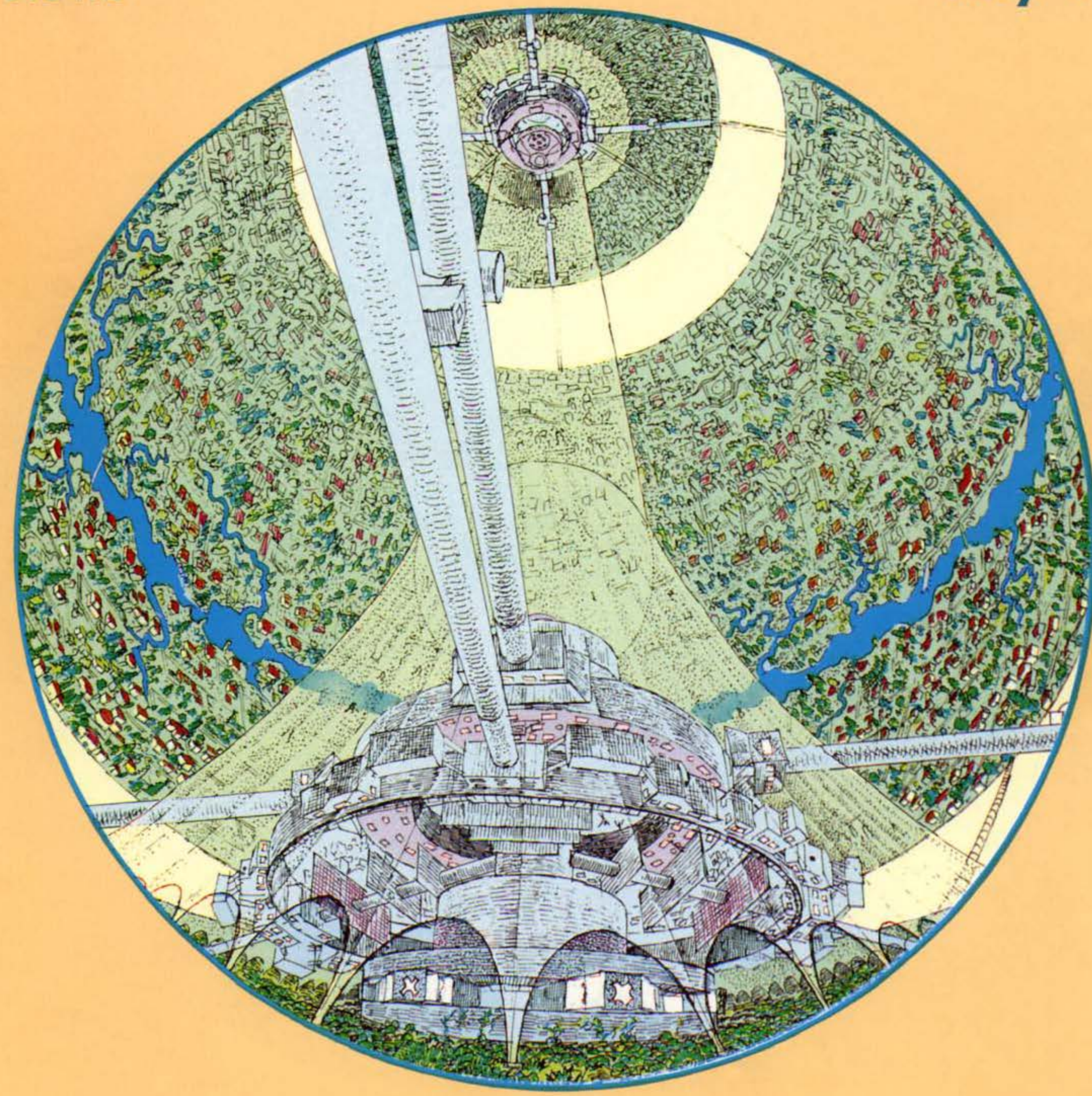
Space Settlement

LATEST DEVELOPMENTS IN SPACE INDUSTRIALIZATION, SATELLITE SOLAR POWER, AND SPACE HABITATS

L-5 News

May 1977



Space Settlement

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Front cover:
BERNAL SPHERE INTERIOR.

A series of concentric buildings and galleries at each end are constructed around the axis of the Bernal Sphere. This fish-eye view is from the edge of the zero-gravity conical safety net which encloses the structures. The foreground area between the windows of the building and the poles that secure the net is wild and overgrown with vegetation. This area is too steep for residences and is not as fully shielded from cosmic rays. The spokes are structural supports with elevators inside (Drawing by Don E. Davis, mechanical color separations by Jonathon Nix).

letters

I would like to comment on Jim Oberg's questions regarding the Moon, in the March *L-5 News.*

He raised the question of environmental effects of the use of a lunar mass-driver, both on the Moon itself and on the regions of space available for use by spacecraft.

Regarding the latter, recent work has made it clear that the lunar-launched mass stream will be very well-defined in its trajectory characteristics, and will be predicted well in advance. Thus, it need pose no more of a hazard to navigation than any other type of space traffic.

Regarding the former, Oberg suggests that the mass-driver could affect the lunar rotation. The mass-driver, in operational use, will exert a force of some 100,000 newtons parallel to the lunar surface, equivalent to a weight of ten tons at the Earth's surface, or of 36,000 tons at the distance of the Moon.

The lunar rotation keeps one side turned towards the Earth. This is not the result of any delicate balance, upset by small continuous forces. Instead, it follows from the distribution of mass within the Moon (to be technical, the ratio of its moments of inertia). It is an extremely stable arrangement. The Moon itself has mass approximately 7.3×10^{19} tons, which is, as mentioned, not completely even in its distribution. The unevennesses amount to far more than 36,000 tons, and one result is that the Moon oscillates slightly around this stable equilibrium. These are the so-called physical librations. Yet these oscillations or librations amount to only some two minutes of arc in the lunar rotation, which is so small that it was not even detected till 1838. So I can only suggest that trying to influence the lunar rotation by means of a mass-driver, is like trying to cause an iceberg to topple over by blowing on it.

Oberg also suggests that it might be useful to provide a tenuous lunar atmosphere, so as to facilitate lunar landing, point-to-point transport (as by aircraft), and communication (by means of an ionosphere). The merits of such a proposal are not at all clear.

To begin, the lunar gravity is not all that bad, and in the absence of detailed designs it is difficult to say whether the saving in propellant mass would not be offset through the extra mass required for an aeroshell or heat shield, parachutes, and the like. Compare (for example) the Viking lander to the rather similar Surveyor lunar lander of a decade earlier.

Regarding lunar aircraft in the Oberg atmosphere, one may begin by asking what would happen if the Earth had no atmosphere. As it is, a 747 or other long-range jet takes off with something like half its gross weight consisting of fuel. If there were no atmospheric oxygen, it would also need to carry that, too. Its mass-ratio would then be very much like that of a rocket, and a simple calculation shows that if equipped with rocket engines, it could attain nearly enough velocity for a transcontinental flight just by flying like an ICBM. So once again it is not clear whether the Oberg atmosphere would make travel by lunar aircraft all that much easier than travel by rocket.

Finally, Bob Farquhar of NASA-Goddard has done a great deal of very fine work on lunar libration-point communications satellites. These would provide much more reliable and efficient communication than any lunar ionosphere, for use by an extensive lunar community. Thus, they would be the lunar counterparts of our Earthside communications satellites, which of course have already replaced most forms of ionospheric communication over the Earth.

I note also that Oberg wonders whether it would still be possible to use a mass-driver in the presence of his atmosphere. The answer is very simple: No.

T.A. Heppenheimer
Heidelberg, Germany

Thinking of the food supply problems that have been discussed in the *L-5 News* recently, I might have a workable suggestion as far as meat goes, We are raising quail (sort of a hobby . . .). The breed we have (Coturnix: Pharoh D-1) lays one egg a day, reaches "laying age" in six weeks and full size in eight weeks. They are as prolific as bunnies-and tastier than chicken. I will keep record and weights, etc., and let you know how they size up as a food source.

I was also wondering what sources are under consideration on L-5 (for L-5?). Sometimes it would seem that a lot of food sources are being overlooked because they are non-western food sources. There are a lot of things that are edible (and highly palatable), that are often overlooked because they are unknown. Over 30% of the world's population delights in sweet manioc (casaba), a tuber that is grown in the tropical regions. I don't know what kind of potential it has as an L-5 crop, but I have the idea that most of the researchers haven't looked into it. (My opinionated opinion!) Has anyone looked into the possibility of raising fish? I know of one variety, Tilapia, that does not require moving water and lives on algae. I also understand that it breeds fairly well.

Shirley Ann Varughese
South Somerville,
New Jersey

(More letters on page 24)

Developing Space Policy

The international implications of space development by nations or corporate entities are extensive. Can a policy be designed for organization, law, and security in space?

Jack D. Salmon

(Prepared for presentation at the XVIII Annual Convention of the International Studies Association, March 16-20, 1977)

When one surveys the alternative technologies and strategies usually recommended for energy policy it becomes quite clear that the industrialized nations perceive the situation as indeed desperate. The most obviously desperate "solution" is that of aggressive war, hinted at in 1974 by American officials claiming that the enormous consumption of the industrialized societies somehow creates in them a "right" to continue their consumption pattern and therefore a corresponding "duty" of resource holders to supply the needed materials. This "duty" would of course be enforced by military means if needed. Given that even the Arabs have limited supplies of petroleum, and the possibilities of major war inherent in such actions, this is at best a short-term, politically expensive and exceedingly dangerous solution.

Slightly lower on the desperation scale come such proposals as that of bulldozing and boiling major portions of several American states in order to secure energy from oil shale, overlooking both the magnitude of environmental problems created and the probability that the herculean efforts required would consume nearly as much energy as they would produce. Massive coal mining may be nearly as costly, although more likely to produce useful output. Nuclear power has failed miserably of its early promises of cheap, clean and limitless power, and even its proponents speak of "Faustian bargains." Fusion power, once devoutly sought, seems increasingly to resemble fission power: it probably will produce radioactive waste products in significant quantity, and massive thermal pollution. It would also contribute to the continued rise of a politically powerful technocratic elite dominating centralized energy systems (see bibliography: Lovins).

Recognition of the great biological and social dangers of the "normal" solutions proposed has produced a whole school of "scarcity politics." Its members range from the relatively sanguine Schumacher and Lovins to the pessimistic Heilbroner or Ophuls, and the truly frightening visions of the Paddocks or Hardin (for all references, see bibliography). Their prescriptions frequently involve draconian population control and reduction programs, drastic reorientation of social and political values, and very different types of technology. It is true that, as Lovins claims, the actions needed to accomplish "alternative technology" solutions are no more drastic than those required to continue policies of "growth as usual" but the latter policies have the great advantage of falling within what Pirages and Ehrlich have called the "dominant social paradigm." Kuhn and others have amply illustrated our intellectual and social preferences for change by incremental processes; the scarcity school is proposing something far more sweeping.

Yet we face a tremendously important quandary: if the developed nations are to maintain the lifestyles to which they have become accustomed, and even more if there is to be any possibility at all for third, fourth, and fifth world nations to realize human dignity, we must not only maintain but enormously increase our energy production. Energy supplies are seen by industrial societies as necessary to maintain a rather plush lifestyle; to the majority of the world's nations, access to vast supplies of relatively inexpensive energy is essential if there is to be any possibility of escaping the developmental dungeon in which they now languish.

Social and political preference is then strong, even extreme, in favor of in increasing the availability of energy. But ecology teaches us that it is not possible to do only one thing: increased energy use will perturb the total environment, at possibly disasterous cost. At some point not too far in the future (at present rates of growth, perhaps little more than a century), continued energy use based on fossil and nuclear fuels will bring the planet up against the ultimate barrier: the ineluctable working of the Second Law of Thermodynamics and consequent planetary thermal balance changes, with possible consequences including extinction of the human species. There is a simple, basic fact: a finite planet cannot contain infinite growth. At some point, growth must stop; the only significant choices open to us are those of when and under what conditions growth will stop.

It is not then possible to solve the problems of the human condition on our planet by means of applying conventional, or even somewhat unconventional, technological solutions. Selected techniques such as geothermal, ocean thermal, wind and solar power can certainly help and should be pursued, but they cannot *solve* the world energy problem. If the developing nations are to continue population growth and aspire to improved material standards of living, most alternate energy sources can't even help very much. The demand will simply be too big, and environmental costs may wash out much of the nominal gains.

But technological optimism-the belief that humanity will somehow find a technological solution to virtually all problems, if it is really needed-possesses tremendous social inertia; it won't stop being part of our dominant social paradigm because of mathematical impossibility. And it's even possible, to the amazement and perhaps the dismay of at least some members of the scarcity school, that there is a feasible technological solution which has a relatively short lead time (perhaps twenty years), promises not only vast supplies of energy but other valuable side benefits such as less environmental damage, and has a high content of adventure and glamour.

The High Frontier

The possible solution is an outgrowth of the technology and science of the last decade; prior to about 1970 it would have been science fiction, or at best speculative science. Technology developed for the Apollo Moon voyages, coupled with geological findings on the Moon and recent spectroscopic analyses of some asteroids, provided the needed technological advances and data base. Professor G.K. O'Neill of Princeton in 1969-70 assigned his freshman physics seminar a problem: "Is a planetary surface the right place for an expanding technological civilization?" From the initial surprising findings flowed other questions and supporting results, leading to what is now a well-developed conceptual design for development of human civilizations in space. One of the major activities of these industrial societies would be construction of very large solar power stations to orbit the Earth and supply electricity to the planet by means of a microwave relay. This energy would be provided by our neighborhood fusion reactor, the Sun, in inexhaustible quantities for millions of years into the future, and would do so at minimal environmental and thermal cost to the planet. This additional energy would permit the developing nations to improve their status and the developed nations to maintain theirs. If the observed pattern of declining population growth in industrial societies holds, the population growth problem should eventually and "naturally" be reduced somewhat. There is even the possibility, if the concept proves out in all aspects, that a significant proportion of the human population could move completely off the planet, thus relieving the world of still more environmental and energy burdens.

This concept is a technological optimist solution to *all* the conventional scarcity problems. By importing energy to the Earth at very low material, environmental and thermal cost the "limits to growth" barriers are pushed back considerably. This buys time to accomplish other requirements if needed Further, the possibility of less stressful and more rapid industrialization of the developing countries, coupled with the possible longer-term migration of significant numbers of people to off-planet locations, may greatly aid in solving the problems of population growth and world social inequality. It is even arguably possible that peace would break out on Earth, since incentives to covet one's neighbor or one's neighbor's resources would seem to be less, while the adventures of the high frontier would absorb national energies. Should apocalyptic war happen, parts of the race might survive in space and begin again.

Problems on the High Frontier

There is now a growing literature of technical and economic analysis of the concept, most supporting its feasibility. R&D programs are underway in both government and private agencies, a citizen's lobby exists, international agencies (including the UN) are taking interest -- for a concept which first came to public notice only four years ago, a very respectable record. But there has been little attention paid to problems of international politics, political or organizational dynamics, and socio-political consequences in general. Technological solutions are useless if society cannot provide the support needed; if the costs are too high, that support neither will nor should be forthcoming (Ford Foundation, ch. 1; Loving).

> *"Space industrialization will probably be adopted, if at all, primarily because of the energy component of the system."*

Among the necessary elements of support for space industrialization are several factors directly related to international politics. This article will offer a preliminary examination of three such factors; international law, international organization, and national security policies.

National Security implications of Space Industrialization

One reason the U.S. is currently short of oil is that for many years a system of tariffs and import quotas kept importation of foreign oil to a minimum, encouraging consumption of oil produced from domestic wells. This policy, which someone has called "drain America first," was justified on the grounds that development of domestic energy sources would make the U.S. independent of foreign sources in time of war. "Project Independence" has been explicitly justified on the same grounds. Additional examples of national concern over the security of energy sources could easily be cited from Japan, France, the United Kingdom, and others. But as the American example shows, we need not assume that policies urged on the grounds of national security necessarily help that cause.

Space industrialization will probably be adopted, if at all, primarily because of the energy component of the system. For economic and social reasons, provision of abundant and low-cost energy energy is of very high priority; for national security reasons, obtaining the energy is a high priority but carries with it the requirement that vital energy sources be protected against destruction or capture. Analyses of the probability that American troops could capture, hold and produce Arab oil fields under hostile action suggested that the bet was rather poor; little more has been heard of the idea. Might solar power satellites (SPS) have similar status?

There are a number of components in the complete system, all essential to successful operation and growth: Earth-based launch and microwave reception installations; the mining and mass-launcher facilities on the Moon; the industrial colony; the SPS itself. All are vulnerable to sabotage, but this is true of any major installation and would presumably be dealt with by normal anti-sabotage methods. There is no obvious reason why sabotage would be more successful here than in any other power system.

Direct attack on the lunar facilities or the colonies would, if mounted from Earth, have a long lag-time due to the distances involved. ABM systems could probably be designed to work under the favorable conditions of vacuum and long warning times; the availability of vacuum and massive electrical power suggests the possibility of laser-based defenses, already under study for use in the more troublesome atmospheric environment. Direct attack on the Earth launch facilities or microwave reception system do not seem in principle any different from attacks on existing power plants and distribution centers: there is no known guaranteed defense in either case, only the general deterrent posture for the superpowers or the conventional defenses available to all nations.

The weakest point is the SPS itself. The SPS and its ground antenna are the only system elements which, if destroyed, would cause immediate loss of energy. Destruction of the other components -- industrial colony, Earth and lunar launch facilities -- would have only delayed effects. All SPS designs are large and relatively fragile targets, close to Earth (approximately 22,000 miles or less), and in fixed orbits. They appear to be relatively easy targets, and their destruction would have large and immediate effects on national defense and economic systems. This makes them high value targets of the type to which an enemy would devote enough of his striking force that defense would be very difficult, and successful defense unlikely.

But destruction of an SPS would be

a major, unambiguous act of war, and presumably would not occur unless core national interests had become involved. To the extent that deterrence works, SPSs should be protected; if deterrence fails, SPSs are simply another item on a long list of hard-to-defend targets. Major nuclear or fossil-fueled generating plants are also vulnerable, although more numerous and less significant as individual targets.

The best, and perhaps the only effective, defense for SPSs may be similar to the defense currently used by the U.S. and the U.S.S.R. for their cities and industries: a mutual vulnerability so naked that each side holds the other's cities as hostages for good behavior. Alternatively, to build upon the functionalist argument, an SPS system which is internationalized and produces power for several nations may thereby become a common good immune to rational destruction. I will return to this point later.

But national security policies must deal with many situations short of war: diplomatic pressure or economic rewards and punishments are normal parts of international relations. Use of "the oil weapon" by some members of OPEC has proven sufficient to alter the foreign policies, or affect particular actions, of a number of nations. It is this fact, more than fear of a cut-off in time of actual war, which gives great impetus to the attempts by a number of nations to reduce their dependence on foreign energy supplies.

An SPS system under national control would serve very well as a peacetime energy supplier, quite beyond the influence of any other nation. The Sun cannot be "turned off," there is no monopoly on space solar power by one or a few nations due to a peculiar concentration of the resource in a few areas; tankers cannot be harrassed or shipping lanes closed; the price cannot be affected by foreign action. Because its input is from a self-renewing source of (for practical purposes) infinite capacity, investment in this option is different from strategies based on exploitation of fossil resources, which would become increasingly expensive and increasingly limited over time. Because the system output is electricity, an energy form which could be used to synthesize other energy forms, such as hydrogen, the SPS system could be a fundamental building block in a varied and quite "independent" energy system.

Although there is clearly need for more detailed study, a first pass national security evaluation suggests that the space industrialization/SPS system has a very favorable potential. If it is possible to design an internationalized SPS in such a way that it cannot be an effective economic weapon and becomes less significant or attractive as a target, we can have the best of both worlds.

An international public policy favoring an internationalized SPS system requires creation of a suitable legal and organizational matrix.

A Legal Regime for Space

Over a period of several centuries there developed a net of national and international law to govern the activities of both states and private individuals on and in the sea. Because of the technological limitations which existed until quite recent times, the legal regime of the sea dealt with the margins of the ocean (territorial waters), a narrow layer at the top of the ocean within which fisheries were conducted, and with rules for navigation and passage on international waters. The sea floor and deep ocean activities in general were rarely important enough to be legally noticed. But recent technological developments, economic pressures, and national security concerns have combined to produce not only interest in but considerable conflict over a restructured and extended law of the sea. In particular, the political and economic demands of the poorer nations for a share of the oceans' wealth have been resisted by the wealthier nations who possess the technology necessary to exploit the ocean and gather its wealth.

"Space law is still a rather new field with few precedents, vested interests or entangling rules."

Space law has a similar, if shorter, history (Lay and Taubenfeld, ch. 3). It has grown rapidly but incrementally, following technological feats which aroused a need for some legal integument, and has roots in several areas: arms control and national security, desire to advance international cooperation (Kash), economic needs, political rivalry, and even civil damage claims (who is responsible if a chunk of French satellite falls on Cousin Herman in Chicago?). It seems reasonable to assume that serious consideration of space colonization will arouse the same type of questions as have arisen since technology made it possible to exploit ocean resources more fully. The outcome of law of the sea negotiations may thus be quite significant for space law as well.

However, the differences between sea law and space law may be as significant as the similarities. In particular, space law is still a rather new field with few precedents, vested interests or entangling rules (Finch; Lay and Taubenfeld). Such principles and practices as do exist are quite broad and generally enabling as much as restricting. This adolescent state may benefit space colonization: if there can be described soon an appropriate, architectonic model to organize and guide development, decisions may be made and programs established in the near future, and with some confidence.

The complex and interdependent nature of large-scale space industrialization makes it desirable that our conceptual models deal with whole systems. A legal equivalent of the systems design method much used in NASA's engineering development may be appropriate, in which one attempts to construct an integrated model of all relevant systems and then optimize performance of the total system rather than maximize the performance of a particular part. This of course requires that social, political and economic factors be part of the analysis, integrated with technological designs. Although this would be one of the largest projects of social analysis ever proposed, it is not in principle impossible and is in fact a type of world order model (Falk; Mendlovitz). NASA has stressed the additional values produced by space program "spinoffs" into the civilian economy, such as biomedical devices, ceramics and systems engineering; a social science project of this magnitude might well prove quite valuable for its secondary social and methodological results as well as for its primary purpose. The study might show insuperable difficulties and avoid diversion of vast resources into a doomed program; if the results are promising, problem areas and solutions would have been illuminated and the project both improved and speeded (Bobrow).

The legal profession is probably the most advanced non-technological profession in space matters. Several international treaties, both bi- and multi-lateral, already cover a number of specific topics. National and international legal conferences meet frequently, the American Bar Association has a Committee on Aerospace Law, there is a legal subcommittee of the UN Committee on the Peaceful Uses of Outer Space, and legal panels have been prominent features in more technically-oriented conferences (e.g., the International Astronautical Federation).

Who owns resources in space? Who can own them? Under what conditions? How may they be used? How are economic costs and benefits to be apportioned? These questions must be dealt with in international public policy for space, as they are now being threshed out in maritime law.

Our chief current source of space law is the 1967 "Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial

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Arthur Kantrowitz proposes

A Science Court

An idea that has been around for a while, and is now gaining widespread support, the science court is discussed in depth by Dr. Kantrowitz, its originator.

L-5 INTERVIEW by Eric Drexler

Dr. Arthur Kantrowitz, a member of the L-5 Society, is chairman of Avco Everett Research Laboratory and senior vice-president of Avco Corporation. His research work has included physical gas dynamics, magneto-hydrodynamics power, high power lasers, cardiac assist devices, strategic technology, and social control of technology.

Drexler: What purpose would a science court serve?

Kantrowitz: The science court is a procedure intended to produce a statement of the scientific facts when these facts are necessary for the making of public policy. To a great extent it has been discussed in terms of problems: the problems of our environment, the problems of nuclear power, and so on. However, I think that as far as people who are interested in large-scale space programs are concerned, it should be regarded as a procedure which might have some utility in assessing the facts about the benefits and the costs of, for example, a space industrialization program. It might help change a situation in which many people will reject these opportunities without having examined the technology in sufficient detail to find out "what is wrong with it." It is on the difficulty of starting anything new, posed by the tactic of ridicule (which has always been the tactic against anything really new and important), that it is hoped that the science court procedure could have an impact.

Could you give an example of this?

If, for example, one would ask any of the leading proponents of space industrialization to defend his claims against a tough cross-examiner, in the presence of scientific judges who are neutral toward the question, who are not biased against it or in favor of it, and if, for example, someone like Peter Glaser would claim that he could produce electrical energy from a solar satellite for so much a kilowatt-hour, he could be challenged to substantiate his claim in detail. The question would not be whether his claim sounds good, but where did this number come from, and where did that calculation come from, and what extrapolations are involved, and so on. I think that this would be a service to the space industrialization program.

How would the court operate?

I would say that the key rules in this system are that you deal with facts only, that we don't make any political or value judgments, or make any recommendations of that sort, that you separate advocates from judges, and that you do the whole thing in public. Those are the only rules that everybody seems to be agreed upon. The procedure was worked out by a task force of the presidential advisory groups and is reported in more detail in the August 20 issue of *Science* magazine.

A factual statement might be that a ten gigawatt satellite solar power station would cost a certain amount to set up. We won't say whether such things are a good idea or not. We won't get into the question of whether or not conserving energy is good for your soul, but only whether you can produce energy this way, or conceivably how much energy you could save by certain conservation measures.

The procedure would start after the case managers had been chosen on both sides. They would screen suggested judges for prejudice and, if both sides accepted them as unprejudiced, and if both sides accepted the details of the procedure, then it could go forward. We would try to see if they could be mediated to get agreement on statements of fact, but if not then each side would be asked to substantiate their claims in detail and would be cross-examined. If finally no agreement could be made, then the judges would write a statement of what they thought the facts were on that particular question.

How are equivalent decisions made today? What would the science court replace?

Well, there certainly is a process today. How it goes, in dealing with complicated technical issues, is quite variable. For example, one way is by a referendum such as recently was held in California on nuclear energy, in which the public votes on whether nuclear power shall go forward. I think mostly it votes from confusion. Few people today have spent the enormous amount of time that is necessary to understand the technology of nuclear power. Nevertheless, everybody votes about it, despite an enormous uncertainty about what the facts are. That way has the advantage that the whole thing is done in the open. Frequently it is *not* done in the open. Decisions about technical matters are frequently made by political figures who sometimes use the confusion about the facts to make their lives more comfortable, to conceal value judgments that they'd rather not discuss in the open, and to avoid the uncomfortable need to exercise real leadership. If, for example, our new president would undertake to lead the country into an adventurous space program, I think he would go down in history as a very great leader. However, if you consider what he would have to undertake to do this, you realize that it would be almost impossible. To convert a scientific and engineering community that has become used to extreme conservatism back to an adventurous policy would be almost impossible for him. However, if, for example, the satellite solar power station had gone through such a procedure and the facts that were delivered by a credible procedure were that this is a practical, cost effective, environmentally acceptable way of getting all the power we might need, then indeed it would make life much easier for a political leader who wanted to be courageous to make the decision, "let's go this adventurous way."

The science court has been rather controversial. What have some of the objections been?

The objections that have been raised to the science court divide into several classes. First, there are those who say that you can't do it because you cannot separate facts from values or political or moral judgments, that wherever there is any uncertainty people will inevitably be biased in their judgment of the technical uncertainty by the way they want the answer to come out. I would respond to that class of criticism by saying that the separation of facts from values is fundamental to all science, that you can only do science on those observations of nature on which all people can agree. People will not agree so generally on value considerations. I think that one of the things that has gone wrong that leads to the pessimism and conservatism that we have today is the intrusion of value-laden arguments into what are purportedly factual discussions. How I would respond to people who say that you can't do it is that it is high time that we tried as best we can to separate out the factual questions, to deal with them as best we can, and to perfect our methods of eliminating prejudice. I think that if you set out consciously to separate facts from values you will do better than is done today, when no attempt is made to make that separation, when it is not considered unethical to introduce your politics in distorting the facts as submitted to the public.

The moral scientist will lie?

The moral scientist will lie, or one could put it as the students at the University of Moscow do. They have the standard description of philosophy that students have developed the world over, that it is like searching for a black cat in a dark room. They also take courses in Marxist philosophy, which they identify as searching for a black cat that isn't there in a dark room. Then they take courses in Marxist-Leninist philosophy, which they have identified as searching for a black cat that isn't there in a dark room and periodically announcing, "I've got it!" That epitomizes to my mind better than anything I know the role of the ideologue in the distortion of facts. The invasion of what purports to be science fact as purveyed by one list of Nobel Prize winners or by another list of Nobel Prize winners opposing them is just the distortion that the students of Moscow University were complaining of. It is the ideologue driven by the pressure of his ideology to find the black cat.

Regarding the objection that you can't find unbiased judges (and that might have some truth in it) I think that if you submit the judges to a screening process, where both sides will accept them as unprejudiced, you'll be better off than when you don't have such a procedure. That is a procedure copied from the law. While nobody could argue that there will be no traces of bias present, it might be an improvement over what we've got, where there are no such protections,

A third criticism is summarized by asking "Who guards the guardians?" The best answer I can make is that this procedure should always be done in public. In fact, it should be done more than in public, one should make an aggressive effort to interest the public in these scientific questions, which are really basic to their understanding of what their future is going to be like, through an effort to capitalize as best as one can on the drama that is inherent in a confrontation between two people where one is stating a fact whose validity is very important to him, he's built his life around it, and another man has his career based on exhibiting how well he can take apart this statement. One can have some confidence that after a procedure like that is over, and after all the blood has been wiped up, that indeed people have been motivated to get all the facts out. I think that the questions that would be dealt with are so important to the future that we should have a procedure that will achieve the credibility that it gets by public exposure. Of course it is true that if such a procedure goes on day after day after day, the public will lose interest in the whole thing to some extent unless it is very cleverly staged, which I don't think it will be. Nevertheless, it should attract more interest than such procedures do now when they are closed to the public completely.

A frequent objection has been that the science court will declare that the Earth is flat. The possibility that a procedure of this sort might reproduce some of the features of medieval and renaissance church courts is really based on a misapprehension. Those courts attempted to impose upon science the values of the medieval church. They had no concern with the separation of scientific fact from religious dogmas, so they were quite a different thing.

A very wise woman who has thought a

(Continued on page 16)

Boeing designers answer questions about Satellite Solar Power

Gordon Woodcock and Ralph Nansen, two men in the forefront of SPS design, tell why satellite solar power is the way to go, and give tentative answers to some environmental questions.

Interview by Norie Huddle, with Carolyn Henson

Ralph Nansen is the Satellite Solar Power program manager for Boeing Aerospace Company in Seattle, and Gordon Woodcock is the SSPS study manager. They were interviewed by Carolyn and Norie at the American Institute of Aeronautics and Astronautics annual meeting in Washington, D.C.

Carolyn: A lot of people question why it is necessary to put solar power stations out in space when you can collect solar energy here on Earth. Could you comment on this? Why would you want to have these in addition to, say, the central towers here on Earth, which I understand that Boeing is working on.

Woodcock: A lot of people are working on the central tower concept, including Boeing. It's a little closer in technology, of course. There are really two main reasons for going into space. The first has to do with the basic difficulty in the utilization of solar energy: you have to spread out over such a large area to collect the amount you need. In space you need about one-sixth of the area that you do on the ground, in terms of the actual collectors. First, because the sunlight is more intense because there is no atmosphere; second, the shadow periods, although they do exist, are very brief and represent less than one percent outage factor; third, more subtle but very important, is that we can point our collectors at the Sun, whereas on the Earth you have to live with whatever direction the ground happens to be pointing. The Sun goes across the sky and you have to track it with all these mirrors.

Carolyn: So tracking presents a serious problem with Earth solar power?

Woodcock: It does, but certainly a solvable problem. It has been solved.

Carolyn: But it costs a lot.

Woodcock: It costs some the second reason for going into space, again related to the large areas required by collectors, is that the design loads are so close to zero that we're having a little trouble defining just what they are. It's almost certain to be true that the actual design loads on one of these structures will be imposed by the assembly process rather than by the operational process.

Carolyn: You don't have to worry about windstorms or birds sitting on collectors or things like that?

Woodcock: If all we had to worry about was the satellite itself, that advantage would be enormous. But we do have to have a ground receiving station, and, interestingly, by the estimates we have worked out so far (we haven't worked on the ground receiving station very hard), ninety-five percent of our total system mass is in the ground and only five percent is satellite. That's because the ground receiving station does have to withstand gravity and wind loads.

Carolyn: What is the ratio of the area taken up by a ground receiving station versus an equivalent-sized solar power station on Earth?

Woodcock: The rough cuts we've taken of that are ten to one in favor of space-based power. It turns out, interestingly enough, that the total area of the ground receiving station is quite comparable to the total area of a satellite. There is no fundamental reason why this is true, it is more of a coincidence than anything else.

Now, the reason that I say ten to one Instead of six to one is that because of the situation of having to track the Sun across the sky, with a ground solar power plant, something less, I believe, than fifty percent of the land covered actually is collector; the rest is space between collectors. So there is a big difference.

Really, you're putting this in the context of an "either-or" situation, and that's not exactly right. To begin with, ground solar power is closer in technology and, second, it lends itself naturally to intermediate load service. The space system lends itself naturally to base load service and would be considerably less well suited to intermediate load. The two tend, therefore, to be complementary.

Carolyn: Shifting here, what kinds of power costs can people expect from solar space power, what kinds of environmental advantages, and what kind of time frame can we expect to see this happening in, if work proceeded in a reasonable fashion with no delays in funding or anything?

Woodcock: Well, starting from the top, the concept involves the placing of large power stations in a geostationary orbit, which collect solar power and convert it to electricity, beam it to Earth on radio waves, reconvert it to electricity for commercial use on the ground. Each station would be able to produce on the order of 10,000 megawatts of useful power. That is, for example, enough to run New York City. So, a reasonable number of satellites-say, fifty to one hundred, would be enough to run the whole country, if that were necessary. The benefits of the satellite system have to do with its relatively benign environmental impact, which is true of most solar energy schemes. Its ability to run day or night and not be bothered by weather or sunlight, its relatively small consumption of resources to construct the station because of the advantages of construction and collection of solar energy in space, and finally, because there doesn't seem to be any kind of capacity limit that we can find. That is, however much energy you need, you can get it from this source. The only limit we know of is that if energy utilization by man grows indefinitely, eventually you reach a point where you've got a thermal burden problem on the Earth. What I mean is the Earth receives a certain amount of energy from the Sun in a natural manner. In our utilization of all energy sources (except ocean thermal difference and ground solar power), we release additional heat into the environment. If you project the current growth rates for the use of energy for about 150 years, you get to the point where the artificial induction of energy into the Earth's environment -- power consumption -- becomes about one percent of the natural energy source. Somewhere along there you begin to expect some difficulty with climate change. (The Sun's input of energy to the Earth varies a few percent from time to time anyway.) Now, it's probably unlikely that the energy consumption on the surface of the Earth will grow that much for reasons of population limits and other factors. And, interestingly, the satellite form of power, although it does impose a thermal burden because the electric power that is utilized eventually turns to heat after you have used it, has very little waste thermal heat-it is dumped in space, not on the Earth.

As to the costs involved, I don't think we're in a position to make firm quotes. We've made a number of estimates and the range we've published in terms of the cost of electricity in 1975 dollars ranges from about 25 mills per kilowatt hour to about 75, and that's a rough representation of the uncertainty that we presently see. (These are bus bar costs. You'd have to add about 10 or possibly 15 mills to that to get retail costs.) That just about compares with the range of retail costs today. You find that the hydro projects in the Pacific Northwest and other locations, where the capital costs of the facilities have already been written off, run for operating costs of 3 to 4 mills. There the retail rates are around 15. . . I think I pay around 18. Some people in Seattle pay a little less than 15. The other extreme, in the continental U.S., tends to be in the New York City area, where people pay 80 to 90. Now these satellites would behave in one respect like hydro power, because we use the typical accounting scheme of depreciating them over thirty years; there is no reason to think they'd be shut off at the end of thirty years. And after that time, they'd look like hydropower, with an operating cost in the 3 to 5 mill range.

You asked about time. That's a very interesting question. If you take the largest known oil reserves in the world, Saudi Arabia's, and you divide their known reserves by their current production rate, they're going to last forty years at the current production rates. Presumably, most of the other sources will be gone by then. Now nobody knows for sure how much there is yet to be found and there are a bunch of elegant theories with bell-shaped curves and all that sort of thing. By the end of the century, oil will be in short supply, and by the middle of the next century, it will probably, for all practical purposes, be gone, except for feedstocks for certain plastic industries and so forth. The range of scenarios we've looked at for constructing a system of this nature range from: (1) having a full go ahead for the whole system, which would take around twelve to fifteen years. There isn't any indication that there will be any such "go" signal in the near future. (2) A development that goes through some sort of pilot development phase, which most new energy sources do, looks more in the twenty to twenty-five year range. But there aren't any technological barriers preventing us from starting any such program. We don't have to invent a means of doing this or that.

"We're talking about scaling up space operations by something on the order of thousands. And there is no reason why that can't be done. . . "

Norie: What do you see as the major obstacles for getting this program underway?

Woodcock: I can see two. One is the credibility gap. We're talking about scaling up space operations by something on the order of thousands. And there is no reason why that can't be done, but it certainly causes people to be concerned about the feasibility. The truth of the matter is that our space operations today are on a very, very small scale. The annual NASA budget, for example, is just about equal to the annual profit of the world's largest oil company. That is an interesting statistic that most people don't know.

The second problem has to do with the fact that the development cost to bring in this type of solar power is probably higher than for the other kinds to which people have been exposed. Part of this is because we have to virtually create a new industry of space industrialization. The development cost is not high in comparison with the benefits; in fact, when you envision a whole program of this nature, then the cost of electric power derived from this kind of source-assuming you expand it to a useful size, lots of satellites getting lots of power-becomes quite low. If you try to recover all your development costs it raises the cost by a few percent. I would guess, however, that the total investment in this kind of a system would not be larger than it has been for other kinds of high technology new energy. I haven't seen any figures for the total development costs of fusion energy, but I would guess they are comparable. From what I know of the development of nuclear energy as a practical commercial source of energy, I would guess they are comparable. It's very difficult to get a good handle on the nuclear developments because there was a lot spent for weapons and it's hard to determine what the technology transfer is.

Carolyn: I wonder if you could comment on the traffic requirements for ground launched satellites.

Woodcock: One of the things that concerns people about this concept is the fact that the transportation system we've found to be economically practical for this purpose involves the use of a fully reusable rocket system, not ninety percent reusable, like the Shuttle, but completely reusable; about twice the size of the Saturn 5 Moon rocket, operated up to as many as ten launches a day. Now this is a somewhat startling requirement to most people; in the Saturn program we launched at most four vehicles a year. Even the Shuttle will probably fly about every two weeks once it gets into the operational phase. So ten launches a day is kind of mind-boggling to people used to the space business. The vehicle we're talking about is fifteen million pounds fully fueled, so ten liftoffs a day is about 150 million pounds a day, and that's a pretty big number. But if you take any of the large commercial airports and look at the vehicles they launch -- commercial aircraft which weigh on the average about 350,000 pounds -- they typically launch (if you can use that term) about 500 flights a day, and the total there is about 15 million pounds a day. So it's not at all outside our operational experience for flight systems; we just don't launch space vehicles at that rate. But there is no reason why we couldn't. In fact, the fleet size requirements for doing those ten launches a day, because of the potential of fast turn-around, is on the order of a few dozen vehicles.

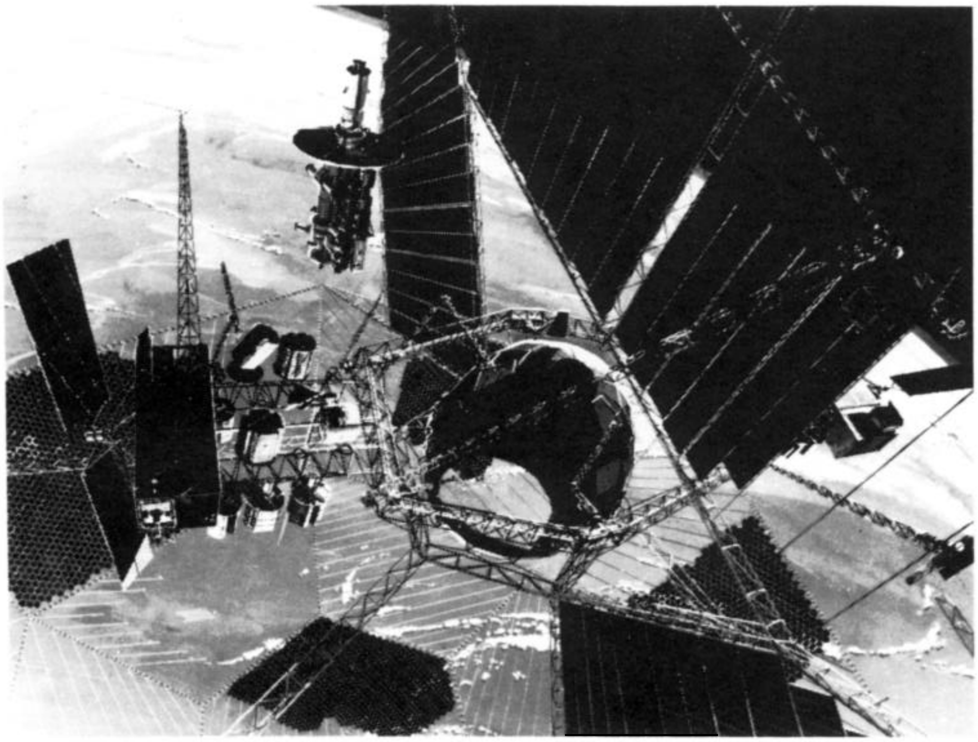
Norie: What position are you at now? Where do you go from here in terms of research?

Woodcock: The program is. you can't even call it a program. Studies have been funded by NASA over the past two or three years. And there were some studies before that -- I think the first started in 1971 or 1972. A typical level of effort would employ six to fifteen people, depending on the size of the study and how long it was conducted. These studies and some key technology demonstrations, particularly in the area of microwave power transmission have convinced quite a number of people at NASA that the thing is technically feasible. The economic factor is still a little too uncertain to determine if it is economically feasible or not. At any rate, this year the study that we are conducting is at slightly under the million dollar level. There is another study that will be of a comparable level, issued from a different NASA center. They'll probably have that one underway in March or April so the level of study and the level of technology activity has gone up. The responsibility of the program may be transferred from NASA to ERDA and, in fact, some of the funding was money from ERDA that came through NASA. Now I might point out that the study was contracted in two phases: the first phase is under contract and the second phase is on option. So the government has not contracted at the present time to spend the whole $975,000, although we expect that they will. The planning that has been discussed for after the current phase of study involves approximately another year of study, part of which would be government in-house-looking over what the contractors do and making their own assessment. At that point, NASA is talking about what they call a "technology-advancement decision," not a decision to do the program, but a decision to fund the development and demonstration of the key elements, particularly in the areas of space construction, energy conversion and power transmission.

The position we expect to find ourselves in at the end of the current study is that it is technically feasible and that it is or is not economically feasible. In the latter case, I suppose we would quit. But the trend of our figures now is in the direction of improvement in economical feasibility, rather than the reverse. So I think we'll probably find ourselves in the position of saying yes, we think it is technically and economically feasible but here are some issues that need to be answered by tests before we can be sure.

Carolyn: What in the work that Boeing is doing is different from the Glaser work?

Woodcock: In terms of the concept, not very much. The concept we're dealing with is basically the Glaser concept. If you read his patent, you find that what he is actually patented is a satellite that would convert sunlight to solar energy by "some means," (not necessarily solar cells) and then transmit it to Earth by microwave power beam. That's basically the concept we're studying. We're trying to find out which of the energy conversion means is the best way to go, where is the best place to construct the thing, and to improve our estimates of mass and cost. I think probably the main contribution we've made is to bring a systems approach to bear on the problem, starting from an economic analysis. There are potential ways of getting the costs in the ball park,



Boeing's SPS Construction Base Concept

particularly space transportation cost. I think until we started working, no one really thought they had an answer to that one.

When you talk about several launches a day of a big, fully reusable vehicle, the costs really can be very low. The fundamental floor under the cost of the transportation is the price of the fuel, just as it is under the flying of an airline or driving an automobile or whatever. Using hydrogen costs appropriate to electrolysis, we find that the cost of putting a pound of payload in low Earth orbit in terms of the cost of buying fuel, is about three dollars.

Carolyn: How does that compare with air freight costs?

Woodcock: Depends on what you're sending and how far. It's a bit higher than domestic air freight but if you're shipping from here to Europe, then I think it's fairly comparable. Now the total cost of flying this vehicle by our current estimates is about five times that because we have to amortize our vehicle, have to operate it, do a little bit of maintenance on it after every flight, and there are a bunch of factors which bring the total cost to three to five times the fuel cost range. We think those estimates may be a little conservative, but we're still talking about dollars per pound that are a tenth or less of that projected for the Shuttle. And so, although possibly conservative, the numbers are a little bit surprising to people who are used to thinking of space transportation costing in the neighborhood of a thousand dollars per pound.

Norie: Have you done any work with environmental impact, or do you consider that premature?

Woodcock: Environmental impact is never premature.

Norie: Good, I'm glad to hear you say that!

Woodcock: We can't find any. I talked a little in my paper today about the land-use situation, but that doesn't seem to be very much of a problem because the land use is comparatively benign. People constructing things on the ground have a tendency to scrape the surface off with a bulldozer first, but that's not necessary in this case.

Norie: How about in terms of effects on the atmosphere?

Woodcock: The atmosphere emissions by the space transportation system would be small by comparison with those currently experienced with the commercial air fleet. We're burning a less polluting fuel, mostly hydrogen. Now we do distribute some of the emissions into the stratosphere which the present commercial air fleet doesn't do, but the principle known causes of stratosphere problems are NO, and fluorocarbons which we don't have. A rocket engine doesn't create NO, because there isn't any nitrogen in the combustion process. In the lower atmosphere, it is believed that it may create some by external combustion; that is, you see that rocket taking off with a great tail of fire. It is the result of the fact that the fuel to oxidize the mixture in the rocket engine is optimized for maximum performance, and there's a little excess fuel. The indications are that by the time you get into the stratosphere, you probably aren't creating any NO, because the secondary combustion appears to go out and the plume is very low pressure and very cool . . . and the things that maximize NO_x formation are high pressure and moderately high temperature. From what I know of the process, it doesn't look as if there will be a significant NO_x problem.

The other problem is the microwave situation. Microwaves are far less hazardous than ionizing radiations, like x-ray machines, or whatever. But there are some effects and some problems. We presently recognize in this country an exposure standard of ten milliwatts per square centimeter, but if you've read the microwave stuff, then you know the Soviets use a standard that is one-thousandth of that. And there is a great deal of controversy in the technical literature over what the standards ought to be and over what the effects are and that sort of thing. The nature of our SPS system is that we believe we could live with the Soviet standard with very minor cost/effect on the system if that were necessary.

There's one thing I like to bring out early on the microwave thing. I think it is probably a very important effect and I think practically everyone looking into this area has missed the significance-at least if they've considered it, they don't write about it. This has to do with the nature of the microwave beam itself. Microwave power comes in two principle forms. There is a continuous wave form, as in the microwave oven or an industrial heating application where you just turn the power on and it's on continuously. The other form is radar, which is pulsed. The exposure or flux limits that are discussed are always the average power level and not the peak. One can illustrate very simply the thing I'm getting at here by imagining that I've got a little box here on the table that's got a little mechanism of some kind inside, and there's an electrical terminal on top and I tell you the average voltage applied to that terminal is six volts. Most people realize six volts is not sufficient for you to feel it. Common lantern batteries are six volts. But if you were to touch that terminal, you would get a hell of a shock, because what I didn't tell you is that the voltage is applied at 6000 volts at one millisecond pulses, once a second.

Norie: Minor details.

Woodcock: Well, in a way, that's the comparison between pulse microwave energy and continuous microwave energy. I think that when we go about setting standards we should make a clear distinction between the kinds of forms that the microwave power can take. As best we can tell, the SPS could live with microwave standards that were stringent enough to cause most other industries a lot of trouble, for example, the television industry. Now there are some uncertainties associated with the propagation of the microwave beam through the ionosphere and through the atmosphere and I know of no way to resolve those completely without doing tests.

Norie: What kinds of problems do you think might arise?

Woodcock: The only kind of problem in the atmosphere is a little bit of scattering from the weather. There's not enough scattering to be a biologic effect but there could be a radio frequency interference with other RF spectrum users and that can be predicted. The guys who are looking at that carefully say that the problem is workable. The other one is the ionosphere and radio waves passing through the ionosphere will heat it a little bit-well, actually, quite a lot. There have been a number of experiments conducted where the ionosphere was intentionally heated by radiowaves. They picked a frequency at which the heating effects were fairly strong and, yes, you can do all kinds of things. You can change the electron density and so forth. I can't find any reason to believe that environmental alteration of the ionosphere has an impact in the ordinary sense. Heating experiments have been conducted down to 5 to 10 megahertz, and can get pretty strong reactions. The effect decreases with the square of the frequency. The frequency we have in mind (for our system) -- the 2450 megahertz frequency -- doesn't interact with the ionosphere very much; it's about 200 times higher than the frequencies that do react strongly.

So even though we're talking about relatively intense beams by Earth standards, by the standards of those heating experiments, we're expecting very little interaction. But if there were more than we expect, or an interaction of a different nature than we expect, the result on the beam could be to scatter it or something like that and make it more difficult to control. There are only two ways of exploring that problem. One way is to conduct some heating tests in the ionosphere at the SPS frequencies, using a large radio astronomy dish like the one at Arecibo, Puerto Rico. The other is to build a full-size SPS and find out what will happen.

Norie: What do you think will happen?

Woodcock: Well, initial Arecibo tests are going on now. The ionosphere physicists keep talking about these experiments at frequencies other than the one we want to use, but I think some of theseexperiments must be conducted at the SPS frequency. There is a second band we could use at 5.8 gigahertz, but it would be a little harder to engineer it. It would have still less ionosphere interaction, but more with weather.

Carolyn: On that higher frequency, what would be the effect of the amount of sunlight intercepted by the rectenna? Wouldn't you have to have the elements closer together?

Woodcock: I'm not sure how much difference it would make. Yes, you would have to have smaller antennae and more of them. There are a whole bunch of effects we haven't explored. The possibility of using this other frequency only came up a week or so ago.

Norie: Have you done anything in conjunction with other aerospace groups? Or with other countries like the Soviet Union or Japan in terms of trying to coordinate some of your research findings and discuss various possibilities of where to go from here in research?

Woodcock: The basic development is taking place primarily in the United States. There is some activity in Germany. The only association has been some interactions at symposia and papers given, with no interaction at all that I know of with the Soviet Union. The primary interface that various companies have in the United States is through NASA. Our contractor reports are attended by other contractors and we have some subcontract association with General Electric and Hughes for some studies and we have had others like Garrett and other selected companies. The primary work is similar to the way we do studies in other areas. But right now there is no activity outside of the U.S. as far as cooperative ventures.

Norie: Do you think this is likely to change?

Woodcock: Very likely, because if we're successful in evolving this total concept it becomes such a big industrial base that it is very doubtful that such involvement would not occur. In the aerospace and related technical fields, people share technology results pretty freely and, further, if the work is contracted by the government as most of this work is, then the reports (unless classified) are mostly in the public domain once they've been provided to the government. This is true since the Freedom of Information Act. NASA practices a very open and free policy of distributing these reports to all of the industry people interested and just about anyone that is interested in them can get them unless they have run out of copies.

Norie: Do you have any suggestions how a group like the L-5 Society can be constructive or effective in this whole development?

Woodcock: I think that although I have some technical disagreements with L-5's proposals for the way to go about this program, they reach effectively a segment of society that we do not-and that is the university people.

Norie: I take it you have had talks in the past on the technological aspects you disagree on?

Woodcock: Oh, yes! (Much laughter from him and Carolyn.)

Carolyn: Actually, I won't take a stand on that, but we do definitely stress

(Continued on page 17)

Hitching a ride into space on the Shuttle, Spacelab will carry palletized experiments exposed to conditions in space. Here's what happens.

In preparation for the Shuttle era, the European Space Agency is developing Spacelab. Spacelab consists of two basic elements-a pressurized module and an unpressurized pallet (or pallet segment) which can be used separately or in combination. In the Second Spacelab Mission, experiments should be planned for a Spacelab configuration consisting of three, four, or five pallet segments. The pressurized module will not be used. The pallet is an unpressurized platform to which instruments such as telescopes and antennas that require direct exposure to space may be mounted. The pallet provides basic services to the instruments, such as power, data distribution and thermal control.

Spacelab is carried to and from orbit by the Space Shuttle. It remains attached to the Orbiter throughout the flight and is controlled from the Orbiter aft flight deck. Figure 1 shows a typical pallet configuration of Spacelab in the Orbiter during its orbital stay.

Major external features of the Spacelab pallet configuration are shown in Figure 1, also. It consists of pallet segments which may be arranged in various ways. A pallet segment is approximately 2.9 meters long, 4 meters wide, and may be independently suspended in the Orbiter payload bay or it may be structurally connected to another pallet segment to form a pallet train. Either the individual pallet segments or the pallet train are attached to the Orbiter with a set of attachment fittings.

A subsystem igloo is mounted to the forward pallet and provides a pressurized volume to accommodate Spacelab subsystems normally mounted in the module. An instrument pointing subsystem (IPS), mounted on the pallet, provides precision pointing for payloads which require greater pointing accuracy and stability than is provided by the Orbiter. Verification flight instrumentation is carried on the Second Spacelab Mission to measure subsystem performance and environments.

The U-shaped pallet segments are covered with floor and side panels with inserts for mounting of light payload equipment. A series of hard points attached to the main structure of a pallet segment is provided for mounting of heavy payload equipment. The pallet, subsystem igloo, aft flight deck equipment, and IPS, are interconnected with power, signal and other utility lines for subsystem and payload equipment. Utility bridges support the subsystem and payload utility lines.

Figure 1 shows Spacelab in an exploded view. The subsystem igloo mounts to the forward pallet. The IPS can be located in any position on the pallet train. Controls and displays are located in the Orbiter aft flight deck at the payload specialists station. In the Second Spacelab Mission, the work station for the payload specialists is the aft flight deck. A maximum of two payload specialists can work simultaneously at the aft flight deck. Optional locations are provided for experiment electronics-pressurized equipment can be located at the aft flight

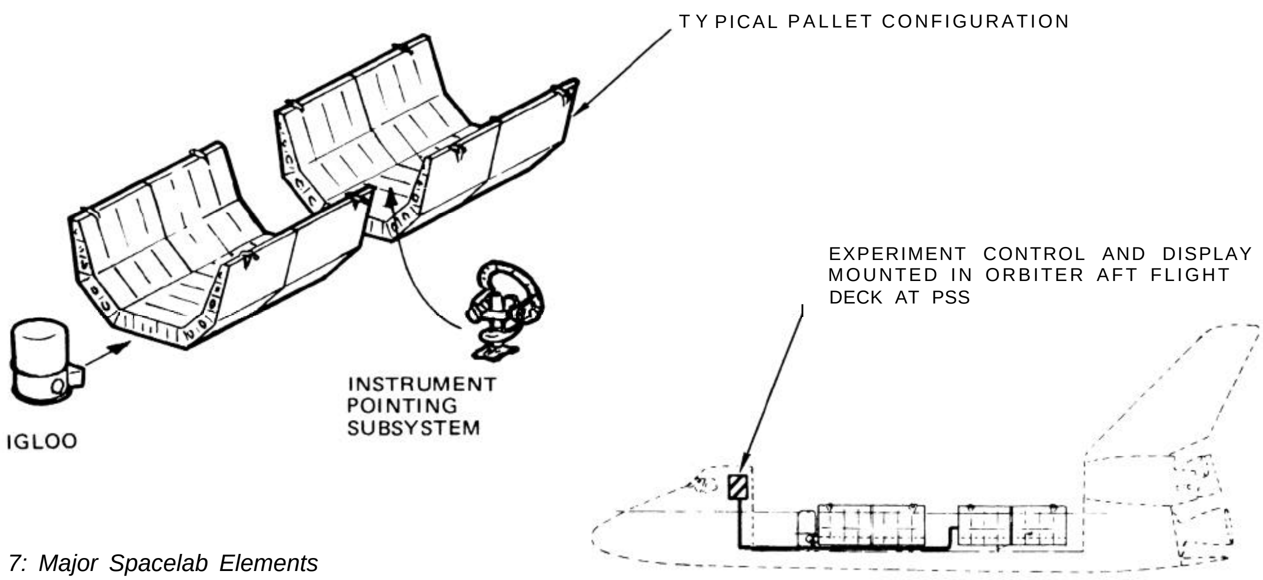


Figure 7: Major Spacelab Elements

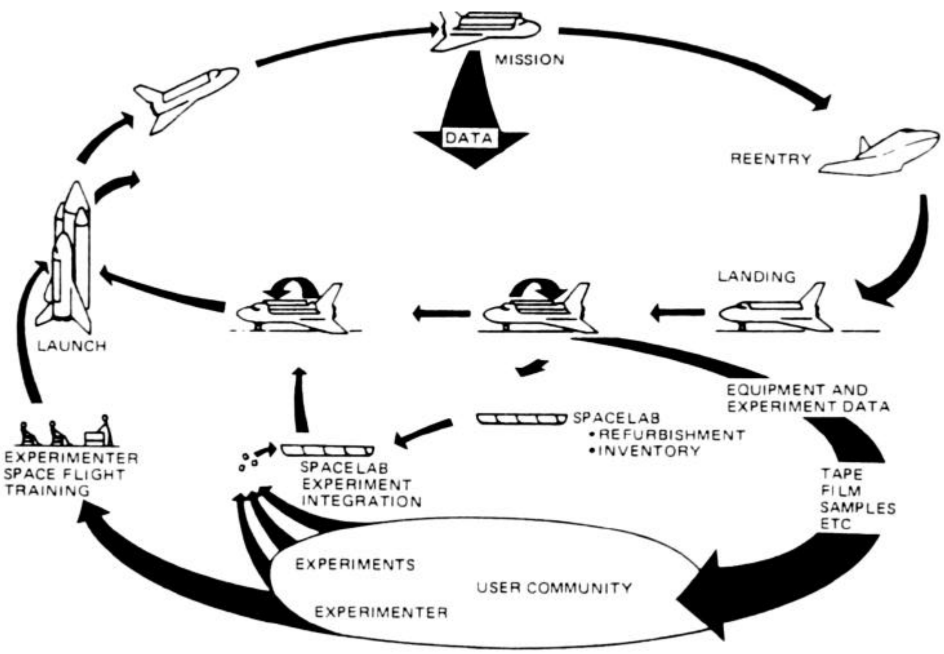


Figure 2: Shuttle-Spacelab Operational Profile

deck if crew access is required. Unpressurized equipment can be exposed to the space environment existing on the pallet or IPS.

In operational use, the experiment will normally be integrated on the pallet and on the IPS and checked out as a complete assembly. Interface connections with payload equipment mounted in the payload specialists station and with bay-mounted equipment will be verified after equipment installation in the Orbiter.

Spacelab includes many services for the users provided by autonomous and Orbiter-dependent subsystems. Modular design of subsystems allows a choice of part of the subsystem equipment by the users so that support for each mission is optimized.

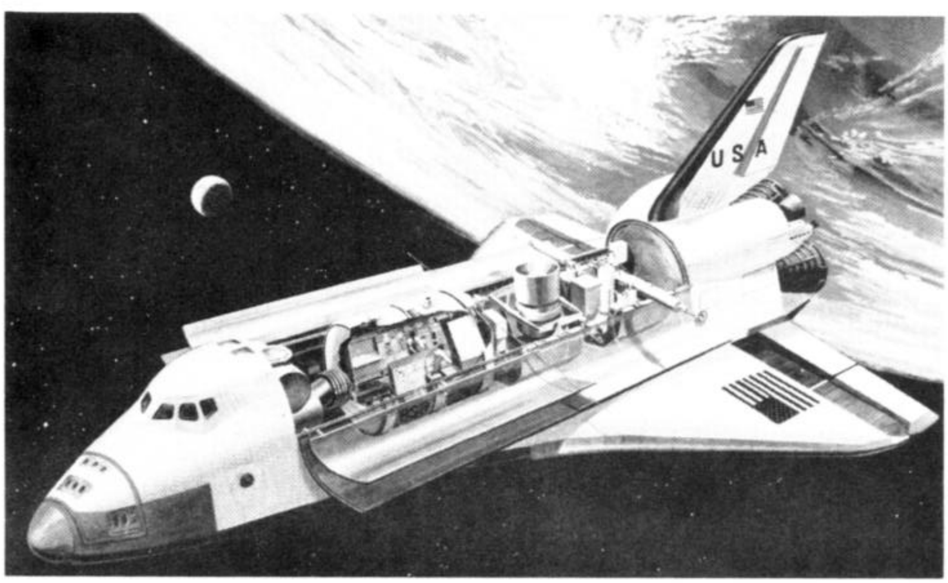
The Spacelab environmental control subsystem (ECS) comprises elements for thermal control of pallet mounted experiment equipment. Oxygen/nitrogen atmosphere at sea level pressure and other crew habitability support such as food, drink, sleep, hygiene, and waste management facilities are provided by the Orbiter.

The electrical power distribution subsystem (EPDS) distributes the basic electric power derived from the Orbiter's fuel cells to Spacelab subsystems and Spacelab payloads.

The command and data management subsystem (CDMS) provides numerous support functions, including data acquisition, formatting, display and recording. Onboard checkout and caution/warning are provided for both subsystems and Spacelab payloads. The CDMS provides three identical computers: one dedicated to data processing of Spacelab payloads, one dedicated to subsystem data processing and one backup computer. The CDMS subsystem is largely independent from the Orbiter subsystems, but is controlled from the payload specialists station located on the Orbiter aft flight deck. Communications with ground facilities, either directly to a Spaceflight Tracking and Data Network (STDN) station or via the Tracking and Data Relay Satellite (TDRS) system, is provided through the Orbiter communication system.

Figure 2 shows typical Spacelab operation cycles. Users' equipment is integrated into Spacelab, which is subsequently installed in the Orbiter. In the launch configuration, the Space Shuttle System consists of the Orbiter, a large external tank which provides propellant to the Orbiter during launch and two solid rocket boosters. This configuration is launched and propelled by the solid rocket boosters and Orbiter main engines.

The solid rocket booster and the external tank are jettisoned before reaching orbital velocity, with orbital velocity being achieved by the orbital maneuvering system. When the desired orbit has been achieved, the Orbiter and Spacelab will be activated and the doors of the Orbiter cargo bay will be opened to expose Spacelab to space for the duration of the on-orbit mission. Before reentry and landing, the Spacelab systems will be deactivated and the doors of the Orbiter cargo bay will be closed. After landing, Spacelab and the Orbiter will be refurbished as required and prepared for the next flight in separate ground operations cycles.



Artist's concept of the Spacelab being carried by the Shuttle. Both the pressurized module with payload specialists and the pallet segments are in place.

L-5 in Congress-Part 2

Dr. Brian O'Leary, in his testimony before the U.S. Senate, proposes that the legislators take a serious look at plans for space industrialization. Part 1, testimony by Dr. T. Stephen Cheston, appeared in the April issue.

Dr. Brian O'Leary, as our readers should remember, is holding the fort at Princeton while Dr. O'Neill is at MIT The folio wing testimony was presented before the Science and Space Subcommittee, Committee on Commerce, Science and Transportation, United States Senate. It was presented by Dean T. Stephen Cheston of Georgetown University on March 17, 1977:

Mr. Chairman and Members of the Committee:

I appreciate the opportunity to express my views on the nation's space program. The opinions and recommendations I will present are attributable, in part, to experience derived from diverse roles I have played with respect to space exploration over the past 16 years -- as a space scientist, astronaut, critic, experimenter on a planetary mission, congressional energy consultant, and, most recently, as a participant in the development of an exciting new concept.

About six years ago, when NASA started development on the Space Shuttle program, I opposed spending $5 to $10 billion on this new space transportation system for a number of reasons. I felt that a commitment to this project would divert NASA's resources from its more fundamental goals of space science and applications and that public apathy would make it difficult for NASA to muster the larger budgets required to simultaneously meet those goals while being able to make full use of the enormous growth in the capacity of Earth-to-orbit transportation offered by the Space Shuttle. At present, the bulk of development funds for the Space Shuttle has been spent and it is currently in the test flight phase. In my opinion, it would be unwise to stop this project under any circumstances that I could imagine.

Nevertheless, some of my predictions appear to have come true. Over the past several years, worthwhile programs have been cut back severely-particularly planetary exploration and advanced studies. Public interest in the space program has not been strong. "Apathy is NASA's Biggest Foe" is the title of an article written by Jonathan Spivak in the February *25. 1977, Wall Street Journal.* "NASA itself," writes Spivak," has failed to advance its own causes effectively." The search for meaningful major goals in space exploration and exploitation will undoubtedly be a major task for your Subcommittee under its new jurisdiction. At present, finding a unified long term objective for full and efficient use of the Space Shuttle seems to be difficult or elusive.

Rather than trying to probe the reasons underlying this perception, I would like to emphasize a major theme which is just beginning to receive serious consideration. The concept I will be discussing is well-matched to the capabilities of the Space Shuttle during the 1980s and 1990s. and would require no major new development in Earth-to-space transportation. If tests prove out existing studies, a large share of the nation's energy problem may be solved by the turn of the century. The implications are potentially enormous.

The concept, first proposed by my Princeton colleague, Gerard K. O'Neill, suggests that the cost of retrieval of resources from the Moon or asteroids is far less than that from the deep gravity well of the Earth. These non-terrestrial materials would be processed in space by continuous solar energy into satellite solar power stations, which would supply to the Earth central station electricity by microwave link from geosynchronous orbit. Economic analyses suggest a favorable cost-benefit ratio for delivered electricity when compared to coal and nuclear power, and the environmental cost appears to be far less.

It may be surprising, at first glance, to find that such a project could be undertaken over the next 10 to 20 years within the constraints of NASA's current annual budget, and that no major new technology development is required. Yet studies continue to show these to be facts. A step-by-step program could be developed which could demonstrate the concept before a final, irrevocable decision involving billions of dollars would be made.

The problem is in having the foresight to take the first critical steps in determining whether such a program is entirely feasible and worthwhile. Unfortunately, the current trend is in the other direction. Satellite solar power and space industrialization are the subjects of recent and ongoing NASA studies, but the few million dollars of funding allocated to these studies has been cut back this year. A Lunar Polar Orbiter resource prospecting mission proposed by NASA is also in jeopardy. And the work which has begun to synthesize these three areas-prospecting, industrial operations in space and satellite solar power-has been funded at the $100,000 level with major unanswered questions being postponed indefinitely from year to year. I believe it reasonable to conclude that a lack of foresight in allocating such a small fraction of the nation's space budget to making a thorough assessment of a potentially vital energy option constitutes a lack of public responsibility.

If this concept appears to be feasible and in the public interest, a decision in favor of its development would have several positive effects: (1) it would solve a large gap in world energy supply during a period of dwindling non-renewable resources, serious threats to the environment and international stress; (2) the achievement of self-sufficiency in space could lead to outlets for human survival and opportunities for exploration; (3) it would help redress balance of payments imbalances and free the United States from dependence on Arab oil; (4) it would provide continuity and challenge for the nation's aerospace talent which contributed so effectively to the achievement of Apollo; and (5) space would again capture the public imagination, tapping what I feel to be a pervasive, though currently latent, constituency. Over the past year, about 5,000 inquiries have been directed to us in Princeton about our work.

To give an example of what could happen as early as the 1980s. I would like to describe a scenario which is the subject of a special symposium, "New Moons: Towing Asteroids into Earth Orbits for Exploration and Exploitation," held at the Eighth Annual Lunar Science Conference in Houston. The scenario starts with the launch from Earth of a long, narrow solar-powered electric motor called the mass driver, a device which is currently under development. Fifty weekly shuttle flights would be required. The motor is assembled in a low Earth orbit, then is launched on a trajectory toward a nearby asteroid. With a rather low expenditure of energy, the motor reaches the asteroid and slowly tugs it into a very high orbit around the Earth. By 1990, this "new moon," weighing several million tons, could begin to be processed into enough satellite solar power stations to meet a significant portion of the nation's increased demand for electricity at the turn of the century. The total cost would be many times less than the several hundred billion dollars of proposed capital expansion of coal and nuclear power plants, even under the most conservation-minded extrapolations in electricity demand.

It is tempting to dismiss these scenarios as speculative fiction. But the studies are indicating the reverse. There are numerous historical analogies to unexpected developments in technology. The Apollo Program, for example, was successfully carried out from its inception in eight years within its planned budget.

(Continued on page 20)

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"The Impact of Space Colonization on World Dynamics," J. Peter Vajk, *Technological Forecasting and Social Change, 1976.*	P14	$ 2.38
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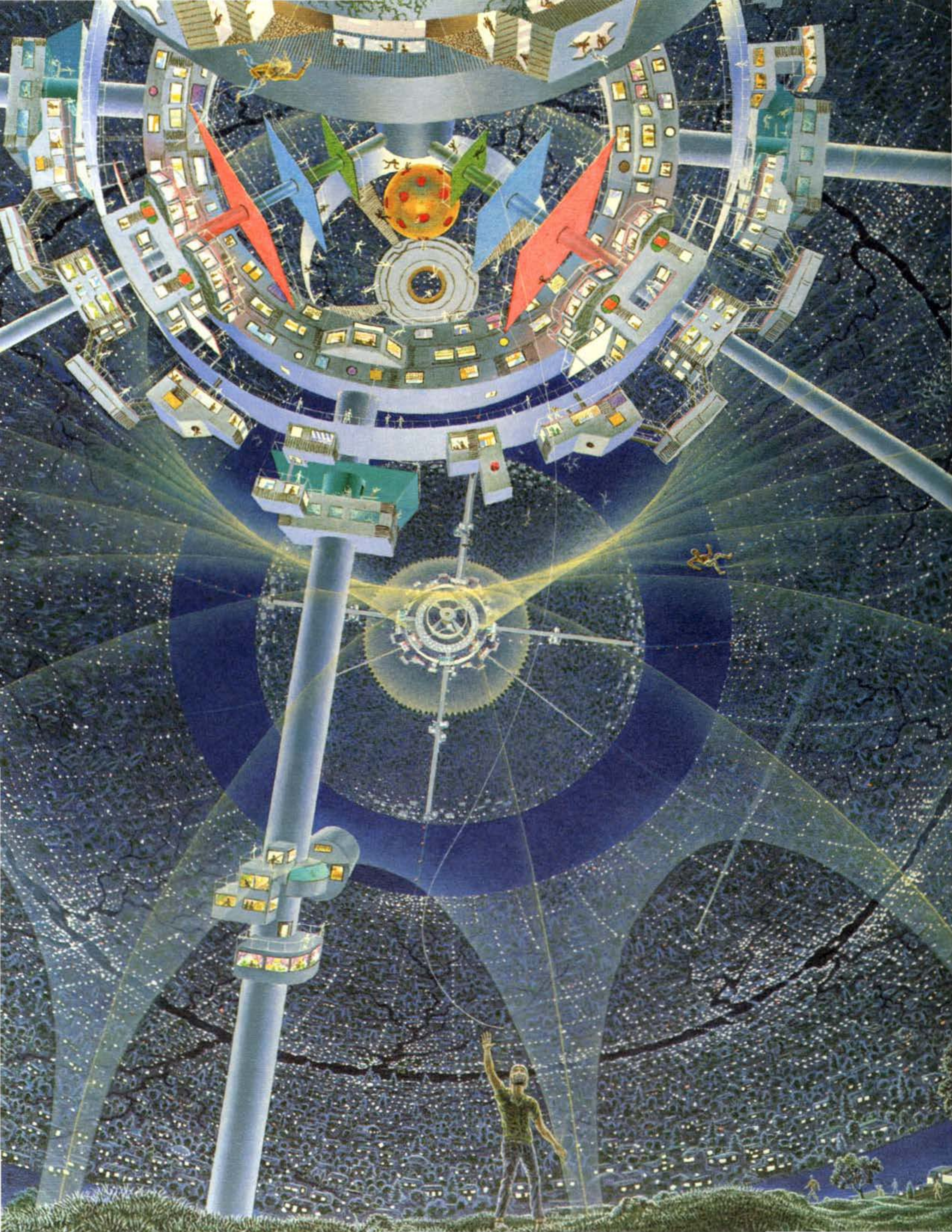
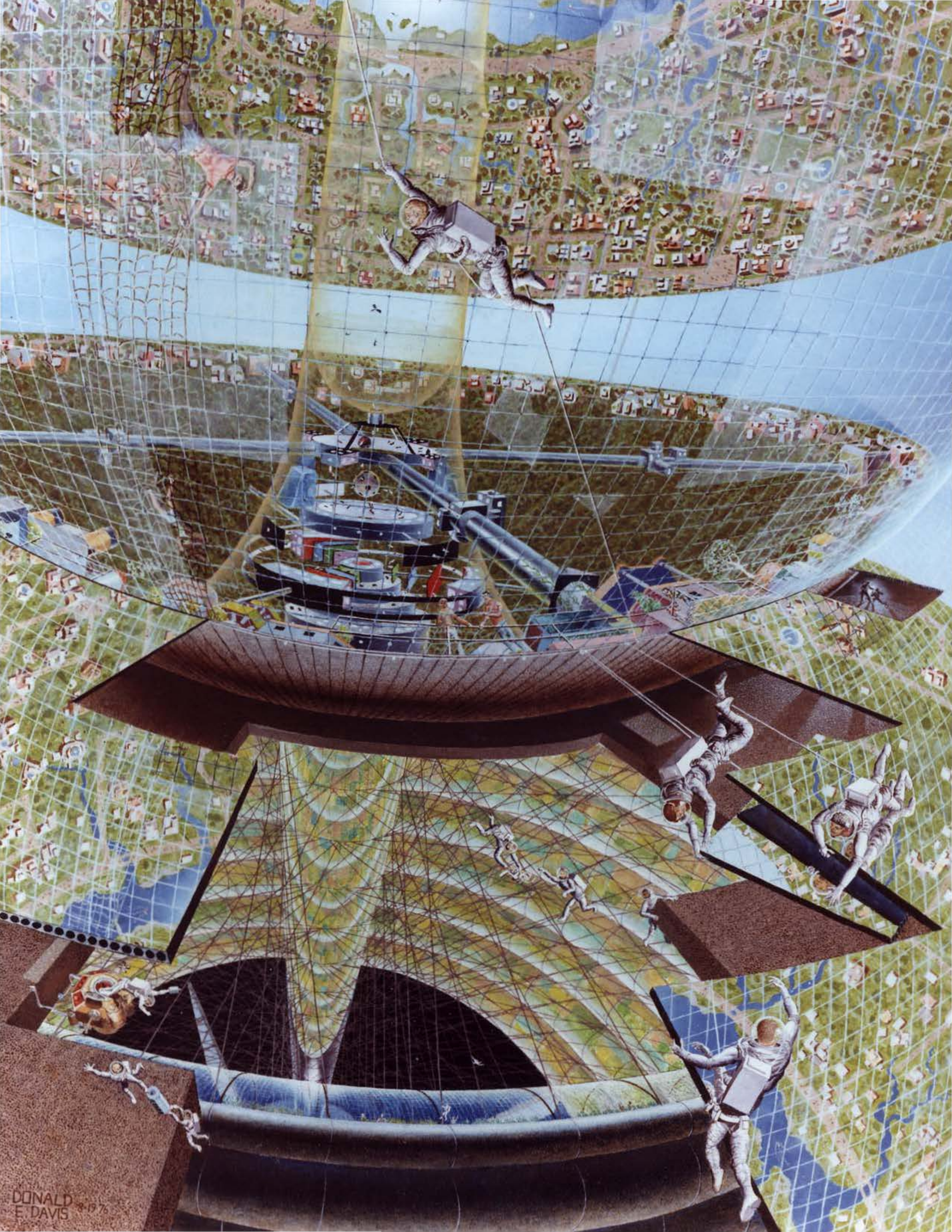
SPECIAL NOTE: *Space Settlements, A Design Study* (the 1975 NASA/Ames Summer Study) is available for $5 from the U.S. Government Printing Office, Washington, D.C. 20402. The stock number is 033-000-00669-1.

Inside center, left: BERNAL SPHERE INTERIOR.

Constructed around the axis of the Bernal Sphere is a series of concentric buildings and galleries. The ceilings point toward the zero-gravity point. A conical net encloses the entire structure (see archlike openings). In this night view, the man in the foreground is standing near the edge of the zero-gravity area. The rope he is reaching for is used for climbing sports. At center right a man is sliding down the net (Painting by Don E. Davis).

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Inside center, right: BERNAL SPHERE ASSEMBLY.
The final shielding and mirrors for the Bernal Sphere are being put into place. This view is from the outside of the windows during the day. The cosmic ray shielding in the foreground is a cutaway view. Inside the window, people are in shirtsleeves and are crawling up a net. The concentric buildings and the net that encloses them can be seen at the axis of the Bernal Sphere (Painting by Don E. Davis).

Policy

(Continued from page 3)

Bodies," now in force for over seventy countries (U.S. Treaties and Other International Acts Series 6347). But it is now comparatively old, pre-dating the Moon-landing and O'Neill's synthesis. It has already become the subject of many suggestions for revision (Kash; Christol).

This treaty established the broad principle that "use" of celestial bodies is open to all nations; but neither any territory in outer space nor outer space itself is "subject to national appropriation by claims of sovereignty." Exploration and peaceful experimentation is permitted, but implementation of a space industrialization program of the type and scope envisioned by O'Neill will clearly raise allegations of illegality if any single nation attempts such a program. Certainly the mining of lunar materials and their transport into space for construction purposes is more than a strict reading of the treaty permits; J.H. Glazer has even argued that construction of a fixed-orbit colony might be construed as "national appropriation" of a portion of outer space. A Canadian study in 1967 recommended that Canada claim an area of space for use by synchronous orbit satellites (Johnson), and in December of 1976, a claim to control of geosynchronous orbit space over equatorial states was advanced by a group of eight equatorial nations (Bogota Communique, December 4, 1976). The claim may not stand, but the fact that it has been advanced suggests that large-scale space development may prove Glazer a prophet.

Further, outer space and celestial bodies are reserved by the Treaty for "the benefit and in the interests of all countries, irrespective of their degree of economic or scientific development, and shall be the province of all mankind." This principle seems very close to what the developing nations are demanding in maritime law conferences; clearly space law must deal with this demand in some form.

Christol has proposed an evolutionary approach, involving creation of an international organization to manage space development. He argues that the present vague space regime permits nations or organizations under their supervision to exploit space resources provided only that no claims to sovereignty are made, and that the use made is both peaceful and internationally beneficial. Even so, "the problems of exploiting the natural resources of the space environment is very similar to that posed in the exploitation of the resources of the deep seabed and ocean floor. In each instance there is a need to focus on the management of such resources by way of an operating regime or authority, which, in order to be most effective, would undoubtedly take institutional form." In particular, the pressure for a share in the oceans' benefits coming from developing and non-coastal countries will surely be matched in space development as developing and non-space-traveling nations become aware of potential benefit and seek to channel it in their direction. Institutionalizing the program in an agency subject to international control seems a likely preferred strategy for "have nots"; the space-going nations may resist.

Because of the potential for loss of control, major space-going nations may prefer other alternatives. The similar situation in law of the sea negotiations has produced a warning from William Rogers, U.S. Undersecretary of State for Economic Affairs, that "many of the developing countries are trying to impose a doctrine of total internationalization on the industrial countries, which alone have the technological and financial capacity for mining the seabeds in the foreseeable future. The U.S. has offered to find financing and to transfer the technology to make international mining a reality. But total internationalization is out of the question. . . . There are limits beyond which we cannot and should not go."

"A multi-lateral treaty might create a class of internationalized, less-than-sovereign legal entities in space, with sufficient legal capacity to accept limited legal rights and obligations."

Outright violation of international space law by some great power would be costly, and potentially destabilizing: a national program to acquire exclusive control over important extraterrestrial resources, and to construct large platforms in space, would merely arouse national security fears in other countries. Presumably strong counterpressures would be aroused. But full internationalization seems too much to expect at this time.

Re-interpretation of existing law and principles may, however, permit important space development by some middle road between national exclusivity and an unlikely "space government." Glazer has sought to apply traditional state-centric law to outer space development and has found several possible avenues. Under his flexible interpretation of current law, one possible option would be the resurrection of the concept of a "free city" which was applied to Danzig and Trieste. A multi-lateral treaty might create a class of internationalized, less-than-sovereign legal entities in space, with sufficient legal capacity to accept limited legal rights and obligations. These entities would be neither solely national instruments, nor themselves nations, and would thus neatly evade the problems of "national appropriation" while simultaneously allowing their sponsoring nations to exercise control in the most significant matters. Perhaps NATO, EEC, Comecon, or other multi-national groups could sponsor such a "free city," thus maintaining the existing legal regime while evading broader international control.

Something similar to the "free city" may be in the minds of both O'Neill (1976) and Peter Glaser (1976). They refer to what are probably international, or at least multi-national, space industry operating organizations which seem to resemble the International Telecommunications Satellite Consortium (Intelsat). Intelsat was created by multi-lateral treaty as an "international public utility" to operate and regulate international satellite communications. Such a model might meet legal requirements as postulated by J.H. Glazer, but does present some political and organizational problems, which will be noted below.

Christol, and others drawing on analogies from current sea law controversy, assume that national resource competition in space will not automatically benefit all nations and therefore contemplate the necessity of some variety of international organization to meet demands for greater equity of benefits. Glazer's models would attempt to avoid a future in which space development is "monolithically centralized" by preserving an essentially single-country exploitation model or by creating a special-purpose "loophole" device such as the "free city" for use by groups of nations. Christol's model suffers from the usual infirmities of large international organizations which must be multi-functional, deal with very important matters, and satisfy a broad range of national interest; Glazer's are still likely to spark the rivalry and controversy that would be aroused by unambiguous single nation actions, without providing any offsetting benefits.

A third alternative might build on Glazer's plus the models provided by the U.S. Constitution's separation of powers model and some of the usual features of anti-trust laws. Space colonization and industrial exploitation is clearly a complex, interdependent, specialized enterprise. We may analytically subdivide it in several ways, only one of which -- location of activity -- will be used here for illustrative purposes:

1) Earth-based (at least until well along in the program) activities such as

surface-to-orbit shuttles, managerial coordination, financing, marketing, and industrial production;

2) lunar-based mining and associated operations;

3) colony-based industrial fabrication;

4) satellite power station operations.

Accepting Glazer's premise that it will be easier and just as suitable to adapt existing law rather than to invent new modes, we may construct an "anti-trust" space law regime which permits any one country or international organization to operate in no more than one (or two or three, depending upon the degree of "safety" desired) of the above listed sub-divisions. A central coordinating organization would probably be necessary for efficient operation, but it could be international and could be barred from direct involvement in operating areas. Those who propose measures to control the oil multinationals frequently construct similar models (Blair).

Space exploitation will require extensive interdependence between the several operating divisions listed above, but the "anti-trust" provisions would require their legal and political separation. Under the logic of separated powers, in which each "branch" has a self-interest in both cooperation with the other branches and in checking their unrestrained growth and power, it may be possible to avoid both extremes of "monolithic centralization" and nationalistic aggrandizement. Each member nation should be able to assure that its interests would not be endangered, but a norm of cooperation would be necessary for successful exploitation. The American federal government has operated for two centuries on a similar model: some degree of inefficiency and risk of deadlock has been accepted as the price for prevention of tyrannous government, while the overarching need for cooperation forces compromise. Perhaps a similar, functional division of powers in space can provide a key to both legal and political institution-building. Additionally, such a model automatically spreads financial burdens and benefits across a number of countries, thus easing the problems of raising capital and simplifying the problems of distribution of profits.

Some Organizational and Political Possibilities

The organizational and political devices used for space exploitation will be shaped by, and will continue to shape, the legal model established. Current space law and practice, as well as normal international rivalry, seem to rule out the possibility of some single nation dominating all areas of space industrialization. The 1967 Outer Space Treaty requires that all space activities must be under the "authorization and continuing supervision by the appropriate State Party to the Treaty" (Art. VI), which equally, clearly rules out the possibility of a wide-open private enterprise approach in which governments stand aside. Finally, unless something highly unexpected happens in the theory and practice of world government, there is unlikely to be anything approximating "space government" on the supranational level.

Assuming a space law regime which is neither a single, all-embracing government nor real anarchy, organizations involved in space industrialization must utilize models which are flexible. An international legal regime and its organizational components must work both on Earth and in space, and must work with individuals and groups who will no doubt also remain subject to their own national laws in areas and roles not controlled directly by international space law. A similar condition exists in regard to ocean law, in which individuals may be subject to international law, to the laws of their nation of citizenship, or to the laws of other nations, depending on the particular conditions.

"An international legal regime and its organizational components must work both on Earth and in space . . ."

There is a tendency to extrapolate from existing models of space organization into the future, although this probably will produce an inappropriate model for space industrialization. Existing space organizations deal with narrow functional and usually technical problems: communication satellite operation, resource surveys, meteorology. Although complex, these are relatively impersonal and small scale, focused on technology (Steinhoff). Models of organization which have appeared in space industry literature, such as the "Ensat" (O'Neill, 1976) or "Sunsat" (Glaser, 1973) models, assume a relatively narrow focus, technology-dominated, functional organization held together primarily by economic motivations. There is a clear analogy to Intelsat, the International Telecommunications Satellite Organization.

Skolnikoff (pp. 159-160) has modeled the effective international organization, particularly those which are technology-related, as being characterized by highly specialized and technical subject matter, having a clearly defined and restricted function, with a membership limited to only those nations directly involved in the technology and operation (thus, a small number in most cases), and with an organizational structure allowing representation and control based on the recognition of unequal power, stakes, and expertise of the members. Further, public interest, economic and political stakes would ideally be narrow and limited. In brief, the organization is more administrative than political. Intelsat seems to meet most of these requirements rather well, and has been successful. But can this model apply to space industrialization?

According to the O'Neill scenario, within some thirty years there would be a human population in space numbering at least 10,000 and perhaps as much as a million. Because of the rapid growth capabilities of the system and the presumed great attractiveness of life in space colonies, that number could grow geometrically-into the billions. Certainly, even numbers of people approaching a million would be beyond the scope of Skolnikoff's model: in 1970 more than ten national governments had populations of less than one million, and a majority of the world's nations had fewer than ten million population. This scale of human population suggests that politics will be at least as important as bureaucratic organization.

In addition to sheer numbers of people in space, there is the expectation that very large proportions of national and international energy systems will depend upon satellite solar power. Massive economic stakes will be involved. National, even planetary, economic and social well-being could depend upon the energy, industrial products, and perhaps raw materials produced in space. Simultaneously, according to the plan, the space colonies themselves would be in the process of reducing their dependence on Earth by developing asteroid resources, space agriculture and machine facilities. This reversal of roles, from space colonies dependent on Earth to the opposite condition, will clearly have political consequences.

Something analogous to this process has happened before in human history, in the great colonial migrations of the seventeenth through nineteenth centuries in the Western world, and in other cases throughout recorded history. Colonies begin as administrative, functional organizations, but develop internal and external politics. Parent countries have always insisted upon a significant voice in the affairs of their offspring, and successful colonies usually have sooner or later drawn free. During this process both the colony and the sponsoring nation had to adjust to the development of new economic relationships, new value constellations, new types of both cooperation and friction; that is, to conflict and its resolution by political means. Whether one sees space communities as colonies which will seek liberation, or as economic dependents which will grow in power and eventually rival the mercantilist core powers which established them (Gilpin), there is clearly a potential for rivalry between nations on Earth over control of space industry, between colonies in space, and between Earth and the colonies. The Skolnikoff technology-oriented model is clearly not applicable to space industrialization.

At the opposite extreme would be an organizational mode dominated by representational and economic equity concerns rather than functional expertise, with multi-purpose functions and something approaching universal membership. The organization would deal with high stakes, high public interest, and a complex set of demands. Formation of this organization would be of great significance, since the terms of its charter would be an important part of the stakes. It is not unreasonable to expect development of what approximates a universal government for space to be slow in formation, diluted to a least common denominator, and difficult to work. Indeed, it seems unlikely to happen at all.

Between the Kropotkin-like "mutual aid" of an "Ensat" and the pitfalls of a "space government," there may be reason to refer again to the "anti-trust" model. This model is essentially a variety of functionalism, proposing that the advantages of cooperation will be sufficient to entice nations into accepting a buffered system within which they cannot control but can prevent others from controlling, and can nonetheless gain the material advantages sought.

Advocates of space industrialization, particularly for energy production, typically cite economic studies indicating that their preferred alternative is less costly than other alternatives, and point to its possibility of very profitable long-term operation. Even though these are good advocacy points, it is still true that any project designed to supply a major proportion of the world's energy will be enormously expensive. Current space industrialization studies indicate initial costs will run from as low as $40 billion to perhaps $200 billion over twenty-five years, a range of about fifteen to twenty-five percent of what the U.S. electric utilities expect to spend on capital during that same period. In increasingly burdened capital markets, as nations attempt to deal with the capital needs of not only increasingly-expensive energy but a host of other demands, there will probably be great reluctance by any one nation to shoulder an additional capital burden of this size.

There is a history of U.S.-Soviet negotiations on ways to save money by joint space projects, and of somewhat more successful arrangements between the U.S. and several non-communist countries for cost-sharing, such as launches of satellites (Kash). All these projects together would aggregate far less than the minimal initial costs of space industrialization. It is clear that saving money does not always overcome political objections, but it helps (White). For the wealthier nations, there should be a willingness to pay some political price in order to obtain important economic help. The poor nations conversely may be able to pay only a small portion of the economic cost, but be willing to do so in return for some political voice in a program of very great potential importance to them. By dividing the space industry system into several program elements, and organizing economic and political participation around them, it should be possible to accommodate a number of variations in national size, wealth, goals, etc.

An organization composed of and responsible to several different nations, with nationals of several countries involved, should be sufficiently full of security leaks to make it very difficult for any nation to mount a security threat through the space industry system. The complex ramifications of organizational coordination should create sufficient bureaucratic structure and integration to allow nation-states a number of options for normal interest-group maneuvering as part of the check-and-balance system. In brief, the technological motivations of efficiency, economy, and effectiveness may, in this case, require for their political acceptability the use of a political structure capable of frustrating any level of efficient action which might constitute a threat. If space industrialization is to proceed, the political price must be paid.

"Current space industrialization studies indicate initial costs will run from as low as $40 billion to perhaps $200 billion over twenty-five years."

Summary

It is a curious fact that human societies frequently exhibit an inertia akin to that of physical bodies under Newton's Laws. Although the advice of Schumacher, Lovins, and others urging a simplified lifestyle and ecological adjustments may be the essence of wisdom, it violates the dominant social paradigm of the industrialized societies which would have to accept and live by it. These societies have demonstrated a preference for social problem solution by means of very large scale, complex technology: nuclear power systems, massive waterworks to move rivers rather than people, supersonic planes rather than a slower pace of life. The energy crisis has brought forth chiefly programs for increased energy supply; population explosions have produced the advice that we should "increase the banquet of life" rather than limit the diners. In view of this observed regularity of human behavior, coupled with the apparent technical and economic feasibility of space industrialization, it seems quite reasonable to believe that this article is dealing with a real future.

We have not been particularly good at dealing prospectively with the socio-political aspects of technological developments, even when they could reasonably have been foreseen long before their arrival. Many of the social and political ramifications of nuclear energy systems, ocean mining technology, computerized personal data systems, and many other recent technologies could have been -- and sometimes were -- foreseen, but little or nothing was done about them until quite late. Technology assessment and forecasting are gaining respectability and attention as means of changing that pattern.

For technological development of the potential importance and comparatively fast time scale of space industrialization, we urgently require simultaneous efforts toward assessment and institution-modeling. This article presents preliminary models for both international law and organization, and a preliminary assessment of some basic national security questions aroused by the concept of space industrialization. No fundamental obstacle to realization of the concept is apparent. Design criteria for central elements of the legal, organizational, and security components of the concept are described. In keeping with Ophuls' (pp. 228-29) definition of "design" as the approach which seeks to produce an outcome "by establishing criteria to govern the operations of the process so that the desired result will occur more or less automatically, without further human intervention," I have emphasized basic structural and motivational elements. Thus, the legal structure recommended emphasized incremental change and use of existing national and international legal models; the organizational structure assumes that nations will continue to exhibit nationalist concern for security and participation; the national security model emphasizes the neutralization of the system rather than its active defense.

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Science Court

(Continued from page 5)

good deal about this procedure, Margaret Mead, has said that all social inventions over the course of time are corrupted. It's kind of a pessimistic view, but she isn't really pessimistic, she just notes that this is what happens to social inventions, that in the course of time the people who are devoted to doing the procedure properly move away from front center and others who have other motivations, like making a good living out of this business, move toward front center and give it an entirely different aspect. She has also made good suggestions for slowing that corruption, such as the importance of having a cadre of trained people who supervise this procedure, and who are dedicated to delaying, at least, its corruption.

I think that those who believe such a procedure might have too much authority to some extent balance off those who think you can't make it work at all. While I think both of those arguments have some relevance, they are a little out of phase. At first I think it will be very difficult to make it work at all; later when you've learned to make it work well, or really before then, you should start thinking very seriously about preventing the procedure from being corrupted too quickly.

How did your interest in this procedure first arise?

It arose out of my involvement with the space program in the late 1950s and early 1960s. I was appointed to a committee which was charged with drawing up a space program for the Air Force in the year 1960. I was exposed to a lot of folklore from the early space pioneers, and it became apparent to me that Earth-orbital assembly would be a powerful technique on which all kinds of space adventures could be built. This had been suggested by many of the original pioneers in space thinking, but in that period there was a slogan that tried to compress the differences between American and the Soviet space programs into a few words: that the only things that we lack that the Russians have are bigger boosters. That slogan received enough currency to enable it, in a sense, to drown out the earlier and I think still very sound ideas about Earth-orbital assembly. Nevertheless, this committee, after thinking about it a good deal, reached the conclusion, and I was one of the driving forces, that Earth-orbital assembly was at least as important a direction for the U.S. space program as building bigger boosters. The two were treated more or less equally. Well, this resulted in a committee report which had no classified information in it at all. It reached the White House where there was a space council set up at that time. We received the instruction that there were to be twenty-five copies of this only, they were all to be classified top secret, and all twenty-five were to be locked up in the safe in the executive office of the White House, in which as far as I know they remain to this day.

That persuaded me that there was something quite wrong with this whole system. I tried other routes. I went to the members of the president's science advisory committee (I knew some of them personally) and undertook to convince them that if we were going to the Moon, which was then under discussion, we could do it at least ten times more cheaply with Earth-orbital assembly than the way it was being done. We had boosters in Atlas and Titan which could put stuff into low Earth orbit at about a thousand dollars a pound. The price is of course almost unchanged today, although in different dollars. You needed about 250,000 pounds in orbit to do the Apollo kind of mission, which would have cost 250 million dollars. This is a tremendous difference from the twenty billion that it did cost. Maybe you'd have to launch a good deal more stuff into orbit, more than the quarter of a million pounds, to allow for Earth-orbital laboratories, assembly stations, and what have you. Maybe it would have cost ten times that much, two and a half billion, but I don't see how it could have cost twenty billion dollars. I undertook to convince people of this. While I managed to convince a considerable number of scientists, I discovered that I couldn't have any influence on the policy, nor could I get a proper hearing, even though at that time I was known to the space community because of my work on reentry. That persuaded me that we needed a new institution, and so I gave it a good deal of thought. By 1967 I had published it in several places, and I started to try to persuade the Congress of its validity, with thus far no visible success.

What progress has been made towards testing the science court idea?

It has attracted a certain amount of attention, and some people have been kind enough to say that it is an educational notion. Whether or not it will receive the attention needed for the development of a new procedure is still problematic, though several universities are preparing proposals for the National Science Foundation, which has said that it has some interest in funding experimental trials of this procedure. I would hope that the next year or two will see half a dozen such attempts to try it out and develop the procedure to the point where it can be of some use.

Boeing on SPS

(Continued from page 9)

the possibility of using extra-terrestrial materials in the things we publish.

Woodcock: I find some interesting parallels between the L-5 Society and the American Rocket Society in the 1920s and 1930s.

Norie: For example?

Woodcock: Well, the American Rocket Society of those days evolved into the AIAA. It started out as a group of enthusiasts for a very new technology who were regarded by most people as a bunch of nuts. . . and which evolved over a period of years into a major industry and one of the most respected technical societies.

Norie: Makes you think of. . . wasn't it Copernicus? Wasn't he the one who was considered pretty much of a kook and had to recant or else face death?

Woodcock: No, you're thinking of Galileo. Copernicus never fell into that trap. He was the guy who understood the political system well enough not to publish his book until he was on his deathbed.

Carolyn: Well, I guess we have to admit we've come a long way.

Woodcock: Yes, a long way politically from the days when people could get burned at the stake for having revolutionary ideas, particularly when they are religious and philosophical ones.

Norie: Would you have any suggestions of how a group like L-5 might be able to improve its credibility gap?

Woodcock: I think what you have to do is fairly simple. You try to make an appointment with some of the people you have in mind and tell them what it is that you want to talk about. And then talk and get to know them on a personal basis. That's by far the most effective means of communication of ideas, particularly with someone who isn't necessarily very receptive to the idea. If he gets to know you personally and you don't seem like such a strange type after all, then he might decide that your ideas may not be so strange, either, and might bear some careful looking into.

Nansen: Using space solar power as a national goal addresses every single major problem the country has. In the economic area it creates significant jobs simply because it puts money into labor-intensive industry and you get a high ricochet effect of creating more jobs because of that. It's the highest of any industry. It's going into the high technical industry which addresses the fundamental attack against inflation. One of the key ways to grow without inflation is to increase productivity. That's a fundamental feature, and the only way you can increase productivity is to raise the level of technology. Therefore any activities that address high technology in a large way attack the fundamentals of stopping inflation.

And, of course, the next thing is that it is a fundamental attack on the energy problem looking at an inexhaustible source with essentially an infinite capacity that can be competitive with other sources and can eventually be a solution to the energy problem. Another feature is that because it is high technology and would develop the basic utilization of space for practical purposes, it also helps our position in the world relative to other nations. A lot of the potential technologies developed are useful not only in the civil side of our country's activities but in the military also. So there are some secondary benefits.

Norie: Don't you think that the military possibilities are something that might scare a lot of citizens away? They certainly scare *me!*

Nansen: It's possible if you think of some of the potential ways of using it, but we're looking at it strictly as a commercial utilization to develop commercial power. Solar power has a characteristic very similar to hydroelectric power in that after you amortize your capital investment, there are no fuel costs; therefore, you can potentially get your power costs very low if the system works as we foresee it. And also that particular feature is very important to holding down all energy costs. Right now all our energy is essentially generated by depletable finite sources and so with increasing demand and decreasing resources, the inevitable result is rising prices. They will continue to rise -- and I think there isn't any way to stop them -- until you develop an inexhaustible source that will put a lid on it. As soon as you develop an inexhaustible energy source to the point where it is practical, then you essentially put a lid on energy price growth on other sources as well.

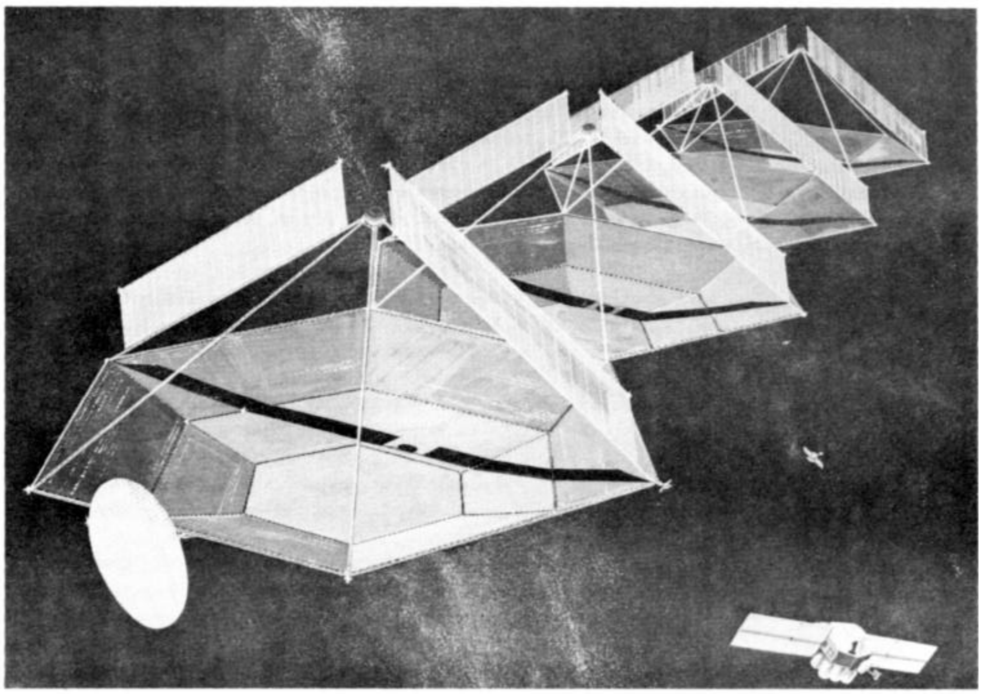
Norie: They have to be competitive?

Nansen: Right. Therefore as a national goal it seems practically ideal. There is hardly any drawback that we can see. Environmentally it's clean. It has everything going for it.

Norie: Have you come in contact with the book *Small Is Beautiful,* by E.F. Schumacher?

Nansen: No, I'm not familiar with it.

Norie: You might be interested in checking it out. It's a beautiful statement about the need for changing the direction of modern society and deals, in part, with the concept of having small, locally based factories using intermediate rather than high technologies, to support the local population and to increase the self-sufficiency of the local area. Would you see these two systems as potentially being compatible?



Boeing's Photo-thermal Solar Power Satellite Design

Nansen: Yes. With this kind of power, you can bring the power to the area in which you want to use it. You're not tied to any region or any specific area. You don't have to bring the industry to where the power is available, you can just bring the power out to where you want your factory, for example, in the midwest. There is really no big natural power generating source in the midwest, and, therefore, the Dakotas lack a lot of heavy industry, simply because they don't have readily available energy for them. So they have the opportunity with this kind of system to spread the base out.

Norie: How about wind or ground-based solar?

Nansen: If development in this program follows in the typical fashion of programs like this, it would stumble along for quite a few years gradually increasing in activity levels but it would take a long time, simply because the basic power generating system is not scaleable. You can't scale SPS down to small units and get a useful amount of power. To make it pay, you have to go to a big investment, and in order to do it, you need to develop not only the power generating system, but you also need to develop the transportation system, the baseline for operations. You need to develop man's capability to live, work and operate in space. So you have a whole bunch of parallel activities. Now the only way that you can really make that kind of progress happen, traditionally, is to make a very large commitment in the massive investment required to make the whole thing happen. Now the only way you can do that is essentially to make it a national goal. Otherwise, you can't get the necessary funding over a short period of time which is really required to bring something like this into being. And fortunately it is the kind of system that will have payback to all the people. It is not a product that is selective to a few individuals that get the benefits. In this case, everyone in the nation, and ultimately in the world, would receive benefit from it. Therefore, it has the ability to have personal appeal that will encourage their support for a massive investment. And all of the kinds of exciting and big things we've done have gone like this. For example, going to the Moon. There was a situation in which everything had to be developed. I believe it was May of 1961 that Kennedy made the announcement that we'd get to the Moon within the decade. Well, at the end of that year every single major element of the Saturn-Apollo program was under contract. It moved fantastically fast. The whole industry was mobilized. NASA was mobilized.

Carolyn: Did they think of the lunar module concept that early?

Nansen: It was very sketchy. The technical base in 1961 for landing on the Moon was not as good as it is today for space solar power. We believe we are further along and know more about space solar power today than we did about going to the Moon in 1961.

Woodcock: Both Ralph and I were in on the early phase days of the Apollo program so we are speaking from a certain perspective on this thing.

Nansen: Yes, we were there from the very beginning. We landed in 1969 in eight years with a program of about the size and development effort that we're talking about here with space solar power. So you can conceive of doing the first basic step of this thing in as short as eight years, if we went at the pace of the Apollo. And, as a matter of fact, in most ways, that is the cheapest way to do something on a massive scale-to do it as fast as you can. You waste some money, but the overall savings generally are much greater.

Carolyn: I don't understand what you mean by overall savings.

Nansen: Well, when you gear up an industry, you have 100,000 or 200,000 people directly working on the program. Now if you are going as fast as you can and pushing them really hard, then the block of time you're going to employ those 200,000 people is eight years. Whereas, if you do things slowly and orderly, you might not have 200,000 people. You might have 150,000 people and take twenty years instead. So every day you have that work force and are paying them during the development period is money that goes into the program without any economic returns. So the faster you do it the fewer days you have to pay them during the period you're still getting nothing back. You can therefore reduce development costs by reducing the time it takes you to do the job. to a point. After all, if you go too fast, then you waste things and make mistakes. But generally speaking the quickest you can do it is the cheapest.

Woodcock: I think the comparison you want to make-using the Apollo time frame, which is the best comparison we have for this kind of program-is that this is about how long it would take you to establish a construction facility. Then you could start to construct the first satellite and there would be a little bit more time to go through the construction. In this kind of a commercial program it probably makes sense to go to a prototype for redesign and reconstruction before you go into actual production. That is, by the way, exactly what we do in the commercial airplane business, especially the 707. The first commercial jet transport was a hand built prototype and from that we learned enough about what the design should be to go into production. Now we go directly into production on commercial aircraft.

Norie: One thing I'm quite interested in is the potential for international cooperation in this whole area. I should think that the Japanese with their energy crisis would be extremely interested in getting involved in this and would also have a lot to offer in electronics and other fields.

Nansen: As a matter of fact, this system has so many components and subsystems involved that many of these could be broken down and development could be semi-independent of other things. For example, the thermal engine satellite, where each individual mirror facet has to be steered individually and it needs to track the Sun and the cavity absorber and direct sunlight there, and it has to be able to move through a small number of degrees to correct for any inaccuracies in the basic satellite pointing or in deflection of the structure. So there are sensing units and actuators there to steer these facets that would be a representative sort of thing that a country like Japan would produce because it involves a small sensing system of some type, undoubtedly electronic, and a drive system. And they will be required by the thousands-pretty near millions when you look at a production run of satellites. So a country like Japan with its high rate of production of solid state devices would be ideal.

There all kinds of systems of this nature-engine systems, generator systems-when you're talking about thermal satellites or photovoltaic systems, switchgears or photocells, antenna elements.

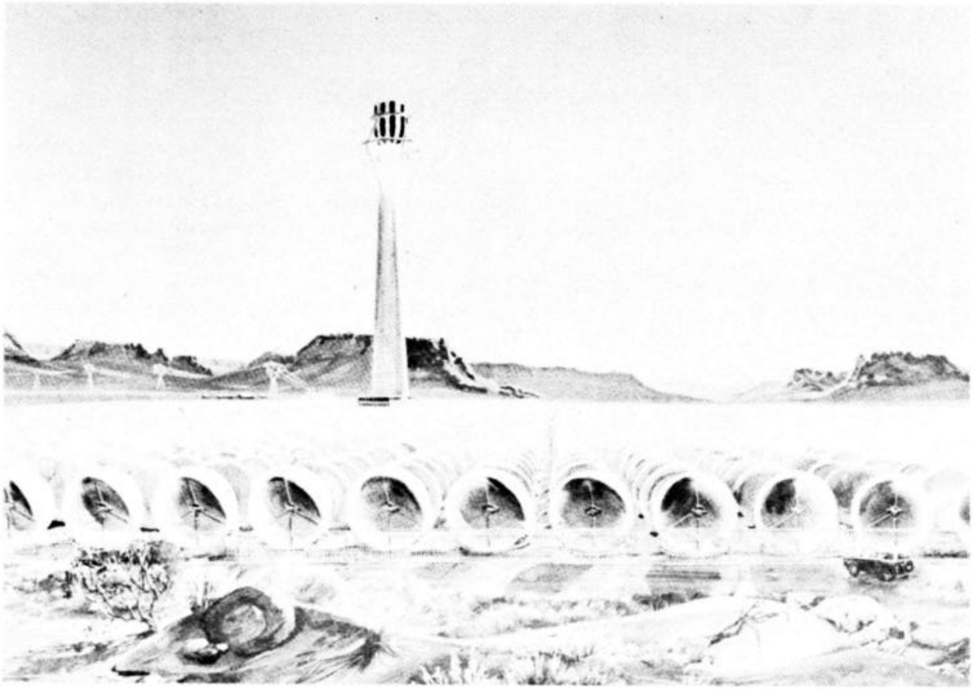
Woodcock: It's really hard to imagine a program like this getting off the ground without some element of international cooperation.

Nansen: Orbit locations, potential traffic control, and similar issues will certainly require new international agreements. That much power going into microwaves and the potential of radio interference has to be considered throughout the world, not just in the U.S. Some basic international agreements have to be reached.

Woodcock: Let me point out one thing about inexhaustible energy sources -- this one or any other -- that is a very powerful economic consideration. In the past half dozen or so years, we have seen a not steady but monotonical increase in the cost of energy. One reason is that the sources are finite and getting more and more finite all the time; the cost has nowhere to go but up. Provided you have the kinds of characteristics that we have in SPS (e.g., no capacity limit), the source of energy is free and non-depletable and the cost is in the device that collects the energy. As soon as you get a practical system on line, then the cost of energy will go down, because then you'll get better and better at it. As you get better at it, then you can make things cheaper, and since the source is not limited in any reasonable, practical sense, that would probably make a big contribution to this problem of inflation which some economists believe is basically driven by the cost of energy and not by other things.

Nansen: Well, it attacks it two ways. It attacks it for the reason Gordy stated which is the relation between basic energy cost and inflation. Plus it increases the technology level which increases productivity and that is the key source of national growth without inflation. You have to increase productivity or you cannot do that. So we address inflation from two directions.

Woodcock: It's possible in the economic world to regard inflation as a tax. It's the most regressive tax of all, more regressive than the sales tax. If you really look at how inflation hits different sectors of the economy, the people with the least income are hurt by it the most.



Boeing's Ground-based Solar "Power Tower"

The people with the most income are hurt by it the least and some may be helped.

Norie: In the new Carter administration there's a lot of talk given to the problem of inflation. Has there been any attempt to get in touch with people in the Carter administration to find out their feelings about this whole program?

Woodcock: We haven't made any real attempts yet. The administration is pretty busy right now just getting into office. But certainly this type of thing should be very appealing to him because it addresses the kinds of things that he has been saying that he is going to do. It addresses just about every problem he said he wants to tackle and it also is a dynamic, exciting adventure that I think would be very appealing. So we expect a good response, but we haven't tried yet.

Norie: It seems that one of the big differences between what you're exploring and what the L-5 Society is interested in has to do with the use of extra-terrestrial materials. I guess you are taking a more conservative approach.

Woodcock: (pause) I guess you could call it more conservative.

Carolyn: I guess you're not accustomed to being called conservative!

Woodcock: (laughing) No. Shall we say that the program we at Boeing advocate involves a good deal less technical uncertainty to make the thing work.

Nansen: We're trying to lay out a basic system that you can look at today and say, yes, we can do every single technical aspect of that. We have proven in some way or another that we can do each one of the things we're talking about. And you can't say that today if you start talking about using materials from the Moon. This doesn't mean that someday that's not going to be practical. It's just that we don't have the technology at hand and, frankly, what we're looking at is a close-in start to attack the energy problem with our program.

Norie: In other words, you want something that has very high credibility. .

Nansen: Yes.

Norie: . . . at every step of the way.

Nansen: That's right.

Norie: And then after you get there. .

Nansen: Then you can improve it, or explore other possibilities. We're trying to start from a known position, and then find how to make it better with the unknown.

Norie: That seems reasonable considering the way the government works.

Nansen: Yes, it has to be practical. You see, the period that either most people or the government would accept a large investment in space-to explore or develop-is gone. We have gone through our "exciting period" in space. This happens in every field. Now what we're faced with is this: if we want to proceed, we've got to do something practical, something with economical return. It has got to be a utilitarian operation. So in order to do the other exciting things, you've got to have somebody pay the bill. And the best way to pay it is to develop a good source of income. That's what the SPS program represents. And at the same time, it would develop the capabilities of the transportation system, the capability to live and operate in space. It would give us the opportunity to go do other things at very minimal cost because you've made your major investment in the tools.

Carolyn: Could you give us a ballpark figure of the investment in R&D as well as the capital investment to get your first operational satellite sending power in bus bars?

Nansen: Well, you don't have a good hard number, but you can kind of estimate it if you look at the Saturn-Apollo program if you escalated it to today's inflated dollar. That's about the development bill. As for the capital cost, there's quite a range, as Gordon said earlier. But it looks as if it is not significantly higher than the projected costs of new nuclear plants, the breeder reactor type. I t's about that range of capital cost in terms of dollars per installed kilowatt hour of generating capability.

Norie: On Project America, we visited Los Alamos and were given a very interesting presentation by one of the scientists there about possible forms of energy in the future. Their emphasis is on nuclear fusion. According to the man who talked with us, they had heard a discussion on the solar space satellite concept, and they rejected it on the basis of cost. As I remember it, they said it would cost too much to put the things in orbit.

Nansen: Oh, the first time most people look at our satellite program they say the same thing simply because they're equating today's space costs of communication satellites. A communication satellite may cost $10,000 a pound because they are small, complex systems, one of a kind with very sophisticated (dense) electronical packaging and today's transportation costs are $600 a pound.

Woodcock: To get it into geosynchronous orbit today is about $5,000 a pound.

Nansen: So when you extrapolate these kinds of costs-and that's what people do who don't understand the system-then it's totally unfeasible. But when you tackle these problems and lay out the kind of system we have, then it becomes totally different. It is a commercial venture of a completely different order of magnitude.

Woodcock: The usual way of dispensing with the SPS concept is to say that the cost of transporting into geosynchronous orbit is $10,000 per kilogram, which is about right for the Titan I I I, and that the satellites by the most recent publications weigh about ten kilograms per kilowatt. So all you have to do is multiply those two numbers together and you come out with $100,000 per kilowatt. And that is clearly not an acceptable cost. That's about the amount of consideration that the concept gets from lots of people.

Norie: Is that perhaps because they have a competing scheme and don't want to give you any more consideration?

Woodcock: I'm not sure that's generally true. I think that when people think about space-and they've got plenty of reason to think this-they think of something that's exotic, exciting, and certainly expensive. There are some very fine and historical parallels in that area. One can find statements made by people who should have known better-by that I mean physicists, aerodynamicists and so forth-a few years after the Wright brothers and when airplanes were already flying. They said, it's conceivable that airplanes could be developed to the point where one could somehow struggle across the Atlantic with a few passengers, but that the costs would be so exorbitant that no one could afford it except the rich capitalist who could afford to own his own yacht; that visions of fleets of giant aircraft carrying ordinary people great distances across the Atlantic have just got to be wholly visionary. There is no way that is ever going to happen. Now, this statement was made about 1910, after airplanes were flying. Another quote was made in 1926 by, I believe, an astronomer. And this was after Goddard's first rocket flight had been published. Of course, Goddard had written a book in 1919 in which he said that one might conceivably send a rocket to the Moon and this guy went through a little bit of arithmetic to show, as one can readily do, that the energy per unit mass of something that is going to escape the Earth is far greater than the caloric content of any known fuel. And he said that for this reason the idea of shooting things at the Moon was obviously ridiculous. It simply gives an example of the irrationality that extreme specialization will carry some scientists to! You can find more quotations of that nature than you can find space to print them. One of the best sources of many of them was a book published some years ago called *Profiles of the Future* by Arthur C. Clarke.

To go back to costs, another point is that in the early phases of a program cost estimates tend to be low. There's good reason for it. It's not that people are liars or that they're incompetent or ignorant. It's simply that in the early days of a program designed to accomplish a major objective, one is unable to identify all the elements of the program.

Norie: Could you point to some of the spinoffs of the space program so far?

Woodcock: There are lots of them. All kinds. Some of them direct, some of them pretty indirect. I think the whole miniature computer essentially happened because of Apollo, pocket calculators. . .

Nansen: It's fascinating to think that if you could get in a time machine and go back about thirty years and show one of these pocket calculators to a reasonably competent engineer or scientist, he would have had to conclude that it works by magic!

Norie: Could you comment on the problems of maintenance and repair of the SPS? Would there be a problem of meteors crashing into it, etc.?

Woodcock: Major damage would be fairly negligible because it would require considerable impact. It isn't a significant economic factor. Minor damage would be expected on a routine basis and would have to be repaired. That seems to be a second or third order factor in terms of expense.

Interestingly enough, if you look at the flux of large objects-by that I mean meteorites larger than the typical pea-sized meteorite -- the natural flux of objects of near -- Earth space is far less than the flux of manmade objects. And there is a problem of collisions between man made objects and things as large as the SPS. This is currently under evaluation.

Norie: Do you mean man made objects like satellites?

Woodcock: Satellites, too but most notably junk. When a satellite is launched, there is usually one active satellite and several pieces of junk like spent stages, shrouds and separation mechanisms.

. . .Congress

(Continued from page 12)

To have contemplated its completion within twelve years of the launch of Sputnik in 1957 would have appeared heretical.

I am proposing the open discussion, timely funding and systematic progression of a concept which would have enormous implications for this nation and the human race. With this goal in mind, I have the following recommendations for the Committee's consideration in dealing with NASA and Carter Administration during the next few years:

(1) Work with NASA to identify those long term goals which are consistent with the public interest and are of fundamental importance.

(2) Help clarify agency jurisdictional problems. For example, the lines of responsibility for satellite solar power between NASA and ERDA are not clear and may be retarding a timely study of the concept. The capabilities of NASA in this area, in my opinion, are extraordinarily strong.

(3) In order that informed decisions be made, use the Committee's power of authorization in restoring vigor to the most promising programs which have long lead times, which require study and development, and which may develop into a major activity. This would include opening a dialogue with the Office of Management and Budget and reversing some of their decisions-for example, cuts in the modest funding of satellite power, space industrialization and the Lunar Polar Orbiter.

(4) Take part in presenting to the American people those options which appear to be most promising once they have been studied and partially developed.

(5) Participate in debates and decisions on these issues after the data are made available.

I hope you agree with me that an exciting concept has been developed. For the first time in history, the vast quantity of energy and materials available to us in space present an imaginative and practical new outlet for human experience.

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news

CLOSED ECOLOGY TESTED FOR SPACE

Science News

Permanent colonies in space, Earth-orbiting stations and piloted flights to other planets are all possible applications for life-support systems that function as closed ecologies, providing air, water and food through a variety of mutually dependent biological systems. A recent Soviet test sustained three people for six months in a system that provided oxygen by recovery from atmospheric carbon dioxide, water from "photosynthetic regenerative process" and included the production of "a certain amount of grain and vegetables." The result, according to I.I. Gitelson and colleagues from the Soviet Academy of Sciences, "established beyond question that a small, steadily operating, essentially closed system of 'substance-turnover' involving man is quite feasible. . . ."

LUNA 24 SAMPLES INSPECTED

Three U.S. lunar scientists (Dr. Michael B. Duke, NASA/Johnson Space Center; Dr. G.J. Wasserburg, California Institute of Technology; and Dr. Charles H. Simonds, Lunar Science Institute), visited Moscow on December 13-15 to examine lunar materials returned by the Luna 24 mission last August and to arrange for the transmission of samples for study by U.S. researchers. Luna 24 returned a 2 meter long, 8 millimeter diameter core from southeastern Mare Crisium, which has not been sampled previously by U.S. or Soviet missions. The site may contain material from nearby highlands and material from the ray crater Giordano Bruno some 1200 kilometers away.

A Soviet-American space cooperation agreement provides for the exchange of samples from each of the lunar returns. The U.S. has provided 3 grams of sample from each of the six Apollo missions; the Russians have reciprocated with 3 grams of Luna 16 and 2 grams of Luna 20 samples, plus two small fragments of Luna 20 rock provided separately.

Considering the fact that the Russians return has been 100 and 50 grams, respectively, for Luna 16 and 20, their cooperation in this exchange has been exceptional.

ERDA

ERDA, NASA SANCTION LARGE SCALE WIND POWER PROJECT

The following is an announcement from ERDA that details a windpower project that has been funded. Of interest to space enthusiasts is the scale of the project.

A huge rotor blade, half the length of a football field, will be built in 1977 as part of the Energy Research and Development Administration's (ERDA) program to develop a new generation of wind energy conversion systems.

Under the program direction of ERDA, the National Aeronautics and Space Administration's Lewis Research Center, Cleveland, Ohio, has selected the Kaman Aerospace Corporation of Bloomfield, Connecticut for negotiation of a contract for about $2 million to fabricate the 150-foot blade.

The purpose of the contract is to determine if a blade this size can be built and handled. Rotor blades of this nature and size have never been built before. Two blades of this size, spanning 300 feet or approximately the length of a football field, would be needed for a wind turbine rated at about two megawatts of electric power for a site with average wind speeds of 14 miles per hour.

Detailed design studies of such wind turbines are scheduled to begin later this year. By the time the large blade has been built and tested, and design studies have been completed, ERDA and NASA will have enough data to determine the course of the future test program for wind turbines of this size.

Wind turbines this large would be larger than the existing 100 kw experimental wind turbine in Ohio, which has blades spanning 125 feet, and the two 200 kw wind turbines of the same size which are scheduled to be built in 1977-79.

They would also be larger than the two 1.5 megawatt wind machines being designed and built for ERDA and NASA by the General Electric Co. for installation and testing in 1978-80. ERDA is pursuing development of even larger wind machines because studies show that the cost of energy decreases with increasing the size of the machine.

Construction methods used in building this large blade will derive from methods for building helicopter blades. The largest helicopter blade in use is about 55 feet long.

Kaman's rotor blade will be made primarily of glass fiber and will weigh about 12 tons. It will undergo static and dynamic testing at the company's Connecticut plant.

SOLAR ENERGY ABSTRACT JOURNAL AVAILABLE

Solar Energy Update, a monthly abstract journal from the Energy Research and Development Administration (ERDA), has been made available on a subscription basis.

The journal abstracts and indexes reports, journal articles, conference proceedings, patents, theses and monographs on solar energy, including photovoltaic, solar thermal, and ocean thermal power plants, tidal power and wind energy.

Solar Energy Update (NTISUB/c/145) for 1977 is available from the National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, Virginia 22161 for $27.50 a year, including a cumulative index. Single copies may be purchased for $3.25. Subscription rate for outside the North American continent is $40 a year and $6.50 for single copies.

Solar Energy Update is intended to be an ongoing supplement to *Solar Energy: A Bibliography,* which contains references to information entered into ERDA's Technical Information Center data base before 1976. Stock number and price of this bibliography are as follows: TID-3351-RIP1 (Volume 1, Citations) -- $13.75 for domestic and $27.50 for foreign; TID-3351-RIP1 (Volume 2, Indexes) -- $11.00 for domestic and $22.00 for foreign.

inside the L-5 Society

NEW COORDINATOR FOR L-5 SOCIETY, Western Europe

The West European Branch of the L-5 Society has a new coordinator and membership secretary, and a new secretarial address. Please send all membership correspondence, dues, requests, and items for the branch or international news magazines to:

Roger Sansom
L-5 Society (WE) Coordinator
45 Wedgwood Drive,
Lilliputt, Nr. Poole,
Dorset, United Kingdom.

The WE Branch has begun to reissue the Branch Newsletter and does hope to issue a regular monthly edition again.

"I believe that the Branch can look forward to another exciting twelve months as we pioneer the items that will be needed for the space community and space industry programs of the next few decades." --Phillip J. Parker, outgoing coordinator.

Stewart Nozette, L-5 member from Tucson, gives a lecture on space at the Museum of Science and Industry in Chicago.

FROM THE OFFICE

Space Settlement, the new quarterly special edition of the *L-5 News* begins with this issue. Advertising space will be available in *Space Settlement* in future issues. For information regarding rates, circulation and other information, please write: Advertising, *Space Settlement,* 1620 N. Park Avenue, Tucson AZ 85719.

The staff hopes you like this long issue. The Don Davis paintings were put inside so you can take them out easily. If you want to see more issues like this one, take *Space Settlement* down to your local library and get them to subscribe. Next month's *L-5 News* will be shorter, but will be filled with exciting news from the Princeton conference (it seems that about 10 percent of our members will be there). Printing some of Eric Drexler's latest work on solar sails is also being considered.

NASA 1975 SUMMER STUDY

The NASA 1975 summer study, *Space Settlements, A Design Study,* is out! The information is somewhat out of date (which is unavoidable on a topic that evolves this fast), but the printing and graphics are absolutely first rate. There are eight beautiful color plates in this 8½ by 11, 185-page book with a color cover. At $5.00, this has to rate as the bargain of the year. The editors, Richard Johnson and Charles Holbrow, NASA and the GPO have certainly done an excellent job on this.

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Short reviews of recent articles will be featured regularly in the bibliography update, as well as mention of books and periodicals about space.

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(Cont'd. from inside front cover)

I was wondering if solar power by microwave beam heats the Earth. Both nuclear and fossil energies do: nuclear through its wastes into the ocean and fossil fuel by the greenhouse effect. The heat these energies give off will melt the ice caps and flood many major cities of the world. If solar power via microwave doesn't heat the Earth, this gives solar panels in space one more advantage over its counterparts.

Richard Hankins
La Mesa, California

After this last winter, melting the icecaps seems a good deal less likely.
All *energy sources heat the Earth, solar via microwave heats it less than nuclear or coal (waste heat is radiated in space). However, human energy use is still very, very small in comparison to the solar flux.* **--K** H

I completely agree with Barbara Hubbard's comments in the January *L-5 News* under "Why Space Now?" It is a question of timing whether we go into space colonization now or later in view of the energy situation on Earth. I hope we pick up the option now instead of procrastinating until the time comes when we realize we do not have the energy to emigrate. If the present trend continues, which seems very likely, more and more of our energies are going into maintenance channels for things like subsistence and less into developmental areas.

There is another point I would like to mention in favor of going out now and that is from a competitive standpoint as viewing Earth against the background of the cosmic community. This may at first seem a shaky basis to support the massive effort involved in space colonization since we have not as yet come into contact with another culture. Statistically, the question was answered long ago and projects to communicate with them are proliferating at a greater rate than are our preparations to *meet* another culture.

I would rather see more of this energy going into channels that will get us out to them rather than have them meet us for purposes of colonization. We should be thinking more along lines of becoming technological equals or we might find ourselves in a satellite status relative to the cultures who were energetic enough to make it.

I very strongly agree with the remarks of Dr. Leary in this regard and think that the impulse for this venture should be generated from the "grass roots" level. If the project is approached through institutional and bureaucratic channels, it will soon become buried in red tape and and invite disbursement of funds into areas other than colonization.

The biggest boost space colonization could receive at this time would be to have Dr. Leary and Captain Freitag change jobs. Judging from the interviews (which are most interesting) Captain Freitag seems to look upon the whole adventure as a dubious risk. Dr. Leary, on the other hand, is the pioneering type of individual who would be best suited for the office of Advanced Programs at NASA.

Richard Semock
APO San Francisco

Personally, I like Jesco von Puttkamer's "push/pull" approach (L-5 News, *November, 1976, page 2) to space settlements. That is to say, we need both the radical visionaries to "pull" us toward their hopes of the future and the pragmatic and cautious people who look at where we are now and think about how to "push" ourselves into the future. How does this relate to Leary and Freitag trading jobs? Just imagine what would happen if NASA were populated by starry-eyed individualists? The non-starry-eyed taxpayers would be darn skeptical about any proposals coming out of NASA and in short order would pressure the President into firing those far-out people.*

On the other hand, if the idealists can get the Great American Taxpayers to back their projects, then those pragmatic "push" people at Advanced Programs will be able to push just as hard as the folks like Leary are pulling. How about giving the folks at NASA a hand? -Carolyn Henson

I was happy to see the essence of the concept of the Fourth Kingdom as the lead in your January 1977 "soft" issue of the *L-5 News.* The cover artwork by J. Nix was especially exciting to me. The art was appropriate with its dramatic symbolism, reinforcing what the words are trying to say. I am convinced the knowledge of this evolutionary imperative resides just below the surface of consciousness of nearly everyone in the human family. Symbolic artwork, such as you have featured, can help reach through all of the irrelevant clutter in our consciousness and bring a new awakening to many.

In your very fine review of O'Neill's *The High Frontier,* Carolyn, you resolved with a few swift strokes of the pen a possible philosophical problem in the L-5 Society. You referenced O'Neill's interests in terms of "within this century, life can begin spreading outward into the Galaxy." And I totally agree that if the Galaxy is our ultimate goal, we can go on constructively debating and carrying out the probable intermediate steps humanity will take before eventually leaving this solar system. The pathway out may include any or all of the following: colonies orbiting Earth, Moon, Sun or other planets; colonization of many of the planets and/or some moons of Jupiter; industrial and scientific space activities in orbit and/or on the Moon, etc. There is increasing evidence people were thinking of space travel thousands of years ago. They could not have imagined the myriad of mechanical devices and scientific approaches civilization had to practice with and perfect to finally come up with a capability to leave Earth's gravity.

William J. Sauber
Midland, Michigan

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Corresponding with Professor O'Neill before the 1975 Princeton Conference, I raised some of the same questions as does John Holt in *Skeptic* about the possible military risks of space research, industrialization, and habitation. The best source of information that I have found on the subject since then was a book, *War and Space* (Prentice Hall), by Robert Salkeld who also participated in the conference. Unfortunately, the book is now out of print, but it may still be found in some libraries.

While warfare is not a pleasant topic, the book was surprisingly reassuring in at least one sense: Mr. Salkeld points out that all fixed or low-orbiting weapons (such as Mr. Holt's speculative "death-ray" satellites) are vulnerable to counterattack. The only area of real invulnerability is deep space. (Just try to locate and intercept a cruise-missile-sized weapon somewhere out there among the asteroids.) If man's propensity for war cannot be contained, I'd just as soon it be satiated as far from Earth as possible. And from L-5.

So, yes, of course there are risks in space development. It would be foolish to deny it. But I'm now convinced that the potential benefits far outweigh any such risks. (Indeed, warfare on Earth will be just that much more likely to occur if we do not make use of the resources available in space.)

Philip M. Blackmarr
Los Angeles, California

The book War and Space *is available in xerographic form from the L-5 Society for $7. How about a new edition, Bob?*

Aristotle was not aware of the asteroid belt though he wrote quite a lot about persuasion. We are more than merely aware of the existence of the asteroids. We know that the asteroids and the Moon are reservoirs of mineral wealth-the stuff of which space colonies are built. Yet we must concern ourselves with the same elementary question that occupied Aristotle: What is the process by which one is moved to action? How is it that people are persuaded?

To realize the goal of the L-5 Society, that of disbanding in a mass meeting at L-5, a great many people will have to be moved to perform some very significant actions.

Unfortunately, the mere fact that it is technologically feasible to construct space colonies is not an argument that will sway the masses, and their leaders in government and business, to initiate a space colony construction project. For example, controlled fusion reactions are not presently technologically possible but are hotly pursued.

Something else controls the spigot; what is it? Modern persuasion theory generally holds that if an appeal does not touch a person's values it will be ineffective. Furthermore, appeals to personal values (e.g., self-preservation, personal freedom, financial well-being and self-esteem) are more likely to lead to action than are appeals to non-personal values such as "brotherhood" or "exploration and expansion." Among the personal values, the value which is affected most directly and most immediately will dominate. If all are equally threatened, self-preservation is far more powerful as a determinate of action than is financial well-being or self-esteem.

When the Soviets took the lead in the fictional "space race," many Americans perceived a direct threat to a plethora of values including self-preservation and self-esteem. Financial considerations became subordinate until we felt the threat had dissipated. Countries run deficit budgets and create inflationary conditions in order to appease threats to personal values posed by their neighbor's ICBMs, MiGs, and Phantoms.

How is it that an appeal or persuasive condition comes to affect a value hierarchy? It generally seems that if the facts supporting an appeal are believed, values will be affected. Thus appeals for birth control will not tinge self-preservation values and hence will go unheeded among those who don't believe the world is overpopulated or who don't believe overpopulation is the cause of resource scarcity.

Thus an ideally persuasive campaign must be backed by facts which are credible and verifiable. The speed with which the desired action will be implemented will largely be a function of how directly the audience perceives the appeal to affect salient personal values less how directly the appeal is perceived to affect contradictory values.

"Your money or your life?" If we think (s)he'll shoot, we'll usually pay.

Our biggest and broadest problem with space colonization is to make credible the claim that the presence of a burgeoning population and industrial establishment is a direct threat to the life and freedom of every citizen of the world. Unless people believe that an advanced industrial system operating on the skin of a planet immediately endangers their personal value hierarchy, few people will be convinced of the need to transplant people and industry to space. At the expense of sounding cynical about a man I very much regard, I doubt if Kennedy wanted Americans to go to space merely "because it's there." More likely is the explanation that we went because the Soviets were there. We believe something; that something affects salient personal values directly and immediately, and we act-quickly.

Another problem we have is that of generating widespread belief in space colonies as an attractive, practical and economical alternative habitat. Acceptance of this argument will affect all the values which motivate us to either stay where we are or move to a more attractive city, state or country (world?). Denial of this argument but acceptance of the overindustrialization argument would create a public policy which might incorporate ecological considerations but would not provide for space colonies as an "escape valve" in case policy did not work as planned-not an uncommon observation.

Accomplishment of these two persuasive tasks would likely result in rapid implementation of space colonization. A slower implementation could result from acceptance of the energy crisis as a serious personal dilemma and of solar satellite power stations as a practical alternative. Hopefully these power stations would be modern day "goldmines" or "crossroads" from which communities would spawn.

The grimmest scenario is one where nature does the convincing. When our planet pathologically convulses with overpopulation and overdevelopment it becomes problematic whether or not we could launch a space colonization project.

Dr. O'Neill and the L-5 Society are pursuing a rapid implementation path in demonstrating the economic viability and attractiveness of space colonization. Pursuing this path alone may eventually get us space colonies-though it may come after an immense amount of scarcity-induced human suffering. Patience may be a virtue, but in this context procrastination is a far more serious vice.

It is equally necessary for us to persuade people of the immediate nature of the survival crisis. Since any major project requires years of lead time, we must drive home the point that dangerous trends (e.g., scarcity and pollution) must be reacted to as if they were full-blown crisis situations. Despite the necessity of this line of argument for rapid implementation of space colonization, it is a path full of dangerous traps. Space colonization proponents hardly need to be further hampered by being dubbed "doomsday prophets." Such a persuasive campaign must be forceful yet subtle-a difficult condition to maintain. The structure of such a forceful/subtle campaign will need the input of many people and blossom after countless hours of thought. For our goal to be realized, such a campaign will have to be pursued on some sort of a significant level.

History from Aristotle's time to the present is replete with inane things that humans have been persuaded to do. I'm certain we all agree it is time we were persuaded to do something intelligent. L-5 is empty, the Moon is drowning in locked-in oxygen, and the asteroids are just waiting for a pick and shovel.

Martin Rothblatt
Los Angeles, California