Towards The Orthomolecular Environment

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Introduction

In the early part of the twentieth century Anton Tsiolkovskii first introduced the idea of human colonies in Space in a work of fiction. In **The World, the Flesh and the Devil,** the Physicist, J.D. Bernall, elaborated somewhat on the concept, but, like Tsiolkovskii, his contribution was promptly forgotten. John W. Campbell Jr., in an editorial in the publication **Analog/Astounding Science Fact and Fiction** in 1960, stimulated more interest in Space colonies for a few years until, with the general disenchantment in Technology, indifference set in once more, apart from the writing of G. Harry Stine (1975).

In 1974, Gerald K. O'Neill began the current movement to promote colonies in Space (O'Neill, 1974). So well developed are the ideas of Dr. O'Neill and his followers that many influential people of many walks of life, and many political and ideological persuasions, have publicly supported such a movement.

However, scant attention has been paid to the medical implications of large numbers of people living in Space. In particular, there has been no hint in the literature that the orthomolecular approach might be the most appropriate to consider such implications. Let this now be rectified, and orthomolecular medicine be inextricably linked to the coming mainstream of human history.

The Orthomolecular Environment

To paraphrase Linus Pauling, Orthomolec-iular Psychiatry may be defined as the treatment of psychiatric disease by the provision of the optimum molecular environment, particularly nutrients, for the cells of the brain. It was soon found that the mind/brain could not be divorced from the rest of the body, and that the same principle could be applied to other types of diseases—hence, orthomolecular medicine, defined as the management of diseases in general by the provision of the optimum molecular environment for the body.

Let us take these ideas a little further and look at the broader concepts that underlie the orthomolecular hypothesis. What we are seeking is not a narrow, purely biochemical approach, to the treatment of human

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disease, but a provision of the total optimum environment for the human organism to prevent and treat its ills. We can label this the Orthomolecular Environment or, better still, the "Ortho Environment", How can we define this Ortho Environment? We can list its characteristics quite easily (Table 1.)

Table 1. Definition of the Ortho Environment.

THE ORTHO ENVIRONMENT
Free of Pollutants of Air, Water, and Food (including Allergens)
Optimum Nutrition, i.e. unrefined foods, variety of foods, vitamins and minerals
Optimum Radiation
Optimum Gravity
Optimum Social Environment

Practicing orthomolecular physicians are familiar with the first two items. We do our best to keep our patients free from pollutants and allergens. We try to instruct our patients to follow the best nutrition for their individual needs. But current economics and the present environmental crisis so often conspire to prevent proper compliance against the patient's own best intentions, frequently through factors that we can know nothing about.

Alexander C. Schauss has had considerable success demonstrating the effect of our radiative environment on our health. For example, we surely all advise the parents of hyperactive children to change the decor of the patients' bedrooms to pink—with dramatic positive results. But the effect of microwaves is still controversial. And even pure sunlight is not a total blessing.

What is the optimum social environment? I do not know. What is certain is that the ideologies of our history, be they religious or political, have succeeded in making the lives of countless millions of people utterly miserable. Even worse, the present conflicting Utopian philosophies threaten the very survival of our species.

And what is the optimum gravity for human beings?

Planetary Chauvinism

The practitioners of orthomolecular medicine are no strangers to prejudice. Not one of us has avoided the indifference and outright hostility of our less well read colleagues.

As women suffer from male chauvinism, so orthomolecular physicians suffer from toximolecular chauvinism.

Let us now become aware of another form of prejudice and be on guard against it. We are only too aware of the hazards of thoughtless and misapplied technology, and much of our time is spent in counselling our patients in returning to a lifestyle that might, at a superficial level, seem to be more primitive, more natural. The danger is, of course, that we can forget the disadvantages of how our forefathers lived, and, also, forget the very real advantage of living in the present time. For example, who would seriously consider living without antibiotics (recognising their hazards as well), or seeking a maternal mortality rate of 50 percent during pregnancy and labour (recognizing some of the less attractive aspects of modern obstetrics at the same time)?

The arguments against the main theme of this discussion may be summed up by one term—Planetary Chauvinism.

In 1969, O'Neill posed a question to some of his brighter students. The question was: "Is the surface of a planet really the right place for an advancing technological civilization?" (O'Neill, 1977). The answer was an unambiguous "No!" Why? When the advantages and disadvantages of civilization on a planet and in Space are compared and contrasted (Table 2.) the only reasonable conclusion is that there are very clear cut advantages to Space. In particular, life on the surface of a planet has the dangerous proneness to induce in the intelligent inhabitants of that planet that false sense of security known as planetary chauvinism, or the assumption that, because our species evolved on the surface of a planet, therefore it is somehow preordained that we must forever confine ourselves to it.

Table 2 Contrasting civilization on a planet and in Space.

PLANETARY CHAUVINISM

"Is the surface of a planet really the right place for an advancing technological civilization?"

FEATURE	PLANET	SPACE
Room	Limited	Limitless
Energy	Limited	Limitless
Resources	Limited	Limitless
Atmosphere	Toxic to most industrial processes	None
Gravity	Imposes high energy costs	None
Vulnerability to ecological disasters	High	Localised only
Security	False	"Eggs in more than one basket"

Human Colonies in Space

With the Space Shuttle (LBJ Space Center, 1976) now coming into operation (Plates 1 and 2), it now seems not quite so ridiculous to consider the practicalities of establishing human colonies in Space. As currently envisaged, by a so-called bootstrap process whereby each step pays for the next step, the first, independent, self-supporting colony may be established within the next twenty years, largely constructed from lunar materials (which we know are there in useful quantities), at a total cost no greater than the present annual U.S. defense budget spread over twenty to thirty years (O'Neill, 1975). Its initial economic justification likely would be as the site of construction of large scale, cheap, orbiting, solar power stations (Plates 3 and 4), planned as the source of very cheap energy for the Earth, again the source of materials being the Moon (Glaser, 1977).

The designs envisaged for the early colonies are either cylinders (Plate 5), spheres (Plate 6), or toroids (Plate 7), because within present engineering constraints such structures can most easily confine the atmosphere necessary for the colonies to be habitable. As the bootstrap process continues and the human population in Space rises, large cylinders seem to be the most likely design to be used still consistent with current engineering limits, providing an aesthetically attractive environment (Plates 8, 9, and 10), with the capacity to house large numbers of people on a substantial area (Table 3). Whatever the design, because it is assumed that people will need an induced gravity for long term health, the structures will be rotated to provide the physiological equivalent of gravity through centripetal (not centrifugal) force.

I would like to question the assumption that we need gravity for the maintenance of health.

Physiology of Weightlessness

The flights of the manned spacecraft of both the U.S.A. and the U.S.S.R. have given a substantial and consistent understanding of the physiological response to living in conditions of weightlessness for considerable periods of time (Pace, 1977). The effects are summarized in Table 4, and are very similar to those seen in patients confined to bed for long periods.

However, unlike bed rest, weightlessness may have some very positive advantages. These are shown in Table 5.

Table 3 The Evolution of large Space colonies, their populations and their habitable areas.

CYLINDRICAL SPACE COLONIES Using conventional agriculture, without specialized agricultural units

Model	Length	Radius	Area	Period	Population	
		km	km	km2		*$ec*
1	1	0.1	0.63	21	5,000	
2	3.2	0.32	6.43	36	200,000	
3	10	1	62.83	63	1,000,000	
4	32	3.2	643.4	114	10,000,000	

Table 4 Principal effects of lack of gravity.

PHYSIOLOGY OF WEIGHTLESSNESS

Loss of Calcium, including from bone Loss of muscle mass Fall of total red blood cell number Fall in blood viscosity Caudal redistribution of body fluids Loss total sodium, potassium, chloride and water

Table 5 Contrasting bed rest *and* weightlessness.

BED REST AND WEIGHTLESSNESS

Bed Rest	Weightlessness
Patient confined	Patient mobile and active
Decalcification hard to prevent	Decalcification prevented easily
Blood flow sluggish (tendency to pulmonary thromboembolism)	Brisk blood flow
Pooling of secretions (tendency to hypostatic pneumonia)	Unopposed ciliary drive of mucus
Hard to be gainfully employed	No restriction of employment

Weightlessness as Treatment

I have speculated elsewhere (Paterson, 1981) that weightlessness may have a very strong potential in the therapy of many common diseases. For example, cardiac diseases cripple through ischaemic pain, or "pump" failure, or a combination of both. Whatever the mechanism, the methods currently used in management are based upon the principle of reducing the load on the myocardium either by drugs or surgery. The same result is obtainable by removing the load penalty imposed by gravity. Similar benefits are likely in diseases of the respiratory, neurological, musculoskeletal and reproductive systems.

In the last example, for instance, it takes little imagination to see how the problem of sexual dysfunction could be effectively managed in weightless conditions. Without gravity, also, it seems that labour would be much more efficient and easy, with obvious consequences to the quality of offspring produced. For the attendants too labour would be easier to conduct with much easier access to the labouring mother's perineum. The serious problem of toxaemia of pregnancy, or pre-eclampsia, is also likely to surrender at least somewhat to weightlessness since the pathophysiological changes observed in this condition are the reverse of what is seen in astronauts.

Gravity and Psychiatric Disease

Depression is one of the commonest psychiatric conditions. I would like to suggest that gravity, if not a causative factor, may be a strong contributory factor. When we, the supposed normals, feel at less than our best, how hard is it for us to drag ourselves out of bed against the weights of our own bodies? For someone who is clinically depressed it is much harder again. We see them dragging themselves into our offices with weight of the world's cares upon their shoulders. Contrast this with the euphoria experienced by all astronauts once they left the Earth.

Depression is one of the commonest symptoms of schizophrenia. In my practice, I find it to be one of the symptoms that responds to orthomolecular techniques least predictably. And, of course, it is the manifestation of schizophrenia that carries the highest mortality rate through suicide. If weightlessness is a euphoriant factor, then it can be a most potent tool for reducing the wastage of lives from the scourge of schizophrenia.

In anxiety states there may also be benefits from lack of gravity. The manifestations of anxiety are due to an overstimulation of the sympathetic side of the autonomic nervous system. But, for day-to-day activities, that side has to be stimulated anyway to cope with the stress of gravity burdened duties. If that burden could be relieved then the stimulus for the state of anxiety, or its maintenance, would be considerably lessened.

But lessened gravity alone is not the only contribution that the colonies in Space would make to Medicine.

Nutrition in Space

If the settlements in Space had to rely solely on terrestrial sources for their food then, clearly, the very idea of Space colonies would be impractical. Consequently much thought has gone into the provision of "closed ecosystems of high agricultural yield" (Henson and Henson, 1979; Johnson and Holbrow, 1977). Those studies available have shown that, with current agricultural technology, high yields of food may be obtained.

The soil would be lunar soil to which water and nitrogenous compounds would be added. This has already been shown by NASA to be highly fertile. Initially the water, nitrogenous materials, and carbon compounds would have to be brought up from the Earth, with, *of* course, recycling of the wastes from the biological activities aboard the colony. Later, these basic materials would be obtained at considerably lower cost from the carbonaceous chondrite type of asteroids, brought to the vicinity of the Earth-Moon System by low cost propulsion techniques, such as high performance Light Sails.

There are clear cut advantages to carrying out agriculture in colonies in Space as shown in Table 6 (Johnson and Holbrow, 1977). Obviously a high priority will be the use of as many, varied organisms as possible for variety of foods and as insurance against mishap with any one staple. Some anticipated crop yields are shown in Table 7 (Henson and Henson, 1977), based upon the experiences of places such as Israel and Abu Dhabi. Animal protein could be obtained

Table 6 Advantages of Agriculture in Space.

	ENHANCEMENT OF AGRICULTURE	
Factor	**Space Colony**	**Terrestrial**
Light	Greater by 7.5	Reduced by atmosphere &
Photo period	24 hours	clouds 12 ± hours
PCO_2	Up to 400 Pa	17 Pa
Water	Regular irrigation	Weather dependent
Temperature	Optimised for species	No control
Season	4 per year	Usually only 1
Crop damage		
From weather	0	Wind, rain, sleet, hail & snow
from pests & insects	*	5 -15 % loss of crop
from weeds	*	2.5- 5% loss of crop
from disease	*	10-60% loss of crop
	* controlled by quarantine	

Table 7 Possible crop yields in the Space colonies.

OPTIMISED CROP YIELDS

Crop	**Yield g/m2/day**
Wheat	150
Tomatoes	82
Cucumbers	89
Cabbage	47
Radish	50
Broccoli	28

from feeding the waste vegetable matter and surplus production to such animals as rabbits, chickens and goats. Rabbits are probably the most efficient producers of meat that are already domesticated. Chickens can provide many times their own weight in eggs, the best total nutrition available. Nanny goats (bred by Al to prevent the smell that the presence of Billies induces), weight for weight are the most efficient ruminants for milk production, and can also yield meat and clothing.

The Hensons (1977) have estimated the average diet as shown in Table 8 yielding the vitamin and mineral content as shown in Table 9. An alternative estimated diet is shown in Table 10 (Johnson and Holbrow, 1977). This latter is marred by the inclusion of sugar, but I rather suspect that the colonists in Space will have too much sense to adulterate their nutrition with this substance. Whichever estimates are taken, it is clearly seen that that diet is more than adequate for the average healthy person.

Table 8 Estimated average daily diet according to the Hensons.

AVERAGE DAILY DIET PER PERSON				
Crop	**Area** m^2	**Biomass** kg	**Food mass/day** g	**Protein** g
Grain	16	70	250	30
Fruit &Veg.	6	26	750	10
Meat	11	40	143	40
Milk	5	20	2,500	64
Eggs Total	0.5	1.5	15	5
	38.5	165.5	3,658	149 = 3,000 Cals.

Table 9 Contrasting the planned vitamin and mineral content of the Space colony average diet with the "Recommended Daily Allowances".

VITAMIN AND MINERAL CONTENT

NUTRIENT	**SCav.diet**	**RDA**
Vit.A(iu)	14,399	4,915
Vit. C(mg)	144	56
Niacin (mg)	33	15
Riboflav. (mg)	2.1	1.6
Thiamine (mg	2.2	1.2
Ca (g)	0-88	0.82
P(g)	1.57	0.82
Fe(mg)	17	13.6
K(mg)	3,549	
Na (mg)	1,680	
Linoleic Ac. (g)	1	*
Cholesterol (mg)	319	

Table 10 Average daily diet as estimated by NASA for Space colonists.

ALTERNATE AVERAGE DAILY DIET PER PERSON

Source	**Amount**	**Calories**	**CHO**	**Fats**	**Protein**
	g	g	g	g	g
Meat					
Trout	40	78	0	4.6	8.6
Rabbit	40	64	0	3.2	8.4
Beef	40	142	0	12.8	6.3
Chicken	40	49	0	1.3	8.8
Produce					
Eggs	24	39	0.2	2.8	3.1
Milk	500	330	24.5	19	17.5
Dry Plant					
Wheat	180	608	130.1	3.6	24.3
Rice	100	363	80.4	0.4	6.7
Sugar	100	385	99.5	0	0
Veg. & Fruit					
Carrots	100	42	9.7	0.2	1.1
Lettuce	100	14	2.5	0.2	1.2
Peas	150	126	21.6	0.6	9.5
Apples	100	56	14.1	0.6	0.2
Potato	100	76	17.1	0.1	2.1
Tomato	100	22	4.7	0.2	1.1
Oranges	100	51	12.7	0.1	1.3
Totals	1814	2445	417.1	49.7	100.2

For the patient with nutritional dependencies or maladaptations, it would be a good basis from which to make the appropriate orthomolecular changes.

Since the structures in which agriculture is to be carried out are isolated from the main body of the colony and from each other (Plates 8 and 11), disease control, after extreme care had been taken over the quality of the organisms brought from the Earth, would be by isolation and aggressive sterilization by vacuum and direct solar irradiation of the unit(s) involved in any disease outbreak. The use of pesticides or herbicides is not anticipated. The effect of this on human disease will be most interesting to observe.

No provision is made for the processing and adulteration of foods, since harvesting will be constant and food distribution will be organized for the most rapid turnover possible or practicable. Little except emergency storage is envisaged. The effects of this on people prone to sensitivity to sugar, artificial colorings, flavorings and preservatives will be interesting to observe.

Indeed, the above considerations will make the coming Space colonies the best possible, massive, testing grounds for the predictions of the orthomolecular physicians.

Physical Environment of the Space Colonies

As currently planned, almost the sole source of illumination for the Space colonies will be sunlight reflected into the interiors of the communities by giant mirrors. Variations in the composition and areas of the mirrors will alter the quality and quantity of light in the colonies. The mirrors can be closed off to produce artificial night. This will allow for experiments to find out what is the optimum day/night cycle, what are the optimum climatic conditions, for human beings and their health.

Experiments can be carried out with variations of the ambient pressure and the partial pressure of the individual gases in the atmospheres of the colonies to determine the best for our species, not what we assume to be the optimum. For example, in patients with chronic obstructive pulmonary disease, what role is played by the sheer gaseous viscosity of the air moving in and out through the bronchi in the energy burden imposed by the condition? I suggest that a reduction of the ambient pressure with maintenance of the partial pressure of the oxygen will substantially improve the well-being of such patients.

All industrial activities will be carried out well away from the habitable pressure hulls of the colonies. This isolates the colonists from all possible pollutants except those produced by their own bodies, which will be dealt with by other living organisms just as efficiently as occurs on Earth. Any true industrial wastes (not what are merely called "wastes" just because of our own laziness in failing to put them to economic use) will be driven off by the Solar Wind and out of the Solar System. The effect of a lack of industrial pollution on the health of the people in Space will be fascinating to observe.

Social Environment of the Space Colonies

One of the most exciting possibilities emerging from the Space colonies is the chance to carry out large scale experiments on the viability and validity of the various ideas of social reform, political or religious. Each colony (and there would likely be many of them, each with a population between ten thousand and ten million) could be inhabited by people with one professed way of life, ideology. If the social fabric of the people aboard is not compatible with a responsible attitude to the community by the individual then all too easily the physical structure of the colony could be neglected and allowed to fail. The consequences of such a failure would be drastic and spectacular making for a very thought provoking object lesson.

The death of its followers would be the price to pay for any unsuccessful social system.

Another factor of importance would be that, unlike previous colonizing ventures, colonization in Space would be carried out by the highly motivated, highly intelligent, highly trained cream of our population. They would not, at least for some centuries, be impinging on other ecological systems or other civilizations. The guilt feelings so repressed and yet so obvious among our North American populations would not recur.

Moreover I feel that Space colonization would be the non-violent equivalent of war. As in war, the healthily stressful, survival mode of life would draw people together, give their lives obvious meaning, instill responsible attitudes to their fellows, and relieve them of much neurosis.

Unlike war, the purpose of the colonists' lives would be to build, not destroy; to conserve and enhance life, not kill; to spread our populations out across the Universe and liberate them from the past, not tyrannise them.

We have just passed through the frontier era of history on this planet. There are many who feel the need to challenge new frontiers. Nowhere on Earth can this outward urge be relieved. Perhaps much of our present difficulties have as their origin our inability to give an outlet to this urge. Certainly, once these people would become involved in what we call the "High Frontier", then we may anticipate that the Earth will enter an era of stability.

Conclusions

We have seen how the migration of our species into Space may bring us into the environment that most closely approximates the optimum for human beings, the Ortho environment, fulfilling as it does the criteria for such an environment, i.e. absence of pollution, optimum gravity, optimum social system(s). The test of such a suggestion will be the health over the long term of the people in Space as compared with the health of their brethren remaining behind on Earth. I believe that the medical effects will confirm the hypotheses of the orthomolecular physicians once and for all, and may link orthomolecular medicine inextricably with the coming mainstream of human history.

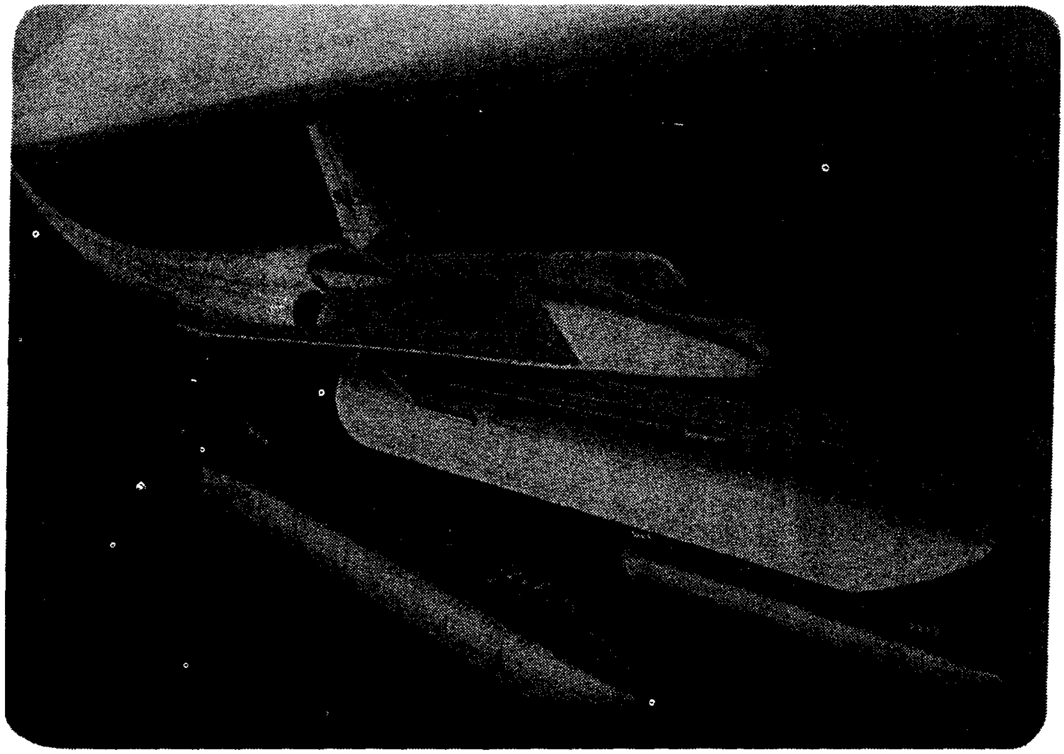

Plate 1 - The Space Shuttle at 130 seconds after launch ejecting the giant, reusable, booster rockets. These will drop gently into the sea under parachutes, while the Orbiter continues under its own power into orbit with the fuel contained in the large, external, fuel tank.

Plate 2 - The Space Shuttle, having performed its mission in low Earth orbit, and having used the atmosphere to slow it down from orbital speed, will return to its home base, landing like a high speed glider.

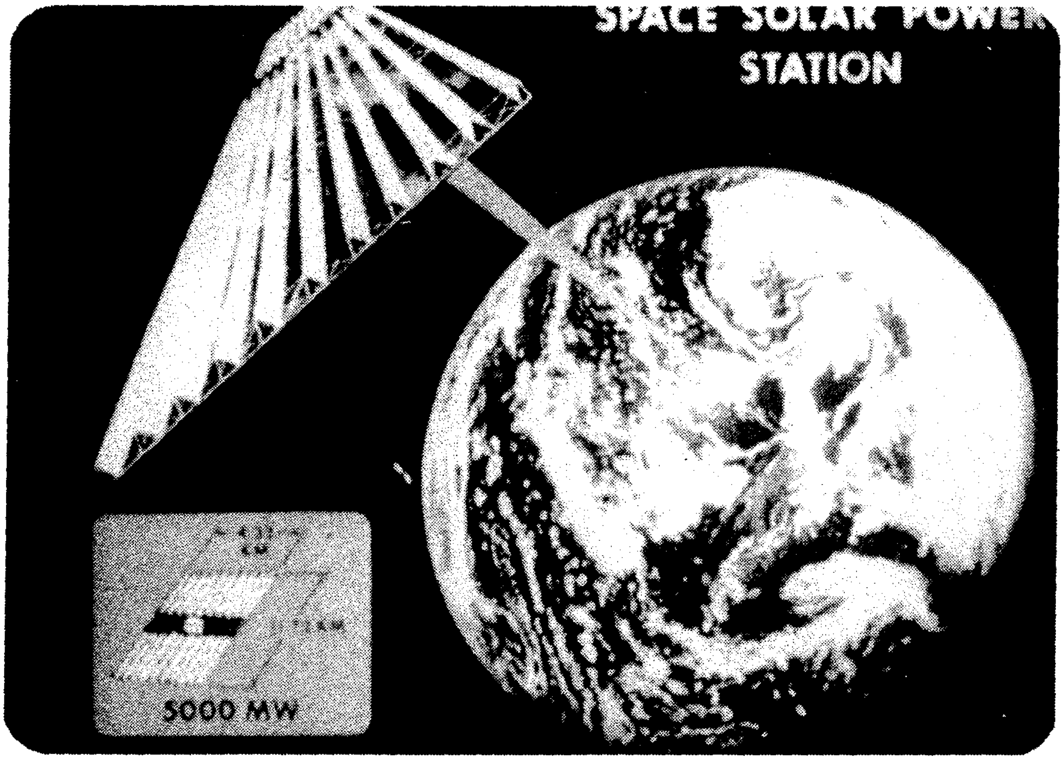

Plate 3 - Original, and still currently accepted, concept of a solar cell based orbital power station, as developed by Peter Glaser of Arthur D. Little, Inc. Its enormous size and light construction are possible because it does not have to withstand its own weight. The microwave beam that carries its power to the Earth can only remain concentrated if it is pointing exactly at the special receiving "rectenna" on the ground.

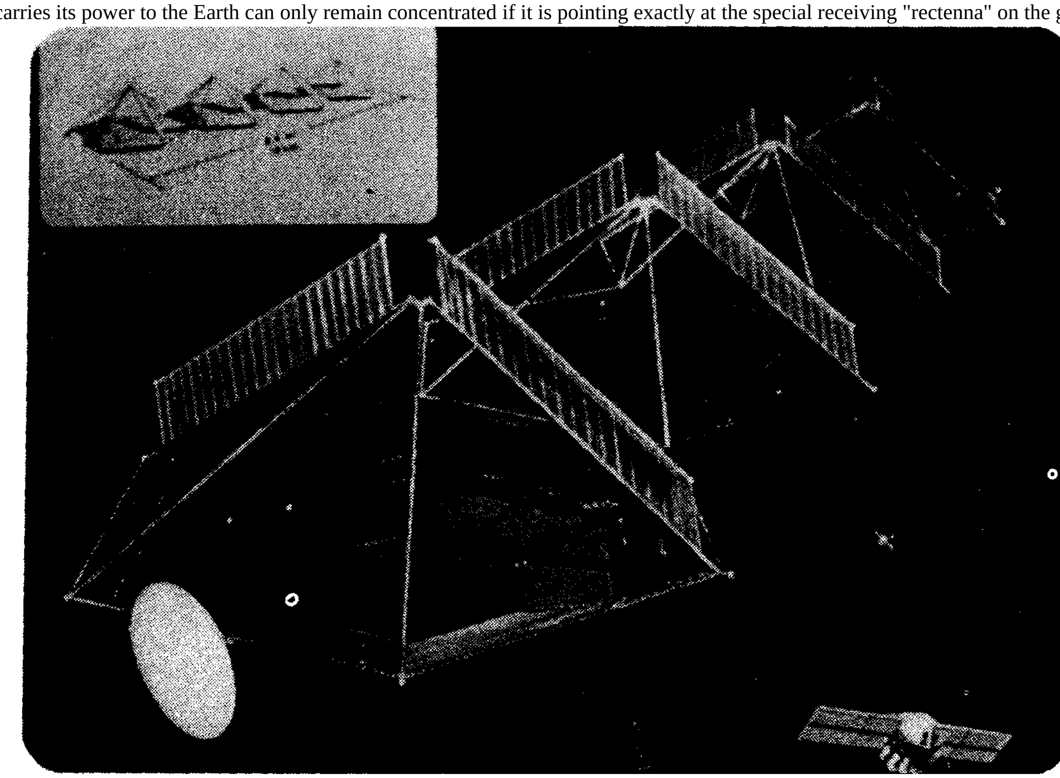

Plate 4 - An alternative concept of an orbiting power station developed by the Boeing Aircraft Corporation, based upon the more conventional idea of focussing solar heat with giant mirrors on water driven, turbo-generators. The vanes serve to radiate waste heat away. The microwaves transmitted to the Earth are converted to electricity for normal distribution and use.

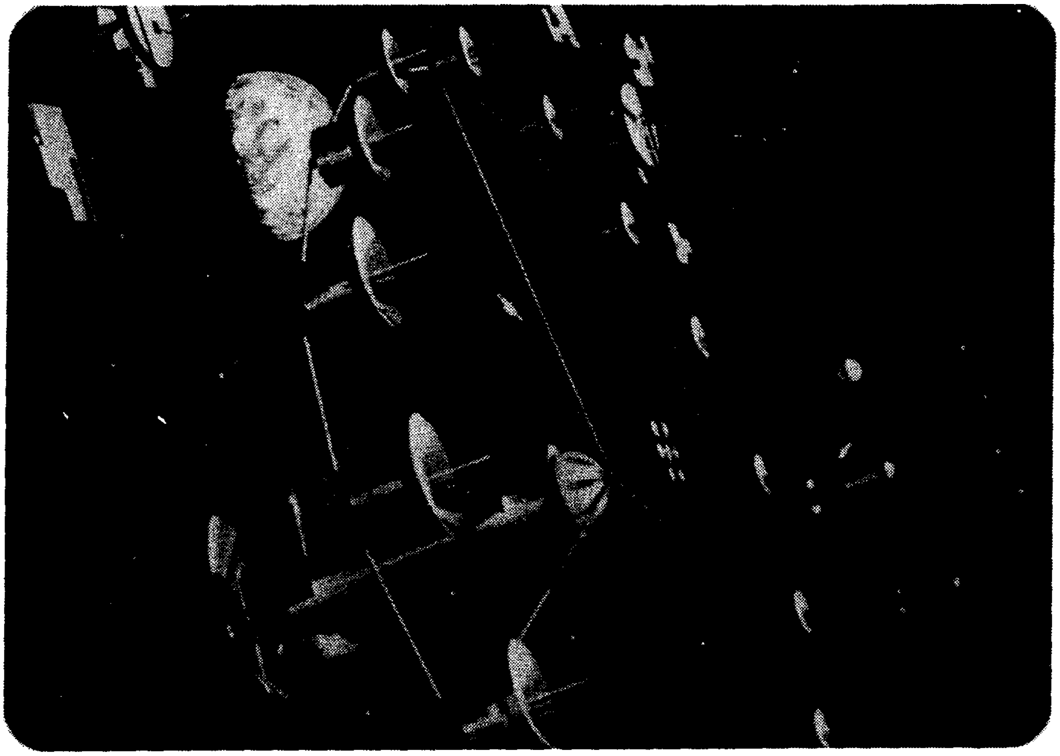

Plate 5 - O'Neill type Island One Space colonies, each pair of cylinders housing ten thousand people, the cylinders being paired so that the mutually transferred angular momentum keeps both cylinders pointing at the Sun for the flat mirrors to reflect the sunlight through the "solars" into the "valleys" where the people live or their agriculture is carried out. Other, self-contained, agricultural units lie in a ring around the main colony structure, isolated from each other.

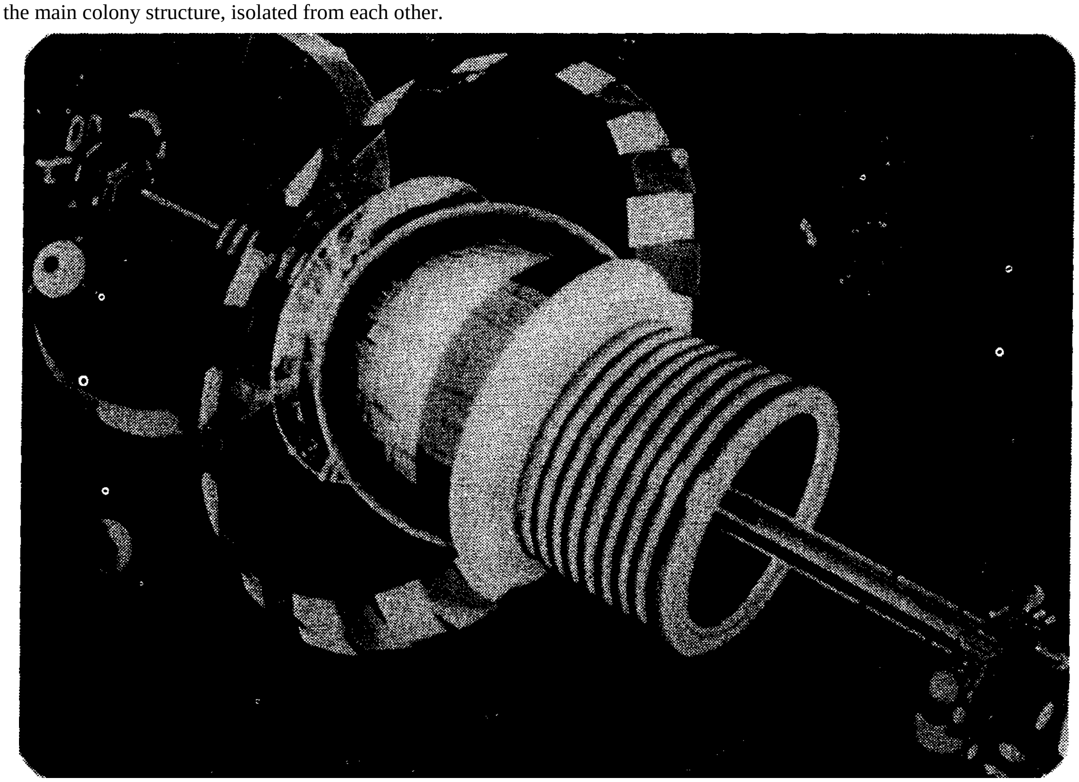

Plate 6 - Bernal Sphere, one mile in diameter, housing ten thousand people in small, compact villages. The light is conducted into the interior by a complex arrangement of mirrors which can be adjusted to vary the amount of illumination. Agriculture is carried out in the "Michelin tyre"-like rings, each with their independent mirror systems, each able to be sealed off from the others. Industry is carried out well away from the main body of the colony.

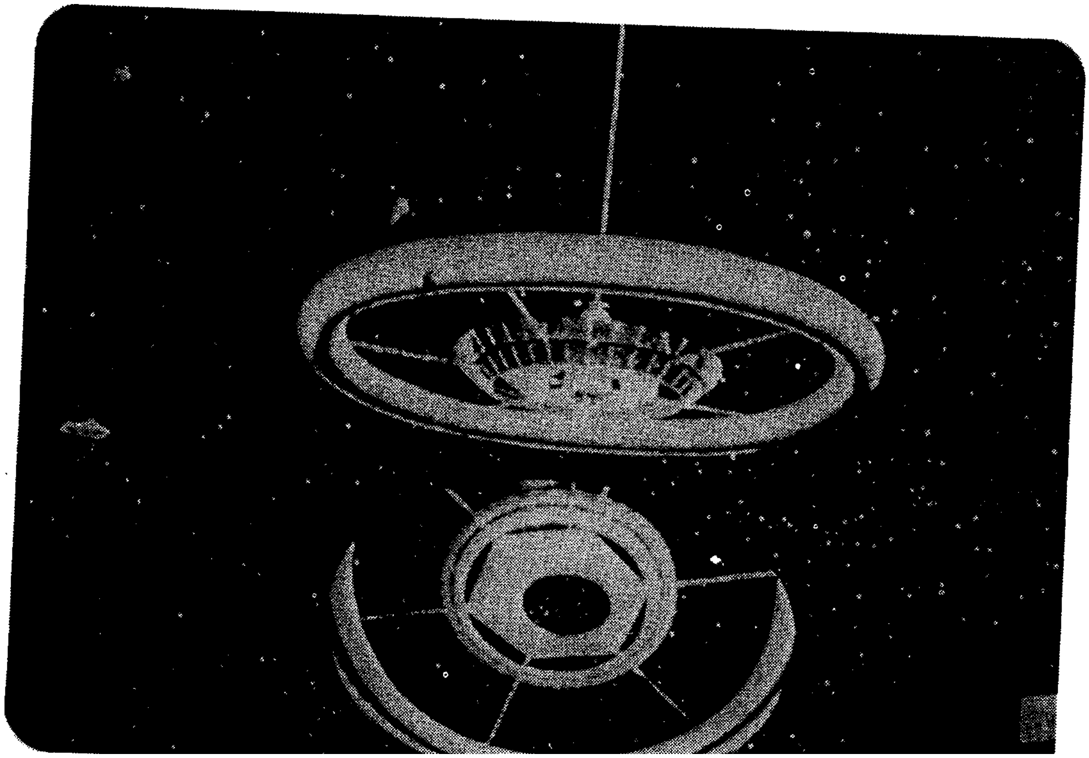

Plate 7 - Stanford Torus, a development of the more familiar wheel shaped Space community, again holding ten thousand people, the light reaching the interior by three separate mirror systems. No provision is made in this design for extra agricultural units. This is the most favoured plan by NASA.

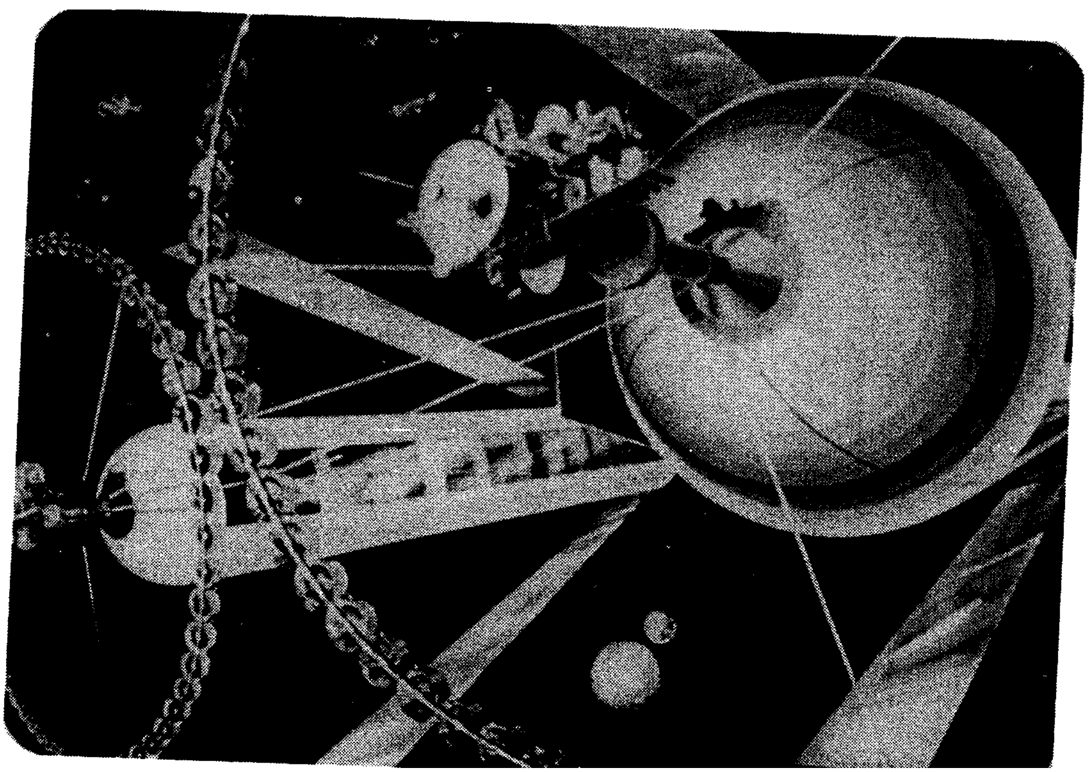

Plate 8 - Full scale O'Neill type Island Four, with each cylinder 32km long and ?.2km in radius, each holding ten million colonists. Each pair of cylinders is coupled together in a way that requires no external force to keep them pointing at the Sun so that their mirrors can control the amount of light coming in. Agriculture and industry are carried out external to the main body of the colony freeing the interior for quality of life of the inhabitants.

Plate 9 - Island Four seen from the side with detail of the capstan system for the mirrors by which climate and the day/ night cycle is controlled. The time taken for the construction of each of these large colonies is eight years. Since each colony, once it is fully operational, can be occupied in building new colonies, the geometric rate of growth of the numbers of colonies soon outstrips the capacity of humans to breed to occupy them. By the turn of the 21st century Earth's population may fall to between one and two billion people.

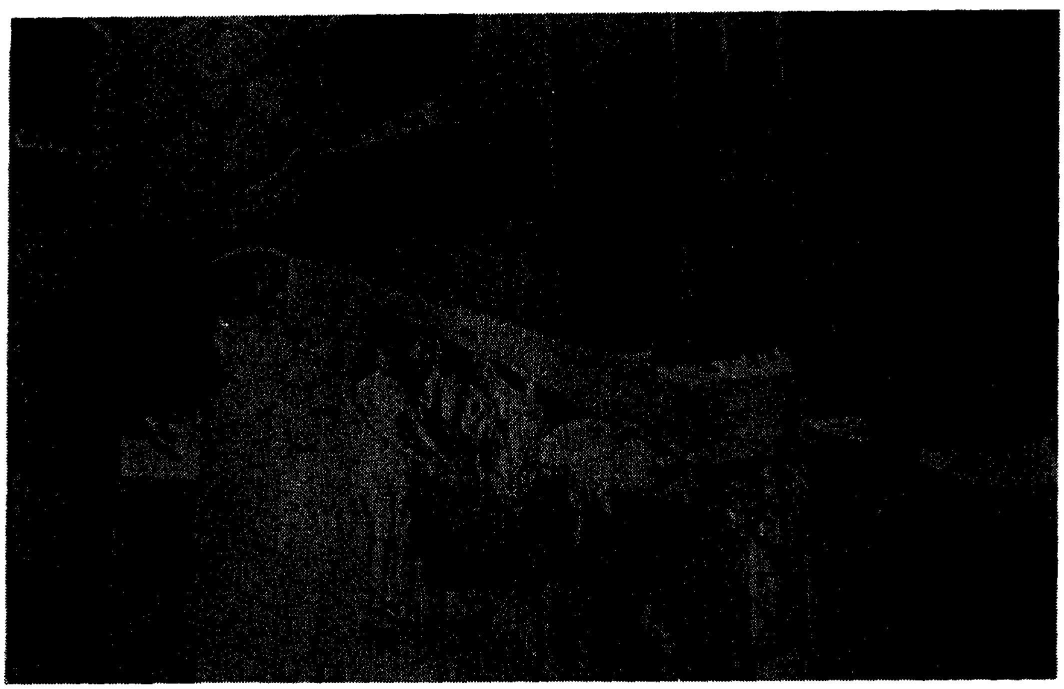

Plate 11 - Interior of agricultural unit of O'Neill type Space colonies. Since each unit is isolated from the colony and its fellows, the conditions in each can be varied to provide the optimum growth, and each may be sealed off and sterilized in case of an outbreak of some pestilence. The vegetation in the colonies serves not only as a food source, but also to remove the carbon dioxide exhaled by the animals and people, and to purify the air of any potentially toxic gasses that might accidentally appear.

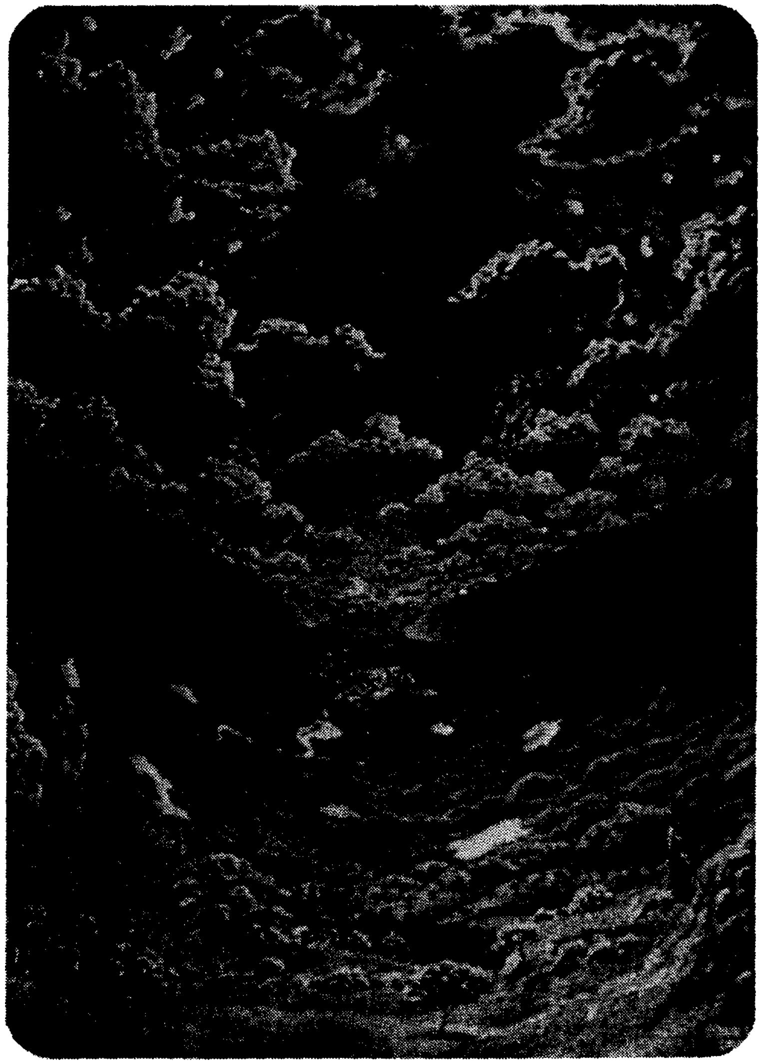

Plate 10 • Interior of Island Four during eclipse of the Sun by the Earth. The cylinder is so large that it has its own weather with clouds, breezes, and even showers. The emphasis in the landscaping is on open parkland, green with plant life, with open bodies of water, and no noxious organisms. The homes are clustered together in compact yet private villages, cities being avoided.

Acknowledgements

The illustrations in this paper were provided by the L-5 Society of 1620 North Park Avenue, Tucson, Arizona 85719, an organization which was formed in September, 1975, with the purpose of promoting Space development in governmental, industrial and private sectors. Its principal aim is to disband itself in the first Space colony at L-5, the Lagrangian libration region number five, in the same orbit as the Moon, but following 60 degrees behind it.

References

GLASER, P.E.: Development of the Satellite Solar Power Station, Space Manufacturing Facilities: Proceedings of the Princeton/AIAA/NASA Conference, May 7-9, 1975, Ed. Grey, J., American Institute of Aeronautics and Astronautics, 115-128, 1977.

HENSON, H.K. and HENSON, CM.: Closed Ecosystems of High Agricultural Yield. Space Manufacturing Facilities: Proceedings of the Princeton, etc. Conference, 1975, AIAA, 105-114, 1977.

JOHNSON, R.D. and HOLBROW, C. (Eds.): Space Settlements-a Design Study. NASA SP-413, 113-124, 1977.

LYNDON B. JOHNSON SPACE CENTER: Space Shuttle. NASA SP-407, 1976.

O'NEILL, G.K.: The Colonization of Space. Physics Today, 32-40, September, 1974.

O'NEILL, G.K.: Space Colonization and Energy Supply to Earth; Testimony before the Sub-committee on Space Science and Applications of the Committee on Science and Technology, U.S. House of Representatives, July 23, 1975.

O'NEILL, G.K.: "Is the Surface of a Planet Really the Right Place for an Expanding Technological Civilization?" Space Colonies, Penguin Books, 22-30, 1977.

PACE, N.: Weightlessness: a Matter of Gravity. NEJM, 297, 32-37, 1977.

PATERSON, E.T.: Space Settlements-the Medical Perspective. J. British Interplanetary Society, October, 1981.

STINE, C.H.: The Third Industrial Revolution. G.P. Putnam and Sons, New York, 197.5.