Cosmic Colonies

Gerard K. O'Neill

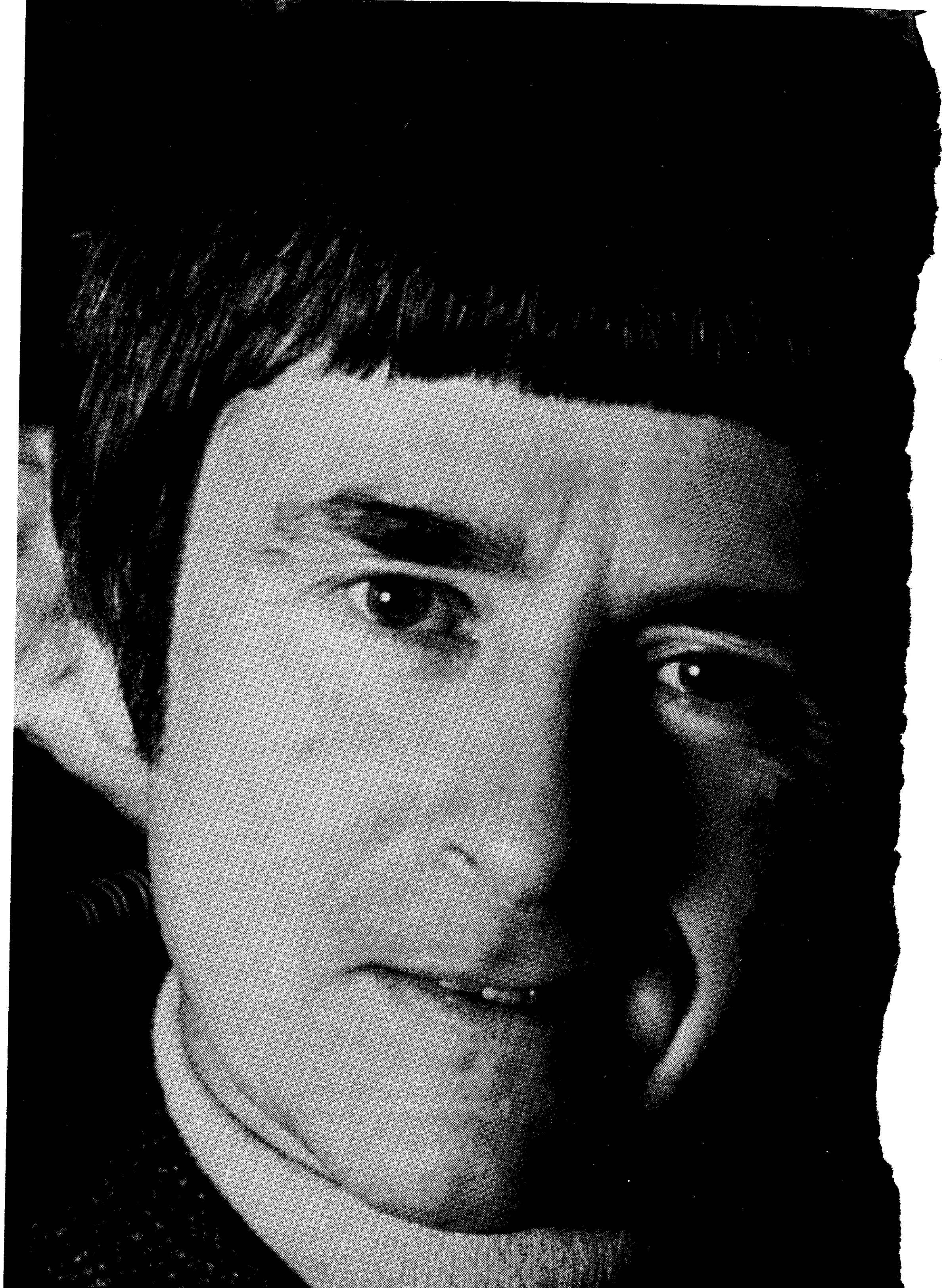
Every star around us is a favorable target for human migration. You don't have to wait for just those stars that happen to have earthlike planets; they may be very few and far between.

Ever since Christopher Columbus made the rounds of potential royal backers, the exploration of new worlds has required as much persuasive salesmanship as it has intrepid navigation. Few men in that tradition have been as articulate as Professor Gerard K. O'Neill, a high-energy physicist who has become a prominent advocate of human colonies in space.

In both scientific and popular articles, in lectures and on television, and in his successful books The High Frontier *and* 2081, *O'Neill has argued that the unlimited energy and materials of space could make possible a new and attractive life for millions of people. In his view, the established practice of launching costly chemical rockets should be replaced as soon as possible by permanent habitation and large-scale manufacturing in space. What's more, while his predecessors advocated metal-walled, compartmentalized "space stations," O'Neill envisions colonies that resemble the earth, with soil, greenery, even blue sky, sunshine, and clouds.*

The concept behind O'Neill's space colonies — that there's more potential energy in high orbit than on earth — is elegantly simple, a characteristic that has become the hallmark of his brilliant career. His first contribution to science came in 1956, when, as a twenty-nine-year-old physics instructor at Princeton, he worked on a new proton accelerator, a machine that made accelerating protons collide, permitting physicists to study the quirks of subatomic particles. Until that

Photograph: Pat Hill



time, it was felt that particles had to accelerate and collide within the same chamber, a prerequisite that resulted in all sorts of design difficulties and expense. O'Neill's "simple" solution? To have subatomic particles accelerate in one machine and collide in another. Though his skeptical colleagues challenged his ideas, O'Neill went on to design a "storage ring" that could store accelerated particles awaiting collision. Today, most subatomic particle accelerators are based on O'Neill's storage ring concept.

"Perhaps it was the experience of that previous transition from incredulity to acceptance," O'Neill said, "that encouraged me to continue working on space communities, another 'crazy' idea that carried the same sort of logic. In both instances, the numbers came out right."

O'Neill's "numbers" convinced him, in 1969, to hold an exploratory seminar on space colonies for a few of his students. He waited five more years before finally finding a forum in print. But O'Neill does not regret the lag. "It gave people a chance to think about the possibilities," he said, "and to make their own assessments. People would raise questions and I'd go off and think about them and find solutions, and that was very worthwhile. The ideas kept evolving all along, but there's nothing I regret or would like to retract."

In 1974, following that small conference in Princeton, space colonization began to attract national attention. Since then, O'Neill has divided his time between teaching and working for his vision of the future. At home, he and his wife, Tasha, direct the nonprofit Space Studies Institute, dedicated to research on habitation and manufacturing in space. And today, O'Neill also spends much of his time working on Geostar, a satellite system that would allow millions of people to communicate "from anywhere to anywhere with pagers no larger than a pocket calculator."

"The system would be especially valuable," said O'Neill, "in terms of aiding the victims of a crime. If someone who subscribed to Geostar was attacked, he or she could simply push a button; within half a second, a police car would know the identity of the victim, as well as the exact *location of the crime."*

When O'Neill isn't designing space colonies or raising money for Geostar, he finds time to relax — by flying a light plane to workshops, lecture dates, and Washington, D.C.

The pace clearly agrees with him. At fifty-six, he looks a dozen years younger, and he discusses space colonization and industrialization with as much enthusiasm and animation as if the idea had just taken hold of him. While the rest of us may have to look to space for unlimited energy, Gerard O'Neill displays it here and now as he points the way. Professor O'Neill was interviewed by Monte Davis in 1979. I spoke with him on the telephone in 1982 and again in 1983. A synthesis of the three discussions follows.

OMNI: Why did you start advocating the colonization of space in the first place?

O'NEILL: My motives were largely humanistic. The Club of Rome concluded that as population continues to expand, we'll have to abandon the development of greater individual freedom and accept a much more regulated life with diminished options — not just for us, but for our children and their children and so on forever. I reacted to that with dismay and shock. It sounded like a hell of a world to leave to my kids.

OMNI: How would space colonies help us expand these freedoms and options once more?

O'NEILL: First of all, there would be fewer people living on Earth and an increasing fraction living in space, where there's unimaginable room. Those in space colonies would of course find the situation much more open and free. They'd be living in relatively small-scale structures, in habitats that would be community-size rather than nation-size. With a few thousand to perhaps fifty thousand people in each space colony, government could be as simple and intimate as a New England town meeting. Yet each colony could be quite self-sufficient, using pure solar energy to generate power for travel, agriculture, environmental control, and so on. Since the colony would be growing its own food, there would be no reason for it to tie into a large-scale governmental structure. As far as defense is concerned, colonies suspended in empty space could be widely dispersed. Here on Earth, no one can enlarge land area without crossing a border and going to war with a neighbor; a great deal of our warfare is essentially territorial. Look at everything that goes on in the Middle East and all that's happened in Southeast Asia. There were ideologies involved, of course, but behind a great deal of those conflicts were simply the aggrandizement of reaching out, crossing a border, and taking over more territory. In a space colony, on the other hand, there would be no need to run that risk. It would be easier simply to build additional colonies nearby. Space dwellers would have a lot less hassle in their lives than we do.

OMNI: Do you think that space colonies might affect even those people who decided to remain on Earth?

O'NEILL: Absolutely. The earth, of course, would eventually become far less crowded. Beyond that, important psychological effects would occur almost immediately. If you go back and consider, for example, Shakespeare's plays, you'll realize that they were being written at just the time when settlement of the New World was a very big issue. In Shakespeare's day, relatively few people had actually gone to the New World, but the opening up of that window of opportunity had already had an important effect on the lives, and literature, of the people in Europe. There were products coming back from the New World to the Old; there was always the possibility of people picking up stakes and moving. The very existence of the New World expanded options, enhanced freedoms, and even helped produce a man with the vision of Shakespeare.

Space colonies would clearly produce that spirit once again. Furthermore, we'll see a great deal of two-way travel to the space colonies. A lot of people who continue to make their homes on the earth will find a trip to the space colonies and back as economical as a long-distance trip in a jetliner. By 2050, some two hundred million people may be making annual trips out into space and back again. People will be going on business, on vacation, for all sorts of reasons. There are going to be people who will maintain two homes, one in space and one on the earth.

OMNI: It sounds a lot more tempting than owning a stretch of Riviera or a Swiss chalet.

O'NEILL: Yes, but the most important impact on Earth-dwellers might be a bit more subtle. The small-scale, self-sufficient communities in space will be very much heeded by people on Earth, encouraging them to dictate their own terms to central governments. Influenced by the freedom of space, they'll start demanding more local authority and relatively autonomous, decentralized communities. If their demands aren't met, they'll immigrate to space — and stop paying their earthly taxes. If you look back in history, you'll find that that sort of emulation, that sort of action by imitation, is very, very powerful. The French Revolution, for example, was largely set off by the American Revolution. And the revolutions that broke up all the old European monarchies were largely outgrowths of the one in France.

OMNI: Dr. O'Neill, what exactly would these utopian space habitats look like? Do you have a best guess?

O'NEILL: The design that's come out of all the engineering studies has been named Island One. It's a sphere most likely made of aluminum. It would be almost a mile in diameter, with two large regions of windows where sunlight would be reflected in; sunlight would be reflected [instead of direct] because you don't want to allow any straight-line paths through which cosmic rays could enter. In fact, the habitat would be completely shielded against cosmic rays with five or six feet of plain old dirt; in this case, moon dirt. The whole colony would rotate slowly to produce the earth's normal gravity for the people inside.

OMNI: I take it that people would live along walls lining the inside of the sphere. They would be pulled toward those walls by the force of the sphere's rotation. The walls would, in essence, serve as the ground.

O'NEILL: Yes, that's right, more or less. I should add that earth-like gravity would exist only at the equator. As you walked along the interior of the sphere toward the poles, the force of gravity would get weaker and weaker. Along the axis of rotation, which runs from pole to pole, there would be no gravity at all. Thus, most inhabitants would live along the equator. The old and infirm, who have trouble getting about, of course, might choose to live along higher or lower latitudes, with less gravity to impede their motion.

OMNI: You've suggested that these low- and zero-gravity regions would allow earthly inhabitants to pursue unusual types of sports.

O'NEILL: Well, in addition to all the usual Earth sports, which are played on a flat, two-dimensional surface, people could engage in athletics played on three-dimensional fields. The best candidate would be body contact sports, like soccer and football. I suspect that a lot of the games will probably use fewer players than the corresponding Earth sports because they'll just be so much more complex in their motion.

OMNI: In your book *The High Frontier*, you mention the sensual wonder of zero gravity, honeymoon hotels . . .

O'NEILL: You can expand on those at your leisure. I leave the details to the imagination.

OMNI: If you say so. I'll settle for a detailed description of the colony's interior.

O'NEILL: Okay. If you dwelled within, you'd feel as if you were living in a fairly steep valley, like the kind found throughout the mountainous regions of Italy. There would be terracing and there would be lots of lush greenery. The sun would seem to rise in the morning and set at night, an effect accomplished through a complex array of mirrors. Some homes may come with a spectacular design detail built into a living room wall: a window opening out onto the immensity of space. At least for the early colonies, the climate would be temperate.

OMNI: Like Carmel, California?

O'NEILL: Yes, that sort of thing.

OMNI: What would these inhabitants see when they looked up into the middle of the sphere?

O'NEILL: In the bigger colonies they may see a sky with clouds. That sort of effect would be created much the same way it is on Earth. Here, of course, clouds are created naturally, as a result of the instabilities of the atmosphere. The ground is continually heated, and it, in turn, heats air masses directly above it. When those air masses heat, they become lighter, and therefore they rise up past the cooler air around them. When the hot air gets cool enough, it condenses, and clouds are the result. To create clouds in a space colony, we can simulate the same atmospheric instabilities. That, however, may not be possible in the smallest, very first settlements.

OMNI: Would inhabitants of those colonies look up to see people and trees hanging upside down from the wall directly opposite them?

O'NEILL: Yes, they would, but, then again, you have to think about the question of scale. Even the smallest space colony would be about five hundred meters in diameter, and that means you'd have a third of a mile from your backyard to the backyard immediately above you. Recall, if you can, what it's like to fly a third of a mile above the ground in an airplane: you simply don't see details. You can tell a town is there, and, if you have good eyes, you may be able to see somebody riding a bicycle. But you can't see who it is.

OMNI: It's clear how we may create clouds and an earthlike day and night, but what about the rest of the space colony environment? Is our biological and ecological knowledge really up to creating the lush landscapes you envision?

O'NEILL: Some people feel, on philosophical grounds, that it would be good to create a closed environment that would maintain itself and be ecologically stable in all respects. Others say — quite rightly — that we're nowhere near achieving that on Earth, so how can we hope to do it in space? Well, that's not what we hope to achieve. Remember, there are botanical gardens all over the world where many different plant species thrive in a controlled environment — sometimes with desert and rain-forest plants just a few yards apart. You don't just turn it loose, you garden it . . . but it's not going to go by itself; it's not going to be a closed, inherently stable ecosystem any more than a botanical garden is. Artists' conceptions of space-habitat landscapes do not represent a natural climax forest, and they were never intended to.

OMNI: Now I'll turn the question around 180 degrees. You suggest that the environment in a space habitat could be as pleasant as that of an Italian hill town or, say, Carmel, California. But why settle for that? Shouldn't space habitats provide new ways of life, new ways of organizing social space? Obviously, one of the most important factors in advancing your ideas has been your demonstration that the habitats could be like Earth, but if you're building a world from scratch, shouldn't the sky be the limit?

O'NEILL: I felt I had to do an "existence proof" to show that it is *possible* to create an earthlike environment in space. I have no doubt that in the long run people born in space are going to do all sorts of new, strange, different things with the habitats they'll build.

I think it's fair to say that until I began looking into this question, everyone had assumed that life in space meant a very unearthlike situation. The Russian pioneer of space travel, Konstantin Tsiolkovsky, came closest to suggesting an earthlike environment with his greenhouses. His excellent designs, put forth seventy-five years ago, were basically tubular and very efficient. He had a lot of the essential ideas right: to go for unlimited, clean solar energy outside the planet's shadow; to make use of the resources from asteroids. Aside from him, almost everyone thought of space as a route from here to there. The destination was always assumed to be a planetary surface. But once you say that space itself can be the destination rather than just a corridor — that you can build large, earthlike environments in space — you get a radical change in viewpoint.

OMNI: That's true. The first settlers would probably be far more willing to give space a try if they knew their new home would resemble the earth. But how would we go about building these initial colonies in the first place?

O'NEILL: The materials for the first space colony would come from the surface of the moon. We'd get material from the moon to the vicinity of the colony by means of a Mass-Driver, a machine we're researching here at Princeton.

OMNI: What exactly *is* the Mass-Driver?

O'NEILL: Well, it's an electromagnetic catapult. Basically, electric current would be pulsed through coils of aluminum wire, generating a magnetic field. The magnetic field would then accelerate a small bucket packed with a sphere of lunar material about the size and weight of a baseball. The material would leave the bucket and accelerate through space toward its destination. The acceleration, in fact, would be quite high, up to about eighteen hundred gravities. That means you'd go from zero to about three hundred miles per hour in the first seven thousandths of a second.

OMNI: But if you're going to send material through space, why make the payload so small?

O'NEILL: It turns out that in the vacuum environment of the moon, there is no particular restriction as to how big or how small the payload should be. But when you go through the cost optimization for this machine, you see that it would be far more cost effective to send a large number of relatively small payloads than to send a few very big ones.

OMNI: So in other words, this Mass-Driver would just keep catapulting material . . .

O'NEILL: Like a machine gun.

OMNI: Like a machine gun, toward the exact spot in space where it would be used to build the colony.

O'NEILL: Not quite, actually. There is an intermediate stop. It turns out that it's easier to send material influenced by the gravitational pull of the earth and the moon to a particular location about forty thousand miles from the moon.

OMNI: I see. You'd have a space station up there to collect the material?

O'NEILL: Yeah, actually just a very simple collector, consisting of a cylindrical tube open at one end.

OMNI: And from that point it would be relatively inexpensive to bring the material to the site of the space colony?

O'NEILL: Yes, very simple, because at that point you're already in high orbit, and you don't have to apply any high thrust to move things from one place to another. All the hard work has been done by the Mass-Driver.

OMNI: Once this lunar dirt arrives at the site of the intended colony, though, how would it be converted into the metals and minerals needed to build the sphere?

O'NEILL: The lunar soil would arrive at a processing plant that would turn it into pure elements: oxygen, silicon, aluminum, iron, magnesium, titanium, calcium, and various other substances. The Space Studies Institute gave a grant of $100,000 to Rockwell International to do the chemistry of the separation of lunar soil into pure elements. And that research has now been completed, with very good results. They've just written their final report, and it indicates that they now know all of the chemical reactions required. With that information in hand, we can now go on to the next step of building a very preliminary model of a pilot plant.

OMNI: What sort of Earth-based effort would be required to send up the first processing plant and Mass-Driver?

O'NEILL: That's a question we've addressed in a series of workshops funded by NASA and our own Space Studies Institute. We concluded that a set-up to process lunar materials into pure elements could be built on a scale small enough to fit in the present shuttle payload bay. A plant that size could process two thousand tons a year, and it could operate unattended for long periods. We found that the only components subject to wearing out would be containers for the higher-temperature chemical reactions — and those could be replaced from spares by standard hand-and-arm industrial robots in fixed mountings. Our overall conclusion was that you could make the jump to a minimum production level with less than twenty shuttle launches. To reach that first level, only a few people would be needed, mainly for installation and occasional maintenance.

OMNI: It's hard to imagine so few people building a chemical-processing plant or Mass-Driver.

O'NEILL: The essential notion is that nearly everything is assembled and tested on Earth before it's taken up in units sized to the shuttle's cargo bay.

OMNI: What about cost?

O'NEILL: For the first step? Well, as I said, there's no denying it's a big step; I can't imagine doing it for less than billions of dollars. Quite possibly, though, we could do it for under ten billion, which puts it on the scale of something like the Alaskan pipeline. That's not out of reach for an industrial consortium or even for a large group of individuals that gets contributions from all over the world.

OMNI: To get that kind of commitment from individuals, you'd need a program very different from Apollo — not that it wasn't exciting to see human beings on the moon, but the astronauts were so few and so specially prepared that it was hard to identify with them.

O'NEILL: Yes, many people have concluded that it's a pity the Apollo program didn't develop more logically. It was highly visible and goal-oriented but essentially one-shot. What was there to do for an encore? If we had had space manufacturing and habitation in mind from the start, we'd have gone about it very differently — and space colonization could well be happening now, because it would have a continuing direction and purpose.

OMNI: Yet, a lot of people argue against your proposals, saying that space colonization is a "technological fix," a cop-out that evades dealing with our problems on Earth.

O'NEILL: You make the solution of any problem more difficult when you constrain the range of answers you're willing to consider. By opening up the option tree, you find new possibilities, such as moving fuel-burning industries off the earth into space, where they can run on clean solar energy. Certainly over the last few years we've recoiled from high-technology plans, indeed from any large-scale initiatives that might have profound consequences, because we've felt very acutely the sense of original sin that grew out of the Vietnam War. But that war was politically motivated, not technologically motivated.

OMNI: Yet those opposed to your ideas say they're defending the taxpayers' money against wild-eyed dreamers. They'd rather concentrate on immediate goals with immediate payoffs.

O'NEILL: Experience has shown that when the payoff is near-term, private industry can do a better job than government. But government does have a unique role that it should be filling, and that's to support research toward the development of whole new industries that are going to give millions of new jobs in ten or twenty years. Private companies can't fill that role, because it's beyond their time horizon. The Japanese understand that difference, and that's one of the main reasons they're clobbering us economically.

If the country is in economic difficulties, we ought to be, above all, concerned with how to make more money — to create new wealth and productivity. Before you have any money either to save or to redistribute, you've got to go out and make it. My own feeling is that if there's a dollar that's not desperately needed to keep people from starving, we should be spending it in a way that will earn back ten more dollars. Then we'll have seven dollars to spend on improving the human condition, three for this or that, and still have our original dollar.

OMNI: Then you think that space manufacturing and habitation can be productive on a far larger scale than the spin-offs we received in the 1960s?

O'NEILL: Much more so. We have a high standard of living and high labor costs, and in an increasingly technological world we have only a few years in any new field before others begin selling our innovations back to us at prices we can't match. That's happened with home electronics and a lot of other things, and it may happen soon with computers. Space offers a peaceful new development in which we could play a leading role. What else do we have to offset what some economists predict will be a hundred-billion-dollar trade deficit by 1985?

OMNI: What kinds of payoff do you foresee? It's not likely to be worthwhile to ship either raw materials or finished products down from the colonies.

O'NEILL: One recent study by the Aerospace Corporation concluded that over a number of years there will be good reasons to have several tens of thousands of tons of satellites in high orbit. We'll need at least that to do a thorough job of solving problems right here, to do remote sensing and monitoring of the Landsat type, to improve communications, air-traffic control — all the gathering and transmission of the information that is clearly going to become an even more important part of our lives than it is already.

OMNI: You obviously believe these first space colonies would actually make a profit through the construction and maintenance of satellites.

O'NEILL: Oh, yes. Without a profit such colonies wouldn't get built. The biggest potential payoff would be in the construction of solar power satellites [satellites that would collect energy from the sun and beam it back to Earth in the form of microwaves]. Now, each solar power satellite would weigh about 100,000 tons, so they're big. However, the electric power output of each such satellite would be equivalent to the output of about ten nuclear power plants. Thus, each solar power satellite would be valued at more than $10 billion. An initial investment of $10 billion would be required to build the facilities to produce these satellites. But since a space colony could probably build one satellite each year, the annual profit, after the first year, would be about $10 billion.

OMNI: Can you describe the people who would live and work in these first colonies?

O'NEILL: The early colonies would hold anywhere from ten thousand to fifty thousand occupants. A pretty large fraction of the people there would be rather sophisticated repair experts: they would be able to fix complex electrical and mechanical robotic machinery; they would be able to fix the processing plants; and they would have a lot of knowledge about fairly sophisticated process chemistry.

There would also be a fair number of children in the early space colonies. After all, the whole point of building residential communities in space would be to accommodate people whose tours of duty are so long that they would take their families with them.

OMNI: Would there be many scientists?

O'NEILL: I'd love to say that lots of them would move to the colonies. But I'm afraid that not many scientists will be able to justify the trip in the early days. Those who could certainly benefit a great deal, of course, would be observational astronomers studying deep space. In fact, there would probably be big telescopes near the early colonies for deep space observation.

OMNI: But wouldn't scientists in the colonies have a much better chance of finding evidence of extraterrestrial intelligence than their colleagues on Earth? After all, there would be no atmosphere to obscure their view of the cosmos.

O'NEILL: Well, if you wanted to set up a big radio receiving array to search for radio signals from another civilization, it would certainly be much more effective to do so near a space colony. After all, if scientists ever *did* find a signal, the first thing they'd try to do would be to lock on to it, and check it continuously over a long period of time. But if their radio receiver was located on the surface of the earth, then the antenna, along with the planet itself, would rotate away from the signal every twenty-four hours. A radio receiver in space, on the other hand, could keep track of the signal constantly.

OMNI: Back to more practical matters: How would the inhabitants of the space colony collect energy for themselves?

O'NEILL: Simply by having collector mirrors attached to the outside of the colony itself. The sunlight in space is about one and a half kilowatts per square meter, and it's there all the time. So it means that a colony with a relatively modest-size mirror could collect enormous quantities of power.

OMNI: What about growing food?

O'NEILL: The question of agriculture in high orbit has already been addressed by the Russians. They've kept people in enclosed environments for six months or so, growing wheat, making bread. It's worked out well, and they've even done some experiments in space. It's likely that agricultural modules at the colonies would be based, in part, on that initial research. Essentially, I envision agricultural cylinders attached to, but separate from, the main sphere. Since plants grow best with less air, these cylinders would have a low density of oxygen. They would be kept hot and moist for most crops, and day length would be controlled with aluminum foil shades that could shut out the sunlight. To reach these agricultural cylinders — or to reach industrial cylinders that would also be separated from the main colony — inhabitants would just walk from their homes at the equator up to the poles. There they would enter a large tunnel, or access corridor, leading to the agricultural and industrial areas. The tunnel would also lead to docking ports for ships entering or leaving the colony.

OMNI: That brings up another question: How would people travel from one space colony to another? With conventional, shuttlelike ships?

O'NEILL: Oh, no. The best vehicle would be one that doesn't require an on-board engine, or even an on-board crew. It would just have to hold an atmosphere and some comfortable seating. Basically, the craft would be attached to a cable powered by an electric motor. It would be slowly accelerated in a precomputed direction up to a traveling speed of one or two thousand miles per hour. Then it would drift in free flight through the vacuum of space until it came to the next colony, where it would simply hook up to another cable and slowly come to a halt. This sort of trip might take about an hour, depositing the travelers in a colony that might have a totally different culture, language, and climate than their own.

OMNI: Sounds like a good cheap vacation for the wanderlusting colonist. But won't some colonies be located more than a thousand miles apart? I thought you envisioned such habitats throughout the cosmos.

O'NEILL: If you were to come back in a hundred years, you'd see space colonies all over the solar system. In my book *2081*, I located one of them many light hours out from the sun, considerably beyond the planet Pluto. It was possible for that colony to have an earthlike environment and an earthlike amount of sunshine because of large collecting mirrors. You could even locate space colonies around just about any star. In fact, every star around us is a favorable target for human migration. You don't have to wait for just those stars that happen to have earthlike planets; they may be very few and far between. One day an Island One sphere, adapted with technology beyond the limits of present-day science, may set off for another part of the Milky Way. Generations of inhabitants would live their lives in transit, but eventually the colony would reach that distant star. By my reckoning, a space habitat could last for several billion years — plenty of time to reach its destination.

OMNI: At that distant date, how would space colonies obtain all the things needed for survival?

O'NEILL: The colonies would have the whole mix of industries here on Earth, because at that point the major markets would be other space colonies, rather than the earth itself. That's a natural evolution, one that occurs in every colonial movement. You start out supplying things for the mother country, but in the long run, a colony builds up to the point where its major trade is with itself.

OMNI: Wouldn't those colonies located out past Pluto or in a distant solar system become dangerously isolated from the rest of humanity?

O'NEILL: It's a question of what you consider "dangerous." They certainly wouldn't be exchanging goods with other groups. However, I think that being a great distance from someone like the Ayatollah Khomeini would be a big improvement. Colonists would become very independent; they'll undergo a lot of cultural evolution, generate enormous cultural diversity. By the time we have colonies around a number of different stars, there obviously are going to be different historical trends in these various areas. The habitats will, of course, continue to receive information from the earth, but it would be after a time delay of several years. They would also send information, presumably of a scientific and literary nature, but, again, that information would reach the earth only after a time lag of several years. There would be a great deal of communication, but the farther you got away from the earth, the more out-of-date the information would be. Some of those newer stellar centers may even become centers at the forefront of human civilization and knowledge.

OMNI: Those colonists might be more advanced than people living on or near Earth?

O'NEILL: Sure, that's again been a tradition in human history. When a bunch of interesting people break out and settle in a new area, they tend to be inventive, they tend to push forward and do things *before* the people they leave back home. That could very well happen again.

OMNI: Your ideas are now embraced by many of your colleagues, and the people at NASA as well. But when you introduced this fantastical vision in 1969, it was, understandably, met with a great deal of skepticism. Can you describe the struggle you went through to get to the point of acceptance you're at today?

O'NEILL: The basic problem was my realization that building and living in space colonies was technologically within our grasp. Therefore, I didn't want my ideas to be in any way tainted by science fiction. I could have published the space colony concept in fictional form — that would have been very easy to do at any time. But the whole point was to get it out as a reviewed article in a scientific journal, and that's what took all the struggle. That didn't happen until 1974, when my first space colony article was published in *Physics Today.*

OMNI: When you talk to congressmen and others who influence public planning and spending, how do you appeal to them? Are they more interested in economic prospects or in beating the Russians, or do they share your excitement and belief that this is a challenge we must rise to?

O'NEILL: I really don't tailor my statements to the audience, although I underline some things here and there. I find that elected representatives tend to have quite a good sense of their constituents' underlying feelings and desires — not surprisingly, since they do get elected! And many of them sense a national feeling of frustration, a feeling that the country isn't moving anywhere or is even falling back. We have for so long been a nation identified with new ideas, new technology, new social experiments, and now we seem to be losing that position. Where do we go from here? These representatives look at a new possibility like the colonization or industrialization of space, and they wonder: Is America going to be a part of this revolution or sit back and watch other countries take the initiative?

I think that the movement in space is going to happen, whether it's done by Americans or not. That substantial numbers of people will eventually make space their routine environment is inevitable, if we don't blow ourselves up first; the imperatives pointing that way are so basic and so consistent with previous human history.

OMNI: Some people are uncomfortable with the idea that life in space would mean life with a demanding, interdependent technology around them at all times.

O'NEILL: Getting those first colonies built would be demanding, yes. But when you go a little further and ask what life would be like in a space habitat, I think it turns out to be in many respects a *less* demanding technology than we have at present. You don't need internal combustion engines; you don't need big power grids; you don't need elaborate communications networks, because within the habitat it's all line-of-sight; you don't need high-strength materials. Take a terrestrial problem, the manufacture of fertilizer for agriculture. With a six-inch pipe at the focus of a solar mirror, you can combine nitrogen and oxygen to get the high-energy precursors of fertilizer in any quantity you need. That's a lot simpler and cleaner than burning fossil fuels to make chemical fertilizers, the way we do now.

OMNI: Don't you need sophisticated recycling, especially of water?

O'NEILL: If you have a reasonably tight pressure vessel, you shouldn't lose any of it, and you'd have plenty of energy to distill it. We have serious problems recycling on Earth, because we keep losing bits of what we're recycling and it gets dispersed in very low concentrations throughout the environment; in a space habitat, keeping track would be a lot easier. Overall, day-to-day life in a space habitat wouldn't require much technology above the level of some of the better agriculture you find around the world today — agriculture that's not even necessarily carried on by literate people.

OMNI: It's taken a lot of work, but you've at least started the ball rolling toward a national constituency for space colonization. Would it be fair to say that private groups could make that initial effort in case no massive government support is forthcoming?

O'NEILL: Well, it's certainly interesting to ask: Can it be made small enough to be nongovernmental? People are now appreciating in all sorts of detailed ways that the smaller you can make the first step, the better off you are. That idea ran through the workshops I described earlier. For example, we aren't locked into the plans for a Mass-Driver on the moon. You can draw up a very stripped-down scenario involving only chemical rockets, say, by setting up the lunar processing plant chiefly to extract oxygen, which is 40 percent of the unselected Apollo samples, and which constitutes 85 percent of the total mass of rocket propellant. An automated fifteen-ton unit would yield something like four hundred tons of liquid per year, which is enough for an awful lot of rocket flights bringing materials up into orbit.

OMNI: The Apollo lunar module wouldn't make a very effective cargo carrier, though. Aren't some new vehicles going to be needed?

O'NEILL: Yes, we'd probably need three new but conventional vehicles: an interorbit freight-transfer vehicle, an interorbit passenger carrier, and a vehicle that could soft-land and take off from the lunar surface. None of them requires a big, new engine. They're in the class of the Apollo service and propulsion module, completely within the limits of what we've been designing for the past fifteen years. But we still have to build them.

OMNI: Any other projects on the horizon, Dr. O'Neill?

O'NEILL: Right now I'm working on Geostar, a satellite communications system that could be used by private individuals for a moderate price. It's very practical and not "blue sky" at all. The network we're planning would be based on a system of supercomputers on the ground and satellites in orbit. Four satellites would be used for coverage of the Americas, and ten for the rest of the world. The satellites I'm talking about would be in the same weight class as those RCA has been making for the last ten years. And there would be inexpensive transceivers of about the same size as a pocket calculator, which individual people could buy from places like Radio Shack. What subscribing to the system would give you is the capability to communicate, with short telegraphic messages of thirty-six characters or so, from any place to any other place in the world, and at the same time have your position measured down to a precision of a few feet.

I have two daughters in their twenties, and they're interested in the security issue. If they were walking alone on the street and were threatened by an attacker, they could push a button on the transceiver. Within half a second, the satellite would have located the nearest police car and informed the patrolman of the exact location and identity of the victim. Within another half a second, a subscriber would get a message saying that help is on the way. I've been working on this invention for a number of years, and last year [1982] the U.S. Patent Office granted my claims.

OMNI: Would we all be hooked up?

O'NEILL: The system could handle many millions of subscribers. We've already formed the Geostar Corporation to set up the system. The response and the backing seem to be tremendous. There's just a lot of work to be done.