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The closed world of ecological architecture

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This article explores how and why imagined and real environments in space came to serve as models for ecological design of earthly landscapes and buildings in the 1970s. It claims that life in space came to represent the peaceful, rational, and environmentally friendly alternative to the destructive, irrational, ecological crisis down on Earth. Spaceship management aimed narrowly at the biological survival of astronauts, an ethic which also came to dominate ecological design proposals on board Spaceship Earth. The result was a design programme which was at the expense of a wider aesthetic and social understanding of the human condition. The article reviews the work of leading ecological designers of the period, such as Ian L. McHarg, John Todd and the New Alchemists, Alexander Pike and John Frazer, Brenda and Robert Vale, Ken Yeang, Phil Hawes, and others. It situates their projects in the perspective of ecological research methods of the period and puts forward an understanding of their thinking in the context of space exploration. Today's challenge is to escape the intellectual space capsule that ecologists have created for environmentally concerned architects.

Introduction

'Space exploration [has] created for architects, landscape designers and city planners the conceptual basis for a wholly new approach to the design of human settlements', the renowned professor of architecture and environmental design at Columbia University James M. Fish noted in 1971.[1] The ecological approach to the construction of space cabin environments for astronauts linked space exploration to design. These space cabins, Fish argued, should serve as models for environmentally responsible landscape and architectural designs on Earth.

This article argues that imagined and real environments in space were of key importance for the historical development of the ecological design of landscapes and buildings on Earth. It may come as a surprise to a field known for trying to design with nature on the ground that the programme of space colonisation has been their underlying ethic. Ecological design is inspired by a biologically informed vision of humankind embedded in an Arcadian dream of building in harmony with nature, according to its admirers, who do not draw connections to space exploration.[2] The following pages claim that living in harmony with the Earth's ecosystem became for the majority of ecological designers a question of adopting space technologies, analytical tools, and ways of living. Their aim was not only to improve life on Earth, but also to design an escape from industrial society. Most ecological architects believed that industrial society was doomed and that their task was to design

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bio-shelters or eco-arks modelled on space cabins in which one could survive if (or rather when) the Earth turned into a dead planet like Mars. Social life within these buildings resembled the technologically informed lifestyle of astronauts monitored and managed by the scientifically minded ecologist. Life in a future ecologically designed world was focused on biological survival at the expense of wider cultural, aesthetic and social values of the humanist legacy.

The article will proceed first with a general discussion of why space research became important to ecological debate about architecture. The next sections will move from large open to smaller designs, starting with landscape planning and ending with the architecture of autonomous enclosed buildings. These attempts to mirror closed ecosystems within space cabins resulted in designs construed as enclosed microcosms of the living world.

Space ecology and the environmental debate

Imagined and real environments in outer space were to environmentally concerned designers models for how to handle the ecological crisis on Earth. This use of the space cabin, or the astronaut's *oikos*, as the model for nature's household continues a long tradition in ecology of modelling nature on human homes.[3]

The politics of colonising outer space was important for the development of ecological debate, methodology, and practice in the 1960s and 1970s.[4] The problem of how to build closed liveable environments in space for astronauts came to occupy a number of ecologists. By diagramming the flow of energy as input and output circuits in a cybernetic ecosystem they were able to suggest ways to construct new artificial ecosystems in space. They were initially engaged in researching the construction of self-sufficient closed ecological systems within submarines and underground bomb shelters. With the space programme of the 1960s, this know-how was used to suggest construction of closed ecological systems within space capsules, ships, and even colonies. Ways of building closed ecological systems within a space colony or a spaceship were of key importance if astronauts were to live self-sufficient lives independent of supplies from the Earth. Important ecological methodology and terminology related to such ecosystems emerged from what was commonly known as the science of 'cabin ecology' in reference to the space cabin of the astronauts.

Serge Chermayeff and Christopher Alexander were probably the first architects who became aware of the importance of space research to ecological design. Their *Community and Privacy* (1963) began by noting the environmental erosion of the human habitat through the invasion by suburbia of farmland and wilderness. To Chermayeff this was a personal matter, as his country home in Cape Cod, Massachusetts, was in danger of being enclosed by dense development and industrialisation. As a remedy they thought humans should build their own autonomous ecologies instead of exploiting the natural one. It was an urgent 'need to design fully functioning self-contained environments, capable of sustaining human life over long periods' instead of creating buildings which exploited the environment. As a source of inspiration they pointed out that '[b]oth the nuclear submarine and the space capsule have been designed to support

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life over protracted periods without the possibility of escape'.[5] Although they saw a danger in 'the capsule syndrome' of claustrophobia in such closed environments, they still believed that architects should strive towards making buildings ecologically autonomous instead of designing them in a way that caused exploitation of natural resources.

Community and Privacy became a widely read book and various architects came to experiment with the construction of self-contained ecological 'capsules' for their clients. Two of them noted that the patrons were not thrilled by the prospect of living in closed environments in order to spare natural sceneries. It was a 'difficult task of introducing the public to the notion of living in a condominium apartment in the middle of a countryside'. To others, 'the ecology of privacy' suggested promising research into human behaviour within enclosed buildings, for example, a student's territorial defence within a library.[6]

Richard Buckminster Fuller read *Community and Privacy* with great interest, and would soon adopt space ecology as his chief approach. As the engineer of a series of domes used for military purposes and a keen admirer of the Navy, he knew at first hand the importance of military research. As early as 1963, he would note that 'billions of research dollars' had 'been applied to a closed chemical circuit of ecologic [...] living of moon-rounding men'.[7] Around the same time Fuller started using cabin ecology in his lectures as a model for understanding life on Earth. 'I've often heard people say, "I wonder what it would feel like to be on board a spaceship", and the answer is very simple. What *does* it *feel* like? That's all we have ever experienced. We are all astronauts',[8] he explained in his *Operating Manual for Spaceship Earth* (1969), a book which basically postulates using cabin ecological engineering manuals to solve environmental problems on board Spaceship Earth. The image of being a space traveller had obvious appeal in a period in which the public was spellbound by the US's Apollo programme. Fuller implied that the Earth was a huge mechanical ship traveling in space, and keeping that Ship on a steady course became the chief topic of his numerous lectures. To readers of *Playboy*, for example, he would fancy utopian new cities on the moon complete with their own closed ecological systems. They were to be chemically free of politics, and instead steered by designers and scientists constantly managing their ecological balance and harmony. He inspired many designers, such as Ulrich Franzen and Paul Rudolph, who in a similar fashion drew up futuristic cities on 'spaceship earth' modelled on imagined space colonies.[9]

This turn towards space ecology as a beacon of hope should be understood in the context of gloomy ecological predictions for the Earth. In the late 1960s and early 1970s a series of alarming reports came to dominate environmental debates. Paul Ehrlich's *The Population Bomb* (1968) and The Club of Rome's *Limits to Growth* (1972) may serve as examples of literature causing intense debates about the future of industrial societies and ways of avoiding a global ecological collapse. Architects were also among the concerned. A special 'Designing for Survival' issue of *Architectural Design* published in 1972 may serve as an example.[10] It was adorned with an image of a human skull emerging

from industrial pipes which captures the mood of the articles: humankind would face a certain death unless something was done with all the pollution. The task of designers, the articles in the issue argued, was to secure the biological survival of the human species by incorporating ecological principles in future buildings.

The ecological state of the world was only one of many disturbing issues, such as the Cold War, the Vietnam War, violent Civil Rights demonstrations, and the struggle for women's liberation. In this period of questioning of authorities, the space programme came to represent a beacon of hope for the counterculture. People of the so-called '"68" generation', the historian Mark Kurlansky has argued, viewed space exploration with 'tremendous excitement'.[11] New soft-tech solutions emerging from space research were presented in the *Whole Earth Catalog* as attempts to establish productive reconciliations between the natural and the technological realms.[12] The royalties from this hugely popular catalogue for counterculture lifestyle were used to finance research into the ecological colonisation of outer space. Its editor, Stewart Brand, was a firm believer in the value of space colonisation. His financial and intellectual support was not without controversy, though the large majority of his readers shared his belief that space colonies could provide well-functioning environments for astronauts seeking to push human evolutionary expansion into outer space.[13] Moon or Mars colonies could save earthly species from industrial destruction and possible atomic apocalypse on Earth. They also could, at least in the thoughts of the architect Paolo Soleri, provide humans with a healthy spiritual place.[14] In the 1970s, environmental ethics became an issue of trying to live like astronauts by adapting space technologies such as bio-lavatories, solar cells, recycling, and energy-saving devices. Technology, terminology, and methodology developed for the ecological colonisation of space became tools for solving environmental problems on Earth.

A series of scholars, economists, politicians and environmentalists of the period also pointed toward space ecological research as a remedy for the eco-crisis. The economists wrote about the virtue of closed (as opposed to open) economic systems within spaceships.[15] United Nations politicians talked about the need for global steering of 'spaceship earth' through that organisation.[16] Concerned environmentalists adopted 'spaceship earth' as a key concept signifying the importance of scientific steering.[17] It was especially the notion of an ecological 'carrying capacity' for a given number of astronauts within a spaceship that was systematically used to analyse carrying capacities on Spaceship Earth. Population biologists like Paul Ehrlich, Richard L. Harriman and Dennis C. Pirages, for example, fashioned every aspect of life on Earth in accordance with a spaceship's carrying capacity of astronauts. To them spaceships were like possible Noah's Arks sailing away from an ecologically doomed Earth. They even wrote a homage to Noah as a prologue to their book *Ark II* of 1974:

> Noah had ample warning from a respected authority to build his Ark, and he used his time to good advantage. Skeptics laughed, ridiculed, and drowned—but Noah, the original prophet of doom, survived.[18]

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'We too have been warned', they continued, before plunging into a massive analysis of the Earth's gloomy biological future and the need to refashion the globe's environmental disorder according to the imagined 'Ark II' in space.

Scholars in astronautics and space ecology were delighted by the adoption of their methodology and approach by other disciplines and the larger public.[19] Ecologists working on more earthly environments adopted the managerial language of space exploration in their analysis of human activities. Howard Odum, for example, made a book-length case for understanding earthly ecosystems and human activity in terms of an astronaut's life in outer space in his widely read *Environment, Power and Society* (1971). 'The biosphere is really an overgrown space capsule, and the questions about carrying capacity are similar', he argued. The book was written for a wide audience and was frequently quoted by landscape designers and architects of the period. He did not use the space capsule as a vague analogy or metaphor, but as an ontological claim about the world. His methodological reductionism of all biological life (including human behaviour) to charts of energy circuits became the justification for his proposals for scientific management of both natural and human households.[20] Such analogies to spaceships were not an effort to popularise ecological knowledge, as ecologists also in intramural studies explored the relevance of space ecology in understanding the Earth as one closed ecosystem.[21]

Seeing the world as one integrated cabin ecological system was reinforced by the Arab oil embargo of 1973–1974 which showed how events on one side of the globe could dominate politics on another. The subsequent literature about alternative energy sources and savings came to highlight the importance of seeing local initiatives in a global perspective. The US National Science Foundation and the National Aeronautics and Space Administration (NASA) were suddenly 'pouring millions of [research] dollars into solar heating' in an effort to find a viable alternative to oil.[22] The space programme would create an entire solar cell industry. Its clean energy represented for many a possible transition from an age of fossil fuels to a brighter future based on space ecological technologies. The aim of this research was to obtain the same level of self-sufficiency as commandos in harsh territories or astronauts in future space colonies: 'The military has developed a fairly sophisticated technology for the autonomous servicing of permanent and temporary communities in a variety of environments including harsh ones—such as the arctic and space', a commentator noted in *Architectural Design*. 'Much of this knowledge could be put to better use. Useful systems include survival packs for pilots baling out over the arctic, [and] life support systems for astronauts'.[23]

The ability to see the environment on Earth as a whole, anthropologists and historians have shown, presupposed a privileged point of view from space.[24] This global perspective came with the ability of seeing the Earth from outer space. Such images were first taken by astronauts in December, 1968 and they would in the subsequent years generate wide public appreciation. 'A view of the earth from outer space gives our generation a perspective never before experienced in history', one urban

planner noted, 'we are passengers on a planet involved in the intricate cycles of life'.[25] The view from outer space triggered planning on a scale that was previously unthinkable. The Greek urban planner and architect Constantinos A. Doxiades, for example, drew up plans for global settlements. He argued that humanity, thanks to dramatic population growth, was 'heading towards a universal city, towards a city which will cover the whole world, towards Ecumenopolis'.[26]

Ian McHarg's fitting of Spaceship Earth

In terms of landscape design, Ian McHarg became particularly influential. As professor at the Department of Landscape Design at the University of Pennsylvania, he came to inspire a whole generation of designers. It is worth investigating his *Design with Nature* (1969) in some detail, since he used cabin ecological research tools in his suggestions for global landscape management.

Although considered revolutionary by many of his readers, McHarg's book represented a continuation of his previous work. He grew up near Glasgow in Scotland where he learned to appreciate urban planning in the tradition of Patrick Geddes. After the war he went to Harvard where he studied architecture from 1946 to 1950 under Walter Gropius. The importance of science to design was very much part of the Bauhaus approach, at least as it was taught by Gropius. In his lectures Gropius encouraged his students to learn from the biological sciences. He warned against capitalistic greed that could come to dominate human life unless architects were nurturing an 'organic social structure' by designing with natural and not capital forces: 'Overwhelmed by the miraculous potentialities of the machine, our human greed has interfered with the biological cycle of human companionship which keeps the life of a community healthy', he warned his students. What they should do was to '*love and respect the land almost religiously*' so that it was not 'bulldozed out of existence'.[27]

Inspired by his mentor, McHarg would promote science-based modernist architecture and planning, along with respect for nature. He praised the grand landscape design of the Tennessee Valley Authority, for example, as 'a great vision', because of its commitment to biologically informed planning and restoration.[28] The managerial perspective of large-scale planning, he argued in 1963, was like being 'far out in space' looking 'back to the distant earth'.[29] Environmental problems were due to the 'anarchy which constitutes urban growth' without this proper view from above.[30]

McHarg would frequently refer to the importance of ecology, although it was not until 1966 that this came to the forefront of his approach to landscape design. The occasion was the year-long visit to the Department of Landscape Design by the South African ecologist John Phillips (1899–1987). Phillips had spent his student years in the same landscape as McHarg, with his mentor Isaac Balfour, the Scottish ecologist and colleague of Geddes. In South Africa Phillips was known for his close friendship with his patron, the country's long-time Prime Minister Jan Christian Smuts. Based on Smuts's book, *Holism and Evolution* (1926), Phillips developed an holistic theory of ecology for which he coined the term 'the biotic community' as its key concept.[31] Through Smuts's philosophy, he sought to establish

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an holistic understanding of the environment which explained actions of individual species in the light of the dynamics of an entire biotic community.

It was Phillips who introduced 'the holistic approach' to architects and regional planners, arguing that they ought to include ecology and 'all forms of life' in their designs.[32] His challenge came in a special 'Ecology in Design' issue of the journal *Via* in 1968 where a series of planners and designers embraced his views. Jack McCormick wrote that ecological methodology represented, virtually, 'flower power' to planners.[33] Louis Kahn pondered whether to design an ecological garden for his Salk Laboratory (and decided instead to go for a minimalist garden of stones to evoke spiritual 'powers of anticipation' among its users).[34] Fritz Morgenthaler and Aldo van Eyck saw in Phillips's holism a return to the wisdom of primitive designs.[35] What all agreed on was the importance of drawing connections between ecology and other disciplines. As Nicholas Muhlenberg noted: 'we must consummate a marriage between a reluctant bridegroom (ecologist) and a blushing bride (economist), sending the minister (planner) along on the honeymoon'.[36]

McHarg was no less enthusiastic about Phillips and holistic ecology. In view of destructive industrialism, he saw in his approach an environmental philosophy that enabled humans 'to participate in the environment in a way appropriate for survival, and emerge as a fit agent in evolution'.[37] He adopted Phillips as his chief mentor, praised him for his 'valuable advice and criticism' in the preface of *Design with Nature*, and would later in life recall how 'the legendary South African ecologist' had 'contribute[d] scientific insights' to his book.[38] It was made possible thanks to a grant from the Conservation Foundation, and he framed the conservation ethic of his patron in Phillips's holistic terms.

The ecological crisis, McHarg argued in *Design with Nature*, was caused by reckless laissez-faire economy, individualism, Western capitalist greed, chaotic urbanisation, fragmentation of social structures, and lack of planning. As a remedy he pointed to the holistic ecology of 'the Orient', a perspective which was non-anthropocentric, implied orderly planning, and respect for the biotic community. Personally, he recalled his childhood's Scotland where he could tell apart 'the industrial toil which Glasgow represented and the beautiful countryside' in the city's surroundings.[39] Intellectually, he projected this difference into a grand critique of Western anthropocentric industrialism versus an Oriental harmonious naturalism. McHarg thus came to continue the British colonial tradition of imagining moral alternatives in the exotic Orient, embodied in the South African ecologist's thinking.

In *Design with Nature*, the imagined life in outer space came to represent this holistic 'Oriental' alternative to the havoc of Western anthropocentrism. The US's space programme was well underway, with the first unmanned spacecraft landing on the moon while McHarg wrote his book. In the last week of 1968, Apollo 8 sent photographs of the Earth as seen from space, an image which McHarg adopted in a modified form to adorn his book cover. The image of the Earth as a whole was to evoke the environmental ethics of the astronaut: 'We can use the astronaut as our instructor: he too is pursuing the same quest. His aspiration is

survival—but then, so is ours', McHarg argued.[40] The importance of the perspective of the 'moon traveller' to understanding ecological relationships on Earth had everything to do with the life-support systems of space cabins. The astronaut's photograph of the Earth as a whole embodied the 'Oriental' wisdom of ecological holism which was different from destructive Western compartmental reasoning.

Travelling in space forced the astronaut to realise human biological dependence on the ecological stability of the space cabin. 'This realisation of dependence was a crushing blow to anthropocentrism', McHarg believed, since the astronaut could not survive if the ship did not sustain its own ecological balance.[41] The Earth should be viewed in the same way as the space capsule: 'In enlarging the capsule, the objectives remain unchanged; to create a self-sustaining ecosystem—whose only import is sunlight, whose only export is heat—sufficient to sustain a man for a certain period of time'.[42] McHarg would emphasise again and again that people on board Spaceship Earth were governed by the same laws as astronauts. The 'astronaut's diet', for example, was something the ecologically concerned citizens on Earth should eat, since it was presumably grown within the carrying capacity of a self-sustained space cabin.[43]

In the future, McHarg imagined, humans would build and settle in 'a space buoy' located between the Moon and the Earth. Here the ecologists were to 'reproduce a miniature farm' within an artificially built biosphere providing the astronauts with food. It was supposed to be an organic community of plants, insects, fish, animals, and birds designed to have a carrying capacity for several astronauts. Here the astronaut was supposed to function as 'a natural scientist and an excellent research ecologist. [His] major task was clearly not only understanding the system, but managing it. Indeed, while the astronaut had learned a great deal of indispensable science, his finest skill was that he could apply this in the management of the ecosystem. We could now call him an intelligent husbandman, a steward.'[44] To McHarg, the astronaut and the life in the future 'space buoy' served as a human ecological utopia.

The design of a future human settlement floating in space became McHarg's conceptual model for how to proceed with landscape design on Earth: 'The astronaut learned that he had lived in a capsule that was a poor simulation of the earth, but that the world was, indeed, a capsule.'[45] Following the managerial strategy of managing energy in the space capsule he suggested creating 'an ecological value system in which the currency is energy'.[46] One should first make an ecosystem inventory of an environment, investigate its changing processes, and identify its limiting factors. In the next step one should attribute values to the ecological aspects of the landscape, determine what changes would be permited and prohibited, and finally identify indicators of stability and instability in the system. It was a method designed to determine minimum social cost and maximum social utility for humans as well as nature. Through this utilitarian reasoning, landscape design was to mobilise nature's own 'intrinsic value-system in which the currency is energy and the inventory is matter'.[47]

This value system was based on space ecological analysis, and he used it to analyse landscapes as diverse as the dunes of the New Jersey shoreline,

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the Richmond Parkway in New York, and the suburbs of the Valleys north of Baltimore. Working from the ideal of the perfectly managed closed ecosystem in the imagined space colony, there were attempts to find ways to plan these earthly landscapes so that they gradually would turn into environments resembling imagined biotic communities in outer space. McHarg fashioned the landscape designer as a cabin ecological engineer managing and surveying the environment in analogy to how NASA's Ground Control in Houston kept a close eye on the cabin ecological circulation of energy and materials within a spaceship.

Design with Nature became a phenomenal success with over three hundred and fifty thousand copies sold over a period of thirty years. It received several hundred reviews, out of which only one, according to McHarg, was critical.[48] The book was taken seriously by scholars, administrators, and lay people alike. Indeed, it changed the field of landscape design which from then on embraced the ideals of space ecosystems. It also changed McHarg's life. He became a celebrity in design circles, and would gather large audiences for his lectures. On the occasion of the American Association of Architects' 'Day of Awareness' at their Boston Conference in 1970, for example, McHarg gave an honorary lecture about the importance of ecology for design. The lecture was all about the importance of space capsule ecology to the study of landscapes: 'What's true of the capsule is true of the world', he argued, pointing to the similarities between interacting and recirculation processes in spaceships and what happened in environments down on the Earth.[49] What architects should do, he said, was to think about humans as animals in an evolutionary struggle: 'We are in this business of adaptation for survival. That is the real definition of architecture', he argued in reference to the Darwinian principle of survival of the fittest: 'Architecture should not be called architecture; it should be called fitting.'[50]

Humans were not 'fitting' very well, McHarg claimed in a series of articles and lectures that became increasingly gloomy during the 1970s. Looking at human activity from the perspective of a 'space voyager' proved that humans were 'an epidemic' and 'disease' destroying the environment at an alarming rate.[51] Humans were not living within the carrying capacity of their closed ecological system in comparison with the astronaut's ideal life within the space capsule. Only through 'fitting' of landscapes and buildings could humankind hope to succeed biologically as a species.[52] Design should adjust to 'basic human needs', a concept McHarg based on the astronaut's needs in a space cabin.[53]

Fitting local space arks for human survival

Ian McHarg's suggestions for remodelling industrially hammered landscapes as space ecological communities were met with widespread support. The activities of the influential New Alchemy Institute may serve as an example of how some of his ideas were carried out on a local scale.

One of the few scholars who had actually tried to build a closed ecosystem was the biologist and New Alchemist John Todd. Space enthusiasts were especially impressed with his experiments with fish-farming, which was highly relevant to imagined future farming in outer space. Todd agreed that his

experiments had 'many of the attributes of a space colony', but he would in 1977 'consider it unsafe to attempt to simulate liveable environments [in space] from our present biological knowledge'.[54] What he sought to do, in collaboration with a series of ecologists, was to build a closed ecosystem on Earth before trying to build one in space. After all, 'if stable and productive closed ecosystems could not be made to function on Earth they certainly would not function in orbit', and definitely not on the Moon or on Mars.[55] As a consequence, he sought to build closed ecological systems on Earth and develop an ecological managerial system for land and buildings inspired by the ideals of imagined future space colonies.

The New Alchemy projects began in 1969. Trained in agriculture, aquaculture, comparative psychology and ethnology, Todd was teaching a course in 'doom watch biology' at San Diego State University in California when he decided to do something about the sad state of the Earth.[56] As he later explained to a *New York Times* reporter: 'I got tired of ringing the alarm bell all the time. I want constructive alternatives.'[57] With the oceanographer and fish ecologist William McLarney he founded the New Alchemy Institute to pursue the cause. Their slogan 'To Restore the Lands, Protect the Seas, and Inform the Earth's Stewards', captures the spirit of this back-to-the-land commune which cherished a blend of political anarchism, environmentalism, and anti-urbanism.[58] Scientifically they used ecology and cybernetics in their construction projects, first in 1969 near Woods Hole, Cape Cod, next in 1973 in the Limón province of Costa Rica, and finally in 1976 on Prince Edward Island, Canada.

The New Alchemists were motivated by a deep-seated fear of not surviving the Earth's coming ecological collapse. Their chief metaphorical narrative was the Bible's story of Noah, who once built an Ark on God's advice to save the believers along with a pair of each animal on Earth from the Great Flood. Their entire project revolved around surviving the impending catastrophe, and their strategy was to emulate Noah. They fashioned themselves as 'builders of "lifeboats" and "arks"'that 'will be needed desperately' if humanity were 'to avoid famine and hardship' caused by population growth, rotten capitalism, and greedy exploitation of natural resources.[59] They put their hope in constructing a closed ecological lifeboat that would keep biologically afloat in case the larger ecosystem sank. It was a matter of survival to achieve ecological self-sufficiency, according to a review article about their Arks in *Science*, because they expected modern agriculture 'to collapse, maybe within 10 to 20 years'.[60] A *New York Times* reporter visiting the Cape Cod Ark in 1976 could not help noticing this 'apocalyptic wariness' among the New Alchemists. 'Maybe we're only a spark in the dying embers of our civilisation', Todd explained to the journalist.[61]

The name, 'New Alchemy', was inspired by pre-modern alchemical theories about the reciprocal relationship between the microcosm and macrocosm of the world. The ideal house should be like a microcosm of nature's household. As 'a productive and self-contained microcosm', the design elements of the Arks mirrored the ecological principles of the Earth as a whole.[62] Wind generators and greenhouse windows provided the New Alchemy Institute

with renewable clean energy just like the sun provides energy to the Earth. A large sun painted on the windmill in Cape Cod was to make the point more obvious to visitors, who included an engineer who published a report about it in *Science*.[63] Solar-heated fish ponds (inspired by fish farming in Maoist China) represented the oceans and provided the residents with fish. In Cape Cod they were covered by a Buckminster Fuller dome which was a mini-representation of the Earth. Intensive vegetable gardens embodied the Earth's biota and grew food for the Alchemists. They produced their own power from burning methane generated from their sewage system in an effort to mimic chemical processes within Earth.[64] An elaborate compost system mimicked the Earth's soil processes which circulated by providing food for a flock of chickens who represented the Earth's birds. Carefully designed buildings integrated the windmill, the fish ponds, the gardens, the manure, the composting, the chickens, and rooms for human activity in one entity. As experience grew with each new Ark, the New Alchemists aimed at solar-heated and wind-powered greenhouse-aquaculture buildings. The Ark on Prince Edward Island came closest to the ideal. It was built following diagrams for the movement of energy, matter, food, sewage, plants, and humans in the buildings. It had no reliance on outside energy, and thus came to represent a step toward a self-sufficient architecture that mimicked the ecological processes of nature as a whole.

There were striking similarities between the Ark projects of the New Alchemists and ecologically construed space colonies. The attempt to escape the environmental destruction on Earth by building Arks or spaceships, the progressive idea of being at the edge of human future living, the same methodological foundation in ecosystem theory, and the belief in constructing closed ecological systems for biological survival were based on space ecology. It was 'like improving a spaceship while flying through space', two visitors commented, when they were set to maintain the New Alchemist's ecosystems.[65]

Measured in terms of visitors, the New Alchemy Arks became a huge success. By the mid-1970s the Ark at Cape Cod had became a 'New Age Mecca of sorts' with a larger turnout of visitors than the New Alchemists could handle. Some were put to work on the land while others were taken on guided tours of the facilities. In effect, the Arks evolved into ecotourism resorts that through bold admission fees would supply the projects with badly needed funding.[66] The message the visitors were to take home was that in order to survive the forthcoming ecological catastrophe one had to build self-sufficient ecological architecture which did not rely on external resources. A journalist visiting in 1976, for example, described how Todd pronounced his 'evangelical' message 'like a high-church Episcopalian' announcing that they had the 'means of survival should ecological or economic disaster strike'.[67]

Some scientists and architects took great interest in the New Alchemy Arks. McLarney engaged his friends at the marine biological station in Woods Hole, who used their spare time researching alternative ecological fish farming technologies.[68] The Arks' ability to reduce energy consumption and achieve material self-sufficiency engaged ecologically concerned scholars such as S. David Freeman,

Barry Commoner, Herman Daly, Lynn Margulis, and Richard Stein.[69] Architects and designers were also among the visitors. Todd, with his wife Nancy Todd, advised them to build ecological 'living machines' (instead of modernist 'machines for living') which were to function as tiny microcosms or mirror images of the macrocosm.[70] Their book *From Eco-Cities to Living Machines: Principles of Ecological Design*, published first in 1980, and revised in 1984 and in 1994, was for over a decade the standard introduction to ecologically informed architecture. Complete with advice on how to build with solar-panels and bio-lavatories, and the recirculation of energy and material, the Arks came to represent the cutting edge of ecological design.

Despite all the efforts, by the early 1980s the Earth was still being 'raped biologically' by industrial society and the need to get ready for the coming ecological doom was as urgent as ever.[71] To be fully prepared for the impending catastrophe the New Alchemists started to experiment with 'Ocean Arks' equipped with a vegetable greenhouse, freshwater distillation systems, aquaculture pools, animals, and even tree crops. Following the call of Noah, the Ocean Arks were designed to save their sailors and species from the coming flood of ecological disasters. They were to be sailing self-sufficient closed ecological spaceships on the oceans of a dying Spaceship Earth.

The capsule syndrome in ecological architecture

The New Alchemists were not the only ones interested in building closed autonomous ecological systems. It became a trend among ecological architects who struggled towards encapsulating buildings so that the inhabitants would be sheltered against the coming doom. Attempts by the cabin ecological industry to transfer its knowledge about space designs to Earthly buildings was met with enthusiasm by architects who responded with proposals for buildings that gradually became more and more self-sufficient and enclosed, reaching a climax with the fully encapsulated Biosphere 2 of 1991.

A leading cabin ecological firm was the Grumman Corporation which in the 1960s was building aeroplanes for the US Air Force and produced aerospace technology for NASA. They played a vital role in the Apollo programme by developing and operating the so-called Grumman Lunar Module, in which the Corporation took much pride. As the first fully integrated artifact ever designed to operate solely outside the human environment, it was to the employees a major technological achievement setting the standard for their work. With the slump in space business in the early 1970s, the Corporation tried to diversify by developing products for the civil consumer market. The result was a series of innovative designs, such as a modular housing unit based on the Lunar Module, a waste disposal system inspired by space recirculation technology, a sewage system inspired by the astronaut's lavatory, and an energy efficiency system for homes that incorporated solar cells. These design suggestions and technologies were sold under the label 'Grumman's Integrated Household System' and were promoted to architects as an ecological remedy to environmental problems. The system

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applied technologies and design approaches 'initially used in the design of life support systems for spacecraft'.[72] Their suggestion for a system of water circulation within a home, for example, was basically an earthly version of Grumman's designs for water circulation and treatment within a spacecraft (Fig. 1). Grumman's way of connecting different apparatuses within a building into a coherent whole caught the attention of designers. Their study of buildings as a closed ecological system in analogy to a closed spaceship raised eyebrows and inspired environmentally concerned architects.

Equally stimulating were new household prototype technologies developed by the Lockheed Missiles and Space Company in California. It had developed technologies for a lunar base which it argued would be ideal in solving many of the ecological imbalances on Earth. Thanks to a series of

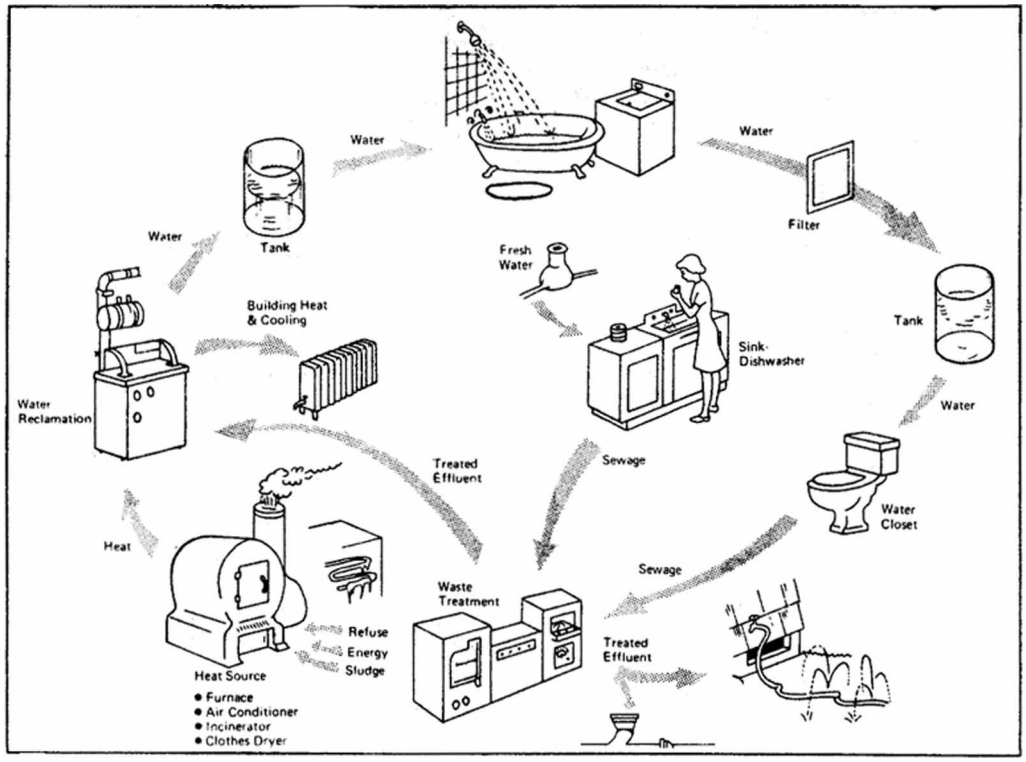

Figure 1. 'Grumman's Integrated Household System' published in *Architectural Design*, 42 (July, 1972), p. 423. The Grumman Company used its know-how from the construction of space cabins to suggest an ecological reordering of buildings on Earth.

technologies for waste, air, food and energy management, the space cabin thus came to represent the rational and scientific way of ecological living. On board Spaceship Earth, a Lockheed salesperson argued, humans were polluting their cabin with carbon dioxide, they were hardly recycling their waste, and they did not generate enough energy from the sun. It was consequently urgent to transfer technology from space capsules to the Earth.[73]

The technology developed by Grumman and Lockheed inspired projects like the 'Integral Urban House' at Berkeley in California. Launched in 1972, it was built as a closed habitat providing an ongoing life-support system for its inhabitants.[74] They read Odum's *Environment, Power and Society* (1971) and used it to analyse how building designs could contribute to energy management, resource recirculation, and water conservation by regarding a house as an unified whole. By integrating all biotic and a-biotic factors within a closed system they sought to construct a building that would function independently as a space cabin. The 'life-support system' was a key word borrowed from the space industry which signified a complete system nurturing its inhabitants without relying on resources from the outside world (except rain and energy from the sun).

The Integral Urban House project caught the attention of academics such as Sean Wellesley-Miller and Day Chahroudi, the co-directors of the Solar Energy Laboratory at the Massachusetts Institute of Technology. Impressed by the project and inspired by the New Alchemists, they set forth to improve the technical aspect of integral ecological design. The result was the Bio-Shelter. It was to function as an 'autonomous house' with an inbuilt ecosystem that aimed at generating enough food for the residents' basic needs whilst also giving 'shelter' against the imminent ecological collapse of industrial society. It resembled 'the ecological bomb shelter' developed by the military. In comparison, though, it was to have a more active community outreach programme.[75] The complete self-sufficiency of the Bio-Shelter was modelled on 'a space ship', although they did not believe in colonising outer space.[76]

This type of research was not only a US phenomenon. Alexander Pike and John Frazer, at Cambridge University, formed a similar research group investigating the relevance of cabin ecological systems to architecture. As a response to the worrying news about the ecological state of the world presented at the United Nations Conference on the Environment in Stockholm in 1972, they aimed at constructing ecologically autonomous buildings that would function independently of the Earth and thus not harm the environment. '[W]e have lost our innocence', Pike argued, referring to the architectural community's support of industrial growth and ecological exploitation. As a remedy he proposed design that aimed at economic 'contraction in place of growth, preaches austerity in place of plenty, and aims at the development of a simplified, labour-intensive society to replace the sophisticated, machine-based order that we are now beginning to find so troublesome.'[77] Closed ecological buildings promised to be labour intensive, and, consequently, obstacles to economic growth. They were to be self-sufficient and thus help to undermine industrial society, while at the same time pointing to a more

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environmentally friendly future. Despite voicing scepticism towards industrialism and technology, Pike let a host of industrial technologies determine his architecture that focused on integrating waste, water, air, and heat technologies into an ecological whole. The aim was to use ambient solar and wind energy, to reduce energy requirements, and to utilise human household and waste material (Fig. 2).

One of Pike's students, Brenda Vale, started a Soft Technology Research Community to investigate her teacher's thinking on a farm in Montgomeryshire, Wales.[78] The Community was to explore inexpensive buildings that did not lose heat and benefited from solar power. Together with her husband Robert Vale, she built an 'autonomous house' which aimed at circulating all its materials and energy on site as a closed ecological system. There was to be no linkage to local water, gas, electricity or drainage systems. It was to be 'a house generating its own power and recycling its own waste'.[79] Technically they mobilised hydrogen and oxygen fuel cell units that provided auxiliary power in the Gemini and

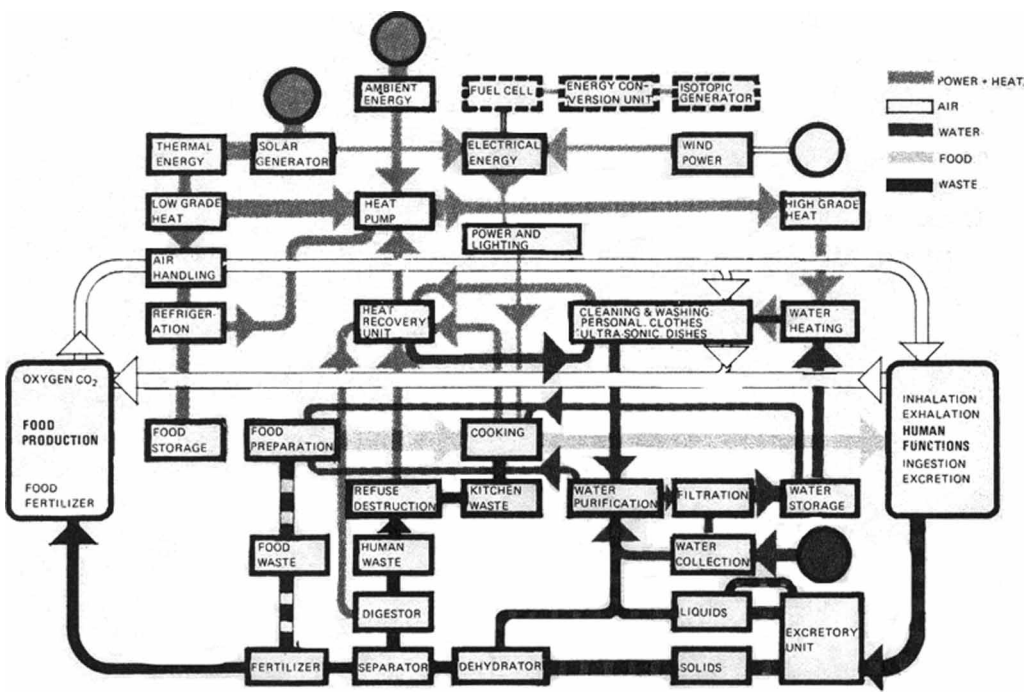

Figure 2. Alexander Pike's 'Basis diagram for a hypothetical autonomous servicing unit.' At Cambridge University he suggested ways to reorder buildings so that they would be as autonomous as cabin ecological systems and thus not harm the environment. Pike, 'Cambridge Studies', *Architectural Design*, 42 (July, 1972), p. 442.

Apollo space capsules. The autonomous house was not a romantic back-to-the-land vision. Such 'dropping out' was 'a game for those with private means', they noted in a sarcastic reference to the ultra-hippie Drop City in Colorado. Instead they sought, like the New Alchemists, to create a shelter in which they could survive the coming doom of industrial society. The construction of autonomous buildings was 'important for the survival of mankind' if (or rather when) environmental disaster struck.[80]

In their subsequent work, Brenda and Robert Vale would discuss and evaluate 'green' architecture according to its technological and biological performance as closed ecological systems.[81] In these publications, the visual aspect of design was hardly deemed important. At times of deepening environmental crisis, what mattered was to build architecture that could offer shelter from the coming doom.

Such ideas were also pursued by Kenneth Yeang, a student of Frazer's who matriculated in 1971 and completed a doctoral degree in 1980 about ecological architecture. He came to the forefront of ecological architecture during the building boom in Malaysia in the 1980s and early 1990s, although his conceptual thinking dates back to his Cambridge years.[82] At that time, Yeang worried about overpopulation, deterioration of habitats, pollution, radioactive fallout, and suburban sprawl. As a remedy he proposed an ecological approach to architecture through bionics. By imitating processes in nature, architects could find new environmentally friendly designs for human life. The use of biological analogies for design, he argued, would secure 'optimum survival' for humans, since such design would benefit from the long evolutionary process of survival of the fittest.[83] His chief example of successful bionics was 'a space craft' copying the circulation of matter and energy in nature within a closed artificial ecosystem. The 'space capsule' was like 'an autonomous ecosystem' functioning in equilibrium and 'completely independent' of its surroundings.[84] The space craft became the principal module for Yeang's design, which he used to 'appraise' a building by making 'an orderly inventory of the energy and material inputs and outputs' so that one could measure its effect on the environment.[85] Although Yeang saw disadvantages to closing a building to the external environment (except for energy input), he also saw major advantages. The internal circulation of material resources would reduce its environmental impact. Moreover, '[b]y being closed, the internal environment can also be culturally insulated from the cultural context of locality'.[86] In other words, a building was to be sealed off both environmentally and culturally from industrialism. Creative use of verandah walkways, for example, could allow many buildings, including bioclimatic skyscrapers, or perhaps even cities, to be entirely closed off from the external industrial world.

The theoretical underpinnings for these projects came in *Designing with Nature* (1995), a book which was based on his Cambridge thesis and in its title clearly inspired by McHarg. 'In many respects, the problems of survival in an isolated man-made micro-life-support system (as in a spacecraft)', Yeang argued, 'resemble the problems encountered in humans' continued survival in the "global life-support system" or the biosphere.'[87] He suggested

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adapting survival techniques in space by building micro-life-support systems within buildings. His chief source of inspiration in terms of ecology was Odum's analysis of energy flow within space cabins. He borrowed from Odum the study of the carrying capacity of astronauts in spaceships, and applied it to an analysis of a building's carrying capacity for its inhabitants. He also reused the 'life support systems' Odum suggested for astronauts in his technical proposals for 'micro-life-support systems' within buildings.[88] Recirculation consequently became a key concept, since the buildings ideally were to function as spaceships only receiving solar energy from their surrounding environments. Yeang would study the role of lifts in order to make more efficient systems for recirculation within a building, stress the importance of optimising passive modes of energy in closed environments, and investigate whether plants could grow underground as 'eco-cells' deep inside developments.[89]

Measured in terms of enclosure, ecological architecture came to a climax with the construction of the Biosphere 2 building in Arizona which was to provide a model for how humans should live within Biosphere 1 (the Earth). It was the first fully enclosed ecosystem and for many architects a model for the future of ecological design. The idea grew from discussions at the Synergia Ranch, a commune near Santa Fe in New Mexico which included the architect Phil Hawes and the oil-magnate Edward P. Bass. They were inspired by the University of Arizona's Environmental Research Lab, which since 1967 had been engineering a building that would integrate energy, water and food as one ecosystem.[90] Hawes, the Biosphere 2's principal architect, based his drawings on his 1982 outline of 'Architecture for Space Colonies'. It represented a continuation of his previous projects in New Mexico in the 1970s which focused on applying space ecosystem principles with circulation of energy and materials within a building.[91] Bass, the investor, believed space technology would play a key role in solving the world's ecological and social problems. His aim was to develop cabin ecological technology for energy-efficiency, recycling, waste processing, sewage management, microbial composting, and other emerging solutions to the environmental problems on Earth. The development and patenting of such technologies were to provide Bass with a solid profit.[92]

The scientific rationale for Biosphere 2 was to prove that ecological colonisation of space was a viable idea. 'Closed ecology systems can free us from Malthusian limitations by making the Solar System our extended home', one proponent argued.[93] The ecologists Dorion Sagan and Lynn Margulis described the scientific aims in *Biospheres from Earth to Space* (1989). 'Imagine for a moment you are building a large ship that will travel through space', they encouraged the reader, before plunging into a detailed analysis of how the science of ecology could enable people to 'live in space indefinitely without the cost of importing supplies.' Scientifically it was a question of figuring out the 'carrying capacity' of a closed ecosystem with respect to how large a crew of astronauts an artificial biosphere could support. 'Successfully running a new biosphere would show people what it takes to make it in our beloved old one', they also argued, by pointing to the relevance of such

ecological research to 'astronauts' making living quarters on board 'Spaceship Earth'. Moreover, 'to settle Mars' with new populated biospheres, could provide 'protection in case of nuclear war' and 'curb global population growth' on Earth.[94]

The aim of the Biosphere 2 was also to build a shelter in which Bass and his friends could survive in co-evolution with thousands of other species in case the eco-crisis turned Biosphere 1 into a dead planet like Mars. Similarly to the above-mentioned ecological architecture, scientists and designers of Biosphere 2 fashioned themselves in the image of the Biblical Noah. They believed that 'The Glass Ark' could secure their personal survival while at the same time saving some of the world's biodiversity.[95]

Biosphere 2 was completed in 1991 and sealed, after eight 'biospherians' dressed in space suits had marched through the air-lock. They promised to stay there for two years. 'The project's participants say it can show how to colonise other planets or survive ecological catastrophe on this one', a journalist reported from the widely publicised event. Soon rumours circulated about a smuggled bag of supplies for the hungry biospherians, and fresh air being pumped into the building.[96] With crew members suffering from lack of oxygen, a decision was made to pump more of it into the building, although it effectively ruined the value of the experiment since the building was supposed to be sealed. Nature did not easily conform to the space cabin concept, later reviews of the project claimed.[97] It was apparently a relief to the crew when they—in space suits—marched out of the airlock in September, 1993. Despite the trouble, the Biosphere 2 building became a model for ecological architecture, setting the standard for a growing field.[98]

'Ouroboros' architecture

In 1976 the architectural students at the University of Minnesota followed the above trend by building their own self-sustaining ecological house. They named it '"Ouroboros" after a mythical dragon which survived by eating its own tail and faeces'.[99] This is a telling image of what ecological architecture came to be in the 1970s: a way of designing which fed on its own ideas and gradually closed itself off from developments in the rest of the architectural community. Its followers sense of self-sufficiency resulted in a sect-design for the believers whose recycling of resources and ideas led to a lack of interest in an outside world simply described as 'industrial' and thus not worth listening to. As a consequence many environmentally concerned designers came to function as astronauts living intellectually within their own ecological capsules. Their somewhat narrow focus on the circulation of energy and efficiency of buildings came at the expense of a wider cultural, aesthetic and social understanding of architecture and the human condition. As William McDonough and Michael Braungart, two recent environmental architects, have noted about previous ecologically construed buildings, '. . . efficiency isn't much fun. In a world dominated by efficiency, each development would serve only narrow and practical purposes. Beauty, creativity, fantasy, enjoyment, inspiration, and poetry would fall by the wayside, creating an unappealing world indeed.'[100]

One should note that not all architects concerned with environmentally friendly design of the period endorsed space ecology. Richard Neutra, for one, thought using money for space research was a waste.[101] Others, like Moshe Safdie, developed environmentally sensitive and innovative architecture without reference to ecology.[102] Similarly, to avoid harming the landscape, Malcolm Wells chose to build a 'gentile architecture' underground which had little to do with space cabin design principles.[103]

What one can conclude is that space ecology has been of significant importance for the emergence of much of the ecological designs of the 1970s and beyond. The framing of landscapes and buildings in terms of life within space cabins enabled the emergence of an ecological ethic for humans modelled on the scientifically manageable astronaut. It was an ethic which favoured a technological and scientific view of human beings at the expense of wider social and cultural values. Perhaps the time has come to break out of the intellectual capsule ecological space analysis has created for many environmentally concerned architects.

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