L-5 NEWS

A Newsletter from the L-5 Society
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L-5 IN 1990, A CINCH

IF PUBLIC SUPPORTS IT

At a joint board meeting of the National Space Institute, January 21, John F. Yardly, NASA Associate Administrator for Space Flight, said:

"I think it would be a cinch to inhabit the moon, and it would also be a cinch to inhabit L-5. . . I know it is mind boggling, but still, a colony of 10,000 people at either place would be very straightforward . . . . Both of these could be done by 1990 if there was appropriate public support."

SENATE HOLDS HEARINGS ON SOLAR POWER SATELLITES

January 19 and 21, the Subcommittee on Aerospace Technology and National Needs held hearings on "Solar Power from Satellites." Those testifying January 19 were Peter E. Glaser of Arthur D. Little, Inc., Richard W. Taylor of Boeing Co., Gerard K. O'Neill of Princeton University, and G. Harry Stine, author of "The Third Industrial Revolution." January 21, the Subcommittee heard testimony from Edward J. Greenblat of Econ, Inc., William B. Lenoir, a scientist-astronaut with NASA, and John M. Teem, ERDA's Assistant Administrator for Solar, Geothermal and Advanced Energy Systems. Edward R. Finch, chairman of the Aerospace Law Committee of the American Bar Association, and Amanda Lee Moore submitted written testimony.

The Senate Aeronautical and Space Sciences Committee formed the Ad Hoc Subcommittee on Aerospace Technology and National Needs last July. The members are Senators Wendell H. Ford (D-Kentucky), Chairman; John C. Stennis (D-Mississippi); Howard W. Cannon (D-Nevada); Paul Lazalt (R-Nevada); and Jake Garn (R-Utah). Ex-officio members are Frank E. Moss (D-Utah) and Barry Goldwater (R-Arizona). The counsel is James T. Bruce.

Following are excerpts from the testimony:

DEVELOPMENT OF THE SATELLITE SOLAR POWER STATION

Testimony of Dr. Peter E. Glaser, Vice-President, Engineering Sciences, Arthur D. Little, Inc.

The advantages resulting from solar energy conversion with the SSPS in synchronous orbit are as follows;

(1) The amount of solar energy available in synchronous orbit ranges from six to fifteen times that available in areas receiving copious sunshine on Earth.

(2) The solar energy in orbit is available nearly continuously except for short periods around the equinoxes, at which time the satellite will be shadowed by the Earth for a maximum of 72 minutes a day. Averaged over a year, this shadowing results in only a one per cent reduction of the energy that would be available if the SSPS were continuously exposed to sunlight. Furthermore, the shadowing will occur near midnight at the receiving antenna site, when power demands are lowest. Therefore, energy storage is unlikely to be required.

(3) Synchronous orbit represents a favorable operational environment for the SSPS because zero gravity conditions and the absence of wind and rain and other natural environmental effects permit the deployment of large-area structures with minimal weight. Hence there is a marked reduction in the materials used per unit of delivered power. In addition, the space vacuum permits the operation of microwave generators and other components without the evacuated enclosures required on Earth. Moreover, because the SSPS in synchronous orbit is stationary with respect to a desired location on Earth, the microwave beam can be directed to most receiving antenna sites in the vicinity of major power users. These sites can be established on low-value land or offshore. Furthermore, because the receiving antenna is transparent to solar radiation and permits rain to reach the land below it, opportunities for multiple land use are provided.

(4) The environmental effects of the SSPS and the associated space transportation system are projected to be within acceptable limits. First, all waste heat associated with solar energy conversion and microwave generation can be rejected to space. Second, no waste products are generated. Finally, the microwave beam densities can be designed to meet international standards.

Power Transmission to Earth

There are several approaches for transmitting the power generated in the SSPS to Earth. Of these, the microwave method uses state-of-the-art or achievable technology to obtain high efficiency in generation, transmission, and rectification. Moreover, it promises to satisfy environmental requirements and safety considerations. Microwave transmission and rectification technology is based on demonstrated results from commercial use and developments to meet military requirements. Mass production of more than one million microwave devices serving an annual market of half a billion dollars in the United States alone, is indicative of the commercialization of the technology.

The transmission of power from orbit to Earth by laser, although receiving considerable attention, is not the preferred choice because of the low efficiencies associated with the conversion of electricity into laser power and the reconversion of laser power into electricity. In addition, the absorption of laser beams in the atmosphere, and by clouds, would reduce the overall efficiency of power transmission to an unattractive level.

The possibility of concentrating sunlight with mirrors placed in synchronous orbit to overcome the diurnal variation of solar energy on Earth has also been explored. Such an approach is unattractive because of the large area of concentrating mirrors that would be required in orbit to achieve a reasonable concentration factor at a location on Earth and because of the losses from absorption in the atmosphere.

The successful implementation of the objectives of the SSPS should lead to the elimination of society's energy-related concerns. But even beyond this, it represents an opportunity to enter not only a new era of energy resource development but, in a broader sense, the first steps toward the industrialization of space and the extension of civilization beyond the confines of the Earth's surface.

POWER SATELLITE CONSTRUCTION FROM LUNAR SURFACE MATERIALS

Testimony of Dr. Gerard K. O'Neill, Professor of Physics, Prince ton University

INTRODUCTION

This document should be regarded as reinforcing the viewpoint that research into satellite power makes sense. There are two features of the orbital manufacturing of satellite power stations which provide an additional basis for that viewpoint beyond that which is provided by the ground-launch method. First, with orbital manufacturing it appears that satellite power can become economically viable and have profound impact on a relatively short time scale. Second, with orbital manufacturing it appears that satellite power can become economically effective without the development of lift vehicles any larger or more advanced than the space shuttle.

The key points in orbital manufacturing are:

(1) The use of materials from the surface of the moon. Because of the low gravity of the moon and its vacuum environment direct launch of lunar materials into space would be practical: per pound, the necessary cost in energy would be only one-twentieth as great as from the earth, and on the moon ground-machinery, much more efficient than rockets, could provide the necessary launch speed. From the Apollo project we know that the unselected soils of the moon are typically 40% oxygen, 20% silicon, and 20-30% metals by weight. The metals, mainly aluminum, iron, titanium, and magnesium, would be usable as construction materials.

(2) The "bootstrap process." In the orbital-manufacturing approach, it would only be necessary to put into high orbit a relatively small quantity of equipment, corresponding in mass approximately to one satellite power-plant. That equipment, in the form of a highly productive, human-operated manufacturing facility (SMF, space manufacturing facility), would process lunar surface materials to build others of its kind, as well as power satellites. In that way the growth in time of the number of power satellites would be geometric, like the series 1, 2, 4, 8, 16, 32, instead of linear, 1, 2, 3, 4, 5, 6, as would be the case for ground-launched satellites.

(3) Dependence only on the vehicle system we are already building, the space-shuttle, and on a simplified shuttle-derived freight rocket. It has been very difficult to attract large-scale private investment for power satellites, in part because the lift costs for these advanced vehicles are so uncertain.

If SSPS power is to have major impact on the problems of energy resources and dependence, a way must be found to build and locate large numbers of SSPS plants (up to 20 to 40 per year of 5-Gw size) and the electricity rates at which they operate must be low enough so that they will achieve market penetration, being chosen for new construction in preference to alternative (coal or nuclear) plants. If those two conditions are not met, SSPS power can be no more than an exotic rarity, classed with hydroelectric and geothermal among fringe sources (1 to 5 percent) of energy. I think that with the addition of the orbital manufacturing concept, satellite power can become economically viable.

In the long run it may well be that the people working at the orbital manufacturing facilities may build very comfortable and earthlike habitats. Much of the public interest in this concept may be due to that possibility. In the early days, though, it seems almost certain for economic reasons that the orbital facilities will house a selected, highly-qualified, highly-motivated population, nearly all of whom will be working, and working hard. The orbital facility will be much more like a Texas-tower oil rig, or a construction camp on the Alaska pipeline, or like Virginia City, Nevada, in about the year 1875.

Recommendations

I suggest the following as essential components of a balanced program leading toward satellite power:

(1) The vigorous continuation and successful operation of the space-shuttle.

(2) Continued development of micro-wave power transmission, leading toward pilot-model demonstrations here at ground level of phased-array power transmitters as well as planar receivers.

(3) Detailed study of the electro-magnetic mass-driver, not only as a launching device but for the easier role of high-thrust, high-velocity reaction engines for use outside the atmosphere.

(4) Research on earth into long-term physiological effects of oxygen atmospheres and of rotation. Success in these studies could reduce substantially the cost of construction of a habitat for the workforce at an orbital manufacturing facility.

(5) Study of continous-flow chemical processing methods for minerals similar to those found on the moon.

(6) Conceptual study of a human-rated version of the LDEF (Long-Duration Exposure Facility): a test laboratory capable of being put into orbit by the shuttle, in which the long-term effects of partial or zero gravity and of various rotation rates could be studied.

(7) Studies on earth of high-yield agriculture, under conditions of controlled atmosphere and abundant solar energy, with human intervention (as is customary in agriculture on earth), as necessary, to maintain stability.

(8) A balanced set of design studies of earth-to-low-orbit vehicle systems, emphasizing:

(a) Minimum development cost,

(b) Minimum cost per pound of payload,

(c) Minimum adverse effect on the biosphere, but with less emphasis on massive single payloads.

For example, shuttle-derivative freight rockets of moderate size, and single-stage-to-orbit fully reusable vehicles of moderate size, would receive greater attention if this recommendation were followed.

(9) A continued moratorium on the development of nuclear rockets. If our calculations are correct, the availability of liquid oxygen for refueling in high orbit, as a result of the processing of lunar materials, would give to ordinary chemical rockets a higher performance than could be achieved by nuclear stages.

(10) Study of space-stations larger than a human-rated LDEF: facilities whose components could be launched by the shuttle or by a shuttle-derived freight rocket, and which when assembled would be suitable as construction and maintenance shops for larger objects. In my opinion the emphasis in these space-station studies should be on productive work, not on physiology, because I see no reason why the purely physiological questions could not be answered earlier and at much lower cost by a human-rated LDEF.

(11) Design studies of large power satellites, emphasizing reliability, simplicity, ease of manufacture and conservative technology, with less emphasis on the achievement of minimum weight.

(12), Study of an unmanned asteroidal probe, emphasizing the confirmation of carbon, nitrogen and hydrogen resources in the asteroids.

In closing, I would like to comment on the question of the jurisdiction of executive agencies. This fiscal year the federal government has budgeted 678 million dollars for nuclear fission research, 147 million for nuclear fusion, 253 million dollars for fossil fuel research, and 25 million for solar power research. Most of that is channelled through ERDA. If our calculations are correct, a most promising lead toward low-cost power *without* the development of any new technology, exists by the combination of space resources with present-day knowledge in the fields of turbogenerator and microwave engineering.

Under these circumstances, it would seem wise to channel a modest amount of energy-research funds, perhaps from ERDA through NASA, to explore whether this promising new lead is as good as it looks so far. If it does prove out, the expenditure this year of perhaps 0.1% of federal energy research money in the new direction could possibly advance by a year the time at which this nation could become energy-independent, and in so doing could save billions of dollars at a date when the energy shortage becomes even more severe than it is now.

The potential of high-orbital manufacturing has come into consideration so suddenly that it is natural to place realization of the concept far off in time. It is important therefore to emphasize that the establishment of a first beachhead in space would require a technology no more advanced than our own.

The freight-rocket on which such a program would depend would be a simple derivative of the space shuttle that is already in an advanced stage of development; the shuttle itself would be essential to the manned portion of the early activities. The mass-driver, novel though it would be, could be designed down to its last engineering details on the basis of science which is already thoroughly understood; no high temperatures or high stresses would be required for its operation. The availability of liquid oxygen at L5, as a waste product of the chemical processing of lunar materials there, would so change the economics of transport between low orbit and L5 that an ordinary chemical rocket, given that source of its heaviest fuel component, could perform at a level which could otherwise be reached only by an advanced nuclear rocket of a kind never yet built.

The challenge, then is not to break through to a new level of understanding, but to combine in an effective way knowledge which we already have on hand.

THE THIRD INDUSTRIAL REVOLUTION

Testimony of G. Harry Stine

One does not consider anthropologists as super-historians, but they are because they think in terms of millennia, not just years or centuries. It was an anthropologist, the well-known Dr. Carleton S. Coon, in his book *The Story of Man,* who proposed a fascinating thesis:

"Man has been converting energy into social structure at an ever-increasing pace. As he has drawn more and more energy from the Earth's storehouse, he has organized himself into institutions of increasing size and complexity."

Inherent in Coon's thesis is both a warning and an ultimate solution.

Our social institutions are now so large, so complex, so varied, and so worldwide that we are drawing enormous amounts of energy from the Earth. But, as our national space program has at last shown everyone, the size of our planetary home is finite. There is a finite amount of natural energy sources that has been stored up in Planet Earth for eons . . . and in less than 250 years we have consumed a large percentage of it.

If we attempt to rely solely on Earth's energy resources as we have in the past, we know that we are going to run short in time periods estimated from 25 years to 250 years in the future, which means that we are going to have growing shortages of energy.

As we begin to run short of energy, the first social institutions that will fail from lack of energy are the most recent ones, the most sophisticated ones, the most delicate ones. These are the international social institutions, the ones that keep us from killing each other most of the time. As these international social institutions fail, we may well slip back into a New Dark Age, and there is great peril in letting this happen.

Another futurist, Dr. Krafft A. Ehricke, stated to me during conversations on the night of launching Apollo 17, "If we fall back into a New Dark Age this time, we do so with our fingers on the nuclear triggers."

The eminent international scientist, the late Dr. Henri M. Coanda, once remarked to me, "There is no shortage of energy. We are surrounded by energy. We must only learn how to use it."

Coanda's remark is certainly true when we discard the idea of "closed system Earth." Yes, the bounty of Planet Earth is finite. But Planet Earth does not stand alone. It is part of a much larger system, the Solar System. And in the Solar System is the only operational, on-line nuclear fusion reactor in our immediate neighborhood that we know of at this moment: the Sun. It radiates continuously some 80,000 horsepower from each square yard of its surface.

Obviously, if we could collect only a fraction of this solar energy-both on the surface of the Earth and in space-there is enough there to satisfy our needs. It is certainly one source of energy that will allow us to modify Coon's energy thesis, to expand it so that we are converting the natural energy of the Solar System into social institutions. The use of energy from the Sun and from space gives us *time* to work on all the other difficult problems that face us, and it gives us the energy needed to support the very complex and sophisticated social institutions that we must develop to keep away from those New Dark Ages and their nuclear triggers.

Projections by the Department of the Interior indicate that by 1985 the United States will be consuming 116.6 quadrillion BTUs. (A BTU is a measure of energy; it is the amount of energy required to raise the temperature of one pound of water by one degree Fahrenheit.) Of this amount of energy, 23% will be wasted and must be discharged into the only heat sinks we have available: our planet's atmosphere, waterways, and oceans. The same projection shows that by 2000 A.D., the United States will consume 191.9 quadrillion BTUs of energy and will waste 27% of this because of inefficiencies in converting from one form of energy to another-coal to electricity, for example. This amounts to 51.8 quadrillion BTUs of energy up the stack that we must somehow get rid of safely. That's almost half of our total energy consumption of 1985!

On the basis of these projections, it behooves us to do something more than work out ways of supplying more energy to consuming processes on Earth . . . or we may eventually boil in our own juices, to use a figurative term.

But we can think about starting to relocate the industrial users into space, thereby lessening the 30% requirement industry has of energy consumption and, probably, lowering the energy losses at the same time.

With all due respect to the Department of Interior personnel who have made these energy projections, I suggest that they were established on the basis of "closed system Earth" whose potential trials and tribulations have been so loudly proclaimed by Meadows and his colleagues in their celebrated study, *The Limits to Growth.*

However, as Ehricke has pointed out, "The world is no more closed than it is flat."

A better way of life was the promise and hope of the American Revolution. I believe the American people still have the frontier spirit that brought us through the American Revolution and two industrial revolutions to date.

What better time than the bicentennial of the American Revolution for America to declare its commitment to the Third Industrial Revolution, the betterment of the entire world by the utilization and exploitation of space?

Gentlemen, I really believe we're going to solve our problems and that we will probably survive. Thank you for allowing me to preach revolution to you !

NASA STUDIES

Statement of Dr. William B. Lenoir, Scientist-Astronaut, National Aeronautics and Space Administration

We have studied the several concepts for satellite power systems, including those that you have heard described earlier in these hearings. The concept of a photovoltaic satellite power system discussed earlier by Dr. Peter Glaser of the Arthur D. Little Company and the thermal satellite power system concept discussed by the Boeing Company are both good conceptual design studies. Some of their estimates and projections may be somewhat optimistic, but, overall, they appear to be possible. We have no significant criticism of either system. To the level of present understanding, the photovoltaic system and the thermal system appear equally viable. Both options require significant technology advances, as well as further definition, and should be pursued further by NASA and industry.

The space colonization concept presented by Professor O'Neill is not really a satellite power system so much as it is a method to build one. It involves advanced space technology and capability (as do the satellite power systems) and has not been reviewed by NASA in this context to the depth necessary for evaluation of its applicability to satellite power systems. The concept has additional implications, but basic ideas, such as the emphasis on manufacture in space, may be the ultimate key to viability of satellite power systems.

In addition to assessing the above systems, we are performing system definition studies inhouse. We have developed a preliminary configuration of the orbital power plant portion of a system presently under definition and analysis at the Johnson Space Center. At the present time, its major differences with previously mentioned systems are the structural configuration and two transmitting antennas making it equivalent to two 5,000 mw power plants. (For comparison, Consolidated Edison of New York has a present installed generating capacity of 7,300 mw; Greater Houston, 6,800 mw; and all of TVA, 14,900 mw.) The solar energy converter has not been selected yet. Both photovoltaic and thermal converters remain under consideration.

We are presently in the middle of a Microwave Power Transmission Project under the joint auspices of the Lewis Research Center and the Jet Propulsion Laboratory. As part of this program, over 30 kw of power has been delivered

to a load after being transmitted almost a mile on a microwave beam. 17 high-intensity lights were powered by energy transmitted from the source generator to the receiving rectenna.

Studies into future transportation systems sponsored by the Off ice of Space Flight are being applied to satellite power systems. These studies, along with more specific studies into heavy-lift launch vehicles and ion-powered orbit transfer vehicles, are indicating that an extension of today's known technology can yield transportation costs of $20-$lOO/lb. to geosynchronous orbit. This is the cost range suggested by most satellite power system studies for the system to be competitive. Our studies into transportation system technologies indicate this to be a challenging, but attainable goal.

The assembly of the satellite power systems is one of the most critical areas in making cost projections. Present studies into large space structures and their assembly, teleoperators, and manufacturing in space are being applied to this area.

To summarize, the potential of satellite power systems appears promising, and further investigations should be made. Scientific breakthroughsare not required. Only a modest commitment to the next phase is required at this time; a large scale commitment is not appropriate.

It is generally accepted that solar energy will play a significant role in the solution of the energy growth problem facing the country and the world. I feel strongly that the prospects are very good that solar energy from space will prove to be feasible and economical.

ECOSPACE: The Economics of Outer Space -and the Future

Testimony of Edward R. Finch, Jr., and Amanda Lee Moore

The critics of expenditures for the space program consistently argue that these resources-especially the billions of dollars and the manpower-should be directed to solving man's earthbound and more immediate problems.

Habitats in Space. The dream of 10,000 people working and living in outer space now has the support of firm financial and technical programs. In two recent seminars on the feasibility of space stations it was concluded that space colonies have a future and could be operating by early in the twenty-first century. At the XXVth International Astronautical Congress in October of 1974, it was reported that the U.S.S.R. made direct proposals for East-West cooperation on large space stations, lunar bases, and other ambitious projects. Reports have been made on specific topics such as location of the orbiting colonies, materials to be used in their construction, basic supplies of raw materials for the orbiting colonies, means of producing food for their thousands of inhabitants, and legal and social structures for the colonies.

A major project of the first group of settlers would be to construct large solar energy satellites that would convert solar heat to electricity and then to microwaves, which would then be beamed down to earth for reconversion to electric power. Revenue from this activity would finance expansion of the colony. Lunar raw materials would make the construction economically feasible, and so the terms of a new Moon treaty take on added significance.

Legal and social regimes would have to be created for this unique situation without depriving the inhabitants of basic rights and freedoms. The question of granting governmental or ultimately statehood status to these colonies must be seriously considered. International law would have to restructure its earth-bound criteria when applying the rule of law in space.

SATELLITE POWER SYSTEMS

Statement by John M. Teem, Assistant Administrator for Solar, Geothermal, and Advanced Energy Systems, ERDA

It is the view of ERDA that SPS is a concept for the use of space which should be objectively defined for subsequent consideration and comparison with other alternatives. In the search for solutions to energy problems, none should be arbitrarily dropped from consideration. All should be defined with sufficient detail to determine if further development is justified.

The Nation has made a major investment in developing space technology which has several potential applications. One of these is to obtain electrical energy from several different sources, particularly nuclear and solar power plants, and to beam it to earth by microwave. If this use of space can effectively and economically contribute to the solutions of energy problems in an environmentally acceptable way, it should become a part of the national energy R&D program.

ERDA was established to bring together and direct Federal activities relating to research, development, and demonstration of the various sources of energy, to increase the efficiency and reliability in the use of energy, and to carry out other related activities. In order to perform its mission, ERDA intends to investigate and develop, if warranted, all possible sources of energy. The development of some technologies is absolutely essential, while the development of others is more supportive and complementary. This distinction is based upon four criteria:

(1) In which time frame does the technology produces its initial energy impact?

(2) Does the energy output of the technology substitute directly for oil and gas supplies?

(3) What is the stage of development of the technology in the spectrum from the laboratory to the marketplace?

(4) How substantial an energy contribution would successful development of the technology make possible?

Determination of priorities is also based upon such considerations as the energy benefit versus the cost of developing and installing an alternative energy source, preservation of material resources, and environmental impact among other things. On such a basis, ERDA has already determined the need to investigate and further develop the most promising methods of utilizing solar energy.

It is our understanding that in making its decisions on the fiscal 1977 budget the administration concluded that no direct funding for energy R&D should be included in the NASA budget because the basic responsibility for the development of energy technology for terrestrial applications rests with ERDA. Based on this premise it was determined that the NASA concept for a satellite power system should be considered among other alternatives by ERDA based on its merits as a potential energy source. Since this decision was reached too late for consideration in the FY 1977 ERDA budget, we have no funds specifically identified for the satellite power system. Nevertheless, we plan to give it full consideration within the priorities of our overall solar energy program.

SPACE-BASED SOLAR POWER CONVERSION AND DELIVERY

Statement by Edward J. Greenblat, Assistant Vice-President, ECON, Inc.

The major findings are summarized below. These findings depend upon the resolution of the technology areas summarized below. Many of these technologies require significant developments. Of particular importance for the economic and technical feasibility of SSPS is a "heavy lift" launch vehicle sized to *at least 182 x 103* kg. (400 x 103 Ibs.). Also, it should be noted that risk analysis of the development programs and operations is a required step before any "hard" conclusions may be drawn regarding the economic viability of the systems.

- The SSPS may be cost effective with respect to terrestrial systems by 1995. Since most terrestrial concepts depend upon non-renewable energy sources, the economic viability of SSPS may be enhanced relative to terrestrial systems beyond 1995. Adecision to fund a limited SSPS development program to further knowledge that would lead to a development decision is economically justified.
- SSPS would repay its total $44

billion DDT&E by CY 2013 with less than 60 units, were alternative terrestrial systems' generation cost 35 mills/kwh. This result requires an SSPS buildup rate that provides at least ten percent of U.S. installed generation capacity.

- The economic results do not include the relative social and environmental impacts that would be associated with the systems that were compared. Differences between terrestrial generation systems and the SSPS may be significant.

GEOSYNCHRONOUS POWERSAT

Statement of Richard W. Taylor, Vice President, The Boeing Company

Like Dr. Glaser's satellite, our Powersat would generate electricity in geosyncrhonous orbit and transmit that energy to Earth. The satellite would be illuminated more than 99 per cent of the time by sunlight undisturbed by Earth's atmosphere or weather.

The essential difference between our configuration and Dr. Glaser's resides in the method of converting this sunlight to electrical Power. We would utilize a heat engine converter rather than solar cells.

'Thousands of acres of plastic film mirrors much like those being developed under our ERDA contract would concentrate sunlight into a solar cavity. This heat would drive a set of helium gas turbines which, operating on a closed Brayton cycle, drive alternators. Waste heat is radiated into space.

We have emphasized turbine heat engine converters because we feel that they are achievable within a natural growth of existing technology. In other words, we believe that we have developed a concept which does not demand any great technological breakthrough.

The solar cell option, however, is attractive. If the necessary technological breakthroughs do occur, the economics of photovoltaic power satellites could compare favorably with the heat engine option. We will never know without taking the first steps.

Gentlemen, you must help the Executive Branch set its options. To some, the immediacy may not be apparent. But, if we wait until the crunch is upon us, we again will find that we will pay whatever we must to obtain energy.

And then, indeed, the price will be high-without any hope of amortizing the investment.

The studies must begin now. If we wait until the lights go out, until the last lump of coal and the last drop of oil are gone, we-and our children-will be caught bundled in longjohns reaching for alternate sources of energy which won't be there.

RECORDS OF THE HEARINGS

One of the staff of the Committee told the L-5 News that they expect to be able to make the complete records of the hearings available to the public in the very near future. Those interested should write to the Ad Hoc Subcommittee on Aerospace Technology and National Needs, U.S. Senate, Washington, D.C. *20510.*

HIGH EARTH ORBIT PLASMA ENVIRONMENT

People tend to overlook the fact that large spacecraft, both for space colonies and the satellite solar power spacecraft, do not operate in a vacuum, but in a natural plasma. My own work in magnetospheric dynamics has forced me to become knowledgeable in the general field of electrostatic charging on space-craft. A vehicle at geosynchronous orbit can charge to hundreds of volts negative in the sunlight and as high as 14,000 volts negative in eclipse. Due to plasma inter-actions, these potentials are with respect to the distant plasma as a zero reference. Such potentials might affect surface erosion due to ion bombardment but probably do no other damage. However, the same mechanism of spacecraft-plasma interaction can charge different parts of the spacecraft to different potentials. In general, the sunlit side will be held to small potential's due to emission of photo-electrons and the dark side will try to charge to about the temperature of the ambient electrons (i.e. about 10,000 volts). This differential charging can and does cause serious difficulties. Discharges occur which have been shown to destroy amplifiers, logic subsystems, and, in one case, probably caused the complete failure of geosynchronous spacecraft. Possible cures are a current research topic of much interest. The brute force solution of surrounding a spacecraft with a conducting coating is not practical for anything except small scientific spacecraft -even then, the cost of coating solar cells is enormous.

My colleagues, E. Whipple and D. Reasoner, are interested in both SSPS and space colony vehicles. Our initial studies indicate that the SSPS will have much more difficulty with charging than other spacecraft because of its size. The ten-kilometer typical dimension of SSPS is midway between the ion-cyclotron and electron cyclotron radii at GSO. This causes electron shadowing which just doesn't occur on normal (one to ten meter) spacecraft. The SSPS also takes about three seconds to enter eclipse, and during that time large currents could flow from the sunlit to dark side. There are several other potential problem areas in addition to these which we are proposing to NASA to study in detail.

Many of the same problems apply to L-5. Even though the plasma environment is less severe on the average, still the lunar orbit passes through the earth's magnetic tail every month. The instruments left by the astronauts (Reasoner's CPLEE instrument in particular) measure these particles. Theoretical calculations based on the charging produced by the observed plasma show that dust migration induced in this way can easily account for the observed surface differences between the front and back sides of the moon. (Note the front side of the moon is always sunlit when in the geomagnetic tail. The far side is then always dark. A space colony would be similar in orientation.)

I do not expect that the plasma-spacecraft interaction will be impossible to solve, but it is another area that must be explored before billions are committed to hardware.

Sherman E. DeForest

WASHINGTON VOLUNTEERS NEEDED

A recent "public" meeting of ERDA's General Advisory Committee was held February 4 and 5. ERDA's notice of the meeting was not released until February 2, and did not reach the L-5 Society in the mail until February 12. It would be helpful for ERDA to announce its public meetings somewhat more in advance than this.

Until ERDA's policy is changed, a volunteer in Washington is needed who can check with ERDA's Office of Public Affairs every day and who will assign local L-5 members to attend and report on these meetings.

The meeting of February 4 and 5 was of special interest as the topic of discussion was the ERDA fiscal '77 budget. Due to an administrative over-sight, the budget failed to include funds for several ongoing NASA ground and space-based solar power research projects which had been transferred to ERDA for fiscal '77. In Senate hearings January 21, 1976, John Teem, Assistant Administrator for Solar, Geothermal and Advanced Energy Systems, in response to questioning by Sen. Wendell Ford (D-Kentucky), testified that he had not been informed that these projects had been shifted from NASA to his authority until the previous week.

In Tucson, February 13, Senator Barry Goldwater (R-Arizona), when asked about the problem of funding the solar power satellite projects now that they have been transferred to ERDA, said, "Well, we're going to take that up next week when I'm back."

TEEM RESIGNS

President Ford has accepted the resignation of Dr. John M. Teem, Assistant Administrator for Solar, Geothermal and Advanced Energy Systems, effective January 31, 1976.

In his letter of resignation to the President, Dr. Teem said he was leaving ERDA "for several pressing personal reasons." He said he had no plans for the immediate future.

Dr. John M. Teem had been Assistant Administrator for Solar, Geothermal and Advanced Energy Systems, Energy

Research and Development Administration (ERDA), since his confirmation by the Senate on March 19, 1975. The President nominated him to the position on March 4.

He had been responsible for organizing, planning, and directing Federal programs in solar energy (direct thermal applications, solar-electric, and bioconversion to fuels), geothermal energy, fusion energy (magnetic confinement) and research programs in basic energy sciences (materials, molecular, mathematical, geological, and nuclear) and in high energy physics. He served as Chairman of the Geothermal Advisory Council and of the Laser Planning and Coordination Group, advising the ERDA Administrator.

Dr. Seamans appointed Dr. Robert L. Hirsch Acting Assistant Administrator for Solar, Geothermal and Advanced Energy Systems. Dr. Hirsch has been Director, Division of Controlled Thermonuclear Research since 1972. He joined the Atomic Energy Commission in 1968 after working on space power systems at Atomics International and experimental plasma physics at the ITT Industrial Laboratories.

ERDA NUCLEAR ENERGY PROGRAM: THE BREEDER

A new division was created in the Energy Research and Development Administration (ERDA) to facilitate development of the Liquid Metal Fast Breeder Reactor (LMFBR) program as a viable means of energy production for the future.

The elevation of the LMFBR program to full division status reflects both the importance assigned to the program by ERDA and the Government's determination to carry the program forward with proper safeguards and sound environmental considerations. Dr. Seamans Jr., Administrator of ERDA, has concluded that "a continued strong research effort in the LMFBR program and supporting programs would provide sufficient data by 1986 for ERDA to make a decision on the acceptability of widespread commercial deployment of such advanced nuclear plants."

Unfortunately, ERDA has not recognized the feasibility of solar satellite power stations (SSPS), which provide a more economical, far-reaching, and environmentally integrated plan for continued growth and expansion of energy capabilities. As of yet, no ERDA funds have been appropriated for research and development of the SSPS system.

ERDA NAMES SPACE MANUFACTURING COORDINATOR

January 20, 1976, H. H. Marvin, Director of ERDA's Division of Solar Energy, announced the assignment of H. Richard Blieden, Assistant Director for Solar Energy Applications, to act as coordinator for contacts on "the construction of satellite solar power stations within orbiting manufacturing facilities."

ERDA POSTPONES DENVER NATIONAL ENERGY R&D PUBLIC MEETING

The Energy Research and Development Administration has postponed the public meeting on its national energy R&D plan scheduled for Denver on March 3-4 because of a delay in publication of the updated 1976 version of the plan.

The plan, "A National Plan for Energy Research, Development and Demonstration: Creating Energy Choices for the Future," was previously scheduled for publication in late January, allowing time for public examination of the plan before commenting upon it at the Denver meeting in March. But publication is now expected in March, so the Denver public meeting will be rescheduled a month or more after that. A new date will be announced.

ERDA's plan was first presented to the President and Congress last June. It is updated every year in connection with the President's submission of new budget requests, including ERDA's. It reflects the agency's considerations of whatever changes may have taken place in the energy R&D picture. This includes public comment upon the plan as registered, for example, in the series of public meetings ERDA holds on the plan. Denver is the third public meeting in the series.

Delay in publication of the updated version of the plan results from an extended amount of time required to complete the process of review involving more than 20 agencies within the Executive Branch.

ECONOMIC ANALYSIS SUBMITTED TO FEA

A detailed economic analysis of the space industrialization/habitation approach to solar power satellite manufacture was recently submitted to the Federal Energy Administration. The author, Mark Hopkins, is currently pursuing a Ph.D. in economics at Harvard. He has done work in cliometrics (mathematical modeling of history), in association with Fogel and Engleman, authors of *Time on the Cross.* He was a participant in the NASA/ARC/Stanford Summer Study on Space Colonization. Copies of the analysis are available to L-5 Society members. As it is a lengthy document, we would appreciate a donation of $4 to cover copying and mailing expenses.

JOINT FASST-L-5 SOCIETY PRESENTATION PLANNED

The National Congress on Aerospace Education is holding a convention April 2 in Las Vegas and has scheduled presentations by FASST and the L-5 Society. As an economy move FASST and L-5 plan to send one of the Tucson L-5 staff to represent both organizations, and split the transportation cost between them. A contribution of $50 would cover the Society's half of the cost, and would be most appreciated by both organizations!

O'NEILL'S NEWSLETTER

An article by G. K. O'Neill, "Settlers in Space," is scheduled for publication in the World Book Encyclopedia Annual, Science Year 1976, Chicago, September 1976.

There was an article in the Philadelphia Inquirer's Today Magazine, November 23, 1975, "Colonies in Space," by Joel Shurkin.

Early in 1975, Princeton University discontinued its clipping service. As a result, we do not know of newspaper or magazine articles on space colonization unless clippings are sent to us by interested friends. We would appreciate receiving such clippings in order to maintain an adequate record.

People who wish to give lectures may wish to get in touch with us. Slides, reference documents and a 4-1/2 minute animated movie will be made available to lecturers by our office, at cost, if we are given adequate notice (2-3 weeks) of the need.

Lectures presently scheduled:

University of Michigan, Ann Arbor, Michigan, Tuesday, March 2.

American Institute of Aeronautics and Astronautics/Lunar Science Institute Lecture at Johnson Space Center, Houston, Texas, Tuesday, April 13.

Frontiers of Science Lecture, University of Florida, Gainesville, Florida, Wednesday, April 14.

Lecture in connection with National Bicentennial and State Centennial Celebration, University of Colorado, Boulder, Colorado, Wednesday, April 28.

The Princeton group now consists of: Gerard K. O'Neill, Brian O'Leary, Pam Csira, Roger Miles (volunteer), Virginia (Ginie) Reynolds, Ruth Miles (1/2 time), Fran Arnold (1/4 time), David (Hank) Bushnell (volunteer, 1/4 time), Sarah Michlem (volunteer, 1/4 time), and is supplemented by an important group of volunteer workers, some at a considerable distance from Princeton.

All members of the Princeton group, with the exception of G. K. O'Neill, expect to be in residence at Princeton during the remainder of the 1975-76 academic year. He will be in the Palo Alto area in February and March, taking shifts on a high-energy physics experiment. During that time he can be available only rarely for lectures or interviews; any inquiries should be addressed to Princeton.

Those interested in receiving the newsletter on O'Neill's activities should write Virginia Reynolds, P.O. Box 708, Princeton, New Jersey 08540.

IMMORTALITY

The prospect of traveling through the universe and colonizing and creating new worlds is terribly exciting. It offers the promise of fantastic adventures, untold riches, and pleasures beyond comprehension. But space travel is not for small minds encased in fragile, sickly bodies of limited lifespan. Only immortals, or those moving toward immortality, will have the determination to explore the illimitable reaches of the universe. The sooner we realize this the faster things will happen.

As I see it, the key to future progress is to remove the crushing burden of mortality from the human psyche, at least to some degree. This can be accomplished by the active pursuit of immortality-the control of aging, the extension of youth, and the postponement of death.

Fortunately, recent scientific advances indicate that these goals can probably be achieved. But even the possibility of their achievement will have a profoundly positive effect on human thought and behavior. It will free people to unleash the full force of their imaginations and to view the future as a vehicle for the attainment of their most cherished dreams.

Saul Kent
Woodstock, N.Y.

Saul Kent has published a book, Future *Sex, Warner Pap. Lib., 1974, and writes a column called 'New Frontiers of Research" for* Geriatrics *magazine.*

INSIDE THE L-5 SOCIETY

WASHINGTON ACTIVITIES

Seven L-5 members went to Washington for the Senate hearings. They were Edward R. Finch, Dan McHugh, and Brad Shaheen from the New York Metropolitan Chapter; Eric Drexler of Cambridge, Massachusetts; Richard C. Mesce of Los Angeles, California; and Keith and Carolyn Henson of Tucson, Arizona.

The evening of January 19, the Committee for the Future and the L-5 Society held a party in honor of those who have been working for what Barbara Hubbard of the CFF calls "a choiceful future." Especially honored guests were Jesco von Puttkamer, who is coordinating space industrialization studies at NASA; Nichelle Nicholes, communications officer on the Enterprise; Carl H. Madden, Chief Economist of the U.S. Chamber of Commerce; Neil Hosenball, Chief Counsel for NASA; Edward Cornish, editor of the *Futurist;* Charles Lombard, Minority Counsel for the Senate Aeronautical and Space Sciences Committee; G. Harry Stine, author of *The Third Industrial Revolution,* and George S. Robinson, Assistant General Counsel for the Smithsonian, whose recent book, *Living in Space,* will be reviewed in the next L-5 News.

Our thanks to the Committee for the Future and R. F. Friedman for their help in covering the expenses for two L-5 staffers to come to Washington.

L-5 ALLIES

January 20, 1976, a committee of four L-5 members, Dan McHugh of New York, New York; Eric Drexler of Cambridge, Massachusetts, and Keith and Carolyn Henson of Tucson, Arizona, met with Charles C. Hewitt, Director of the National Space Institute, and Neil Ruzic, one of its founders and the author of "The Case for Going to the Moon." The group decided that cooperation between the two organizations would be fruitful. Since then the National Space Institute has been especially helpful by providing us with the transcript of a question and answer period with NASA's John Yardly, reported elsewhere in this newsletter. The L-5 News, in return, has aided them in preparing their upcoming newsletter. Those interested in receiving it should write to:

National Space Institute
1911 N. Fort Meyer Dr., Suite 408
Arlington, VA 22209

MEMBERSHIP SERVICES

Charles Barnard of Menomonie, Wisconsin, is designing the L-5 Society membership card and a general purpose poster which can be used to advertise local meetings and lectures. The Society continues to offer slides for use in lectures; they cost about 35 cents each to make. A large set of 32 slides is available, and a smaller set of 16. Both sets include pictures of Earth seen from space, the moon, the Earth seen with the moon's horizon in the foreground, the Boeing and Arthur D. Little power satellite concepts, slides of the illustrations in G. K. O'Neill's testimony before Congress last July, the cover of *Science* (December 5, 1975), illustrations of the "Stanford Torus," a space shuttle in flight, and a diagram showing the Earth/Moon system and libration points. The larger set includes a number of schematics from the NASA/ ARC-Stanford Summer Study on Space Colonization.

The L-5 Society appreciates donations to cover the expense of providing slides.

GIFT SUBSCRIPTIONS

Our thanks to people who sent in gift Groundhog Day subscriptions. One member asked whether a student buying a subscription for a nonstudent was entitled to the student rate. The answer is, "Yes."

The next big holiday approaches with the speed of a government bureaucrat trying to remedy an oversight in the fiscal '77 budget: you guessed it, April Fool's Day.

ARTICLES AND NEWS

The L-5 staff welcomes unsolicited articles and news. We would like to especially thank the offices of Rep. Morris Udall (D-Arizona) and Sen. Barry Goldwater (R-Arizona), the staff of the Senate Aeronautical and Space Sciences Committee, and the National Space Institute for their assistance in gathering news for this issue.

L-5 SOCIETY MEMBERSHIP FORM (PLEASE TYPE OR PRINT)

NAME: _____

COMPLETE ADDRESS: _____

AFFILIATION (OPTIONAL): _____

TITLE or POSITION (OPTIONAL): _____

I am - - a m n o t - - interested in being active locally.

___ Back issues available, $1.OO each.

___ Please enroll me as an L-5 Society Member. I am enclosing a check for $ _____ (regular membership $20.00: student membership $10.00).

___ Please enter an institutional membership to receive the "L-5 News" for our organization/library as indicated above. We enclose a check for $ _____ (institutional or library membership $100; special library subscription with one month delayed mailing $20).

COMMENTS AND REQUESTS _____

L-5 NEWS

L-5 Society
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Tucson, Arizona 85719
(602) 622-1344

Please send in address changes as soon as possible. Type or print clearly and include Zip Code.

L-5 STAFF

The L-5 Staff this month included Eric Drexler of Cambridge, Massachusetts, and Tucsonans Julie Rogers, Andrew Germaine, Janet Duvê, Daniel Lomax, and Keith and Carolyn Henson.

Several more L-5 activists from around the country are planning to put in time on the staff this spring and summer. We await their arrival impatiently as there seems to be an unending supply of work at the office!

Keith and Carolyn Henson renew their offer of free room and board for visiting L-5 staff in the balmy winter resort of Tucson.

SPREADING THE WORD

The L-5 staff would like to thank Michael Michaud of Washington, D.C., Jay Huebner of Jacsonville, Florida, G. K. O'Neill of Princeton, New Jersey, the *Mercury Messenger,* and FASST for their work in bringing the L-5 Society to the attention of the public.

A large portion of our new members have come in as a result of letters to the editor in scientific and professional publications. It is more effective for L-5 members who are not on the newsletter staff to submit such letters (otherwise we can be accused of "blowing our own horn").

By the way, February 2 (Groundhog Day) was a historic date for us: we received a letter addressed:

The L-5 Society
Tucson
Arizona
U.S.A.

Our thanks to the U.S. Post Office for excellent service!

space: unretouched photo

ERRATA

L-5 members who received copies of William Agosto's paper, "Space Production of Solar Power Stations," which were marked "draft copy" should make the following changes:

Page	*Change*
4	10,000 times (to) 3,000 times
8	5 watt tube (to) 5 KW tube
9	80% efficient (to) 85% efficient
	5 watt amplitrons (to) 5 KW amplitrons
	two schottky barrier diodes (to) a schottky barrier diode

Copies which were not marked "draft copy" have already been corrected.

VERIFICATION OF NEWS

Currently there is a degree of doubt as to whether there will be any government funding to continue research into solar power satellites in fiscal 1977. A thorough treatment of this issue will be delayed at least until the next issue.

The L-5 staff has a number of documents and a bushel of rumors on the subject. Several L-5 members are researching the problem; in addition, we await some administrative decisions on the part of ERDA which could prevent any funding discontinuities in these ongoing research projects.

Although it is the practice of major news magazines to include rumors, speculation, leaked documents, and information attributed only to "high government sources," the L-5 News reserves such "information" for use only as background material for our researchers.

XEROXES

Xerox copies of the newsletter have been responsible for many new members. We appreciate those who spread the news about the L-5 Society.

However, there is a certain large bureaucracy in Washington which receives two complimentary copies each month, has no members, and yet several dozen of its staff say they read the newsletter month after month.

A similar situation holds for a certain large corporation headquartered in Washington.

Sample copies are O.K., but please, guys, join-we need the money. (We'll keep your membership secret if you want.) The L-5 News is supported only by membership fees, free labor, and donated office space.

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