SPACE STUDIES INSTITUTE

OPENING THE HIGH FRONTIER® FOR A BETTER FUTURE

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"The Vision"

by Gerard K. O'Neill

Survival

We have to understand that, at the deepest possible level, opening the high frontier means making possible and ensuring the survival of the human race, and not just the human race but all of those other species of animals and plants who have grown up with us in this wonderful thin biosphere on the surface of the Earth, the place which may be, as far as we know, unique in the whole universe.

Life is extraordinarily rare, extraordinarily precious and we have a great duty to preserve it, not necessarily to have it expand to some particular total number of individuals, but to have it spread in a way that will ensure its safety. We know that we are on a very fragile planet.

We have the capability to destroy ourselves, and yet we have not quite broken free of the limitations of that thin biosphere of the Earth. Once we do so, once there are ordinary, living, breathing human beings along with their plants, their animals, their food crops and so on, building biospheres of their own, expanding farther and farther away through the solar system and eventually out to the stars themselves, the human race will be truly unkillable. I think that at the deepest level, that has to be our motivation.

A Hopeful Future

When we look back in history to the earlier waves of colonization, the thing that is impressive about them is that it wasn't the rich and the famous who migrated, it was the people who felt that in the surroundings they came from, there wasn't enough room for their creativity, their expansion, their freedom, their chance simply to make a decent living for themselves, and to support their families. We know how bad things are now in many parts of the world. The deforestation of almost every part of the tropical jungle is a terrible tragedy which is going on right now, on a timescale of years and decades at most. We know that the pressure to colonize, the pressure to go into new areas, open up new places where people can live, is very great and always has been. But if we look back at the successful colonizations of the past, and that of the North American continent is uppermost in our minds, we see that it was largely, although not entirely, young people who came. It was people who had the courage to go and try something new. It was the people who felt the situation they came from was, in many cases, intolerable.

If we look around us at the world we live in today, a world of increasing over-population, we see that some of the same pressures that were there before are here again. There are many people in the world who feel that they're in places and in situations that are repressive, that don't give them adequate scope to even make decent livings for their families, certainly not to live in freedom. When we open up the high frontier by building colonies in space, there is going to be room for people who want to leave the Earth to go out and to develop their own colonies. When you ask about the aspirations of people throughout the world today, they are mostly very modest aspirations; a decent living, a chance to live in freedom. Those are the basics. That's the second important thing about opening the high frontier, and I think that in doing so we are following a history which began when the first fish came out of the water and became amphibians. The expansion into new ecological ranges is a natural part, not just of human history, but of all of the history of life.

In opening the high frontier, there are important things which we can do very directly for the Earth itself, for people who will be living here in the near future. One of the most important things has to do with energy. As you know, there is a very close correlation between the amount of energy which is spent by a society and the standard of living of that society. People have tried lots of ways to beat that relationship, but aside from doing all the conservation that we can, we can't do very much about it. It's remarkable how close that correlation is. So the question becomes, how can we provide the amount of energy which a growing set of societies throughout the world really needs, without destroying the Earth in the course of it? We're not very comfortable about nuclear power. We're certainly not very comfortable about burning fossil fuels, because within less than forty years, the build-up of carbon dioxide in the atmosphere is going to produce a very serious greenhouse effect.

So, where are we going to get the energy which is so necessary for the aspirations of those people, particularly in developing societies, on the surface of the Earth? The best answer that I've been able to find after a lot of careful investigation and research is to take that energy from the Sun.

Sunlight as a source of energy is not very practical if you wait until it reaches the surface of the Earth to intercept it. For one thing, the day/night cycle turns it off at least half the time. Second, unless you happen to be in the middle of the Sahara desert, cloud cover turns it off part of the rest of the time. Also it's a source which changes its direction in the course of the day, making it very difficult and awkward to use. But if one intercepts sunlight high above the Earth, in a place where it's permanent, in high orbit, and then converts it to some harmless form that retains the energy (the present best choice is low-energy radio waves of a low enough frequency that they can't be damaging), transmits that radio wave energy to the surface of the Earth, and converts it to ordinary electricity that we can plug into, one has a solution to the energy problems of the world.

An Obvious Idea

The fundamental idea that the next ecological range, the next place for the human race to expand to is in fact colonies in free space itself, rather than the surfaces of planets, goes back a long time in human history. The first person who wrote it down, in what seems to me to be a coherent and thoughtful and well-reasoned way, was Konstantin Tsiolkowski, who wrote in Russia in the early years of this century. He certainly understood the fundamental idea that if one gets out into free space, one has solar energy as a free and inexhaustible and totally reliable source of energy to power a human civilization, and he also had the fundamental idea that there's a lot more room out there than there is on the surfaces of any of the planets of the solar system. The next writer that particularly caught my attention was Dandridge Cole. Dandridge Cole's writings in the 1960's looked at the possibility of converting asteroids to colonies that could be used for human habitation.

1969 - 1974

In the years from 1969 to 1974, I looked at the logic of building habitats in space and realized that, from very simple physics, it made sense. There is constant sunlight there as a free energy source; there is plenty of room; there are materials in space adequate to build space habitats for thousand of times the present population of the Earth; one can provide atmospheres simply by enclosure rather than by holding an atmosphere in with the very weak force of gravity, as we do on planets; and one can provide rotation for a gravity that Dr. Newton taught us about some 300 years ago. All of these things are obvious, they're not complicated physics, and they make logical sense.

When I did my five years or so of work on my own, talked about it with other people, there came a point where that volume of reasoned and logical evidence was such that it was possible to have it published in a scientific journal and that had been my goal. I didn't want to publish the work as science fiction because that would give it the wrong cast. So finally in 1974, I did reach the threshold of being able to publish that work in a reviewed scientific journal. Very quickly the idea spread throughout the world and the general public caught on remarkably quickly. They understood the point of what was being said. It was in those five years of independent work that I also learned about the precursors, Tsiolkovsky and Cole, and the fact that they had been through much the same reasoning that I had, but many years earlier.

The Founding of SSI

From 1974 to about 1978, a considerable part of the work that was done on the research, on opening the high frontier, was supported by NASA. Of all the work that was done, in terms of volume, the work of the 1976 NASA-Ames summer study on space habitats is among the most important. It was a large group of people, about 55, working very intensely over the entire summer. It drew from scientific and technical and engineering backgrounds a wide variety of very intelligent people. Now, at the same time that NASA very helpfully supported that work and supported some of the intermediate work on what are called electromagnetic mass-drivers, (accelerators for launching material from the Moon), there were also frustrations associated with dealing with the federal government. Once a year the federal government characteristically changes its mind as to what is the goal and the reason for work it's supporting. I found, finally, that with all the good will that there was, and there was a great deal from people within NASA, and with all of the good relationships that had been set up, it was still becoming a drain that so much of my time and effort had to be devoted to meshing with the official governmental system. I really wanted to concentrate on the work itself.

In founding SSI, we decided we were not going to be a lobbying organization, there were plenty of those already, and we were not going to argue and be political about trying to get the federal government to do the job for us. Instead, the funding would come from the people themselves who were going to benefit from the opening of the high frontier. So, from its founding in 1977, SSI has been supported by individuals through membership campaigns and, very importantly, through the Senior Associates of SSI. Those are the people who have supported SSI to the level that allows it to fund the specific research programs in science and engineering that have made it so unique. And will continue to open the high frontier until there is the break-out into the whole new ecological range of the solar system.

The "Space Program"

We need to understand the roles that the individual human beings will play in the opening of the high frontier as opposed to the role that the various federal governments will play. I say various federal governments because, as has happened in high energy physics and a number of other areas, we cannot assume that it will be the US federal government that will be the leader forever in space programs.

The dual roles are quite different. Let me illustrate by an example. Perhaps the most extreme example of a federal type of program would be a program with the goal of some sort of activity on the planet Mars. It's a very long-term program, thirty to forty years. It is not connected very much in the way of economic justification. There is a lot of very good science that can be done that way, but this is something that one could not imagine people doing because they are interested in going out and making better lives for themselves, which is the primary rational of the high frontier. The federal government, or the federal governments of many countries, in doing a series of projects which would at some point result in landing people on the planet Mars and establishing some sort of habitats there, can be doing a great deal that cannot be done by individual people or by the private sector. This involves worthwhile projects of developing the infrastructure of space vehicles and the technology of long-term habitation in space.

We need a fair number of government-type projects in order to provide the infrastructure for the creativity, the ingenuity, the drive of individual people to open up what is to me a much less sterile, much more exciting, much more vibrant, kind of space program which is the space program of the high frontier. The corresponding event, if one goes back to the American West, is that of the transcontinental railways. The transcontinental railways could not be built by the settlers who came out and settled Oklahoma and Kansas, that had to be done by a cooperative effort of private capital and the federal government. One big difference was that they did have a very strong economic driver behind them. It was expected that the transcontinental railroads were going to be very profitable.

I believe the Mars program, the program to go and land people on the surface of the planet Mars, to be very worthwhile. It sets a long-term goal for a portion of our space program, the federally funded portion. The really exciting thing about it is, not so much the end point, but those things that can be done very early on. We need, and we do not have at the present time, a vehicle which can go from low-earth orbit to the surface of

the Moon and back again. We had it back in the Apollo days. What we need now is a much more economically effective, totally reusable kind of vehicle that can do that.

To me it is very exciting that one of the first things one would do in developing the technology for manned exploration of the inner solar system, is to try everything out first on the surface of the Moon. One would have to be developing the space vehicle which can make voyages of a few days before one develops the space vehicle that can make voyages of years, as is required for going to Mars. Mars is of interest not only scientifically but because it is the only other planet in the inner solar system to which people can go in any reasonable way. They'd have to live in the same way they would live in space colonies, namely in enclosure.

The National Commission on Space Report

One of the critical milestones of the past twenty years has been the appointment and then the work of the National Commission on Space. Important because of the way that ideas formerly thought not to be in the mainstream of space development have come to be accepted in the course of the thought, the reasoning, the discussion that has gone on over the past ten to fifteen years.

If you study the report of the National Commission on Space, you'll find some very important things. One is that, in contrast to the idea of the Apollo project, it's not a one-shot proposal. We're not proposing that someone go to a particular planet, plant a flag, put some footsteps there and come home. In fact, very specifically, the Commission's report avoids naming specific goals of that kind. Instead it proposes the gradual development of an infrastructure that would make it possible for us to move people farther and farther out into space.

The other thing that, to me, is particularly important about the work of the Commission was that fifteen people agreed that it would be central to any development of space in the near future that we boot-strap our way out by using non-terrestrial materials at every stage of the way. Fifteen years ago that was not at all a mainstream idea; now it is, as a result of the National Commission on Space.

The only practical way to go out into space from now on is going to be to use the energy and material resources that are there waiting for us. Just as when we came to the North American continent, whether we came ten thousand years ago, as the earliest Americans did, or whether we came a few hundred years ago, as the western Europeans did, we didn't come carrying everything. We came carrying tools, and we used the indigenous materials to make it possible to live and to work there. That's the way it's going to be in opening up the space frontier. I believe that's a very important conclusion of the National Commission on Space. The other conclusion, that we're not going to do one-shot missions, is another very important part of the final report.

It doesn't mean that we're not going to Mars. Sure we will. I hope that we'll be going to other places that are out there, already places that have names attached to them, but not as a one-shot kind of thing like the Apollo project, for all of its magnificent success. It's going to be part of a continuing development that will open up the solar system for human beings.

Scientists, Citizens and Space

There is a relationship between science and the opening of the space frontier that I think we need to understand. Science has been carried on since relatively early in human history, always as one or two percent of the budget of whatever else was happening at the time. People's first thought is to live, eat, work, and keep their families healthy and alive. They devote a tiny fraction of what they produce to opening up new scientific frontiers. The space program has been backward up to the present time because it has been nothing but science and things which were done for political purposes. There hasn't been any production of economically valuable elements that have resulted directly from it. (I leave aside discussion of spinoffs in the course of this program).

I think the really critical thing about the next phase in opening the space frontier is going to be that we will see the growth of actual economic productivity in space. We will see a restoration of the proper balance through such things as the construction of solar power satellites, and the building of space colonies which will house the work force that will be working on valuable things in space such as oxygen production, and building power satellites. We're going to see the economic activity, as being the major activity and it will be then very proper and very easy to justify a strong and continuing scientific program as being the necessary advance guard of that economic and productive activity in space. I believe that it will be one of the most exciting things about this next phase of space development.

Our Stepping Stone: the Moon

We, as living beings on the surface of the Earth, are extraordinarily lucky because there's been provided for us not just this precious surface, this biosphere that we've evolved in, but also, tantalizingly close to us, a sister planet, the Moon.

The fact that the Moon has been there, it's been visible to our earliest ancestors, it figures even in our body rhythms, is very important. Now when we come to the next phase of the development of space, it's going to be critically important. We already know from the great success of the Apollo project that it is possible for human beings to go over that distance and to return safely, even within the technological limits of the early latter half of the twentieth century. But now as we approach the end of the century we see the Moon in what is properly a more sophisticated way. We see it as a place we can get to within a very few days travel time. Also, it is so close to us that it takes radio waves less than three seconds to make the round trip between there and the Earth, making teleoperations very straight-forward and viable.

I don't believe, when individual people begin to do operations on the surface of the Moon, that they will be looking for ways to employ people. They will be trying wherever possible, to find ways through observation with television and controlling with radio, for stations here on the surface of the Earth to do the necessary work. That's the inexpensive way of starting out any sort of industrial operation, whether it's in nearby space or whether it's on the surface of the Moon.

The Moon is a source of minerals which we know about thanks to the Apollo project. It's very rich in oxygen. That's the most popular element in the surface soils. It's rich in silicon, it contains lots of aluminum, lots of iron, titanium, and magnesium. All the things, in fact, that we need for many of the products of an industrial civilization.

We haven't proven yet that there are organic substances there, like carbon, nitrogen, and hydrogen, but it is possible. And some of the most interesting science that could be done on the surface of the Moon, about the surface of the Moon, is to find out whether in the lunar craters at the extreme north and south poles, which have been shadowed for many millions of years, there may be an accretion of carbon, nitrogen, and hydrogen ice that never melts because the Sun never reaches it. We think there is an excellent chance that there are such organics on the surface of the Moon. Some twenty years of scientific theoretical research indicate that there should be. One of the programs which SSI has supported very strongly is the development of a lunar-polar probe, a special spacecraft which would go into orbit above the poles of the Moon, surveying the entire lunar surface in the course of every month and looking down into those permanently shadowed craters with special sophisticated instruments to find out if there's carbon, nitrogen, and hydrogen ice there.

That would be one of the most exciting scientific discoveries about the planets that we can imagine at this time. And the one, I would say, with the greatest potential for immediate payback in terms of our development of the inner solar system.

We know that the surface of the Moon is easy to reach. We know it's the place we will try out every kind of habitat that we have in mind to locate farther out in the solar system. It's a wonderful testing ground, it's a wonderful source of materials, and all in all it's the obvious next place that we have to go.

People have spoken of a "Return to the Moon." I think that's an inappropriate kind of phraseology to use. We really never have been there before; we just came, looked around for a few days at a time, picked up a few samples and ran home again. That's not being there. When we go to the Moon this time, it's really like going to the Moon for the first time in the sense of the products we're going to get from it and what we're going to learn from it. To me that's very exciting, not only as a scientific, but also industrial and technical development of the near part of the space program and a critical element in our development of habitats in space.

Space Colonies

Because we have become so accustomed to the certainty that human civilization is going to move outward from the surface of planet Earth into habitats in space, we forget that these are ideas that were still new and strange a few years ago and it's worth reviewing the logic in why this must be so.

What will space colonies be like? First of all, there's no point in going out into space if the future we see there will be a sterile future of living in tin cans. We have to be able to recreate, in space, habitats as beautiful and as Earth-like as the loveliest parts of planet Earth -- and we can do that.

The reasons come down to some very simple scientific facts. First of all, what about the source of energy of space? It's the free energy of the Sun, that nuclear reactor conveniently placed for us nearly a hundred million miles away. Sunlight is constant, unvarying, very powerful, and when a space colony is set up in the proper way, the Sun is always in the same location relative to it. That is not just in the vicinity of the Earth but much farther out in space where it is possible to have light-gathering mirrors which can produce the same solar intensity that we have here on Earth at the distance the Earth is from the Sun. We can provide our energy at any location that we like within the solar system, even as far out as the planet Pluto and beyond.

The second requirement for the survival and the flourishing of life is the enclosure of an atmosphere. In enclosed habitats one can hold an atmosphere. We know that the important thing is that from an esthetic of human living, those habitats have to be big. We don't want to be living in something as small as a spaceship. And, within the limitations of ordinary materials like steel, glass, and aluminum it is possible to build space habitats as large as miles across -- habitats that would be as large as a whole county here on the surface of the Earth. That is enough to provide green fields and forests, grass, trees and flowers and parks, the sort of surroundings that people love to live in, when they're given the opportunity. The scale of space colonies is essential to their being attractive places for the expansion of human civilization.

What about growing food? We know that green-house agriculture grows the very best food that we have here on the surface of the Earth and the wonderful thing about it is that when growing food in controlled, enclosed environments, one doesn't have to add insecticides or pesticides because one is keeping out the pest. There's no need, really, to import mosquitoes from the surface of the Earth.

The other thing that we require in space habitats is gravity. Here we have evolved and so have the other flora and fauna of the Earth. We need to provide that same Earth-normal gravity for the proper development of our bones and for the proper development of all the plant and animal species. Ours is the only planet where earth-normal gravity is provided. Mars has about half as much. Venus is uninhabitable. Mercury is even more uninhabitable in many ways, and the others are terribly far away. But in a space habitat, anywhere in the solar system or beyond, we can rotate the habitat at a slow rate to provide Earth-normal gravity by the rotational "gravity" of centrifugal force. Newton taught us how to do this several hundred years ago and we know exactly the speeds of rotation that are required. It doesn't even take any power. Once you set a space habitat rotating, it will rotate essentially forever. Maybe you will need a tiny electric motor to make up for losses from the friction of bearings, but that's about all you will require.

We do need one more thing for long-term flourishing of life in space and that is protection from cosmic radiation. We can get that very simply by the slag, the waste products from the processing of metals and glass that we would use for building the shells of our space habitats.

What about the shape? The best shape of a space colony has been determined, as a result of many years of engineering research, to be spherical. A sphere is the most economical kind of vessel to employ for containing the pressure of an atmosphere. A sphere also has some other very nice properties. Among them is the fact that you will have earth-normal gravity at the equator but that within a fifteen minute walk you could go to the north or south pole of the habitat and there be in zero gravity, be able to float free and to swim in the air in the same manner that the astronauts and cosmonauts in their tiny space craft do at the present time. There will certainly be whole new series of zero and low gravity sports developed as a result.

Everything that we need for the survival and flourishing of not just human life but all life can be found in space. We haven't as yet put names to those places. But just as we name ships, just as we name new cities, we will be naming our habitats in space. And they will have names in many different languages because those habitats in space will represent for all nations the room for expansion, the room for new opportunity for the people who want to move out into a new environment.

To the Stars!

Many generations of the writing of science fiction stories have very interestingly failed to take into account the development of space colonies. But when one thinks beyond even the next century to the development of human civilization, not just throughout the solar system but to stars that are beyond the solar system, there is a very exciting result from the practical existence of space habitats. Once we have proven to ourselves, as we very soon will, the right and best ways to build space habitats for our own solar system, it will be then very easy and natural to think of the stars that are nearest to us.

Once we considered that in order to go beyond our own solar system, we would have to find an earth-like planet around a Sol-type star. It might take a thousand light years to do this. Now, every star that we can see in our telescopes is a source of energy. A certain amount of trimming of the spectrum by filters is enough to give us the solar spectrum of Sol, our own Sun.

We know that we can make earth-normal gravity in space habitats, we know that we can enclose ordinary air, to create the exact environment that we need. Around every star there are vast amounts of materials, either in the form of minor satellites or of asteroid belts.

It means we don't have to go a thousand light years away in order to go beyond our own solar system. Our descendants, in my guess, of as little as a hundred years away are going to be starting out to the nearest star to settle human civilization around that star as well. We can see, then, the gradual development of humanity, and not just humanity but the flora and fauna that have evolved with us, to all of the stars in the near vicinity of Sol and eventually out throughout our whole galaxy.

We Are the Pioneers!

Like all revolutionaries, when we labor to make possible the break-out to the high frontier, we can get discouraged sometimes. We have to be reminded of several things. One of them is that when people put their minds to it, they make things happen extraordinarily fast. The whole Apollo project was not even ten years from the start of the concept to the successful realization. Almost anything that's technically within present possibility can be done within a ten-year time span when people set their minds to it.

So don't be discouraged, particularly by governmental time scales. Don't be discouraged by programs that are announced that are going to take thirty or fifty years to complete. That's the governmental program. That's not going to be the real space program of the future. The real space program of the future, the one that's going to make a difference in human history, will, in part, make use of some of the infrastructure developed by federal space programs, but very quickly it's going to springboard off those and use the creativity, the hard work, and the ingenuity of people exactly like yourselves -- and some of you will be deeply involved in it.

A second thing to remember, particularly at this time, when the US federal space program has been through a low spell and when it may seem that the fundamentally right ideas of opening the high frontier are

struggling for realization, is that, throughout all of human history, there has been nothing that has ever looked so absolutely rigid, so absolutely eternal as an establishment just before it's about to break apart completely. It's been true in every revolution you can think of. Rigidity is characteristic of a system which is just about to be replaced by something better. I think it is going to happen in the space program because of the dedication, the hard work, the contributions, all of the ingenuity that you are bringing to it. You are the people who are going to make it happen. It really is a revolution. It is a peaceful revolution, it's a revolution for the good of everyone in the world. It's not a revolution that's going to hurt people, it's going to help them instead. It's a revolution into which we can all throw ourselves and all of our energies, with full hearts.

The third thing to remember is that even the enthusiasts can be far too conservative about how long it is all going to take. I think the best example is Konstantin Tsiolkovsky himself. You may have read his works and you know that the pioneering work of his, which described an early form of space colony, said that the human break-out from planet Earth, the very first trip of human beings out beyond planet Earth to the Moon and beyond was going to happen all right, but it was going to happen only in the year 2017.

The Apollo project beat that by almost half a century. We have to keep that in mind when we realize that almost anything can happen in a ten-year period if we set our minds to it. And that even someone who was as much a forward-thinker, as much of an enthusiast, as Tsiolkovsky himself, was fifty years too conservative in setting the date for the very first precursor of the human break-out into space. Think of that and let us all be encouraged and work hard to make it happen and happen fast.

Note: This text was prepared from the speech delivered by Gerard K. O'Neill for the March, 1987 National Space Society Conference Keynote Address.