansionist, technology-driven, unregulated global economy, and for unfettered technological adventurism. Environmental concern and ecological awareness had served as the basis for a powerful new critique of modern technological civilization beginning in the nineteen-fifties. Through the development of a whole-systems, techno-ecological discourse from the sixties through the nineties, both technology and nature were reconceptualized in a way that depicted whole-systems technological development as a compatible and even necessary extension of life on Earth. By the end of the twentieth century, however, the critique of modern industrial, chemical and nuclear technologies that was embedded in this techno-ecological reconceptualization had been reabsorbed by the dominant technoscientific discourse and employed to advance the interests and priorities of global networks of information technologies and economic relations.

The final chapter argues that the characteristics that enabled the discourse of techno-ecological systems to by-pass the old nature-versus-culture, technosphere-versus-biosphere dichotomies are precisely the characteristics that allow it to justify and legitimate the global information economy and technoscientific practices of the late twentieth and early twenty-first centuries. The key characteristic is *complementarity*, a feature whereby conflicting, even mutually exclusive, qualities or possibilities are also equally and simultaneously essential. Complementarity in the techno-ecological system allows the question of human control to remain ambiguous and undecided, so that humans are paradoxically both empowered to create techno-ecological systems and relieved of responsibility for them. For the application of this concept I am relying primarily on the work of Arkady Plotnitsky, whose *Complementarity* (1994) provides a theoretical framework for understanding the twentieth-century anti-epistemological discourses the arose from Niels Bohr's interpretation of quantum mechanics and Georges Bataille's concept of general economy.

Review of Literature

My dissertation makes a contribution to the growing body of cultural studies concerned with the relationship between nature and technology since World War II. Like my own, these works tend to recognize the post-war period as a watershed, establishing in the latter half of the twentieth century a new set of relations between the artificial and the natural, the technological and the organic. But while biology and the human body are the primary reference points for scholars such as Haraway and Hayles, my study makes the central claim that the convergence of technology and *ecology* has been an equally important force giving shape to America's post-WWII information culture.

Haraway's work is at the forefront of cultural scholarship concerned with the convergence of nature and technology. Her studies of technoscience combine historical, cultural, and feminist analysis to show how post-war science and technology have shaped the world discursively, politically, and materially (Haraway 1985, 1989, 1991, 1992, 1997). Haraway aims her work at the "integrated systems" of the post-war period: global economic and cultural structures and the pervasive, powerful networks of scientific and technological relations that support them. Such systems are the instruments through which a militaristic, racist, patriarchal, and exploitative dominant world culture colonizes the globe and sustains its hegemony. At the same time however, these integrated systems – precisely through their transgression of natural and technological boundaries – continually open up possibilities for resistance. Nature, Haraway states, is "artifactual." Organisms are "made in world-changing technoscientific practices by particular collective actors in particular times and places." Understanding nature as an artifact, by one turn, facilitates the exploitation of both human and non-human "others." But by another, recognizing nature as a human construct provides opportunities to "unbind ourselves from the sun-worshipping stories about the history of science and technology as paradigms of rationalism; and [to] refigure the actors in the construction of the ethno-specific categories of nature *and* culture" (Haraway 1992). The central refigured actor for Haraway is the "cyborg," part organism and part machine (Haraway 1985).

Like Haraway, Hayles writes about the post-war processes that began to blur distinctions between bodies and machines, reality and simulation. In *How We Became Posthuman* (1999), Hayles argues that after World War II information was reconceptualized as a disembodied thing in itself, separate from any material substrate. The redefinition of organic bodies as patterns of information made it possible to imagine that such patterns could migrate across physical forms, that a human mind, for example, might be downloaded onto a computer. In Hayles's analysis, cyborgs, in fiction and in reality, demonstrate the implications of understanding organisms and information in this way. One of the primary consequences, she contends, has been the dissolution of the liberal humanist subject, that rational, autonomous, self-conscious individual positioned since the Enlightenment as the locus of knowledge and agency.

This dissolution presents both risks and new opportunities, according to Hayles. The liberal humanist subject, formed throughout centuries of Western culture, was coded as male, white, and heterosexual. Subjects who deviated from that norm were to varying degrees less than representative of humankind, less than fully realized products of Western Enlightenment. Hayles shows how the early cyberneticians such as Norbert Wiener struggled to hold onto the liberal humanist subject, even as cybernetics and information theory were dismantling it. In the dissolution of the liberal humanist subject Hayles sees a risk that similar racist, sexist, homophobic and other biases might re-coalesce around some new entity, such as "artificial intelligence." Her hopes for a different, more egalitarian and democratic outcome lie in "distributed cognition," the idea that subjectivity might be amalgamated, heterogeneous, and continually reconstructed within networks of interrelations among people, organisms, and technologies.

The prospect of “distributed cognition” shows how essential it is to begin considering the role of *ecology* in post-war constructions of machines and organisms. The techno-ecological system, after all, describes precisely this kind of network of interrelations. More than that, however, such heterogeneous, “ecological” models (decentralized, flexible, interrelated, diverse) are frequently proffered by cultural critics as an alternative to the established order of hierarchical, atomistic, rigid, homogeneous relations.[4] These critics may be unaware that their model has already been appropriated within a discourse that associates global networks of information technologies with ecological and countercultural values.

Haraway, Hayles, and others writing about the merger of the natural and the artificial tend to focus on organic bodies, especially human organisms and their genes (Doyle 1997, Kay 1997, Keller 1995). There is even a tendency to *equate* nature with bodies, as Mark Seltzer does in *Bodies and Machines* (1992). “Nothing typifies the American sense of identity,” Seltzer writes, “more than the love of nature (nature’s nation) except perhaps the love of technology (made in America).” Seltzer’s book, he says, “traces the relays between the natural and the technological that make up what might be called the American body-machine complex” (Seltzer 1992). “Nature,” even “nature’s nation,” for Seltzer, becomes a reference to the human body rather than to the natural world. That is, biology rather than ecology is presumed to be the realm of convergence for the organic and artificial.

While critics have explored the cultural effects of cybernetics and biology, there has been no equivalent exploration of the confluence of cybernetics and ecology in cultural discourses and representations. Though there is a substantial body of scholarship on “nature” as a shifting category in postmodern culture (Robertson, et al.1996; Cronon 1996; Bennet and Chaloupka 1993), little of it is rooted in developments of post-war ecology. Where scholars working in the cultural studies mode have taken up post-war ecology in an extended way, they have not explored connections established through cybernetics between a model of whole-systems nature and a model of whole-systems technology (White 1998; Ross 1991; Warren and Cheney 1991).

The historians of science and the environmental historians writing about twentieth-century ecology have of course traced the influence of cybernetics on post-war ecology (Bocking 1997, Worster 1994, Golley 1993, Hagen 1992, Mitman 1992; Taylor 1988). Their studies tend to be restricted to the realms of scientific practice and policy, however. That is, they generally do not follow the dissemination of ideas from restricted technical and scientific communities into the culture at large or investigate the ways in which these ideas and practices shape discursive procedures and modes of representation. They are not, in other words, studies of culture but studies of scientific communities and ideas.

While historians of environmentalism do mark the migration of ecological ideas from science into broader communities, they are primarily concerned with environmentalism as a social movement (Worster 1994, 1988; Gottlieb 1993; Bramwell 1989; Hays 1987). The cultural values adhering to environmentalism (“beauty, health and permanence,” in the case of Hays, for example) may be central to their accounts, but ultimately they do not address their studies to the formation and operations of overarching cultural discourses and representations.

So while studies of culture and technoscience have not addressed ecology, works in the history of ecology and environmentalism have not concerned themselves with the central cultural questions raised by the confluence of ecology and cybernetics: What new discourses of nature and technology were made possible, and how have they been put to use? I believe that post-war constructions of ecology and technology were mutually formative, and that examining the two in relation with one another can benefit both cultural historians' engagement with technoscience, and the history-centered understanding of post-war ecology and environmentalism. For example, where, in studies of technoscience, the cyborg emerges as the central figure from the "implosion" of information technologies and biology, a different figures arises from the confluence of post-war technology and ecology: the *techno-ecological system*. An examination of "spaceship Earth," space colonies, Gaia, Biosphere 2, bionomics, and other systems reveals the central roles played by ecological models and environmental concerns in determining the way people would understand a world-wide culture of globalized information technologies. It also shows how cultural forms – *The Whole Earth Catalog*, *CoEvolution Quarterly*, "outlaw" alternatives to mainstream nature/culture relations – made scientific concepts and certain technologies part of a countercultural imaginary, investing them with dreams of some better, more sustainable and egalitarian future. Such countercultural and ecological values have inoculated the global network of information technologies against the criticisms that only a couple of decades earlier had described the technologies of modern civilization as fundamentally at odds with the biosphere.

Finally, though I understand my project to be situated within that niche of cultural analysis concerned with post-WWII nature, technology and science, I also situate it within a tradition of American Studies scholarship that holds the cultural engagement with nature and technology central to Americans' lived experience. This tradition began with the "myth-symbol" school established by Americanists such as Henry Nash Smith (*Virgin Land*), R.W.B. Lewis (*The American Adam*), and Perry Miller (*Errand into the Wilderness*). Later scholars working in this tradition included Leo Marx (*The Machine in the Garden*), Roderick Nash (*Wilderness in the American Mind*), Richard Slotkin (*Regeneration through Violence*), Annette Kolodny (*The Lay of the Land*), and Vera Norwood (*Made from this Earth*). Though I write about "discourses," rather than about "myths, images and symbols," I think of my work as an extension of an older school of American Studies engaged in the interdisciplinary study of *ideas* about nature and technology, ideas that took many different cultural forms, circulated in a wide variety of cultural contexts, and were put to various kinds of cultural work.

Notes

[1] The term “cyborg” was first used in 1960 by scientists in the space program (Clynes and Kline 1960). Donna J. Haraway began using the term in the 1980s in her feminist critique of technoscience (Haraway 1985). Myriad others have used it since, including in this study Edwards (1996), Galison (1994), Hayles (1999), Keller (1995), Latour (1993), Mirowski (2002), and Pickering (1995).

[2] See Hayles (1999), and Seltzer (1992).

[3] The cybernetic ecosystem model has remained central to the popular understanding of ecology since the 1960s, thanks in large part to the fact that it is the operative model within most corners of environmentalism. See Gottlieb (1993), Merchant (1992,), Worster (1988; 1994). The cybernetic ecosystem within ecology, however, reached its peak in the 1960s, with the International Biological Program, but then declined in influence among ecologists from the 1970s on, due in part to a factor Tansley identified right from the start: the ecosystem is necessarily a mental construct; there is no way for an ecologist in the field to actually isolate one in order to study it. See Hagan (1992) and Golley (1993).

[4] In addition to Hayles, see White (1998), Capra (1996, 1982), Latour (1993), Rifkin (1991).

CHAPTER 1
THE BIOSPHERE AND THE ECOSYSTEM: CONFIGURING EARTH AS A WHOLE SYSTEM, 1925-1945

> Photographs of the earth show that it has a green-blue color. The planet acquired this pleasant distinction, it appears, after turning in the sunlight for about three billion years. Solar energy, arriving at its surface at the rate of two calories per square centimeter per minute, ignited the processes of life in the primordial waters. The earth, in consequence, soon became endowed with an atmosphere of approximately its present composition. For about a billion and a half years the mixtures and compounds of the principal constituents of the air and water – the light elements carbon, hydrogen, oxygen and nitrogen – have been maintained in steady state by cyclic passage through the tissues of plants, the animals that eat them, and the decomposers of both. The biosphere – this thin film of air and water and soil and life no deeper than ten miles, or one four-hundredth of the earth's radius – is now the setting of the uncertain history of man. – *The Biosphere,* 1970.

The paragraph above comes from the editors of *Scientific American* in their forward to a 1970 collection of essays on the biosphere. It encapsulates what by that time had become a widely accepted understanding of planet Earth. First, it identified the planet as a singular ecological entity spinning in space. Such a perspective was established in a spectacular way two years before, when the Apollo 8 flight to the moon began sending back full color images of the whole planet, depicting in a new way its cosmic context, its essential *planetness*. Second, this ecological entity was understood to be a thermodynamic system composed of both living and inert matter. As solar energy is absorbed and materials cycle within, the biospheric system maintains itself in dynamic equilibrium. Third, the system's resources are finite, and it can adjust to disruption only within limits. And fourth, human beings pose a danger to the biosphere, and thus a danger to themselves, by exceeding the planet's limitations and threatening disruptions from which the system may not recover.

Since the 1960s the *system* has been a major conceptual tool not only for mapping the relationship between people and planet but for establishing that relationship as one of the central questions in late twentieth and early twenty-first century American experience. Though some of the specifics of the science may have changed in the ensuing decades, the basic features of this description remain intact within scientific fields, and also within American culture in general.

This chapter, divided into three sections, addresses the question of how this understanding of Earth first came about. The first section locates the origins of the system model in the thermodynamics-based physics of the early 20th century. With roots in nineteenth-century physics and physical chemistry, it was applied in the early decades of the twentieth century in a variety of diverse fields, including physiology, sociology, and geology, as well as ecology. Its use in the twentieth century has been closely tied to the quantum revolution in physics that occurred at the turn of the century.

In the chapter's second part, I examine the application of the system model to the planet as a whole, through the Russian geologist Vladimir I. Vernadsky's formulation of the concept of the *biosphere*. In Vernadsky's biosphere, inert and "living" matter (i.e., organisms) are mutually formative, and both function as physico-chemical elements within the operations of an encompassing thermodynamic system. Humans, too, are functional units within this larger system, but by the twentieth century they are exceptional ones. According to Vernadsky, humans became the planet's primary geological force and the global presence of modern technologies formed the basis of an emerging new geosphere, called the *noösphere*.

Part three examines the formulation of the ecosystem concept in the 1930s. The British ecologist, Alfred Tansley, used the system model to conceive a new ecological entity, which, like Vernadsky's biosphere, encompassed both biotic and abiotic components. Tansley proposed the ecosystem concept as an alternative to the reigning metaphor in ecology, the "superorganism." The ecosystem concept moved ecology away from taxonomy and idealized constructs, toward a focus on process, dynamics, empiricism and quantification. Both the biosphere and the ecosystem served as strategies for examining *wholes* in nature without either losing sight of their complexity through crude mechanistic reductionism, or resorting to unscientific vitalist explanations.

As these concepts refigured the surface of the planet in terms of *whole systems*, they inevitably raised the question as to where people fit in. Were humans just another functional component within the system, or did consciousness and technology still justify locating them outside of the rest of nature? As we shall see, in the logic of the whole system, humans are curiously located both inside and outside at the same time. Throughout this study, this dual, contradictory status of humans will appear as a defining characteristic of the whole systems that emerge in the twentieth century to encompass both nature and technology.

The Thermodynamic System

In the first three decades of the twentieth century an increasing number of people in a variety of sciences began to use thermodynamics-based models to reconceptualize their fields. In biology, Lawrence J. Henderson (*The Fitness of the Environment*, 1912), and in physiology, Walter B. Cannon (*The Wisdom of the Body*, 1932) combined thermodynamic principles with the notion that living things possess their own internal environments. Building upon the work of nineteenth-century biologist Claude Bernard, they described organisms as self-regulating entities dependent upon inputs of energy and matter. Cannon coined the term "homeostasis" to describe for organisms a trait equivalent to "equilibrium" in inorganic systems. The biologist R. A. Fisher began developing a thermodynamic model of genetic natural selection in the late teens (Fisher 1918). American ecologist Charles C. Adams, well in advance of the development of the ecosystem concept, advocated organizing the fledgling science of ecology around a model of self-equilibriating thermodynamic systems (Adams 1913). In 1926, the same year that Vernadsky published *The Biosphere*, Alfred J. Lotka published *Elements of Physical Biology*, a volume that shared Vernadsky's general approach of using thermodynamic principles to treat living and non-living matter as constituents of a single, integrated entity. Lotka was not an ecologist, but his work, like Vernadsky's, had an enduring effect on ecology. All these thermodynamic models of complex entities were too new to be mainstream during the early twentieth century, but in many areas – including sociology and ecology – such models would become dominant in later years. Moreover, this general approach would diffuse throughout ever-widening scientific, technical and cultural circles in the twentieth century.[1]

Why thermodynamics? Physics and chemistry had long stood at the top of the hierarchy of the sciences, because they dealt with the most fundamental laws and substances of the material universe, and also because their experimental methods yielded controlled, quantifiable, repeatable results that could be used to rigorously defend conclusions. In the late nineteenth and early twentieth centuries biologists and other life scientists looked to physics and chemistry for models of how to conduct their scientific investigations (Allen 1975).

This was also a period, however, when the physical sciences were changing rapidly. By the late nineteenth century it was clear to many that classical, mechanistic, Newtonian physics by itself was inadequate for explaining the development and processes of living organisms. Perhaps the stickiest problem had to do with the irreversibility of time. In the Newtonian world, phenomena were entirely reversible, like the movements of a machine or the motion of billiard balls. The life-trajectories of organisms, however, clearly were not. Rather, living things were subject to “time’s arrow” and thus appeared to possess a directionality Newtonian physics could not explain. Darwin’s theory of species evolution further underscored the apparent irreversibility of biological processes.

Another problem with fitting organisms into Newtonian systems was that Newton’s laws held only for closed systems, that is, self-contained systems like the solar system, wherein no outside influences interrupt the stability achieved by the constituent masses and forces. Living things, in contrast, are continually subject to external influences, and in fact dependent upon them for survival.

Thermodynamics, in contrast, was a branch of physics that addressed both open systems and irreversible processes. It developed apart from Newtonian physics, first through engineering scientists, who were concerned with the design and efficiency of steam engines. The first law of thermodynamics began with Carnot’s early nineteenth-century discovery that a given amount of energy would produce the greatest possible amount of work by means of a reversible machine. Some years later, through the discoveries of Robert Mayer, James P. Joules, and the work of William Thomson (later Lord Kelvin), this principle was formulated into the law of energy conservation, which stated that the quantity of energy in the universe was fixed; though it may be endlessly transformed, no more would be created and none would be lost. Physics-oriented biologists such as Helmholtz made use of the first law of thermodynamics in the mid-nineteenth century, gradually edging the study of the physics of organisms away from the laws of masses and forces toward concepts of energy and work.

The first law of thermodynamics, the law of energy conservation, did not contradict Newton, but the second law presented a challenge to Newtonian physics comparable to the challenge presented by living things. This principle, also discovered by Carnot in the early nineteenth century, was formulated in precise terms by Rudolph Clausius a generation later. It stated that matter and energy tend inexorably toward the uniformity of total equilibrium. Left alone, hot things – from coffee cups to stars – will cool down until they and their surroundings are the same temperature. Cold things warm up according to the same principle. So too will matter disorganize and dissipate over time until eventually all things are indistinguishable. The second law of thermodynamics, defining the principle of *entropy*, stated that the entire universe, unlike some abstract Newtonian perpetual motion machine, will ultimately succumb to heat death, dissolution, and complete static equilibrium. This prospect had dispiriting philosophical implications, as Henry Adams famously conveyed in his meditations on the Virgin and the Dynamo. Like the life-course of an organism, entropy pointed in an irreversible direction. And like life, it suggested that process and dynamics, relationship and function were the essential qualities to investigate, not just structure and mechanics.

The nineteenth century biologist Claude Bernard applied thermodynamic principles to living things, arriving at the observation that, though decay and dissolution were their ultimate fate, organisms were capable of staving off the degrading effects of entropy, at least temporarily. Instead of dissipating into uniformity, living things marshal matter and energy into patterns of organization as they grow, develop, and sustain themselves. Within limits, they can regulate their internal environments to adjust to changing external conditions. The great difference between living and nonliving things appeared to a number of nineteenth and early twentieth century scientists to hinge on the ability of organisms to maintain themselves in a moving or dynamic equilibrium, whereas nonliving things tend toward a condition of static equilibrium.

Along with the field of thermodynamics itself, another great accomplishment of nineteenth-century physical science was the development of physical chemistry, a model that used thermodynamics to describe chemical systems in terms of physics. This model was first developed by J. Willard Gibbs, an American physicist at Yale. In the 1870s Gibbs extended the thermodynamic model beyond uniform physical systems into complex, heterogeneous chemical systems. He did this by means of equations that added to the standard physical independent variables – entropy and volume – a specific number of other independent variables equal to the number of components in the system. All the chemical as well as thermal and mechanical properties of complex systems could be derived from Gibbs's new model. In other words, he had devised a way to explain complex chemical systems with a rigor and precision theretofore possible only for much simpler physical systems. The new concept that resulted, called chemical potential, proved not only a major theoretical advance, it also had extensive industrial and practical uses.

Thus, as the thermodynamic model pointed toward the limitations of Newtonian physics, it also promised a route beyond those limitations: the success of physical chemistry seemed to pave the way for extending physical laws and the methods of exact science into all sorts of complex entities, whether chemical, organic, social, or geological.

Entropy and Quantum Physics

The leading nineteenth-century physicists working out the implications of the principle of entropy did not believe they were undermining Newton's hegemony. As Depew and Weber point out, both James Clerk Maxwell and Ludwig Boltzmann felt their thermodynamic explanations were substitutes for as yet unperceived Newtonian operations taking place at more fundamental levels (Depew and Weber, 1985). Only in the twentieth century, when quantum mechanics applied the concept of probabilistic thermodynamic systems to subatomic particles did it become clear that Maxwell and Boltzmann's discoveries would not shore up the universality of Newtonian laws but instead demonstrate the limits of their applicability.

The radical upheaval that took place within the very bedrock of the scientific endeavor – the overthrow of the Newtonian paradigm by quantum mechanics and relativity – suggested that other fields might likewise be reconfigured, their standing categories and principles reconceptualized, in light of the new understanding of the universe.[2] There was no obvious, direct correlation between the weird and esoteric discoveries of quantum mechanics and more familiar objects of study, such as animal populations, organic bodies or geological formations.[3] But the thermodynamic model could be applied to any of these complex systems, and thermodynamics had not only survived the twentieth-century revolution in physics, it had been instrumental in it.

The revolution in physics began in the 1890s with the discovery of x-rays and radiation, those surprising, invisible emanation that disrupted faith in both the immutability of the elements and the conservation of energy. Quantum theory, developed in the first years of the new century, rested upon a model in which material objects were not fixed, determinate masses in the Newtonian sense, but probabilistic distributions of randomly moving atoms. Planck derived this theory by applying a statistical interpretation of thermodynamics (statistical mechanics) to problems involving subatomic particles. Einstein likewise came to the new physics via thermodynamics; his earliest publications concerned the foundations of the second law, and it was he who, in 1916, made clear the significance of Planck’s use of a probabilistic thermodynamic model in describing quantum behaviors (Woolf 1980).

In the wake of the quantum revolution, the principle of entropy acquired the kind of stature previously reserved only for Newton’s laws. Einstein maintained throughout his life that thermodynamics was the only universal physical theory that would never be overthrown (Einstein 1948: 33). Planck contended that the laws of thermodynamics were universal and irrefutable. Arthur Eddington wrote in 1929, “The law that entropy always increases – the second law of thermodynamics – holds, I think, the supreme position among the laws of Nature. . . . [If] your theory [of the universe] is found to be against the second law of thermodynamics I can give you no hope; there is nothing for it but to collapse in deepest humiliation” (Eddington 1929: 71).

In such a climate, thermodynamic models could be tried out in new areas by Vernadsky, Lotka, Henderson, Fisher, Adams, and many others with considerable confidence, and with an eye toward dismissing old arguments and ushering in new disciplinary paradigms, in the same way quantum theory had overtaken the old Newtonian paradigm.

Vitalism versus Mechanism

One central, standing argument the system model addressed was between vitalistic and mechanistic conceptions of life. Amid the shifting paradigms in physics during the early 1900s, there was a resucitated hope for the application of mechanistic laws to biology. Jacques Loeb, the Harvard physiologist, had taken up the standard of Helmholtz's mechanist project, updating it with a call for experimental rigor. For too long, according to Loeb, biology had been dominated by the speculation and metaphysics of towering figures such as Haeckel and Weismann. Instead, he argued, biologists should be developing methods of quantitative experimentation that would be strictly reductionistic and would justify a concept of living things that was purely, even radically, mechanistic. Loeb published his program in *The Mechanistic Conception of Life* in 1912. By the 1920s he had attracted a sizable following for his ideas among biologists and non-biologists alike (Loeb 1964).[4]

At the same time, the biologist Hans Driesch, the philosopher Henri Bergson, and others were sparking renewed interest in "vitalist" conceptions of life. They contended that living things were animated by qualities – Driesch's "entelechies;" Bergson's "*élan vital*" – that were not reducible to mechanistic physical and chemical explanations.[5] Like Loeb's mechanism, vitalism was an idea with ancient roots, which was now being updated and reconsidered in light of the recent, profound upheavals in the physical sciences. From the neo-vitalists' perspective, classical, reductionist, mechanistic physics had clearly failed to explain much about living organisms. For one thing, the overriding characteristic of organisms was their immense complexity. Reductionistic approaches had proved by definition unable to account for that complexity. Better to seek an explanation for life, argued the neo-vitalists, within the patterns of organization and interrelationships inherent in whole, complex bodies. The mechanists, in turn, argued that, whatever a "vital impulse" or "tendency" might be, if it did not belong to the realm of the material world and could not be measured or tested for in the field or in a laboratory, then it had no relevance to science.[6]

The thermodynamic system model appeared to scientists such as Henderson, Vernadsky, and Adams as a means for moving past this conceptual conflict. Where the mechanists tended toward gross oversimplification, the thermodynamics approach recognized the complexity of whole systems. And where the vitalists tended toward idealism beyond the pale of trustworthy science, the system concept was strictly materialist, empirical, and grounded in quantification.

The Living and the Nonliving

The trend in the life sciences at the end of the nineteenth century had been away from natural history – away from description and speculation—toward more rigorous experimentation, quantification, and an emphasis on process, a shift from the static to the dynamic and from structure to function (Allen 1975). This change occurred as life scientists sought to emulate the physical sciences in the precision and rigor of their methods, and incorporate physico-chemical principles, such as the principles of action and reaction, into their perception of living things. A focus on process also developed under the profound influence of Darwin's theory of evolutionary change. Though in the early decades of the twentieth century reductionists such as Jacques Loeb worked to isolate biological processes and explain them in terms of the mechanistic actions of molecules, increasing numbers of life scientists were interested in the processes and functions of whole organisms.

The emerging model of the organism was that of a complex entity whose many parts worked together to maintain the integrity of the whole. Biologists such as Herbert Spencer Jennings depicted the organism as a "complex of many processes, of chemical change, of growth, and of movement" (Jennings 1962).[7] Studying such an organism became less a matter of isolating individual parts and more about understanding the complex network of relations among the parts. Given organisms' complexity and the complexity of the external forces acting upon them, understanding the processes by which they regulate themselves physiologically and behaviorally became a central challenge for many life scientists in the early twentieth century.

The study of how an organism maintains its internal equilibrium within changing external conditions automatically located the organism within an environment. The organism itself, let alone its separate parts, could not be understood in isolation, nor construed as subject to a few simple physical forces. Rather, organisms were enmeshed within complex interrelationships with other organisms and with the inert world they inhabited. This construction of the organism was consonant with Darwin's theory of natural selection, which explained the form and essence of living beings in terms of their relationship with their environment.

In addition to biologists, this model of the organism had special appeal to both sociologists and ecologists in the first decades of the new century. Noting a shift in how "organism" was used among sociologists, Cynthia Russett writes, "During the nineteenth century men had tended to single out one factor as the all-sufficient cause of social evolution. The newer attitude, on the other hand, promoted a rejection of unilinear causation and its replacement with an empirical pluralism recognizing a multiplicity of causes. This generation of social scientists had before them, for the most part, an image of mutual dependence as it operated in the theory of organism. Here life itself depended on the interplay of the living being and its environment" (Russett 1966: 69).[8]

Ecologists, concerned precisely with the interplay of living beings and environment, likewise embraced this organic model of complexity, interaction, and interrelationship. In Frederick Clements's influential theory, a plant community was literally a "complex organism." The interacting parts of the community corresponded to the interacting cells of an organic body; the community developed and proceeded through a life cycle just like an organism. According to Clements a plant community such as a forest was in possession of a physiology, which worked toward maturity and the maintenance of the whole entity in a state of equilibrium within a stable environment, a state which he called *climax* (Clements 1905).

The thermodynamic models introduced by Henderson, Adams, Vernadsky and others in their respective fields also recognized complexity and emphasized process, interrelationship, and mutual dependence. The matter of *environment*, however, shows one important way in which the thermodynamic model was fundamentally different from the organismic models developed by Jennings, Clements, and others. The thermodynamic model did not place an organism, whether metaphorical or literal, *within* an environment; rather, it envisioned a *system*, which consisted of both organic and inorganic parts. By *system* Henderson, Adams, and Vernadsky had in mind the kind of complex physico-chemical system defined within physical chemistry. As Henderson wrote in 1917, "Just as Newton first conclusively showed that this is a world of masses, so Willard Gibbs first revealed it as a world of systems"(Henderson 1917). Within such a system, the organism was not merely subject to environmental influences, the organism and the environment were mutually formative, and together constitutive of a larger whole: the system.

Henderson, in his 1913 classic, *The Fitness of the Environment*, argued that not only do living things adapt to their environment, but their environment – consisting of matter, energy, space and time -- evolves so as to be fit for life. "The fitness of the environment," he wrote, "is one part of a reciprocal relationship of which the fitness of the organism is the other. This relationship is completely and perfectly reciprocal; the one fitness is not less important than the other. . ." In statements presaging Lovelock's Gaia hypothesis sixty years later, Henderson concluded that the physical and chemical properties of Earth – the presence of water, carbonic acid, and the compounds of carbon, hydrogen, and oxygen – do not form merely an inert field accidentally and imperfectly capable of sustaining living things.[9] Rather, this "atmosphere of solid bodies does actually provide the best of all possible environments for life." "No other environment," he claimed, ". . . could possess a like number of fit characteristics or such highly fit characteristics, or in any manner such great fitness to promote complexity, durability, and active metabolism in the organic mechanism which we call life"(Henderson 1913: 271-273).

That same year Charles C. Adams published his *Guide to the Study of Animal Ecology*, in which he began to delineate the "dynamic-process" ecology he would explore over the next few decades. Like Henderson, Adams's method was built around the model of the thermodynamic physico-chemical system developed within physical chemistry, subject to the flow of energy and the circulation of matter. He agreed with Henderson, that the world is comprised of systems: "From electrons, atoms, molecules, chemical compounds, colloids, cells, tissues, organs, individuals, and culminating in the community and association, is seen in each a dynamic center or microcosm, about which revolves other systems, in turn revolving as a part of a larger system in ever widening expansion, each in turn subordinated to a higher order of dominance, the culmination of interacting systems" (Adams 1918).[10] Adams combined the idea of the thermodynamic system with the image of the complex, interacting organism. Within his dynamic-process ecology, organisms were energy transformers, and the object of ecological investigation was the process by which energy changed form and circulated through environment and organism. The processes of ecological change were, in Adams's view, both biological and geological. That is, Adams described a relationship in which not only does the inert environment act upon the organism, but the living being shapes the non-living environment. An organism is, he wrote, "an agent which expends physical and chemical energy, producing stress and exerting pressure and expending energy on other substances" (Adams 1918)[11]

The distinction I am drawing from these examples is between a model in which living beings were understood to be located within an environment which acts upon them and prompts in them physiological and behavioral responses, versus a model in which living beings and non-living matter are co-constitutive of, and functionally equivalent within, a supraentity called *system*. The organic model that developed at the end of the nineteenth century did not go away in the twentieth; it found, rather, a long and productive career in a wide variety of fields, including ecology.[12] But in the particular lineage of ideas I am tracing, it is the *system* model that becomes most important.

One of the more profound implications of this model was its dislocation of life from any privileged position relative to nonliving things. The transformation of life into "living matter" was a means for subordinating living things within a larger pattern of function and organization. Living beings differed in character from non-living things, but in terms of their role in the primary processes of the larger system, living and nonliving things were fundamentally the same. As we shall see in the next section, the biosphere as a whole depended upon their unceasing interaction. Life in the absence of inert matter was unimaginable. Yet "if life were to cease," Vernadsky wrote, "the great chemical processes connected with it would disappear. . . A stable equilibrium, a chemical calm, would be permanently established. . ." and the "face of the Earth would become as immobile and chemically passive as that of the moon, or the metallic meteorites and cosmic dust particles that fall upon us"(Vernadsky 1998: 56-57).

Vernadsky and The Biosphere

Though he was an enormously well-respected and prolific scientist in the Soviet Union up to his death in 1945, V. I. Vernadsky, born in 1863, was and still is relatively unknown among Westerners. George Vernadsky, a Russian historian, brought his father's writings to the attention of his colleague at Yale, the ecologist George Evelyn Hutchinson, in the 1930s. With the younger Vernadsky's help, Hutchinson saw to it that some of the

Soviet geologist's writings were translated into English and published in American journals. The editor's introduction to "The Biosphere and Noösphere," which appeared in *American Scientist* in 1945, called Vernadsky "one of the most remarkable scientific leaders of the present century," but in truth his influence on Western science had been marginal (Vernadsky 1945).

After a few brief appearances in the 1940s (Vernadsky 1944) Vernadsky again dropped out of sight in Western scientific literature, so much so that James Lovelock could develop in the 1970s and 1980s the Gaia hypothesis, with no knowledge of Vernadsky, even though he drew extensively upon the concept of the biosphere and arrived at many of the same ideas Vernadsky had proffered fifty years before (Lovelock 1979). As Lovelock has since noted, he was not alone in his ignorance of Vernadsky: the 1983 book, *Earth's Earliest Biosphere*, which included contributions from twenty of the world's leading Earth scientists, neglected to mention Vernadsky even once (Lovelock 1988: 10-11).

The biologist Lynn Margulis in particular has attempted to remedy the matter of Vernadsky's neglect. She ranks him with Einstein, Mendel, and Darwin, and includes *The Biosphere* among the "most important and seminal scientific works"(Vernadsky 1998: 14-15). "What Darwin did for all life through time," she writes, along with Dorion Sagan, "Vernadsky did for all life through space"(*ibid*.: 18). That is, just as Darwin made clear that all living things, including humans, are united through time via a common evolutionary lineage, so Vernadsky demonstrated the fundamental fact that all living things share a "materially unified place, the biosphere" (Margulis and Sagan 1995: 47).

The implications of this fact, argue Margulis, Sagan, Lovelock and others, lead to a radically new understanding of life: as a single, unified planetary entity.

Vernadsky lectured at the Sorbonne in the early 1920s on subjects that a few years later coalesced into *The Biosphere*. During his time in Paris, he was part of a loose circle of thinkers that included Pierre Teilhard de Chardin, Edouard LeRoy, and Henri Bergson. This group was concerned with the evolution of the planet as a whole, discussing not only Vernadsky's *biosphere*, but also what they saw as Earth's next, rapidly emerging evolutionary development, which they called the *noösphere*. This was the biosphere in a new state, reshaped by human activity, by the technologies and designs of humankind considered as a single, global totality. Though Teilhard de Chardin would give it more mystical qualities, for Vernadsky the noösphere was strictly a geological phenomenon describing the realm of physical planetary changes brought about by humankind's colonization of the planet's entire surface. "The noösphere," he wrote, "is the last of many stages in the evolution of the biosphere in geological history"(Vernadsky 1945: 10)[13]

Vernadsky's main claim in *The Biosphere* was that life, considered as a single, planetary entity, is the Earth's primary geological force. Using the energy of the sun, living things transform and redistribute the planet's inert matter. "There is," he wrote, "a continual migration of atoms from the inert matter to living matter and back again"(*ibid*.: 1). The surface of the Earth is characterized by this activity. The atmosphere, the water, the particular chemical make-up of the entire planetary surface are as they are because of the operations of life carried out within the region Vernadsky labeled *biosphere*. The number and variety of these geological transformations increase over time as life spreads, diversifies, and draws more and more of the planet into the biosphere.

In Part One of *The Biosphere*, Vernadsky describes his subject from the outside—the biosphere in its cosmic environment. Viewed from space, he wrote, the biosphere can be understood as "the surface that separates the planet from the cosmic medium"(Vernadsky 1998: 18). As a celestial object it is subject to cosmic radiations, the most prominent of which is the energy that falls upon it from the sun. Vernadsky called this energy the "obvious bond" that unites the biosphere with the universe and provides a "precise basis for viewing the biosphere as both a terrestrial and a cosmic mechanism." The biosphere's most distinguishing feature and most important function is its ability to transform solar radiation into electrical, chemical, mechanical, thermal, and other forms of energy. It is "activated" by the sun's radiation, which it stores and converts into "free energy capable of doing work on Earth"(*ibid*.: 44).

The means by which this transformation happens is "living matter," the organisms that comprise life on Earth. Photosynthesis is the obvious and dominant mechanism for storing and transforming solar energy. From the operations of green organisms stem innumerable further manipulations of energy and matter, from the maintenance of an oxygen-rich atmosphere to the creation of new physical elements in the laboratories of scientists. As Margulis and Sagan put it, in Vernadsky's biosphere, "the material of Earth's crust has been packaged into myriad moving beings whose reproduction and growth build and break down matter on a global scale"(Margulis and Sagan 1995: 45).

Part Two of *The Biosphere*, "The Domain of Life," places the biosphere in relation to the planet's other geological components: its core, sima (mantle), and crust.

These basic geological classifications, like the term *biosphere* itself, Vernadsky drew from Eduard Suess, the eminent nineteenth-century Austrian geologist. Suess had invented the term *biosphere* in 1875, describing the planet as a body of concentric envelopes – the barysphere, the lithosphere, and the biosphere (Suess 1875).[14] He identified the biosphere as “a specific, life-saturated envelope of the Earth’s crust”(Vernadsky 1998: 91). But whereas Suess’s approach to geology, in the tradition of natural history, was primarily descriptive and taxonomic, Vernadsky was concerned with function, process, and dynamics. He thus turned Suess’s static classification into an evolving entity with changing and quantifiable characteristics.

The biosphere, according to Vernadsky, extends no more than a few kilometers beneath the Earth’s surface and a few kilometers above. Its limits are defined by those conditions of temperature, pressure, chemical composition, energy, and physical states under which life is able to exist. By the time of *The Biosphere*, Suess’s scheme of concentric geological envelopes had been elaborated considerably, and Vernadsky situated the biosphere among the several geospheres geologists identified as comprising the Earth’s crust, including the hydrosphere, the atmosphere, the lithosphere, and others. These terrestrial envelopes were arranged concentrically, though their borders and shape could be somewhat asymmetrical and indistinct. Vernadsky refered to advances in physical chemistry that allowed these geospheres to be understood as complex physical and chemical systems subject to the laws of equilibrium and modeled in mathematical form. Like the other geospheres, the biosphere is characterized by the relationship among the independent variables of pressure, temperature, physical state, and chemical composition. The biosphere is also fundamentally distinct from the other geospheres, however, because of the presence of “living matter.”

Though *The Biosphere* identified life as a *geological* force, its sights were set as much on the science of biology as on geology. Vernadsky sought a way of defining the totality of living organisms in terms of physics and chemistry. His objective was to arrive at “a precise quantitative mathematical expression of. . . living nature in its indissoluble connection with the external medium”(Hutchinson 1943). Living nature was not equivalent to non-living matter; Vernadsky discussed the major differences between organisms and inert bodies in both *The Biosphere* and “The Biosphere and the Noösphere.” Nevertheless, living things were so completely a part of cosmic and earthly physico-chemical processes that they could rightly be considered “living matter,” a term Vernadsky felt held some distinct advantages: in addition to providing a conceptual basis upon which organisms and their environment might be treated as a whole, the term *living matter*, in the name of good science, steered clear of the “realm of philosophy, folklore, religion, and the arts,” which, Vernadsky contended, clung to the word *life. Living matter*, instead, “is but a scientific empirical generalization of empirically indisputable facts known to all, observable easily and with precision”(Vernadsky 1945: 6).[15] Vernadsky took credit for introducing the term “living matter,” which, as he wrote in 1943, “now seems to be firmly established in science.” And, indeed, whether or not Vernadsky was responsible, the term was in use by the early forties, most notably by scientists such as Erwin Schrödinger, working, like Vernadsky, to explain biology in terms of physics and chemistry (Schrodinger 1944).

Just as the biosphere as a whole is a thermodynamic field receiving, storing, and transforming the sun's energy, each organism contains its own internal thermodynamic field. This *milieu intérieur* is maintained in "dynamic equilibrium," meaning it responds to external changes, such as changes in temperature, so as to keep itself in a stable state.[16] This is one of the fundamental differences Vernadsky identified between living and inert matter. The chemical environment within an organism becomes unstable when the organism dies; its compounds re-enter the thermodynamic field of the biosphere and once again become a source of energy for further transformation (Vernadsky 1998: 50-51). The Earth's surface thus takes its character from "the mutual action of cosmic forces on the one hand, and . . . the interplay between matter and energy. . . on the other"(*ibid*.: 100).

Vernadsky drew upon the example of physical chemistry to devise his new approach to global geology. "Most recently," he wrote in *The Biosphere*, "it has become possible to perceive the complicated chemical and physical structures of the crust, and form at least a simple model of the phenomena and systems of equilibrium that apply to terrestrial envelopes." What made this modeling possible was Gibbs's mathematical formulation of the relationships among multiple independent variables within complex systems. "All of the empirically-recognized geospheres can be distinquished by the variables of Gibbs's equilibria," wrote Vernadsky. The sole exception was the biosphere, which included an independent variable Gibbs did not account for: "living matter"(*ibid*.: 97). Vernadsky's goal, like Lotka's, was to extend Gibbs's model into systems that contained living things. In so doing, he would sidestep the pitfalls of both mechanism and vitalism – his model would be empirical and quantitative without reducing the complexity of his subject (ibid.: 51-53). Such a reconceptualization of the planet was possible once it was framed in terms of Gibbs' thermodynamic system model rather than Newton's mechanics.[17]

The Ecosystem

The British ecologist A. G. Tansley probably was unaware of Vernadsky's *The Biosphere* when he coined the term *ecosystem* in 1935.[18] Nevertheless, like Vernadsky, Tansley used the model of the thermodynamic system to circumvent the vitalism-mechanism impasse, and to represent nature in terms of physico-chemical wholes encompassing both living and non-living matter. In ensuing decades, Tansley's *ecosystem*, like Vernadsky's *biosphere,* would become a standard way of describing nature on the surface of planet Earth.

Tansley proposed the ecosystem concept because he believed the reigning ecological model, the "superorganism" or "complex organism," was being pushed in a dangerously literal direction. At the turn of the twentieth century, the botanist Henry Chandler Cowles had determined that vegetational change in a given region proceeds by means of *succession*, the gradual development and adaptation of "plant societies" to their physical environment, which culminates in a relatively stable "climax community." The great Midwestern ecologist Frederic Clements worked this developmental picture of vegetational change into a physiological model. Vegetational communities, Clements claimed, were superorganisms themselves, and succession a description of their life-cycle. They developed from embryo to maturity like individual organisms. The plants that comprised the superorganism worked together as interacting parts, and the community as a whole maintained itself in dynamic equilibrium within the shifting conditions of its environment by means of physiological processes (Clements 1905; Hagen 1992).

Clements’ superorganism model provided a productive method of ecological research and valuable explanations for ecological processes in the early twentieth century. Nevertheless, the exercise of translating vegetational communities into organismal terms was at times rather forced. Tansley argued in 1920 that vegetational communities might be considered “quasi-organisms,” in that they exhibited *some* of the features of individual organisms, but by no means all (Tansley 1920). Clements’ model was ultimately an extension of what seemed to Tansley an outdated scientific paradigm concerned with tracing progress toward ideal states. It was Tansley’s wish to see ecology abandon such idealism and take its cues from 20th century physical sciences by developing along empirical and quantitative lines.

Tansley was inspired to suggest an entirely new ecological entity in rebuttal to a series of papers from the young South African ecologist John Phillips. In 1934 and ‘35 Phillips published in the *Journal of Ecology* three articles that pressed Clements’ superorganism, in Tansley’s view, “to its logical limit, and perhaps beyond” (Tansley 1935, 285). Phillips treated the vegetational community literally as a complex individual organism. Succession, therefore, like the development of an individual organism, could take only one path, which was always progressive, and which could lead to only one kind of climax or state of maturity. Just as an acorn develops inevitably into an oak, in Phillips’ view, the complex vegetational organism follows a path toward a destined climax state, directed entirely by factors within the complex organism itself. In contrast, Tansley held that while they bore striking similarities with organisms, developing vegetational regions were shaped by both internal and external factors, that their development could, under some circumstances, regress, and that their eventual climax state was not fixed or preordained (*ibid*.: 292).

What bothered Tansley most about Phillips' approach, however, was his evangelism on behalf of the "doctrines" of emergent evolution and holism. *Emergence*, articulated in the 1920's by C. Lloyd Morgan, held that in both organic and inorganic nature, new things are created which could not be predicted from their antecedents or constituent parts (Morgan 1928). Two hydrogen atoms combine with one oxygen atom to form water, which has characteristics neither hydrogen nor oxygen possess. Similarly, evolution procedes by leaps, as new biological entities emerge unpredictably from their predecessors. For Morgan and others this idea was itself an attempt to move past the protracted mechanist-vitalist debate. But Phillips, in Tansley's view, used it, along with the "complex organism" model, to shore up a philosophy of holism that created for ecology the same problems as did vitalism: an orientation toward untestable, unempirical explanations for idealized constructs.

Still, Tansley recognized that a strict, materialist-reductionist approach to ecology was also a mistake, for clearly in nature there were functioning *wholes* comprised of highly integrated parts that could not merely be disentangled and dissected. As much as anything, the problem, in Tansley's view, was one of terms. "Complex organism" for him was clearly an unhelpful way of describing ecological entities. But "on linguistic grounds" so was the term *community*. "A 'community'" he wrote, ". . . implies *members*, and it seems to me that to lump animals and plants together as *members* of a community is to put on an equal footing things which in their whole nature and behavior are too different" (ibid.: 296). In any case, neither "organism" nor "community" took into account the fact that the *wholes* on the surface of the planet are comprised of both living things and their non-living environment. A better way to think of conglomerates of plants and animals, he suggested, was as "the living nuclei of *systems*" (*ibid.*: 297). The fundamental ecological concept was, Tansley wrote,

> the whole *system* (in the sense of physics), including not only the organism-complex, but also the whole complex of physical factors forming what we call the environment of the biome – the habitat factors in the widest sense. Though the organisms may claim our primary interest, when we are trying to think fundamentally we cannot separate them from their special environment, with which they form one physical system. It is the systems so formed which, from the point of view of the ecologist, are the basic units of nature on the face of the earth (*ibid.*: 299).

By *system*, Tansley meant very directly the kind of integrated, equilibrium-seeking physical wholes identified by modern physics. "These *ecosystems*, as we may call them," wrote Tansley, ". . .form one category of the multitudinous physical systems of the universe, which range from the universe as a whole down to the atom." Ecosystems, like other systems, attain equilibrium through the organization and mutual adjustment of their component parts. "There is," according to Tansley, "in fact a kind of natural selection of incipient systems, and those which can attain the most stable equilibrium survive the longest." Among the vast array of overlapping, interlocking systems in the universe, the ecosystem, wrote Tansley, is of the gradually developing, highly integrated variety. Its equilibrium is delicately balanced and dynamic, meaning it is constantly adjusting itself to maintain stability amid changing conditions. Succession is "a progress toward greater integration and stability," while climax "represents the highest stage of integration and the nearest approach to perfect dynamic equilibrium that can be attained in a system developed under the given conditions and with the available components" (*ibid*.: 299-300).[19]

The *ecosystem* so conceived represented a tremendous conceptual leap from its predecessors. As with Vernadsky's biosphere, living things lost their privileged status and became, along with non-living matter, mutually formative components of a larger, encompassing entity. The ecosystem concept oriented ecology toward process and dynamics and away from taxonomy and natural history; toward the particular and the material, and away from the ideal and unverifiable. In so doing, it circumvented the mechanist-vitalist binary by providing a rigorously materialist, empirical way to address wholes without reducing their complexity.

Tansley introduced the ecosystem concept in 1935. In 1942 Raymond Lindeman published (posthumously) "The Trophic-Dynamic Aspect of Ecology," which was the first full-blown field study organized around the ecosystem concept (Lindeman 1942). Lindeman studied the food cycle relationships within a Wisconsin lake, which he identified as an *ecosystem*, comprised of both biotic and abiotic components. He traced the flow of solar energy through this system, measuring its physico-chemical transformations as it was converted into food by "producers," eaten by "consumers," and broken down to basic chemical elements by "decomposers." His groundbreaking paper showed the ecosystem to be a powerful concept that lent itself to rigorous empiricism and quantification – just the kind of hard-nosed science Tansley hoped ecology might cultivate.[20]

A central force behind Lindeman's ecosystem study was the same ecologist who had helped usher Vernadsky's ideas into Western ecology, Lindeman's mentor at Yale, G.

Evelyn Hutchinson. Just as he worked to get Vernadsky published in English, Hutchinson fought for Lindeman's paper against the reluctant editors of *Ecology*. Lindeman's "trophic-dynamic" approach to the study of an ecosystem was, as Lindeman wrote, "closely allied to Vernadsky's 'biogeochemical' approach (*ibid.*: 399). Thus, through Hutchinson, Vernadsky's biogeochemical system model met Tansley's ecosystem concept. As we shall see in the next chapter, after the War Hutchinson would also be instrumental in arranging the marriage of this whole system model of ecology to the whole system science of control and communication in animals and machines known as cybernetics.

The Place of People

Like Darwin's theory of natural selection, the refiguration of Earth in terms of whole systems – the biosphere, the ecosystem – had the effect of integrating humans into the natural history of the planet. While plant communities and animal populations could be studied at a distance, without necessarily even raising the question of their relation to people, it was an unavoidable fact that humans were themselves enmeshed within ecosystems and inescapably a part of the biosphere. But at the same time, humans were not *merely* another component of these systems. They were also, according to Vernadsky, elements of radical planetary change, bringing about an entirely new global, evolutionary state, which he called *noösphere*, the sphere of mind. And in the case of the ecosystem, Tansley conceded that it was in a fundamental sense an artificial construct, a convenient conceptual "isolate." In fact the surface of the planet was so completely of a piece, there was no real way to delimit one ecosystem from another. In the case of both the biosphere and the ecosystem, humans were thoroughly inside, with the rest of the living and non-living matter, but at the same time always curiously outside as well. This dual, contradictory location of humans, I will argue throughout this study, is characterstic of the whole system model of nature that emerged in the twentieth century.

In *The Biosphere* Vernadsky did not address humans as different from any other type of living matter, but in later writings he identified them as exceptional. “In the twentieth century,” he wrote, “man, for the first time in the history of the earth, knew and embraced the whole biosphere, completed the geographic map of the planet Earth, and colonized its whole surface. *Mankind became a single totality in the life of the earth*” (Vernadsky 1945: 8). Viewed in biogeochemical terms, humans had become a large-scale *geological* force, responsible for moving and processing significant quantities of the Earth’s chemicals and minerals, changing the physical character of land, air, and water, and even bringing into existence artificial chemicals and elements. This sizable impact on the face of the Earth was the result not of humankind’s physical mass, which remained small compared with the size and mass of the entire biosphere, but of the human brain. The planet’s surface was being overlaid with a sphere of human invention. “There is no spot on earth,” Vernadsky wrote in 1943, “where man can not live if he so desires. . . At the same time, owing to the mighty techniques and successes of scientific thought, radio and television, man is able to speak instantly to anyone he wishes at any point on our planet. Transportation by air has reached a speed of several hundred kilometers per hour, and has not reached its maximum” (Vernadsky 1943). These twentieth-century developments signaled for Vernadsky the passing of the biosphere into the noösphere, the sphere of “mind.”

Vernadsky's ideas, especially the subordination of living things to the larger system, and the movement from biosphere to noösphere, are representative of how, in the twentieth century, a planetary perspective was prompted by the expanding human presence around the globe, and how questions of the relationship between people and planet came to center upon the matter of technology. In truth, twentieth-century human civilization presented a problem for Vernadsky's explanation of the biosphere. How did modern, global technologies fit within the schema of Earth as a natural entity unto itself, with its own evolutionary history and its own physiological processes?

Vernadsky's answer was to naturalize technology, to enfold it within the planet's evolutionary destiny. It was a solution troubled by a central contradiction. On one hand humans operated *inside* the systemic processes of the biosphere as biogeochemical agents of the planet's geological evolution. But on the other, the noösphere constituted the "reconstruction of the biosphere in the interests of freely thinking humanity. . ." (Vernadsky 1945). That is, humans were situated *outside* the biospheric system, capable of consciously or unconsciously altering the face of the planet in ways that might either a) suit themselves, or b) destroy themselves. In either case, human were not, from this angle, merely "living matter," determined by external laws and functionally equivalent to the Earth's chemicals and minerals.

Tansley also was forced to wrestle with the question of where to locate humans relative to the ecosystem. "It is obvious that modern civilised man upsets the 'natural' ecosystems. . . on a very large scale," he wrote.

> But it would be difficult, not to say impossible, to draw a natural line between the activities of the human tribes which presumably fitted into and formed parts of 'biotic communities' and the destructive human activities of the modern world. Is man part of 'nature' or not? Can his

> existence be harmonised with the conception of the 'complex organism'? Regarded as an exceptionally powerful biotic factor which increasingly upsets the equilibrium of preexisting ecosystems and eventually destroys them, at the same time forming new ones of very different nature, human activity finds its proper place in ecology (Tansley 1935: 303).

This would seem to integrate humans thoroughly into nature by refusing to privilege ecosystems that have not been disrupted by modern human activity. Put another way, there is no meaningful distinction between nature and humans, including modern technological civilization.

But at the same time, the very concept that organizes these ideas – the ecosystem – was itself artificial. Drawing from the methods of physicists, Tansley found it valuable for ecologists to "isolate systems mentally for the purposes of study, so that the series of *isolates* we make become the actual objects of our study. . ." The nature into which he integrates humans, then, is itself a human artifact. "Actually," Tansley states, "the systems we isolate mentally are not only included as parts of larger ones, but they also overlap, interlock and interact with one another. The isolation is partly artificial, but is the only possible way in which we can proceed" (*ibid*.: 300). In other words, Tansley constructed nature on the surface of the planet in terms of whole systems, but none of these could actually be delimited and identified as a discreet, tangible entity unto itself.

The problem of where to locate humans, inside or outside, was inherent in the construction of the planet in terms of whole systems. Under the organismic paradigm, there was no problem. Humans responded to their natural environment in a number of ways, including by creating technologies. Humans and their technologies were not part of the function or evolutionary destiny of any encompassing entity, and thus the question never arose as to whether technology served any purpose other than human convenience and survival. But in the system model, humans were two different things at once: they were functional entities within the system of the biosphere and the ecosystem, and at the same time independent agents. They could look at the biosphere from a distance and see it in its cosmic context, as Vernadsky did. But the biosphere they observed from the outside inescapably contained them as well. Similarly, the ecosystem was both their natural environment and their mental construct.

The next chapter looks at how this systems model of nature combined after World War II with cybernetics, the science of information control in animals and machines. With both nature and (certain) technologies defined in terms of whole systems, boundaries between not just the living and the inert, but the natural and the artificial, the born and the made, the organic and the machinic, began to dissolve. It became possible to imagine entities – techno-ecological systems – in which nature and technology were mutually formative components.

Notes

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[1] For analysis of the impact of the thermodynamic system model on biological and social sciences in the twentieth century, see Martindale (1960), Wiener (1961), Russett (1966), Allen (1975), Kingsland (1985), Wicken (1987), Depew and Weber (1995).

[2] On the overturn of old paradigms by the quantum postulate, see Levy (1932), Bohr (1934), de Broglie (1953), Heisenberg (1958), Blin-Stoyle (1959), Capra (1982).

[3] Schrodinger would provide a quantum explanation for genetic mutation in *What Is Life?* (1944).

[4]For a concise summary of Loeb and the mechanistic approach to biology in the early twentieth century, see Allen (1975).

[5] Driesch (1907, 1908); Bergson (1911).

[6] Henderson, *The Fitness of the Environment*, 1913. ". . .[I]t appears certain that at least in a few instances, and possibly quite generally, purposeful tendencies exist in the organism which seem to be inexplicable by natural selection or any other existing mechanistic hypothesis. It is not too much to hope that a scientific explanation of these phenomena in whole or in part may some day be found; but meantime they constitute the natural subject of vitalistic speculation. A field remains, though limited, where the physical scientist cannot yet successfully subdue the vitalist, however strong his conviction of the errors of vitalism." p. 292. Also see Blin-Stoyle (1958).

[7] See Kingsland (1985), pg. 19.

[8] Russett provides a history of the equilibrium-seeking thermodynamic system model in 20[th] century sociology. Lawrence Henderson played an important role in establishing the whole system model in both biology (*Fitness of the Environment* 1913), and in sociology (*Pareto's General Sociology* 1935). Using ideas from Italian nobleman Vilfredo Pareto (*Mind and Society* 1935), Henderson brought to bear on sociology many of the same ideas Vernadsky applied to earth science, especially Willard Gibbs's physico-chemical system model. Henderson was at the center of the "Pareto Circle" which formed at Harvard in the 1930s to explore Pareto's system model. This circle included Talcott Parsons (*The Social System*, 1951), who would firmly establish a system-based approach to sociology in the post-War period, and Walter B. Cannon (*The Wisdom of the Body*, 1932), whose ideas so influenced cybernetics founder Norbert Wiener (see Chapter 2).

[9] The Russian ecologist Alexej M. Ghilarov, reviewing Vernadsky's biosphere concept, likewise notes the correlation between Henderson's ideas and the Gaia hypothesis (Ghilarov 1995: 193).

[10] See Kingsland (1985).

[11] See Kingsland (1985), pp. 21-22.

[12] See Worster (1994).

[13] Vernadsky did not discuss the noösphere in *The Biosphere*, but addressed it in later writings (Vernadsky 1945).

[14] Vernadsky's reference to "the face of the Earth" in the first sentence of *The Biosphere* was a nod to Suess's influential work, *The Face of the Earth* (1904-1909).

[15] According to Margulis and Sagan, "In one deft verbal stroke Vernadsky cut loose centuries of mystic clutter attached to the word 'life'" (Margulis and Sagan 1995: 45).

[16] This idea traces back to the 19th century French physiologist Claude Bernard, whose concept of the *milieu internal* was important to 20th century physiologists such as Henderson and Cannon, and through them the early cyberneticians. See Wiener (1961).

[17] According Ghilarov, "Vernadsky even claims that the view of the world, based on Newtonian mechanics, was in many respects artificial, maintained only by the educational system, whereas Einstein's approach is much more natural and convenient for human perception" (Ghilarov 1995: 198).

[18] For a review of Tansley's career, see Hagen (1992) and Godwin (1977).

[19] The key characteristic of a system, in Tansley's definition, was its ability to maintain itself as an integrated pattern of organization. "What I have called an ecosystem," he wrote, "is far less integrated than an individual animal or plant, but it shows itself capable, nevertheless, of a certain degree of integration, of a certain resistance to disintegrating forces, and thus of maintaining, in certain cases, a *relative* dynamic equilibrium for centuries or even millennia. We do not know enough to say whether the equilibrium of an ecosystem is always false, but it is certain that its plants and animals, together with all the inorganic factors on which they depend, work together to create a balanced structure which is self-maintaining, and that is the essential characteristic of a physical system" (Tansley 1939: 515-16). That this "balanced structure" was at base also a "convenient mental isolate" and not a physically discrete entity unto itself created a basic conceptual difficulty Tansely did not address.

[20] Lindeman, measuring the flow of energy through the ecosystem, was not concerned with the individual components of the system, but rather the dynamic processes defining the system's overall pattern of organization. By way of contrast, consider the method of ecological study developed by Frederic Clements, who staked out five-meter plots of prairie into "quadrats" and counted individual plants, then statistically derived a map of the larger floral region. (See Pound and Clements (1898), and Tobey (1981).) The quadrat method reflected Clements' basic typological orientation, compared with the turn toward process reflected in Lindeman's ecosystem study. The quadrat also illustrated Clements' assumption, as Hutchinson put it, that "the community and the environment must be separated and should not be considered as forming part of the same ecological unit" (Hutchinson 1940: 268). In the biogeochemical approach favored by Lindeman and Hutchinson, the "community" and its "environment" were mutually constitutive components of "the same ecological unit," namely the *ecosystem*.

CHAPTER 2
THE CYBERNETIC ECOSYSTEM, 1945-1970

There were few conceptual developments more influential and far-reaching than cybernetics in the years after World War II. Cybernetics supplied a model of control and communication that was rooted in machine theories of information, but which appeared applicable universally to all self-organizing, self-regulating systems, including biological and social systems, from cells to civilizations. It served as a new theoretical direction not just for information-based technical innovations, such as computers and automated processes, but likewise for nearly every life and human science as well. The organismic models employed in preceding decades within biology, physiology, anthropology, sociology, economics, psychology, and many other fields, were themselves transformed through cybernetics into models of systems that maintain themselves through processes of information feedback. (Mirowski 2002; Kay 1997; Keller 1995; Heims 1991; Haraway 1989; Wiener 1961).

Ecology was no exception. The ecosystem concept, proposed by Tansley and put into practice by Lindeman in the pre-war years, was refigured in cybernetic terms after the war. Eugene Odum's 1953 textbook, *Fundamentals of Ecology,* served as the vanguard of an influential movement within ecology for which cybernetic ecosystems were the basic ecological unit, eclipsing the older "superorganism" model. For a period in the 1960s and early 1970s, ecosystem ecology was the field's leading paradigm.

The postwar rise of ecosystem ecology brought status and attracted research funds to the fledgling field in a time of mounting environmental concern. The concepts and methods of ecosystem ecology conformed the science to the "managerial ethos" of the post-war period (Worster 1994). Cybernetics gave ecology an *engineering* orientation that promised greater human control and manipulation of nature. In contrast, pre-war animal ecologists such as William Morton Wheeler and Alfred Emerson had aimed their studies at discerning nature's laws of community and cooperation, which they hoped humans might learn to apply to their own troubled social relations. After the war, critics observe, the search for moral guidance in nature gave way to a technocratic mindset concerned with energy budgets, rates of productivity, and computer modeling. In other words, cybernetics turned ecology into a technoscience (Mitman 1992; Hagen 1992; Taylor 1988; Kwa 1987).

If we see only the ecosystem's complicity in postwar managerialism, however, we miss two other important roles it has played since the mid-twentieth century. First, the ecosystem concept was the central model of nature around which environmentalism formed from the fifties through the seventies. Thus, in addition to shoring up technoscientific managerialism, it was also crucial to a potent and sustained critique of modern industrial civilization and a point of justification for an alternative set of cultural values. Second, the ecosystem concept forced a distinction between types of technology: the environmentally dangerous technologies of modern society, the epitome of which was the bomb; and a new order of technologies built upon the same universal principles of cybernetic whole-systemness as nature itself.

These effects of the cybernetic ecosystem come into focus when we recognize the depth to which nature and technology have been mutually formative, both discursively and materially, since World War II. This chapter argues for a more complex understanding of post-war representations of nature and technology based on their mutually formative relationship. In contrast to historians of ecology, such as Worster, Mitman, and Taylor, I point to the association of the ecosystem model with an influential and sustained challenge to the modern technological order. At the same time, I hope to add to critiques of technoscience, from scholars such as Haraway, Hayles, and Keller, a recognition of the extent to which information technologies were folded into this fundamentally ecological critique of modern industrial technologies and values. With this chapter we begin to see how information technologies, in certain crucial contexts, would come to be associated – through ecological channels – with alternative values and futures, an association their discourse still turns upon.

The aim of my study as a whole is to narrate the intertwined discourses of environment and technology in the late twentieth and early twenty-first centuries. The previous chapter discussed the formation of the whole-system model of nature and the pre-war context in which it took shape. This chapter looks at how the fusion of cybernetics with ecosystem ecology after the war provided a new way of conceptualizing nature/technology relations. It places this new conceptualization in the context of a growing sense of crisis, an escalating anxiety about the ecological dangers of a global, bewilderingly complex technological civilization.

Cybernetics

The MIT mathematician Norbert Wiener was the primary founder of the science of cybernetics. During the war years he worked on the difficult problem of antiaircraft artillery control. His solution combined humans and machinery in an information-based, self-guiding system of gunnery controls, servomotors and calculating devices. Out of this research came a paper titled "Behavior, Purpose, and Teleology," which Wiener published with Arturo Rosenblueth and Julian Bigelow in 1943. The paper described "purposeful behavior" in both machines and living organisms in terms of information feedback. Machines, like organisms, receive input and produce behavior or output in turn. When a portion of that output circles around to become input again, the machine acquires a means for responding to the effects of its own behavior. Its behavior becomes purposeful when this circuit of information feedback guides the machine toward a goal. A torpedo with a target-seeking mechanism exhibits purposeful behavior, for example, whereas a bomb that simply falls to earth from an airplane does not. Structurally, organisms and self-directed machines may be far different, but in terms of behavior they can be classified together as an order of things that are purposeful and predictive. Such behavior, whether exhibited by an organism or a machine, depends upon the circular feedback of information.

Wiener expanded these ideas in his widely-read 1948 book, *Cybernetics, or Control and Communication in the Animal and the Machine.* Two years later he published *The Human Use of Human Beings*, a less technical collection of essays about cybernetics for the general reader. Wiener also spearheaded a series of multidisciplinary conferences on cybernetics, sponsored by the Josiah Macy, Jr. Foundation, between 1946 and 1953. The Macy Conferences were attended by mathematicians such as John von Neumann, social scientists including Gregory Bateson and Margaret Mead, the ecologist G. Evelyn Hutchinson, physiologists, psychologists, engineers and many others.[1] Along with Wiener's writings, these conferences contributed to a rapid spread of cybernetics into social, biological, communications and other sciences during the late forties and fifties.

The ideas encompassed by cybernetics were not necessarily new. The steam engine governor had long been recognized as a self-regulating mechanism, for example, and electrical engineers had been using the concept of feedback since the 1920s (Mayr, 1970; Mindell, 2000). What was new after World War II was the generalization of these ideas into universal principles (Bowker 1993; Galison 1994). They applied to all complex, self-regulating, purposive systems, regardless of physical substrate – organic or mechanical, natural or artificial. Also new was the embodiment of these ideas in a new order of technology.

Cybernetics was closely allied with an overlapping group of technical and theoretical endeavors that together formed the core disciplines of post-war information technologies: information and communications theory, systems analysis, game theory, computer science, and operations research (Lilienfeld 1978; von Bertalanffy 1968). Evelyn Fox Keller calls the collection of these disciplines *cyberscience*. They shared, as she states, “a common task (the analysis of complex systems), a conceptual vocabulary for dealing with that task (feedback and communication – circular causality), and a mode of representation (of complex systems as interacting networks or circuits)” (Keller 1995; 84-85). As the principles of cyberscience were applied within the natural and human sciences, organisms, social groups, economies, psychologies, physiologies and more were explained according to theories of information-based communication and control.

The central functional entity in this complex of ideas and representations was the *whole system*. Cybernetics made use of essentially the same kind of *system* I examined in Chapter One: the thermodynamic model from which Vernadsky conceived the biosphere; the system concept Tansley used to describe ecological conglomerations that maintain themselves in dynamic equilibrium. Like Verndasky and Tansley, Wiener began with the problem of entropy: given the second law of thermodynamics, how is it that some entities are able, at least temporarily, to stave off heat death, maintain themselves as islands of order in a universe winding down toward total homogeneity? Wiener's answer was *information feedback*. Homeostasis (what Tansley and others called *dynamic equilibrium*) was achieved through a system's ability to monitor and respond to information about its own changing status within its environment.[2] A body employs a number of means to cool itself when conditions heat up, for example, but only so much as is needed to remain within the narrow range of comfortable temperatures. The process reverses before things get too cold. The body has this ability to maintain a constant temperature because it can monitor and respond to its own informational "output." Information about the body's temperature is constantly fed back into its own temperature-regulating mechanisms. The same process takes place in cybernetic machines: in the case of an engine governor, for example, informational output (speed) circles back around to become input again, so that the governor can keep the engine speed inside defined upper and lower limits. The ability to self-regulate through information feedback is a function of a system's pattern of organization. Non-cybernetic entities – a stone, a star – are constantly in the process of losing their order (albeit quite slowly, from our perspective). Cybernetic systems, however, are organized in such a way as to continually (purposively) maintain their order against ineluctable entropy.[3]

An emphasis on the *wholeness* of the system addressed the problem of its complexity. Modern life science had for much of its history pitted organic holism against mechanistic reductionism. The problem with organic holism had always been its tendency toward vitalism, the attribution of qualities animating or emergent in the whole, which could not be identified empirically and so eluded rigorous scientific proof. The problem with reductionism was that, in breaking down the organic entity into its constituent parts, the living whole was lost; organic beings were, in some perplexing way, more than the sum of their parts. Tansley's ecosystem concept, as we saw in the previous chapter, was an attempt to circumvent this stand-off, to address the complex whole on a rigorous empirical basis, thereby avoiding the sins of both vitalism and reductionism.

Cybernetics used the thermodynamic system to the same end. The system could be thought of as a "black box," the details of whose complex insides could be ignored in favor of an analysis of the functional whole.[4] There was no attempt to open the black box and reduce the whole to its parts, but the scientific consideration of the whole now did not depend upon the presence of some unmeasurable quality or force (*elán vital*, or *entelechy*). Rather, the system's function was attributed to the complex pattern organizing its many parts. Its character and behavior could be empirically addressed through analysis of what goes into the black box (energy, information), and what comes out (the same, in different quantities, at different rates, in different forms). Cybernetics – and systems analysis in general – thus found a way to be holistic without being vitalistic, and materialistic without being reductionistic. With cybernetics, Wiener wrote, "the whole mechanist-vitalist controversy has been relegated to the limbo of badly posed questions" (Wiener 1948: 44).[5]

Learning to understand and even design the control mechanisms of complex systems was tremendously appealing in the Cold War era, when the complexity of the world itself seemed to be growing at an exponential rate. Automated industrial processes, complex new technologies, expanding networks of global communication and transportation, and so many other dimensions of the postwar world exceeded the ability of any one body, nation, or global organization to keep control. Cybernetics showed that self-regulating systems employed *negative* feedback to keep their variables within prescribed limits. But if a system went awry, a *positive* feedback loop might develop, in which case deviation beyond the limits would not be corrected but compounded. In such a case, a system could oscillate out of control with alarming amplitude and devastating consequences: the spread of cancer throughout a body, the escalation of the nuclear arms race, the collapse of an economy, the failure of global environmental systems. In the age of nuclear weapons and other global technologies, massive power and communications networks, and complex world-wide economic relations, the implications of system failure were unprecedented in their potential for disaster.[6]

In the complex postwar world, “systems thinking” was not just a theory of control but its means as well, and this is the point upon which cyberscience begins to receive its harshest criticism. Having strong ties to the military, and being integral to the momentous postwar intertwining of science, technology and society, cyberscience has been deeply implicated in the global technoscientific power structures that have dominated the postwar world. According to Mirowski, “each of the cyborg sciences traces its inception to the conscious intervention of a new breed of science manager, empowered by the crisis of World War II and fortified by lavish foundation and military sponsorship” (Mirowski 2002: 17). Cyberscience was Big Science, extravagantly funded and equipped, often planned, managed, and deployed as part of an industrial or military operation. It framed the biological, the technological, and the social all in terms of problems of information exchange and system control, and it prescribed for those problems strategies of "command, control, communication, and information," conventionally shortened to C^3I. The construction of the world in such terms facilitated the deep, global interpenetration of technoscientific control. (Mirowski 2002, Hayles 1999; Edwards 1996; Haraway 1989). For the systems scientists, writes Robert Lilienfeld, "the world as a gigantic laboratory is their world, and their conception of systems is a world they can manipulate in order to make science. In manipulating that world they are not simply making science, they are ruling the world" (Lilienfeld 1978: 280).

Scholars have paid particular attention to how information-based theories of control and communication came to define and manipulate organic bodies in the postwar period. Lily E. Kay, for example, examined the "striking discursive shift" that took place in molecular biology in the 1950s as "molecular biologists came to view organisms and molecules as information storage and retrieval systems." According to Kay, "Heredity came to be conceptualized as contemporary systems of communication, guidance, and control" (Kay 1997: 24). Doyle refers to this shift as "the technoscientific construction of the body as a site of genetic remote control," out of which would later emerge the theories of sociobiology and a strategy for mapping genomes (Doyle 1997: 8).

The reconceptualization of the organic in technoscientific terms within biology has been a key element in the much larger and more thorough technoscientific refiguration of the world after World War II. The *cyborg*, of course, is this refigured world's representative entity. Donna Haraway, who pioneered these concepts, writes of "the implosion of the technical, organic, political, economic, oneiric, and textual that is evident in the material-semiotic practices and entities in late-twentieth-century technoscience.” This implosion forms the matrix out of which emerge hybrids of organisms and machines: cyborgs. Representative cyborgs, according to Haraway, include the “seed, chip, gene, database, bomb, fetus, race, brain, and ecosystem.” Such figures, she writes, are “imploded germinal entities, densely packed condensations of worlds, shocked into being from the force of the implosion of the natural and the artificial, nature and culture, subject and object, machine and organic body, money and lives, narrative and reality. Cyborgs are stem cells in the marrow of the technoscientific body” (Haraway 1997: 12-14).

The cybernetic ecosystem emerged out of this post-World War II cyborg-producing technoscientific matrix, as we shall see in the next section.[7] It was a conceptual instrument for rendering nature amenable to C^3I strategies of global technoscientific power, ultimately coming to define the planetary habitat of the late twentieth- early twenty-first-century globalized human species (Haraway 1997: 58). But in its particular history, it is important to note that the cybernetic ecosystem also served as a tool for a powerful critique of the modern technological order and thereby opened a door for a new global technological regime that resists analysis solely in terms of technoscientific command and control. The cybernetic ecosystem described the conditions and mechanisms by which both local and global environments could fail utterly as habitats for humans. Those conditions, it seemed to increasing numbers of people starting in the 1950s, were being brought about by modern global technological civilization itself. Heading off the collapse of planetary natural systems seemed to depend upon scaling back human population, achieving steady-state economies, and re-directing the trajectory of technological development. As much as it facilitated the technocratic management of natural environments, the ecosystem concept also led to the conclusion that nature was so complex a system humans risked their own futures by interfering. For many people, the ecosystem counseled caution and restraint rather than headlong technological and economic expansion.

The cybernetic ecosystem's capacity for challenging the modern industrial order would come to serve as a cornerstone of the techno-ecological discourse that arose in the sixties, as we shall see in the next chapter. In this discourse modern industrial civilization would be understood as dangerously maladaptive. Cybernetic whole systems technologies, in contrast, would be imagined as a radically different order of machine that conforms to the universal laws of complex whole systems and promises a future in which nature and technology might be reconciled. The cybernetic ecosystem provided the whole-systems model for the nature side of this techno-ecological equation.

Ecosystem as Cybernetic System

Yale University ecologist G. Evelyn Hutchinson attended the Macy conferences on cybernetics at the invitation of Gregory Bateson, who had been his boyhood friend in England. As we saw in the previous chapter, Hutchinson was drawn in the thirties and early forties both to Vernadsky's biogeochemical model of the biosphere and to Tansley's ecosystem concept. Both ideas formed around the model of the thermodynamic system, which maintains dynamic equilibrium through the circulation of materials and the flow of energy. Since cybernetics took shape around this same system model, it seemed a valuable new set of ideas to bring to bear on an ecological concept Hutchinson had already been instrumental in formulating. In particular, Hutchinson used the concept of circular causality as a means for describing the mechanisms by which ecological systems regulate themselves (Hutchinson 1948).

These ideas – circular causality, information feedback, purposive behavior in complex systems – even before "cybernetics" was coined by Wiener to encompass them, seemed the foundations of a new era to the phalanx of scientists fleshing them out after the war. Lawrence Frank, a social scientist and Macy conference stalwart, argued in1948 that a new "climate of opinion" was in the making, which was transforming the life and social sciences, as well as philosophy and even the arts. Mechanistic, reductionist science had dispelled supernatural explanations and yielded tremendous advances in the understanding of the natural world. Based on such successes in the physical sciences, the life and social sciences had followed a similar path, but discovered more recently that the more an organism or personality is reduced the less it reveals about the purposive behavior and integrated functions of the whole. Theories of information feedback and circular causality, however, were providing a new way to address this problem. "As I see it," Frank wrote, "we are engaged, today, in one of the major transitions or upheavals in the history of ideas, as we recognize that many of our older ideas and assumptions are now obsolescent and strive to develop a new frame of reference to give us a clearer and more comprehensive understanding of the basic processes underlying all events" (Frank 1948: 192).

The older ideas being brushed aside belonged ultimately to the physical science of a bygone era. The life and human sciences up to that point had been operating on a model grounded in eighteenth-century Newtonian physics, according to Frank, wherein forces act upon isolated entities, producing direct, predictable behaviors in a chain of linear cause and effect. In the new model, multiple variables in a complex system respond to one another in a field of circular causality. Where this pattern of interrelationship involves negative feedback, a system's behavior can be purposive, or goal directed.

By adopting this new model the life and human sciences were once again following the lead of physics, conforming themselves to the picture of the universe revealed a half-century before by relativity and quantum physics. "[W]e are facing the inescapable and far-reaching implications of what began about the year 1900," wrote Frank. Specifically, the new physics showed "an elemental feedback or circular process" at the foundations of the physical universe, as subatomic particles emit and absorb quanta of energy in fields of interrelationship. Further, Heisenberg's indeterminacy principle showed that the line between subject and object is arbitrarily drawn. This principle, wrote Frank, "indicates a wider and more fundamental situation in biology, where we must recognize that the dynamic processes which we should like to study cannot be isolated by the investigator from the organic field in which they operate, without sacrificing much of what should be observed and measured" (*ibid.*: 192-3).

Having reconfigured social and biological worlds in accordance with 20th-century physics, it seemed reasonable to the early cyberneticians that people trained in the hard sciences should begin applying their knowledge to pressing social and biological problems. Indeed, a number of prominent physicists turned to biology around mid-century, most notably Irwin Schroedinger, whose 1944 volume *What Is Life?* became a touchstone for the postwar generation of molecular biologists. Gregory Bateson, writing in 1946, urged physicists and other natural scientists to contribute to basic research on human problems. These scientists, he reasoned, were already trained to address the "complex interrelations of multiple interdependent variables." "Atoms, astronomical bodies, electric circuits, servomechanisms, and computing machines," Bateson wrote, "are the only structured entities for which most of the formal epistemological problems have been worked out, and it is therefore reasonable to challenge the experts in these fields to try their skill upon the most complex entities known to exist in our universe" (Bateson 1946: 717).

If complex social and biological systems were functionally the same as complex physical systems, then perhaps it made sense to approach them as electric circuits, servomechanisms and computing machines. Frank found it ironic that "in order to bring into biology and psychology the concept of purposive behavior and teleological mechanisms, we have leaned so heavily upon the models of man-made machines and artificial systems, such as computing machines, guided missiles, and other complicated electronic devices" (Frank 1948: 191). One can practically witness the birth of the cyborg as these early cyberneticians began modeling biological systems on information machines. "We wish to apply notions from the field of communication to the study of the behavior of living organisms and their nervous systems," wrote Wiener in 1946. "To do this is to treat the nervous system like an automaton" (Wiener 1948: 207).

Though perhaps ironic, neither Frank nor Wiener found it unusual to try to understand organisms in terms of machines; there was a long history of this in science, after all, dating back at least to Descartes. What was different in the mid-twentieth century was the type of machine employed. The cyberneticians were redefining organisms, and in the process also identifying a new order of technology, one with the attributes of organisms – memory, adaptability, goal-seeking behavior. This was quite different from the old clockwork model, wherein "once the spring is wound," as Wiener wrote, "the figures on the music box are not affected by anything else in the world" (*ibid.*). Machines capable of self-regulation through information feedback acquired "the most important characteristic of a living organism. . . its awareness of the outer world" (*ibid*.: 208). Thus, it became possible to see organisms and information machines as functionally equivalent once both were characterized as cybernetic *whole systems* enmeshed in fields of circular causality.

Where Wiener approached the nervous system as a self-regulating whole system, Hutchinson did the same for ecological processes. At the 1946 conference on teleological mechanisms, he delivered a paper titled "Circular Causal Systems in Ecology" (Hutchinson 1948), which began with the premise that groups of organisms are in complex, mutually interactive relationships with their environment, and that through such mutual interaction paths of circular causality develop that enable populations and environments to persist together as self-correcting systems. Hutchinson identified two approaches to the study of such ecological systems: the biogeochemical approach, which describes the circular causal system in terms of the circulation of some material, carbon or phosphorous, for example, through the biotic and abiotic environment; and the biodemographic approach, which describes systems in terms of fluctuations in the size of populations. The paper was part of Hutchinson's attempt to construct a grand synthesis of biogeochemistry and population ecology. Mechanisms of negative feedback were formally analogous, Hutchinson argued, regardless of the type of ecological process they regulated. A mathematical model of negative feedback, therefore, could serve as a tool of ecological analysis across otherwise unrelated self-regulating processes, from the growth of individual organisms to the persistence of an ecosystem. Like other scientists pursuing cybernetics at mid-century, Hutchinson believed he was dealing with universal laws. Though the synthesis never happened, the paper anticipated what would become two major branches of ecology in the following decades: systems ecology and community ecology (Taylor 1988; Hagen 1992).

The ecosystem concept rose to prominence within the science of ecology with the publication of Eugene Odum's textbook, *Fundamentals of Ecology*, in 1953. It was the first book on ecology to make the ecosystem a central concept. Odum credited the influence of Hutchinson, whose ideas were transmitted to Odum partly through lecture notes supplied by his brother Howard T. Odum, a student of Hutchinson's at Yale. The number of ecosystem studies accelerated after 1953 and ecosystem ecology, sometimes known as cybernetic ecology, swiftly became a dominant paradigm within the science, reaching its zenith with the International Biological Program in the late 1960s and early 1970s (Kwa 1987; Hagen 1992; Worster 1994).

Many factors contributed to the success of the ecosystem concept in the 1950s. An influx of government funding for ecological research provided ecologists with an incentive to quickly develop new research programs and test new ideas. The association of the ecosystem concept with cybernetics placed it on the leading edge of science. In addition, growing public concerns about environmental threats, especially nuclear fallout, made welcome an easily understood model of nature that integrated humans into a global environment, explained how problems originating in one corner of the world could later crop up in distant and unexpected locations, and suggested possibilities for managing the environment more effectively.[8]

The fit between ecology and cybernetics was in some ways intrinsic. Cybernetics hinged on constructing parallels between technological and physiological systems, but there was also in its logic an implicit consideration of *environment*. The behavioristic approach to studying nature and technology, which Wiener, Rosenblueth, and Bigelow advocated in their 1943 paper, defined behavior as "any change of an entity with respect to its surroundings." The study of an entity according to its behavior, rather than its internal structure, necessarily required placing it in relation to its environment. As an example of the technological application of this behavioristic model W. Ross Ashby demonstrated for the Macy conferees his "homeostat," an electrical model of an organism that responded to environmental changes, keeping essential internal variables within preset limits. If a variable exceeded its limit the homeostat "died."

The behavioristic approach of cybernetics depended upon the construction of entities as "black boxes," whose internal structures may not be known, but whose behavior could be understood through the assessment of input and output. In much the same way, ecosystem ecology was concerned with the measurement of energy and materials flowing into and out of an ecosystem. In the approach to the study of ecosystems pioneered by Bormann and Liken, the ecologists could study the system dynamics of a watershed by measuring the input of precipitation and the output of the watershed's draining streams (Hagen 1992). Using the language of cybernetics ecologists explained the cycling of energy and materials through ecosystems in terms of input and output and the self-regulating mechanisms of ecosystems, from ponds to the biosphere, in terms of information feedback (Odum and Patten 1981).

The development of a cybernetic model of ecology seemed to advance the cyberneticians' claim that they were dealing with universal principles. From the metabolism of biological cells, to the physiology of individuals, to the regulation of populations, and finally to the integrated biotic and abiotic environment itself, the principles of cybernetic systemness held throughout nature, crossing boundaries of both scale and substrate. Ecosystem ecology extended the naturalization of cybernetics systemness to the whole planet.

Ecosystems and Cultural Values

Scholars who have written about the influence of cybernetics on science and society rightly call attention to its origins within the command-control-communications-and-information structures of the military.[9] They have identified in the spread of cybernetics a discursive and technological extension of military power into realms of civilian life. Paul Edwards argues that the development of computers after World War II was inseparable from the discourses and practices of Cold War militarism (Edwards 1996). Peter Galison locates the cybernetic worldview in the wartime construction of a part-human, part-machine enemy, namely, the planes and pilots that became the targets of Norbert Wiener's wartime research (Galison 1994). Andy Pickering describes the development of the "World War II regime," which grew out of the intersection of science and the military, transforming other cultural spaces in the postwar decades through the generation of "cyborg objects" and "cyborg sciences" (Pickering 1995). Ecosystem ecology was itself one of these "cyborg sciences." It drew both material support and ideological structure from the C^3I sensibilities of Cold War institutions. Much of the early funding for ecosystem research came from the Office of Naval Research, and later from the Atomic Energy Commission.

Historians of ecology Donald Worster and Gregg Mitman indict ecosystem ecology for its mechanistic depiction of nature, its engineering ethos, and its reflection of the values of managerial capitalism (Worster 1994; Mitman 1992). Lamenting the passing of an organic model of ecology that emphasized community and cooperation, Mitman writes that with the rise of ecosystem ecology, “Nature had become a system of components that could be managed, manipulated and controlled. The ecologist’s task increasingly became that of environmental engineer; ecologists were to be professional managers who could monitor and fix the environmental problems created by human society” (Mitman 1992: 210).

These assessments of ecosystem ecology’s place within the dominant values of postwar American culture are undoubtedly on target. Yet it is also true that the ecosystem concept was instrumental in the formulation of alternative cultural values beginning in the 1950s. In the subsequent decades, the ecosystem concept was put to use by environmentalists, feminists, war protesters, nuclear technology protesters, and many others as a model of nature that implicitly justified a rejection of not only technocracy and militarism, but a variety of other values and practices as well, including sexism, racism and consumerism.[10] Seeing the world as an ecosystem demanded a reconsideration of social and political relations precisely because modern technologies had become uncontrollable, inescapable, global in scope, and, in potential, unimaginably destructive. To any other reason for altering the trajectory of modern technological civilization, the ecosystem concept persuasively added the threatened collapse of life-sustaining processes worldwide and the extinction of the human species. For many people the ecosystem concept lent scientific legitimacy to the view that the values at the core of modern technological civilization were dangerous and wrong.

In addition, and crucially, the ecosystem concept suggested to scientists such as Eugene Odum and Barry Commoner, to technologists such as Buckminster Fuller, and to many others, that an alternative set of values could be found rooted in the fundamentally cybernetic laws of nature. Complex interconnectedness, interdependence, and a finely sustained balance appeared to be at the center of nature's complexity, not individualism, waste, selfish competition and brutish power. Humans ignored the circular causality inherent in nature at their own peril; they risked making their own environment uninhabitable, their own future unsustainable.

The meaning and use of an idea within a scientific discipline does not necessarily conform to its meaning and use outside that discipline. The institutional practice of ecosystem ecology in the postwar decades unquestionably had more to do with a faith in scientists' ability to manage environmental problems than in reformulating human/nature relations. In turn, the popular use of the ecosystem concept was not overly concerned with scientific precision or application; its use was more a case of a new concept being folded into a centuries-old disposition that looked to nature for an antidote to the poisons of over-civilization. Yet it is important to remember that postwar environmentalism in the U.S. was largely initiated and led by scientists whose arguments against the established paths of technological development were rooted in late-twentieth-century scientific systems concepts of nature. Activist scientists such as Barry Commoner, Rachael Carson, Paul and Louise Ehrlich, and Garrett Hardin served as conduits through which ecological concepts entered popular discourse attached to criticisms of modern technological society. As Commoner wrote in 1971, “This partnership between scientist and citizen is, I believe, the clue to the remarkable upsurge of public action on environmental issues that we have witnessed in the United States in recent years” (Commoner 1971: 198).

To trace the formation of values around the ecosystem concept it is especially helpful to look at the example of Eugene P. Odum. His *Fundamentals of Ecology* was largely responsible for establishing the ecosystem concept as a dominant paradigm within the science of ecology. Major portions of his research were conducted in the service of the Office of Naval Research and the Atomic Energy Commission, and so were deeply integrated into Cold War institutions that promoted nuclear technologies and embraced the C^3I logic of postwar technoscience. Yet over the three editions of his textbook, from 1953 to 1971, Odum increasingly sounded alarm over the ways in which modern technological civilization violated the cybernetic laws of nature and corrupted the natural environment.

Eugene Odum, along with his brother Howard T. Odum, first applied ecosystem ecology in the early 1950s in their study of the coral reefs near Eniwetok Atoll in the south Pacific, the site of U.S. nuclear weapons testing in 1948 (Odum, E.P. and Odum, H.T. 1955). This experience would leave two important marks on the Odums’ formulation of ecosystem ecology. First, it linked the application of ecosystem ecology to nuclear technologies. Radioactive isotopes could be traced through the trophic levels of the coral reef ecosystem, clearly demonstrating the flow of material and energy. Ironically, such isotopes would come to be a useful tool intentionally applied in the study of ecosystems, while the implications of large amounts of radioactive materials coursing through the global ecosystem would form the basis of concern over the ecological effects of nuclear testing. Second, the Odums determined that two essential characteristics of the coral reef ecosystem were mutualism and stability. The algae and coral at Entiwetok, they observed, had co-evolved and were mutually dependent upon one another. Further, they concluded, millions of years of natural selection had perfected the self-regulation of interacting species and favored the stability of the system as a whole. Thus, the nature the Odums described in their study was characterized not by competition and growth, but by cooperation and stability. Though they did not suggest that these natural principles should be extended to human society, they did express hope that by understanding how millennia-old ecosystems sustain themselves, humankind might find a way to stabilize its relationship with nature, which "seems," the Odums stated, "to fluctuate erratically and dangerously" (ibid.: 291).[11] It was a striking model of nature to emerge from military-funded, cyborg-scientific research in the context of Cold War tensions.

The first edition of *Fundamentals*, published in 1953, devoted little space to radioactive isotopes beyond recognizing their usefulness as environmental tracers. Public health issues Eugene Odum felt ecology should address included animal-borne diseases such as malaria and rabies, and diseases linked to sanitation. By the publication of the second edition of *Fundamentals* in 1959, considerable controversy and concern had arisen over the testing of nuclear weapons worldwide. Odum devoted a chapter to radiation ecology in his updated volume, but more particularly he added language that positioned himself, and the practice of ecology, on the side of caution and restraint in the debate over nuclear technologies. In his section on the risks of nuclear technologies, for example, he warned that "we could give 'nature' an apparently innocuous amount of radioactivity and have her give it back to us in a lethal package!" (Odum 1959: 467). Odum developed a concern about the storage of nuclear waste after spending time at the AEC's Hanford reactor in Washington state. "Although fallout problems are presently in the public eye," he wrote, "waste disposal from peaceful uses of atomic energy is potentially a far greater problem, assuming again that we do not have an all-out atomic war" (*ibid*.: 480).

The 1959 edition of *Fundamentals* began to extend the natural principles of stability and mutualism Odum found in the Eniwetok coral reef to human behavior and attitudes toward nature. The 1953 book stated, "Careful study and cooperation with natural cycles rather than wholesale 'tamperings' beyond our ability to comprehend would seem to be the sensible road to take if we are to avoid detours (perhaps permanent!) in the achievement of true dominance and the complete orderliness of man and his environment." Rethinking the goal of "true dominance" he added in 1959 the following: "It would be much safer (and much more pleasant) if man accepts the idea of sharing the world with many other organisms instead of looking at every square inch as a possible source of food or site to make into something artificial" (*ibid*.: 489).

In the 1971 edition, Odum added a chapter on pollution and environmental health, as well as a chapter, written by G. Dennis Cooke, on the "Ecology of Space Travel," in which the "life-support system" of space vehicles became an extended metaphor for the global ecosystem, a metaphor Odum would return to repeatedly thereafter. In the preface to the third edition, Odum writes, "Practice has caught up with theory in ecology. The holistic approach and ecosystem theory, as emphasized in the first two editions of this book, are now matters of world-wide concern." He was, in this edition, explicitly concerned about how "man is to survive his self-generated environmental crisis."

> It is man the geological agent, not so much as man the animal, that is too much under the influence of positive feedback, and, therefore, must be subjected to negative feedback. Nature, with our intelligent help, can cope with man's physiological needs and wastes, but she has no homeostatic mechanisms to cope with bulldozers, concrete, and the kind of agroindustrial air, water, and soil pollution that will be hard to contain as long as the human population itself remains out of control (Odum 1971: 36).

Odum exhibits in this statement an unfortunate gendering of humankind and nature rooted in a modernist-masculinist discourse linked to the exploitation of both people and nature.[12] He also demonstrates a certain, albeit shaky, faith in the scientist's ability to address environmental problems, showing perhaps his complicity in the reigning managerial ethos Worster and Mitman identify. The statement also contains, however, a pointed indictment of modern technological society that is grounded in the language and logic of cybernetic whole systems, as it came to be applied to the natural world. Such a statement was by the early 1970s, and remains, a fairly standard position held by environmentalists.[13]

So while ecosystem ecology was in many ways rooted in the militarized managerial structures of postwar technoscience, the ecosystem concept was used by both scientists and laypeople to construct arguments against conventional notions of technological progress, to protest against specific technologies, and to legitimate alternative cultural values. This view of the cultural life of the ecosystem concept adds an important dimension to our reading of cybernetics by bringing into focus an application of cybernetic ideas that lay outside the logic of the dominant postwar power regime and its C^3I structures.

As they used the ecosystem concept to protest the tenets of modern industrial society, both scientists and non-scientists aligned aspects of cybernetic systemness with alternative values and futures – visions of a human society less destructive and warlike, emphasizing cooperation over competition and stability over unrestrained growth, in accordance with the lessons and laws of nature. Though romantics and organicists had long looked to nature for remedies for the ills of civilization, there were important differences in this new turn toward nature. First, ecological arguments grounded in ecosystem ecology did not necessarily hinge upon the inference of a superior moral order pervading nature, but on empirical facts. The system of nature comprised a network of interrelationships capable of being corrupted beyond repair. The dangers to humankind were material, not just spiritual. Second, the scope of the threat was unprecedented. With the advent of thermonuclear weapons, the possibility of an irreversible corruption of the human genome, or even the complete destruction of life on earth, became a reality. Where romanticism and organicism in the past had sought reconciliation with nature as a matter of right living, the new environmentalism sought, as its first concern, survival. The cybernetic ecologists who became activists in the postwar years may have been interested in the revival of the human spirit, but their primary concerns were the scarcity of resources, overpopulation, environmental poisoning, and nuclear destruction.

This ecology-induced association between cybernetics and alternative cultural values would become an important dimension of the discourse on information technologies and the rise of the "information age" that closed out the twentieth century in

American culture. Cybernetic ecology depicted nature in terms of whole systems regulating themselves through processes of negative feedback. Nature was a black box, too complex to manage in every detail, but clearly enough understood to know that its mechanisms of self-regulation were subject to breakdown. Positive feedback loops could develop, which could send natural systems spiraling out of control. In fact, mid-twentieth century technological civilization seemed to be pushing natural systems toward collapse, with potentially fatal consequences for humankind. But as it identified modern technologies – the bomb, pesticides, industrial pollutants – as unsustainable, cybernetic ecology also suggested that a different order of technology could bring about a different future, that is, cybernetic technologies operating on the same universal principles of whole-systemness as organisms and the natural environment.

Ecosystems and Technology

How could the cybernetic ecosystem concept at once reconfigure nature in technological terms and decry technological civilization as suicidal? There was a more complicated relationship between the ecosystem concept and technology than has been depicted by the historians of ecology. Mitman, Worster, Kwa and Taylor all point to the shift from organismic to mechanistic representations of nature in explaining the transformation of ecology into a managerial technoscience in the latter half of the twentieth century. I would add to their discussions two points of qualification.

First, the rise of ecosystem ecology had at least as much to do with managing technology as with managing nature. While there was interest in engineering ecosystems to increase their biological productivity, the overarching utility of ecosystem ecology centered on its potential for assessing environmental damage and heading off ecological collapse. By the 1960s it had become apparent to many scientists and public officials alike that the technological means of controlling nature were themselves out of control. Ecosystem ecology was folded into programs aimed at addressing the global environmental risks of technologies, not merely rendering the environment more amenable to technological manipulation.

Second, cybernetic ecology forced a distinction between *types* of technology: on one hand, modern technologies that polluted the environment and destroyed natural systems; and on the other, cybernetic technologies that operated on the same universal laws of systemness as nature itself. In considering the shift from organic to mechanistic metaphors in ecology after WWII, it is essential to remember that cybernetics had redefined both the organic and the mechanistic in terms of *whole systems*. In the logic of the cybernetic ecosystem, one order of technology was fundamentally at odds with the operations of natural systems, while the other suggested that certain kinds of machines were indistinguishable from nature at its most fundamental level.

The rise of ecosystem ecology in the 1950s coincided with a broader shift in the life sciences during the postwar years, a shift away from models of nature that emphasized community and cooperation, toward an understanding that keyed on competitive individuals. Historian Gregg Mitman explains this shift partly in terms of Cold War cultural values, which placed individualism and competition at the center of democratic society and objected to collectivist ideas that might be associated with either fascism or communism. Though Mitman does not explore a specific correlation between ecosystem ecology and competitive individualism, he underscores ecosystem ecology's links to the Atomic Energy Commission and the military, and identifies in it a managerial and engineering sensibility consonant with the dominant values and ambitions of postwar America. "The ecosystem blurred the distinction between inorganic and organic by reducing everything to energy as the common denominator," writes Mitman. "Nature had become a system of components that could be managed, manipulated, and controlled. The ecologist's task increasingly became that of environmental engineer; ecologists were to be professional managers who could monitor and fix the environmental problems created by human society" (Mitman: 210). This new role for the ecologist stood in stark contrast to the prewar hopes of those University of Chicago ecologists who are the subject of Mitman's book. Alfred Edwards Emerson, Warder Clyde Allee and others, Mitman shows, sought within nature examples and principles of community and cooperation that might justify similar values in human society. Their search was ended, he argues, when biology and ecology became tools of engineering. "Once biologists can invent a blue pig that flies or create and manage artificial ecosystems, how can nature be normative, how can it give definition and purpose to humankind if nature itself increasingly becomes a human construct?" (*ibid*.).

Mitman does not acknowledge the emphasis ecosystem ecologists such as the Odums placed on mutualism and coevolution as elements essential to the self-regulating mechanisms of ecosystems, nor their challenge to headlong economic expansion and technological adventurism. More generally, he fails to note that ecosystem ecology was exceptional among the life sciences transformed by cybernetics in the critique of modern technological civilization it made possible. Managerialism was part of the story of ecosystem ecology, but so was an environmentalism that cautioned against interference in natural systems.

Like Mitman, Donald Worster places ecosystem ecology squarely within the "managerial ethos" of postwar America and indicts it for its part in the demise of an ecological vision guided by respect and deference to nature rather than a desire to manipulate and control it. Worster depicts the history of ecology as a struggle between these two dispositions: the "arcadian" values of interdependence, wholeness, "fellow-feeling," versus the "imperialist" values of objectification, conquest, competition and control. The rise of ecosystem ecology, according to Worster, landed ecology on the side of the imperialists. It described nature in strictly technical and economic terms, identifying "producers" and "consumers" with "energy budgets" expended with varying degrees of "efficiency." Ecosystem ecology, he argues, turned the science over to technicians, engineers, and managers, and took it out of the hands of idealists who had sought in the prewar years to establish an ethics of harmony, balance, and cooperation through the study of nature. "The 'new ecology' that emerged in the middle decades of the twentieth century," writes Worster, "sees nature through. . . the forms, processes, and values of the modern economic order as shaped by technology" (Worster: 293).

Like Mitman, Worster does not consider that for the Odums and others employing the cybernetic ecosystem concept, there were important distinctions to be made when thinking about the relationship between nature and technology. For Worster, the parsing of technological orders looks like random flip-flopping between metaphors. "Just as the ecosystem concept kept blurring the lines between living and nonliving components," he writes, "so it mixed mechanistic and organic metaphors to a confusing degree. Was the Earth alive or dead? Sick like an organism or malfunctioning like a machine? Did it need a physician or an engineer? Eugene Odum tried to have it both ways" (Worster: 370).

Joel B. Hagen, in his book on the origins of ecosystem ecology, similarly refers to the "januslike" quality in the Odums' ecosystem concept, their tendency to shift between machine and organic images (Hagen: 128). Worster and Hagen do not take into account that the kind of machines most useful to the Odums for understanding ecosystems were the ones of interest to Wiener, Frank, Bateson and other cyberneticians: machines that exhibited the characteristics of organisms and communities of organisms – machines of interest primarily because, to the degree they behaved like natural systems, they appeared to bear out the universality of the properties of self-regulating, self-organizing whole systems.

Chunglin Kwa argues that the machine metaphor undergirding the ecosystem concept invoked for scientists, policy makers, and the public of the 1960s a view of nature as an object that could be controlled, manipulated, designed and fixed. This machine metaphor, according to Kwa, "made possible a shared conception of how environmental problems were to be defined, and how their solution should be envisaged" (Kwa: 433). When it came to the question of whether Congress would appropriate funds for the gigantic International Biological Program during the 1960s and 1970s, it was the Program's commitment to systems ecology that tipped the scales, argues Kwa, for the ecosystem model of nature suggested the possibility of managing and controlling the environment through technical expertise. An ecology centered on the values of fellow-feeling and cooperation, his study implies, would not have won the government's commitment of support for global ecological research.

Kwa's interpretation of the acceptance of ecosystem ecology in the context of the IBP confuses the management of nature with the management of technology. "The identification of ecology (and more specifically systems ecology) as the kind of basic science needed to provide background knowledge for the solution of environmental problems like pollution," Kwa writes, "proved to be of the utmost importance in finding funds for the IBP" (Kwa: 421). In the next paragraph he writes, "The apparent potential of ecology, in particular systems ecology, to provide the basic science approach to problems of environmental management, appears to have been the most important single factor in winning political support from the House of Representatives" (*ibid.*: 422). This conflation of "solving environmental problems like pollution" with "environmental management" allows him to frame ecosystem ecology in terms of the manipulation of nature rather than the containment of technologies.

However, the officials Kwa quotes as they debated the merits of the IBP seem clearly concerned with heading off uncontrollable ecological problems by changing modern technological civilization. "If we do not make certain adjustments soon," says one biologist testifying before the Congressional subcommittee deciding whether to fund the IBP, "natural forces will take over and bring about the 'biological steady state.' As rational human beings we cannot leave the restoration of the steady state to such natural forces as the equalizers of the past – war, famine, and pestilence" (*ibid.*: 424). According to another expert witness, "We have now reached the limits of the earth and we are faced with the urgent problem of achieving homeostasis in natural energy systems with man as a member. . . Hopefully, our deep concern over environmental improvement represents the signal in a cybernetic system to set in motion the negative feedback essential to bringing our populations into steady state within humanized ecosystems" (ibid.: 424-5). As Kwa shows, it was the hope of hearing participants that the IBP might "develop a system of forewarning so that [the results of IBP-related ecological studies] can be fed into our technological planning to prevent disaster" (*ibid*.: 425). From such testimony Kwa derives a central theme: "Nature is seen as a *system* that can be *controlled* and *managed*" (*ibid*.: 425). But rather than presuming ecosystem ecology would supply the tools for fixing the machinery of nature, the hearing participants described a more complex situation, in which humans and nature together comprised a whole system, which, if forced beyond its limits, would self-correct in ways likely to be harmful to humankind.

Kwa mistakenly equates *system* with *machine*, and fails even so, like Worster and Mitman, to take into account the distinctions cybernetics forced among types of machines. In identifying a machine metaphor in system ecology, for example, Kwa sees no real difference between "the steam engine, or the computerized automatic machine" (*ibid*.: 434). He treats the *cybernetic whole system* as a stand-in for *machine* instead of as a pattern of organization enabling the self-regulation and purposive behavior of complex entities, whether natural or technological. As a result, Eugene Odum's ecosystem concept appears to him as a kind of subterfuge. Odum's *Fundamentals* alludes to an organic model of nature, Kwa writes, but in fact "Odum's 'ecosystem-organism' is an 'ecosystem-machine' in disguise" (*ibid*.: 427). In Kwa's view, Odum depicts nature primarily as a "self-governing thermal machine, a combustion engine" that "can run out of fuel, that can be overworked or in some other way faces the possibility of being destabilized so that it cannot survive." According to Kwa, this conception of nature makes possible the hope that engineers of ecosystems might "achieve perfect control," which ultimately is the "programme of cybernetic ecology" (*ibid*.: 429).

But Odum's description of the "cybernetic machinery of nature" is much more subtle than that, and his ambitions much more humble. The ecosystem concept was built around the model of the thermodynamic system, as we saw in the previous chapter. It thus is concerned with the flow of energy and the transformation of matter, like a thermal machine. But it is a "secondary informational network," superimposed over the conservative energy-matter processes, that gives the system its order, according to Odum. It is through feedback loops of information that the system maintains itself against entropy. "What . . . are 'the invisible wires of nature' that comprise this secondary network?" Odum asks.

> They are all the factors, processes and interactions that we collectively know as natural history which serve to mediate the movement or transformation of energy-matter. They are all the nonconservative uses by organisms of the physical media (air, water, soil, sediment); of the surfaces, gradients, and objects (including other organisms) dispersed within the media; and of the sights, sounds, tastes, odors, touches, pressures, magnetic fields, and other possible sensory cues provided by physical, chemical, and biological signals available in the environment that contribute to the orderly flux of conservative substance in the biosphere. The grand laws which define the conditions of existence (gravity, conservation, dissipation, limiting factors, etc.) are all part of the information network. The time of day or year, the height of the sun above the zenith, the position of the moon, temperature; all these are part of it (Odum and Patton: 890).

Ecosystems are cybernetic, in Odum's view, precisely because they control themselves through networks of information. The ecosystem's "cybernetic attributes emerge passively out of large and complex decentralized system organization," according to Odum. "The interplay of material cycles and energy flows, under informational control, generates self-organizing feedback with no discrete controller required" (*ibid.*: 888). It is on this basis that Odum justifies drawing analogies between nature and machines that behave the same way. He stresses that the cybernetic processes of systems of different levels of organization – ecosystems, organisms, or human-made servomechanisms – are analogous, not homologous. “Clearly,” he writes, “an autopilot and the thermoregulatory system of a mammal do not operate by homologous structures.” It is rather the analogy itself, and the “willingness to accept it,” that allows the ecologist to identify the “cybernetic machinery of the ecosystem” (*ibid*.). Put another way, finding analogies between different orders of cybernetic systems is, for Odum, a heuristic strategy for understanding ecosystems. In this regard, Odum is rather like Bateson, who, as we saw earlier, believed that, since cybernetic whole system principles were universal, scientists should begin applying to the exploration of biological and social systems the understanding already attained regarding physical and mechanical systems. Though Kwa has Odum reducing nature to a mere “combustion engine,” Odum believed himself to be exploring the universal cybernetic properties of complex whole systems as they operate within natural environments. The point for him was not to represent nature as a machine, but to recognize that nature and certain kinds of machines, as well as organisms, shared the universal properties of complex, self-regulating whole systems.

Ecosystems and Information Technologies

To understand how the ecosystem concept could be thoroughly integrated with information technologies, we can draw upon the work of Eugene Odum’s younger brother Howard. He was an essential contributor to the *Fundamentals* textbook and a pioneering ecosystem ecologist in his own right. As student of Hutchinson’s, he was trained in biogeochemical approaches to ecosystems. The ecosystem concept lent itself to both organic and mechanistic metaphors thanks to the cybernetic system’s indifference to substrate. Where Eugene stressed the organic aspects of ecosystems – development, metabolism, homeostasis – Howard stressed the mechanistic. He emphasized communications and control, and pursued the study of ecosystems through simulations and modeling. He came to focus his research primarily on the flow of energy through ecosystems, eventually developing an elaborate theory of energetics to explain not just natural processes, but social, political, economic and religious systems as well (Odum, H.T. 1971; Odum, H.T. and Odum, E.C. 1976).

Peter J. Taylor identifies “technocratic optimism” as the major theme running through Odum’s work (Taylor 1988). But considered in light of the ecosystem concept’s relations to postwar technologies, that description needs qualification. First, Howard, like his brother, was not at all optimistic about the trajectory of modern technology. His *Environment, Power and Society* (1971) offered, among many other things, a persuasive argument for limiting industrial growth based on an ecosystem understanding of the environment. While he did believe in the environmental management and engineering potentials of his energy-based ecology, the objective of such efforts was not the kind of economic and technological progress pursued by the Hoover-era Technocrats to which Taylor compares Odum. Rather, the goal of ecology, from Odum’s perspective, was to prevent the collapse of nature at the hands of human folly and misjudgment. “In this book,” Odum writes, “energy language is used to consider the pressing problem of survival in our time – the partnership of man in nature” (Odum, H.T. 1971: vii).

Odum was optimistic, however, about the technologies that mirrored the complex networks of nature. These technologies, computers in particular, provided the means for modeling the energetics of ecosystems, and thus served as an essential tool for the ecologist. Moreover, the “network,” for Odum, was the key concept both for understanding nature and for building technologies that would lead to survival rather than extinction. The network represented, in Odum's schema, the connecting pathways through which flow the energy and information that sustain a system and comprise its complexity. Along these lines he developed a means for diagramming ecosystems as energy circuits. He intended throughout his career to design stable, sustainable "systems of man in nature" based on "high-quality, low-energy circuits."

Like the cyberneticians before him, as Odum identified the essential cybernetic functions of complex systems, he dissolved with abandon the boundaries separating the natural, the mechanical, and the social. "The network of society," he writes, "has a form of thinking since it is a computer network in itself, quite over and above those it encompasses – the electronic computers of industry and the even more remarkable computer, the mind of man" *(ibid.*: 245). Describing the simulation of ecosystems through computers, Odum states, "Programming the balanced ecosystem model illustrates the rather automatic translation of energy circuit language to simulation languages once the properties of the model are stated in 'energese'" (*ibid.*: 268). In a section titled, "An Ecosystem as Its Own Computer," he writes, ". . . the many compartments and circuits that constitute systems of man and nature are themselves special-purpose computers." Even so, it is sometimes necessary to build conceptual models of these systems since, "particularly for the great ecological and social systems, the real system is beyond experimentation, and the brain systems have not been able to assimilate the complexity. Thus the model networks hold great promise" (*ibid.*: 270).

We can see in Howard Odum's formulation of ecosystem ecology a deep conviction about the detrimental consequences of modern technological society, the world of bulldozers and bombs. At the same time, he validates information technologies on the basis of their compatibility with natural systems, a compatibility grounded in cybernetic theories of communication and information. In the process he rescues the possibility of a human future tied to technological progress, even if "progress" is redefined in terms of developing tools that make possible species survival and evolutionary adaptation.

Conclusion

Environmental crises in the post-war period, such as nuclear fallout and chemical poisoning, prompted evaluations of technologies on the basis of their impact upon natural environments. For the first time, nature sat in judgment of progress as the world approached an impasse that pitted the biosphere against the technosphere. For many environmentalists, the solution was to redesign and retool, to reject the environmentally unsustainable technologies of the modern era in favor of cybernetic technologies compatible with natural systems. Put another way, the cybernetic ecosystem, in the context of a mid-twentieth-century technological crisis, made possible critiques that distinguished between two orders of technology: environmentally destructive modern technologies, and environmentally compatible cybernetic technologies.

In order to understand this matrix of changing ideas, we must recognize that nature and technology, since the middle of the last century, have been mutually formative and inextricably bound together. Environmentalism opened the door for a discourse crucial to the success of information technologies: in the context of an untenable conflict between technosphere and biosphere, information technologies could appear as a path to a survivable future. Recognizing this relationship between environmental concern and information machines can enrich our understanding of the history of both ecology and technology.

Environmentally compatible cybernetic technologies could be embraced by people looking for alternatives to the modernist values and structures of mid-century American culture. We shall see in the next chapters that a vision of a future encompassing both a sustainable environment and technological progress took shape in a pocket of the nineteen-sixties counterculture that embraced cybernetics and cybernetic technologies, especially computers. Crucial to the development and cultural reception of information technologies was a discourse that characterized them as tools of a new ecological era, operating on fundamentally different values and precepts compared with the machines of the modernist industrial era.

Notes

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[1] There were ten Macy conferences. The transactions of the sixth through tenth conferences were published in a series titled, *Cybernetics: Circular Causal and Feedback Mechanisms in Biological and Social Systems*, Heinz von Foerster, ed., by the Josiah Macy, Jr. Foundation. Von Foerster was also a conference member. *The Cybernetics Group* (1991), by Heims, is a good history of the conferences but is restricted mostly to the social science and psychology dimensions of the transactions. *How We Became Posthuman: Virtual Bodies in Cybernetics, Literature, and Informatics* (1999), by Hayles, also examines the Macy conferences at some length. Hayles is particularly concerned with how the conferences reified information.

[2] "Homeostasis" was coined by Walter B. Cannon as a biological concept analogous to "equilibrium" in physical systems. See Cannon, *The Wisdom of the Body* (1932). Cannon was a friend and colleague of Wiener's father at Harvard and a frequent guest at the Wiener home when Norbert was a child. Cannon also worked closely with Rosenbleuth, with whom Wiener co-authored "Behavior, Purpose and Teleology."

[3] "Life is an island here and now in a dying world. The process by which we living beings resist the general stream of corruption and decay is know as *homeostasis*. . . The oxygen and carbon dioxide and salt in our blood, the hormones flowing from our ductless glands, are all regulated by mechanisms which tend to resist any untoward changes in their levels. These mechanisms constitute what is known as homeostasis, and are negative feedback mechanisms of a type that we may find exemplified in mechanical automata" (Wiener 1968: 85-86).

[4] For the origins of the "black box" metaphor in communications engineering and cybernetics, see Mindell (2000).

[5] The social scientist Lawrence K. Frank, in an introduction to a collection of papers given at a conference he organized on "teleological mechanisms" in 1946, wrote, "The concept of teleological mechanisms. . . may be viewed as an attempt to escape from these older mechanistic formulations that now appear inadequate, and to provide new and more fruitful conceptions and more effective methodologies for studying self-regulating processes, self-orienting systems and organisms, and self-directing personalities. But these new concepts carry no psychic or vitalistic assumptions, nor do they imply that any mysterious, supernatural powers or psychic forces or final causes are operating the system or guiding the organism-personality. The idea of purposive behavior is not a regressive movement to an earlier stage in the history of ideas, but a forward movement toward a more effective conception of the problems we face today" (Frank 1948: 191).

[6] For example, Warren S. McCulloch wrote in 1946, "I know of no utopian dream that would be nearer to everybody's wishes, including my own, than that man should learn to construct for the whole world a society with sufficient inverse feedback to prevent another and perhaps last holocaust. There may at last be time for us to learn to recognize and decrease the gain in those reverberating circuits that build up to open aggression" (McCulloch 1948: 264).

[7] Though I don't make the argument here, I propose that ecosystems are not cyborgs but techno-ecological systems. A central difference is that the natural and the artificial merge

indistinguishably in the case of the cyborg, while nature and technology are maintained as separate though mutually formative components of techno-ecological systems. This is a characteristic of *whole system* at the level of environment. The difference is important to mark when we address the question of the *complementary* relationship between technology and nature-as-environment in ensuing chapters.

[8] For an ecologist's take on Odum's *Fundamentals* and the status of the ecosystem concept within the science of ecology, see Golley (1993).

[9] In addition to those authors mentioned, see Keller (1995); Haraway (1989); Kay (1997); Hayles (1999).

[10] For some environmentalists, a rejection of dominant cultural values and institutions is implicit in the science of ecology itself. As King and Woodyard write in *Liberating Nature: Theology and Economics in a New Order*, "If we embrace an 'ecological vision,' it inevitably will come into tension with mainstream economics and its reliance upon private property as the essential tool for the distribution of scarce resources and the definition of freedom. Both economics and private property, in their ways, violate the primacy of relationship, connection, and sustainability that are the heart of the science of ecology" (King and Woodyard: 78). For a survey of environmentalist thought and movements sharing King and Woodyard's essential position, see Merchant, *Radical Ecology: The Search for a Livable World*.

[11] By the mid-seventies Eugene Odum would point to the coral reef study as an example for humans: "The Pacific coral reef, as a kind of oasis in a desert, can stand as an object lesson for man who must now learn that mutualism between autotrophic and heterotrophic components, and between producers and consumers in the societal realm, coupled with efficient recycling of materials and use of energy, are the keys to maintaining prosperity in a world of limited resources" (Odum 1977: 1289).

[12] See Merchant (1980).

[13] See, for example, *Earth in the Balance*, by Al Gore, or *Biosphere Politics*, by Jeremy Rifkin.

CHAPTER 3
SEEING THE WHOLE EARTH: THE MISSION TO THE MOON AND THE *WHOLE EARTH CATALOG*, 1965-1970

In the years after World War II, many Americans came to see themselves as ecological beings, inextricably enmeshed in relationships with the planet's organisms and elements – and, for better or worse, with the products of their own civilization. As we saw in the previous chapter, there arose in the post-War years a major new critique of modern technologies, fueled by concern that the natural environment was degrading on a global scale. Not only were there visible signs of environmental destruction and resource depletion, but, with the spread of harmful chemicals and nuclear by-products, there were invisible, inescapable environmental dangers as well, capable of corrupting even the most intimate recesses of the human organism: the bones of children, mother's milk, chromosomes.

The U.S. manned space mission of the 1960s began in the context of these new concerns about technology and its effects on the planet. Space exploration and the Earth itself became figures through which people would try to sort out the entwined futures of technological civilization and ecological being. In significant ways the question of nature and technology crystallized around an unexpected artifact of the lunar mission: the view of Earth from space. Pictures taken by the astronauts of the Apollo 8 mission in late 1968 showed the Earth in its essential *planetness*, as a whole and solitary entity spinning in space. This unprecedented view appeared in newspapers, magazines and on television worldwide, and inspired much reflection about the status and future of modern civilization. The space mission represented the epitome of what modern technological society could accomplish, yet at the same time, the image called attention to the problems besetting the planet, including overpopulation, pollution and poisoning, and the exhaustion of resources. The picture of Earth in space provided a powerful affirmation for the growing understanding of humans as fundamentally ecological beings imperiling themselves with their own creations.

This chapter looks at the production and reception of the image of the whole Earth in American culture. It describes how the images produced by the Apollo 8 mission were framed by the experience of the astronauts themselves, and how those conditions influenced the reception of the images back on Earth. What resulted was a perception of the planet as small, frail, limited, precious and rare.

The view of Earth from space, like the space mission itself, elicited two broad, conflicting responses. On one side were progressive modernists, technological optimists who saw space travel as the future, a great opening up of human spirit and potential.. On the other side were romantics, who saw the look back at Earth as perhaps, in the end, the only worthwhile accomplishment of the mission to the moon. For them, the view of Earth from space justified scaling back the voracious technological and economic appetites of modern industrial civilization for the sake of long-term survival on a small, finite planet.

Nascent in the late sixties was also a new discourse engaged in the intersection of nature and technology, one whose aim was to salvage hopes for both technological progress and ecological survival. This was the response we find percolating in Stewart Brand and his *Whole Earth Catalog*. For Brand, the old dichotomy between progressives and romantics, pitting technology against nature, was beside the point. The image of the Earth from space revealed the planet as a “whole system,” the ultimate complex, cybernetic, self-regulating, self-organizing entity. Seeing the Earth as a whole system, Brand hoped, would begin to "bend human consciousness" and provide a perspective from which imaginative individuals might build a future both ecologically sustainable and technologically adventurous (Brand 1971).[1]

The whole-system model described in Chapters 1 and 2 was a scientific and technical construction that applied to both nature and technology, as we have seen. Stewart Brand, through his catalog and other publications and activities, was a key figure in channeling this technoscientific model initially into a particular sixties-era countercultural niche, and from there into broader cultural arenas. Through the decades that would follow the publication of the first *Whole Earth Catalog*, whole-systems ideas would be used in a variety of countercultural – and eventually mainstream – efforts to reconcile nature and technology by configuring them as co-constituents of a more basic, encompassing entity: the techno-ecological system.

"Why Haven't We Seen a Photograph of the Whole Earth Yet?"

On an afternoon in early 1966, twenty-eight-year-old Stewart Brand took one hundred micrograms of LSD, climbed to the roof of a building in San Francisco, wrapped himself in a blanket, and observed the curvature of the Earth. The city highrises were not parallel but seemed to diverge from one another, to fan out as they rose. This suggested to Brand that the city was resting on the surface of a sphere, something he already knew but had never before *seen*. Brand had recently heard Buckminster Fuller lecture on the problems humanity creates for itself by perceiving the world as flat and infinite, and he began to ponder the importance to others of seeing what he was seeing from the rooftop in San Francisco – the Earth as a whole, as a circle that "went clear around and closed upon itself"(Brand 1977a; 1977b).

Why, Brand wondered, had people not yet seen a picture of the planet from space? This was 1966. The U.S. space program was in full swing. After years of extraterrestrial picture-taking, NASA had shown the world "a lot of the Moon and a lot of hunks of the Earth, but never the complete mandala." This fact now seemed odd to Brand, and extremely important. For the rest of the afternoon he set about figuring a way to obtain a picture of the whole Earth which could be broadcast as a "fundamental point of leverage on the world's ills" (*ibid*.).

The next day, Brand placed an order for hundreds of buttons and posters bearing the question, "Why haven't we seen a photograph of the whole Earth yet?" This was the right question, he felt, partly because it accessed the "great American resource of paranoia." He mailed the buttons to people in Congress, to NASA and UN officials, to Russian officials, and to Buckminster Fuller and Marshall McLuhan. Fuller wrote back to say that the question was ridiculous, pointing out that it isn't possible to see more than half of the Earth at one time from any perspective.

Shortly after his mass mailing, Brand put his question on a sandwich board. He donned a top hat and a white jump suit and began selling his buttons for twenty-five cents apiece on the campus of the University of California at Berkeley. When his ejection from the campus was reported in the *San Francisco Chronicle*, his campaign began to gather momentum. He sold buttons at Stanford, Columbia, Harvard, and MIT, eventually breaking even on his $100 investment. Buckminster Fuller recanted his earlier response and offered Brand his help. "I was tapping into a desire people didn't know they had," Brand said (Goldberg 1991: 54).

NASA began releasing long-range photographs of the Earth in August 1966, about six months after Brand took his fateful LSD trip. It seems doubtful that Brand's eccentric campaign played much of a role in this, though an astronaut later told Brand that he had seen people sporting the buttons in Washington, D.C. and at NASA. In any case, by 1967 Brand had the photograph he was looking for: a color shot of the nearly full-disk Earth. It was taken by an Applications Technology Satellite twenty-three thousand miles above South America. Brand put it on the front cover of the first *Whole Earth Catalog*, the popular guide to tools and ideas he founded in 1968. The back cover was captioned, "We can't put it together. It is together."

Photographs of the Whole Earth

The most direct answer to the question of why, in early 1966, no one had yet seen a photograph of the whole Earth, was that such a photograph had not yet been taken. The U.S. had been regularly launching meteorological and applications satellites showing "hunks of the Earth" since 1959. None of the these had orbited far enough from the planet to capture the full disk. Likewise, astronauts had been carrying hand-held cameras into space since John Glenn's historic orbit in 1962, but none had yet flown high enough to see the whole Earth.

The Lunar Orbiter I satellite in August 1966 took the first photograph of the Earth from the vicinity of the Moon. The electronically transmitted image showed a grainy white crescent foregrounded by the gray lunar surface. Also in 1966, NASA's first Applications Technology Satellite (ATS) took pictures of Earth every twenty minutes from a distance of 22,300 miles. From these photographs meteorologists prepared time-lapse movies of changing cloud patterns. The mid-day photos resulted in a nearly full-disk image. The Department of Defense's DODGE satellite, simply to confirm its orientation, took the first color pictures of the full Earth in July 1967. *Life* magazine called this picture the "first color portrait of an angry Earth" (*Life* 1967). Another nearly full-disk black and white shot was taken by Lunar Orbiter 5 in August of that year.

Though photographs from space had been featured in the popular media prior to 1966, most consistently in *Life* and *National Geographic*, no particular emphasis had been placed on obtaining a picture of the whole Earth. When the first pictures of the whole Earth began to appear, they were published in national newspapers, but none excited an inordinate amount of attention (Goldberg 1991: 53). No one besides Brand seemed overly interested even in the November1967 ATS III photograph that ended up on the cover of the *Whole Earth Catalog*. It wasn't until Apollo 8 was launched, at the end of 1968, that photographs of the Earth began to take on culture-wide significance as more than incidental artifacts of the space program.

Several things distinguished the Apollo 8 photographs from the satellite images of Earth generated up to that point. In general, their color and clarity were better. High-resolution photography, primarily aimed at scoping out potential lunar landing sites, was one of the mission's objectives. But most importantly, the Apollo 8 images were taken by humans rather than by machines. Apollo 8 was the first manned, lunar orbit mission, the first time humans had ventured so far from Earth. No one knew for sure whether the spacecraft would be able to break loose from the Moon's gravity when it came time to return home. People worried that three astronauts might be left circling the Moon forever. They had not forgotten the deaths of the three Apollo 1 astronauts in a launch pad fire in early 1967. At the same time, the mission was a sign that the U.S. wasn't far from achieving its astounding goal of landing men on the Moon. Apollo 8 had the attention of the world like no satellite launch ever had. Furthermore, the flight's progress was tracked through live television and radio broadcasts. People all over the world experienced the drama of the event as it happened.

Writer William Styron recounted how he experienced the Apollo 8 broadcast at a party hosted by an academic with a distaste for the manned space program:

> Suddenly, there before us was that stark sphere, the craters, the jagged shadows that one knew to be chaotic mounds of rubble, the glistening white landscape projected against a backdrop of unfathomable darkness. The murmur and laughter of the party diminished and died, and we watched in silence while [Apollo 8 astronaut] William Anders spoke the words from Genesis: *In the beginning God created the Heaven and the Earth,* a*nd the Earth was without form, and void*. . .
>
> Ceremonial words tend to sound hollow and inappropriate generally because they are predictable, touched by the stale hand of prearrangement. But these words, spoken at one of history's truly heroic ceremonials, seemed entirely appropriate, and I remember that a chill coursed down my back and an odd sigh went through the gathering like a tremor or a wind. . . Listen to Frank Borman, whose cheery valedictory brought home the reality, nearly lost in the sheer awesomeness of the occasion, that we were witnessing the exploit not of some crew of demigods or archangels, but of mortally fleshed men like those of us gathered around a winter's fire: "Good-bye, good night. Merry Christmas. God bless all of you, all of you on the good earth."
>
> I glanced at my host, the mistrusting and scornful teacher, and saw on his face an emotion that was depthless and inexpressible (Styron 1988).

The still photographs returned from Apollo 8 took on the aura of the mission's human drama. One of the most frequently reproduced photographs is that of the Earthrise over the Moon's horizon, captured by William Anders as Apollo 8 made its lunar orbits. Stewart Brand put this photograph on the inside front cover of *The Last Whole Earth Catalog* in 1974, crediting it as the picture that "established our planetary facthood and beauty and rareness (dry moon, barren space) and began to bend human consciousness." Notably, its content and perspective are not much different from the Earthrise taken by

Lunar Orbiter I in 1966, which scientists were "jubilant" about, but which hardly anyone else noticed (San Francisco *Chronicle* 1966). In both pictures the partially lit globe of Earth hovers on a jet black background above an illuminated section of desolate Moon. The difference in how the two images were received was mostly a matter of context: one was generated by an unmanned spacecraft, while the other was framed by an unprecedented human drama.

The fact that humans were behind the camera gave the Apollo 8 photographs significance beyond anything a satellite image could achieve. From inception, they were cast within the broader "heroic ceremonial" of the U.S. manned space program, speaking not just of the planet in space but of themselves as well, as spectacles of the human achievement that lay behind them. In this sense they bore out the logic of the U.S.'s basic motivation for launching men into space in the first place. "By having a camera connected to an eyeball connected to a brain," astronaut Anders said before the Apollo 8 launch, "we can really do a job that cannot be done by unmanned vehicles" (Schick and van Haaften 1988: 92). Michael L. Smith writes, "As most of the non-defense subsidized scientific community repeatedly stressed, nearly every measurable space objective – in communications, weather monitoring, exploration of the planets, even military reconnaissance – could be achieved far more effectively, and at considerably less expense, with automated satellites and probes rather than by manned expeditions. Sending men into space was preferable to unmanned projects for only one reason: It vastly enhanced the dramatic impression created by the nation's space exploits" (Smith 1983: 194).[2]

Of all the pictures taken by Apollo 8, it is the Earthrise and the whole Earth photos which were most affecting, and most enduring. Something about photographing not just Earth from orbit but Earth from distant space seemed revelatory and monumental. As Brand noted, “hunks of the Earth” had been generated and widely distributed since the beginning of space exploration. The August 5, 1966, issue of *Life* had featured the “Highest Photos of Earth Taken by Man,” which were of general interest but not quite powerful enough to, as Brand would say of the Apollo 8 Earthrise picture, “bend human consciousness.” To be most effective, the image had to capture the Earth in its ultimate state of *Earthness* – in its essence as a planet, as “whole Earth.” The image’s power depended upon an inscription of the Earth seen as a planet by human eyes. Without that context, the Apollo 8 photographs might have sparked as little enthusiasm as did the Lunar Orbiter I images two years before.

As Apollo 8 began generating images of Earth, the astronauts, and subsequently various media sources, began to comment specifically on the view of Earth from space – a view now permanently framed by the spectacle and drama of the mission itself. The evolution of these remarks shows a shift in attitude about the view of Earth, from respectful but detached observation to wistful affection and nostalgia, as the flight completed its orbits of the Moon and headed back home.

In the first days of the mission, as the spacecraft reached a distance that afforded a view of the whole Earth, the astronauts’ descriptions were enthusiastic but matter-of-fact. From 21,000 miles, James Lovell reported in an air-to-ground transmission: “Boy, it’s really hard to describe what this Earth looks like. I’m looking out my center window, the round window, and the window is bigger than the Earth is right now. I can clearly see the terminator [the line separating the sunlit portion of the planet from the dark]. I can see most of South America all the way up to Central America, Yucatan, and the peninsula of Florida" (Phillips 1969).

About halfway to the Moon, Frank Borman made these observations: "I certainly wish that we could show you the Earth. It is a beautiful, beautiful view with predominantly blue background and just huge covers of white clouds – particularly one very strong vortex up near the terminator."

Later, Lovell stated: "The Earth is now passing through my window. It's about as big as the end of my thumb. Waters are all sort of a royal blue. Clouds, of course, are bright white. The reflection off the Earth is much greater than the Moon. The land areas are generally sort of dark brownish to light brown. What I keep imagining is, if I were a traveler from another planet, what would I think about the Earth at this altitude? Whether I think it would be inhabited" (*ibid*.).

These responses to the Earth-as-planet, seen by humans for the first time, do not go far beyond ordinary descriptions of colors, patterns, and landmarks. The one aesthetic observation made on the way to the Moon, that the Earth is "beautiful," does not begin to communicate the depth of feeling the astronauts acquired after circling the Moon, encountering its lack of color and life, and embarking on the return trip home.

On their next-to-last lunar orbit, the astronauts provided these impressions of the Moon to a live television audience:

Borman: "The Moon is a different thing to each one of us. . . My own impression is that it's a vast, lonely, forbidding type of existence, a great expanse of nothing, that looks rather like clouds and clouds of pumice stone. It certainly would not appear to be a very inviting place to live or work."

Lovell: “Actually, I think the best way to describe this area is a vastness of black and white, absolutely no color.”

Borman: “The sky up here is also rather forbidding; a foreboding expanse of blackness with no stars visible in daylight.”

Lovell: “The vast loneliness of the Moon up here is awe-inspiring, and it makes you realize just what you have back there on Earth. The Earth from here is a grand oasis to the big vastness of space” (*ibid.*)

Their up-close encounter with the Moon, and a deepening realization of how far they were from Earth, seemed to affect the astronauts’ sense of what it meant to be looking at Earth from distant space as they neared completion of their mission and turned their attention toward getting back home. “I think it was the Earthrise that really kind of got everybody in the solar plexus,” said William Anders.

> When we went around the far side of the Moon, into its double shadow from sunshine and Earthshine, I had a very eerie feeling. On the one side there were so many stars it was hard to tell the constellations. On the other there was nothing but black – the Moon. It was a bit like falling into a big black hole.
>
> Then, suddenly, we were looking down at the rough, stark lunar surface with the long shadows of lunar sunset. It looked very desolate, colorless, monotonous, even unfriendly. We had no sooner taken in this somewhat disappointing scene than up popped the Earth. We all saw it at once, and there we were looking back at our home planet, the place where we evolved. Our Earth was quite colorful, pretty, and delicate compared to the rough, rugged, beat-up, even boring lunar surface. I think it struck everybody that here we’d come 240,000 miles to see the Moon and it was the Earth that was really worth looking at (Schick and van Haaften 1988: 92).

Some of the same sentiments are evident in Anders’ often-quoted comment, made while he was still thousands of miles from the planet: “I think all of us subconsciously think that the Earth is flat or at least almost infinite. Let me assure you that, rather than a massive giant, it should be thought of as [a] fragile Christmas-tree ball which we should handle with considerable care" (Darius 1984: 142).

Anders later commented on the shift in attitude he and the other Apollo 8 astronauts experienced in response to seeing the Earth from the Moon: "We were fighter pilots and test pilots out to do a job. But all of us either transcended that or were jerked out of it by the view of the Earth as a sphere about the size of your fist at the end of your arm. When those views came back by television and in photographs, mankind could see for the first time that it existed on a very small, fragile, finite Earth" (Schick and van Haaften 1988: 95).

NASA's astronauts as a group seemed to lack a sense of wonder about what they were doing, to be themselves incapable of imbuing their mission with poetry.[3] The astronauts prior to Apollo 8 had even perhaps, "regretted coming back. . ." according to Italian journalist Oriana Fallaci. The ones who had been in space (though not yet to the Moon), she wrote, had a "rage at having come back to Earth. As if up there they're not only freed from weight, from the force of gravity, but from desires, affections, passions, ambitions, from the body" (Fallaci 1966: 64-5).

These astronauts did not have the experience of seeing the Earth whole after passing over the dark side of the Moon. But as for the Apollo 8 astronauts, as Anders attests, something changed them between the time they entered the Moon's gravity and the time they left it. The Moon made them melancholy and forced them to look at the Earth differently, a difference reflected in the photographs they produced and the comments they made to their worldwide television audience. Their remarks after circling the Moon reveal a kind of homesickness, a longing to return from the alienating environment of Moon and space and spacecraft. On the return trip home they "transcended" their scientific, engineering, goal-oriented dispositions, and began to aestheticize, and even sentimentalize, the planet in their photos and words. The watching world received the Apollo 8 images fully framed by the drama of the mission and their own participation in the astronauts' perspective. Through the astronauts' eyes, they began to see the Earth in a new way, as small, fragile, precious and finite.

Media accounts of the Apollo 8 mission show this evolution in sentiment among news reporters and commentators. Like the astronauts, they placed no special emphasis on seeing the Earth from space while the Moon was still unattained. During the first leg of the trip, much effort was spent, both on the ground and in the spacecraft, in overcoming technical problems that prevented the transmission of a good television shot of the Earth. When the image finally came through, on December 23, the Earth appeared to a *New York Times* reporter as "a sort of large misshapen basketball that kept bouncing around and sometimes off television screens back here" (*NYT* 12/24/68a). The image, at that point still primarily a by-product of the spectacle of the mission, once again justified in public relations terms NASA's decision to send humans rather than mere machines to the Moon. In a December 24 article on European responses to the Apollo broadcasts the *Times* reported:

> Pictures from the capsule, received by satellite, are on the front pages of virtually every newspaper in Europe. Most European television channels are broadcasting all the live transmission from the spacecraft. . .
> Criticism about there being a better use for all the effort and expense is virtually blotted out in the general expression of wonder and admiration. . .
> . . . [T]he general feeling in Europe was summed up in an editorial in The London Times, which said: "The danger of becoming bored by the whole business suddenly vanished for most of us" (*NYT* 12/24/68b).

The presence of humans in space engendered persistent reflection on the state of humanity – though, in the initial stages of the mission, not yet in ways primarily sympathetic to the planet . Most comments still addressed the people/people rather than people/planet implications of the image, finding in the view reason to conceive of a unified humanity, but valuing that unity on the basis of human accomplishment rather than, in Brand's phrase, "planetary facthood." At this moment, press accounts tended to celebrate the triumph of human ingenuity and boldness of spirit. A December 24 editorial stated:

> . . .[T]he drama and interest of yesterday's view of earth from space transcended any prosaic considerations of practical utility. Rather the excitement these pictures aroused among millions of stay-at-homes flowed from the visual evidence they provided of man's successful entrance into a completely new realm, one which poses challenges, opportunities and dangers such as the human species has never before faced. And yesterday's pictures provided a sobering perspective on man's puny earthly works and rivalries, reminding all humanity that nature is the basic antagonist, not other men (*NYT* 12/24/68c).

Christmas Eve saw the astronauts concluding their melancholy impression of the Moon, reading from *Genesis*, and wishing all on the "good Earth" a Merry Christmas. After that, the mood in the press began to change. The Christmas-day front page of the *New York Times* featured poet Archibald MacLeish's now-famous reflection headlined, "Riders on Earth Together, Brothers in Eternal Cold." MacLeish surveyed medieval and nuclear-age conceptions of humanity in relation to the universe, then suggested that the view of Earth from space might correct the misconceived notions of the past and at last provide the proper perspective. Regarding the state of 20th-century humanity up to Apollo 8, he wrote:

> . . . [M]en began to see themselves, not as God-directed actors at the center of a noble drama, but as helpless victims of a senseless farce where all the rest were helpless victims also, and millions could be killed in world-wide wars or in blasted

> cities or in concentration camps without a thought or reason but the reason – if we call it one – of force (MacLeish 1968).

But then, the astronaut's new vision of Earth in its essential *Earthness*:

> And seeing it so, one question came to the minds of those who looked at it. "Is it inhabited?" they said to each other and laughed – and then did not laugh. What came to their minds a hundred thousand miles and more into space. . . was the life on that little, lonely, floating planet, that tiny raft in the enormous empty night. "Is it inhabited?"

Finally, this new perspective revealed the truth about humanity:

> The medieval notion of the Earth put man at the center of everything. The nuclear notion of the Earth put him nowhere – beyond the range of reason even – lost in absurdity and war. This latest notion may have other consequences. Formed as it was in the minds of heroic voyagers who were also men, it may remake our image of mankind. No longer that preposterous figure at the center, no longer that degraded and degrading victim off at the margins of reality and blind with blood, man may at last become himself.
>
> To see the Earth as it truly is, small and blue and beautiful in that eternal silence where it floats, is to see ourselves as riders on the Earth together, brothers on that bright loveliness in the eternal cold – brothers who know now they are truly brothers.

In the years that followed, this final section would frequently accompany the picture of Earth in space, and would become the summation of the modernist discourse framing the image. The Earth "as it truly is" cannot be seen from the surface, only from distant space. And the truth about the planet revealed by this perspective ultimately reveals the truth about humankind: we are, at the most fundamental level, inseparable from one another by virtue of our shared relationship to the planet. "Riders on Earth Together" demonstrated how even modernist progressive rhetorics, such as MacLeish's, now could be recast with a romantic's appreciation of the planet, under the influence of the image of the whole Earth.

By the next day, December 26, the tide had turned even on the *Times*' editorial page. Referring to the Apollo 8 crew, it stated: "The first men ever to journey to the neighborhood of the terribly bleak and lonely expanse of the Moon, they are understandably eager to return to what astronaut James Lovell called ‘the grand oasis in the great vastness of space,’ this green and flowering earth” (*NYT* 12/26/68). In two days the depiction of nature as humanity’s “basic antagonist” had been replaced by an appreciation for the planet as source and sustainer. Seeing the planet in space and interpreting it as ‘angry,’ as *National Geographic* had only a few years before, now was unthinkable. Such a shift in sentiment toward the Earth helped prepare the way for an environmentalist discourse – rooted in romanticism and critical of modern technological society—to spread quickly throughout the culture beginning in the latter years of the 1960s.

Reach for the Stars or Return to Earth?

The space flights that generated the view of Earth-as-planet took place in a time of war, assassination, and social protest, in an age of the mass-mediated primacy of science and technology, in an era of decolonization and neocolonialism, amid the operations of multinational consumer capitalism, and under the threat of nuclear and environmental catastrophe. There was no consensus on what sending men to the Moon might mean under these circumstances, but responses to NASA’s mission generally fell into two categories: it was either lauded as a victory for science and technology, humankind, and America, or else criticized as a waste of effort and resources. The perception of the Earth as small, finite, and fragile was suitable for either perspective.

These two responses can be categorized broadly as progressive and romantic. Both have deep roots in modern Western culture. For progressives the mission to the moon marked a new phase in the advance of civilization. It was a first step into a new frontier, promising an expansion of human possibilities, new knowledge and wealth, new opportunities and adventure. This view, expressed by writers such as Ray Bradbury and James Michener, historian Daniel Boorstin, and scientists Carl Sagan and Wernher von Braun, characterized space exploration as the inevitable extension of the liberal, modernist dream of human progress.[4] As Michener wrote, space exploration is "the specific challenge of our age." To meet that challenge, to pursue "the infinite promise of . . . man's unfulfilled possibilities. . .," according to Boorstin, "we must keep alive the exploring spirit."[5]

Modernist progressives such as Archibald McLeish projected onto the image of Earth a vision of universal humanity, all people sharing a common history, home, and fate. The photo of the whole Earth was for them the culminating image of post-War efforts to establish grounds for worldwide peace, cooperation and progress. Following the war against fascism, racial and national differences ceased to be acceptable typologies for an understanding of "man." Peace and security – indeed, survival – after Hiroshima, in the Cold War era, in the face of decolonization, depended on the discovery of human commonalities. Global unity was asserted in, for example, the United Nation's 1948 Universal Declaration of Human Rights, through the construction of a scientifically legitimated "family of man." "Biological studies lend support to the ethic of universal brotherhood," asserted the 1950 UNESCO statement on race, "for man is born with drives toward co-operation, and unless these drives are satisfied, man and nations alike will fall."[6]

Some critics have noted that the humanist, universalist rhetoric of the post-War period was readily appropriated by U.S. business and political leaders with ambitions for an American global hegemony; that, in fact, the space program itself, though cast as an epic human endeavor, was motivated more by a desire for national power and prestige.[7] In the contest for global influence, as Michael L. Smith argues, it was important for the U.S. to couch its space program in term of benevolent exploration rather than a power struggle, thereby "lending the nation the appearance of a self-assured, mature state seeking knowledge for all humanity among the stars" (Smith 1983: 194).

The image of Earth in space could be easily pressed by progressive, modernist observers into the service of a larger project of American economic, cultural, and political imperialism. Since before World War II, the globe had been a symbol of the advancing forces of modernity, including the development of world-wide media, transportation and communications. And of course the globe had also long been the emblem of empire. In the post-WWII years, the globe often represented Americans' modernist values and international reach, as demonstrated by American movie studios, airlines, world's fairs and any number of other sites. The "one world" MacLeish and other progressives saw in the image of Earth shone to many as a reflection of America's global economic dominance, its faith in technological and economic progress, and its religious sense of global mission (Cosgrove 1994). Their vision of "universal man," in attempting to undo the division of humankind into racial types, also tended to erase the historical, social and cultural specificity of human diversity, and was relentlessly oblivious to women.[8]

In contrast to these progressive responses, space flight and the image of Earth also elicited a romantic response, rooted in the pastoralist critique of modern American civilization.[9] From this perspective, the greatest accomplishment of the mission to the

Moon was not an evolutionary leap of humankind beyond the confines of Earth, nor even a new appreciation of global human unity, but the view of the planet as planet, as an ecological world, the source and sustainer of life, which now, in the late twentieth century, was subject to all manner of peril from the excesses of modern civilization. While progressives looked to technology as the hope of humankind, romantics identified it as the very source of the problem.

By the end of 1968, environmental concern was being voiced more loudly, and across a broader spectrum of American culture than ever before. As it happened, the American Association for the Advancement of Science held a conference in Dallas during the last week of the year, precisely as Apollo 8 was rounding the Moon and heading back home. In a front-page article headlined, “Panel Finds Danger to the Environment from Technology,” the *Times* reported on December 29, “For five hours, one scientist after another stood up and discussed what they termed the grave consequences implicit in the continued use of herbicides in South Vietnam, asbestos in building materials, and deep wells for storage of chemical wastes” (*NYT* 12/29/69). Margaret Mead was one of the group’s featured speakers, as was Barry Commoner, who said, “I believe that unless we begin to match our technological power with a deeper understanding of the environment we run the risk of destroying this planet as a suitable place for human habitation” (*ibid*.)

The progressive and romantic responses elicited by the image of Earth were not always easy to keep separate. Mounting concern about the planet’s health inspired by the view of Earth in space sat side-by-side with admiration and marvel at the technological feat responsible for this new view. The “heroic ceremonial” of the lunar orbit could not be celebrated without also some countervailing twinge of reservation and worry. Writers including Rachael Carson, Barry Commoner, and Paul Ehrlich had outlined for a broad readership underlying incompatibilities between the natural environment and modern technological society (Carson 1962; Commoner 1966; Ehrlich 1968). On December 30, the day the Apollo 8 Earthrise appeared on the front page of the *Times*, an editorial on the AAAS conference read, "Despite the latest major advance in space exploration, this planet is going to be the human race's chief habitat for many centuries to come. The time is overdue for a really major effort to insure that earth remains livable not only today and tomorrow but also decades and centuries from now" (*NYT* 12/30/68). Such rising concern about the health of the planet would lead, two years later, to the first Earth Day celebration, a nation-wide day of lectures, teach-ins, protest, and debate, which inaugurated the environmental activism of the 1970s (Environmental Action 1970).

With the still photographs released by NASA after Apollo 8's safe return home, the view of Earth from space achieved the status of cultural icon. In terms of quality the video images from the spacecraft could not compare to these pictures, which included the remarkable Earthrise as well as full-disk Earth shots of unprecedented clarity and color. NASA made these stills available on December 29, 1968; the next day they were on the front pages of newspapers around the world. In early January 1969, *Life* magazine featured them in a lengthy photo spread. Soon they appeared on posters, in advertisements, on book covers and postage stamps.

Of the many appropriations of the image, the environmental movement's was among the most effective and persistent. Environmentalists had learned the value of pictures as early as 1960, when David Brower and the Sierra Club published the first of its popular fund- and consciousness-raising coffee table books. The books were followed by calendars, which put color wilderness scenes in homes and workplaces throughout the country. And now, quite suddenly, there was the ultimate nature photo: Earth in space. From the environmentalists' position, there was no greater testimony to the veracity of their most central claims: the planet could not be endlessly abused, its resources infinitely exploited, its systems unceasingly compromised. For, despite prevailing behaviors to the contrary, Earth was in fact small and limited and vulnerable. What's more, once it was ruined, there was no place of retreat or redress in the entire universe, at least not within the reach of human beings anytime soon. Choosing to continue along the path modern civilization had set for itself thus was suicidal.

The image of Earth in space was more successful than any picture that preceded it in getting the environmentalist message across. The astronomer Fred Hoyle had made a prediction, back in 1948, that if a picture of the whole Earth were ever generated, it would let loose "a new idea as powerful as any in history" (Hoyle 1950: 10).[10] In 1970 he wrote:

> Well, we now have such a photograph, and I've been wondering how this old prediction stands up. Has any new idea in fact been let loose? It certainly has. You will have noticed how quite suddenly everybody has become seriously concerned to protect the natural environment. Where has this idea come from? You could say from biologists, conservationists, and ecologists. But they have been saying the same things as they're saying now for many years. Previously they never got on base. Something new has happened to create a world-wide awareness of our planet as a unique and precious place. It seems to me more than a coincidence that this awareness should have happened at exactly the moment man took his first step into space (Clayton 1975: 127).

Of course, progressives and romantics alike could express a general sense of environmental awareness and concern. Not even the most fervent technocrat would show contempt rather than some variety of affection for the beleaguered little planet they called home. The progressive point of view, however, consistently placed that concern in the context of the spectacle of the mission to the Moon and its attendant sense of masculinist heroism, interpreted as human achievement and potential. It trusted in technological innovation to resolve the problems. Even so, some progressives conceded, the Earth might indeed one day be a place unsuitable for human habitation. “So in order to insure the entire race existing a million years from today, a billion years from today,” said Ray Bradbury, “we’re going to take our seed out into space and we’re going to plant it on other worlds”(Bradbury 1970).[11]

The romantic, environmentalist perspective, in contrast, shifted the emphasis away from the spectacle of space flight, toward the inscription of Earth. It downplayed the technological feat underlying the creation of the image and focused instead on the finite, precious qualities assigned to the planet from the vantage of distant space. The rhetoric of environmentalism, as demonstrated by the AAAS conference, stressed the growing number of scientifically grounded claims that the small, fragile Earth was in enormous trouble.

The image of Earth in space suggested dual possibilities: the promise of unlimited human progress through ever-advancing technology, and the threat of extinction at the hands of that very faith in technology. Seeing the whole Earth brought out the basic truth that the question of modern civilization’s future hinged on the relationship between technology and the planet, whether Earth was the launch pad for a truly universal human future, or humankind’s inescapable, permanent home. Though the progressive and romantic perspectives on the planet pointed in opposite directions, they also shared the central assumption that modern technological civilization was at a crossroads, that a choice was at hand between an ecologically sustainable future, and a technological future beyond the limitations imposed by the planet. In both cases, the Earth appeared as it had to the Apollo 8 astronauts: small, fragile, and finite.

There was, however, another discourse in the making, one which began to imagine a future capable of accommodating both technological progress and ecological sustainability. Stewart Brand, who first clamored for a picture of the whole Earth, interpreted the image not in progressive or romantic terms, but from a distinctively twentieth-century "whole systems" perspective. In the logic of the discourse that began to take shape in his *Whole Earth Catalog,* Brand pictured the contest between romantics and progressives, the choice between technology and nature, as misplaced from the start. Complex, self-organizing, and self-regulating systems were the entities that mattered, and they could be either organic or mechanical. The whole Earth was not a fragile, limited entity serving merely as the cocoon humankind must either take flight from or nestle into. It was, rather, a complex entity in itself, a techno-ecological system, responsive to intelligent, creative human nudging, fiercely resistant to ignorant, ham-handed exploitation (Brand 1977a).

Stewart Brand's Whole Earth

Brand's reasons for wanting a photograph of the whole Earth, and his use of it once he got it, preceded the "heroic ceremonial" of the Apollo 8 mission. The first *Whole Earth Catalog*, with the satellite-generated full-disk Earth on its cover, came out in the fall of 1968, several months before Apollo 8 reached the Moon. The meaning Brand attached to the image, therefore, was not framed from the start by Lovell, Borman, and Anders as they rounded the Moon and headed home. Instead, the point of seeing the whole Earth, for Brand, was to apprehend it as a "whole system." His expectations for the image were at once wildly idealistic and utterly practical: a whole-system understanding of Earth could both change human consciousness and provide the conceptual and hands-on tools for living sensibly, even creatively, on the planet. Both were necessary.

Brand was immersed in the California counter-culture of the 1960s. Prior to starting the *Whole Earth Catalog*, he was part of Ken Kesey's Merry Pranksters, and he had instigated a number of "happenings," including a multi-media art show called *War God* and a cultural education program titled "America Needs Indians." He and Kesey were responsible for the famed 1966 San Francisco Trips Festival, which featured performances by the Grateful Dead and other area bands, a psychedelic light show, spontaneous multi-media presentations, live theater, and the prodigious consumption of acid, all at once. As already noted, LSD played a part in Brand's realization that the world needed a picture of the whole planet. His depiction of the whole Earth as "mandala" invoked the mystical and psychological explorations attached to 1960s psychedelia. *Mandala* is Sanskrit for circle. It describes a visual device, the *yantra,* which is used for meditation and spiritual centering in Tibetan Buddhism. Jungian psychology uses the image of the mandala to symbolize evolving wholeness. The psychedelics of the 1960s hoped to bring about a large-scale spiritual and psychological awakening, to expand the frontiers of human consciousness through psychotropic drugs. Brand's aspirations for the picture of the whole Earth were similar. He believed in its ability to alter human consciousness like a cultural hit of LSD.

At the same time, he was taken by the idea of whole systems, a concept that began gaining momentum in a variety of sciences in the decades before World War II. As we saw in Chapter 2, it proved itself essential to the War effort and quickly spread into an amazing array of technical and scientific fields in the years after the War. The system, in this context, was a fundamental pattern of organization common to complex entities of all sorts – organisms, societies, plant and animal communities, the brain, the economy, information technologies, and many more. Such systems were self-organizing, adaptive, and heterarchical. It made little sense to dissect these systems and study their individual parts. Their essential quality was the ability to maintain the integrity of their own complex wholeness. Cybernetics was the signal post-War theory of whole systemness, but a cluster of "cybersciences" emerged in the wake of the War: operations research, information and communications theory, systems analysis, computer science and more. The ideas and methods developed in these fields were taken up within psychology, sociology, anthropology, biology, ecology, economics, business, manufacturing, organizational management, and many other areas.

In many cases, as we saw in Chapter 2, the goal and effect of the systems approach was to shore up the "managerial ethos" of the post-War period.[12] Cyberscience facilitated the development of techniques of control over complex organic or social processes by framing them within theories of machine communication, the better to quantify and model them in terms of inputs and outputs of information or energy. But in other hands there was something potentially radical and liberating about the whole systems concept. It countered the reductionistic, atomizing calculus of traditional science by insisting that complex entities were at base irreducible. When applied to social, and especially ecological systems, such as the planet as a whole, this had important implications. It meant all the components of the system – people, technologies, plants and animals, water, rock, and sky – were inextricably interrelated. Whatever happened in one corner of the system had repercussions throughout. What's more, a self-equilibriating system like Earth could adjust to disruptions, but only within limits. After a point positive feedback would lead it down an irreversible path toward failure.

The systems approach was holistic, like organic theories of the past, but it was also rigorously empirical and amenable to quantification. It avoided the old organicist pitfalls of unempirical, untestable vitalism, and it encompassed not just organisms and their communities, but the non-living—technology and inorganic nature—as well. An understanding of the Earth as a whole system provided powerful new *scientific* tools for critiquing modern, global technological society. As biologist Barry Commoner explained in *The Closing Circle*, "[E]verything is connected to everything else: the system is stabilized by its dynamic self-compensating properties; these same properties, if overstressed, can lead to a dramatic collapse; the complexity of the ecological network and its intrinsic rate of turnover determine how much it can be stressed, and for how long, without collapsing; the ecological network is an amplifier, so that a small perturbation in one place may have large, distant, long-delayed effects" (Commoner 1971: 39).

A whole systems perspective supplied the philosophical framework for the *WEC*, a philosophy given substance and force by the picture of the whole Earth. The systems approach also provided tools for acting on that new perspective, for building a different relationship between people and the planet, and this is what Stewart Brand and his catalog were most directly devoted to. For Brand, no one better demonstrated the potential for transforming the built environment through a whole systems approach than the independent, iconoclastic inventor Buckminster Fuller.

Fuller's insights initiated the catalog, Brand told his readers, and he devoted the first two full pages to Fuller's works. In fact, it was a lecture by Fuller that got Brand thinking about the picture of the whole Earth in the first place. One of Fuller's basic principles was that ". . . it is always unsafe to start from anything less than the best Whole-Systems grasp we can manage" (Kenner 1973: 177-78). Fuller found ways to incorporate that whole systems approach into physical design. His most successful and well-known invention was the geodesic dome, a light, strong, easy-to-build structure requiring no internal supports. The U.S. featured his domes in international world's fairs and trade shows, and the U.S. military began using them as temporary structures in the Arctic in the 1950s. Fuller was also known for his "dymaxion" car, which he designed on geometric principles in the 1930s; for demographic maps and charts that divided up space in innovative ways; and for wide-ranging and, to many, eccentric philosophical musings on God, thought, technology, society, and many other topics (Fuller 1969b, 1970; Fuller and Marks 1973; Kenner 1973; Snyder 1980).

In many ways, Fuller was the kind of figure Brand most admired. He was an original thinker, but also a doer; he occupied the dual realms of high concept and hands-on pragmatics. Fuller had a material impact on mainstream society – his domes were widely endorsed and admired – yet he never really fit within the established scientific, engineering, educational or political institutions. *In* the world but never really *of* it, he remained independent, self-educated, a bit of a crank, but enthusiastically devoted, in various unconventional ways, to solving the world's problems and leaving it a better place. Like Brand, he was optimistic that people might build a better world for themselves, but was never utopian.[13] Neither did he put his trust or energy into politics.

Brand adhered during his *Whole Earth Catalog* days to Fuller's dictum that "politicians weren't the main event."[14] Brand told his readers that with Fuller's "empirical curiosity and New England perseverance Fuller has forged one of the most original personalities and functional intellects of the age" (Brand 1968: 3).

In part because of Fuller's optimism and his persistent use of mechanistic metaphors (he coined the phrase *spaceship Earth*), it has been easy for critics to cast him as blindly enthusiastic about technology. One scholar labels Fuller an "arch-progressive and Modernist thinker," but in many ways Fuller's agenda ran counter to the direction of modern technological society (Cosgrove 1994: 284). His *Operating Manual for Spaceship Earth*, for example, while shot through with engineering imagery, pointed readers not toward escaping the planet but toward learning how to keep it running. Certainly the ecological concern implicit in his whole systems perspective was a big part of his appeal to Brand. Ideas in *Operating Manual for Spaceship Earth* can be found in speeches he gave prior to the book's 1969 publication; some version of them was included in the lecture Brand heard in 1966, which got him thinking about the whole-Earth perspective.[15] Fuller's ideas proceeded from an understanding that "We are living on a closed-system earth. . ." In a 1969 speech at Auburn University, Fuller addressed the words "up" and "down."

> These words were invented to accommodate the concept that the world is a plane going out to infinity. In reference to such a plane all perpendiculars are parallel to each other, and therefore lines go in only two directions, up and down. But as man began to fly around his earth he felt that as an aviator he was not really upside down. . . You'll soon begin to catch on that you're living on board a space ship, one on which the words "up" and "down" have no absolute meaning.
>
> If there is an infinite system, then there are an infinite number of resources to be exploited. You can be just as careless and stupid as you want, since there are an infinite number of resources out there and we'll never run out. And there's an infinite amount of space in which you can get rid of all your filth as you waste all

> those resources. But in a closed system you can't do that – and that's the kind of system we're in (Fuller 1970: 52-53).

Fuller's genius at design, his outsider status, his iconoclastic persona and quasi-mystical philosophy made him increasingly popular as a speaker and cultural figure on college campuses in the 1960s. It was his dome design, however, that held the most direct appeal to readers of the *Whole Earth Catalog*. The catalog's first section, "Understanding Whole Systems," was followed by sections on land use and shelters, which featured information on how to build domes and where to find materials for them. The self-educating, self-inspiring reader Brand had in mind was interested in experiments in self-sufficient living. Geodesic domes were cheap, mobile and relatively simple to build—in short the very kind of high-concept, utterly practical tool an enterprising individual might need for building a different sort of relationship with the planet.

In the *Whole Earth Catalog's* statement of purpose, Brand wrote that the "power and glory" of modern civilization was unprecedented, but was present only remotely, within institutions, not individuals. Civilization had succeeded beyond the point where success meant actual gains. Out of this situation, however, was emerging a new "realm of intimate, personal power," in which the individual was winning the ability to "conduct his own education, find his own inspiration, shape his own environment, and share his adventure with whoever [*sic*] is interested." The *WEC* was a resource for helping the individual in this process. It provided information and access to tools it deemed "useful," "relevant to independent education," "high quality or low cost," "not already common knowledge," and "easily available by mail" (Brand 1968: 1).

The *WEC* presented a wide mix of items, with reviews, pictures, descriptions, excerpts, and ordering information.[16] In addition to "Understanding Whole Systems" and

"Shelter and Land Use," the catalog featured sections on "Industry and Craft," "Communications," "Community," "Nomadics," and "Learning." The variety of ideas and materials was eclectic, even bewildering, but they begin to cohere when we understand that a "theory of civilization," as Brand wrote years later, was inherent in the *WEC*. Brand intended for the catalog to hand the tools of an entire civilization over to individuals, thus empowering them to remake the world, and "get it right this time" (Brand 1994: 5). In the 1960s this often meant founding communes and other "intentional communities." More generally, and more enduringly, it meant establishing a set of cultural values, by which people experimented on their own with tools and ideas. As one *WEC* slogan put it, "Do good. Try stuff. Follow thru."

Though steeped in the sixties counter culture, Brand and the *WEC* were not leftist, and not terribly interested in political upheaval. "I think Abbie Hoffman is just great," Brand stated. "But I'd as soon have an epileptic fit as a revolution"(McClanahan and Gurney 1970). And though he was an integral part of the Bay Area hippie culture, Brand was no Haight-Ashbury flower child. Hedonism for its own sake held little promise for changing values, consciousness, or the built environment. Rather, the kind of cultural experimentation Brand embraced most enthusiastically through the *WEC* was represented by the ALLOY event held in New Mexico in the spring of 1969. This gathering of "outlaw designers," "dope fiends," "world-thinkers," "hope freaks," and others "with a functional, grimy grasp on the world," met for three days in the desert between the Trinity bomb-test site and the Mescalero Apache reservation to discuss ideas and theories, materials, tools and methods for building alternative, independent modes of living. Headed by Brand's friend Steve Baer, the event featured a variety of often highly technical demonstrations and discussions of how to design and cheaply build the structures and systems necessary for self-sufficiency. Geodesic domes and whole-systems philosophy, of course, were prominent throughout. *The Last Whole Earth Catalog* (1971) reprinted the entire report of the ALLOY event, a document consisting mostly of photos and quotes from participants. “Take the path you haven’t taken before,” the report stated. “If you want to try a new way, you’ve got to build something” (Brand 1971: 117). “If I had to point at one thing that contains what the *Catalog* is about,” wrote Brand, “I’d have to say it was ALLOY”(*ibid*.: 439).

The essence of the Whole Earth sensibility, then, was to empower the individual with concepts, tools and technologies with which he or she could build something new. (Even “mescaline, psilocybin, LSD, and such,” were thought of as “liberating technologies” at the time, according to Brand (Brand 2001)) An outcome of this mission was an unlikely pairing of the primitive and the cutting edge. In the pages of the first *Whole Earth Catalog*, cheap, reliable hammers and hacksaws, resources for finding buckskin and making moccasins, tips on building sewerage systems and raising goats sat alongside books on cybernetics, information theory, and systems thinking, as well as computer aided design, the “human biocomputer,” and a book called “We Built Our Own Computer.”

Of course, there were myriad technologies included between hatchets and computers – from auto repair manuals, to guitar amplifiers, to a handbook for blasting with dynamite. But computers and other information technologies were embraced with special enthusiasm by Brand and the *WEC*. Brand was on hand in 1962, when young computer programmers at MIT invented the first video game. In 1968, Brand participated in what, in the mythology of personal computer history, has come to be known as the "mother of all demos." This was a demonstration on the campus of Stanford University of methods of human/computer interface that would set the direction for the development of the personal computer, including the mouse, the CTR display, the keyboard, and hypertext. In the seventies and eighties, Brand published regular guides to software as part of his magazine, *CoEvolution Quarterly*. In 1984 he issued a software catalog and magazine, *The Whole Earth Software Review*. In the late eighties he founded the Whole Earth 'Lectronic Link (The WELL), an Internet virtual community for the San Francisco Bay Area. With11,000 active users worldwide it is in many ways a widely-disbursed, electronic version of the sort of "intentional community" the *WEC* encouraged in the 1960s. Brand describes the invention and distribution of personal computers as an example of the values embodied in the *Whole Earth Catalog*. The personal computer "revolution" was carried out by "youthful longhairs," who, in the same spirit as the outlaw designers of the ALLOY event, appropriated advanced technologies to empower individuals and decentralize society – "to undermine the high priests and air-conditioned mainframes of information technology and hand their power over to absolutely everybody"(Brand 1994). For Brand, personal computers are the legacy of the very sixties ethos he and his catalog were so integral to.[17]

As important as technologies, especially information technologies, have been to Brand and the *WEC*, it must be recognized at the same time that ecology has been equally essential to the Whole Earth sensibility. It is the pairing of information technologies and ecology within a cohesive "theory of civilization" that is most distinctive about the discourse Brand helped build through his organizations, events and publications. Brand received a degree in biology from Stanford University in 1960. He studied and conducted field research on tarantulas under Paul Ehrlich, famous for *The Population Bomb* (1968) and other widely-read books on global ecology. Under the influence of Ehrlich's warnings about over population, Brand organized a week-long "Hunger Show" in 1969, which he called "Liferaft Earth." Some 170 people entered an enclosed area in a parking lot in Hayward, California for a week of fasting. Ehrlich, along with Peter Raven, was also responsible for the concept of *coevolution*, which has been so central to Brand's perspective (Ehrlich and Raven 1965). By 1971 ecology and environmental activism were among the best represented areas of the catalog. Brand's later publications, *CoEvolution Quarterly*, *Whole Earth Review*, later editions of the *WEC*, were all infused with an ecological sensibility. *CoEvolution Quarterly*, which began publication in 1974 as a supplement to the *WEC*, introduced to its readers ideas such as the Gaia hypothesis, watershed consciousness, whole system thinking, and voluntary simplicity. Brand has also been personally engaged in environmental work as well, serving as an acting advisor to Ecotrust, a Portland-based group working for the preservation of temperate rain forest from Alaska to San Francisco. He is also a co-founder of the All Species Inventory, a project aimed at identifying all of the species of organisms on Earth in the interests of science and conservation (Kelly 2000).

Undergirding this pairing of information technology with ecology in the Whole Earth discourse is the concept of whole systems, a category of being held as more fundamental and essential than either *nature* or *technology* – a pattern of organization that can accommodate both. To the extent that technologies are whole systems technologies, they need not be in conflict with nature, and they potentially embody the virtues and offer the benefits of complex natural systems: they adapt, decentralize, and diversify. They become useful tools of adaptation and evolution for human beings, promising ecologically sustainable innovation.

The whole systems concept provided grounds for bringing together seemingly incompatible entities in productive ways. "How you get energy is, you take polarities and slap them next to one another," Brand stated. "If you get into cybernetics and your head is just a minute ago full of organic gardening and ecology, then cybernetics starts to come alive for you in a different way" (McClanahan and Gurney 1970). The first *WEC*, in 1968, was eager to generate just that kind of energy.

"We are *as gods."*

Within the Whole Earth discourse, people did not need to pity their home planet for being small, fragile, and vulnerable, as did the romantics who viewed the Apollo 8 image of Earth from space. Neither must humanity give it up for lost and seek a new home among the stars, nor toss out the beautiful baby of science and engineering with the dirty bathwater of industrial civilization. Rather, within the Whole Earth discourse, the planet was depicted as a whole system, an endlessly complex, self-sustaining entity in its own right. "We can't put it together," the *WEC* told its readers. "It is together."

At the same time, seeing the Earth as a whole system meant coming to the realization that humans must make certain practical decisions about how to live on the planet. Unlike those progressives who placed their continued faith in the technological civilization that sent people to the Moon, the Whole Earth adherents believed, with the environmentalists, that modern industrial society was leading toward global ecological catastrophe. Nature/technology relations were in need of drastic reform, which could only be made by trying new things and finding out what works. Such experiments were best conducted not by lumbering bureaucracies and slow-witted institutions, but by self-educated, self-guided individuals equipped with civilization's tools and ideas and a "functional, grimy grasp on the world." In the shift from hierarchy to heterarchy, Brand stated, "we must somehow see to it that the decisions which have long-term consequences are taken by amateurs who understand what they are doing"(Brand 1998: 2).[18]

"We *are* as gods," Brand wrote by way of introduction to the *WEC*, "and might as well get used to it." This was no progressive claim to omniscient power over nature. The small *g* suggested something closer to the deities of Greek mythology, powerful but not all-powerful, imperfect, potentially dangerous, potentially useful agents of change. Quoting anthropologist Edmund Leach, from whom he borrowed the "We *are* as gods" line, Brand wrote, "Read your Homer! Gods who manipulate the course of destiny are no more likely to achieve their private ambitions than are men who suffer the slings and arrows of outrageous fortune; but gods have much more fun!"(Leach 1968).

In the years after 1968, Brand's Whole Earth discourse succeeded in significant ways, where the progressive and romantic responses to Earth's planetness could not. The technological spectacle of the lunar mission, and the inescapably ecological character of the image of the whole Earth, were inseparable, even within the progressive and romantic discourses, a fact which created difficulties of coherence for both. Progressives found that they must willfully ignore, or face inconsolably, the mistreatment of the planet the enterprise of technological and economic expansion had thus far depended upon. The romantic position, in turn, was scandalized by the unavoidable fact that the view of the whole Earth in space was itself the product of the very technoscientific apparatus it held responsible for abusing the planet in the first place. There was no going back to an Earthly nature unsullied by modern civilization. Both positions foundered in part because conceptualizations of both nature and technology, in the years after WWII, were shifting beneath their feet.

Since 1968, the progressive ambitions for space exploration have largely passed from America's collective dreamscape. The realization of romantic hopes for an ecotopian civilization now appear equally remote. Such visions, grounded in longstanding conceptualizations of nature and technology could not be wholly conformed to new definitions, which at once subordinated humans within ecological systems and reconfigured nature through theories of machine communication. And though neither has American society been transformed since that time through experiments in self-sufficient living, it is fair to say that a vision of Earth as a techno-ecological system has succeeded in the extreme.

It would be a mistake to ignore the generous intentions behind Brand's construction of the Whole Earth – his faith in humanity; his trust in democracy; his compassion for suffering people and nature alike; his desire for a freer, more just and healthier world; and his life-long work at realizing his vision. Yet neither can we ignore the contribution this techno-ecological construction of the planet makes in defining the global space within which functions the network of technoscientific practices, agents, and inventions that have come, since the middle of the twentieth century, to exert increasing power over not only human life but Life on Earth. We have only to consult Brand protégé Kevin Kelly to understand the possibilities opened up by a technology understood as fundamentally the same type of entity as the complex beings and interrelationships comprising the natural world:

> The meanings of “mechanical” and “life” are both stretching until all complicated things can be perceived as machines, and all self-sustaining machines can be perceived as alive. Yet beyond semantics, two concrete trends are happening: (1) Human-made things are behaving more lifelike, and (2) Life is becoming more engineered. The apparent veil between the organic and the manufactured has crumpled to reveal that the two really are, and have always been, of one being. What should we call that common soul between the organic communities we know of as organisms and ecologies, and their manufactured counterparts of robots, corporations, economies, and computer circuits?. . . I call them vivisystems. . . (Kelly 1994: 3).

A small, frail, vulnerable planet is no place to build such “vivisystems,” these burgeoning, decentralized, endlessly diversifying, globally networked living machines and technological organisms. To house such things you need a planet-sized techno-ecological system. The following three chapters explore a variety of techno-ecological systems that began sprouting from the Whole Earth whole systems discourse in the later decades of the twentieth century.

Notes

[1]The inside front cover of *The Last Whole Earth Catalog* (1971) was devoted to the famous Earthrise photo generated by the Apollo 8 astronauts as they circumnavigated the Moon in 1968. Brand writes that this image, "established our planetary facthood and beauty and rareness (dry moon, barren space) and began to bend human consciousness." The power of the image, in Brand's scheme, lay in its ability to place Earth within the conceptual apparatus known as the "whole system." In his catalog, Brand accompanied the image with a quote from *Energy Flow in Biology*, by Harold Morowitz: "The flow of energy through a system acts to organize that system."

[2] Also see Abelson (1966) for the statements to Congress from the scientific community expressing doubts about the advisability of sending humans to the moon.

[3] See Mailer (196?) and Fallaci (1966). Fallaci provides this quote from the first American in space, Alan Shepard: "There's nothing romantic about going to the stars, believe me. At bottom it's another commercial enterprise." p. 95.

[4] See Weber (1985); Bradbury (1970); Michener quoted in Hallion and Crouch (1979); Boorstin (1974); Sagan (1978); von Braun (1970).

[5] Michener in Hallion and Crouch (1979); Boorstin (1974).

[6] See Haraway (1989) for an account of the post-War scientific construction of universal "man," which Haraway says was "biologically certified for equality and rights to full citizenship." Scientific claims that humans were naturally cooperative rather than merely competitive depended upon new anthropological studies and new readings of fossil records which searched for human commonalities and supported a portrait of a universal human "family." Edward Steichen's famous 1950s photo exhibit "The Family of Man" was, of course, another influential example of the post-War search for human unity. See Sandeen (1995).

[7] See Haddow (1997) for an account of Paul Hoffman's "one-world" economic philosophy. See Michael L. Smith (1983) and Cosgrove (1994).

[8] See Haraway (1989;1997).

[9] See Marx (1986). The Romantics, American and otherwise, protesting industrial progress, pitting technology against nature, included Carlyle, Ruskin, William Morris, Balzac, Flaubert, Zola, Emerson, Thoreau, Hawthorne. Donald Worster (1994) sketches the history of the romantic, "Arcadian" tradition of nature appreciation, versus the mechanistic view of nature.

[10] Hoyle predicted that "once a photograph of the Earth, taken from the outside, is available, we shall, in an emotional sense, acquire an additional dimension. . . once let the sheer isolation of the Earth become plain to every man whatever his nationality or creed, and a new idea as powerful as any in history will be let loose" (Hoyle 1950: 9-10).

[11] Cited in Weber (1985), p 5.

[12] See Worster (1994), Keller (1995), Haraway (1989). "Cyberscience" is a term coined by Keller.

[13] Brand wrote in the *WEC* by way of introducing the book, *Teg's 1994*, by Robert Theobald and J.M. Scott: "We're generally down on Utopian thinking around here, holding to a more evolutionary fiasco-by-fiasco approach to perfection." *Last WEC*, 1971. 27.

[14] Correspondence with author, 9/14/01.

[15] Brand: "The buildings were not parallel – because the earth curved under them, and me, and all of us; it closed on itself. I remember that Buckminster Fuller had been harping on this at a recent lecture – that people perceived the earth as flat and infinite, and that that was the root of all their misbehavior" (Brand 1977b:168).

[16] The *Catalog* referred the reader to the item's maker, publisher or distributor; in most cases, readers did not order items from the first *WEC* itself. In later issues, more items could be ordered through the *Catalog* itself.

[17] Brand's relationship with information technologies is discussed more fully in Chapter 5.

[18]Brand explains that "'heterarchy' was coined by early cybernetician Warren McCulloch at MIT to designate "networked structures in which the center of control constantly moves to wherever is most relevant and useful. . ."

CHAPTER 4
EARTH AS TECHNO-ECOLOGICAL SYSTEM:
SPACESHIP EARTH, SPACE COLONIES, AND BIOSPHERE 2, 1970-1995

“Ecology and technology find a unity in space.” Gov. Jerry Brown, 1977.

The years after World War II were marked by both the unprecedented multiplication and dispersion of technologies and an equally unprecedented anxiety about their effects. Nuclear weapons, nuclear power, chemical pesticides, and industrial pollutants headed a growing list of technological products and by-products posing potential threats to both human and ecological well-being on a global scale. By the late 1960s this anxiety had been translated into a widely perceived world problematic pitting the technosphere against the biosphere. Modern technological civilization seemed pointed irreversibly toward greater levels of technological development and economic expansion, but the cost appeared more than the planet could bear. Leading scientists, environmental activists, politicians, and many others called for monumental change: a steady-state economy, a scaling back of technology, and a reduction in both human population and the use of natural resources.

The techno-ecological system emerged during these years as a means for imagining how technology and nature might be reconciled, how the prospects for technological development and ecological survival might both be salvaged. Within such systems, nature and technology were not antagonists but co-constituents. The principle concept allowing for this reconciliation was *whole systemness*, a pattern of organization understood as fundamental in the universe, more basic than either “nature” or “technology,” and thus capable of accommodating both. This was not a mainstream way of constructing the world in the late sixties and seventies. It had most currency in those places where the cybersciences met countercultural dreams of social change and experimentation. Thus, Stewart Brand and his circle of thinkers, experimenters, writers and inventors once again serve as guideposts as this chapter traces one of the paths the techno-ecological system took into American culture: space exploration.

The exploration of space in the 1960s intersected with – and even contributed to – a growing consciousness of global ecology. This intersection provided a venue for creating semantic, imaginary, and material techno-ecological systems. In this chapter I'll present examples of each: the metaphor Spaceship Earth, the dream of space colonization, and the Biosphere 2 experiment. Within the Whole Earth whole systems discourse we saw taking shape in Chapter 3, these artifacts of the space era represented a new kind of cultural space – "outlaw areas," in which, Stewart Brand and others imagined, free-thinking, creative, properly-equipped individuals might forge a new civilization, one in which nature and technology were not in conflict with one another but were mutually formative. The whole systems construction of nature and technology made it possible to conceive of a future in which people, technology and nature might flourish together as components of techno-ecological systems.

As a strategy for moving past the technosphere-versus-biosphere problematic, the techno-ecological system obviated a long-standing debate: are people properly inside nature, participants and products of forces beyond themselves; or are people outside of nature, critical observers, knowing subjects addressing knowable objects? Since nature is subsumed within the techno-ecological system, the question shifts from whether humans are inside or outside nature to whether they are inside or outside *the system*. The answer, as we can begin to see in our examination of Spaceship Earth, is that people are paradoxically both inside and outside the system, at the same time. Another way to think of this is that the question, inside or outside, is undecidable. This undecidability, as our look at space colonies will show, leads to a fundamental conflict between human control of the system and the system's self-organizing, self-regulating character. The Biosphere 2 experiment illustrated how this conflict is unresolvable. It further showed that the undecidability of the location of people relative to the system is of the system's essence, that the positions inside and outside are, in the logic of the techno-ecological system, both necessary and mutually exclusive.

Limits to Growth?

In the 1960s a whole constellation of ideas and events made the future of modern industrial civilization appear to many people as something in need of serious critique: the Cold War, Viet Nam, environmental problems, over-population, the space program, the pictures of the whole Earth from space, all this and more contributed to the feeling that global, industrial, technological civilization was fundamentally at odds with the health and security of the planet. This view was held not just by left-leaning advocates of social change. Even President Nixon, in 1970, identified the environment as "the issue of the decade." The Environmental Quality Council Nixon created had this to report in 1970:

> The basic causes of our environmental troubles are complex and deeply embedded. They include: our past tendency to emphasize quantitative growth at the expense of qualitative growth; the failure of our economy to provide full accounting for the social costs of environmental pollution; the failure to take environmental factors into account as a normal and necessary part of our planning and decision-making; the inadequacy of our institutions for dealing with problems that cut across traditional political boundaries; our dependence on conveniences, without regard for their impact on the environment; and more fundamentally, our failure to perceive the environment as a totality and

> to understand and to recognize the fundamental interdependence of all its parts, including man himself. . . We need new knowledge, new perceptions, new attitudes. . . We seek nothing less than a basic reform in the way our society looks at problems and makes decisions (Oates 1989: 14).

This sense of conflict between modern civilization and nature was echoed on many fronts in the early 1970s. Barbara Ward and Rene Dubos, in a report on the environment for the United Nations, characterized the conflict as a “hinge in history.” “Man” occupied two worlds, which were out of balance, “the biosphere of his inheritance and the technosphere of his creation.” The choice now was whether to proceed into a future characterized by more ecological destruction and human suffering, or to pursue a path in which both humankind and nature might at least survive if not flourish (Ward and Dubos 1972: 12).

Choosing the latter path meant making difficult changes, which included perhaps even giving up the idea that human well-being would forever ride the crest of technological innovation. One of the most influential calls for change came from a 1972 report called *The Limits to Growth,* produced by an international collection of scientists, educators, industrialists and government workers known as The Club of Rome. This group convened to examine the complex problems plaguing the world, including poverty, environmental degradation, urban spread, the alienation of youth, and more. In the first phase of the project MIT professor Jay Forrester, one of the signal developers of cybernetics, created a dynamic systems model consisting of five variables: population, agricultural production, natural resources, industrial production and pollution. By changing any of these interrelated variables, Forrester’s model could predict changes in the others and in the system as a whole. After running many possible scenarios, Forrester and The Club of Rome concluded that world population growth and economic expansion, continued at rates consistent with the post-War years, or even much lower, would lead to global disaster, including the exhaustion of resources, the poisoning of the environment, starvation, and much else. The only hope for a livable future appeared to be a halt to human population growth and a global steady-state economy. “The crux of the matter,” their report concluded, “is not only whether the human species will survive, but even more whether it can survive without falling into a state of worthless existence” (Meadows 1972: 197).

The techno-ecological system emerged as a possible alternative to a future of either blind technological destruction or grim economic austerity. In place of the either/or choice proffered by *The Limits to Growth*, it suggested to some a way to preserve the hope of technological and economic growth, and at the same time spare the planet from collapse. This hope rested at the place where nature and technology came together under the banner of the *whole system*.

“Spaceship Earth”

The metaphor, Spaceship Earth, neatly encapsulated a new perspective on the planet that emerged in the 1960s. In the middle of the decade, it invoked humankind’s common lot within the world-encompassing network of relations and risks that had been taking shape since World War II. The metaphor communicated the idea that, in a world defined by globalization and the Cold War, everyone was connected and everyone vulnerable to planet-scale catastrophe. In 1965 Adlai Stevenson told the Economic and Social Council of the U.N., in his final address as U.S. Ambassador, “We travel together, passengers on a little space ship, dependent on its vulnerable reserve of air and soil; all committed for our safety to its security and peace; preserved from annihilation only by the care, the work, and I will say, the love we give our fragile craft" (Stevenson 1979: 828). British economist Barbara Ward titled her 1966 book *Spaceship Earth*, writing, "Modern science and technology have created so close a network of communications, transport, economic interdependence – and potential nuclear destruction – that planet Earth, on its journey through infinity, has acquired the intimacy, the fellowship, and the vulnerability of a spaceship" (Ward 1966: vii).[1] Stevenson and Ward used the spaceship metaphor as a way to raise the same, broad, humanist call for unity that would be invoked by poet Archibald MacLeish in his famous Christmas Day meditation on the Apollo 8 images of Earth: "To see the Earth as it truly is, small and blue and beautiful in that eternal silence where it floats, is to see ourselves as riders on the Earth together. . ." (MacLeish 1968). Despite its substantial accomplishments—of which space travel was certainly one of the most astounding—advanced industrial civilization in the years since WWII had rendered the entire world precarious. The metaphor Spaceship Earth set heads shaking at the irony of an age so advanced yet such a danger to itself.

In the late sixties "Spaceship Earth" became as familiar as the Apollo images of the planet in space. Like those pictures, the metaphor's meaning acquired an ecological dimension that framed the problems of global industrial civilization in terms of the relationship between humans and the natural environment, between technosphere and biosphere. The call for unity among all people was still a primary reason for employing the metaphor, but now that call was justified on ecological grounds. National boundaries disappeared from the distance of space, and all humans could be understood simply as Earthlings, first and foremost ecological rather than political creatures. Their continued survival depended upon avoiding the great, impending threats of the era: blowing themselves up with nuclear weapons or otherwise rendering their environment uninhabitable.

For some observers, the ecological justification for world unity was even more basic than the cooperation needed to prevent nuclear annihilation. By 1972, Barbara Ward, for example, had reframed her concerns about globalization and war in terms of ecology. In *Only One Earth: The Care and Maintenance of a Small Planet*, a U.N. report she co-authored with Rene Dubos in 1972, she wrote, “At the most down-to-earth level of self-interest, it is the realization of the planet’s totally continuous and interdependent systems of air, land, and water that helps to keep a check on the ultimate lunacies of nuclear weaponry. . . It is even possible that recognition of our environmental interdependence can do more than save us, negatively, from the final folly of war. It could, positively, give us that sense of community, of belonging and living together, without which no human society can be built up, survive, and prosper” (Ward and Dubos 1972: 218-9).

A new layer of irony was added to the metaphor with this ecological interpretation: while the venture into space led the attention of a technological civilization back to its inescapable, underlying dependence upon the Earth, the planet in turn was reinscribed as advanced technology—as a spaceship. The metaphor had a peculiar way of folding technology into nature and nature back into technology. Frank Borman, commander of the Apollo 8 mission, provided a good example of this in comments he made in 1972:

> Of all the accomplishments of technology, perhaps the most significant one was the picture of the Earth over the lunar horizon. If nothing else,

> it should impress our fellow man with the absolute fact that our environment is bounded, that our resources are limited, and that our life support system is a closed cycle. And, of course, when this space station Earth is viewed from 240,000 miles away, only its beauty, its minuteness, and its isolation in the blackness of space are apparent. A traveler from some far planet would not know that the size of its crew is already too large and threatening to expand, that the breathing system is rapidly becoming polluted, and that the water supply is in danger of contamination with everything from DDT to raw sewage. The only real recourse is for each of us to realize that the elements we have are not inexhaustible. We're all in the same space ship (cited in Oates 1989:12).

In the logic of the Spaceship Earth metaphor, space technology leads ironically to a new and deeper appreciation of Earthly nature, while Earth is best understood as the kind of technology (a spaceship) that prompted the turn back to nature in the first place. The metaphor's tail-swallowing loop from nature to technology and back again was unobjectionable even to environmentalists otherwise flatly critical of the advanced technologies of modern society, including the space program.[2] The irony went for the most part unnoticed because of the *kind* of technology the spaceship represented. Unlike, for example, the rockets that launched it out of the planet's atmosphere, the impulse behind the technology of the spaceship was not to exert command over nature, but to serve as a surrogate Earth that could sustain vulnerable lives in an inhospitable environment. In the inner space of the spaceship, technology did not conquer nature so much as emulated it in order to keep the astronauts alive. In contrast to older technological metaphors for nature – the clock, for example, or the engine – the spaceship identified humans less as powerful, clever thinkers, and more as fleshy organisms, dependent and not entirely secure.

But while the metaphor was employed to bring attention to the ecological essence of Earth and its inhabitants, its technological component inexorably asserted itself as well.

Within the metaphor, the distinction between the technological and the ecological began to dissolve, particularly around the term “system.” In the space of “Spaceship Earth” the planet’s basic ecological processes were translated as “life-support systems,” as the quote from Frank Borman above shows. In this way, clean air, clean, available water, the production of food, the accommodation of waste could be underscored as both vital and vulnerable. Humans, whether on Earth or in space, could not survive without these systems functioning properly.

“Life-support systems” became a favorite reference for pioneering ecosystem ecologist Eugene Odum, especially after the near-catastrophe of Apollo 13 in 1970. On that mission to the moon, an onboard explosion knocked out the life-support system in the three astronauts’ command module. They were forced to circle the moon without landing, and to improvise use of the lunar landing module’s power and oxygen until they could get home. “The story of the ill-fated mission is worth remembering and retelling,” writes Odum, “. . . for its relevance to our predicament here on ‘Spaceship Earth.’ Our global life-support system that provides air, water, food, and power is being stressed by pollution, poor management, and population pressure” (Odum, E. P. 1993: 1; 1997: 1).[3] The term *system,* by the time “Spaceship Earth” came into use, applied equally to the ecological and the technological. For ecologists like Odum, the “life-support system” aboard a spacecraft was not really a metaphor for Earth’s ecological functions; rather, “life-support systems” were something the two entities – planet and spaceship – had in common. The metaphor Spaceship Earth merely underscored their necessity and the dire consequences of their failure aboard either vessel.

For the authors of *The Limits to Growth*, for Ward and Dubos, for Borman and Odum, and for many other ecologically-minded critics of modern society, seeing the Earth as limited and vulnerable justified their calls for technological and economic restraint. For Buckminster Fuller, however, understanding the Earth as a spaceship provided a kind of clarity about the relationship between people and planet that opened up new and better possibilities for progress. Fuller's 1969 book, *Operating Manual for Spaceship Earth*, depicted the planet quite literally as a mechanism whose operations could be fully comprehended and maintained in good order. In fact, according to Fuller, such comprehension and maintenance were imperative if humans were to survive long enough to fulfill their evolutionary destiny.[4]

Like so many others in the late sixties and early seventies, Fuller believed the world was at a crossroads. If modern industrial civilization did not change its course, it would end in nuclear or environmental destruction. Fuller saw this momentous point in time as the juncture at which humankind would finally ensure its long-term success as a species. Central to the problems of modern civilization up to that time, in Fuller's view, were its increasing specialization and its profligate expenditure of nonrenewable resources. Over-specialization in a species, as evolutionary history showed, was the road to extinction. The exhaustion of resources, as common sense dictated, led toward certain and complete poverty. Fortunately, according to Fuller, developments since World War II were pointing toward better prospects. For one thing, the computer was taking over the oppressive, redundant tasks of the modern industrial economy, leaving people free to think, create, imagine, and invent. The computer was also fulfilling society's requirements for narrowly focused, specialized knowledge and skills, so that people could be true to their natural propensity for comprehensive thinking. Such thinking about the universe reveals its general principles, Fuller asserted. As humans apply these general principles in their activities – to the development of renewable sources of energy, for example – they bring their civilization in line with the powerful, creative, regenerative intelligence of the universe and thus secure for themselves success and prosperity as a species.

Developments in science and engineering since World War II, according to Fuller's *Operating Manual*, had made clear that the universe functions according to the principles of whole systems. The task for humankind was to apply these universal principles within the local venue of planet Earth. The post-War science of general systems analysis provided the means for doing so. Fuller's "operating manual" for Spaceship Earth thus advised bringing systems thinking and analysis to bear on industrial, technological, scientific and every other kind of human activity. The Earth's physical resources were finite, but humankind's potential for knowledge and invention was unrestricted. By applying the general principles of whole systems, people could continually find ways to do more with less. Fuller's own invention, the geodesic dome, was a prime exemplar. It encompassed more space using less material than any other structural design.

There was thus in Fuller's thinking a deeply ecological sensibility. His optimism about the future of technological progress was framed by a "whole systems" grasp of the realities of the planet, which, he believed, would not tolerate much longer a civilization that operated on "superstitious and erroneously conditioned reflexes" rather than on the generalized, universal principles of whole systems. Through this whole systems configuration of "Spaceship Earth," Fuller could envision an alternative to the technological and economic contraction that appeared to so many others as the only solution to the technosphere-vs.-biosphere problematic.

Fuller is sometimes dismissed, like Marshall McLuhan, for his unabashed technophilia.[5] John Woodcock, for example, criticizes Fuller's *Operating Manual* for oversimplifying the Earth, reducing it to a mere machine and "subsuming the biological and political under the laws of mechanics" (Woodcock 1979: 309).[6] Such a take on Fuller is not wholly unfounded: he did depict the Earth as a mechanism, like an automobile, which people could learn to operate and maintain effectively.[7] He was an unapologetic technological optimist whose faith in design and invention sometimes led to flaky, unwarranted claims, as when, in *Operating Manual*, he expressed his belief that computers would resolve the world's ideological impasses (Fuller 1969: 132).

But Fuller was not, as Denis Cosgrove suggests, a technological optimist in the typical mode of the "arch-progressive" modernist (Cosgrove 1994: 284). Not only was his idea of technological progress grounded deeply in the constraints of planetary ecology, it was aimed toward political and social goals quite at odds with the dominant expansionist, modernist, technoscientific discourse in American culture. Fuller held that "a design and invention revolution" could eliminate war; that "wealth is as much everybody's as is the air and sunlight" and must be shared equally, globally. He believed automation would multiply wealth, not reduce employment, but for everyone put out of work by automation, he proposed an annual fellowship for research and development, "or just simple thinking." People might use their grants, Fuller speculated in all sincerity, to go fishing, an activity which affords an excellent opportunity to think clearly. "I would like you to think," he wrote, "what [this fellowship program] may do realistically for living without spoiling the landscape, or the antiquities or the trails of humanity throughout the ages, or despoiling the integrity of romance, vision, and harmonic creativity" (Fuller 1969: 119-20). Fuller's desire to shift human consciousness and culture accounts, perhaps, for much of the popularity he enjoyed among hippies and college students in the 1960s. His faith in human resourcefulness, his unconventional mind, and his counter-cultural dreams, combined with immanently practical, hands-on skills for designing and building things—all this certainly accounts for much of his appeal to Stewart Brand.[8]

In the whole systems discourse emerging from figures such as Fuller and Brand, ecology and technology came together as co-constituents of a larger, life-sustaining techno-ecological system. In the context of a widely perceived technosphere-versus-biosphere problematic, such a system held forth the prospect of salvaging both technological progress and ecological sustainability. In addition, it established a new kind of environment, a cultural space marked off by the boundaries of the system – a space in which people might experiment with new kinds of nature-technology relations, and, growing out of that, new human-human relations, as well. This was the kind of space Fuller envisioned the Earth becoming under the influence of whole systems thinking and design. It was this kind of space Brand had been interested in from the start, as we can see when we consider the self-starting individuals and alternative communities he hoped the *Whole Earth Catalog* might encourage. Presently, we will examine space colonies and Biosphere 2 as further elaborations of the cultural space within the techno-ecological system. But before doing so, it is helpful to explore a characteristic of techno-ecological systems that "Spaceship Earth" illustrates very well.

Central to the centuries-old mechanism-versus-organism, progressive-versus-romantic dichotomies is the question of where humans are located relative to nature, inside or outside. Space exploration, and the look back at the planet, added new levels of poignancy and complexity to this question, since, for the first time, humans had established that they might not always be bound to the Earth. For those who placed faith in the technological progress of modern civilization, the space program showed that humans were above and outside Earthly nature, finally on their way into the cosmos, leaving behind their childhood home, which, while beautiful and precious, was proving too small and limited for an ambitious species like ours. There were no problems human ingenuity and technology could not solve eventually, no limit to our potential for growth and innovation. If there were any doubt, we had only to consider the astounding fact that our emissaries, in 1968, were circumnavigating the moon, glancing back at the site of their humble origins in their rearview mirror.

But there were also those who identified the look back at the Earth as, in the end, the only worthwhile accomplishment of the U.S. manned lunar mission. The image of the whole Earth, for these romantics, only established the fact of our Earthly natures and proved the feebleness of our little jaunt to the moon. As the photos made clear, the Earth was where our attention should be directed. Thinking we could, or should, escape our home world was as foolish as pretending the planet was an infinite storehouse of resources, or that we could expand our numbers and economies exponentially, forever.

This romantic-versus-progressive dichotomy is rendered moot when the Earth is configured as a techno-ecological system. Within the space of the system there is no choosing between the natural and the artificial. Both are necessary; both are essential. The question rather is where to locate people relative to the *system*, inside or out, and this question is always undecidable.

The picture of the whole Earth in space positions us as viewers like astronauts, drifting at a critical distance, out beyond the confines and constrains to which the planet subjects the rest of its inhabitants. From such an extraordinary vantage, humans *are* different from the rest of nature, positioned a little below the angels, a little above the animals. All the while, however, we are looking not merely at an object in space, but at ourselves, inseparable from the very thing held apart. Down there somewhere, and no where else, we lead our inescapably terrestrial lives. The spaceship carrying the Apollo 8 photographers, though invisible in the pictures themselves, did not merely propel people beyond the planet. It also had to sustain them with oxygen and water, feed them, accommodate their waste, protect them from heat and cold, and otherwise substitute for the Earthly environment upon which their physical forms were in every way shaped and dependent. Like the astronauts, we can look out upon “Spaceship Earth” only from within a surrogate Earth, an “Earth Spaceship,” never really removed from our participation in the flow of matter and energy characteristic of our home world and the bodies that grow and evolve there.

The recursive irony of “Spaceship Earth” shows how, once the Earth is configured as a techno-ecological system, the categories “natural” and “artificial,” and “inside” and “outside,” are problematized. The techno-ecological system creates a space in which the question of where to locate people is constantly in play and always unresolved. This becomes more apparent as we consider the idea of the space colony, which Stewart Brand called an “inside-out planet.”

Space Colonies

The idea of building cities in space belonged to Dr. Gerard O’Neill, a physics professor at Princeton University. In 1969 he challenged a group of students with this question: “Is the surface of the planet really the right place for an expanding technological civilization?” Given the polluted, over-crowded, energy-depleted state of planet Earth, the answer seemed, to O’Neill and his class, to be *no*. In the year of the Apollo 11 moon landing, O’Neill looked to space for an alternative. He reasoned that space colonies were within the reach of current scientific and technical capabilities, and could be economically feasible. He envisioned them as satellites, floating between Earth and moon, powered by the sun. In each one, a community of up to a million people might live indefinitely amid an enclosed system of manufactured mountains, forests, animals, streams and lakes. These self-sustaining environments would be constructed as cylinders, generating their own gravity through rotation and growing their food in separate, connected agricultural pods, taking advantage of constant, super-abundant sunlight. The colony structures would be built from materials mined from the moon and from asteroids. Their purpose would be two-fold: to benefit the Earth by relieving over-population, resource scarcity and other problems; and to provide a means for continued, even unlimited, economic and technological growth.

O’Neill struggled to gain attention for his idea for several years, collecting rejection slips from journals and magazines and giving poorly attended public lectures.

Physics Today, in 1974, was the first to publish his article laying out a plan and rationale for space colonies (O'Neill 1974). Also that year, O'Neill was able to organize a conference at Princeton around the space colonies idea, thanks to funding from the POINT Foundation, the non-profit organization Stewart Brand had set up after the success of the National Book Award-winning 1971 issue of the *Whole Earth Catalog*. Fortunately for O'Neill, Walter Sullivan, science writer for the *New York Times,* attended the Princeton conference. Sullivan's article on space colonies appeared on the front page of the *Times*, and from that point forward O'Neill was deluged with attention (Sullivan 1974). *Time* magazine, the *Los-Angeles Times-Washington Post* syndicate, the BBC, the Associated Press, and other members of the media ran major stores on the prospect of constructing human habitats in space. By the summer of 1975, O'Neill was receiving funding from NASA to continue work on his idea, and was giving testimony on the feasibility of space colonies before subcommittees of the U.S. Senate and House of Representatives.

In his Congressional testimony, O'Neill stressed the economic and resource potentials that might be created by space colonization. The OPEC oil embargo had thrust energy issues into the forefront of national concerns. "Both the oil-consuming nations and the underdeveloped third world," O'Neill stated, "are vulnerable to the threat of supply cutoff from the Middle East. The only permanent escape from that threat lies in developing an inexhaustible energy source. . ." (O'Neill 1977: 16).[9] Space colonies, O'Neill argued, could provide escape by harnessing unlimited supplies of solar energy.

In less formal venues, O'Neill expanded his justification for space colonies, holding them up as a solution to a host of problems plaguing the world: over-population, starvation, pollution, economic stagnation, in addition to dwindling energy resources. "[W]e can not only benefit all humankind," he stated at the World Future Society convocation in 1975, "but also spare our threatened planet and permit its recovery from the ravages of the industrial revolution" (O'Neill 1977: 8).

But if the industrial revolution had ravaged the Earth, in O'Neill's view, that was no reason to call a halt to it. The question he started with -- "Is the surface of a planet really the right place for an expanding technological civilization?" – was not a critique of that civilization at all. Rather, by colonizing space, modern technological civilization could continue its course of expansion, even as it repaired the damage left behind on Earth. "The steady-state society, ridden with rules and laws, proposed by the early workers on the limits of growth was, to me, abhorrent," O'Neill stated (O'Neill 1982: 279). In response to the technosphere-versus-biosphere problematic, space colonies provided the option of keeping both by moving the technosphere off the planet. "The vision of an industry-free, pastoral Earth, with many of its spectacular scenic areas reverting to wilderness, with bird and animal populations increasing in number, and with a relatively small, affluent human population, is far more attractive to me than the alternative of a rigidly controlled world whose people tread precariously the narrow path of a steady-state society" (O'Neill 1982: 263-4). One space colonies advocate argued that, if the picture of the world in The Club of Rome's *The Limits to Growth* were accurate, then "it would be irresponsible not to start in immediately on a large-scale program to establish civilization in space" (Brand 1977: 97).

O'Neill's book, *The High Frontier: Human Colonies in Space*, was published in 1976. Written for a general audience, it spelled out O'Neill's rationale for colonizing space, explained in general terms the technologies involved and the developmental steps, and also tried to spark the reader's imagination through a series of letters from a pioneering, fictional couple, Edward and Jennie. The rationale, O'Neill explained, was three-fold: first, space colonies could solve Earth's immediate energy crisis; second, colonizing space would relieve the planet's long-term problem with over-crowding; and third, space colonization provided "the opportunity for increased human options and diversity of development" (O'Neill 1976: 14).

With this last incentive, O'Neill fixed space colonization within an epic story of human progress. The "high frontier" of space was, O'Neill argued, the next logical place for expansion and exploration. The European colonization of the New World had brought humankind to the limits of the Earth. Now resources were scarce and room running out. Fortunately, modern civilization had also developed the means for solving these problems and generating new wealth and opportunity for all humankind: the technological ability to build new worlds in space.

The High Frontier depicted the experience of colonizing space as parallel not to the exploits of the European explorers and conquistadors, but to the bold adventures of Anglo-American families migrating across the western expanse of North America. Thus Edward and Jennie describe with wonder and pluck both the hard work and excitement of settling space. Though the sites and experiences of their new space colony home are breathtakingly new, there is also a familiarity built into colony life: keeping house, eating in restaurants, growing a garden, and so forth. The pioneers find themselves in an exciting new environment, which is nevertheless also comfortable and familiar to the middle-class go-getters who inhabit it.

For Edward and Jennie, however, the adventure continues, as they eventually decide to pull up stakes and head out once again for new territory.

> July 15, 20–: Dear Stephen:
> Your Mom and I are going to write down a record of our trip, to go with the pictures we're taking. Then when you're old enough to read and be interested in it you'll be able to see how you came to be a youngster living in the asteroid belt.
> It's been five years, now, since I joined the Experimental Spacecraft Association. We have an active chapter of it here on Bernal Gamma, and several of the guys in it work with me in the construction business.
> If we were back on Earth, now, and got any wild ideas about setting out on our own to travel in space, we'd be out of our minds. . . Out here, though, we're in much better shape to go voyaging on our own. . . With what we'd saved, and the sale of our house on Gamma, we were able to start with about $100,000. . .
> We've got food on board for two years, if we have to stretch it, lots of seeds, fish, chickens, pigs and turkeys. To get things started when we arrive, we've sunk about half our grubstake in prefabricated spheres and cylinders, aluminized plastic for mirrors, chemicals for crop-growing, and a lot of equipment. . . We've got a whole world to build here, Stephen, so grow up fast and get in on the construction! (*ibid*.: 238-45).

O'Neill was very much aligned with the progressive attitude toward technology and space travel that we saw in Chapter 3. He believed that despite the problems of modern industrial civilization, technology, personal freedom (especially a free market), and individual resolve could set humankind on a path toward a glorious future beyond the confines of Earth. He fully recognized the potentially disastrous global ecological problems created by modern human existence, yet continued to position people outside nature, above it, destined to conquer and control it through technology. In other words, he was a modernist progressive, not a Whole Earth whole-systems thinker.

Nevertheless, his ideas intrigued Stewart Brand, Buckminster Fuller and others of the Whole Earth mindset, who saw in space colonization potential for realizing the Whole

Earth whole-systems ideal. O'Neill emphasized technology in the context of a modernist industrial paradigm, which his plans would transfer essentially intact from Earth into space. In contrast, Brand and other whole-systems thinkers were interested in new technologies from which might emerge new modes of civilization. Whatever their shape, they would not replicate the mistakes of the modern world; nature and technology would be compatible, even mutually formative and co-evolutionary.

Fuller considered the colonization of space the logical, evolutionary trajectory of a species used to traveling through the universe on Spaceship Earth anyway (Brand 1977: 55). Brand's interest moved from "mild" to "obsessive' after hearing O'Neill talk at the World Future Society convocation in Washington, D.C., in 1975 (Brand 1977: 8). He presented O'Neill's ideas in an issue of *CoEvolution Quarterly* in 1975, then published responses from readers and a selection of writers, artists, scientists and others the next year. In 1977 Brand published a book, *Space Colonies*, which included the contents of the *CoEvolution Quarterly* issues, plus additional material exploring the feasibility and desirability of creating permanent habitats for humans in space. It is worth examining this book because it reveals what Brand, his readers, and his circle of contacts saw as the stakes involved in the convergence of technology and ecology in the late twentieth century.

As he reported in *Space Colonies*, Brand heard from 170 *CoEvolution Quarterly* readers and invited commentators who responded to the general question of whether space colonies were a good idea or not. Most of the responding readers were in favor, but the majority of invited responders opposed space colonies. For the most part, the arguments broke down along the standard progressive and romantic lines dividing public attitudes toward the U.S. manned mission to the moon a few years before. Progressives saw space colonization as a grand, even inevitable human adventure, a liberating leap into the future. Romantics objected to the idea, considering it a diversion from Earthly concerns and affections. They saw in the colonization of space an escalation rather than a conversion of the modern, industrial mindset that despoiled the planet in the first place. Among the "notables" resistant to the idea were Ken Kesey, Lewis Mumford, E.F Schumacher, Dennis Meadows (co-author of *The Limits to Growth*), Nobel prize-winning biologist George Wald, and poet Gary Snyder. Those in favor, in addition to Buckminster Fuller, included astronaut Russell Schweickart, biologist Lynn Margulis, her husband Carl Sagan, and architect Paolo Soleri. Of the 21 women who responded (only eight percent of the total), 13 were in favor, including Brand's mother.[10]

The idea's most eloquent and severe critic was Wendell Berry, the agrarian essayist, poet and farmer from Kentucky. For him, the idea that the biosphere might be saved by moving the technosphere into space was morally suspect. "[O'Neill's] concern for the environment," Berry wrote, "leads him directly to a plan to strip mine the moon." Berry and O'Neill, set side by side, provide a very clear picture of the pastoral-versus-progressive dichotomy that has long characterized American debate over nature and technology (see Marx 1964; 1991). O'Neill quite explicitly identified space as the "high frontier," connecting it to Western culture's past migrations, and describing it, in the language of frontier expansionism, as a source of unlimited wealth and opportunity. "The human race stands now on the threshold of a new frontier," he argued, "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. . ." (O'Neill 1977: 8). Berry attacked him precisely for invoking the values of expansionism, exploitation and colonization. "For the sake, perhaps, of convenience," Berry wrote of O'Neill, "he sees himself and his American contemporaries as the inheritors of the frontier mentality, but not of the tragedy of that mentality. He does not speak as a Twentieth Century American, faced with the waste and ruin of his inheritance from the frontier. He speaks instead in the manner of a European of the Seventeenth and Eighteenth Centuries, privileged to see American space and wealth as conveniently distant solutions to local problems" (Brand 1977: 36).

In his role as editor, Brand tried, with difficulty, to position himself outside this dichotomy. Berry accused him of feigning neutrality while using the *CoEvolution Quarterly* to sell space colonization. Brand defended himself by arguing that space technology had raised "a tangle of questions so fundamental as to leave no one uncleaved." The responsible thing to do, he said, was to open up a conversation around those questions, to see whether people wanted space colonization or not. "I believe that *The CoEvolution Quarterly* is useful," Brand wrote in response to Berry, "to the extent that it is impious and acutely observing and a forum" (Brand 1977: 85).

Brand fully recognized the complexity of the issues his publications were confronting. He noted, for example, that the term "space colony" was officially abjured by the U.S. State Department, because of its pejorative associations with Earthly colonizations. The preferred term at NASA was "space settlements." Brand went with "space colonies" anyway. "It's more accurate," he stated. "This time there's a difference in that no space natives are being colonized. And the term reminds us of things that went badly and went well in previous colonizations" (Brand 1977: 5). The title pages of his book featured on one side a drawing of a space colony floating in space, with a hearty "Goodbye Earth!" rising from inside. On the opposite page was a picture of two ancient Native Americans, a man and a woman, standing wrapped in blankets, with a rifle, pony, and travois. They seem to look off toward the space colony. "Goodbye. Good luck," says the man. "Good riddance," thinks the woman.[11]

Whatever the complexities, Brand's enthusiasm for space colonies was hard to suppress. For one thing, he liked Gerard O'Neill. He liked individuals who could cook up something wildly ambitious, make it seem doable, then single-handedly usher it into the world. Buckminster Fuller was just such an individual. For that matter, so was Brand himself. In an interview with O'Neill, Brand appeared as attracted to the idea's history as he was to the idea itself. "Let me pursue this," Brand interjected as O'Neill described the idea's early years of obscurity, "because I am always interested in how ideas take root in a person and then in society. So here you are now with what must be a gradually increasing obsession and not many listeners. Did you take a strategic approach in any way? Or just keep talking and let things find you?" O'Neill responded that, since no publications were interested, he began to talk about space colonies on campuses. "This is what Buckminster Fuller did a while back when no one was buying," Brand stated. "He went to students, and students bought, and then everybody else bought" (Brand 1977: 23-4). Nothing energized Brand more than a self-starter with a big idea and a practical scheme for how to make it work. The *Whole Earth Catalog* and *CoEvolution Quarterly* were aimed at encouraging legions of individuals willing to think things up and try them out.

Brand wanted to see the experiment of space colonization go forward, because, succeed or fail, it would answer fundamental questions about the future of humankind and our relationship to the planet. If built, according to Brand, space colonies would establish the fact that we can leave the Earth. But if the space colony experiment were to fail by some fatal flaw, the answer would be equally profound: we can't.

> If we can learn to successfully manage large complex ecosystems in the Space Colonies, that sophistication could help reverse our destructive practices on Earth. And if we fail, if our efforts to impersonate evolution in space repeatedly run amok, then we will have learned something as basic as Darwin about our biosphere – that we cannot manage it, that it manages us, that we are in the care of wisdom beyond our knowing (true anyway) (Brand 1977: 72).

Brand was content to see the experiment go forward toward either result. "Either knowledge," he stated, "is a kind of growing up." In this regard, his relationship to space colonies was different from either O'Neill's or Berry's. Unlike O'Neill, his interest was not in ensuring the continuation of modern industrial civilization and its dream of dominance over nature. And unlike Berry, Brand did not reject the idea out of hand as yet another, grander manifestation of the dangerous, modern industrial mindset.[12] It was the experiment, the stab at something world-changingly new that most appealed to him. Brand reveled in the design aspects of O'Neill's scheme. He included in *Space Colonies* detailed drawings and technical discussions of the physics of building large structures out of lunar material and placing them in orbit between Moon and Earth. But what really excited him was the promise of a new cultural space, a new venue for thinking up ideas and trying them out. "O'Neill's scheme invites you," Brand wrote, "to give your imagination a Space Colony of one million inhabitants, each of whom has five acres of 'land'. . . Have you any thoughts about how to organize its economy, politics, weather, land use, education, culture? Any thoughts about how to organize your life to get there?" In "free space," as space beyond Earth's atmosphere is technically called, what new civilizations might emerge? What new modes of being? "[F]or those who long for the harshest freedoms," Brand stated, "or who believe with Buckminster Fuller that a culture's creativity requires an Outlaw Area, Free Space becomes what the oceans have ceased to be – Outlaw Area too big and dilute for national control" (Brand 1977: 5-6).

In regard to the lives that might be led inside his space colonies, O'Neill's imagination was rather limited. He referred awkwardly to "new examples of the visual and musical arts" that might accrue aboard space colonies drifting out towards Pluto, but otherwise depicted space colony life mostly as a version of the pleasant lives of affluent Westerners on Earth, only without the guilt, and with absolute control over the environment.(O'Neill 1982: 264). For Brand, however, the new social, cultural, and ecological possibilities of an outlaw area were the real draw, as promising in potential as the desert communes and experimental, Fuller-domed intentional communities championed in the first *Whole Earth Catalog,* back in 1968. [13]

From Space Colony to Ecosphere

Brand was excited by space colonies because they so readily fit within the whole systems paradigm. The rhetorical power of whole systems came partly from their radical leap past old binaries – wave-versus-particle, organism-versus-mechanism, natural-versus-artificial – and their proclamation of a new regime, wherein the old assumptions, rules and categories were rendered inapplicable or even misbegotten. The indeterminacy of the quantum postulate radically circumscribed Newton's laws of causality. Cybernetics, as founder Norbert Weiner stated, consigned the mechanism-versus-organism dichotomy to "the dustbin of badly formed questions." The techno-ecological systems emerging in the post-War era resisted the technosphere-versus-biosphere problematic by defining a new space in which technology and ecology were co-constituents.

In the whole systems discourse, living, complex entities, from organisms to ecosystems, were by definition self-organizing and self-regulating. This meant they necessarily possessed a degree of self-sovereignty, beyond human control. In the case of ecology, this sovereignty could be called *wildness*. Techno-ecological systems, operating on the principles of whole systemness, were likewise imagined as self-organizing, self-regulating, and thus, in some necessary and significant measure beyond human control. They had to be wild to some degree, in the sense of possessing the sovereignty to organize themselves, find their own dynamic equilibrium and follow their own evolutionary path. Otherwise, they could not be said to be living whole systems at all.

For Brand and others trying to reconfigure the world in terms of whole systems, techno-ecological systems instantiated spaces in which old conceptual standoffs gave way to radically new possibilities, and where wildness – an absence of complete human control – was an essential characteristic. Brand wanted to see space colonies in these terms. That was their appeal: their potential for sweeping away old categories and relationships, clearing a space for something new, something which by definition could not be entirely predicted or controlled, but which nevertheless could be encouraged with hopefulness and optimism because organized according to the most fundamental principles at work in the intelligent, creative, regenerative mind of the universe.

Brand's investment in the new and the wild came out in his conversations with both O'Neill, the pragmatic progressive, and Berry, the pragmatic pastoralist. With reference to Thoreau, Brand asked O'Neill, "If 'in wildness is the preservation of the world,' then in what is the preservation of the space colony?" O'Neill responded, "Making it wild, I think. . . [T]he natural development it seems to me, is toward a situation where you have a great many wild species involved, and as wild an environment as you choose to make" (Brand 1977: 30). Even here, O'Neill imagined retaining complete human control, building in *wilderness* (as he misinterpreted *wildness*) to whatever degree might be most pleasing to the colony residents, which is to say, allowing no space for wildness at all.[14] The wildness that would enable the living community inside a space colony to become something unexpected and unpredictable was not within the range of O'Neill's imagination, though it was central to Brand's.[15]

The unpredictable and unexpected emerging from a mammoth project like space colonization was equally unthinkable to Wendell Berry, though for different reasons. Large-scale technological adventurism, unleashing the ill-conceived technoscientific creations of governments and corporations without the least knowledge of their long-term effects on the slow-turning, delicately balanced planet – these were the careless ways of an unsustainable civilization already responsible for nuclear power plants, DDT, and any number of other monstrosities. For Berry, the thought of enjoining space colonization, even as an experiment, was irresponsible. "For me," he wrote to Brand, "responsibility does not require 'that we wade in and see.' It requires that we see very clearly before we wade in" (Brand 1977: 85). Control was as important to Berry's pastoralism as to O'Neill's progressivism, only instead of aspiring to absolute control over nature, Berry was concerned with self-control, with engaging in small-scale activities – family farming, craft shops – where, by experience and tradition, the outcomes were known and the failures containable.

Brand's faith, however, as the name of his magazine indicated, was in co-evolution, the process by which things change and adapt in living relation with one another.[16] Co-evolution was a biological term, but within the pages of *The CoEvolution Quarterly*, Brand expanded it to encompass the joint entanglement of the biological, the social, and the technological, all adapting to and changing one another within whole-system space. Brand saw space colonies as a prime proving ground for how people, nature, and technology might evolve together toward some sort of resolution that had so far remained out of reach on Earth. "I cannot anticipate that resolution," he told Berry. "Evolution (especially co-evolution) defies prediction. Or control. Or even categorical understanding" (Brand 1977: 85).

The question of control, for O'Neill and Berry, hinged on whether people were inside or outside nature. For a progressive like O'Neill, the answer seemed simple: nature was a resource for people to exploit or conserve for their benefit; people were outside nature, increasingly engaged in bringing nature under their control. Likewise, a romantic like Berry had no trouble with the question: people were inside nature; they were Earthly creatures, and only self-control and humble cooperation within their living community could ensure a sustainable future. But these positions held only insofar as nature and technology could be maintained as separate provinces, so long as "natural" was kept apart from "artificial," and "biosphere" from "technosphere."

But the techno-ecological system brought nature and technology together as co-constituents of an encompassing entity, the system. Within the space of this system, the binaries – “natural” or “artificial,” “biosphere” or “technosphere” – were not relevant. Rather, what was relevant was how any given part of the system – organic or mechanical – functioned within the whole system’s pattern of organization, its self-regulation, its adaptation to change. With the dissolution of the nature-versus-technology dichotomy, the question was no longer where people were located relative to nature, but where relative to the system. Were people inside or outside these inside-out planets?

A central characteristic of techno-ecological systems, as represented by the space colony dream, is that this question is always in play and never decidable. In the emptiness of space, there is no system without a human presence, and no human presence without the system. It is not enough to say people either are outside the system, observing from a critical distance, or inside, participating like any other technological or organic component. Rather people are participant-observers, always both inside the system and outside at the same time, though this is paradoxical. As we saw with the view of Earth from space, the only way to observe “Spaceship Earth” is from within an “Earth Spaceship.”

To further illustrate, it is helpful to consider an amazing invention that arose in the 1960s from research on the construction of regenerative environments that could sustain humans in space over long periods of time. This invention, by exobiologist Clair Folsome at the University of Hawaii, was the *ecosphere*, a sealed glass globe containing a simple, self-sustaining ecosystem of algae, brine shrimp, and coral in microbe-rich water. The living relationships inside an ecosphere are so exquisitely balanced, the whole system can flourish for decades, requiring nothing but indirect sunlight. It is a materially closed, energetically open manufactured ecosystem, so commonly available now you can buy one for your coffee table at stores like The Nature Company. Though considerably simpler, the ecosphere is similar to the materially closed, energetically open environment imagined inside space colonies, with the critical difference that space colonies would contain human beings.

If humans were only outside the techno-ecological system of the space colony, they could hold it at arm’s length, like an ecosphere. The critical distance between subject and object would be intact. But techno-ecological systems, however human-designed (or co-designed, along with the system itself), are also environments for human beings, and this creates an essential difference between them and an ecosphere. People are not merely outside, regarding their creation at arm’s length, with objective detachment. They are *also* inside, participating in a self-directing ecosystem along with other species, enmeshed within a dense network of techno-organic relationships. That is, people are simultaneously inside and outside, though this would seem impossible. As in some brain-twisting Escher drawing, it is as though you were holding an ecosphere in your hand and at the same time living inside it.

The presence of people inside the space of a techno-ecological system, such as a space colony, would fold them into the evolutionary development of the system itself. Herein lies the other crucial difference between Clair Folsom’s ecosphere and a techno-ecological system such as a space colony: the ecosphere is not self-sovereign, is not wild. It has been engineered to suspend evolution. It is under the complete control of its initial design. Such could not be the case with a complex techno-ecological system sustaining humans in space, which by definition must be self-organizing and free to evolve in response to changing internal and external conditions.

With techno-ecological systems humans are enveloped by the system as a whole, but paradoxically outside the system as well. This inside/outside position sets in motion a fundamental and unresolvable antinomy between the sovereignty of the techno-ecological system and human control. That is, the techno-ecological system with the sovereignty to become what it will is one thing as outlaw *cultural* area, but as outlaw *biological* area it implies a full range of ecological possibilities that may or may not be conducive to human survival. Some species may flourish while others lose ground or disappear; chemical elements are free to circulate through soil, air and water in quantities and combinations that may or may not be suitable for humans; the whole system may experience wild fluctuations and unpredictable adaptations. In fact, this is what happened inside Biosphere 2: the techno-ecological system could not be both self-controlled and human-controlled at the same time.

Biosphere 2

O'Neill's space colonies were never built. NASA was content, in a post-Apollo era of fiscal restraint and Earth-consciousness, to put its efforts into the space shuttle, a kind of "reduce, reuse and recycle" approach, compared with the estimated $100 billion it would take to build the first space colony. People lost interest. Californians, after Jerry Brown's governorship, no longer cared about becoming the first U.S. state with its own space program. Stewart Brand's own enthusiasms strayed away from outer space, toward the emerging outlaw area of cyberspace, as we shall see in the next chapter. O'Neill continued to pursue his ideas, but away from the public sector. He started a privately supported research organization, the Space Studies Institute, which sought to develop commercially viable space technologies.

O'Neill's space colonies scheme had proceeded on the basis of a false premise, anyway. He claimed from the start that space colonies were within the reach of extant technologies, that nothing he was proposing depended upon some hoped-for technological breakthrough. But this was not true. No one knew how to build a regenerative environment that could sustain humans in space. Maybe the rotating container, the solar collectors, the moon-mining operations and other mechanical dimensions of space colonization were within reach, but not the construction of a complex living community inside. O'Neill never acknowledged this in *The High Frontier*, nor pursued very far how a self-sustaining, materially closed, energetically open ecosystem might be made. He seemed to assume one could pick and choose among Earthly organisms, throw them all together within a volume of climate-controlled space, and expect them to get along.

The U.S. had been interested in regenerative environments for space exploration since the early 1950s, and research efforts on closed ecosystems, involving as many as a hundred scientists and engineers, were well under way by the early 1960s (Meyers 1963: 409-411). One of these researchers was Howard T. Odum, who, along with his brother Eugene, had pioneered ecosystem ecology in the fifties. Within the space program there was a controversy, as Odum described it in 1962, involving three approaches to the problem of long-term space travel. One approach was to build an environment with conventional engineering, relying on the import of fuel and parts from Earth; handling the production of food, the filtration of air and water, and the accommodation of waste through non-biological processes; creating a system "dominated by pipes and electrical control circuits," as Odum put it. The second approach was to support humans within a simple ecosystem, comprising an uncomplicated ecological circuit wherein waste and respiration from humans would nourish algae or duckweed, for example, which in turn would supply oxygen and food for the humans. Such a system would involve only a couple of species and would require some energy and material inputs from Earth. The third solution was a regenerative, multi-species, steady-state ecosystem, “the only system,” Odum stated, “already found self sufficient in nature” (Odum 1963: 430).

Odum was frustrated that NASA leaned toward conventional engineering solutions. He believed human space exploration would be limited and “millions of dollars” would be wasted by the space program so long as the complex ecosystems approach was neglected. The problem, according to Odum, resided in the administration of the space program, quite apart from any scientific or technical challenges: the matter had been given over to engineering and physical science personnel, rather than to ecologists and biologists, by administrators with expertise in neither domain.

NASA relied on conventional engineering approaches to life-support for the Mercury, Gemini, and Apollo programs because that is what it knew how to do, and because the astronauts would not be gone from Earth so long that they could not carry all their supplies with them. However, even in the early 1970s, as the Skylab project got under way and NASA prepared to support people in space for longer periods of time, the solutions still were of the conventional engineering type. Research into regenerative systems during the 1960s had been mostly disappointing.[17] This was so, Odum argued, because the simple ecosystems NASA had emphasized were not complex enough to be stable. Because NASA had pursued limited instead of multi-species, steady-state ecosystems, the “controversy” over different approaches, according to Odum, had by the early seventies degenerated into a “fiasco,” and the space program had cut off its future. Writing in 1971, Odum said,

> An important limit to man’s invasion of space is his life support, his need for a regenerative, complementary ecosystem. Something of a national fiasco has developed, limiting the ability of the United States to put man in space for any length of time. In developing biological regenerative systems for space, the National Aeronautics and Space Administration from 1960 through 1969 refused to recognize that multiple-species designs are required for stability. . . The bias of its supervisors was for hardware control. . . bypassing the miniaturized microecosystems. They considered only cultures of a single population which are always unstable except when under heavy and costly chemical controls. . . A large terrestrial capsule was never given a trial in spite of NASA’s great expenditures (Odum 1971: 287).

From Odum’s perspective, replicating the biosphere seemed the only solution if people were to remain in space for extensive periods of time, out of shuttle range from Earth. What was needed, he wrote, was an experiment, in which “[m]an is kept in an armory-sized structure into which all the materials of the biosphere are introduced along with all kinds of biological components, especially microbiological ones. By the process of learning, loop selection, succession, and evolution. . . a system of man compatible with his food and waste productions in a restricted environment is likely to emerge. . .” (Odum 1971: 286). In contrast to O’Neill’s assumptions about throwing selected organisms together into a confined space, Odum saw the need for a complex compilation of organic and inorganic components functioning together as a single whole system, just like the biosphere. But Odum made an assumption as well, as the quote indicates: he assumed that the system would somehow come together and emerge as a viable environment on its own, learning, selecting, evolving according to the self-organizing principles of whole systemness. Humans would not be in control over each variable, but would be a variable themselves. Odum did not suggest how humans might get along until the system found its equilibrium and achieved stability.

The Biosphere 2 project was just the kind of experiment Odum described. Since there was no armory-sized terrarium for humans on NASA's agenda, a group of independent scientists and engineers associated with the Institute for Ecotechnics decided to take up the task.[18] The Institute for Ecotechnics was founded in 1969 to develop technologies for environmental research and management projects. Its aim was to implement "projects in areas of environmental stress or mis-management to test their capabilities of integrating the technosphere with the biosphere." "Ecotechnics" was conceived as the synthesis of the "ecology of technics" and the "technics of ecology," a concept made possible by modeling both nature and technologies as whole systems (Allen 1991: 2).

The Decisions Team, a group working within the Institute, began to consider how ecotechnics might be applied to space exploration. In the early eighties, this Team formed a partnership with a venture capital firm, Decisions Investment, to develop a model biosphere capable of sustaining humans over a long period of time, a project dubbed Biosphere 2 (the Earth's biosphere being Biosphere 1). This partnership entity, Space Biosphere Ventures (SBV), was chaired by Texas billionaire Edward Bass, who was a member of the Decisions Team and owner of Decisions Investment. Through Biosphere 2, SBV planned to generate research, provide education, and develop marketable technologies that might both improve environmental management on Earth and advance the exploration and settlement of space.

SBV purchased a 2,000-acre tract of desert valley near the Santa Catalina Mountains, north of Tucson, Arizona. The Motorola Corporation's Executive Training Center had been located on the site, so there were already first-rate facilities for a large, long-term construction project. SBV enlisted the expertise of an array of ecologists, engineers, and environmental management professionals, including Buckminster Fuller, who helped design Biosphere 2's tetrahedronal, glass-and-piping outer structure, and Clair Folsome, the ecosphere inventor from the University of Hawaii. In 1984, SBV began building a test module in which to run experiments on a small but diverse closed ecosystem. These tests, conducted from 1987 through 1989, were at first unmanned, then later introduced a single individual for a few days.

The Biosphere 2 structure encompassed 3.1 acres. It contained more than 3000 species of plants, animals, insects and micro-organisms, which populated mini-biomes, including desert, marsh, grassland, rain forest, and coral reef. Beneath the living portion of the Biosphere 2 facility was a vast complex of machinery, a "technosphere" of motors, fans, pumps, tools, pipes and wiring. In addition, a network of distributed computers monitored hundreds of data collection points and controlled all the sensors, valves, pumps and motors in the Biosphere 2 infrastructure. Living quarters, laboratories, and gardens were provided for eight researchers, who took up residence in the air-tight facility for a two-year stint beginning in 1991.

The project received a considerable amount of attention from both the scientific community and the media when the first group of "biospherians" moved in. *Discover* magazine called Biosphere 2 "the most exciting scientific project undertaken in the U.S. since President Kennedy launched us toward the Moon," and Phil Donahue did a live on-site broadcast, calling it "one of the most ambitious man-made projects ever." There was a rather self-conscious attempt by SBV to portray the biospherians and their experiment as a bold adventure into an uncharted world. John Allen, a biospherian and one of the SBV leaders, referred to himself as Vertebrate X, and was given to poetry:

> What a multi-leveled dyad!
> . . .
> Long shot for transcendence
> The long roam throughout
> the Unknowable
> the Unbeable
> the Ununderstandable
> but not the Uncontactable
> Until impossibility itself
> Becomes a local option
> And biospheres co-regulate
> the Universe
> . . .

In an orchestrated bit of fanfare, the eight biospherians, four women and four men, wore identical orange jumpsuits and waved energetically to the crowd before entering the airlock, as though they were off to colonize a distant world or populate a new Garden of Eden. As one observer said, Biosphere 2 suggested simultaneously "visions of a NASA moon base, [and] a countercultural commune" (Luke 1995: 157).

The experiment did not go as well as SBV hoped. Some species died out while others succeeded too well. All the tropical birds, all the honey bees, and all seven species of frogs quickly became extinct. The airtight facility was breached by an aggressive local ant species, which killed nearly all the soft-bodied insects. The human crops suffered blights, infestations, and low productivity, so that the biospherians were chronically underfed. Worst of all, oxygen kept disappearing from the atmosphere, and CO2 levels were difficult to control. Low oxygen made the biospherians sluggish and depressed.

They suffered from irritability and confusion, and were forced to devote a far greater than expected amount of their work time to growing food, leaving little time to monitor species and collect data. Eventually oxygen, additional equipment and food were brought in from outside. When it was discovered that the Biosphere 2 project was not completely self-sufficient and that outside resources were arriving via the backdoor, the project's credibility plummeted. The press began depicting the whole project and its "cultish" biospherians as a New Age farce.

The eight residents emerged from Biosphere 2 in 1993, leaner, oranger (from an inadvertent excess of B12 in their diets), and far from best of friends. A new crew of seven entered the facility for a six month stay the following year, planting new species, introducing pest controls, and taking other measures to try and correct some of the problems with the original mission. But by that time, conflicts within SBV's management were reaching critical levels. Bass, rethinking the project's mission, removed most members of the Decisions Team and installed a new SBV chief executive officer and new science director. Biosphere 2 came under the direction of a new team of scientists from Columbia, Harvard, Yale, Stanford, Australian National Universities, and the Smithsonian Institution, which together formed the Biosphere 2 Science Consortium. Though Edward Bass still owned the facility and surrounding acreage, Biosphere 2 came under the management of Columbia University's Lamont-Doherty Earth Observatory. The institution now administers scientific, educational, and public outreach programs. Biosphere 2 is no longer a self-contained experiment in biosphere replication, but it is the world's largest controlled environment for the study of Earth systems and climate change.

While the facility is still concerned with environmental management on Earth, there is no more talk of space colonization.[19]

Wildness and Control

In some ways Biosphere 2 was the culminating product of that constellation of ideas, anxieties, dreams and perspectives that began coalescing in the late sixties at the intersection of space travel and global ecology. The presence of humans in space contributed to the growing sense of conflict between technosphere and biosphere, but to some it also suggested a way out. At the same time, space exploration served as a venue for imagining how technology might be integrated with nature in a way that preserved both technological development and ecological sustainability. Hopes for such an integration rested on the whole systems model, a pattern of organization more fundamental that the categories “natural” and “artificial,” “organism” and “mechanism.”

As we have seen in the rhetoric surrounding space exploration, the question of how to keep people alive in space turned repeatedly back into the question of how to spare the Earth from ecological destruction. Referring to NASA’s failure to consider adequately the complex ecosystem approach to life-support in space, Howard Odum wrote, “There is a similar failure to understand that man is dependent on his biosphere’s naturally diverse system for regeneration of life support. The world poses the same problem as the space capsule. Management of nature and ourselves in this instance is the same thing” (Odum 1971: 288). Odum saw the problem much as Brand would a few years later: the successful colonization of space would depend upon recognizing the Earthly environment as a complex, diverse, self-organizing, self-regulating whole system. If we understood that system well enough to replicate it in space, we could keep it in good repair on the home planet as well. Likewise, the developers of Biosphere 2 assigned their project the dual purpose of improving people/planet relations and exporting Earthly life out into the universe.

The Biosphere 2 experiment demonstrated a fundamental characteristic of the techno-ecological system: it negated the old dichotomy – nature versus technology—which placed people either inside or outside nature. It installed in its place the question of whether people are inside or outside the system. The answer to this question is that the question is undecidable; people are both inside and outside the system at the same time, though this is paradoxical.

As we saw with space colonies, the undecidable location of people creates an unresolvable antinomy between human control and system sovereignty. On the one hand, the system, with humans fully integrated as "keystone predators," as the Biosphere 2 project identified them, was supposed to organize and regulate itself. System sovereignty – wildness—was a necessary feature of Biosphere 2, according to Walter Adey, a Smithsonian Institution ecologist who worked on Biosphere 2. "We have to accept the fact that the amount of information contained in an ecosystem far exceeds the amount contained in our heads," said Adey. "We are going to fail if we only try things we can control and understand" (Kelly 1994: 145). Writer Kevin Kelly suggested that perhaps Biosphere 2 should be treated as a "zoo within one large cage where everything runs wild, including the observing *Homo sapiens*. The species are free to be themselves and to coevolve with others into anything they want" (Kelly 1994: 162). The Biosphere 2 developers were counting on the system to assemble itself.

On the other hand, there were actual humans inside, people who could not be expected to sacrifice their lives for the sake of biospheric experimentation. “It was a coevolutionary world,” according to Kelly. “The biospherians would have to coevolve along with it” (Kelly 1994: 155). But given that it took millions of years for humans to coevolve within Biosphere 1, it was perhaps unreasonable to expect the biospherians to adapt to breathing CO2 instead of oxygen, for example, within the space of two years. Besides, if the people were to become extinct inside Biosphere 2, the point of the experiment would be lost anyway. No one was interested in sending an unpeopled ecosystem out into space. The experiment demanded both human control and system sovereignty, but found the two incompatible.

The location of people both inside and outside the techno-ecological system positions them as participant-observers, a situation akin to that of quantum experiments. In Heisenberg’s famous formulation of the quantum postulate, the means of observation are never disjoined from the phenomena being observed. The very act of observation influences the outcome of the experiment, leaving no separation that would afford complete objective knowledge. This positions people as not merely observers, but also participants, variables within the experiment itself. Even more radical is the implication that there is no objective condition underneath these interactions, no definitive reality merely hidden from view. Rather, the indeterminacy, the undecidability *is* the reality.

In a similar way, people cannot be eliminated from the techno-ecological system as either participants or observers. To illustrate, we can compare two provocative but contradictory responses to Biosphere 2. One is from Timothy W. Luke, a political scientists who criticizes the project for commodifying ecology and extending managerial control over the biosphere. From Luke's perspective, Biosphere 2 was unnatural, an exercise in progressive hubris that showed people to be outside nature. The other response is from Dorion Sagan, the son of biologist Lynn Margulis and astronomer Carl Sagan. He takes the idea that people are inside nature to its logical extreme, arguing that by replicating the biosphere humans serve as the planet's "genitalia," the means by which the Earth's biosphere is struggling to reproduce itself.

In his essay, "Reproducing Planet Earth? The Hubris of Biosphere 2," Luke interprets Biosphere 2 as an insidious new strategy for reducing nature to an organic machine whose sole purpose is to serve humans – a strategy made all the more objectionable because it wears the disguise of environmental friendliness. While the developers of Biosphere 2 claimed to be carefully, even lovingly, replicating the Earth's biosphere, in fact, according to Luke, they were fabricating "an essentially new synthetic ecosystem." They created a "sub-real" Earth, composed of artificial biomes, "designed to produce particular outputs at some level of 'sustainable yield' so as to fulfill the biodynamic requirements of artificial ecological models." Into this fabricated ecosystem, the developers allowed nothing for its own sake, only those species and other elements they calculated would achieve the overall goals of the project. Compared with the Earth's biosphere, where things can exist quite apart from human utility and where evolutionary happenstance is a prime engine of change, Biosphere 2, in Luke's view, was a "designer planet" (Luke 1995: 159).

Luke's primary concern is that this "designer planet" extended the denaturing work of transnational capitalism. Biosphere 2, he argues, does not replicate a natural or original biosphere, as might exist on Earth apart from human meddling. Rather, it emulates, all too well, the “cyborg planet” the Earth has become under the pervasive, transforming effects of the modern, global, technoscientific human presence. The basic ecology of Biosphere 2, writes Luke, “is essentially cybermechanistic, simulating the now increasingly denatured Nature of earth inside an ecological formation in which humans, computers, mechanisms, and biomasses become one interdependent, co-evolutionary energy generation and conversion circuit” (Luke 1995: 161).

Dorion Sagan would concur with this description of the Biosphere 2 ecology, and embrace it, for just such an interdependent, co-evolutionary, techno-ecological system represents, in his view, a momentous development in the planet’s evolutionary history. In *Biospheres: The Metamorphosis of Planet Earth*, Sagan’s beginning place is the Gaia hypothesis, the theory, developed by James Lovelock and Sagan’s mother, Lynn Margulis, that the Earth’s biosphere can be considered a unique, living individual entity in its own right, a superorganism with its own metabolism, its own self-organizing and self-regulating mechanisms, and its own evolutionary trajectory. In the logic of this theory, all things in the biosphere, including humans and their technologies, are part of Gaia, created by Gaia. Therefore nothing, including technology, can be considered unnatural. “I am convinced,” writes Sagan, “that technology is part of the evolutionary process itself. Technology is *natural*” (Sagan 1991: 16).

Once technology is understood as natural, the technological replication of the biosphere can be interpreted as a planetary reproductive act, according to Sagan. With the creation of Biosphere 2, he writes:

> For the first time we recognize our cosmic role as midwives aiding in the gestation, delivery, and development of a new form of life. Combined with astronautics, biospheric life is uniquely fit to preserve and spread our earthly heritage even after the death of the sun. Arising from Mother Earth

> we find ourselves incestuously involved in her reproduction. As a technological species we have initiated a process of imitation that copies not a gene or an organism but planetary life as a unified ecological system. . . . The projected change of the living Earth is as astounding – and yet, as natural – as the transformation of a crawling insect into a flying one. It is nothing less than the metamorphosis of planet Earth (Sagan 1991: 9).

Compared with Luke, who is concerned with the technological "denaturing" of "Nature," Sagan places humans so radically *inside* nature there is no possibility of *outsideness* at all. Even environmentally destructive technologies are understood as "natural" by Sagan. One species' poison, after all, is another's life-giving element. Atoms circulate through the biosphere in lots of different forms, some more favorable to humans than others. Rather than gauging ecological health according to human standards, Sagan urges his readers to acknowledge that "a polluted planet is noxious to us because we evolved in a differing sort of environment, but it may be paradise for our descendants" (Sagan 1991: 18). In any case, the biosphere is not devoted to keeping humans alive; it existed long before humans arrived and will exist long after they have gone.

Luke locates people outside nature, maintaining an unbreachable distance between "natural" and "artificial." Sagan locates people inside nature, to the extent that nothing can be considered "unnatural" at all. Neither can sustain his position, however, without running into self-contradictions, but it is this tendency toward contradiction that is of the essence of the techno-ecological system.

Luke keeps the distinction between "nature" and "artifice" firmly intact so as to make the point that Biosphere 2 is unnatural. He finds it ironic that the Biosphere 2 developers, while claiming to replicate natural systems, are in fact replicating the denatured biosphere of a planet wholly colonized by a technological species. "Biosphere 2," he writes, "redesigns what is assumed to be the original planet earth into a new, artificial world. But Biosphere 1 is no longer what might be identified as Biosphere 0 – the earth prior to humans' evolutionary emergence. The anthropogenic reengineering of the earth's biosphere carried out over centuries is, in fact, embedded in the fully-enclosed ecosphere of Biosphere 2" (Luke 1995: 160).[20] Thus Luke condemns Biosphere 2 for creating an artificial environment, yet concedes there is no "natural" environment to replicate anyway. The Earth's biosphere itself is already "synthetic."

Sagan's case hinges on the claim that technology's function is not to serve humans but to serve Gaia, that "the biosphere uses humanity to create technology to reproduce herself" (Sagan 1991: 103). His view radically decenters humans, assigning them a biospheric function, but no special value or superior ontological status. "People are not in charge right now," Sagan writes. "For the most part, we are just a tunnel-visioned, self-serving species, highly dangerous to ourselves and to a few other species, and fascinated by the technology we imagine is our own. Such delusions of grandeur and control go hand in hand with the development of powerful technologies, but they are frills to the overall biospheric structure. We exist because other organisms cycle the biosphere with needed materials" (Sagan 1991: 19).

The problem with this formulation is that humans can be wholly subsumed within nature only by eliminating all agency, all *human* sovereignty, which is to say, human control, including self control. This position is so deterministic it renders even the work of Sagan's own argument futile. What difference would it make whether we acknowledge ourselves as the tools of Gaia or keep pretending we are in control? Our delusions of control must have thusfar necessarily served the biosphere's purposes. Through our hubris, Gaia has successfully ushered forth the technology that will in the long term, according to Sagan, add to her vigor and stability. If human consciousness changes now toward humility and recognition of our biospheric interdependence, that too is Gaia's means for ensuring her future, rather than ours. And if we blow ourselves up or poison ourselves into extiction, well, Gaia has her reasons.

Ultimately, however, Sagan does have a stake in human agency. He urges his readers to change their perspective, make different decisions, reorganize society in the interests of both human and biospheric survival.

> The threat we now pose to ourselves has made it imperative for national boundaries to begin to be minimized and for planetary humanity to ally itself to the Gaian ecosystem operating above and beyond all national frontiers. The prime enemy facing us is no longer as obvious as the military powers of any one nation. . . it is rather the far more subtle but steady encroaching collapse of the biological regime upon which we as humans depend. . . . The prime enemy now is the ecological ignorance of the Earth as a single physiological system that will not put up with insults. If Gaia exists, she is, as Lovelock says, no doting English nanny but an organized, self-sustaining system that will react with all the warmth and sympathy of an electronic circuit in the microbrain of an intercontinental ballistic missile. . . . To ensure our mutual survival we must band together, study the Earth as a single system, and be wary of the ecological complacency which suggests that, just because we have survived so far by behaving in a certain way toward the biosphere, such behavior can continue indefinitely in the same way it always has (Sagan 1991: 165).

In the end, humans control their own fate. They even can run afoul of Gaia and expect her revenge, which implies a degree of separation that positions people no longer as involuntary organs in Gaia's body, but as self-controlling agents making independent decisions.

Luke and Sagan both are wrong for being only partially right. We need to recognize, as they do not, that in addressing techno-ecological systems, whether Biosphere 1 or Biosphere 2, the question has shifted from where to place people relative to nature to where relative to the techno-ecological system. For in the discourse of both writers, nature has been incorporated along with technology into an encompassing entity called *system*. Humans are wholly outside this system, as Luke would have it, molding and controlling it toward their own ends. The system's existence depends upon an observing, controlling human presence. However, humans are also wholly inside the system, as Sagan would claim, reliant upon it for their survival. People, whether in Biosphere 1 or Biosphere 2, are participants in the functions of a self-organizing, self-regulating system beyond their control.

Put another way, there are always two contradictory outcomes to the question of the relationship between people and the techno-ecological system. Set up one way, the thought experiment yields evidence that people are inside the system. Set up another way, the opposite appears true. Both results are equally valid, though mutually exclusive. More than equally valid, both are necessary for an adequate description of the techno-ecological model, a description that accommodates all the evidence.

In this way, the logic of the techno-ecological system model mirrors that of the quantum postulate, to which it owes its beginnings, as we've seen in previous chapters. It participates in that larger, whole systems discourse that dispenses with the either/or logic of old binaries – wave-versus-particle, organism-versus-mechanism, technosphere-versus-biosphere, inside-versus-outside – in favor of a both/and logic in which such contradictory system variables are at once equally essential and mutually exclusive.

Chapter 7 is devoted to exploring this both/and logic, the *complementarity* that lies at the heart of the techno-ecological system. Before getting there, however, we will consider how in the Whole Earth discourse *information* became an "outlaw area," similar to outer space, where nature and technology might be reconciled by counter-cultural renegades.

Notes

[1] It was Ward's book Stewart Brand was reading on an airplane in 1968, when he first got the idea for the *Whole Earth Catalog*, a resource aimed at providing individuals with access to tools and ideas they might use to remake the world (Brand 1971: 439).

[2] In the 1980s, Session and Duvall, authors of *Deep Ecology*, will decry the metaphor for depicting the planet as a mechanism. Also see Gaarb (1985; 1990).

[3] Eugene P. Odum's brother, Howard T. Odum, himself a pioneering ecosystem ecologist, likewise employs the "life-support" metaphor to describe the ecological processes that sustain humans on Earth. "When the space program sent men to the moon and back, the most important and costly parts of the equipment – and the ones that ultimately limited the time the men could spend in space – were the many items of machinery and stored goods necessary to provide a life-support system for the astronauts" (Odum, Howard T. and Elisabeth C. Odum 1976: 115).

[4] For a more comprehensive look at Fuller and his ideas, see Fuller and Marks (1973), Marks (1963), Snyder (1980), Kenner (1973).

[5] See, for example, Cosgrove, "Contested Global Visions."

[6] Fuller claims to have invented the term "Spaceship Earth" at the University of Michigan in 1951. While this may be so, Stevenson and Ward seem to be the first to use the term in addressing a wide audience, and there appears to be no connection between their employment of the term and its invention by Fuller.

[7] Woodcock misses the point that Fuller did not think of machines in conventional terms, that he subsumed the biological, the political, *and the mechanical* under the laws of whole systems. In considering Fuller's automobile metaphor, for example, we should remember that Fuller actually invented a car, the "Dymaxion," which operated, as he said, according to the principles of whole system. See Marks (1963), Fuller and Marks (1973).

[8] Brand credited Fuller's insights with "initiating" the *Whole Earth Catalog* (Brand 1968: 3). The *CoEvolution Quarterly* and *Whole Earth Review* were, Brand stated, "the godchildren. . . of Buckminster Fuller" (Kleiner and Brand 1986: 333-34).

[9] Nearly thirty years later, the U.S. would reach the conclusion that it could escape the threat of being cut off from Middle East oil not by colonizing space but by colonizing Iraq.

[10] As with the progressive disposition toward space travel discussed in Chapter 3, there was in the arguments embracing space colonization an embedded masculinist discourse centered on "Man's" conquest of "virgin" territory, in order to spread his "seed" throughout the universe. The gender politics of this kind of discourse on nature and culture have been mapped by Kolodny (1975), Merchant (1980), and others. For analysis of gendered discourse in the sciences see Hayles (1992), Keller (1985, 1992), Martin (1991), Merchant (1980), Schiebinger (1993). Gender analysis represents a promising area for further exploration of the discourses I am examining here.

[11] Brand was familiar with the effects of colonization on Native Americans. Among other activities aimed at raising Native American issues, he had organized a multi-media educational program called "America Needs Indians" in the 1960s. From 1963 to 1966 Brand spent time on Warm Springs, Blackfoot, Navajo, Hopi, Papago, and other Indian reservations. He was married for six years to Lois Jennings, an Ottawa Indian.

[12] Ultimately, Brand's position was closer to Berry's than to O'Neill's. His difference with Berry can be attributed in large part to his whole system outlook, which made it possible to hope for both ecological stability and technological development. Eric Drexler, writing in *Space Colonies*, identified the difference in these positions this way: "Most of those ideologically opposed to expansion into space are oriented in what might loosely be called a limits-to-growth, alternative technologies, decentralized systems direction. Equally, many supporters of expansion into space have a similar orientation, but have seen the planetary/space enterprise in a yin/yang, complementary, co-evolutionary light. They have recognized that limits-to-growth is not a universal dogma or a universal good, that different environments may have different appropriate technologies, and that space may be the ultimate decentralizer" (Brand 1977: 107).

[13] Brand wrote in *Space Colonies*: "In de-emphasizing the exotic qualities of life in Space, O'Neill is making a mistake I think. People want to go not because it may be nicer than what they have on Earth but because it will be harder. The harshness of Space will oblige a life-and-death reliance on each other which is the sort of thing that people romanticize and think about endlessly but seldom get to do. This is where I look for new cultural ideas to emerge. There's nothing like an impossible task to pare things down to essentials – from which comes originality. You can only start over from basics, and, once there, never quite in the same direction as before" (Brand 1977: 72.)

[14] William Irwin Thompson, writing in *Space Colonies*, said, "I don't see anything wrong with setting up a colony in space but I do see something wrong in thinking that one can create wildness by placing it into a container" (Brand 1977: 44). Though opposed to O'Neill's thinking, this sentiment also missed Brand's hope for space colonization. Thompson saw space colonies as containers, but Brand saw them as whole systems, wherein wildness was not contained but was a defining characteristic.

[15] Brand struggled with the question of whether wildness was still possible on Earth. "Wild freedom," he wrote, "trees falling in the wilderness unheard, the unimpeded health of ecosystems – that's our banner. But I wonder it it's already long gone, like the Earth-centered solar system or the seven days of creation. Maybe the image of wild freedom is true even if the fact no longer is, and wisdom can still be based upon it" (Brand 1977: 88). Even as space colonies raised the possibility of an "outlaw area" in space, they also raised the prospect of increasing human control over Earth, something that Brand acknowledged and blanched at. There was talk, for instance, of space colonies providing such unnatural "improvements" as nighttime illumination for crops on Earth. In response to an interview with NASA officials on potential developments in space, Brand wrote this: "Vastly improved air traffic control. Sophisticated radar imaging available to every boat near a coast. The complete replacement of the post office by instant hard-copy transmission via satellite. The tagging and tracking of all nuclear fuel, to prevent theft and blackmail. Listening to the lengthening list, I found

myself dealing with a case of the horrors. My outlaw nomad was yelling from his hill – no, no fair, too much power to the cops! If there is no place to hide, there is no place to really invent. The Earth one big hydroponic garden? Let me out of here" (Brand 1977: 87).

[16] Co-evolution is a concept first developed by Brand's former biology professor at Stanford, Paul Ehrlich. See Ehrlich and Raven (1965). Co-evolution is discussed at more length in Chapter 5.

[17] See, for example, NASA SP-134, *The Closed Life-Support System*, Ames Research Center, Moffett Field, California, April 14-15, 1966. This document is typical of the published reports of a number of NASA-authorized university and corporate studies of life-support systems for space missions exceeding one year. The Soviet Union also conducted research on regenerative systems, with similarly disappointing results. Lewis Mumford described one of these experiments disapprovingly in *Pentagon of Power*: ". . . three Russians – a physician, a microbiologist, and an engineer – voluntarily submitted to a whole year's incarceration in a simulated space ship mainly to establish the possibility of remaining alive in a limited space – twelve feet square – using oxygen and water regenerated from human waste products, dehydrated food, and vitamin-rich watercress and other plants grown in a minimal, sixty-square-foot hothouse. Physically they survived the blank life and the resulting interpersonal tensions. . . But this feat of endurance turned out to be as useless as it was meaningless: since the most formidable conditions of space travel were absent – weightlessness, spatial isolation from the earth, and ever-present possibility of danger from mechanical breakdown, bodily disorders, anxiety over further risks on re-entering the earth's atmosphere.. . . These efforts to determine minimal physical conditions for human survival in space are, it need hardly be emphasized, the precise opposite of an imitation of nature's exuberance and plenitude: those maximal conditions under which life has actually flourished" (Mumford 1970: 307).

[18] The Institute of Ecotechnics moved from the U.S. to London, England, in 1981, from where is continues to work on rainforest restoration, ecological farming, and other projects.

[19] In 2003, Columbia University began looking potential buyers for Biosphere 2.

[20] The developers of Biosphere 2 recognized this, too. Tony Burgess, one of the Biosphere 2 ecologists, said, "Bio2 is a synthetic ecosystem, but so is California by now." Likewise, Peter Warshall, a consulting biologist on the project said, "Walter Adey first used the term synthetic ecology. Then I realized that there were already huge amounts of synthetic ecology in Biosphere One. And that I wasn't inventing a synthetic ecology in Bio2. I was merely duplicating what already existed" (Kelly 1994: 147).

CHAPTER 5
LIVE WIRES:
INFORMATION TECHNOLOGIES
AND THE WHOLE EARTH DISCOURSE, 1965-1995

As far back as the early nineteen-sixties, Stewart Brand identified information technologies, especially computers, as tools that might come in handy for individuals interested in reshaping civilization. He pointed readers to resources for computers in the very first *Whole Earth Catalog*, in 1968; by the end of the nineteen-eighties he had published a software catalog and magazine, written a book on digital media, and started one of the first on-line virtual communities. This chapter traces the relationship between information technologies and Brand's Whole Earth whole systems discourse. It argues that, through this counter-cultural discourse, a deeply *ecological* perspective influenced the way people saw and received personal computers in the nineteen-eighties. This counter-cultural-ecological perspective served to legitimate computer technologies against an older, modernist order of technology by promising a future in which machines empowered individuals within a sustainable global environment, rather than controlled them and destroyed their habitat.

Stewart Brand, along with many others in the latter half of the twentieth century, believed that the world was at a crossroads. Global technological civilization had proved itself fundamentally at odds with the natural systems of planet Earth. Something had to change radically if humans were to avoid despoiling the natural environment beyond repair. This technosphere-versus-biosphere problematic seemed to many people pointed toward one of two options: either humans must intentionally scale back their numbers, achieve a steady-state economy and curtail the proliferation of modern global technologies, or they must suffer the catastrophic consequences of resource exhaustion, environmental poisoning, and population explosion.

Brand rejected this either/or choice. He was in search of a route that would salvage technological and economic growth while still preserving the integrity of the natural world. He already had what he felt were powerful new conceptual tools to work with: whole- systems theories of nature and technology arising out of mid-century cyberscience. A whole- systems perspective suggested that the right kind of machines might share fundamental organizing principles with organisms and ecosystems. Brand's publications, the *Whole Earth Catalog* and *CoEvolution Quarterly*, were in part devoted to exploring these ideas and considering which whole-systems tools might lead to a future in which nature and technological civilization were not opposed to one another. As we saw in Chapter 4, the idea of building self-contained environments for people in space was one avenue Brand explored in the seventies. As we'll see below, "soft tech" was another. He hoped either option would help create a new space – an "outlaw area" – in which creative, self-directed individuals might explore, invent, and experiment with new modes of being, new relationships with nature, technology, and with one another. By the end of the seventies, neither space colonies nor soft tech looked very promising.

Beginning in the 1980s, however, a new outlaw area caught Brand's attention and sparked his imagination: the ephemeral *terra incognita* of cyberspace. The 1980s saw the quick expansion of digital media, the spread of personal computers, and their interconnection into decentralized networks spanning the globe. Brand interpreted these developments in terms of the central Whole Earth whole systems objective: to place powerful tools in the hands of individuals, equipping them to "think up and try out new stuff." Like soft tech communes and space colonies before it, cyberspace seemed as though it could be a venue in which creative, self-guided individuals might remake the world in such a way that technological progress and ecological survival did not rule each other out.

Brand's publications were important conduits for promoting both ecology and information technologies. This was not a coincidence; the two realms were irreducibly linked within the Whole Earth discourse (Kelly 1988). Both were essential to the project of bringing modern civilization into alignment with the whole systems laws of the universe. This chapter examines a number of ideas and developments that accreted to cast personal computers as a technology for moving the world toward the Whole Earth ideal: computer "hacker" culture; Gregory Bateson's ideas about mind and evolution; Douglas Engelbart's human-computer interface research; the personal computer revolution and the advent of virtual communities.

Brand was a focal point for the convergence of ecological, technical and counter-cultural phenomena that together shaped the information environment of late twentieth century American culture. His activities, his circle of contacts and influences, and his publications serve as a record of how those phenomena intersected. He provided perhaps the central public forum and channel of distribution for a discourse that framed cyberspace as a techno-ecological system, within which nature and technology were coevolutionary, mutually formative components. In this chapter, I use Brand and his publications as a means for articulating what would become a widely held understanding of the relationship among people, nature and technology in the age of information.[1]

Soft Tech

To understand what information technologies meant within the Whole Earth whole systems discourse, it is helpful first to look at another class of technologies the *Whole Earth Catalog* and *CoEvolution Quarterly* promoted as an alternative to modern industrial machinery and institutions. This was "soft tech," elsewhere called "appropriate technology" or "alternative technology."[2] "Soft tech" signified technologies, whether traditional or newly developed, that minimized resource consumption and environmental pollution – technologies that could be used to "augment rather than oppose natural systems" (Baldwin and Brand 1978: 4). Soft tech included solar panels, wind generators, earth-covered buildings, and many other tools and techniques that reduced both direct ecological damage and reliance upon the mainstream industrial order.

Soft tech was a mainstay of the *Whole Earth Catalog* from the start. Many of the tools the *Catalog* evaluated and provided access to were small-scale, useful for building one's own dwellings, growing food, or generating electricity free from gargantuan power grids and the bureaucracies and institutions that controlled them. The Whole Earth aim was to equip individuals with tools and ideas they might use to forge new, creative, healthier ways of life. With its emphasis on soft tech, the *Whole Earth Catalog* helped foster a widespread counter-cultural interest in traditional folk ways and self-sufficient living, reflective of a desire for lives and communities more in tune with nature.

There was, however, an important distinction between soft tech in the Whole Earth discourse and the soft tech promoted in many other counter-cultural outlets of the sixties and seventies. The simple-living, back-to-the-land disposition found in the *Foxfire* books, *Mother Earth News* and elsewhere was in most cases grounded in the long-standing tradition of American pastoralism. This tradition, dating back to Thomas

Jefferson and before, exalted nature and championed agrarian life in direct resistance to the juggernaut of mechanization and industrialization (Marx 1964). There was in pastoralism a deep suspicion, if not an outright rejection, of modern technologies. The Kentucky writer and farmer Wendell Berry, for example, advocated plowing with a mule rather than a fossil-fuel burning tractor (Berry 1990).

The Whole Earth take on soft tech was sympathetic to the pastoralist position. Berry and other traditionalists appeared frequently in the *CoEvolution Quarterly*. But soft technology within the Whole Earth discourse was framed less by nostalgia for American country life than by the concepts of whole systemness as they arose from cybernetics around mid-century. The Whole Earth whole systems discourse considered soft tech one, but not the only, approach to the problem of how to retool civilization for compatibility with the planet's living systems. It was an "evolutionary start," a promising mutation in human behavior, which might prove more adaptive than the ecological assault thus far perpetrated by modern industrial technology. Where pastoralists looked to re-establish pre-modern ways, the whole systems discourse looked to generate evolutionary reconfigurations of people/planet relations.

Soft Tech, published in 1978, was like *Space Colonies,* which came out the year before, in serving as a clearinghouse for ideas and opinions surrounding an alternative direction for technological civilization. *Soft Tech* compiled a lot of the soft technology information that had appeared in *CoEvolution Quarterly* in previous years and added some special features, such as a report on the New Alchemy Institute's experimental compound in Canada, a facility devoted to researching and testing ecology-based technologies for producing food, energy and shelter.[3] *Soft Tech* provided information on solar and wind energy, cars and bicycles, steam power and biofuels, building materials and techniques, and much more. It was presented as a snapshot of the state of the art of soft technology experimentation.

Brand co-edited *Soft Tech* with J. Baldwin, who had been the *Whole Earth Catalog's* soft technology evaluator since 1968. Baldwin was a former student of Buckminster Fuller at the University of Michigan. He shared Fuller's enthusiasm for innovative design (Baldwin 1997). Baldwin objected to the "wave of protest and doom books" that in recent years had advanced an "antitechnological excess." He recognized the dire spot modern technologies had put the world in, but he thought it would be a mistake to return to the ways of the past. After all, "our grandparents were in many ways worse than ourselves," he wrote.

> They saw the forests as endless and topsoil beyond measure. The wonderful Cape Cod House assumed an unlimited supply of firewood nearby. Our predecessors wrecked the land and moved west to wreck some more. . . Even the Native Americans did their share of damage. There are lessons in the past, but we shouldn't and can't go back (Baldwin and Brand, 1978: 4-5).

Soft tech, for Baldwin, was a corrective to both past and present. Durable hack saws and homemade lye might be part of the solution, but like Fuller, Baldwin believed in using as much modern science and sophisticated know-how as necessary for doing ever more with ever less. The New Alchemy Institute's project in Canada was particularly attractive to him for its bold pursuit of *new* ideas and technologies: the backyard fish farm greenhouse; the solar-heated, wind-powered food-growing complex. These were the technologies that seemed pointed toward a different kind of future, that seemed like evolutionary adaptations making humans more fit for their natural environment.

Brand was likewise excited by new, innovative approaches to soft tech, but he also exhibited some doubts about how full a solution soft tech might be under conditions of rapid economic and cultural globalization. Rethinking the well-worn soft tech goal of "self-sufficiency," Brand called for a more deeply ecological understanding. "'Self-sufficiency,' he wrote in *Soft Tech*, "is an idea which has done more harm than good."

> . . . [S]elf-sufficiency is not to be had on any terms. It is a charming woodsy extension of the fatal American mania for privacy. . . It is a damned lie. There is no dissectable self. Ever since there were two organisms life has been a matter of co-evolution, life growing ever more richly on life. . . We nations all are in total dependency on systems which have no respect for national boundaries – atmosphere, oceans, ocean life, biotic provinces and our daily Sun, without which nothing. Cultural flow, language, economic flow – this stuff slows up at national boundaries and probably should, but it never stops. To refute George Washington, "Life IS entangling alliances" (Baldwin and Brand 1978: 5).

Brand held his own publications of years past complicit in purveying the mistaken notion of self-sufficiency. Now, in its place, he would substitute "local dependency." He urged his readers to recognize and work within their reliance upon local institutions, people, organisms and natural forces. "And since our world is increasingly cultural, and proportionally ever less physical," he wrote, "the meaning of 'local' is not geographic, at least not only" (p. 5).

In this reconsideration of "local" Brand intimated that global cultural interconnections were becoming as encompassing and complex as global ecological relations. He seemed to anticipate the new kinds of communities that would be possible in cyberspace in just a few years – "virtual communities," composed of people from all over the world, meeting not in physical space but in cyberspace, organizing themselves around common interests and affinities rather than geographic location. In contrast with

Baldwin, Brand in 1978 was pointed toward the view that the planet was already being remade by new technologies – not soft tech, but high tech. His plunge into information technologies in the 1980s – a new magazine, a new catalog, a new book – would reflect his growing confidence in their potential for empowering individuals within the ecological realities of the planet.

But why should this be so? Why would Brand come to see computers as a more promising solution to the problem of technology than windmills and solar fish ponds?[4] Dislodged from lumbering, untrustworthy behemoths like IBM, and put into the hands of curious, creative individuals, computers had long seemed to Brand a revolutionary new tool. As the next sections show, in the Whole Earth whole systems discourse computers were considered compatible with nature rather than at odds with it. In contrast with the smokestacks and chemicals of industrial society, they seemed light, clean, and safe. Through the cybernetic control of information, they were capable of accomplishing much work with little environmental cost.[5] More fundamentally, however, their basic pattern of organization and function was the same as that found in complex living things, like organisms and ecosystems. Since cybernetics had dissolved any strict boundaries between the organic and the mechanical, the natural and the artificial, nothing was to keep cybernetic information technologies from joining the dance of coevolution.

The same could not be said of soft tech. Even the adventurous version promoted by the New Alchemy Institute suggested a world in which humans reconciled themselves to nature by reducing their numbers and scaling down to a sustainable, steady-state economy. One could be increasingly creative in finding ways to make human activities more Earth-friendly, but unplanned, radically new varieties of beings and technologies were unlikely to emerge. When cybernetic technologies coevolved with natural entities within techno-ecological systems, however, anything might happen, and this was a prospect Brand found not just more exciting than soft tech but more essential to the future of both people and planet.

Access to Computers

Brand had become intrigued by computers in the early 1960s during a “mind-opening” visit to the Computation Center at Stanford University. “There I saw young programmers playing the first computer game, ‘Space War,’ on time-shared DEC computers with interactive graphics. I saw a kind of ecstasy in their play” (Brand 2001). He would write about Space War and computer “hackers” at Stanford and MIT for *Rolling Stone* in the early seventies. His article, “Fanatic Life and Symbolic Death Among the Computer Bums,” made clear that what attracted him most about this ecstatic play was the way in which a handful of rogue, creative programmers had converted monolithic mainframes into a powerful personal tool, suitable for unlimited, unregulated exploration. Hackers were for Brand an appealing breed of cultural outlaw, appropriating the highest order technologies in potentially transformative ways (Brand 1974).

The Stanford Research Institute (SRI) Brand visited, along with MIT’s Research Laboratory of Electronics (RLE), emerged in the early sixties as the collective birthplace of hacker culture, the unspoken attitudes and ethics that would drive the development of personal computers from the sixties forward. Beginning at MIT, a small group of students – male, white, technically brilliant, socially awkward, only tacitly encouraged by faculty – taught themselves how to “hack” together programs on university mainframes. Time and official sanction were limited, so the hackers generally worked at night, “stealing” expensive computer time to run programs with no particular practical application. In the course of following their personal obsessions, they generated programming innovations, such as Space War, that began to transform computers from massive number crunchers into tools of creative interaction. Just as importantly, these young programmers cultivated a "hacker ethic" that would both guide the development of personal computers and cast them as machines with counter-cultural potential. The hacker ethic, according to Steven Levy, consisted of these principles:

> * Access to computers – and anything which might teach you something about the way the world works – should be unlimited and total. Always yield to the Hands-On Imperative!
> * All information should be free.
> * Mistrust Authority – Promote Decentralization.
> * Hackers should be judged by their hacking, not bogus criteria such as degrees, age, race or position.
> * You can create art and beauty on a computer.
> * Computers can change your life for the better (Levy 1984).

Hacking, Space War, and the hacker ethic found a second home on the West Coast, where personal computer development was already mixing with flower power. As sociologist Thierry Bardini writes, "The personal computer is in part the product of what in Europe was called 'the generation of '68,' and of its culture as it developed in the San Francisco Bay Area, from the Berkeley Free Speech Movement and antiwar agitation on through the San Francisco Summer of Love and the rise of the Human Potential movement" (Bardini 2000). Hacking and social activism came together around common values: the mistrust of authority; the desire to decentralize power by putting it into the hands of individuals; the feeling that access to information and resources should be as unfettered and egalitarian as possible. Pam Hart, one of the rare female programmers in the late sixties, found ways to enlist her technical skills against the war.[6] "[D]uring the

Cambodia Invasion demonstrations in Berkeley," she told Brand, "a group of us got together and designed a retrieval program for coordinating all of the actions on campus. . . [I]t brought together people who had never worked together before and started them talking and thinking about how it was actually possible to do something positive with technology, when *you* define the goals" (Brand 1974). In Brand's view, the personal computer "revolution" was carried out by "youthful longhairs" who adapted advanced technologies to empower individuals and decentralize society – "to undermine the high priests and air-conditioned mainframes of information technology and hand their power over to absolutely everybody" (Brand 1994). Looking back from the nineteen-nineties, Brand was convinced it was the "hippie communalism and libertarian politics" of the sixties that "formed the roots of the modern cyberrevolution" (Brand 1995).[7]

Brand was in the thick of this merger of counter-cultural activism and personal computer development. His introduction to hacker culture at Stanford preceded the *Whole Earth Catalog*. In 1968 he was invited to participate in Douglas Engelbart's Augmentation of Human Intellect project at the Stanford Research Institute, located across the street from the *Whole Earth Catalog* offices in Palo Alto. Engelbart's research was responsible for many of what would become the standard features of the personal computer, including the mouse, hypertext, and windows displays. Through the *Catalog* and the Whole Earth Access Store, Brand also developed ties to various local efforts by independent programmers and activists, such as Pam Hart at Resource One, to bring computers to the public through community computer centers and public terminals (Levy 1984). And computer resources were included in the *Whole Earth Catalog* from the start, presented, alongside yoga and *Survival Arts of the Primitive Paiutes*, as something worth checking out if you wanted to try building a different kind of world . As Brand stated, "We – the generation of the '60s – were inspired by the 'bards and hot-gospellers of technology' . . . And we bought enthusiastically into the exotic technologies of the day, such as Fuller's geodesic domes and psychoactive drugs like LSD. We learned from them, but ultimately they turned out to be blind alleys. Most of our generation scorned computers as the embodiment of centralized control. But a tiny contingent – later called 'hackers' – embraced computers and set about transforming them into tools of liberation. That turned out to be the true royal road to the future" (Brand 1995).

Ecology of Mind: Two Cybernetic Frontiers

Computers could seem like tools of liberation in so far as they appeared to provide an alternative to the two primary dangers of modern industrial technologies: dehumanization and environmental destruction. The possibility of personal computers and of communal, networked terminals suggested these powerful tools could serve individuals and communities, not just giant corporations and bureaucracies. Just as important was the perception that these machines could be central to an ecologically sustainable civilization. Within the whole systems discourse, a vision of an alternative future began to emerge at the confluence of natural and technological cybernetic systems. Take for example the poem, "All Watched Over by Machines of Loving Grace," by Brand's friend, Richard Brautigan. Brand included it in the first *Whole Earth Catalog* in 1968.[8]

> I like to think (and
> the sooner the better!)
> of a cybernetic meadow
> where mammals and computers
> live together in mutually
> programming harmony

like pure water
touching clear sky

I like to think
          (right now, please!)
of a cybernetic forest
filled with pines and electronics
where deer stroll peacefully
past computers
as if they were flowers
with spinning blossoms

I like to think
          (it has to be!)
of a cybernetic ecology
where we are free of our labors
and joined back to nature,
returned to our mammal
brothers and sisters,
and all watched over
by machines of loving grace.[9]

If Brautigan was being ironic (it is not clear that he was), another of Brand's friends, Gary Snyder, was unquestionably sincere in envisioning "a technology of communication, education, and quiet transportation. . ." in an environment in which "Bison return to much of the high plains. . . ," "deserts [are] left wild for those who would live by skill," and "computer technicians who run the plant part of the year. . . walk along with the Elk in their migrations during the rest" (Snyder 1969).[10] A whole-systems perspective made it possible to imagine a post-industrial civilization in which technology and nature were not at war, but could peaceably coexist.

For Brand, the conceptual convergence of computers and ecology was spurred by ideas from two life scientists, Paul R. Ehrlich and Gregory Bateson. Ehrlich, best known for *The Population Bomb* and other widely-read books on global ecology, had directed Brand's field research on tarantulas at Stanford, where he earned a degree in ecology in

1960. Ehrlich, along with Peter H. Raven was responsible for introducing the concept of *coevolution* in the mid-sixties, an idea which, as we'll see, became key in the construction of techno-ecological systems.

But it was Bateson, with whom Brand became friends in the early seventies, who most influenced his thinking on cybernetics and evolution. Bateson was another of those figures – like Buckminster Fuller and Gerard O'Neill – who sparked Brand's admiration and enthusiasm: an original, iconoclastic thinker; someone with big ideas and a tendency to ignore disciplinary boundaries; someone with unquestionable credentials and widespread influence, but who was a bit of a renegade and tended to operate at the fringes of the establishment. Bateson was the son of British geneticist William Bateson (1861-1926), biology's staunchest proponent of Mendelian genetics at the turn of the twentieth century. In the 1930s Gregory wrote an influential book on New Guinea tribal culture (*Naven*) and, in the forties, published, with his wife Margaret Mead, a photographic study of life in Bali (*Balinese Character*). Later he worked with psychiatric patients and alcoholics in California, and porpoises in Hawaii, in both places seeking a better understanding of consciousness. Both Bateson and Mead had been participants in the Macy Conferences in the 1940s and '50s, at which many of the ideas surrounding cybernetics first took shape. In the sixties, Bateson organized a follow-up conference on cybernetics, called the Wenner-Gren Conference on the Effects of Conscious Purpose on Human Adaptation, at which he invited participants to consider three cybernetic systems: the individual, society, and the global ecosystem.[11] Out of all these experiences came Bateson's best-known work, *Steps to an Ecology of Mind*, published in 1972, by which time he was teaching at the University of California, Santa Cruz. This was the book that captured Brand's attention and prompted him to seek out Bateson at his home at Big Sur. Brand's report on his extended conversations with Bateson, "Paradox," appeared in *Harper's* in 1973.

For Brand, *Steps to an Ecology of Mind* began to answer some of the personal questions he had about cybernetics. As he wrote in "Paradox,"

> I came to cybernetics from preoccupation with biology, world-saving, and mysticism. What I found missing was any clear conceptual bonding of cybernetic whole-systems thinking with religious whole-systems thinking. Three years of scanning innumerable books for the *Whole Earth Catalog* didn't turn it up. Neither did considerable perusing of the two literatures and taking thought. All I did was increase my conviction that systemic intellectual clarity and moral clarity must reconvene, mingle some notion of what the hell consciousness is and is for, and evoke a shareable self-enhancing ethic of what is sacred, what is right for life (Brand 1974, 9).

Bateson's "highly original application of cybernetics, biology, linguistics, psychology, and formal logic to field work with New Guinea and Balinese natives, porpoises, alcoholics, schizophrenics, beetles, and national histories," according to Brand, provided a "rigorous scientific refutation of the notion that rational science is adequate to save us." (Brand 1974, pp. 9-10).[12]

Bateson's central idea is captured in the phrase "ecology of mind." In Bateson's analysis, mind is not limited to human beings but is characteristic of any system complex enough to be self-regulating and self-reflexive. An "ecology" of mind takes cognition out of the exclusive domain of the individual and distributes it over a network of relations. Ecosystems as well as organisms—even, potentially, machines, or people-machine systems – could meet Bateson's criteria for "mind" in the way they respond to stimulation, to "difference." Their response is not one of mechanical, linear cause and effect but rather interpretation. They convert the stimulation of an event into information and place it in a context, and in contexts of contexts, that give it meaning. Recursive processes of interpretation – circuits of negative and positive information feedback – enable the system to learn how to respond. The mind of such systems does not have to be self-aware, only self-referential. By calling these characteristics of complex cybernetic systems "mind," Bateson "aggressively challenge[d] the traditional divisions between organisms and other systems, between individuals and aggregates, and between living and nonliving" (Oates 137).

In addition, the assignment of mentality to complex systems had the effect of turning mere information into "ideas." Where early cyberneticians had tended to define information in terms of "signal" and "noise," stripped of context and meaning, Bateson defined it as "any difference that makes a difference" (Bateson 1979). Making a difference was a matter of context, of meaning. In Bateson's scheme, genetic information embodied in DNA, for example, could be understood in terms of *ideas* at work in the mind of nature. The left-right symmetry of eyes, limbs, nostrils and other body parts found in so many otherwise dissimilar creatures is not just coded information without context but an *idea* for designing organisms in the context of planet Earth – and a good one, given how well it serves beings from grasshoppers and elephants to trout and parakeets.[13] A hard external skeleton is one idea for keeping an organism together. A light, sturdy internal skeleton wrapped in muscle and skin is another. Both ideas, tried and tested through evolution, work well in different contexts. By Bateson's definition, mind is neither mystical nor inherently material; rather, it arises in the patterning of relations and connections within a complex system. An organism is such a complex system, as is an ecosystem, and both are inescapably part of the Earth-encompassing mind of the biosphere.

The "health" of a mind, whether individual or planetary, was the point upon which Bateson's ideas began to suggest an ethic that might fill the gap between scientific and religious whole-systems thought for Stewart Brand. In response to Brand's search for "what is right for life," Bateson answered "sanity," a state in which the mind was balanced and stable and capable of sustaining itself over a long period of time, a state equivalent to ecological "climax" (Brand 1974, 17). Perturbation from which a system could not recover, such as the arrival of Europeans in Hawaii and Bali, Bateson said, resulted in cultural or ecological "insanity" (pp. 17-19). The extension of mind out of the individual and into a system comprising the individual and everything else in his or her environment had deeply ecological implications. "When you narrow down your epistemology," Bateson wrote in *Steps to an Ecology of Mind*, "and act on the premise 'what interests me is me, or my organization, or my species,' you chop off consideration of other loops of the loop structure. You decide that you want to get rid of the by-products of human life and that Lake Erie would be a good place to put them. You forget that the eco-mental system called Lake Erie is part of *your* wider eco-mental system – and that if Lake Erie is driven insane, its insanity is incorporated in the larger system of *your* thought and experience" (Bateson 1972).

For Bateson, the thrust of what drove twentieth-century Western civilization toward cultural and ecological insanity was an inability to deal with paradox. Paradox – a situation in which opposites, such as good and evil, are unavoidably, simultaneously present – is built into the universe, which is to say, into *mind* at the highest level. "A paradox," said Bateson, "is a contradiction in which you take sides – both sides. Each half of the paradox proposes the other." In Bateson's view, the proper approach to paradox was to resist choosing one side over the other. "I think it is so," he said, "that if you sweat out one of these paradoxes you embark on a sort of voyage, which may include hallucinations and trance and all that sort of stuff. But you come out knowing something you didn't know before, something about the nature of where you are in the universe" (p. 31). The "pathology" of Western civilization lay in always endeavoring to avoid paradox by choosing one thing to the exclusion of its opposite. Such choosing, Bateson said, was what Western civilization called "rational purpose." As Brand interpreted this idea, choosing one side over the other, "denies the healthy paradox at the heart of the matter. Rational purpose serving only its own convenience or plan – I want nature *my* way – asks for increasing trouble, the pathology of insistent control and guaranteed frustration, causing *more* insistent control, etc." (p. 33). The course of sanity, in Bateson's view, relied not on choosing sides, but on living with the contradictions, accepting them and letting them be. "All these definitions of self as over *against* other people or the environment – they depend upon not riding with the contradictions," Bateson said (p. 31).

What was the alternative to choosing one side over the other – love over hate, for example?, Brand asked. "The truth which is important," Bateson told him, "is not a truth of preference, it's a truth of complexity. . . of a total eco-interactive on-going web. . . in which we dance, which is the dance of Shiva. You know, the whole of good and evil gets wrapped up in the dance of Shiva. And in ancient Hebrew good-and-evil is a single word meaning 'everything'" (p. 33). Though Bateson was an atheist, his explanations were steeped in religious imagery. The "sanity" of the balanced mind of the universe was for him captured in the idea of the Tao. He used an engraving of Job by William Blake to make the point that God and Satan were inextricable from one another. The “sharable, self-enhancing ethic” Brand was searching for seemed to him possible within a universe where complexity and paradox were the ingredients for health and sanity. Though Brand did not address the matter, the possibility that complexity and paradox might also generate an endless desire for things and stimulation was an impression readers might reasonably gather from the *Whole Earth Catalog*.

In 1974, Brand combined his *Rolling Stone* article on computer bums with his *Harper's* essay on Bateson into a book he called *II Cybernetic Frontiers,* adding some photographs and follow-up information to each part (Brand 1974). Bateson's ecology of mind and the new, interactive potentials of computers were two “particularly poignant and promising” dimensions of cybernetic research. “Our comprehension has grown used to the concepts of matter and energy, but the burden of cybernetics – information – continues to boggle us. Weightless energyless *differences* fly about making patterns which are apparently nothing but which move the somethings with mysterious regularity” (p. 7). Together, these two frontiers suggested that complex, information-based systems were showing themselves to be the basic units of organization and evolution in the universe. They had in common, Brand told his readers, an ability to subvert humankind's “special pride” – it's sense of conscious purposefulness.

To help his readers make the link between computers and ecologies of mind, Brand juxtaposed at the front of *II Cybernetic Frontiers* two photographs, one of space, showing a collection of distant galaxies; the other a screen shot of Space War, looking very much like the picture above it, with points of light clustered and scattered across a field of black. “This book is dedicated to the difference,” read the caption. At the end of the book, the same two photos appeared again, in reverse order. This time the caption read “This book is dedicated to the bond because the difference is the bond.” In other words, the thing separating outer space from the inner space of information machines was the very thing that bound them together: the cybernetic control of information. This kind of quasi-mystical, paradoxical formulation, (as I am arguing throughout this study) is characteristic of the discourse of techno-ecological systems. It dismisses the old binaries and either/or logic of modernity in favor of the radical both/and *il*logic of a “new era,” in which the artificial does not conquer nature but coevolves with it.

It is not hard to see why Brand was so drawn to Bateson’s ideas. They brought together two of his abiding frames of reference – the cybernetic whole-systems thinking of Fuller and the evolutionary ecology of Ehrlich – into a comprehensive model wherein the universe itself worked by thinking up ideas and trying them out, and by distributing information throughout decentralized, increasingly diverse and complex networks of interrelationship. At base, this was exactly the activity Brand saw himself engaged in through the *Whole Earth Catalog* -- channeling differences that make a difference. There was an underlying belief in the Whole Earth whole systems discourse that things would go much better for people and planet if civilization – from its technological developments to its economies and social infrastructures—used the laws of the universe, the principles of cybernetic whole systems, as a model for remaking itself. This belief combined the mystical goal of bringing human activity into alignment with the ways of nature, with the very practical matter of finding a way for humankind to flourish and evolve rather than render itself extinct by destroying its environment or blowing itself up. Where Fuller had emphasized technologies designed in accordance with universal laws of whole-systemness, Bateson emphasized a whole-systems perspective grounded in biological evolution. It was the combination of both within techno-ecological systems that would emerge as most promising in Brand's view. The idea of coevolution, which Ehrlich helped establish and Bateson elaborated upon, became a key concept for describing the relationship between the natural and the technological within the space of the techno-ecological system.

Coevolution

The contemporary concept of coevolution was introduced in a 1964 study of butterflies and their food plants by Paul R. Ehrlich and Peter H. Raven (Ehrlich and Raven 1964).[14] The thesis of their article was that the two had evolved together, each responding to changes in the other. This observation extended the reach of ecological relations into the very formation of species. As it developed, the concept of coevolution discouraged the view that each variety of life form follows its own evolutionary course independent of the creatures that share its environment. Rather, it was a more deeply ecological description of evolution, suggesting that every evolutionary course, including that of humans, involves a dense tangle of competitive and cooperative relations, "life growing every more richly on life," as Brand put it (Brand 1978, 5).

Bateson took coevolution a step further. In his analysis there were two great, interrelated systems at work in changing organisms. One, working over generations, changed them genetically. This was called evolution, and evolution, in Bateson's view, was a matter of relationship – horses and grass, for example, each changing in response to changes in the other (Bateson 1991, 271). The other system changed individuals somatically over the span of a lifetime. This was called *learning*, the process by which an entity responds reiteratively to difference. ". . . [T]hese two stochastic systems," Bateson wrote, ". . . fit together into a single ongoing biosphere that could not endure if either somatic or genetic change were fundamentally different from what it is" (Bateson 1979, 149). There is a "funny sort of imperfect coupling" between the two systems, Bateson said, but the same mechanism is at work in both – a process characterized by trial-and-error change-and-response through circuits of information feedback (Bateson 1991, 280). That is, learning could be thought of as a coevolutionary relationship between the conceptual world of mind and the physical world of matter (Bateson 1979, 51; Bardini 2000, pp. 56, 242-243).

This was the notion of coevolution at work in Douglas Engelbart's research on human-computer interface at Stanford in the late-sixties and seventies. Casting around to see what line of work might be most beneficial to the world, Engelbart had surmised in the 1950s that the central problem of the modern age was the inability of humans to keep up with life's increasing complexity. He was, of course, far from alone in his anxiety: the post-War cybersciences were in general aimed at managing complexity through the control of information. Engelbart's Augmentation of Human Intellect project, which he started at SRI in the sixties, was an effort to address the urgent problem of complexity by transforming computers into personal problem-solving tools. He called his approach "bootstrapping," a reiterative process by which his researchers used the problem-solving tools they were developing to help solve their further tool-development problems. The development process was, in other words, coevolutionary: researchers designed the machines; the machines required that the researchers learn new skills – using a mouse, for example—which new skills in turn facilitated further changes in the machines, and so forth. Engelbart's aim was to change not only computers but the users themselves. He believed that through their relationship with computers, people could be augmented physically and mentally so that they were better adapted for dealing with the increasing complexity so characteristic of post-War life (Bardini 2000). As a consultant to Engelbart's project, Brand participated in what came to be known in personal computing lore as the "the mother of all demos," Engelbart's unveiling of his newly developed interfaces at Stanford in 1968.

In effect Engelbart was designing the personal computer as a techno-ecological system, comprised of a person and a machine in coevolutionary relationship. It is important to note that this system was something different from that other post-War convergence of organism and mechanism, the cyborg. Cyborgs are a fusion of the fleshy and the machinic into a new kind of hybrid being. A techno-ecological system, in contrast, does not fuse the natural and the technological. Rather, it encompasses them in an ecological relationship. Just as Bateson's coevolving horse and grass did not meld into a new "horse/grass" entity but a system in which horses and grass are mutually formative, Engelbart's computer and user did not merge into a single hybrid being, but rather remained distinct, though mutually formative, components of a newly created system.

We might compare Engelbart's work at bringing together people and computers with that of his contemporaries working on artificial intelligence. There, the goal was a fusion of human and machine through the migration of consciousness onto a mechanical substrate. According to J. C. R. Licklider of MIT, AI researchers valued human-computer interfaces such as Engelbart's to the extent they made it possible to write AI programs.

They expected thinking computers to "take over" from organic bodies in the near future (Bardini 238n27). Techno-ecological systems, such as the one Engelbart was designing, required that natural and artificial components remain distinct; the functional essence of systemness lay in the relationship *between* them.

Thus, coevolution, as formulated by Ehrlich, expanded by Bateson, and practiced by Engelbart had become an important concept for Brand by 1974, when he founded *CoEvolution Quarterly*. By that time the *Whole Earth Catalog* had won the National Book Award and had generated enough funds for Brand to start a non-profit organization, Point Foundation, which granted money for a variety of cultural projects.[15] The magazine was organized much like the *Whole Earth Catalog*, with sections for Understanding Whole Systems, Land Use, Soft Technology, Community, Communications, Learning, and Craft. A newly-introduced category, called "Apocalypse Juggernaut, Hello," addressed matters of predicted environmental and economic catastrophe. Supported by Point and subscriptions, but no advertising, *CoEvolution Quarterly* was founded, Brand said, "to see what would happen if an editor were totally unleashed. I would print anything that kept me turning its pages" (Kleiner and Brand 1986, 329).

The articles that kept editor Brand turning pages were various but also fairly consonant with his interests in the life sciences, community politics, technology, religion and culture. The first issue included a lengthy article by Ehrlich, "CoEvolution and the Biology of Community." Early issues featured Gregory Bateson, Wendell Berry, Paul Ehrlich, a play by poet Michael McClure. The Fall 1974 issue was guest-edited by the Black Panther Party of Oakland, California. Conversations with public figures such as California governor Jerry Brown, Herman Kahn, Amory Lovins, Marshall McLuhan, Ken

Kesey and others appeared regularly. The Summer 1975 issue published the first of many articles on the Gaia hypothesis and also introduced a new section on personal computers. The following issue featured Gerard O'Neill's space colonies idea. *CQ* had a modest circulation of about 30,000 through most of its ten years, from 1974 to 1984, but it was unmatched as a conduit for the transmission of a whole systems perspective from scientific and technical circles into a broader cultural arena. As one observer said, *CQ* "helped like no other outlet to diffuse the particular mix of cybernetic thinking and evolutionary ecology that had its center in the notion of coevolution" (Bardini 2000, 243n.24).

The topics, people and perspectives that appeared in *CoEvolution Quarterly*, though multitudinous and wide-ranging, tended most often to meet at the intersection of nature, culture and technology. Like the *Whole Earth Catalog*, *CQ* understood itself to be operating within a pressing technosphere-versus-biosphere problematic. A radical change in the direction of technological development would be necessary if civilization were both to enjoy economic and technological progress and avert global ecological disaster. *CQ* was partly devoted to discovering and provoking discussion about alternatives for that change in direction. Many readers and contributers were oriented toward the pastoralist, limits-to-growth perspective. They rejected the space colonies idea and would resist the Whole Earth turn toward computers in the eighties. But the magazine's frame of reference was always *whole systems*, grounded in post-War theories of information and adaptation. Thus, the alternatives that seemed most interesting and promising – soft tech, space colonies – brought nature and technology together based on cybernetic, whole systems principles. *CQ* and the Whole Earth whole systems discourse modeled the planet as a techno-ecological system (biosphere, Spaceship Earth), and the best hope for the future seemed to it likewise to be found in techno-ecological systems.

From the standpoint of remaking civilization, soft tech and space colonies proved to be failures. As we saw in Chapter Five, the space colonies idea had fizzled out after the brief flurry of activity that surrounded it in the late seventies. Even if the political will to proceed with the project had been mustered, the concept of building a self-sustaining ecosystem that includes humans was untenable from the start given the conflicting, dual requirements of system sovereignty and human control. Biosphere 2 would bear this out in the early nineties.

Soft tech was not a thoroughgoing solution to the problem of technology either, though it was for most of *CQ*'s ten years the most favored alternative. Whatever political, economic, technical, or cultural forces might also have been responsible for its lack of widespread success, soft tech ultimately could not fully succeed within the Whole Earth whole systems discourse itself. Though soft tech could be framed in whole systems terms, it could not avoid being a limits-to-growth-type solution to the technosphere-versus-biosphere problem, rather than a solution that could salvage both technological progress and environmental sustainability within a context that comprehended and preserved the complexity of whole systems. Soft tech promised only a self-restricting world of steady-state economics and modest technological innovation well within human powers to control. It understood people to be dangerously outside of nature, and in need of "synthesis and integration" (Baldwin and Brand 1978, 6). While it may have been an "evolutionary start," as Baldwin called it, it was not a *coevolutionary* one.

A coevolutionary techno-ecological system would entail a fundamentally different model of the relationship between people and nature. Soft tech was aimed at adapting humans to their environment by adopting controllable technologies with containable consequences. It meant trying to eliminate the random and unexpected. Within a coevolutionary techno-ecological system, however, people and machines would be co-adaptive. The evolutionary changes in any system component could, and generally speaking *should*, reverberate unpredictably, uncontrollably, throughout the system, as they do in ecosystems. If it was an adaptive mutation, it would survive, and the system would evolve into something new. Certainly people were not as proficient as evolution at generating variety, the new ideas of the ecology of mind, nor at deciding which of those ideas were good ones. Such new ideas emerged of their own, from the randomness inherent in complex, adaptive systems. As Bateson argued, an element of randomness was essential to coevolution (and thus to techno-ecological systems), for “without the random there can be no new thing” (Bateson 1979, 147). Rather than trying to control every change – “the pathology of insistent control and guaranteed frustration,” as Brand said—it was best to set a complex techno-ecological system in motion and let its components coevolve on their own, for this was the way of the universe itself.[16]

Soft tech assumed the romantic-pastoralist view that people, though they had gotten themselves expelled from the Garden, rightly belonged within nature, and should struggle to get back in. Whether people were inside or outside nature was not even the relevant question in coevolutionary techno-ecological systems, however. Rather, humans were located fully inside the system, encompassed within a complex network of relationships with other, mutually formative natural and technological constituents.

People were also simultaneously fully outside as well, paradoxically empowered to ensure the whole-systems principles of self-sovereignty for the system that subsumed even them. Neither soft tech nor space colonies could pull it off. But personal computers, if they could somehow become cheap and widespread enough, and interconnected over vast decentralized networks, might be a different matter.

Access to Cyberspace

In early 1983 Stewart Brand was asked by the Western Behavioral Sciences Institute of La Jolla, California, to teach corporate executives for six-months in their School of Management and Strategic Studies. They gave him a Kaypro personal computer through which he connected to about forty students located throughout the country. Brand described the experience as “a cold plunge into teleconferencing that swerved my life toward personal computers. . .[T]he project . . . revolutionized my writing, my thinking, my work network, and my business” (Brand 1984, 139). By the summer of 1983 Brand had secured a $1.3 million advance from Doubleday to publish the *Whole Earth Software Catalog* and a companion magazine, the *Whole Earth Software Review*.[17] His perception was that personal computers were changing the “human frame of reference.” The placement of machines that “mimic, enhance, accelerate thought,” into the hands of individuals, not just governmental and commercial institutions, represented a shift in the balance of power. The kind of invention computers made possible could now originate from anyone. “That’s news that stays news,” he wrote, “and good news at that, in the main” (p. 2). The *Whole Earth Software Catalog* and *Whole Earth Software Review* were intended to help individuals use the computer effectively as an interactive tool of invention and life enhancement, to encourage the refinement of personal computing into a craft by providing access to the best in available software.

Out of the advance they received for their new publishing venture, Brand and company acquired their own minicomputer, conferencing software, modems and other equipment for setting up a network of farflung writers and editors. This network, which Brand opened up to the world at large in 1985, became the WELL (Whole Earth 'Lectronic Link). One of the first, and still one of the most successful virtual communities, the WELL was a cultural experiment in bringing spatially separated people together in an electronic medium so that they could talk with one another, exchange information and ideas, share common interests and concerns, and generally function as a community. It was an example of how "local" no longer meant merely geographic, as Brand had said back in 1978. According to veteran WELL dweller Howard Rheingold, Brand "started a low-rules, high-tone discussion, where savvy networkers, futurists, misfits who had learned how to make our outsiderness work for us, could take the technology of CMC [computer mediated communication] to its cultural limits" (Rheingold 1992).

The WELL's first participants included the various regulars associated with the Whole Earth endeavor. As Rheingold described them, they were "the granola-eating utopians, the solar-power enthusiasts, serious ecologists, and the space-station crowd, immortalists, Biospherians, environmentalists, social activists." Another primary subgroup consisted of computer hackers, the "young iconoclasts who wanted to have whizzy tools and change the world," as well as "the grizzled old hands who were still messing with mainframes." Added to these two populations were the deadheads, the community of Grateful Dead fans "looking for a place to happen" (Rheingold 1992).

Once again elements of the counter-culture had come together with computer hackers, drawn by the promise of refashioning the world through information technologies. From this initial amalgamation, the WELL population grew rapidly, to more than 10,000 participants in the nineties.

Completing his immersion into the world of computers in the eighties, Brand spent several months in 1986 investigating the digitalization of telephony, print, and broadcast media at the Massachusetts Institute of Technology's Media Lab. His book, *Media Lab: Inventing the Future at MIT,* was published in 1987. In it Brand took a careful look at the cutting-edge projects underway at MIT – electronic publishing, speech recognition, the digitalization of television and movies, holography, computer animation, and many other dimensions of digital media prevalent today. Brand then examined ways in which such developments could be expected to affect the world, concluding that the new media were "the opposite of industrial machines." Quoting the Media Lab's Jay Ogilvy, Brand stated, "Their function is not the production of same-same-same, but the endless creation of a 'different different difference, because it if it's not different, it's not information" (Brand 1987, 263). Brand must have been gratified to see his mentor Bateson's definition of information now circulating in the very point of origin for new information technologies. Much as Engelbart had hoped for personal computers, Brand saw digital media at MIT as "instruments of culture," "connecting, diversifying, increasing human complexity" (*ibid*).

Brand embraced digital technologies at a point when they first began to effect long-term transformations in the way people would work, play, invent, learn, do business, and communicate. Personal computers had emerged from the place where countercultural dreams of remaking civilization met cybernetic models of information and adaptation – exactly the point of techno-ecological convergence Brand had long occupied. In the eighties personal computers seemed suddenly to be fulfilling their incipient promise: they were a powerful tool available to individuals; they were machines that seemed compatible with both technological progress and ecological well-being; and they were being put to unexpected, potentially transformative uses. In critical ways, the WELL, for example, functioned like the communes Brand had first catered to in the sixties, like the space colonies he had hoped might materialize in the seventies: as an outlaw cultural area, a place where technology was not at war with nature and individuals were free to experiment with new modes of being, new relationships with nature, technology and one another. It was perhaps no accident that Brand selected as the WELL's first director Matthew McClure, a former denizen of the Farm, a long-surviving sixties-era commune. Cyberspace seemed like the sort of space – outside the usual rules of civilization, but attuned to the whole systems rules of the universe—to which Fuller had attributed the great inventive leaps of humankind's past.

Information ecology

Personal computers made possible the techno-ecological systems the Whole Earth whole systems discourse had always been pointed toward. At the individual level, they formed coevolutionary learning relationships with their users. Networked together they formed information ecologies, decentralized, diverse, self-organizing, complex and adaptive. Throughout his *Whole Earth Catalog* and *CoEvolution Quarterly* years, Brand had always felt he was "purveying biological metaphors" (Brand 2001). He did not stop with his plunge into personal computers, for nothing explained the new information environment quite as well as life. In his introduction to *Media Lab*, Brand quoted business writer Peter Drucker:

> Three hundred years of technology came to an end after World War II. During those three centuries the model for technology was a mechanical one: the events that go on inside a star, such as the sun. . . Since the end of World War II, however, the model of technology has become the biological process, the events inside an organism. And in an organism, processes are not organized around energy in the physicist's meaning of the term. They are organized around information (Brand 1987, xiv).[18]

Casting about cautiously for a proper metaphor to describe the emerging world of digital media, Brand wrote, "The human communications environment has acquired biological complexity and planetary scale, but there are no scientists or activists monitoring it, theorizing about its health, or mounting campaigns to protect its resilience." He imagined "ecologists of communications" who might step in to ensure diversity, guard against imbalance, warn of maladaptive practice, like the best biological ecologists -- his old teacher Ehrlich, for example.

We can see just how thoroughly Brand imagined the new information environment to be fulfilling the Whole Earth whole systems ideal by looking at a book proposal he wrote in 1989. The book was never written, but Brand published the proposal in *Whole Earth Review* in 1990, hoping someone else might take up the task of writing it. The title was to be *Outlaws, Musicians, Lovers, and Spies: The Future of Control,* and its contents were to hit on most of Brand's favorite themes. In the emerging information environment, the proposal stated, the old rules of economic and cultural control were being overturned. The new tools of communication were transferring power to individuals. Computers were becoming too dispersed to be controlled by centralized bodies, such as governments or corporations. The "real exploration" going on with digital technologies now was “*pre*commercial.” And it was being conducted by “invisible elites such as librarians, disabled people, programmers, black marketeers, outlaws, musicians, lovers, spies” (Brand 1990, 130). “What people actually do with new media,” Brand claimed, based on now two decades of new-media experience, “is fall in love – with the new medium and with fellow enthusiasts.

> Like musicians they revel in complex new fluencies, delight in composing new works, and become artists, creating beyond themselves. As the rest of the culture lags behind, they find themselves ahead of the laws, limited only by what’s possible rather than what’s decreed. Like spies, they traffic in secrets, explore the hidden real structure of society, and influence events from behind the scenes. Often their unruly inventions become civilization’s tools (p. 131).

Powerful tools were now in the hands of creative, self-directed individuals, who were using them in unregulated, unpredictable ways to remake civilization—in short, the Whole Earth dream come true.

At the core of this transformation was a Batesonian paradox:

> Information wants to be free (because of the new ease of copying and reshaping and casual distribution), *and* information wants to be expensive (it’s the prime economic event in an information age). . . and technology is steadily making the tension worse. If you cling blindly to the expensive part of the paradox, you miss all the action going on in the free part. The pressure of the paradox forces information to explore constantly. Smart inventors and marketers quietly follow (ibid).[19]

The both/and *il*logic of techno-ecological systems was the key point to recognize in the new information environment. As was characteristically the case with the Whole Earth whole systems discourse, the presence of paradox signaled that hidebound rules were changing and a new order underway.[20] “The emerging communications process,” Brand wrote, “is simultaneously self-subversive and self-organizing, deeply at odds with our cultural and economic habits” (p. 131). “Self-subversion” suggested that transformative counter-cultural mechanisms were built into the new environment; "self-organizing" signaled that the new environment operated on the principles of whole systemness – just the potent mix of sixties radicalism and cybernetics Brand had always cultivated.

To understand how this new information environment works, Brand suggested, one needed to see it as an ecosystem.[21] Control no longer emanated from a central location on high. Rather, it came from below, dispersed throughout the complex network of interconnected nodes. "'Control,'" Brand said, "is increasingly seen in the feedback sense – the innumerable tiny local adjustments that keep a market economy or an ecosystem resilient and adaptive. No one's in charge, but the system flourishes" (p. 132). Control, in other words, was a decentralized function of the system itself, a self-regulating mechanism emerging from the complex pattern of interconnection. It was not something in the hands of the powerful few. This was revolutionary and desirable, from Brand's point of view. The closer civilization moved to the whole systems wisdom of the universe the better, for it promised not merely survival, but continual growth, wild diversity, unimagined newness.

The Future of Control

This basic model of the new information environment of the late-eighties and nineties – built upon the unlikely combination of hippie dreams of cultural liberation and post-War theories of information and evolution – would become widespread thanks in no small part to the Whole Earth network of media and contacts. The WELL, for example, became a widely consulted marker of the emerging information culture. The conversations on the WELL entailed much more than friendly chatter among acquaintances, though that was valued, too. Articulate, informed, and prescient discussions among experts and aficionados in emerging fields drew considerable attention from outside. As Rheingold reported, "*The New York Times*, *Business Week*, the *San Francisco Chronicle*, *Time*, *Rolling Stone*, *Byte*, the *Wall Street Journal* all have journalists that I know personally who drop into the WELL as a listening post. People in Silicon Valley lurk to hear loose talk among the pros" (Rheingold 1992).[22] *Whole Earth* editor Kevin Kelly would write frequently about the new information environment and publish a widely read book, *Out of Control*, in the early nineties. Kelly would also serve as an editor for *Wired* magazine, the publication perhaps most responsible for articulating and promoting the culture and values that would rise up around the information economy of the nineties. Brand would also develop ties to *Wired*, as well as to the Santa Fe Institute, an independent research facility devoted to the new sciences of chaos and complexity. Beginning in the late eighties Brand would become co-founder of the Global Business Network, a consulting firm concerned with helping businesses model and plan for the future. Through all these connections and more, the Whole Earth whole systems discourse found its way into the global information economy.

The vast territory of the information economy and culture that defined the 1990s is in need of careful mapping. However, since this study is concerned foremost with the intersection of technology and ecology, I want to map only a part (though an extremely significant part) of that territory by underscoring two prominent manifestations of how the global information environment came to be understood in ecological terms. The first example is Kevin Kelly's "neo-biological civilization." The second is Michael Rothschild's "bionomics." One of my hopes for this study as a whole is that it will help make clear just how central ecological ideas have been in shaping a culture-wide discourse of information technologies. In terms more appropriate to the subject, I want to suggest that in the post-WWII era ecology and information technologies have been in a coevolutionary relationship, together serving as mutually formative components of the techno-ecological system of the contemporary global information environment.

Brand’s motives in providing access to tools and ideas were remarkably consistent: he wanted a world in which technology and nature were compatible, in which individuals were empowered to invent and explore, in which nature’s diversity and creativity, its integrated wholeness and endless invention were replicated in human technology and civilization. His impulse was to encourage freedom, equity, health and justice, to promote humane values, especially in the development of new technologies. His interests in biology, cybernetics, information technologies and much else originated in a desire to improve human lives, as his many charitable efforts and his own writing attest.

As his Whole Earth whole systems discourse found its way into the culture and economy of the nineteen-nineties, however, its most generous, communitarian, world-saving motivations were left behind. The global information environment was widely interpreted in ecological terms, thanks in significant ways to the Whole Earth discourse. But instead of leading to the Whole Earth ideal, it came to justify the technoscientific adventurism of “neo-biological civilization,” and the unrestrained global marketplace defined as “bionomics.” How this happened, I suggest, is in significant ways a function of the very figure Brand mid-wifed and placed his hopes in: the techno-ecological system.

Notes

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[1] Brand published the first *Whole Earth Catalog* in 1968. Other issues and supplements were published at irregular intervals into the 1990s. *CoEvolution Quarterly* began publication in 1974 as a supplement and journalistic offshoot of the *Catalog*. The *Whole Earth Software Review* began publication in 1984, providing evaluations and access to software for the personal computer. Later, Brand merged the *Whole Earth Software Review* and *CoEvolution Quarterly* into the *Whole Earth Revie*w. In addition to these serials, Brand's Point Foundation also released books -- *Space Colonies* (1977), *Soft Tech* (1978) – with content drawn from the *Catalog* and *CQ,* as well as other sources. Brand has also authored a number of books himself, including *Two Cybernetic Frontiers* (1974), and *Media Lab* (1984).

[2] Brand wrote that he preferred the term "soft tech" because "'soft' signifies that something is alive, resilient, adaptive, maybe even loveable." "The other terms," he wrote, "are administrative" (Baldwin and Brand 1978: 5).

[3] John and Nancy Todd founded the New Alchemy Institute in 1969. The Todds' left the institute in the early 1980's, after which it evolved into an educational facility called The Green Center. In the 1980s the Todds founded Ocean Arks International, an organization devoted to ensuring the health of the oceans, and Living Technologies, Inc., a company producing eco-friendly systems combining low technology and sophisticated ecological knowledge. John Todd, who has won numerous design awards and now also teaches at the University of Vermont, credits Howard T. Odum (see Chapter 2) with inspiring him to create sustainable human-nature systems. "I would characterize my life as one of the first people to attempt to decode the language of nature and use it as a blueprint to design the infrastructures of human society," Todd states (http://www.enviroeducation.com/interviews/john-todd/). Todd, like architect Paolo Soleri, was a mainstay of the *CoEvolution Quarterly* discussions of environmentally sustainable design in the 1970s.

[4] In his discussion of the *Whole Earth Catalog* and environmentalism, Andrew Kirk identifies "appropriate technology" and "information technology" as two distinct but comparable paths pursued in the pages of Brand's publications. I am arguing that over time information technologies appeared to Brand as more promising than soft technology for empowering individuals, in part for reasons inherent in the whole systems discourse that framed Brand's views of nature and technology. I also argue, as Kirk does not, that the place of information technologies within the Whole Earth discourse depended upon a perception of them as part of an order of technology that shared with nature universal principles of whole systemness (Kirk 2001).

[3] There is abundant evidence of the negative ecological impact of computer hardware and chip manufacture. Abandoned machines heaped into dumps, for example, can leach dangerous metals into soil and water. Also, the network of computers around the world ultimately depends upon a supply of electricity that comes from burning coal and gas, from damming rivers, from nuclear fission and other ecologically detrimental sources. And of course, far from replacing environmentally destructive industrial practices, information technologies have often been instrumental in advancing their global reach by facilitating the movement of capital, labor and goods in the global economy. For reasons described in this

chapter, it has been easy for the discourse of information technologies to overlook these ecological incompatibilities. Asked in 1996 how computer-based technologies have affected the environment, Brand responded, "We're still in the early part of the curve on these things. Computers have made for greater material and energy efficiency, less need for physical transport, more widespread intelligence basically throughout civilization and culture. All of those things are good news for the environment" (Earth Action Network 1996).

[6] Space War obviously was based on a premise of militarized violence. How did this square with the sentiments of those California hackers looking to use information machines to resist the war in Viet Nam? Brand saw no implicit militarizing threat in Space War because, more than anything, it represented creative, spontaneous, cooperative experimentation with technology. "Spacewar serves Earthpeace," he wrote. "So does any funky playing with computers, any computer-pursuit of your own peculiar goals, and especially any use of computers to offset other computers" (Brand 1974: 77). Brand served in the U.S. Army from 1960 to 1962. He taught basic infantry training and worked as a photojournalist out of the Pentagon. In 1967 he designed and organized "World War IV," public war games at San Francisco State College.

[7] Brand recognized, of course, that business and military institutions also had a good deal to do with the development of computers. The transformation of computers into machines for "the people," he wrote in 1972, "owes its health to an odd array of influences: The youthful fervor and firm dis-Establishmentarianism of the freaks who design computer science; an astonishingly enlightened research program from the very top of the Defense Department; an unexpected market-flanking movement by the manufacturers of small calculating machines; and an irrepressible midnight phenomenon known as Spacewar" (Brand 1974: 39). In a similar vein, historian Roy Rosenzweig writes, "The rise of the Net needs to be rooted in the 1960s – in both the 'closed world' of the Cold War and the open and decentralized world of the antiwar movement and the counterculture" (Rosenzweig 1998: 1531). What mattered most to Brand was the *appropriation* of tools, from whatever source, by creative individuals.

[8] The poem first appered in the sixties in the underground newspaper *The Realist*, later in Brautigan's 1973 book, *The Pill Versus the Springhill Mining Disaster*.

[9] In the early seventies, Lee Feldstein and Efrem Lipkin, inspired by Brautigan's poem, gave the name "Loving Grace Cybernetics" to the parent company of Community Memory, their project to bring computers to the people. They placed an easy-to-use terminal in a Berkeley record store, where it was available for free for the public to post notices, sell cars or furniture, seek apartments, offer services, or just submit musings and opinions. At one point the terminal moved to the Whole Earth Access Store and a second terminal was placed in a San Francisco public library. For a year and a half Community Memory operated as the first online, searchable bulletin board (Levy 1984; Freiberger and Swaine 1984).

[10] Snyder's "Four Changes" essay, from which this quote is taken, first appeared in his book, *Turtle Island*, 1969, and was reprinted in *The Last Whole Earth Catalog*, 1971.

[11] The anthropologist Mary Catherine Bateson, the daughter of Gregory Bateson and Margaret Mead, published her account of this conference, *Our Own Metaphor*, in 1972.

[12] Of Bateson's influence on him, Brand wrote, "Bateson has informed everything I've attempted since I read *Steps* in 1972. Through him I became convinced that much more of whole systems could be understood than I thought. . . that mysticism, mood, ignorance, and paradox could be rigorous, for instance, and that the most potent tool for grasping these essences – these influence nets – is cybernetics" (Brand 1980).

[13] Bateson told Brand, "If the idea of having one eye on each side of your nose lasts longer than the idea of three eyes – one in your forehead and one on each side – then the one which lasts longer lasts longer. Natural selection does not deal with you, who obviously don't last very long, it deals with biological ideas in genomes – programs. The unit of evolution is ideas, it's not organisms" (Brand 1974: 36).

[14] *Coevolution*, which has its origins in Darwin's concept of coadaptation, is defined in ecology as "reciprocal evolutionary change in interacting species" (Thompson 1982: 3). The term had been used prior to the mid-sixties, but it was Ehrlich and Raven's study that established it within the evolutionary sciences. Some earlier studies had employed a similar concept, called "genetic feedback" (Bardini 2000: 243).

[15] The Princeton conference on space colonies, through which space-colonies advocate Gerard O'Neill first gained national exposure, for example, received a grant from the Point Foundation. See Chapter 4.

[16] The science of complexity began gaining momentum in the late seventies and early eighties. The Santa Fe Institute, for example, on whose board of trustees Stewart Brand served, formed in 1984. The Institute was, it stated, "devoted to creating a new kind of scientific research community, one emphasizing the common themes that arise in natural, artificial, and social systems."

[17] The inaugural issue of the *Whole Earth Software Review* appeared in the spring of 1984. The *Software Catalog* was published later the same year. By the end of 1984 budget constraints at Point Foundation led to the consolidation of *CoEvolution Quarterly* and *Whole Earth Software Review* into the *Whole Earth Review*, the first issue of which was published in December 1984.

[18] The quote is from Drucker, *Innovation and Entepreneurship*, 1985.

[19] Brand made this paradoxical claim about the desires of information in *Media Lab*. By the 1990s the first half of it – "Information wants to be free" -- was an often repeated slogan for civil liberties on the Internet (Electronic Frontier Foundation), and for unrestrained commerce in the global information economy (bionomics). Paulina Borsook, in *Cyberselfish*, points out that the Silicon Valley libertarians of the nineties characteristically left the "expensive" half of the paradox out of their sloganeering. They made the mistake Bateson warned of back in 1973: "not riding with the contradiction." See Borsook (2000).

[20] As I have pointed out in various places throughout this study, the both/and logic of the whole systems discourse has its origins in the quantum postulate, which subverted the linear, either/or logic of classic physics around the turn of the century and opened the door for a radically new understanding of the universe. The Whole Earth whole systems discourse

worked in part by employing both/and logic in a continuing process of subverting the categories and arguments of a previous era in favor of the radically new.

[21] For a later example of how ecology could be used to steer the discourse on information technologies see Nardi, *Information Ecologies* (1999).

[22] As Bruce Sterling writes in Hacker Crackdown, “Though the WELL was peopled by chattering hipsters of the Bay Area counterculture, it was by no means a ‘digital underground’ board. Teenagers were fairly scarce; most WELL users. . . were thirty- and forty-something Baby Boomers. They tended to work in the information industry: hardware, software, telecommunications, media, entertainment. Librarians, academics, and journalists were especially common on the WELL, attracted by Point Foundation’s open-handed distribution of ‘tools and ideas’” (Sterling).

CHAPTER 6
THE TECHNO-ECOLOGICAL SYSTEM TAKES COMMAND: GAIA, THE NOÖSPHERE, NEO-BIOLOGICAL CIVILIZATION, AND BIONOMICS, 1975-1995

The previous chapter examined the place of information technologies within the Whole Earth whole systems discourse. It showed how information technologies came to be understood as tools for empowering individuals, in the hope of fashioning a world in which technological progress and ecological sustainability were not mutually exclusive. Within this discourse, the new information environment of the nineteen-eighties and – nineties came to be understood as a techno-ecological system, operating according to the same whole-system laws governing the complex, living things of the natural world.

This chapter looks at other applications of the techno-ecological system that owed much to the Whole Earth discourse, but operated beyond it – the Gaia hypothesis, the noösphere, neo-biological civilization, and bionomics. In each case technology and nature were brought together on the common ground of whole systemness. These systems made possible a vision of the future in which technology was not only compatible with nature but an extension or expression of it.

As we have seen throughout this study, the location of people is always a central question raised by the figure of the techno-ecological system. Gaia, the noösphere, neo-biological civilization and bionomics all depended upon a displacement of humans from the center of the relationship between technology and nature. The systems, in essential ways, asserted that technological development, to the extent it conformed to the universal laws of whole systemness, was beyond human control.

This forfeiture of control over the technological future – to life, to evolution, to the laws of complex whole systems – relieved the burden imposed by the old technosphere-versus-biosphere problematic: that humans were responsible for bringing the biosphere to the brink of disaster through the heedless proliferation of dangerous technologies and the pursuit of endless economic expansion. Such a scenario demanded that future technological development proceed only with the utmost caution. In the emerging discourse of the techno-ecological system, however, technological innovation could proliferate without restraint, in imitation of the fecundity and ingenuity of nature itself. Humans were the conduits and instruments of larger forces pushing life in new directions, beyond the natural into the artificial, toward a richer, more robust, diverse, and adaptive future.

In the information economy and digital culture of the nineteen-nineties, this discourse came to justify unrestrained technological adventurism and an expansionist, global information economy. Ultimately, as the prospects of “neo-biological civilization” and “bionomics” show, it resisted criticism by enfolding the global deployment of whole system information technologies into the natural history of the planet itself. Where the Whole Earth whole systems discourse held the welfare of humankind as its guiding value, the techno-ecological systems examined here made the integrity of the system itself the top priority. In practice, this meant promoting the unimpeded advancement of late-twentieth-century technoscience and the libertarian values of global laissez-faire capitalism that defined the new information economy.

The Gaia hypothesis

The Gaia hypothesis began as a way of envisioning the Earth as a whole system. In the nineteen-sixties and seventies British scientist and inventor James Lovelock was a consultant with NASA, working on the question of whether life might be found on Mars. His central insight was that the Martian atmosphere itself should reveal whether or not the planet supported living things. If there were life on Mars, Lovelock reasoned, one should be able to detect in its enveloping gases evidence of respiring organisms on the surface. After all, examined from space, one of the Earth's most remarkable and distinguishing features was the unlikely mixture of elements in its atmosphere. The Earth's air was full of reactive gases of biological origin, including ammonia, methane, nitrogen and sulfur oxides. The composition of its atmosphere in fact depended upon the life on its surface. In Lovelock's view NASA could save itself the trouble of sending a probe to Mars; he could tell from Earth that the planet was lifeless.

Whatever the value of this insight to the exploration of Mars, it struck Lovelock as an important statement about the Earth. Viewed from space, the whole Earth revealed itself as an integrated system. The image of biological beings superimposed upon the lifeless rock of a planet was in error. Instead, life on Earth shaped and determined the physical and chemical composition of the planet, just as the physical planet shaped and determined the character of life. At the planetary scale, Lovelock concluded, the living and the non-living were mutually formative.

Such a view of Earth suggested that a number of ideas about planetary life needed to be reconsidered. First, life exists planet-wide or not at all. Anything less would be as implausible as half a cat, according to Lovelock (Lovelock 1988). The quantity and distribution of organisms would need to be sufficient to regulate the planetary environment and keep it comfortable for living things. Second, Darwin's concept of adaptation needed to be revised. Species do not merely adapt, through evolution, to the environment they find themselves in. They continually change their physical and chemical environment. Species and environment co-evolve in an indivisible process.[1]

Viewed as a whole integrated system, the Earth could be considered a single living organism in its own right, in Lovelock's estimation. It was self-organizing and self-regulating; through cybernetic circuits of negative feedback, the planet maintained itself in dynamic equilibrium, just as an individual organism maintains homeostasis. Lovelock's neighbor, novelist William Golding, suggested "Gaia" as a name for this planetary organism, from the ancient Greek goddess of the Earth. What was needed for the study of Gaia, Lovelock decided, was not separate disciplines such as geology and biology, but an interdisciplinary science of the planet-as-body: "geophysiology."

Lovelock generated little interest in Gaia with his first publication, a one-page article titled "Gaia as Seen Through the Atmosphere," which appeared in the journal *Atmospheric Environment* in 1972. But that year he began a series of conversations about Gaia with American microbiologist Lynn Margulis. The two of them collaborated on an article, "The Atmosphere as Circulatory System of the Biosphere – the Gaia Hypothesis," which was rejected by *American Scientist* but soon after published in Stewart Brand's *CoEvolution Quarterly* (Margulis and Lovelock 1975).[2] When Brand first approached Margulis about publishing the article, she balked at the idea of it appearing in something other than a professional journal because she feared scientists would not take it seriously. "What do you care what people think?" Margulis remembered Brand saying. "You want to see the Gaia idea out, don't you?" (Margulis 1998: 4). The Gaia hypothesis was vigorously discussed by scientists and laypersons alike in the pages of *CQ* for the next ten years.

The scientific community did begin to debate the Gaia hypothesis seriously upon the publication of Lovelock's book, *Gaia: A New Look at Life on Earth*, in 1979. An "epochal" five-day conference devoted to discussing Gaia was convened in 1988 by the American Geophysical Union. Cosponsored by NASA, the National Science Foundation, and the Mitre Corporation, the conference attracted 150 scientists from around the world.[3] In addition, the Lindisfarne Association, founded by William Irwin Thompson, became a think tank for Gaian topics and their implications for world culture. Early supporters of this group included, along with Lovelock and Margulis, E.F. Schumacher, Gregory Bateson, Stewart Brand, cybernetics pioneers Humberto Maturana and Francisco Varela, and John Todd of the New Alchemy Institute.[4]

Lovelock used his second book on Gaia, *The Ages of Gaia: A Biography of Our Living Earth* (1988), to answer specific criticisms of his hypothesis, especially the charge that Gaia was teleological. How could the variety of living things on Earth have the foresight to coordinate their activities in such a way as to optimize their own environmental conditions, Lovelock's critics asked. Assigning subjectivity to nature was a grave mistake in the conduct of science. The Gaia hypothesis, some scientists thought, described the regulation of planetary conditions but failed to supply an explanatory mechanism (Lovelock 1988, pp. 31-33). In response, Lovelock came up with Daisyworld, a simple computer model that showed how a planet could maintain itself at a steady temperature even when the radiant heat from its sun was not constant.

Daisyworld contained only one type of living thing, daisies, which came in light, dark, and neutral-colored varieties. Daisies would grow only above a certain minimum temperature and would die if conditions got too hot. Dark daisies absorbed heat and so thrived at lower temperatures. As their numbers increased, the planet's average temperature rose, creating conditions more favorable for light daisies, which reflected heat. With greater numbers of light daisies, the Daisyworld temperature tended to drop, opening up new opportunities for dark daisies. Through the flux of light, dark, and neutral daisy populations, Daisyworld maintained a constant temperature even as the heat it received from its sun increased. Though extremely simplified, this model, argued Lovelock, showed how cybernetic mechanisms of self-regulation on Earth could emerge on their own, and be explained without recourse to teleology.

The Gaia hypothesis also led Lovelock to reassess global environmental problems. In his view, too much attention was paid by environmentalists to problems of industrial pollution, ozone depletion, and the risks of nuclear radiation. Those were perturbations that presented no serious threat to Gaia. Through her mechanisms of self-regulation Gaia could compensate over time. What was of greater risk to Gaia was deforestation and the depletion of biota in the oceans. The forests and oceans were the very instruments of Gaia's self-regulation. Altering them significantly could trigger a major change in her physiology, something perhaps akin to what happened in the Archean period, when the accumulation of microbes first oxygenated the planet's atmosphere. Even with another such major change in her physiology, however, Gaia would live on, as she had before.

This shift in environmental concern followed from a more subtle but more profound implication of the Gaia hypothesis: that humans were not the planet's primary concern. From a Gaian perspective, humans were a species like many others. They could alter their own environment, but they could not destroy the living planet. Gaia existed, even in radically different form, long before humans arrived, and she would exist in some form long after humans were gone. As far as industrial pollution and chemical poisoning were concerned, Lovelock said, "the complaint comes not from the patient but rather from the intelligent fleas that infest her" (Lovelock 1988, 155). What's more, it is normal for Gaia to undergo radical transformations that result in a "regime change" among species. The very worst humans could do was trigger or hasten such a change and precipitate the overthrow of their own kind.

> From the long Gaian view, the evolution of the environment is characterized by periods of stasis punctuated by abrupt and sudden change. The environment has never been so uncomfortable as to threaten the extinction of life on Earth, but during those abrupt changes the resident species suffered catastrophe whose scale was such as to make a total nuclear war seem, by comparison, as trivial as a summer breeze is to a hurricane. We are ourselves a product of one such catastrophe. Could it be that we are unwittingly precipitating another punctuation that will alter the environment to suit our successors? (*ibid*.: 153-154).

From the Gaian perspective, advanced industrial civilization was mostly a danger to itself, a view that differed markedly from that of mainstream environmentalism. The most powerful environmentalist warnings held that modern civilization was bringing the entire biosphere to the brink of failure. In his influential book, *The Closing Circle* (1971), Barry Commoner warned that the system of life on Earth was "being driven towards collapse." "Here," he wrote, "is the first great fault of the life of man in the ecosphere."

> We have broken out of the circle of life, converting its endless cycles into man-made, linear events: oil is taken from the ground, distilled into fuel, burned in an engine, converted thereby into noxious fumes, which are emitted into the air. At the end of the line is smog. Other man-made breaks in the ecosphere's cycles spew out toxic chemicals, sewage, heaps of rubbish – testimony to our power to tear the ecological fabric that has, for millions of years, sustained the planet's life (Commoner 1971: 12).

It was the position of Commoner and many others that polluting the planet with toxins and sewage was leading toward the destruction of life on Earth. In Lovelock's view, this made no sense. Such activities might make things unpleasant for humans and a few other species, but they hardly bothered Gaia at all. Obviously, sewage created a delightful environment for certain microbes, for example.

Paradoxically, though the Gaia hypothesis was more profoundly ecological than even the most militant environmentalism up to that point, it suggested humans need not worry so much about the environmental impact of industrial civilization. Lovelock lamented the presence of smog and the loss of the idyllic English countryside to mono-crop agribusiness, but, he admitted, his sorrow was mostly selfish. He wanted the world to be pleasant for his generation and the generations of humans to come, but the Gaia hypothesis made clear that optimizing environmental conditions for humans was not the planet's priority. In response to this sobering thought, Lovelock urged individuals to each find their own way to live harmoniously with Gaia, hoping that the activities of individuals who improved their environmental conditions might spread species-wide, which is what tended to happen among the populations of other species (Lovelock 1988: 235-6).[5]

Gaia was not a fragile, delicate "Christmas tree ball," as Apollo 8 astronaut William Anders had described the Earth on his trip home from the moon.[6] She was, rather, robust, endlessly adaptive and inventive, and quite nearly indestructible. The idea that people might break out of the "circle of life" was altogether impossible from a Gaian perspective. People simply didn't have that much power over the mighty and ancient world they inhabited.

It was not that Lovelock and environmentalists like Commoner disagreed on how the biosphere worked. Both parties understood global ecology in terms of cybernetic systems: the circulation of materials and flow of energy; the natural oscillations of a dynamic equilibrium; adaptation to external changes through feedback loops. Their differences came from where they placed people relative to the rest of the planet. For Commoner, people were outside of nature, with power over the fate of the world. For Lovelock, people could be nowhere but inside the living, planetary whole system. They could make decisions affecting their own fate within that system, but ultimately the system was self-sovereign.

Self-sovereignty is a requirement of complex, adaptive, self-organizing whole systems, as we have seen. Without it, they cannot be called whole systems in the sense that mattered to Brand, Buckminster Fuller, Gregory Bateson, James Lovelock and others shaping the whole-systems paradigm. Gaia’s self-sovereignty meant there was a power and a wildness to the planet that far exceeded human control, something conventional environmentalist thinking failed to grasp. The recognition of this wildness and the limits of human power was sobering and humbling, but it could also be something of a relief. The Gaia hypothesis permitted a kind of grateful submission to larger, uncontrollable forces not possible with Commoner-style environmentalism. Humans were not responsible for the welfare of the entire planet after all.

The implications of subsuming humans within Gaia were taken to their logical extreme, as we saw in Chapter 4, by Lynn Margulis’s son, Dorion Sagan. In *Biospheres* (1991), he argued that from a Gaian perspective, everything on the planet is natural, including technology. As an artifact of Gaia, he said, technology’s function was not to serve humans but to serve Gaia. He was unwilling to condemn flatly the changes in the environment wrought by modern civilization, since, first, one organism’s toxic environment may be another’s paradise, and, second, humankind’s alteration of the biosphere may well be an essential part of Gaia's evolutionary journey. Sagan speculated that in building artificial biospheres, such as the Biosphere 2 project, humans were serving as the means by which Gaia might reproduce herself and populate the galaxy with life.

The Gaia hypothesis, by disclaiming any difference between *natural* and *artificial*, wanted to place humans so radically inside the biosphere as to leave no possibility of an outside position at all. Lovelock had people exercising power over their own fate, though not the fate of the system that contains them. But, as Sagan saw, within the logic of Gaia, there was really no reason to grant humans the agency of self-determination, which was not afforded to any other species. In doing what they do, humans, like termites or plankton, contribute their part to the function of Gaia's great physiological systems. If, unlike other species, we have the idea that we determine our own fate, that idea itself must serve Gaia's ends – perhaps, as Sagan argued, by enabling the development of technologies that would someday provide for her reproduction. Under conditions of such complete ontological equality, humans ultimately lost even that degree of agency Lovelock would grant them, to decide for themselves how best to live. Like Gaia's mechanisms of self-regulation, human activities must necessarily emerge from the complex organizational pattern of the whole system, survive so long as planetary evolution dictates, and die away when they are dysfunctional or maladaptive.

The attempt to place people so exclusively inside Gaia ultimately did not succeed for Sagan, Margulis and Lovelock. Logically and practically their model depended upon a human presence outside as well as inside. The Gaia perspective arose, as Lovelock related, "from a detached, extraterrestrial view of the Earth, too distant to be much concerned with humans" (Lovelock 1988: 236). The Gaia hypothesis depended upon a view of the planet in which humans had no special place, yet that view itself was possible only from an extraordinary vantage point. Like the Apollo astronauts seeing the whole Earth from the vicinity of the moon, the Gaia-gazer must float at a distance from the planet, even as the view itself renders him or her all the more thoroughly Earth-bound. The Gaia hypothesis depended upon the ability of humans to grasp the biosphere as a whole system, but in accomplishing that grasp, humans have already established their separateness, have already done what the hypothesis itself says they cannot do: staked out the difference between themselves and the rest of world.

The paradoxical location of people, simultaneously inside and outside, is a characteristic of techno-ecological systems, as I am arguing throughout this study. In the construction of the whole Earth as Gaia, people were thoroughly subsumed within the living entity of the biosphere and at the same time separated out, observing that entity from afar. They were in the impossible position of beholding from a distance the world that contains themselves.

Though he did not recognize it in these terms, this paradoxical, dual location of people relative to Gaia enabled Lovelock, on one hand, to disclaim any special ontological status for people, and, on the other, to suggest that humans set about replicating Gaia on Mars, so as to make for themselves a second home. The mechanisms of the Gaia system, as Daisyworld indicated, lent themselves to modeling. What if, Lovelock wondered, atmosphere- and soil-forming technologies were exported to Mars, the planet were seeded, and Gaia's brother Ares thereby came to life? Along with his friend Michael Allaby, Lovelock published his speculations on such a scheme as *The*

Greening of Mars (1984). The book took the form of fiction, as Lovelock explained, so the fledgling idea could avoid the withering scrutiny it would otherwise elicit from the scientific community. Nevertheless, the concept spawned three scientific meetings and a new term, "ecopoeisis," or "the making of a home" (Lovelock 1988: 184-6).

As the prospect of "greening" Mars indicated, Gaia ultimately was a technological as well as an ecological entity. That is, in the calculus of the Gaia hypothesis the living Earth was a techno-ecological system. Like other such systems examined in this study, Gaia took shape in the context of a pressing technosphere-versus-biosphere problematic, and was invoked as an alternative to the either/or choice between technological progress and ecological sustainability. In Gaia's case, the strategy was first to decenter humans by subsuming them within an encompassing system which could just as well go merrily along without them. From this perspective the ultimate priority in a cosmic sense became not the survival of humankind but the evolution of the far richer and more enduring whole system called Gaia. The either/or choice of the problematic was thereby nullified because there was no parity: technology lacked the power ever to conquer or destroy the living planet. As Lovelock wrote, Gaia is "immune to the eccentricities of some wayward species like us" (*ibid.*: 177). Secondly, the logic of the Gaia hypothesis, extended to its ultimate conclusion, so radically naturalized technology as to make an either/or choice between technology and environment nonsensical. How could there be a conflict if technology was another expression of Gaia's on-going, evolutionary unfolding toward greater complexity and diversity? Where human-made biospheres and the technology of home-making on Mars were the biology of planetary reproduction, a distinction between technosphere and biosphere became pointless.

Pioneering American ecologist Frederick Clements, early in the 20^{th} century, set forth the idea that plant communities functioned collectively as "superorganisms," developing, adapting, and maturing as though they were single organic entities. The ecosystem concept arose in subsequent decades to challenge the superorganism as the central unit of ecological inquiry. From an ecosystem perspective, the superorganism was an only marginally useful metaphor with no empirical grounding. The ecosystem concept, in contrast, encompassed relations among the organic and inorganic within a system that lent itself to the measurement of circulating materials and flowing energy. By the time Lovelock and Margulis began promoting the Gaia hypothesis the whole systems model had advanced to a point where there was no conflict between the conception of an organism and of a whole system, because organisms, like other complex, self-organizing, self-regulating entities, *were* whole systems.

The Gaia hypothesis granted the living Earth its own self-justifying existence, its own inscrutable evolutionary destiny. The question of the relationship between people and this entity was a difficult one. The problem of human agency in a self-sovereign whole system, as we have seen, is never really resolved. What to make of the paradoxical idea that 20^{th}-century humans, in moving the entire face of the planet farther and farther from its "natural" state, were fulfilling their "natural" role in the evolution of the organism that contained them? One approach was to interpret the planet-changing presence of modern technoscientific civilization as a next, essential evolutionary stage in the life history of the planet. The concept of the noösphere – a sphere of mind superimposed upon or evolving from the living planet – emerged along with the concept of the biosphere in the early 20^{th} century. As we'll see in the next section, it was employed in the latter half of the century as another way of reconciling uncertain technological and ecological futures. Like the Gaia hypothesis, it used the figure of the techno-ecological system to enfold global technological development into the planet's natural history and evolutionary destiny.

The Noösphere

The Gaia hypothesis revitalized recognition of Vladimir Vernadsky's role in defining the biosphere in the early 20th century. As we saw in Chapter One, the Russian geologist conceived of the living planet as a unified thermodynamic system in which the organic and inorganic were mutually formative. This concept was important in shaping the idea of the ecosystem, though in the post-War decades, when the ecosystem became a dominant paradigm in Western ecology, Vernadsky's contribution was largely forgotten. Though his ideas ran parallel to Vernadsky's, Lovelock was unaware of the Russian scientist's work when he published his first book on Gaia in 1979.[7]

The Gaia hypothesis also resurrected interest in another of Vernadsky's ideas, the *noösphere*, which he developed along with Pierre Teilhard de Chardin and Edouard Le Roy during his time in Paris in the nineteen-twenties. The noösphere referred to the global realm of "mind" (from the Greek *noos*) which the three scholars saw forming in the twentieth century as the planet's surface was transformed by the advance of science and technology. Teilhard and Le Roy's conception of the noösphere differed from Vernadsky's, but all three were attempts at reconciling modern civilization with the natural history of the Earth.

In Vernadsky's formulation the biosphere was evolving into the noösphere. In the modern age humankind had become a mighty geological force, changing the material composition of the planet. The twentieth century marked a new evolutionary stage. "[M]an, for the first time in the history of the earth, knew and embraced the whole biosphere, completed the geographic map of the planet Earth, and colonized its whole surface. *Mankind became a single totality in the life of the earth*" (Vernadsky 1943, 8). Everywhere, the presence and work of humans altered the seas, air and land, physically and chemically. The biosphere was acquiring a new physical character, and humankind was the agent of that change.

Vernadsky was a strict materialist, but Teilhard and Le Roy were devout Catholics (Teilhard in fact was a Jesuit priest), and the noösphere for them, though grounded in the science of evolution, had a fundamentally spiritual dimension. For Teilhard, the noösphere was a realm of consciousness forming around the Earth, driven by the advance of modern culture.[8] Consciousness increases, according to Teilhard, as complexity increases. More complex organisms have greater degrees of consciousness. With the advent of humans, the evolution of consciousness took a giant leap into self-awareness and initiated the "hominization" of the world. In the twentieth century, the complexity of the human collective had reached a point where it was ushering forth an entirely new evolutionary stage. The noösphere was forming around the biosphere, not evolving from it but being added to it, as the biosphere itself had been added above and around the original, lifeless rocky crust of the planet. According to Teilhard, humans were the means by which the universe was becoming conscious of its own existence. In the emerging noösphere the plurality of conscious minds were evolving toward unification. Out in the distant future was the "Omega point," at which all conscious minds would converge into one.

Teilhard was a respected paleontologist whose contributions to his field included an instrumental role in the discovery of “Peking Man.” But his ideas on the noösphere were not embraced by most of the scientific community. They were even less well received by the Church, which prohibited him from publishing on the subject. Nevertheless, his most widely-read book, *The Phenomenon of Man*, issued after his death in 1955, struck a chord with a number of influential figures looking for a way to patch the world back together after the devastation of World War II and under the terrifying pall of the Cold War. Biologists Julian Huxley and Theodosius Dobzhansky, and historian Arnold J. Toynbee were among those who found in Teilhard a science-based source of optimism about the future. If Teilhard was right, the forces of evolution were leading ultimately toward a world of peace and human unity, despite existing threats of annihilation. The evidence for this was taking shape all around: in the fact that the knowledge and language of Western science were creating for the first time a globally shared understanding of the world; in the form of new global institutions, especially the United Nations, which some saw as a noöspheric entity of the first order; and in the shape of the technologies of global communication and transportation, which were creating an ever-widening web of interconnection irrespective of national borders.[9] In this regard, Teilhard’s ideas fit within a broader post-war interest in global unity, shaped around the humanist, universalist discourse found in, for example, the United Nation’s 1948 Universal Declaration of Human Rights, Edward Steichen’s famous “Family of Man” photo exhibition, and any number of international trade and culture expositions which, especially in the 1950s, underscored human commonalities and de-emphasized national and racial differences.[10]

Teilhard's central argument was that evolution had a purpose and destination, which was the unification of consciousness throughout the universe. Amid waning faith in the likelihood of humankind's long-term survival, Teilhard offered hope that a greater force was at work, leading the world toward safety, peace and enlightenment. It mattered that his conception of this greater force was not solely theological but also scientific, so that in the latter half of the twentieth century people of science and reason might openly embrace it. Implicit in Teilhard's vision, wrote British biologist Joseph Needham in his review of *The Phenomenon of Man*, "is the conviction that social evolution is continuous with biological evolution, and therefore that what materialist theologians have called the Kingdom of God on Earth is not a desperate hope but a sure development with all the authority of evolution behind it" (Needham 1959, 209). For Needham and other Teilhardians, faith in evolution could engender confidence in the future, where faith in humanity and faith in God were not enough.

It was Teilhard's conception of the noösphere rather than Vernadsky's which caught on in the post-War period, perhaps in part because Teilhard took the future of the planet out of human hands. Vernadsky, the Soviet materialist, writing before the end of the Second World War, saw the noösphere as a realm of human control. The transformation of biosphere into noösphere was not inevitable, but was taking place in the twentieth century as a matter of empirical fact, due to the progress of human society. Humans could quite well destroy it all, as he wrote from within the U.S.S.R. in 1943, but Vernadsky believed so long as people structured their societies in line with natural laws – specifically, the natural law dictating the "biological unity and equality of all men" – a promising future lay ahead. Humans had made themselves into a mighty geological force.

Now they faced the task of "the reconstruction of the biosphere in the interest of freely thinking humanity as a single totality." "[Man] can and must," Vernadsky wrote, "rebuild the province of his life by his work and thought, rebuild it radically in comparison with the past. Wider and wider creative possibilities open before him" (Vernadsky 1945, 9).

In the shadow of Buchenwald and Hiroshima, under the threat of global thermonuclear destruction, it became difficult for many people to retain such faith in human control after WWII. One of the lasting legacies of post-War ecology, in fact, has been an abiding anxiety about the unintended, uncontrollable by-products of modern technoscientific civilization, such as nuclear waste and chemical poisoning. Leading post-War ecologist Eugene Odum, for example, embraced Vernadsky's concept of the biosphere, but objected to his formulation of the noösphere. As Odum wrote in his now-classic textbook, "This [Vernadsky's noösphere] is a dangerous philosophy because it is based on the assumption that mankind is now wise enough to understand the results of all his actions. When the reader has finished with this book [*Fundamentals of Ecology*] I am sure he will agree that we have yet much to learn before we can safely take over the management of everything!" (Odum 1953, 12).

A strong "managerial ethos," as environmental historian Donald Worster termed it, was characteristic of the post-War period, especially for those scientists, engineers and managers armed with cybernetics, systems analysis, and other new tools and ideas aimed at corralling the complexity of the post-War world (Worster 1994). But there was also in these years, as we saw in Chapter 2, a growing apprehension about the dehumanizing and environmentally destructive potentials of modern technologies.[11] At issue was the ability of humans to control their own inventions, especially given the inescapable, global reach of new technological threats, such as DDT and the Bomb.

What Teilhard's noösphere offered was a measure of relief from the overwhelming burden of an increasingly uncertain future. The universal force of evolution, for Teilhard, was equivalent to the hand of God, a spiritual energy working through humankind to achieve its full realization. "Man is not the center of the universe as once we thought in our simplicity," Teilhard wrote, "but something much more wonderful – the arrow pointing the way to the final unification of the world" (Teilhard 1959: 224). Compared with Vernadsky, there was in Teilhard much more ambiguity about the agency of people in the development of the noösphere. On the one hand, he argued that humankind in the twentieth century was awakening to the fact that "it constitutes an organic whole, endowed with the power of growth, and both capable of and responsible for some future" (Teilhard 1975: 13). On the other hand, he argued that that future was pointed inevitably toward the Omega point, toward the unification of consciousness. Humans were responsible for the future, but at the same time that future was foreordained and beyond their power to derail.[12]

However theologically inflected this argument was for Teilhard, the paradox at its heart was characteristic of techno-ecological systems employed in the second half of the twentieth century to reconcile uncertain technological and ecological futures. The noösphere concept was particularly appealing for these purposes as global information technologies came of age in the latter part of the century. Teilhard saw the very substance of the noösphere arising from the planet-wide formation of complex interconnections. Just as consciousness advanced with the increasing complexity of nervous systems in organisms, so it advanced with the increasing complexity of global technological interconnection, according to Teilhard. The technological substrate of the noösphere formed like a planetary nervous system, moving toward the development of a single, self-reflective, planetary organism. “Is it not,” he wrote of the noösphere, “like some great body which is being born – with its limbs, its nervous system, its perceptive organs, its memory – the body in fact of that great living Thing which had to come to fulfill the ambitions aroused in the reflective being by the newly acquired consciousness?” (Teilhard 1959: ?).

The importance of technologies of interconnection in Teilhard’s noösphere assured his ideas a place in the nascent whole systems discourse. Though he died on the cusp of the information age, Teilhard was attuned to the emerging potential of information technologies. They were one of the central elements of the “organic system” of noöspheric interconnection. “. . . [H]ere I am thinking,” he wrote, “of those astonishing electronic machines (the starting-point and hope of the young science of cybernetics), by which our mental capacity to calculate and combine is reinforced and multiplied by the process and to a degree that herald as astonishing advances in this direction as those that optical science has already produced for our power of vision” (Teilhard 1959: 110). Emerging technologies of communication, Teilhard claimed, placed the minds of people around the globe for the first time in constant proximity to one another. “[T]hanks to the prodigious biological event represented by the discovery of electro-magnetic waves, each individual finds himself henceforth (actively and passively) simultaneously present, over land and sea, in every corner of the earth” (*ibid.*: 240).

This technological development was a “prodigious biological event,” in the sense that it laid the foundation for the development of a global “technological brain.” Such ideas influenced Marshall McLuhan in the 1960s, as he fashioned the image of the world as global village, drawn together by “the new electronic interdependence” (McLuhan 1966: 31).[13] In the early eighties, British lecturer Peter Russell identified the emergence of a “global brain” in a way that married Teilhard’s noösphere to Lovelock’s Gaia. “If humanity were to evolve into a healthy, integrated, social superorganism,” he wrote, “this transformation could signal the maturation and awakening of the global nervous system. Gaia might then achieve her own equivalent of self-reflective consciousness. . . Gaia would become a conscious, thinking, perceiving being, a being functioning at a new evolutionary level with faculties quite literally beyond our imagination” (Russell 1983: 231).

Teilhard’s noösphere was useful to scientists such as Huxley and Dobzhansky, looking in the post-War years for a biological basis upon which to hang their hopes for the future of global humankind (Lane 1996); to one-worlders, such as Robert Muller, who saw the U.N. as a sign of the planet’s orthogenetic progress (Muller 1978); to Christian environmentalists such as Al Gore, seeking grounds for ecological, social and spiritual reconciliation (Gore 1992); and to cultural critics, such as Marshall McLuhan, who saw a new civilization taking shape as a result of increasing global technological interconnectedness (McLuhan 1966). In the nineteen-nineties it was the Internet that seemed on its way to fulfilling Teilhard’s vision. This more recent invocation of the noösphere served essentially the same purposes as prior uses – to argue that evolutionary forces were at work on the world as a whole, leading it toward a higher, better, more well-adapted state. However, it is crucial for the purposes of this study to note that by the nineteen-eighties and -nineties, the noösphere was characterized not as a technological, biological, or social adaptation of the human species, but as an evolutionary development of the planet as an entity unto itself. The noösphere indicated that the Earth was evolving into a techno-ecological system.

Russell, cyberspace philosopher John Perry Barlow, and others interpreted the expanding global network of computer interconnection as a noospheric nervous system leading toward the birth of a unified planetary Mind (Russell 1983; Kreisberg 1995). "With cyberspace," according to Barlow, "we are, in effect, hard-wiring the collective consciousness" (Kreisberg 1995: 4).[14] Thus the "planetary neural-network of the Internet," wrote *Wired* reported Jennifer Cobb Kreisberg, becomes "fertile soil for the emergence of a global intelligence" (*ibid*.: 3).

Like the Gaia hypothesis, the noösphere subsumed humans within a larger system with its own agenda, headed in its own direction. The planet appeared as a single being, developing toward some state of increased complexity by means of the same baffling unfolding of destiny that turns an acorn into an oak and a tadpole into a frog. Located inside this developing, self-organizing, self-regulating system, humans could surrender control of their technological and ecological futures to a larger force – the operations of systemness, evolution, Life – trusting that all was working toward the universal good.[15] The demonstrably untrustworthy ability of humans to control their inventions and manage their environment thus ceased to be an issue, since technological development was enfolded within natural, universal processes.

However, even as control was relinquished to a larger force, humans, paradoxically, were also still in charge. That is, they needed to be outside the system, as well as inside it, so that they could ensure the system's integrity, guarantee the pattern of organization by which the system retains its self-sovereignty, choose techno-ecological paths guided by whole systems principles. Human agency, elusive as a quark, somehow both existed and did not exist. Where it did not exist there was relief from the dreadful burden of the future. Where it did, it came to be directed by a moral imperative centered on ensuring, extolling, encouraging whole systemness itself.

With the planet so constructed, humans, in their capacity as purveyors of technology, were in the strange position of being subordinated to the evolutionary development of the global techno-ecological system and at the same time responsible for it. Concluding her article on Teilhard and the Internet, *Wired* reporter Jennifer Cobb Kreisberg wrote:

> We should not question the forces that are connecting our neurons, [Teilhard] argues; rather we should expand our own awareness and embrace our new complexity. Teilhard would readily see the Net as a necessary step along this path. At this point, the earth needs humanity to build the noösphere. As we become conscious of our group mind, a new relationship with the earth emerges (Kreisberg 1995: 5).

Such a statement was characteristic of the content of *Wired* magazine, a leading voice of the new digital culture of the nineteen-nineties: the expanding network of technological interconnection enveloping the globe is not something to be questioned, but embraced as both necessary and inevitable; it is creating a future in which people and planet are at last reconciled, the old difficulties by-passed as the whole-systems operations of planetary evolution steer technological development toward unpredictable but ever more richly complex, diverse, and robust new forms. People, now that they understand the universal laws of whole systems, bear responsibility for mid-wifing the many quasi-organic/quasi-technological entities struggling to be born. As researcher Chris Langton said, "there are these other forms of life, artificial ones, that want to come into existence. And they are using me as a vehicle for reproduction and for implementation" (*ibid.*: 4). Consigned by Gaia and the noösphere to a primarily functional role, people have no choice but to surrender control of their inventions to these forces, trusting that they ultimately are leading in a positive direction.

One possibility for that new evolutionary direction, according to long-time Brand associate Kevin Kelly, was a "neo-biological civilization." By the end of the twentieth century, Life, in Kelly's view, was finding ways to jump the chasm between the natural and the artificial, the born and the made, the organic and the machinic. The world was quickly being populated by living, complex quasi-technological, quasi-biological systems destined to evolve, diversify, merge, diverge and transform continually toward some unknown future. In the natural history of the planet, humans thus appeared to function as a kind of Bering Strait, across which Life was now venturing in order to reach a new world. No longer at the center even of civilization, humans were thus released from responsibility for what the world might become, even as they bore an obligation to facilitate the birth of that new world.

"Neo-biological civilization," like "bionomics," which I discuss later in this chapter, represents the logical, though unforeseen extension of the whole systems discourse Stewart Brand and others set in motion in the sixties, with humans displaced from the center of the relationship between nature and technology, strangely both integral and incidental to techno-ecological systems that have lives of their own. It is a discourse that legitimates the life-penetrating, globalizing technoscientific products and practices of the late twentieth- and early twenty-first centuries.

Out of Control in Neo-Biological Civilization

Kelly, an editor of both *Wired* magazine and the *Whole Earth Review*, heralded the coming of "neo-biological civilization" in his book, *Out of Control: The New Biology of Machines, Social Systems, and the Economic World* (1994). Kelly chronicles the many ways in which human-built things are becoming more like living things. The logic of nature, Kelly asserts, is being designed into advanced technologies, so that computers, robots, industrial processes, information networks, economies, and much more behave more and more like organic beings and communities. They are adaptive, self-sustaining, diverse, decentralized, and coevolutionary. Undergirding all complex self-organizing systems – social, natural, or mechanical – Kelly argued, are common principles and behaviors that emerge from the systems' very patterns of organization. At an accelerating rate, technoscience is uncovering those principles and patterns and learning how to implement them in the construction of complex technological systems. As a result, distinguishing between the natural and the artificial, the born and the made, is becoming increasingly difficult, and moreover *unnecessary*. Both Gaia and the noösphere figure prominently as signs that the laws of whole systemness governing complex technological and biological entities are both global and evolutionary.

In Kelly's view this is all in all a good thing, for it means humans have at last learned how to conform themselves to the proven wisdom of nature. The industrial era, with its gears and springs and clockworks, its smokestacks and poisons, could build only crude machines that did combat with nature, assaulted the environment, and never themselves came in any sense to *live* in the natural world. In neo-biological civilization, by contrast, technology learns from nature's example and embodies the very logic of life. Complex technological systems possess the sovereignty – like an ecosystem or an organism – to self-organize, to find their own way in the world, to adapt, if they can, to a changing environment, and allow evolution to decide what might continue on and what should fall by the wayside.

Granting technological systems sovereignty over themselves means, of course, that humans relinquish control over their own creations – hence Kelly's title, *Out of Control*. In a neo-biological civilization, people manufacture adaptive, self-organizing, self-regulating systems, then turn them loose into the world. This is the great risk and great reward of the neo-biological world. It promises technologies of unpredictable inventiveness and a robust ability to sustain and even reinvent themselves. Humans, having ushered bio-logic into their own creations, in turn must let these technologies live their own lives, as it were.

The migration of the logic of Life into technological systems, Kelly suggests, signals a dramatic shift in the relationship between technology and nature. In the gear-and-girder world of modern industrial society, engines and factories and various mechanizations "conquered" nature, (seemingly) tamed the forces of the universe and bent them to human will. By the nineteen-nineties, however, nature was the one calling the shots. The future of technological civilization appeared to lie not in subduing nature but in emulating it, comprehending and conforming to its ways, consulting it for ideas and solutions, even preserving it as a storehouse of wisdom (Kelly 2000).

At the core of this change in the status of nature – from foe to partner; from obstinate slave to wise teacher – is a shift in the location of people. In the modern era, people were either inside nature or outside. For those who placed faith in the technological progress of modern civilization, humans were above and outside Earthly nature, knowing subjects regarding the disconnected objects that comprise the physical world. For others, the romantics and pastoralists, people were foremost Earthly creatures. Though industrialization brought expulsion from the Garden, people nevertheless belonged to the Earth and needed to restore themselves to nature.

In Kelly's neo-biological civilization, neither nature nor technology, but the techno-ecological system is the key figure. In it, nature and technology co-exist and co-evolve. The question of where to locate people relative to nature, as is always the case with techno-ecological systems, is moot. Instead, the pertinent question is where to locate humans relative to the system. The answer is that they are both inside and outside the system at the same time.

In Kelly's book, people create "vivisystems" of infinite type – from robotic bugs to simulated ecologies to the Biosphere 2 project in the Arizona desert – as though mining another of the world's riches, this time the secrets of complex whole systems. And yet at the same time, it is not people acting as planetary rulers but Life itself which dissolves the barrier between the natural and the artificial, the organic and the machinic. Life uses people as a means for colonizing new territory and spreading itself beyond original nature. As Kelly writes, "We should not be surprised that life, having subjugated the bulk of inert matter on Earth, would go on to subjugate technology, and bring it also under its reign of constant evolution, perpetual novelty, and an agenda out of our control" (Kelly 1994: 472).

Kelly doesn't explicitly acknowledge this dual, impossible positioning of people relative to the techno-ecological systems of neo-biological civilization; rather, he unselfconsciously alternates between statements which give humans agency over nature and statements which subsume humans and their technologies within the larger forces of evolving life. In various places, however, he refers to humans as "gods," a descriptor which captures their liminal, suspended status in neo-biological civilization. "This, then," Kelly writes, "is the dilemma all gods must accept: that they can no longer be completely sovereign over their finest creations" (*ibid.*: 4). The small *g* is important. The forfeiture of control is essential to creating successful complex technological systems. Thus humans cannot be omnipotent big-G God. But at the same time, they are not quite like every other Earthly creature, either, since they, like God, now know something of the secret of making things come alive, of making "somethings from nothing." People in neo-biological civilization are thus rather like the gods of mythology: endued with a supernatural ability to influence the world, yet themselves subject to the uncontrollable forces of their own natures and actions.

Summarizing the principles at work in all the neo-biological systems he surveys, Kelly identifies "the nine laws of God." Anyone wishing to be a god, to create organized, self-perpetuating somethings out of the soup of chaotic, inert matter, "can go pretty far" he states, " . . . while sticking to these nine rules" (Kelly 468):

> Distribute being: "The spirit of a beehive, the behavior of an economy, the thinking of a supercomputer, and the life in me are distributed over a multitude of smaller units. . ."

> Control from the bottom up: "[O]verall governance must arise from the most humble interdependent acts done locally in parallel, and not from a central command."
> Cultivate increasing returns: "Anything which alters its environment to increase production of itself is playing the game of increasing returns. And all large, sustaining systems play the game. The law operates in economics, biology, computer science, and human psychology."
> Grow by chunking: "The only way to make a complex system that works is to begin with a simple system that works. . . Complexity is created. . . by assembling it incrementally from simple modules that can operate independently."
> Maximize the fringes: "A diverse heterogeneous entity. . . can adapt to the world in a thousand daily minirevolutions, staying in a state of permanent, but never fatal, churning. . . In economic, ecological, evolutionary, and institutional models, a healthy fringe speeds adaptation, increased resilience, and is almost always the source of innovations."
> Honor your errors: "Error, whether random or deliberate, must become an integral part of any process of creation. Evolution can be thought of as systematic error management."
> Pursue no optima; have multiple goals: "In creating something from nothing, forget elegance; if it works, it's beautiful."
> Seek persistent disequilibrium: "A Nothing . . . is both equilibrium and disequilibrium. A Something is persistent disequilibrium – a continuous state of surfing forever on the edge between never stopping but never falling."
> Change changes itself: "To get the most out of nothing, you need to have self-changing rules" (*ibid:* 469-472).

In Kelly's view, the nine "laws" for making something out of nothing represent the revealed wisdom of the universe. "These nine principles," he writes

> underpin the awesome working of prairies, flamingoes, cedar forests, eyeballs, natural selection in geological time, and the unfolding of a baby elephant from a tiny seed of elephant sperm and egg.
>
> These same principles of bio-logic are now being implanted in computer chips, electronic communication networks, robot modules, pharmaceutical searches, software design, and corporate management, in order that these artificial systems may overcome their own complexity.
>
> When the Technos is enlivened by Bios we get artifacts that can adapt, learn, and evolve. When our technology adapts, learns, and evolves then we will have a neo-biological civilization (*ibid*.: 471).

From this quote we can begin to see how crucial it is to neo-biological civilization that people have the status of gods, both empowered over nature and subservient to it. The nine principles, as Kelly says, "are now being implanted" into a wide variety of human creations, but by whom? Humans, who have figured out the secret of life? Or life, which has “an agenda out of our control?” It is necessary for Kelly to employ the passive voice to keep the source of agency ambiguous and the paradox of neo-biological human/nature relations intact.

If humans are the sole agents bringing uncontrollable artificial systems to life, then they have, in the end, not escaped the folly and perils of modern industrial society after all. The problem with industrial-era technology was always its unintended consequences, its blindness to the fact that it was enmeshed in a tangle of ecological relationships. Nuclear fallout, industrial pollutants, environmental poisons, as we have known from *Silent Spring* forward, were the uncontrollable by-products of some of the most advanced technologies of the modern era. In the context of a human-controlled future, they seemed a blundering kind of suicide.

The new technologies of the neo-biological era, in contrast, represent a fundamental reorientation of technology, toward a world in which nature and technology are not at war with one another but meet upon the common ground of *whole systems*. Yet these new technologies are still, necessarily, uncontrollable, which means humans must continue to release their creations into the world without knowing the consequences, with no assurance that they are not seeding the conditions of their own demise. If humans are the agents of neo-biological civilization, then they bear a terrible responsibility for gambling with the future.

If, on the other hand, the mysterious force of evolving life itself has ultimate responsibility for enlivening technology, humans are off the hook. They can bring into being with abandon an infinite array of new techno-organic entities, without the worries and grave responsibilities that bore down on them in the past. They need only have faith that the whole-systems laws of evolving life, working through them, are inherently good and lead unfailingly toward a better, richer world of both technological progress and ecological health. Now that the laws of whole systems are known, to do other than encourage and celebrate the continued expansion and diversification of whole systems technologies would be to foolishly impede the advance of life itself

Human agency, under these circumstances, must be directed toward ensuring that technological, social and economic development conform as rapidly as possible to the laws of whole systems complexity. An outline of the moral philosophy arising from that imperative is apparent in the "nine laws of God." The system must have the sovereignty to work on its own, to organize and regulate itself, to grow and prune back and change direction as needed in order to flourish. No central coordination or governance can make this happen. Rather, it emerges spontaneously from the system's complex pattern of organization. The individual elements that make up the myriad nodes of the whole system must be free to experiment, mutate, create of their own volition, needing no comprehensive understanding of the larger whole of which they are a part. It is nevertheless through their uncoordinated, ceaseless innovation that the larger system ultimately attains its living qualities, its ability to adapt to change, to diversify, to survive adversity, to evolve. For the system to flourish it must never stagnate or reach equilibrium, but must constantly surge ahead, dynamically adjusting and reshaping itself on countless fronts – and by these efforts maintain itself as a living thing with an unpredictable but nonetheless promising future. These were the whole system rules underpinning the biosphere and ecosystem concepts in the early twentieth century, and they were rule for the new information economy and digital culture of the nineteen-nineties, as well.

Bionomics

The basic tenets of Kelly's neo-biological civilization appeared also in one of the most influential ideas coursing through the information economy of the nineteen-nineties: "bionomics." A term originated by Michael Rothschild in his book of the same name, "bionomics" asserted that the free market economy and the natural environment are parallel systems, operating in the same way, upon the same principles. "A capitalist economy can best be comprehended as a living ecosystem," Rothschild wrote. "Key phenomena observed in nature – competition, specialization, cooperation, exploitation, learning, growth, and several others – are also central to business life. Moreover, the evolution of the global ecosystem and the emergence of modern industrial society are studded with striking parallels" (Rothschild 1990: xi).

Chief among the parallels Rothschild identified was the central role of information. The essence of organisms is the information scripted in their DNA, he claimed. All living things and the communities they form depend upon the execution and replication of genetic instructions. In the economic realm, technical information serves the same function. Manufacturers and markets owe their existence to the accumulated, replicable technical know-how of humankind. Each enterprise and industry uses a bit of the vast, expanding poolof information to develop its market niche, identify its opportunities, use its resources and survive. Both systems, he said, are constructed in complex hierarchies: in the case of nature, the hierarchy moves from cells, to organisms, to populations, to species, to ecosystems; in the economic environment, from workers, to departments, to firms, to industries, to economies. Though they operate at different paces, both systems evolve, diversify, grow and contract in similar ways. Of central importance to Rothschild was the fact that both systems are self-organizing and self-regulating. No single entity is in charge of either an ecosystem or a free market economy. It is rather the laws of systemness, working through the interlinked but uncoordinated activities of many decentralized agents, that give both systems their liveliness and resilience.

Rothschild's hope in drawing this analogy between environment and economy was to dispel musty economic ideas that were, in his view, holding back growth and innovation. The economics born of an earlier era modeled the economy as a simple, cyclical machine running in the Newtonian world of linear cause and effect. Such a model suggested that the economy could be controlled and directed by government policy and managerial intervention. In fact, argued Rothschild, as we now know, capitalist economies have never behaved that way. "Like ecosystems," he said, "economies are spectacularly complex and endlessly adaptable" (*ibid*.: xiv). They operate according to the nonlinear logic of whole systems and are self-controlling. The only help they need from government is protection from interference. With bionomics, Rothschild stated, "the traditional notion of government's economic role – pushing the buttons and twisting the dials of society's economic machinery – is replaced by a vision of government as the astute cultivator of society's economic ecosystem, patiently nurturing the natural processes of growth" (*ibid*.: xv).

Published just after the break-up of the Soviet Union, *Bionomics* had a self-congratulatory quality to it. Rothschild assured his readers that bionomics was beyond any outdated socialist-versus-capitalist debate. From his perspective, the question was settled, not by politics but by nature. Bionomics, he wrote, “regards capitalism as the inevitable, natural state of human economic affairs. Being for or against a natural phenomenon is a waste of time and mental energy” (ibid.). Recognizing capitalism and nature as the same type of system quelled any doubts about how an economy should be organized. In fact, the original title of his book was *Bionomics: The Inevitability of Capitalism*. In later editions, the title changed to *Bionomics: Economy as Ecosystem,* perhaps because, as the book won popularity, it was clear that its appeal lay in its central analogy.

Bionomics received a glowing review in the *Wall Street Journal* in 1991, and from there became a hit, especially among the entrepreneurial class of Silicon Valley. Rothschild began speaking to venture capitalists and other groups that were driving the explosion of information-based commerce. Soon The Bionomics Institute was formed, convening an annual conference, disseminating information and even launching its own software company, Applied Bionomics, Inc. (Borsook 2000). “The Economy Is a Rain Forest” bumper stickers and other bionomic ideas became pervasive in the digital culture of the nineties.

Former *Wired* writer Paulina Borsook criticized bionomics for its part in shoring up the extreme libertarian politics of the California high tech crowd. Bionomics, she argued in *Cyberselfish* (2000), validated the idea that government should be reduced to an absolute minimum, that taxes for public services were a drain on the “economic ecosystem,” and that social problems could be resolved by leaving the economy to function on its own. She complained that the advocates of bionomics were hypocritical in not recognizing the debt their entire industry owed to the public sector. They failed to remember, she wrote, that “there wouldn’t be a Silicon Valley, or a microprocessor industry, without huge federal defense contracts, that there wouldn’t be a Silicon Valley without what was once the best and best-funded public educational system in the country, that there wouldn’t be a Silicon Valley without that peculiarly American mixed economy of free market and regulation. . .” (*ibid*.: 262).

The charges against bionomics also included its potential for disregarding anyone in the system who simply could not compete in the battle for scarce resources. Rothschild, however, was quick to dispel the idea that bionomics was an updated version of either social Darwinism or sociobiology. The key difference, he stated, was that in social Darwinism social developments were understood as an extension of natural evolution, leading to justifications for “strengthening” the entire system by eliminating “inferior races” and those who could not compete economically. In the case of sociobiology, the argument is that not just organisms but cultural practices are determined by genes. The cultures best at ensuring the genetic survival of their members therefore “win” in competition with less fit cultures. Rothschild found the political implications of social Darwinism and sociobiology completely objectionable. By contrast, he claimed, bionomics stresses that the economic and the natural are parallel systems, but otherwise separate. Like the bird’s wing and the bat’s wing, the economic system and the ecosystem evolved independently, though they are analogous. “According to the bionomic view,” Rothschild wrote, “genetic information and technical information independently evolved into an ecosystem and an economy of striking similarity because both realms of information confronted the problems of survival in environments with limited resources”

(Rothschild 1990: 349). As a result, there are no grounds in bionomics for making claims of either natural superiority or genetic determinism.

Bionomics was an elaborate rationalization for an expansionist, technology-driven, unregulated global economy. The remarkable thing about it, in the context of this study, is that it formed its argument around the model of nature as ecosystem. Scarcely twenty years before the same model had been used to justify calls for the radical curtailment of global economic activity. The Club of Rome's influential study, *The Limits to Growth*, for example, had in 1972 issued the warning that unless the human population declined and a global steady-state economy were achieved, the world was in for a tremendous ecological catastrophe (Meadows 1972). What made this shift in perspective possible was the figure of the techno-ecological system, which defined the terms under which technological progress and ecological survival could be compatible.

The reconciliation of nature and technology required a new view of both. Information technologies were understood as fundamentally different from the poisonous, resource-intensive technologies of the industrial economy. They did not do war with nature but rather conformed to the deepest whole-systems laws of living things. And nature could no longer be seen as fragile and beleaguered. Rather, planetary life was understood as a force far more powerful than any human contrivance. It was robust and resilient, infinitely inventive and adaptive, neither slave, nor victim, nor foe. The technologies and economy that emulated nature, then, would likewise grow and diversify, matching the biosphere's abundance, complexity and productivity.

Central to bionomics – as with Gaia, the noösphere, and neo-biological civilization – was the displacement of human agency. In the Limits-to-Growth approach to nature and technology, humans were responsible for bringing the planetary environment to the brink of disaster through their headlong pursuit of technological development and economic expansion. Human behavior was out of control and needed to be brought into line with the ecological realities of the planet. But with the world reconfigured as a techno-ecological system, humans were no longer the central agents. It was evolving, complex techno-ecological systems that were in charge, and out of human control. In the case of bionomics, technical information – the analog of genetic information – was the agent of change. As Rothschild wrote, "Technology, not people, holds center stage in this view of economic life" (Rothschild 1990: xiii). Humans, as conduits of whole-systems forces, could allow technological development to proceed of its own accord without concern that it might conflict with the ecological health of the planet. It was, after all, now an expression of the same laws that govern nature, a co-constituent, along with nature, of a larger, encompassing whole system. Humans served the dual role of participant/observer, both inside the techno-ecological system, as nodes of independent economic and technological action, and outside it, as custodians and guarantors of system integrity.

We are as gods

Stewart Brand's famous epigraph for the *Whole Earth Catalog* begged for a frank admission that humankind, by the late twentieth century, was neither omnipotent master of the planet, nor just another species plodding blithely along: "We *are* as gods and might as well get used to it," he wrote. In the 30th anniversary reissue of the original 1968 catalog, Brand explained that he cribbed the quote from British Anthropologist Edmund Leach's 1968 book, *A Runaway World?*(Brand 1998).[16] Leach's concern, as his title indicates, was that people were sitting passively by, overwhelmed by a world that seemed to be careening out of control. He urged his readers to see science and technology as powerful tools they might use for shaping the future of humankind, rather than as uncontainable, disembodied forces leading the world toward some catastrophic end.

Similarly, Brand's interest was in empowering individuals by placing in their hands the "tools of civilization" and encouraging them to strike out for Outlaw Areas in which they could experiment with remaking the world in a way that allowed for both prosperity and ecological sustainability. Grounded in the ethos of nineteen-sixties counter-culture, his consistent, primary concern was improved conditions and opportunities for humankind. Even in the nineteen-eighties, when personal computers seemed to him the ultimate, empowering tool, he tended to approach them from a position that kept people rather than machines at the center of his concern. As "gods" humans were suspended somewhere above the rest of the Earth, though still a little less than angels.

In the nineteen-eighties and -nineties the whole systems discourse, aided in no small measure by the influence of Brand, helped define the technological and cultural changes that were taking place as a result of the boom in information technologies. But as it spread it also came unmoored from Brand's originating values, which kept human agency and welfare at the center. Brand intended to endue individuals with the power to control their world by handing them the tools of a civilization that threatened on its own to veer out of control. By the end of the twentieth century, however, this whole systems discourse had once more taken control out of the hands of people. We can see this change particularly in Rothschild's bionomics, which gave primary agency to technological information within an “inevitable” “natural” economic system. The same was the case with Kevin Kelly’s neo-biological civilization, in which the force of life itself drives technological progress.

But the whole systems discourse could not *only* remove control from human hands, for then things would be no different from the old pre-modern paradigm, in which people, unequipped with science and technology, were prey to uncontrollable nature. Neither could control appear to reside strictly in human hands, however, for that was the source of the modern world’s slide toward self-induced destruction. The whole systems discourse, therefore, relied upon the paradox, the baffling both/and illogic of the quantum era, in which things could have two mutually exclusive characteristics at once, in which people and their surroundings were never separate, and yet never not separate either – and in which this basic unknowability did not mask some less elusive, underlying reality but was itself all the reality there was.

With Rothschild and Kelly, the whole systems discourse came to promote uncritically the unfettered technological adventurism and expansionist, global information economy of the nineties. Humans were fully empowered to create their world, and at the same time completely the instruments of the larger forces of the universe. Kelly, Brand’s protégé at the *Whole Earth Review,* was thoroughly steeped in Brand’s whole systems discourse, but there was a crucial difference between his characterization of people as “gods” and Brand’s. Kelly’s gods worked not with the welfare of humankind as their primary concern, but in the service of the whole systems logic of the universe. In practice this meant advancing as a first priority the interests and resources of technoscience.

The reprioritization of values, from human-centered to system-centered, was made possible by the discursive operations inherent in the techno-ecological system itself. In the discourse of the system, the location of humans is always ambiguous, never resolved. They are both inside the system as fully enmeshed participants, and outside the system as observers charged with ensuring system integrity. It is in this indeterminacy that the world, as techno-ecological system, comes to seem both a human artifact and a natural inevitability. The next chapter is devoted to further exploring the discursive procedures of the techno-ecological system.

Notes

[1] Lovelock would not recognize it until later, but his ideas shared much in common with the concept of the biosphere devised by the legendary Russian geologist, Vladimir Vernadsky, in the nineteen-twenties and thirties. As the first two chapters of this study show, Vernadsky's ideas were central to the formation of the ecosystem concept. Lovelock was of course well versed in modern ecosystem ecology, but by the time Lovelock was writing Vernadsky was all but unknown in the West. The Gaia hypothesis eventually inspired a revival of interest in Vernadsky's work. See Lovelock, *The Ages of Gaia*; Vernadsky, *The Biosphere*; Samson and Pitt, eds., *The Biosphere and Noösphere Reader*.

[2] Margulis and Lovelock's article was published in the British journal *New Scientist* and in Carl Sagan's astronomy journal *Tellus* prior to appearing in *CoEvolution Quarterly*. Sagan was married to Margulis and it was Sagan who put Brand in touch with her (Kleiner and Brand 1986).

[3] For an account of this conference see Lawrence E. Joseph, *Gaia* (1990).

[4] Papers from Lindisfarne Association conferences are included in Thompson, ed., *Gaia: A Way of Knowing* (1987).

[5] For himself, Lovelock chose to live on thirty acres of woods and meadows in England, a privilege he no doubt recognized was unavailable to most people. Regarding his lament of the changes around his home he wrote: "So why should I fret over the destruction of a countryside that is, at most, only a few thousand years old and soon to vanish again? I do so because the English countryside was a great work of art; as much a sacrament as the cathedrals, music, and poetry. . . is there no one prepared to let it survive long enough to illustrate a gentle relationship between humans and the land, a living example of how one small group of humans, for a brief spell, did it right?" (Lovelock 1988: 232).

[6] See Chapter 3.

[7] Lovelock acknowledged the connection between Gaia and Vernadsky's biosphere in *The Ages of Gaia* (1988).

[8] Le Roy's ideas about the noösphere, though similar to Teilhard's, were not identical. However, it was by Teilhard's work that the noösphere idea would receive attention throughout the rest of the century. Therefore, I have concentrated on his thinking rather than Le Roy's. For Le Roy's account of the noösphere, see *The Biosphere and Noösphere Reader*, Samson and Pitt, eds. (1999); Le Roy, E., *Human Origins and the Evolution of Intelligence*, (1928).

[9] In 1978, United Nations economist and leading Teilhardian Robert Muller wrote, "While there are no cellular particles in the human body that are sufficiently 'intelligent' to detect or determine the direction of biological evolution and then change themselves accordingly, such as system *is* being developed for the human species as a whole. In my view, the United Nations and its specialized agencies, together with the mass media and many international

efforts, are becoming this collective brain or macrocephalus of humanity" (Muller 1978: 183; Lane 1976: 4).

[10] See Cousins (1945), Mumford (1950), Haraway (1989), Sandeen (1995), Haddow (1997).

[11] See Carson (1962), Ellul (1964), Marcuse (1964), Mumford (1966), Commoner (1966; 1970), Roszak (1973).

[12] As a further example of how this manifests in Teilhard, take the following quote from an unpublished essay written in 1951. Evolution, he argues, has in humankind reached a new stage of self-consciousness. If the world were to become aware of this reality, ". . . the zest for action, the impetus to action, would be re-born and re-bound in our hearts in step with the ever greater evolutionary effect we have to make in order to ensure the progress of a complexity whose burden becomes progressively heavier to bear. This, we must never forget, is the dynamic condition essential to survival for a biogenesis that has definitively passed in us from the state of passively experienced evolution to the state of auto- or self-evolution" (Teilhard 1970: 309). Humans are now charged with ensuring by their conscious effort the progress of complexity, but this itself is evolution's or Life's essential strategy for self-perpetuation.

[13] McLuhan embraced Teilhard's idea that modern technologies, by extending humans senses, had shrunk the world. He accepted Teilhard's noösphere, though not his "uncritical enthusiasm for [this] cosmic membrane." "This externalization of our sense creates what de Chardin calls the 'noösphere,'" McLuhan wrote, "or a technological brain for the world. Instead of tending towards a vast Alexandrian library the world has become a computer, an electronic brain, exactly as in an infantile piece of science fiction. And as our senses have gone outside us, Big Brother goes inside. So, unless aware of this dynamic, we shall at once move into a phase of panic terrors, exactly befitting a small world of tribal drums, total interdependence, and super-imposed co-existence" (McLuhan 1966: 32).

[14] Barlow first achieved widespread notice for his observations on cyberspace as a participant in conversations on the WELL in the 1980s. He went on to found the Electronic Freedom Foundation, which supports freedom of speech and civil liberties in a variety of digital realms. He is a paragon of the computer-bum-ex-hippie nexus that formed around personal computers in California in the 1980s, as discussed in the previous chapter. Without fail, references to Barlow cite the fact that at one time he contributed lyrics to the Grateful Dead.

[15] Within the whole systems discourse, *systemness, evolution, Life* are most fundamentally different expressions of the same force.

[16] Brand actually misquotes himself in this short introduction to the 30th anniversary edition. Instead of "might as well get used to it," as appeared in the original, he remembers it as "might as well get good at it." His intended meaning probably had not changed, but the difference is worth noting. After thirty years of getting used to it, perhaps getting good at it was the greater hope.

CHAPTER 7
COMPLEMENTARITY

Whatever its other scientific and cultural uses, the whole system model has been a strategy for moving past discursive schisms that seemed otherwise unbridgeable. We saw this in the formulation of the biosphere and ecosystem concepts, where the system model consigned the longstanding mechanism-versus-vitalism debate to the "dustbin of badly formed questions." Reductionist mechanistic approaches, while empirical, lost the essential qualities of the complex wholes they dissected; holistic vitalist explanations, while keeping the whole intact, relied upon properties (Bergson's *élan vital*, for example) which could not be empirically identified and examined. The whole system model, such as Tansley's ecosystem, did not reconcile mechanism to vitalism, but leapt over the problematic altogether. Likewise, the techno-ecological systems we have examined by-passed the post-war technosphere-versus-biosphere stand-off. In both cases the model worked by discarding the logical premises and conceptual framework of the problematic itself, encompassing formerly conflicting elements together within a new entity, the *system*, which functioned according to a more fundamental set of principles.

As a discursive strategy, the techno-ecological system constructs particular representations of the relationship between nature and technology. The globe-encasing network of information technologies, for example, is, in the discourse of the techno-ecological system, co-evolutionary with the natural systems of the planet itself. In the context of a potentially catastrophic conflict between the technologies of modern civilization and the natural environment, such an understanding salvages prospects for both technological progress and ecological survival.

It also does the work of justifying and legitimating certain technologies and technoscientific practices. The techno-ecological system known as cyberspace, for example, framed networks of computer-mediated communication as a new kind of "outlaw area," where new and better relations among humans, nature and machines could be cultivated in a decentralized, interconnected, self-organizing, self-regulating, fundamentally *ecological* environment. Compared with an order of massively destructive technologies, or to "soft" technologies designed with diminishing prospects in mind, networks of personal computers could appear as a path to a more prosperous, innovative, and livable future.

This chapter identifies the discursive procedures that enable the techno-ecological system to do this kind of cultural work. At its core is *complementarity*, a feature whereby conflicting, even mutually exclusive, qualities or possibilities are also equally and simultaneously essential. Complementarity is the discursive procedure through which the techno-ecological system asserts the *both/and il*logic of the quantum postulate over the *either/or* logic of the classical, Newtonian mode of representing the world. Through complementarity, the techno-ecological system admits the patently self-contradictory condition wherein people are both fully inside the system and fully outside the system at the same time. To use an example we have already considered at length, the meaning of the image of the whole Earth from space hinged on the viewer being both subjective observer and objective participant simultaneously, though this is impossible. Complementarity describes an uncontainability, an irreducible loss of representation, or what I have called *wildness*, upon which techno-ecological systems depend in order to do their cultural work, including justifying global information technologies in the context of a whole-systems understanding of the planet.

Complementarity

The quantum postulate turned the logic of classical, Newtonian physics on its head. Prior to the discoveries of Planck, Einstein, and Bohr in the early twentieth century, the scientific understanding of the physical universe had depended upon a paradigm in which discreet, independent physical phenomena could be observed objectively and undisturbed by scientists and their instruments. Data from submicroscopic experiments, however, showed that this distinction between observing subject and observed object did not hold at the most fundamental level of physical reality. Physical systems could not be observed in an undisturbed state; at the same time, the state of an observed system was never unambiguous. The very act of observation itself determined the phenomena observed. As Niels Bohr wrote, "an independent reality in the ordinary physical sense can neither be ascribed to the phenomena nor to the agencies of observation." As a result, "an unambiguous definition of the state of the system is naturally no longer possible, and there can be no question of causality in the ordinary sense of the word" (Bohr 1987: 53-4).[1]

These two statements, as Arkady Plotnitsky notes, form the "central anti-epistemological implications of quantum mechanics" as presented by Bohr (Plotnitsky 1994: 67). Bohr identified in the quantum postulate a radical unknowability, an "inherent irrationality," that defied the logic of the classical paradigm. It was impossible to determine, for example, that light was either a particle or a wave, for it could behave like both, depending upon how the experiment to observe it was set up. Similarly, if the exact location of a particle were known, then the particle's momentum could not be precisely determined, and vice versa. Bohr called such pairings – particle and wave; energy and time; momentum and location – "conjugate variables." The concept of "complementarity," which he introduced in 1927, described the condition in which the conjugate variables of a system were both essential and at the same time mutually exclusive, a logic-defying circumstance which nevertheless was the only way to account for all the experimental data. What made this *il*logic truly radical was the implication that there was no definitive, unambiguous reality merely hidden from view; the unknowability *was* the reality.[2]

I made the argument in Chapter One that the early-twentieth-century revolution in physics spurred scientists in other fields into attempting equivalent, radical reconceptualizations, in keeping with the new understanding of the physical universe. The key to this reconceptualization for Charles C. Adams (ecology), Lawrence J. Henderson (biology), Walter B. Cannon (physiology), Alfred J. Lotka (physical biology), and others was the thermodynamic system model, a conceptualization that not only survived the quantum revolution but gained in stature in its wake. Still others looked for ways to apply principles of quantum mechanics itself to realms outside of physics. Irwin Schroedinger's *What Is Life?* is a famous example, as is Alfred North Whitehead's *Science and the Modern World*. In Chapter 2, we saw how cybernetician Lawrence Frank used the quantum revolution to argue that the biological and social sciences should be reconfigured in terms of a circular causality that implicated the observer together with the observed (Frank 1948: 192-3). As Plotnitsky writes, "that nature or matter itself (if one could still speak of either) behaved so strangely has had, and continues to have, a profound impact on modern intellectual history across different fields – be it science and mathematics, the history and sociology of science, the philosophy of science, philosophy, or critical theory, or literature and art – and their interactions" (Plotnitsky 1994: 84).

General Semantics

Alfred Korzybski's general semantics was one of the most elaborate attempts to reform non-physical science in light of the changes that had occurred in physics. Korzybski's ideas, especially the relations he drew between paradox and sanity, were important to Gregory Bateson, so there is a very direct historical connection between general semantics and the formation of the techno-ecological discourse I have been pursuing in this study.[3] More generally, though, we can see in Korzybski an example of a broader tendency to dismiss an older conceptual framework or mode of representing the world – one associated with the determinate, linear causality of Newtonian physics – and to establish in its place a new mode of representation associated with quantum physics, which has at its core an essential unknowability. This general anti-epistemological mode of representation would become an essential quality of the techno-ecological whole system discourse.

Korzybski identified Newtonian physics with a two-valued, either/or mode of evaluation, which he traced back to Aristotle. Our relations with the world "inside and outside our skins" on a daily basis often appears to be two-valued, according to Korzybski. "For instance," he wrote, "we deal with day *or* night, land *or* water, etc. On the living level we have life *or* death, our heart beats *or* not, we breathe *or* suffocate, are hot *or* cold, etc. Similar relations occur on higher levels. Thus, we have induction *or* deduction, materialism *or* idealism, capitalism *or* communism, democrat *or* republican, etc. And so on endlessly on all levels" (Korzybski 1958: xxi).

Aristotle's two-valued system molded the orientation of western civilization up to the twentieth century, according to Korzybski. "The man on the street, our education, medicine and even sciences, are still in the clutches of the system of Aristotle," he wrote in the preface to the 1941 edition of his *Science and Sanity*. And while it may have been satisfactory "2,300 years ago, when conditions of life were relatively so simple, when orientations were on the macroscopic level only, and knowledge of scientific facts was practically nil," Aristotle's method was not adequate for the modern world of 1941 (*ibid*.: xxxviii).

The either/or splits in Aristotle's system became "complete and institutionalized" in the language and culture of western civilization, according to Korzybski. But in the twentieth century, the problems with the Aristotelian system were becoming unavoidable. In physics, for example, Einstein had shown that time and space could not be empirically split. Heisenberg and Bohr had demonstrated the inseparability of the observer and the observed. The split between body and mind was likewise refuted in medicine and biology. In short, Korzybski believed western civilization was in the midst of a shift from the centuries-old Aristotelian model, of which Newtonian physics and Euclidian geometry were sub-systems, to a new non-Aristotelian paradigm, characterized by the anti-epistemological implications of the quantum postulate. "Modern scientific developments," Korzybski wrote, "show that what we label 'objects' or 'objective' are mere nervous constructs inside of our skulls which our nervous systems have abstracted electro-colloidally from the actual world of electronic processes on the sub-microscopic level. And so we have to face a complete methodological departure from two-valued, ‘objective’ orientations to *general, infinite-valued, process orientations*, as necessitated by scientific discoveries for at least the past sixty years” (*ibid*.: xl).

General semantics was Korzybski’s attempt at constructing a non-Aristotelian system for making meaning, which, he hoped, would eventually chase the embedded Aristotelian either/or logic out of the sciences, and, more broadly, out of the institutions, language and thought-patterns of modern civilization. The new general semantic non-Artistotelian orientation would, among other things, replace “static, ‘objective,’ ‘permanent,’ ‘substance,’ ‘solid matter’. . . orientations” with “dynamic, ever-changing. . . electronic process orientations.” Likewise, “two-valued, ‘either/or,’ inflexible, dogmatic orientations,” would be replaced by “infinite-valued flexibility, degree orientations.” “Two-valued ‘certainty,” would be replaced by “infinite-valued maximum probability;” “static absolutism” by “dynamic relativism;” the “Newtonian system” by an “Einsteinian or non-Newtonian system.” The abstract “organism-as-a-whole” model would be replaced by an “organism-as-a-whole-*in environments*” model. And where the old Aristotelian orientation had avoided “empirical paradoxes,” the new system would face them directly (*ibid*: xl-xlii).

Korzybski’s general semantics is an example of how scientists and thinkers in the first half of the twentieth century began to extend the radical conceptual implications of the quantum postulate into other fields. Central to these radical implications was a rejection of the either/or logic of the classical model, in favor of the logic of complementarity, or what I have been calling the “both/and *il*logic” of the quantum postulate. As Abraham Pais wrote in *Niels Bohr’s Times*, “complementarity can be formulated without explicit reference to physics, to wit, as two aspects of a description that are mutually exclusive yet both necessary for a full understanding of what is to be described" (Pais 1991: 24).[4] Complementarity, in other words, can become part of more general discourses, quite distant from the particulars of quantum mechanics. In this extended sense, as Plotnitsky defines it, complementarity is, "a very broadly conceived interconnectivity, except that it equally implies, under certain conditions, the possibility of mutual exclusivity, conflictuality, irreconcilable features of description, and other forms of discontinuity. . . " (Plotnitsky 1994: 75). As I am arguing here, this extended complementarity became an essential discursive feature where technology and ecology converged around the concept of the whole system.

General Economy

The philosopher Georges Bataille developed a theoretical framework – "general economy" – to describe the anti-epistemological discourses that began to develop in the twentieth century, in contrast to the classical mode of representing the world, which we have thus far associated with Aristotle and Newton (Bataille 1985, 1988-90). This concept, "general economy," is useful for understanding how complementarity works in the discourse of the techno-ecological system – in particular, for understanding what I have called "wildness," that crucial quality of techno-ecological systems that escapes human control.

As Plotnitsky notes, Bataille was responding to cultural conditions that he felt could no longer be accounted for in classical terms: modernist literature and art; modern social sciences, psychology, and mathematics; and especially modern physics. His general economy depended upon "a cluster of entropy and energy metaphors" (Plotnitsky

1994: 34). Like many others we have encountered in this study, Bataille adopted the thermodynamic system model as a means for reconfiguring standing categories and problematics in the early twentieth century. In the case of general economy, Bataille used entropy to explain unrecoverable and "meaningless" losses of energy and representation. Plotnitsky compares this loss in general economy to the unknowability of Bohr's complementarity, as he identifies the major anti-epistemological conceptual framework operating in the twentieth-century. Both historically and theoretically, the anti-epistemological implications of the quantum postulate directly shaped Bataille's formulation of general economy (*ibid*.: 18).[5]

Bataille called the theories and representations of the classical period "restricted" economies. Examples included Newton's physics and Hegel's dialectic, as well as Adam Smith's and Karl Marx's economic models. In each of these cases, there was a conservation of meaning and representation: determinate causality in a physical system; the dialectical synthesis; value in labor and capital. In a general economy, however, there is an inevitable, irreducible loss of representation and meaning: excesses of energy that "can only be lost, without the slightest aim, consequently without any meaning" (*ibid*: 20). General economy, according to Plotnitsky, "includes the activities and elements left out of restricted economies and classic paradigms. . .

> That which is left in the margins and claimed to be reducible or treated as contamination of classical theories – the unconscious, the meaningless, the improper, the distasteful, the impure, the wasteful, the perverse – is not only incapable of being marginalized or reduced, but is in fact constitutive of that which is unequivocally opposed to these contaminating forces and is supposed to be purified of them – the conscious, the meaningful, the proper, the tasteful, the pure, the normal (*ibid*.: 28).

Thus, general economy does not eliminate the restricted economy, but rather "recomprehends" it, much as quantum physics and relativity "recomprehended" classical, Newtonian physics, delimiting the realms in which its principles generally do and do not pertain. In general economic terms, for example, there is never an absolute Hegelian synthesis, but an irreducible loss of representation and knowability in relations between conjugate, complementary variables. General economy "exceeds" the binary (Aristotelian, Hegelian, or other) "without uncritically dispensing with it or ignoring its extraordinary resources" (*ibid*.: 75). In the case of the techno-ecological system, as we have seen, the binary variables – nature and technology; local and global; inside and outside – remain essential to the relationship between people and the planet; but it is the fact that they are never fully synthesized and exist in complementary relation with one another that makes the techno-ecological system a general rather than a restricted economy.

Bataille used the word "sovereignty" to designate the expenditure of energy which escapes utilization – the irreducible loss of representation – signifying, as we have seen throughout this study, that the question of control, or lack of control, lies at the heart of such anti-epistemological discourses (Bataille 1970: 215-16).[6] In the same sense, I have used the word *sovereignty* to designate the self-organizing, self-regulating essence of techno-ecological systems, which by definition escapes human control. As we saw in the examination of the Biosphere 2 project, for example, the replicant biosphere, in order to function as a true self-organizing, self-regulating whole system, required the sovereignty to establish its own dynamic equilibrium. In that process, the gasses comprising the "atmosphere" fluctuated precipitously, and some species thrived, while others went "extinct." The sovereignty to self-regulate and self-organize by definition lay outside the control of the humans both inside and outside Biosphere 2. It generated conditions in which the human inhabitants could not survive, and thus in which the experiment as a whole could not succeed. As Plotnitsky writes, “general economy makes its configurations fundamentally uncontainable and uncontrollable” (*ibid.*: 29). In the case of the techno-ecological system, this uncontrollability can be thought of as *wildness,* with all its associations of danger and unpredictability, romance and freedom.

Paradox and Wildness

In addition to the freedom to self-organize, self-sovereignty in the techno-ecological system implies an “out of control” potential for bringing something unexpected and unpredictable into the world. This, after all, was the constant motivation behind Stewart Brand’s pursuit of techno-ecological systems: he believed the co-evolution of nature and technology, in the context of the universal laws of whole systemness, could conjure forth more sustainable and beneficial entities, ideas, and inventions than had thus far been generated by the lumbering institutions and assumptions of the modernist paradigm. The both/and logic of co-evolutionary whole systems provided a way past the old either/or categorical standoffs. “How you get energy,” Brand said, as we saw in Chapter 3, “is, you take polarities and slap them next to one another. If you get into cybernetics and your head is just a minute ago full of organic gardening and ecology, then cybernetics starts to come alive for you in a different way.” As the authors of a 1970 profile of Brand in *Esquire* magazine stated, “tension between opposites, between control and no control, between making it happen and letting it happen, defines the line that Stewart’s whole life and work play along. You could substitute almost any pair of opposites, or apparent opposites, and on one level or another they'd still apply" (McClanahan and Norman 1970: 98).

The importance of *paradox* to Brand was evident in his conversations with Gregory Bateson, as we saw in Chapter 5. Along with Bateson, Brand perceived "riding with the paradox," rather than choosing one side of a contradiction over the other, as a path toward innovation, multiplicity, sanity, enlightenment. To illustrate the point, Bateson gave the following example:

> There are two forms of colonial administration. There is that form of colonial administration which says that the natives have got to be like the colonists. This is missionary endeavor, all that, and becomes a tyranny. The other form of colonial administration says that the natives have got to be like themselves and had better not change. 'They have such a beautiful sense of rhythm.' Then poetry freezes and everything dies and the flowers can't make seed and nothing goes. So neither of these will do. To do either becomes imperialism (Brand 1974: 33).

The objective was not to choose one over the other, said Bateson, but to embrace the complexity that arises from not choosing, the complexity of a "total eco-interactive on-going web. . . in which we dance" (*ibid*.).

To the thinking of Brand and Bateson, it was the modern human's insistence upon choosing between contradictory elements that led to social and cultural "insanity." The mistake lay in pursuing the "pathology of insistent control" in a universe that was fundamentally, and marvelously, uncontainable and uncontrollable (*ibid*.). The path to sanity, to sustainable innovation, to healthier relations among people, technologies and nature, lay in bringing technology into alignment with the ways of a nature understood as irreducibly complex, indeterminate, and interactive. In the discourse of the techno-ecological whole system, the unpredictably new and innovative arises out of letting go of control, allowing the paradox to remain unresolved, the complementary variables unsynthesized. Attempts at resolution or synthesis lead to the contained predictability of the restricted economy. Without the wildness of the general economy, the convergence of technology and ecology slides back into the either/or mode of the previous paradigm and provides no escape from the old, stagnant dichotomies: nature versus culture; organism versus mechanism; technosphere versus biosphere.

In the course of this study, we have seen how various parties have tried to wrangle the general economy of the techno-ecological system back into a restricted economy, by resolving its paradox and synthesizing its complementary variables. For the political scientist Timothy Luke, for example, there was no nature in Biosphere 2. The odd structure in the Arizona desert was completely artificial, a "sub-real" Earth serving only the hubristic ambitions of its human creators. Luke attempted to resolve the complementarity of Biosphere 2 by dismissing the nature variable, counting everything as "technology," and thereby placing control and responsibility purely in the hands of people. He did not account for the necessary wildness of the self-regulating, self-organizing techno-ecological system, which made it by definition impossible for its human participant-observers to control. In contrast to Luke, Dorian Sagan dismissed the artificial variable, and called everything "nature." The technologies of Biosphere 2, Sagan argued, were the instruments of Gaia, the means by which the planet would come to reproduce itself. Like Luke, Sagan's interpretation could not account for the failure of Biosphere 2, but for opposite reasons: he did not allow for the necessary control and responsibility of people, who could not permit the human Biospherians merely to go "extinct" while the techno-ecological system organized and regulated itself toward some dynamic equilibrium. Neither Luke nor Sagan recognized that Biosphere 2, as conceived, was a general rather than restricted economy, in which the complementary variables, nature and technology, could not be synthesized. They did not see Biosphere 2 as a system in which both human control and system control were essential and simultaneously mutually exclusive.[7]

Once the fundamental paradox of a techno-ecological system is resolved – the complementarity of its variables dismissed by subsuming one within the other, for example – it ceases to be a techno-ecological system at all. It becomes another restricted economy, locked into the problematics of an older paradigm. For example, once the dream of self-sustaining, human-inhabited ecosystems in space was abandoned, Biosphere 2 became a human-controlled laboratory rather than an outlaw area promulgating techno-ecological co-evolution.

Michael Rothschild seemed to recognize the importance of asynthesis as he drew out the implications of bionomics: the global, self-regulating, decentralized, technology-driven economy of the information age and the global, self-regulating, decentralized, DNA-driven ecosystem could not be merged together. If they were, then bionomics would become merely another social Darwinism or sociobiology – that is, another modernist restricted economy horrifically justifying the survival of the strong and the elimination of weak. Rather, Rothschild insisted that the free market economy and the ecosystem were parallel systems, developing under similar conditions, according to the same universal laws of complex whole systemness. “According to the bionomic view,” Rothschild wrote, “genetic information and technical information independently evolved into an ecosystem and an economy of striking similarity because both realms of information confronted the problems of survival in environments with limited resources”

(Rothschild 1990: 349). As a result, he argued, there are no grounds in bionomics for making claims of either natural superiority or genetic determinism. Bionomics, in other words, constructs the planet as a techno-ecological system comprised of parallel but mutually exclusive sub-systems, one economic, the other ecological. The two sub-systems imply and justify each other, but must remain separate, though mutually constitutive of the larger system. Otherwise, the encompassing system becomes a determinate, restricted economy, rather than an indeterminate, general economy, and cannot surmount the either/or logic of the old nature-versus-culture binary with the both/and illogic of complementarity.

Kevin Kelly, whose “neo-biological civilization” was addressed along with bionomics in Chapter 6, likewise understood the general economic character of techno-ecological systems. He stressed that complex, self-organizing, self-regulating whole systems must by definition exceed human control. In that uncontrollability lay all their power to adapt, flourish, surprise, and carry forward the infinite diversity and resourcefulness of Life itself. He located humankind in the curious dual-position of “god,” simultaneously empowered to create new “vivisystems,” and subservient to vast, universal powers pushing complex, living whole systems into ever newer and more innovative configurations.

In contrast to such an embrace of wild, uncontrollable complementarity, consider the way Gerard O’Neill conceived of space colonies: perfectly controlled environments, in which the natural elements were hand-selected and put into the service of human comfort and utility. It took Stewart Brand, with his orientation toward cybernetic whole systems, to imagine space colonies as outlaw areas in which humans, nature, and technologies might experiment with radically unpredictable new relations. That is, space colonies were general economic techno-ecological systems in Brand's discourse, but restricted economic technologies in O'Neill's.

Studies of technoscience, from Haraway, Keller, Hayles, and others, depict the convergence of organisms and machines as a merger, a synthesis, or in Haraway's term, an "implosion," into a new type of hybrid entity, the cyborg (Haraway 1997: 12). I am not challenging that description, but only asserting that in the case of whole systems technologies and whole systems ecology, the convergence depends upon asynthesis rather than synthesis. That is, while cyborgs are a "fusing of cybernetic device and biological organism" (Hayles 1999: 84), in the techno-ecological system nature and technology are never fully synthesized, though they are at the same time co-evolutionary and mutually constitutive of the encompassing system. Without the indeterminacy that hinges upon the asynthesis of its complementary variables, the techno-ecological system loses its power to dismiss the technosphere-versus-biosphere problematic, to salvage hopes for both technological progress and ecological sustainability, or to justify the order of globally networked information technologies in the context of the planet's ecological systems.

Inside/Outside

Nature and technology are one set of complementary variables in the techno-ecological system, analogous (though not perfectly so) to the wave-particle pairing in subatomic systems. They are mutually exclusive and unsynthesizable within the system and yet equally essential to it. To call the techno-ecological system only *natural* is to reduce it immediately to a restricted economy that leaves out human control; to call it only a *technology* is also to reduce it to a restricted economy, one in which nature has no sovereignty. At the same time, to say that in the techno-ecological system nature and technology have fused together likewise reduces the general economy to a restricted economy, for once that synthesis takes place, there is no more paradox, no loss of representation, no complementarity. Techno-ecological systems are, rather, indeterminately both natural and technological.

The location of people relative to the system forms the other central pair of conjugate variables. As I have contended throughout this study, people are both fully inside and fully outside the techno-ecological system at the same time. In the old, modernist binary, people are either inside nature or outside. Being inside nature is associated with premodern life, organicism, interconnectedness, romanticism, subservience to the laws of nature. Being outside nature is associated with modernism, technology, objectivism, progressivism, control over nature. This inside-versus-outside dichotomy became particularly evident in the years after World War II, when global technology-driven environmental crises forced the question of humankind's relationship with the planet. The techno-ecological system came into being as a means for moving past this inside-versus-outside, biosphere-versus-technosphere impasse.

We can see how the inside-versus-outside dichotomy works at the planetary level by looking at Tim Ingold's essay, "Globes and Spheres: The topology of environmentalism" (Ingold 1993). Ingold argues that premodern civilizations depicted the world as a sphere, or a series of concentric spheres. Humans were located at the center of the sphere and looked outward, toward more expansive levels of engagement with their "lifeworld." The Yup'ik Eskimos, for example, imagined the world as a sphere at the center of which dwelt people, who, traveling in any direction, eventually arrived at the place where the Earth folds up into the heavens. Similarly, medieval Europeans envisioned themselves at the center of concentric spheres. By ascending upward through the spheres via increasingly refined sensory attunement, one could gain comprehensive knowledge of the universe. In contrast, according the Ingold, modern people perceive the world as a globe. It is not their lifeworld, but an object they can observe with detachment from a distance. From the global perspective, humans live on the surface of the world, not at its center. The world is a "*tabula rasa* for the inscription of human history," the biosphere a surface upon which modern humans have interposed a layer of their own creation: the noösphere. This, Ingold states, is the "complete obverse of the medieval conception" (*ibid*.: 37).

Ingold uses this sphere-versus-globe schema to explain the environmental destruction wrought by modern technological civilization. "The dominance of the global perspective," he writes,

> marks the triumph of technology over cosmology. Traditional cosmology places the person at the centre of an ordered universe of meaningful relations. . . and enjoins an understanding of these relations as a foundation for proper conduct toward the environment. Modern technology, by contrast, places human society and its interests *outside* what is residually construed as the 'physical world', and furnishes the means for the former's control over the latter. Cosmology provides the guiding principles for human action *within* the world, technology provides the principles for human action *upon* it. Thus, as cosmology gives way to technology, the relation between people and the world is turned inside out (*ibid.*: 41).

In response to the technosphere-versus-biosphere conflict, Ingold, like the authors of *The Limits to Growth* and many others, implies that humankind, for the sake of its long-term survival, must turn its back on technology and somehow restore a premodern way of thinking and being in the world. For him, the conflict between modern technological civilization and the global environment suggests two options: either people find a way to locate themselves back inside of nature, or they destroy their world by continuing to see themselves outside and in control of nature.

This was precisely the either/or choice Stewart Brand hoped to avoid. The techno-ecological systems he pursued responded to this dichotomy in two ways: first, they identified an order of technology that was not at odds with nature, but was rather parallel to nature, the same kind of entity; second, they dismissed altogether the question of whether people were inside or outside of nature, replacing it with the question of where to locate people relative to the system. Nature was encompassed, along with complex, cybernetic technologies, within the larger system: Spaceship Earth, space colonies, Biosphere 2, cyberspace, etc. People could not be solely inside the techno-ecological system, for, as Brand stated in *Two Cybernetic Frontiers*, “the rules of articulation of a system are inarticulate within that system” (Brand 1974: 7). Humans needed to be outside techno-ecological systems in order to build them, as well as to ensure and articulate the rules, the values, the essential goodness of the universal laws of whole-systemness. However, people could not be solely outside the techno-ecological system either. They needed to be able to live within the system, deferring to the sovereignty of the system to self-organize and self-regulate. Otherwise, by definition, the system could not be a complex, cybernetic whole system at all. If people were strictly outside the system, then the system would be a restricted rather than general economy, without the inventive wildness to ensure its evolutionary future by continually becoming the unpredictably new. If people were strictly inside the system, then the system again would be a restricted rather than a general economy, a fully determined system indifferent to human choice or agency. Instead, the question of where people are located, inside or outside of the system, is undecidable, and through this unknowability, this complementarity, the system gains its ability to keep the question of control ambiguous, freeing humans to be at once the source of and the instruments of the increasingly complex, pervasive, world-encompassing network of techno-ecological relations.

Conclusion

The complementarity of the techno-ecological system allowed, as we have seen in the case of Brand, a way out of the either/or logic of the technosphere-versus-biosphere, nature-versus-culture impasse. It neither chose one variable over the other, nor synthesized the two. Instead, it admitted them both as simultaneously essential and mutually exclusive. Through the discourse of the techno-ecological system, Brand could envision a future in which networks of creative, independent individuals, equipped with the proper tools and a “functional, grimy grasp on the world,” might build new relations with one another and with their environment through their own powers of invention, while at the same time the natural systems of the planet might continue to function in good health. What’s more, within the techno-ecological system, technology and nature might co-evolve, strengthening the ability of each to adapt, change, diversify, invent, and thrive.

With Kelly, Rothschild, and others who came after Brand, the purpose of the techno-ecological system began to change. Instead of empowering individuals to improve their lives and the health of their environment, the convergence of ecology and technology within a whole systems discourse came to serve the purpose of legitimating and perpetuating a doctrine of complex whole-systemness. “Bionomics” and “neo-biological civilization" were abstractions far removed from Brand's Fuller-domed "hope freaks," his networked hackers, his "musicians, lovers, outlaws, and spies."

By the nineteen-nineties, the whole-systems discourse had thoroughly constructed the Earth as a techno-ecological system. Being on Earth was like being in the Apollo spacecraft, like living in a space colony or in Biosphere 2, like residing in cyberspace: at once natural and artificial, at once an encompassing world and an object to be manipulated and maintain, simultaneously technological and ecological. The ambiguity of control that arose from this irreducible complementarity functioned to justify the global information economy and legitimate unrestrained technoscientific adventurism. Brand's iconoclastic individual had been replaced by the immense juggernaut of late-twentieth-century technoscience as the "god" empowered to bring about new relations among people, machines, and nature.

Notes

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[1] Cited in Plotnitsky 1994: 66-7.

[2] Heisenberg's indeterminacy principle was a mathematical expression of these same features of quantum mechanics – the limits of simultaneous exact measurement of complementary variables. See Heisenberg (1958).

[3] See Chapter 5 for a discussion of the impact of Bateson's ideas on Stewart Brand. See Harries-Jones (1995) for a brief discussion of Korzybski's influence on Bateson.

[4] Cited in Plotnitsky 1994: 72.

[5] As Plotnitsky writes, "In quantum mechanics, one must always deal with the fact that irreducible, irrecoverable losses in the representation of the behavior of quantum systems do take place and that one must relate both one's interpretation and theory to these losses, which can only be done by means of general economy" (Plotnitsky 1994: 72).

[6] Cited in Plotnitsky 1994, pg. 20.

[7] For an example of a scientist's embrace of the paradox, contradictions, complementarity in whole systems models of nature and technology, see Daniel B. Botkin, *Discordant Harmonies: A New Ecology of the Twenty-First Century* (1990). Botkin argues that decentralized, parallel-processing computer operations should be used as a model for understanding biological and ecological entities.

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