The High Frontier, the Megastructure, and the Big Dumb Object

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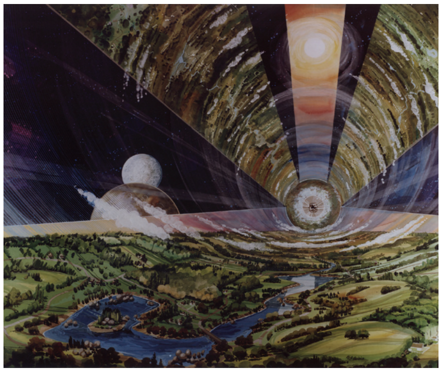
Gerard O'Neill designed his first space colony in 1969, in collaboration with his freshman physics students at Princeton[1]. O'Neill's work with space colony design, developed and published throughout the next decade, would be a kind of high-water mark for technological optimism. His vision of endless resources and expansion into the solar system was almost an inverse to the predictions of immanent collapse outlined in the Club of Rome's *Limits to Growth* and other popular futurist science from the same era. It is useful to examine O'Neill's colony proposals as a design project of the 1970s, in parallel with other threads from that period: connections to the imagery and narratives of science fiction, the idea of the Megastructure in architecture, and finally, the vagaries of the design process itself, somewhere between collaborative consensus and visionary leadership.

O'Neill's first work, developed from the Princeton course, was finally published in *Physics Today* in 1974[2]. It was further developed in a conference at Princeton over the summer of that same year, with the support of a grant from Stewart Brand's Point Foundation.[3] The Point Foundation was the publisher of *CoEvolution Quarterly*, the successor to Brand's *Whole Earth Catalog*. These design concepts were detailed and revised at another summer conference in 1975, this time at Stanford with funding from NASA.[4] The year 1975 also saw O'Neill testifying before Congress on his work and publishing it in CoEvolution Quarterly. The space-colony designs developed via these venues (NASA seems to have preferred the term 'space settlement'[5]) come in three types, based on three geometric primitives: The O'Neill Cylinder, the Bernal Sphere, and the Stanford Torus.

The cylinder design appeared first, published in the 1974 article, based on his work with students five years earlier. O'Neill spent much of the article working out the details of this colony type: two miles in diameter, twenty miles long, capable of housing "several million" people. This type, in the scenario sketched out in *Physics Today*, was imagined as a later model, "Model 4," appearing twenty years after the initial construction of a "Model 1" type. "Model 1" would be much smaller, built for 10,000 individuals.[6] The Bernal

Sphere and the Stanford Torus, both first worked out at the NASA-funded summer conference in 1975, were attempts to design this smaller, first-phase "Model 1" configuration. All three rotated to provide artificial gravity inside. These structures would be the hometowns for people put to work building large solar-power satellites, beaming microwave energy down to an Earth which was, in the early 1970s, just feeling the effects of dependence on fossil fuels.

All three versions—sphere, torus, and cylinder—were illustrated shortly after the 1975 study by NASA artists Don Davis and Rick Guidice. These paintings and others were published in a 1977 report from the 1975 study,[7] and in O'Neill's 1976 book, *The High Frontier*.[8] The paintings are in the public domain, have been widely reproduced, and still remain some of the most familiar images of speculative space science from the period between the Shuttle and Apollo programs.



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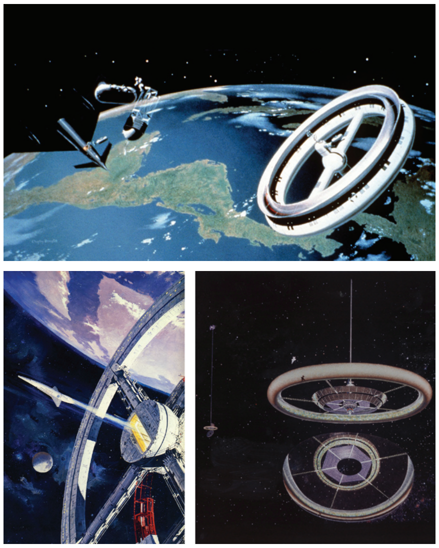

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THE PAINTINGS

The images are compelling. The landscapes wrap up, over, and around the viewpoint, enfolding us in a warm cultivated great outdoors which is at the same time revealed as a vast interior, underscored by framed glimpses of the even bigger cold outside. Sublime within sublime. The views of the colonies from space are no less impressive, the huge blank surfaces of the primitive volumes are contrasted with small bits of articulated scale and detail at docking ports, manufacturing nodes, and communications arrays. Often there will be a small transport ship for scale. The whole composition floats in a space enlivened by painterly textured swirls of background nebula and planets; the hostile environment of high orbit gone amniotic.

These images don't exist in a vacuum. They are a part of a rich matrix of visual language, with linkages stretching out to connect science-fiction concept art, NASA public relations campaigns, and the renderings produced for urban development and architecture projects. They exist, like all of these pieces of visual culture, partly to motivate political and economic capital, and partly to invoke a sense of wonder in the new.

Follow, for example, the theme of the large wheeled space colony with adjacent spaceplane. We can track it from a painting by Chesley Bonestell for Collier's Magazine in 1952.[9] Bonestell worked with rocket scientist Wernher von Braun to create the image, part of a series of illustrated articles based on von Braun's plans for space exploration. Bonestell's other credits include architectural rendering and design; he helped create the Art Deco detailing and eagles of the Chrysler Building while at William van Alen's office.[10] As a science fiction illustrator, he painted covers for magazines, and background art for several movies. The paintings from Collier's have since inspired several books, a Disney miniseries, and, indirectly, the concept art for Stanley Kubrick and Arthur C. Clarke's film and book *2001: A Space Odyssey*, produced in 1969.

Design artwork for *2001* was painted by NASA concept artist Robert McCall for Kubrick and Clarke, under the direction of science consultant

Figure 1: An O'Neill Cylinder space colony interior, Rick Guidice for NASA, 1976

Figure 2: 24 years of wheeled space habitats, from left to right: Chesley Bonestell with Wernher von Braun for Collier's Magazine, 1952; Robert McCall with Frederick Ordway III for Kubrick and Clarke's 2001, 1969, Don Davis with Gerard O'Neill for NASA, 1976

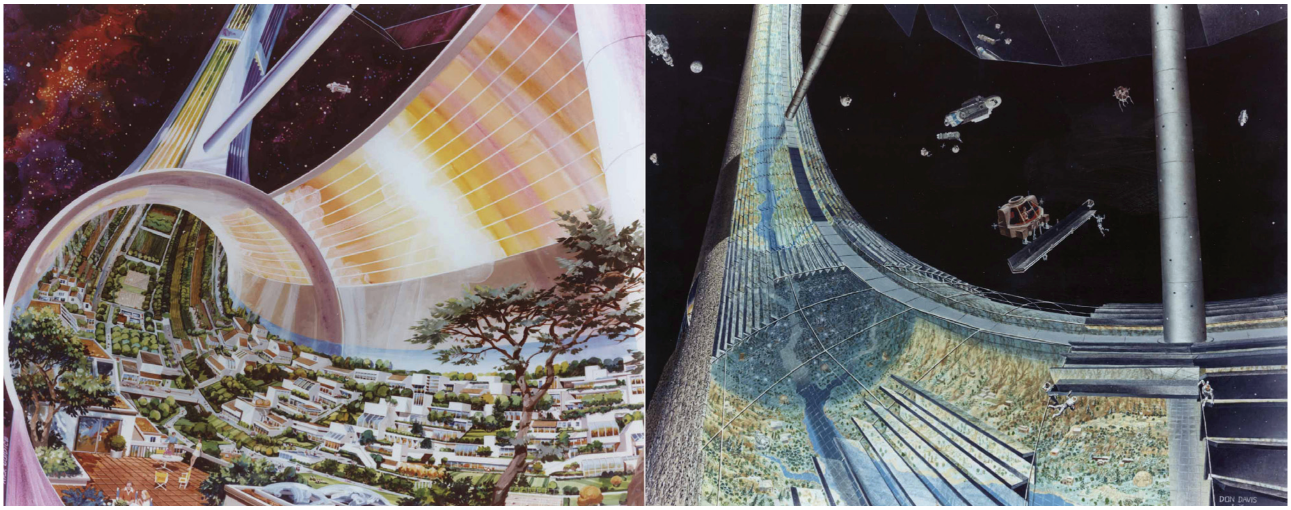
Fredrick Ordway, III, himself a rocket scientist and avid collector of space exploration paintings.[11] Ordway is also the owner of the Bonestell/von Braun originals. An image of a rotating space colony, with its iconic Pan Am Orion III spaceplane, a late 1960s hot-rod update of Bonestell and von Braun's delta-winged town-car 1950s model, is on the cover for the first edition of Clarke's book, and several posters for Kubrick's film.

The next image above is by Don Davis, a former student of Bonestell's. Painted in about 1976, this is one of several created, as he recollects: "under the direction of (NASA) public affairs director Pete Walker and other experts."[12] This is an illustration of a Stanford Torus, its scale much larger than either the Bonestell/von Braun or McCall/Ordway space stations. While these earlier schemes are in low-Earth orbit, all of the O'Neill designs are intended to be parked at the L5 point, an area of high orbit where the Earth and the moon's gravity interact in a way that creates a stable zone in space. It's telling that, even though its existence this far from Earth would be unlikely, Davis has included a tiny spaceplane in his painting as a scale reference, emphasizing it by letting its shadow fall on the gritty radiation shielding at the exterior of the torus. Davis's spaceplane is a purely formal device, linking the painting to its predecessors, and at the same time calling out the crucial difference in scale: this is like that, but different—it's much, much bigger.

THE MEGASTRUCTURE

To look more extensively at the interior details of these colony designs, its necessary to bring to bear another concept about scale from the design lexicon of the 1960s and 1970s: the Megastructure. Japanese metabolist architect Fumihiko Maki offers a definition in his 1964 book *Investigations in Collective Form*: "a large frame in which all the functions of a city or part of a city are housed. It has been made possible by present day technology. In a sense, it is a man-made feature of the landscape. It is like the great hill on which Italian towns were built."[13] The imagery of the Italian hill town has dominated built and unbuilt Megastructural projects since Kenzo Tange's Tokyo Bay proposal in 1960,[14] and the completion of Moshe Safdie's Habitat project for Montreal's Expo 67.

In the 1960s, the base assumption that many Megastructure projects presupposed was that the existing fabric of the city itself was a hostile environment. Traffic, pollution, crowding, disparate standards of living, all these were tied to inefficiencies inherent in outdated, inflexible planning modes.[15] Megastructures represented the possibility for centralized planning without inflexibility. Creating the potential for adaptation and reconfiguration built-in from the start was the way forward. Infrastructure and land—Maki's "great hill"—was decoupled from building. Stewart Brand, in his 1994 book *How Buildings Learn*, would refer to this concept as 'layer shearing': site, structure, skin, services, space plan, and stuff, are all changing, but at different rates.[16] The proposal based on this assumption is clear: the informal repetition and combination of standardized parts, on a longer lasting frame or substrate, is an effective way to break down the scale of large singular



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urban projects while maintaining the unity and economy of industrial production. This is the visual and organizational logic that produces the urban interiors of the space colony renderings.

Thomas Heppenheimer, a participant in O'Neill's 1975 summer study, and the author of the 1977 book *Colonies in Space*, described the architectural design strategy:

> Modularity does not mean uniformity ... In the colony, the modularity would be at an intermediate level: wall panels, windows, roof sections and the like. Though uniform in size, these could be combined in a very large number of variations. The architects would be working with standardized elements, seeking to develop a larger number of floor plans and home designs which would be built from them.[17]

Architect and educator Patrick Hill, another participant in the 1975 study, worked out the details and layout of some potential structures based on this scenario.[18] As at Safdie's Habitat, to make the most livable space out of a limited footprint, he has proposed structuring the overall arrangement of these units into what Reyner Banham has called 'Terrassenhauser':[19] sloped terraces of housing that allow each unit to open onto an outdoor space on the roof of the unit below. Heppenheimer's book, when describing this configuration, directly referenced Habitat '67.[20] In the Stanford Torus, the terraced housing blocks were uniquely able to accommodate the sloping cross-section of the interior, as shown in Hill's drawings, and in the paintings of the other NASA artist on the project, Rick Guidice. The convex hill of Maki's Hill Town becomes concave.

The Guidice interiors were drastically different from the same views as painted by Don Davis. This difference reveals a tension inherent in the project itself, centered around the deceptively simple question of population density. Guidice showed very contemporary layouts of the structures within the colony, with garden apartments and landscape integrated into green roofs and balconies. Don Davis preferred to paint the colony interiors empty, as if just at that point in construction before the first people moved in.

Figure 3: Stanford Torus interiors, Rick Guidice, left, and Don Davis, right, for NASA, 1976

On his website, Davis described this painting, hinting at some of the details behind these artist/engineer collaborations: "The 1975 NASA Ames/ Stanford University Summer Study worked out the broad engineering requirements for a toroidal shaped space colony design. This painting used the design, but I refused to fill the interior with the 'shopping mall gone mad' clutter of other drawings."[21]

THE NUMBERS

The Stanford Torus, as planned in 1975, can support 10,000 people at 510 square feet per person. In his discussion of density within the Stanford Torus, Heppenheimer has again invoked the hill town, only this time the towns were not Italian, they were the French villages of Saint Paul and Vence.[22] The assertion was that the density of these towns, at between 300 and 500 square feet per person, represent a better benchmark for the feel of the Torus interior than the comparable density of Manhattan, at 415 square feet per person. This density would be mediated by the segregation of commercial, service, and transportation activities to the lower levels of the torus, where presumably, lack of open space and reflected sunlight would be compensated for by access to the higher quality space above for everyone.[23]

When looking at the numbers behind the design proposals, it's hard not to be struck by the sometimes-drastic factors used when deviating from baselines. Whenever possible, estimate of risk was rounded down, and assumption of benefit was rounded up, or even multiplied by a factor of 2. The most striking case is in agricultural yield, as the report from the summer study says: "Crops were estimated assuming a yield double that of the world record for that crop."[24] This prodigious yield was projected, in the summer study, to be the result of supercharging the atmosphere of the growing areas with carbon dioxide, adjusting the mirrors so that the sun is shining around the clock, and assuming zero crop loss caused by pests, insects, weeds, or disease, enforceable with quarantine and exposure to vacuum for sterilization if necessary.[25] In another section of the study report, estimates of requirements for public open space were rounded down, from an average of almost 200 square feet per person, to a new value of slightly more than 100 square feet per person: "Because the space habitat contains agricultural areas that can be in part used as open space, a lower value of open space in the residential area is adopted."[26] Taken together, these two variables seem to indicate that half the available parkland will be a paradise for plant life only, forever sunny, warm, and humid, with 23 times the normal amount of carbon dioxide in the air.

In the CIAM Athens Charter of 1933, a group of European urbanists posited that the "four functions of the city": living, working, recreation, and circulation, should, in future proposals, remain distinct and clearly articulated.[27] O'Neill and his team had recognized that the creation of carefully tuned environments within the space colony allows for an unprecedented level of urban functional segregation. Each of the four functions can have its own daylight cycle, its own atmosphere, temperature and humidity, even, as O'Neill laid out in the 1974 article, its own specific level of spin gravity.[28] The other possibility afforded by the environment of space has not gone unnoticed, if things go wrong, the administrators of the colony can use the hostile environment outside to isolate and kill the segregated areas.

O'Neill's own attitude about cities can perhaps best be suggested by two examples. Don Davis' painting of the interior of a large, late model O'Neill Cylinder, showed a mountain stream, a family on the banks, with cabins dotting the hills and a city in the distance. Stewart Brand put this painting on the cover of his 1977 CoEvolution Book *Space Colonies*. The book included a feature article by O'Neill reporting from the first conference at Princeton, which Brand's Point Foundation had helped fund, a year before the larger, NASA-funded summer study. Brand wrote about this image:

> The painting of the interior of a "Model III" cylindrical Space Colony by Don Davis appears on the cover of Space Colonies. It has inspired more belief and roused more ire than any other artifact associated with Space Colonies so far. The man-made idyll is too man-made, too idyllic or too ecologically unlikely—say the ired. It's a general representation of the natural scale of life attainable in a large rotating environment—say the inspired. Either way, it makes people jump."[29]

Brand then went on to publish over 40 pages of solicited and unsolicited commentary on O'Neill's space-colony concepts, from correspondents including Lewis Mumford, Chip Lord, Ken Kesey, Bucky Fuller, and Richard Brautigan. Davis, recalling this ire and inspiration in a piece of biographical writing published on his website, remembered the image: "It was painted this way under the direction of Gerard O'Neill himself, who related a recent impression of the vantage point from Sausalito being an excellent scale reference for a possible setting inside a later model cylindrical colony."[30]

In *The High Frontier*, in the middle of a discussion about the benefits of separating industry and agriculture outside the colony, O'Neill again invoked an Italian village and perhaps that same view from Sausalito, when he wrote: "Even at the high-population density that might characterize an early habitat, that arrangement would seem rather pleasant: a house in a small village where life could be relaxed and children could be raised with room to play; and just five or ten miles away, a small city, with a population somewhat smaller than San Francisco's, to which one could go for theaters, museums, and concerts."[31]

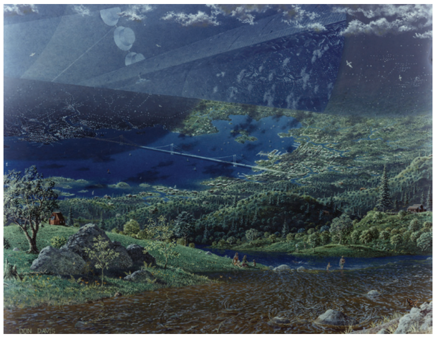


Figure 4: O'Neill Cylinder interior, Don Davis for NASA, 1976

THE BIG DUMB OBJECT

In a letter to the editor of *Physics Today*, after the appearance of O'Neill's 1974 article, a correspondent wrote enthusiastically:

> I read with interest and pleasure Gerald (sic) K. O'Neill's article "The Colonization of Space" (September, page 32). As an avid science-fiction reader, however, I was distressed to see that O'Neill did not mention two recent stories directly related to his concepts. These stories are "Rendezvous with Rama" by Arthur C. Clarke … and "Ringworld" by Larry Niven … The first of these discusses the cylindrical geometry in consid-

> erable detail, and the second scales the concept to a ring of about 1 AU radius, about 200,000-km wide and with 100-km sidewalls. I hope some of your readers will read these books as well as the fascinating article.[32]

O'Neill replies, somewhat harshly:

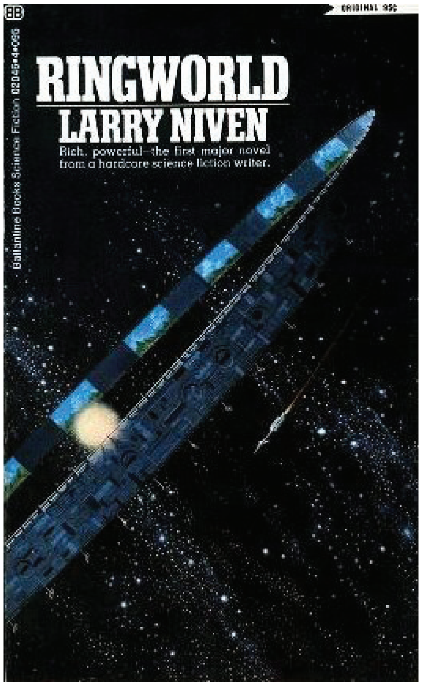
> Although I admire the work of Arthur Clarke and Larry Niven, the recent science fiction stories were not mentioned because, in my opinion, they contained no useful ideas contributory to a practical scheme for space colonization. In particular, neither contained the geometry described in the September article.[33]

This response is revealing. O'Neill had been working since 1969 to get these concepts into print, and whether they had arrived at the ideas independently or not, the two science fiction authors had beat him to it.

In 1982, science fiction critic Roz Kaveny published an article in the British journal *Foundation* entitled 'Science Fiction in the 1970s: Some Dominant Themes and Personalities.' In this article she introduced the critical concept of the Big Dumb Object, as a way to describe things like the eponymous artifacts of Niven's *Ringworld* of 1970 and Clarke's *Rama* of 1973, both rotating structures built by alien intelligences and discovered by human explorers. The Big Dumb Object, as referenced in the *Encyclopedia of Science Fiction*, has an effect on the humans who encounter it: "the very fact of being confronted by such artifacts regularly modifies or confounds their mental programming and brings them that much closer to a CONCEPTUAL BREAKTHROUGH into a more transcendent state of intellectual awareness. (see also SENSE OF WONDER)"[34]

In the 1970s, during a rare confluence of technocratic vision, post-hippy utopianism, popular sci-fi culture, high energy prices, and high optimism, O'Neill and his cohort brought global human awareness a bit closer to some kind of conceptual breakthrough. Part of the key to that sense of wonder was the recognition, in architecture, in science fiction, at the Whole Earth Catalog, the Point Foundation, and NASA, that we could build the hill town, but only after we've built the hill. The key to both the Megastructure and the space colony as conceived by O'Neill is that the substrate is independent of the superstructure. It is at a larger scale, and changes at a different, slower rate from the activity and organization of daily life. Previous ideas about rotating space stations, by Bonestell, von Braun, McCall, Kubrick, Ordway, and others, had proposed them as simply a collection of rooms, completely filling available volume. O'Neill was the first to see them as a potential new ground, and use them to enclose a neutral habitable space, wrapped inside a Big Dumb Object, and organized by a Megastructure.

The insight, that a structure of sufficient scale is essentially a new ground, was shared by Maki, O'Neill, Clarke, and Niven in the 1960s and 1970s. But this shared conceptual substrate did not last long. The layers sheared too steeply. The sense of wonder, that this recognition affords, breaks down when the adaptability of the Megastructure is only allowed to exist at the level of the building component and the typical plan. Where O'Neill's



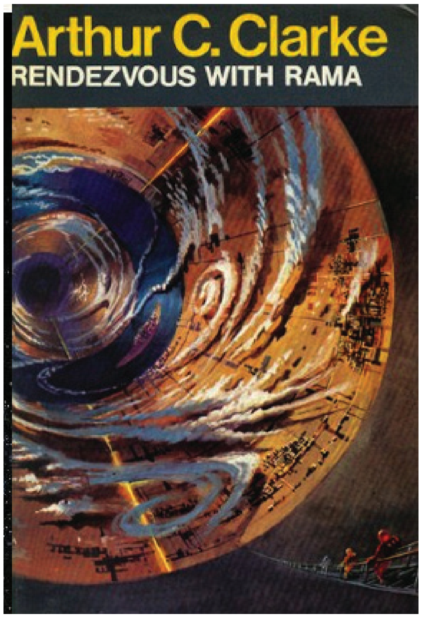


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Figure 5: Bottom, Rendezvous With Rama, Arthur C. Clarke, 1st UK Edition, Bruce Pennington, cover artist, published 1973. Top, Ringworld, Larry Niven, 1st US Edition, Dean Ellis, cover artist, published 1970

breakthrough fails is at the point where he neglects to recognize both the debt to science fiction, and the responsibility to the potential of the dense urban Megastructure. When there is flexibility in the plan of the buildings, but not in the arrangement of the functions of the city, the Big Dumb Object collapses back into the hard shell of the centralized planning concept, and the transcendent frontier is left for others to come closer to next time. ◆

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