L5 NEWS

November 1978

L-5 NEWS

A PUBLICATION OF THE L-5 SOCIETY

VOL. 3, NUMBER 11, NOVEMBER 1978

In this issue:

Publication office: the L-5 Society, 1060 E. Elm, Tucson, Arizona 85719. Published monthly. Subscription: ¢12.00 per year, included in dues ($20.00 per year, students $15.00 per year). Second class postage paid at Tucson, Arizona and additional offices.

Membership Services: L-5 Society, 1620 N. Park Avenue, Tucson, Arizona 85719. Telephone: 602/622-6351.

Change of address notices, undeliverable copies, orders for subscriptions, and other mail items are to be sent to:
L-5 Society
Membership Services
1620 N. Park
Tucson, AZ 85719

Cover: Record breaking second crew of Salyut-6, Vladimir Kovalyonok and Aleksandr Ivanchenkov, who hosted visits by Polish and East German "guest cosmonauts". (Photo courtesy **Novasti.**) (*Note this is a mockup of Salyut.*)

Russia's "Guest Cosmonaut" Program
A Commentary

Triumphant return of Czech cosmonaut Vladimir Remek. (Photo courtesy Orbis.)

by Jim Oberg

With the end of the recent token space flights by East European cosmonauts, Moscow has once again demonstrated its skill in the political exploitation of space events. New 'space firsts' have been racked up, and world attention has again been focused on Soviet space achievements. But Western observers have been trying to determine the real significance and purpose of this series of cosmonaut launchings.

These international flights have been made as an adjunct to the ongoing expeditions involving the Salyut-6 space station. For almost a year, Soviet piloted and human-related spacecraft have been launched to orbit at a rate of about one per month. Old American records have been shattered, and new Soviet launches break records set only months before by previous Russian space crews.

But however important these long flights are, they clearly do not have the glamour of the 'foreign cosmonauts', who have attracted attention to an otherwise dull space expedition.

Three week-long "guest-cosmonaut" flights were made, one each in March, June, and August. On Soyuz-28, Czech Air Force pilot Vladimir Remek was co-pilot; on Soyuz-30, it was Polish pilot Miroslaw Hermaszewski; on Soyuz-31, it was East German Air Force officer Sigmund Jahn. All the actual flying was done by experienced Soviet cosmonauts.

Superficially, the missions looked like purely political 'hitch-hiker' stunts. They seemed to have been designed solely for the purpose of strengthening the hands of the pro-Soviet regimes in each country. Nothing appeared to have been done that could not just as easily have been done by all-Russian crews. Indeed, little was accomplished that would have been missed if the flights had not taken place at all.

For some mysterious reason probably connected with low level of training of the pilots (the East Europeans each got little more than a year of preparation, while Russians have had from four to ten years of training), all three flights were launched at nearly the same time of day, late in the afternoon. Since this condition is only met once every two months, the requirement often dictated that the flights occur at inconvenient and useless phases of the marathon expeditions.

That is, the Czech flight was launched only a week before the end of the 96-day expedition last March, a timing which could have had no logistical, psychological, or practical justification. The Polish flight was launched only days after the beginning of the second long-term expedition, again without any practical need. Only in the case of the German flight was there anything substantial accomplished, when the visiting crew left their new "Soyuz" craft and returned to Earth in the old Soyuz used by the Russians in June. If there had been no "foreign cosmonaut" program at all, only the last of these three flights need ever have been flown.

The purely symbolic nature of these flights is further underscored by the fact that only one flight will be made for each Soviet-bloc country. In case of accidents, two pilots from each country underwent training. The first three pairs arrived in Moscow in December 1976, and new pairs of candidates from Hungary, Romania, Mongolia, Bulgaria, and Cuba began training last March, but only one from each country will fly.

Considering the political gains to be made, it would not be too surprising if the Cuban space pilot were selected on racial as well as national and ideological grounds. Moscow would be understandably delighted if the first black in space were to be launched on board a Soviet spaceship.

In many ways, the foreign cosmonaut program is reminiscent of the "woman in space" stunt fifteen years ago. Apparently on direct Kremlin orders, the Soviet space program waived all standards of flying skill and picked a popular young factory worker to receive a minimum amount of space training. Valentia Tereshkova made her headline-grabbing flight, after which her backup girls were fired and she was grounded forever, assigned to political and public relations duties for the rest of her life. The same fates probably await the East European cosmonauts.

When the "guest cosmonaut" program was first announced in mid-1976, Western observers naturally assumed that the East European co-pilots would be the civilian scientists and engineers who had for years been working with their Soviet colleagues on cooperative unpiloted space activities. They were clearly the most qualified for conducting useful space experiments.

But on the other hand, the East European intelligentsia is generally considered politically unreliable by their governments. A defection from the "guest cosmonaut" program, especially after the flight, would ruin the whole value of the effort. So instead of *qualified* individuals, *safe* individuals were chosen.

Remek's background seems typical of these standards. He is a staunch member of the Czech communist establishment, the son of the deputy defense minister. After the Russian invasion of 1968, flight cadet Remek (he then was only 19) was part of a small cadre of pro-Soviet loyalists who toured armed forces units lecturing on why the Soviet takeover was a blessing. And prior to his selection as a cosmonaut-trainee, he had spent many years in Soviet military schools and institutes.

Hermaszewski, too, is a member of the Polish communist ruling class. His brother is a top Air Force general. The background of the East German is believed to be similar.

Little is known about the backup cosmonauts from Eastern Europe, except that their spaceflight chances are now zero. The Czech backup Oldrich Pelczak, the Polish backup Zenon Jankowski, and the East German backup Eberhard Kollner have returned home, their usefulness ended and their once in a lifetime chance for a space mission now aborted.

Why didn't the Russians allow both Remek and Pelczak to fly without a Soviet pilot on board? The two Czechs would have landed their spaceship in West Germany!

The reception of Remek in Czechoslovakia was not all that the political theorists had hoped, since the Czechs have developed a sharp sense of humor about Soviet domination. Remek became the butt of numerous pointed jokes and ridicule.

Why, for example; didn't the Russians allow **both** Remek and Pelczak to fly the Soyuz-28 mission without a Soviet pilot on board? Wags answered that in that case, the two Czechs would have landed their spaceship in West Germany.

And why did Remek come back from space with red hands? Baffled and worried space doctors inquired urgently about the cause of this hitherto unknown space malady, but Remek explained it: "Well, in space, whenever I reached for this or that switch, the Russians cried "Don't touch that!" and slapped my hands."

The timing of the present Soviet "guest cosmonaut" program does not seem to have been an accident. It coincides with the beginnings of West European activities leading up to the launch of the first astronauts from Western Europe for Spacelab flights in 1981.

After a year of screening, three Europeans have already begun space training in Europe and America. They are all qualified engineers and scientists: Ulf Merbold from West Germany, Wubbo Oeckels from Holland, and Claude Nicollier from Switzerland. They will take turns flying on sequential Space Shuttle missions which carry European Spacelab experiments.

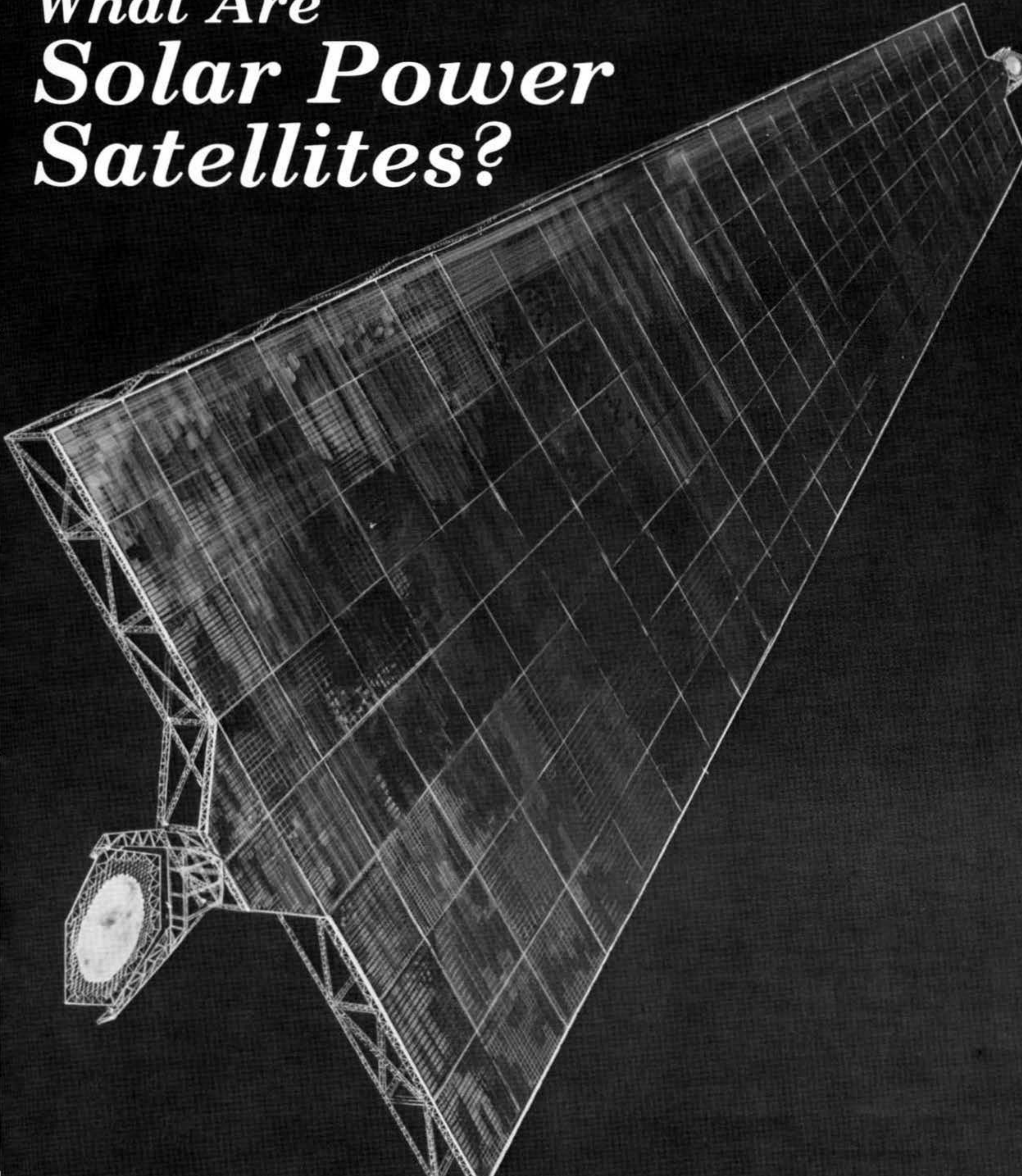
These future European astronauts achieved their status through professional standards, and are going to be as fully trained as their American colleagues. They will make genuine contributions to the success of the Spacelab missions. In these and other ways, this program is markedly superior to the Soviet "guest cosmonaut" program, with one major qualification: *the Russians did it first.*

Curiously, despite the Soviet priority for the selection of foreign nationalities for one-time space debuts, Moscow has still exluded many of its own domestic minorities. No cosmonauts have been (or are likely to be) Latvian, or Armenian, or Kazakh, or Jewish, or any other non-Slavic ethnic group. But for the propaganda value, additional foreign cosmonauts may well be selected in the coming years from North Korea, Vietnam, Albania, Ethiopia, the Palestinians, and other useful nationalities.

Despite the symbolic beginnings of this "foreign spaceman" program, it may yet continue and expand into something more practical and justifiable. The American Spacelab program of the 1980's,with its "space quests" from Western Europe, Japan, Australia and other space-minded countries, may prod Moscow into expanding its own program in a more substantive way. And the suggested Shuttle-Salyut docking in 1982-1983 may provide justification for Russia and America actually exchanging astronaut-trainees for that flight. The procedures and practical considerations have already been worked out.

Those possibilities may fully justify the otherwise purely public-relations approach exemplified by Moscow's current "guest cosmonaut" stunts. Symbols created for one purpose often have a life of their own, and "breaking the ice" for foreign nationals in space may be a valuable psychological development in the history of space exploration. Short-term Soviet propaganda benefits and motivations may fade as the long term world benefits become evident.

What Are *Solar Power Satellites?*



A solar power satellite 20 km long and 5 km wide. The circular structures on each end are microwave antennas.

What Are Solar Power Satellites?

by Carolyn Henson

Solar power satellites may someday catch the Sun's energy and beam it to Earth.

How will they collect energy?

They might use silicon or gallium arsenide or "sandwich" solar cells to convert sunlight directly to electricity. Or they might convert sunlight to heat which can power thermionic converters or turbogenerators. There are other possible ways, as well.

How will they get the energy back to Earth?

One way is with microwave beams, another is by infrared laser. Both can pass through clouds, although a rain storm can block the infrared light.

Once the energy reaches Earth it must be converted to electricity. Microwaves are converted by rectifying antennas. An infrared beam might be fed into a "reverse laser" or specially tailored solar cells which would convert coherent light into electricity.

How intense would the microwave beam be?

At the center of the beam it would be 23 milliwatts/cm^2 (A milliwatt is a thousandth of a watt. Noonday desert sunlight is about 0.1 watt/cm^2.) Three kilometers from the center of the beam the intensity falls to 10mw/cm^2, the US industrial standard for safe exposure. The most stringent microwave guideline in the world is 0.01 mw/cm^2. This level is reached about 13 km from the center of the beam. This level could be reached far closer to the center of the beam by using slightly more costly transmitter optics.

You may wonder how the microwave antennas could compete with ground solar power plants. (After all, the microwaves the antenna receives are less than a quarter of maximum sunlight intensity.) First, the microwaves are converted back to electricity about 90% efficiency, whereas sunlight is unlikely to be able to be converted at any better than 20% to 30% efficiency. Second, the microwaves come in at the same intensity day and night all year long. Thus a given area of microwave antenna could provide 3 to 10 times as much electrical output as the best possible Earth based solar farm.

What would energy from a solar power satellite cost?

Researchers believe the capital cost, including the ground receiving station, would range between $1000 to $2000 per kilowatt installed capacity. This would be competitive with nuclear and ground-based solar power. However, it should be emphasized that these are estimated costs.

How large will solar power satellites be?

...power satellites are...a major stepping stone towards opening up the solar system for human habitation.

The most popular design at present would be almost 100km^2 — about the size of Manhatten island. A satellite that size would provide ten gigawatts (10 billion watts) of electricity. This is enough to power the entire city of New York with plenty to spare. Because of inherent optical limitations, to be economical a microwave style power satellite would have to be at least 25km^2 in area, transmitting 2.5 gigawatts. Some researchers have suggested the use of giant microwave mirrors in space as a way to deliver smaller power beams. Power satellites using laser transmission could also be much smaller.

Where will solar power satellites be located?

They might be placed in orbit where they will be continually, or almost continually, in the sun. Geosynchronous orbit has advantages because the satellite would always hover over the same place on Earth. There are several sun-synchronous orbits where the satellite circles Earth along or near the dawn-dusk line.

How will power satellites be built?

They might be prefabricated and shipped into orbit where space workers would build them.

Another possibility is that ores from the Moon or asteroids could be processed into raw materials in lunar or space factories. Power satellites, space craft, space habitats and more could be built in these factories. However power satellites are built, they are a major stepping stone towards opening up the solar system for human habitation.

Why do researchers believe solar power satellites could be the key to cheap and plentiful power?

First, sunlight in space is abundant — six to ten times as much per area as we receive on Earth. And it isn't interrupted — no long winter nights and rainy spells.

Second, space solar collectors can be made out of exceedingly light materials. In free fall they need only resist tidal forces, orbital perturbations, micrometeorites, solar wind and light pressure. Earth structures are subjected to gravity, wind, rain, hail, roosting birds (and their inevitable aftermath) and more.

Third, solar power satelites are a young technology. Remember how pocket calculator prices plummeted? Space transportation, solar cells, space processing, fabrication, construction, mining of extraterrestrial materials, and more are following the same trajectory.

We've told you what the solar power satellite is. But we left one thing out. It is also controversial. That's what the next pages are about.

This supplement published by the L-5 Society, 1620 N. Park, Tucson, AZ 85719

Solar Power Satellites: Boon or Boondoggle?

Solar power satellites (SPS) once inspired nothing worse than disbelief. But now that their technical feasibility has been established, anti-SPS forces have started doing their homework. Collected here are a series of pro and con statements. The individuals quoted were never all in the same room together. This "debate" is composed from statements made by Senator Charles Percy (R-IL), Garry DeLoss, a professional lobbyist with the Environmental Policy Center, Mark Gibson, who did a study of SPS at the University of Maryland; Gordon Woodcock, solar power satellite study manager for Boeing, and Carolyn Henson, editor, ***L-5 News.***

Are solar power satellites a boon or a boondoggle? Judge for yourself.

Mark Gibson

Estimated R&D costs, just to develop technology— $40-80 billion (JPL estimates $60 billion).

Estimated cost per satellite— $15 billion. (Peter Glaser quotes $7.6 billion for a 5 gigawatt satellite, other figures go as high as $40 billion.)

Total cost: about $500 billion!

Cost to develop the Heavy Lift Launch Vehicle is $10 billion, included in the R&D costs.

Cost per kilowatt estimated at $1000-1500/kw, in the range of other power sources (nuclear is $1100/kw). As Charles E. Hansen, director of International Business Services, points out in his Report on Economic and Technology Development of the SPS, the aerospace industry has a past record of underestimating costs of large projects. He suggests that we should expect the cost to be at least double the projected cost, raising the cost to $2000-3000/kw, well out of the competitive range.

The cost projections vary greatly between reports. The discrepancies make the validity of any of the figures rather doubtful.

Component costs — The percentages of the capital costs quoted for the receiving antenna costs are as follows: Peter Glaser — 17%, Johnson Space Flight Center — 42%, Marshall Space Flight Center — 8%. For a $7.6 billion 5 Gw satellite, Glaser predicts the receiving antenna to cost $1.3 billion. run at least $2 billion.

Transportation costs—The costs of propellants are assumed to be the same as today's costs. The cost of transporting materials is assumed to be $10-20/lb, while the present shuttle costs are $300/lb. Increases in transportation costs will significantly increase the total system energy costs as well as the total cost.

According to NASA, in order to be competitive with terrestrial systems, the SPS must meet all projected electricity demands by 2025. This means that 1120 **Gw (112 ten Gw SPS) must be installed at** an average implementation rate of 3.37/yr. Any lowering of the rate or the level of installed capacity would significantly increase costs. The systems could be cost-**effective at 300 Gw (30% of the electricity demands).**

All terrestrial cost comparisons with the SPS have been between solar power tower (which is not economical) with a back-up system and the SPS without a back-up system. This deflates the SPS costs while inflating the costs of ground-based systems. It also overlooks other viable, economic ground-based systems and decentralized energy systems.

NOTE: At present, the amount of energy produced that is converted into electricity is approaching 30%. (U.S.)

...the aerospace industry has a past record of underestimating costs of large projects.

Gordon Woodcock

The costs to develop the technology have been estimated at $150 to $250 million. Costs through engineering test units in space have been estimated at $3 to $6 billion. In fact, no one has proposed that 40 to 80 billion dollars of government funds be committed. These large sums represent the total development and industrialization investment required to build the first 10,000 megawatts of SPS generating capacity and also provide the industrial capacity to continue to install 10,000 megawatts per year indefinitely. Government funds need not be spent for all of this. If the SPS is economically sound, commercial investment would be expected to provide the bulk of the $40 to $80 billion.

Further, it is not presently proposed that this entire program be accomplished. The legislation now before Congress would fund sufficient technology and environmental research to enable a responsible evaluation as to whether such a program should be accomplished. The issue of the tens of billions of dollars arises out of confusion between (a) true technology research, and (b) the creation of sufficient industrial capacity to install generating capacity on a reasonable scale.

SPS proponents have included industrialization costs in candid statements of the total real costs involved in bringing a major new energy system into being. The problem has been candidness is accounting all identifiable costs rather than in SPS being an exceptionally high cost system. (Under the **bookkeeping rules usually adopted by distributed-energy enthusiasts — interest costs not considered — the construction of even just the first SPS at 40 to 80 billion dollars would be economically feasible. That is to say, if all of the presently — identified development costs were written off against a single SPS, it would pay for itself in about 30 years if interest costs were not considered.)**

Overruns have been experienced by the aerospace industry, particularly in weapons systems where the maintenance of a technological edge over the military competition is accorded more importance than minimizing costs. In fact, the propensity of the aerospace industry for cost overruns is no worse than that exhibited by construction of sports stadiums. Cost overruns do not arise from inability to estimate cost, but rather than a tendency of procurements agencies to change their minds about what they really want; from competitive bidding to beat the competition; and from poor management. In the case of the Boeing Company, about 75% of its business comes from delivering aircraft to commercial airlines at fixed price, with performance and delivery date guarantees, and in a market in which all development costs are incurred by Boeing and amortized against eventual delivery of 300-500 airplanes, most of which are not yet sold at the time the project is launched. If Boeing were not capable of accurately estimating costs, the company would have long since gone bankrupt.

It is important to recognize that solar power satellites have not yet entered the phase of competitive cost estimating in which under-bidding the competition is of significant importance. The cost estimates that have been published are those that have been calculated by the cost models.

Garry DeLoss

The supposedly objective cost estimates for the SPS are being made by the corporations, NASA space flight centers, consulting firms, and academicians who have a vested interest in encouraging a massive government commitment to SPS. This leads to a cost estimates that are mere self-fulfilling prophesies, or what one critic, Dr. John Cummings of the Electric Power Research Institute, calls 'legislating all the answers.' Richard Caputo, who directed a two-year Jet Propulsion Laboratory (JPL) study of the SPS recognized the same pattern of behavior, and characterizes the cost estimates he examined as based on 'assumptions of success' rather than a real data base. The SPS proponents appear to begin by calculating the cost goal which the total SPS system must meet to compete with other energy sources, and then allocate that cost goal among the various subsystems of the SPS. Hence, they tend to reach similar conclusions about the total cost of the SPS based on widely varying estimates about the costs of the sub-systems.

GW

The idea that the current SPS cost estimates are simply allocations of cost goals probably came from papers published by myself and Gregory in about 1974, in which such allocations were shown, and argued to be attainable. This allocation of goals, by the way, is widely used; it is called "Design-to-Cost." Design-to-Cost analysis defines, on an overall economic basis, a set of cost targets for a system or a project. These targets are then allocated against elements of the system, and the design activity attempts to meet, or beat, the allocated targets. SPS cost figures published in 1976-78 are cost estimates and not target figures. The present cost estimates indicate that SPS electricity will be competitive with the centralized sources, e.g., breeder reactors and fusion, with which SPS should be compared. It is nonsense to compare SPS with rooftop solar collectors because these systems address different segments of the energy market.

MG

Energy payback period—estimates go from a low of 3 years to a high of 16 years. Gordon Woodcock:

A recent JPL study (900-805, Aug. 1978) determined energy payback periods of 0.7 to 1.6 years; Boeing estimates are 1 to 3 years. The consumption of rocket propellants to launch one SPS per year is equivalent to less than 1/1000th of current U.S. fossil fuel consumption. Conversion of natural gas (a supposedly scarce resource), that is now **wasted by burning at the wellheads**, into propellants would suffice to launch **more than 50** SPS's per year.

It is nonsense to compare SPS with rooftop solar collectors because these systems address different segments of the energy market.

One article alleged a high use of platinum. That SPS design was abandoned over five years ago. Current designs use **no** platinum and very little aluminum. Small quantities of refractory metals are used in certain speciality parts. Critical resource consumption is miniscule compared to that for most other energy options and especially so compared to that for ground-based solar. The **principal raw material requirements for** current SPS designs are sand (for silicon, glass, and concrete) and steel, which has replaced aluminum in the ground receiver support structure. Requirements for foreign-supplied resources likewise have been minimized.

MG

In order to put an SPS in space, new equipment must be developed, including a Heavy Lift Launch Vehicle which is to be five times the size of today's rockets. The cost is estimated by Boeing to be $10 billion. Large launching complexes are needed to handle the weight of the rockets. Some sort of automatic assembly "factories" as well as other equipment for stock flights must be developed.

To put enough SPS in orbit to meet our electricity needs, there will have to be 4-6 flights daily for 30 plus years. Grumman estimates 150 launches per satellite, using a rocket with a carrying capacity of 400,000 lbs. NASA's present shuttle has a carrying capacity of 65,000 lbs. Other estimates go as high as 500 flights/satellite.

GW

It is sometimes argued that space-based arrays must be more expensive than ground-based arrays. The argument is based on the premise that something technically sophisticated must cost more than something simpler. One can, however, buy a scientific pocket calculator for fewer 1978 dollars than one could buy a high-quality slide rule in 1968 dollars. As a result, one can no longer buy a high quality slide rule at all. Since solar cells used in the SPS will be of lighter weight than those presently under development for ground-based service, they will therefore consume less resources and ultimately be lower in cost. Further, for a ground based system, the structural support systems will dominate the ultimate cost of photovoltaics; whereas in space, structural systems are minimized due to lack of gravity and wind. Space-based photovoltaic systems should ultimately become much cheaper in cost per unit area as well as collecting about six times as much energy per unit area as the equivalent ground-based system.

GD

The SPS proponents prefer to set up the straw man of a centralized solar energy powerplant alternative and then knock it down by claiming high costs for land acquisition, electricity storage, and transmission lines up to 2,000 miles long from solar powerplants concentrated in the Southwestern states. Even the most objective of the SPS studies, the report by JPL, compared the SPS with what its director has described as the 'worst solar terrestrial options,' centralized solar energy powerplants at sites remote from their markets . . . The JPL study concluded that the SPS would cost more than a land-based, centralized solar energy powerplant using a solar thermal process and fossil fuel backup system, and about the same as a centralized photovoltaic solar energy system with a fossil fuel backup system.

If the SPS costs were compared with decentralized solar electric systems using photovoltaic cells, the SPS would look

(Continued page 9)

Arthur Kantrowitz is seen here against a backdrop of the Andromeda galaxy. (Photo courtesy Charles Divine.)

The Solar Power Satellite in the Time of Timidity

by Arthur Kantrowitz

The time of timidity is best defined by contrast with the idea of progress. Progress to my mind is best described by the distinguished philosopher of science, Sir Karl Popper's description of the scientific method, namely it is trial and the elimination of error. By contrast, in the time of timidity we eliminate the errors first. Before we act in the time of timidity we will insist on a certainty human beings can never attain.

Perhaps there is one way that predictability can be achieved. If we make life hard enough for the creative people among us, then maybe they will not endanger the technological forecaster. Contrast this with a typical time of technological progress. Adlai Stevenson, in an address he made inaugurating a Xerox research laboratory, told a story about how F.D.R. in 1937 wanted to get the best estimate of the scientific community as to what was coming in the next decade. Accordingly, he summoned a committee of

Progress is best described by . . . trial and elimination of error . . . In the time of timidity we eliminate the errors first.

the best scientists in the country, and as Stevenson describes the result, he found himself "on a par with the greatest scientific minds of the time, —for I, too, failed to foresee nuclear energy, antibiotics, radar, the electronic computer and rocketry." In a time of timidity technological forecasting is not so frequently disrupted by technological surprise, thus the elimination of error before trial is a doctrine which carries within itself the basis for its plausability. If, indeed, we become a stagnant society, then predictability will at last be accessible to us. There are two caveats that I'd like to be sure you remember. First, that perhaps the domain of timidity might not be all inclusive. Unless the idea of progress can be stamped out everywhere we must expect that technological surprise might still intrude from those barbarian domains where the idea still survives. The second caveat is that in the nearly stagnant society any residual action may result in irreversible side effects whereas in a time of technological progress unanticipated side effects, which do not appear until years later, can be more readily dealt with by a technology which will have greatly advanced in the meanwhile. Thus, there are important forces that drive the nearly stagnant society toward complete stagnation or more hopefully toward a renewal of vigorous technological progress.

In my opinion the most important statement that has been made on the solar power satellite, after Peter Glaser's original proposition, is the carefully considered judgement on the feasibility of that proposition to be found in Amory Lovins' article in **Foreign Affairs,** October 1976, which made the whole thing clear by the statement: "The schemes that dominate ERDA's solar research budget—such as making electricity from huge collectors in the desert, or from temperature differences in the oceans, or from Brooklyn Bridge-like satellites in space—do not satisfy our criteria, for they are ingenious high-technology ways to supply energy in a form and at a scale inappropriate to most end-use needs. Not all solar technologies are soft. Nor, for the same reason, is nuclear fusion a soft technology."

It is important to understand that in this statement we hear the expression of a categorical imperative reminiscent of religious imperatives. This is a view which today has wide currency in Washington and in particular in DOE. I would quote the Department of Energy document: "Satellite Power System (SPS) Concept Development and Evaluation Program Plan, July 1977 — August 1980," dated February 1978. This document describes the most important issue of societal interactions of the solar power satellite concept as "the centralization of power sources, and hence society . . ." The proposition to reverse the centralization of society and to deny the United States energy opportunities because they do not fit the quasi-religious views of a small minority on the centralization of society constitutes a tyranny that the majority of the United States needs to understand far better than it does today.

My prediction is . . . that the time of timidity will destroy the solar power statellite OR . . . the solar power satellite will destroy the age of timidity.

In moving toward the decision to build a demonstration Solar Power Satellite we must, of course, assess the required technology and possible side effects as well as we can. However, we must anticipate that there will be considerable scientific and technological uncertainty regarding these assessments. We can expect a continuation of the partisan invasion of scientific uncertainty we have already seen. One of the problems of our time is that we lack any credible process for dealing with the high level of noise created by this partisan invasion. When there is active partisanship, partisan voices tend to obscure what scientific information we do possess. The development of due process for dealing with scientific controversy would make an important contribution by dispelling some of the fear of the unknown which is characteristic of the time of timidity.

Since we live in a time when predictions are fashionable, I'd like to make a prediction. My prediction is that the solar power satellite will not fly in the time of timidity, that the time of timidity will destroy the solar power satellite **OR** (and this is one of my fondest hopes) the solar power satellite will destroy the time of timidity.

Peter asked me to try to set the tone for this gathering, and I would propose:

Arise creators of worlds yet
unimagined
You have nothing to lose but your
limits.

(Invented for a review of **Limits to Growth**)

This is the text of a speech presented at the annual meeting of the Sunsat Energy Council, October 5, 1978. Dr. Kantrowitz is one of the foremost researchers in lasers and artificial hearts. He is a member of the board of directors of both the Sunsat Energy Council and the L-5 Society.

A solar power satellite under construction.

even worse. Decentralized solar energy systems would be lower cost than centralized solar energy systems used in the JPL study because transmission costs can be eliminated, land acquisition costs can be reduced by using air spaces over rooftops and parking lots, and waste heat can be put to work near the generating site.

Objections by SPS proponents that electricity storage costs are an insurmountable barrier to lowering the cost of land based solar energy . . . have to be taken with a grain of salt. The people who suggest that major reductions in the cost of electricity storage are not likely are the same people who are extremely optimistic that costs for the various subsystems of the SPS will fall drastically.

GW

Solar power satellites and distributed energy systems really aim at different segments of the energy market. In a true economic sense, there is little competition between them. The distributed energy enthusiasts' arguments against the application of solar energy to centralized, continuous-supply energy systems are ideological rather than factual. In the first place, the often-advocated use of solar energy for home heating deals with an already decentralized energy system: almost every home already has its own heating plant. The appropriate argument is that home heating should switch from fuel-consuming to non-fuel-consuming energy sources. This is a relatively simple cost tradeoff which each consumer can make for himself.

Electricity generation could, of course, be decentralized. The technology has been available for decades in the form of diesel or gas turbine generators. Diesel generators at the neighborhood level would consume no more fossil fuels than centralized power generation; the slight differences in efficiency would be made up by differences in losses in power distribution. Diesel generators would require far less land than distributed solar electric systems, would require far less storage since they could run at night quite easily, and would have all the other so-called advantages of decentralized solar electricity except that they consume fuel and produce air pollution.

In order to illustrate the facts of the "diseconomies of scale" argument, I have constructed Table 1. This provides an approximate comparison of three distributed options with two centralized options. All are configured as continuous, rather than intermittent, supplies. Several points are significant:

- Some energy storage was allocated to the diesel/gas turbine system to allow for peaking.
- The storage allocated to solar photovoltaic is probably grossly inadequate unless cloudy-day backup capacity is available; no costs were assigned for such backup.
- The idea that storage costs can be drastically reduced is probably fallacious: Storage of electrical energy is today an economically mature market. Everyone who drives an automobile has under the hood an energy storage system for which the costs have been minimized for decades by intense economic competition: the battery.
- Installation costs for distributed systems were ignored. They will be significant for for distributed photovoltaics.
- Photovoltaics were priced identically for ground-based and space-based systems.

My conclusions from the table are that:

- Economies of scale are real.
- SPS may be able to compete with nuclear power, especially breeder reactors.
- Fuel-burning decentralized systems approach cost-competitiveness, but their costs are dominated by fuel costs, which makes the future uncertain. I do know of at least one instance where a building developer in New York City has recently elected to go with diesel generators in the basement of the building rather than buying power from Con-Ed at their rates, which apparently exceed the 6-7¢ kWh rate estimated for diesels.

...much energy could be saved if the hundreds of billions of dollars proposed for SPS development were instead spent on improving energy.

All of this is not intended to discredit the idea of distributed energy systems. There are many applications for distributed systems where large-capacity storage is not required or where centralized electricity is not available. In these cases, distributed energy systems offer advantages. In addition, there seems to be little advantage in generating energy in a high grade form, i.e., electrical, and then converting it to heat for heating buildings. Heating by direct collection of solar energy will continue to improve in economic attractiveness compared to consumption of fossil fuels.

When one examines the energy market rationally, it is clear that we need both central and decentralized systems for power generation. Arguing that SPS competes with decentralized energy is fallacious, because it does not. Decentralized and centralized solar energy aim for different sectors of the overall energy market and each should be evaluated on economic and environmental grounds with respect to legitimate alternatives.

GD

A utility receiving electricity from an SPS would require a reserve of standby power capacity equal to or greater than the SPS power of five gigawatts.

GW

Power pools carry from 10 to 20 percent reserve capacity and the loss of a five gigawatt generator in a 50 gigawatt power pool would not be catastrophic. In fact, the existing intertie between the Pacific Northwest and Southern California pools now transfers up to 4 gigawatts over a single transmission corridor. The loss of this transmission is equivalent to the shutdown to a SPS in terms of its effect on the power pool; these power pools today deal with that eventuality.

It is true that a 5 gigawatt unit size is uncomfortably large, even impractical, for many individual utilities and power pools today. However, in the time frame in which SPS power could be available, this does not appear to be a serious problem. In addition, smaller SPS's down to 2000-2500 megawatts are quite feasible; this smaller size would undoubtedly be built initially.

GD

No report on SPS economics that I have reviewed includes speculations on how much energy could be saved if the hundreds of billions of dollars proposed for SPS development and deployment were instead spent on improving energy efficiency.

GW

Conservation is frequently advocated as a more economical solution to our energy problem than construction of new energy sources: "the cheapest power plant is one that is never built." Actually, conservation and construction of non-fuel (i.e. solar) energy sources are economically equivalent: both are capital-intensive, neither consumes fuel. Conservation is more economical only to the extent that conservation measures are cheaper in cost per unit energy than new plant construction. It stands to reason that rational people will opt for the most economical of the alternatives. Many conservation measures are, today, indeed cost-effective, especially better insulation in homes, and are being implemented.

The potentials of conservation have been sometimes grossly overrated. The statement has been made that conservation techniques could cut energy use in building by as much as 600 gigawatts of generating capacity. In the first place, the entire United States does not have 600 gigawatts of generating capacity. Further,

TABLE 1.
DISTRIBUTED VS. CENTRALIZED COST COMPARISON ILLUSTRATION

	Gas Turbine Generator	Diesel Generator	Distributed Solar Photovoltaic	SPS	Nuclear Plant
Generator Unit Rating	32.5 MW	5 MW	1 MW	5000 MW	1000 MW
Nominal Duty Cycle (hr./24 hrs.)	92%	92%	25%	100%	100%
Storage Required	2 kwh/kw rating	2 kwh/kw rating	3.2 kwh/kw rating	0.1 kwh/kw* rating	—
Net Avg. Output	26.65 MW	4.1 MW	180 KW	4960 MW	1000 MW
Distribution Loss	5%	5%	5%	10%	10%
Plant Factor	.8	.8	.95	.9	.7
Net Avg. Useful Output (kwh/kr)	1.775×10^8	2.73×10^7	1.42×10^6	3.52×10^{10}	5.52×10^9
Generator Cost Factor	Current Cost	Current Cost	$40/M², 16%	$40/M² plus other system costs.	Current Cost
Generator Cost	$4.2 million	$1.25 million	$312,500 (7812 M²)	$10 billion	$1.2 billion
Storage Cost ($50/kwh, 10-yr. life)	$3.25 million	$500,000	$160,000	$25 million	—
Switchgear & Power Processor Cost ($50/kw for switchgear and trans; $150 for DC-AC converter)	$1.63 million	$250,000	$104,000	Included in generator cost	Included in generator cost
Fuel Rate	$3.13\ kw_{th/kee}$	$2.78_{th/kwe}$	—	—	$3\ kw_{th/kwe}$
Fuel Cost, $/kwhr th	.016	.016	—	—	.002?
Fuel Cost, $/kwe	.05	.05	—	—	.006
Total Plant Cost, (excludes installation and land cost for distributed systems)	$9.08 million	$2 million	$576,500	$10.3 billion	$1.2 billion
Annual Capital Charge Factor (depreciation, interest, taxes and insurance)	.18	.18	.18	.18	.18
Capital Cost/kwh	.0092	.013	.073	.051	.039
Storage Replacement Sinking Fund	.002	.002	.011	> .0001	
Distribution Cost/kwh	.002	.002	.002	.01	.01
Total Cost/kwh	.063	.067	.086	.061	.055

*Buffering to reduce transients if SPS beam shuts off.

electric power is not ordinarily used for space heating. I estimate the national space-heating usage as about 300 gigawatts thermal, equivalent to about 100 gigawatts electric. The figure of 600 appears to be about ten times too high.

MG

Defects are inevitable considering the size and high power level of the satellites. Repairs will be expensive if not impossible. Environmental degradation in space will cause some power loss due to micro-meteorites and proton radiation. Solar storms may cause severe damage to the cells.

GW

The results of the SPS system studies to date indicate that SPS's will be extremely reliable; these results must, of course, be regarded as very preliminary, and need confirmation by research and engineering tests on components and subsystems.

Carolyn Henson

US astronauts and Soviet cosmonauts have performed successful repairs on an Apollo command module (Apollo 13), Skylab and Salyut. Because SPS consists of many identical units in parallel, it will usually be possible to continue operation while technicians repair and maintain the satellite. There will be no lack of people vying for a chance to work as SPS technicians.

GD

Saboteurs could attack the receiving antennae, which would have almost indefensible perimeters of many miles, or the high voltage transmission lines.

Sen. Charles Percy

SPS would further legitimatize our spending vast amounts on orbital arms systems.

GW

As for vulnerability, **all** energy systems are vulnerable, especially foreign supplies. Almost any system *except* SPS is vulnerable to terrorist action. The idea that a terrorist could do much damage to an SPS receiving site recognizes neither the size nor redundancy of the receiving system.

An arms race in space, cited as one of the possible outgrowths of SPS, will tend to arise as a result of existence of strategic resources in space. Systems already in space have great military significance and the possibility of "war in space" has been discussed in the news media for the past few years. This is already a reality and I don't see it as very relevant to current or proposed SPS research.

MG

The largest potential environmental problems are related to the number of space flights necessary to deploy an SPS. The pollutants and exhaust from the rockets will create water vapor in the ionisphere, heating the upper atmosphere (greenhouse effect) as well as other possible problems.

The fuel is assumed to come from coal gasification plants. These plants, according to NASA reports (my studies), may require up to 400 million gallons of water daily, 60% more than a city the size of Houston uses. These plants are still in the experimental stage, the environmental effects of their operation have not been fully considered.

GW

The engines contemplated for SPS launch vehicles will burn methane or hydrogen and oxygen. The principal exhaust product is water vapor, with significant amounts of carbon dioxide, carbon monoxide, and hydrogen. Nitrogen oxides cannot be produced in the primary combustion process because no nitrogen is present. Secondary combustion occurs as the rocket jet mixes with air; this process will produce some nitrogen oxides, but the amounts will be small by comparison to circumstances where the same quantity of fuel is burned with air in the primary combustion process.

If nuclear power plants are required to employ cooling water holding ponds, their land use is about equal to an SPS rectenna.

The total quantities of fuel required to place an SPS in geosynchronous orbit are roughly 850,000 tons of methane and 150,000 tons of hydrogen (plus about 3 million tons of oxygen). At an SPS construction rate as high as 2 to 4 per year, the fuels consumed by the SPS launch fleet (let's assume it operates out of the Kennedy Space Center in Florida) would be roughly equal to the fuels consumed by cars and trucks in Florida. Another way to evaluate SPS launch fuel usage rates is that the fuel consumption required to place one 10,000 megawatt SPS in space is about equal to the annual fuel usage of one 1000 megawatt fossil fuel plant. Thus, the total pollution burden, considering the relatively clean combustion of the rocket engines, is very small. The issue has to do with where the pollution goes— the rocket vehicles will deposit some of it in the upper atmosphere. Analytical studies are presently being conducted by the U.S. Department of Energy to determine the effects of SPS launch operations on the upper atmosphere.

MG

The receiving antenna requires large areas of land; the size is inversely proportional to the intensity of the microwave beam. A 10 GW SPS with an intensity of 20 milliwatts/cm^2 would need 2500 plus km^2, including an exclusion area. This is equal to 2/3 the size of Rhode Island. An SPS of this size would probably require 2 receiving antenna rather than one large area. These requirements present enormous land-use planning problems.

There is talk of utilizing the underlying land. This would be both impractical and uneconomical as the area would have to be completely shielded from the microwaves.

CH

Land under the rectenna is shielded from microwaves for the same reason you can't hear the car radio when you drive under a concrete bridge: steel reinforcement bars block out the radio waves. A metal grid open enough to let through the short wavelength electromagnetic radiation we call "light" is a barrier to the longer wavelength radiation we call "microwaves" and "radio waves".

GW

One such statement asserted that a NASA study "could find only 69 potential sites." Not mentioned is the fact that 69 sites would more than double the present total U.S. baseload electrical generating capacity.

As for launch vehicles, Boeing studies indicate that they can be operated from the current facility (KSC) to sustain an SPS construction rate of one per year. Ultimately, equatorial launch sites may be preferred. Preliminary studies have indicated feasibility of locating a floating launch site in international waters.

This is not to dismiss the land use problem. Rectenna siting **will** be a problem, but land use is a problem for all energy systems. The SPS land use is at least relatively benign.

SPS land requirements compare more favorably with alternatives than might be supposed. In the case of the SPS, the ground terminal itself (rectenna) requires a lot of area; in the case of most alternatives the support operations, e.g., mining, require a lot of area also. The only energy option that appears to be significantly less land-use critical than SPS is nuclear power. If nuclear power plants are required to employ cooling water holding ponds, their land use is about equal to an SPS rectenna. SPS's don't need cooling water.

MG

The U.S. microwave safety level is 1000 times higher than that of the USSR: US—10 milliwatts/cm^2, USSR—.01 milliwatts/cm^2. These standards are based on the effect on body tissue, while USSR standards are determined by the effect on the nervous system. The US standards will be redone by Dec. 1979.

What are the effects of direct exposure to a high-intensity microwave beam on birds, airplane passengers, air-borne species?

What are the consequences of long-term, low-level radiation on the whole population? Microwaves have been shown to cause central nervous system disorders, cataracts, genetic changes, and have been identified as possible factors of cancer development and Sudden Infant Death.

Microwaves may cause heating of the upper atmosphere by as much as 1000-2000° K, according to Fred Koomanoff of the DOE SPS program. This heating could cause local weather changes and possible larger scale climatic changes.

There is potential for interference with radio frequency systems because of the high power levels (gigawatts) of the beam. By heating the upper atmosphere and the formation of ion belts, the SPS could interfere with commercial radio and TV communications, radio and radar navigation systems, radioastronomy, amateur radio.

The receiving antenna captures 90% of the beam; 10% is dispersed by atmospheric particles. Areas of both low- and high-level microwave radiation can occur up to 500 miles from the receiving antenna. (This is why microwaves have not replaced power lines for terrestrial electricity transmission.)

GW

The use of electromagnetic radiation to transmit energy raises potential environmental issues. The effects of microwave-band radio waves on the atmosphere are well-understood and are essentially nonexistent. The effects of microwaves on the ionosphere, the extremely tenuous ionized fringes of the upper atmosphere, are less well-known. Significant concern has been expressed that the ionosphere would be disrupted by power beams. Recent experiments, however, indicate that the effects are much less than supposed by some investigators; neither thermal runaways nor instabilities were seen at simulated intensities twice those proposed for SPS use. These tests indicate that ionospheric effects will not be a detriment to power transmission; additional tests are needed to confirm this preliminary result.

The effects of electromagnetic radiations on living things are also of concern. The microwave power beam system currently proposed for SPS utilizes energy intensities too low to be of immediate physical danger. Further, the more intense region of the beam would be absorbed by a receiving antenna. The principal concern is related to long-term effects of the small amounts of beam energy that spill over outside the receiving area.

The spillover levels are within the range of experience of significant numbers of people exposed to the same kind of radiation from radio transmitters, microwave ovens, and other similar sources; nonetheless, before embarking on a large-scale program to transmit power from space by this means, one would wish to be considerably more sure than we are today that there really are no long-term, low-level, harmful effects. Thus, the research programs presently proposed for solar power from space give major emphasis to environmental effects assessments as well as technology research.

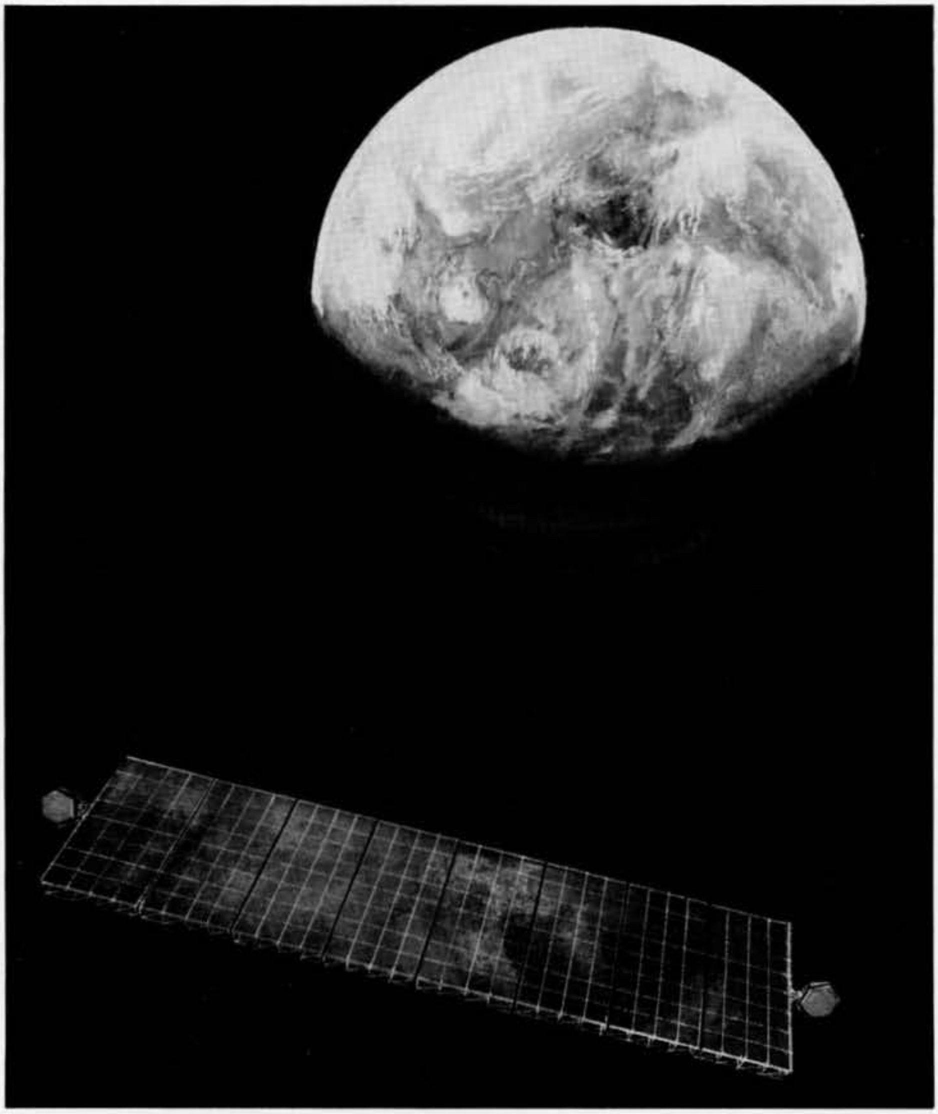
Environmental questions cannot be separated from the technology questions. The level of public exposure to microwaves from SPS's will depend on the technical performance of the beam control system. This can be measured in the laboratory once test hardware is developed. Thus, SPS environmental impact assessment depends on the accomplishment of a research program such as the one presently under consideration by the Congress.

Depending largely on the outcome of assessments of the microwave environmental issue, SPS could turn out to be one of the most environmentally benign of the energy options presently considered possible, compared with the quantity of energy produced. This possibility alone is sufficient justification for the modest research program presently before the Congress of the United States.

CH

If the microwave transmission system is unable to meet environmental standards, laser transmission may be substituted. NASA and DOE are currently studying this option.

Is the debate over? Not yet! If you wish to join the SPS debate, send your statements and questions to Editor, L-5 News, 1620 N. Park, Tucson, AZ 85719.



The microwave receiving rectifying antenna (rectenna). The uncultivated area around it has been closed to human access in order to limit microwave exposure. Under the rectenna the microwave level is very low, allowing cultivation of crops.

A Solar Power Satellite Bibliography

"Satellite Power Stations: a New Source of Energy?", William C. Brown, **IEEE Spectrum,** March 1973.

"On the Feasibility of Small Power Satellites", K. E. Drexler and T.A. Heppenheimer, **Journal of Energy,** May/June 1977.

"Rationale for High Energy Lasers in Space", John G. Rather, May 1978 (a paper prepared as part of a Department of Energy study).

"An Orbiting Solar Power Station", **Sky and Telescope**, April, 1975.

"Solar Power from Satellites", Peter E. Glaser, **Physics Today**, February 1977.

"Alternate Approaches to Space-Based Power Generation", D.L. Gregory, **Journal of Energy,** March/April 1977.

"Perspectives on Satellite Solar Power", Peter E. Glaser, **Journal of Energy**, March/April 1977.

"Space Solar Power — the Transportation Challenge", Hubert P. Davis, **Space Manufacturing Facilities II,** pub. AIAA.

"Solar Power Satellites — Space Key to Our Power Future", Gordon R. Woodcock, **Astronautics and Aeronautics,** July/August 1977.

"The Potential of Satellite Solar Power", Peter E. Glaser, **Proceedings of the IEEE**, August 1977.

"Economic and Environmental Costs of Satellite Solar Power", Peter E. Glaser, **Mechanical Engineering**, January 1978.

"Satellite Power System LEO vs. GEO Assembly Issues", John Mockovciak Jr., Rudolf J. Adornato, **Journal of Energy**, January/February 1978.

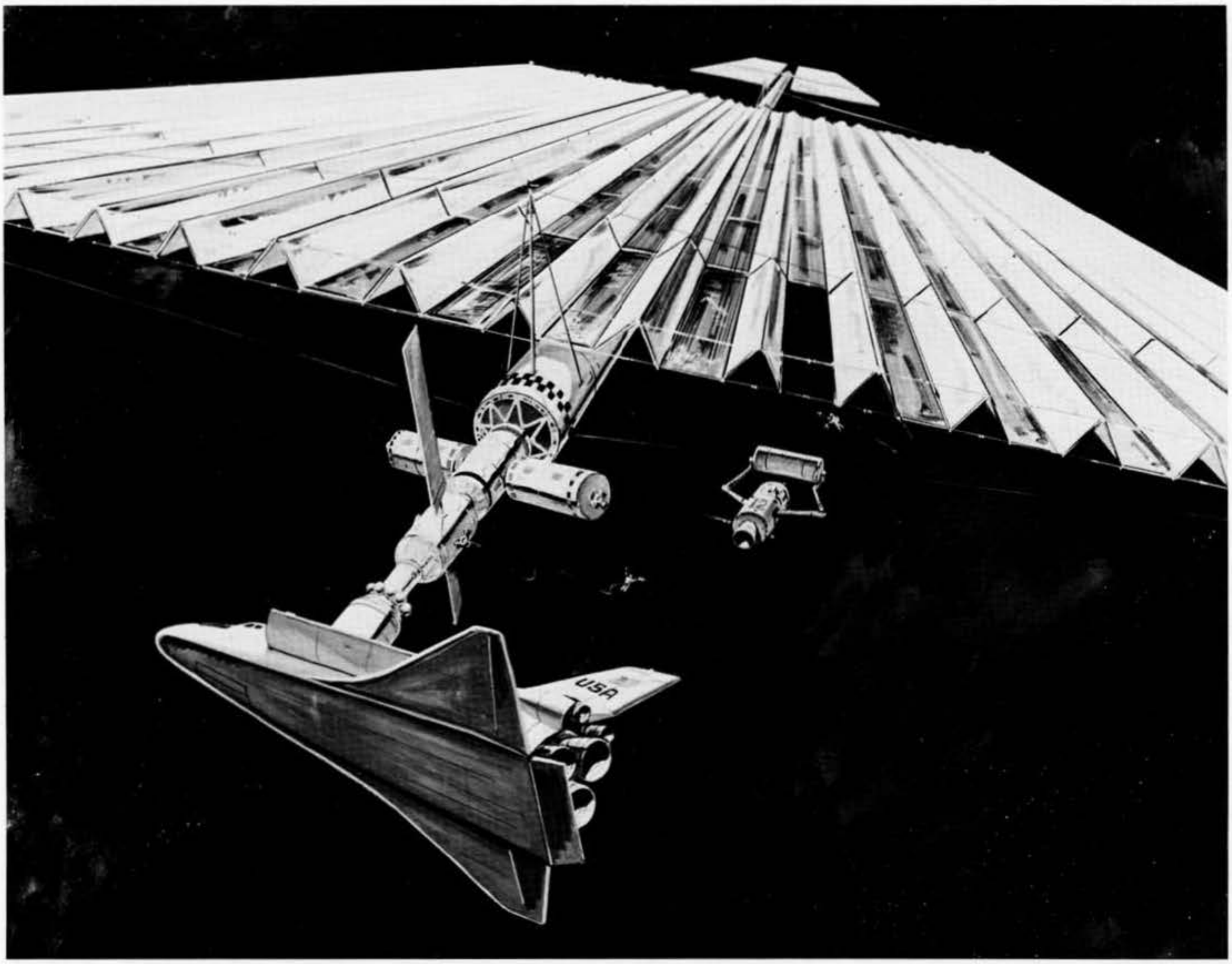
"Space Colonies and Energy Supply to the Earth", Gerard K. O'Neill, **Science**, December 5, 1975, Volume 190, Number 4218.

Solar power satellites, as this special supplement to the L-5 News shows, raise many unanswered questions. Will they aggravate the orbital arms race? Are microwave or laser transmission of power safe? Will they be able to deliver power at a reasonable price — and can we afford the initial investment? The list goes on.

What does the L-5 Society have to say about this? We believe that the nations of the world should face the energy problem by pursuing any and all possible solutions. At this date, we believe the SPS is a possible solution.

We won't get solar power satellites built by opposing other energy research projects. It won't give any credit to the New Space program if we become a mirror image of virulent SPS foes. We hope L-5 members will help set an example of how civilized people go about solving a problem: look at all the alternatives, study them carefully, do some tests, and make decisions without resorting to insults or hyperbole.

SPS may flounder in a morass of technical, environmental or economic problems. Or it may provide Earth with large quantities of cheap, clean power. We don't know yet. But the cost of finding out is small compared to the benefits it could bring.



A demonstration solar power satellite. It could be built before 1985.

NEWS BRIEFS

Egypt to Put Small Payloads Aboard Space Shuttle

The Egyptian government has reserved four small self-contained payloads to be flown on the Space Shuttle in the 1980 s. At a NASA headquarters ceremony held last July 13, Dr. Mohamed Shaker, Minister of the Embassy of Egypt in Washington, D.C., and Dr. Farouk El-Baz, Research Director for the Center for Earth and Planetary Studies, Smithsonian Institution, presented NASA officials with a down payment to reserve Shuttle space.

The payloads, commonly called "getaway specials," can weigh no more than 90 kilograms and be no larger than .5 cubic meters. They are flown on the Shuttle on a space available basis for scientific research and development purposes.

The Egyptian purchase marks the first foreign educational use of the payloads program. Egyptian students will compete in a nationwide contest by submitting proposals for an experiment to be flown aboard Space Shuttle missions. Evaluation of the proposals will be under the direction of El-Baz.

Far-Out Crime

If the US media has any impact on its nation's criminals, the "forcible financing" of space colony construction may become as popular as hijacking once was.

It all started when Steven Masover, 19, held up a bank in Menlo Park, California last November. Apprehended with $78,000 in cash, an unloaded gun, a fake bomb, and three hostages, it looked as if Masover was slated for a long stay behind bars. However, when his trial came up, he told the jury that he had only borrowed the money in order to invest it in a space colony, and claimed he had planned to pay it back in 20 years or so.

The district attorney made the mistake of claiming that investing the loot in space colonies would be "permanently depriving someone of their money, in common horse sense". The jury, apparently believing otherwise, freed Masover.

Masover was recently awarded a scholarship to attend the University of California at Berkeley where he plans to study physics.

And . . . in case you were wondering . . . no, Masover is *not* an L-5 member.

LA Space Capitalists Form Investment Club

On October 13, 1978 the Space Development Company was officially formed, following two months of preparation. The purpose of the partnership is to accumulate sufficient capital to undertake the serious industrialization of space.

When we began discussing private investment in space industrialization and settlement, we were faced with a difficult question: how can a group of small investors become involved in a one hundred billion dollar enterpise? The Space Development Company is our answer to that question. As an investment club, we can pool our resources immediately, and evolve into a corporation as our assets increase. In the short term our main activity will be to expand our assets through wise investments and additional capital subscriptions. Determining the specific steps from an investment club to an operating company will require more research and discussion.

As the company grows, we want to consider many options for developing space. We also want to offer whatever assistance we can to others who are interested in starting their own investment groups. If you have any suggestions, or if you would like to find out more about our club, write to; Terry C. Savage, SDC Agent, 1900 Dufour, Apt. 16, Redondo Beach, Ca. 90278.

Please note: this is *not* to be construed as an invitation to join the Space Development Company. It is a *private* partnership.

Carter Announces Space Policy

"No news is good news" say veteran Carter watchers in the aftermath of his Oct. 1 speech in Cocoa Beach, Florida. Some space program boosters were upset by a **Los Angeles Times** article which reported that "The National Aeronautics and Space Administration's budget, now $4.3 billion, may shrink significantly . . .". However, a close examination of this speech and a press release dated Oct. 11 reveal that the "new" Carter space policy is mostly more of the same.

In Cocoa Beach Carter told the audience, "I am often asked about space manufacturing facilities, solar power satellites and such other large scale engineering projects. In my judgement it is too early to commit the nation to such projects. But we will continue the evolving development of our technology, taking intermediate steps that will keep open possibilities for the future."

However, Carter made no commitment to any specific intermediate steps such as technology development on the ground, assembly of structures in space, or a space power module.

The October 11 press release, the "White House Fact Sheet on US Civil Space Policy", went into more detail. "It is neither feasible or necessary at this time to commit the US to a high challenge space engineering initiative comparable to Apollo . . . . It is too early to make a commitment to the development of a satellite solar power station or space manufacturing facility due to the uncertainty of the technology and cost/benefits and environmental concerns. There are, however, very useful intermediate steps that will allow development and testing of key technologies and experience in space industrial operations to be gained. The US will pursue an evolutionary program that is directed toward assessing new options which will be reviewed periodically by the Policy Review Committee. The evolutionary program will stress science and basic technology integrated with a complementary ground R&D program — and will continue to evaluate the relative costs and benefits of the proposed activities."

So, while Carter may not have come up with anything new, at least he hasn't tried to close the door on our dreams.

Inside the L-5 Society

High Schools Debate Power Satellites, Space Colonies

Across the United States thousands of high school students are avidly researching and orating on the space colonization concept. This year's high school debate resolution reads: "Resolved; that the federal government should establish a comprehensive program to significantly increase the energy independence of the United States." Of course it was not long before many of the more enlightened debate teams realized the potential of space colonization and power satellites under the imperatives of the topic. The participation of high school students in discussions on space will help further the goals of the L-5 Society by involving some of the people most likely to be in L-5 by 1995 — today's high school students.

We hope that the members of the Society will take interest in the attempts of debators promoting the L-5 ideal by tailoring your remarks on the subject to encompass discussions on how a program of space development could significantly increase (the energy independence of the U.S. Articles in **L-5 News** and popular magazines on the subject are of the greatest benefit as they are easily available to most high school students. Researchers, including ourselves, will be attempting to contact many supporters of the colonization effort and attempt to find elusive evidence that we might not uncover elsewhere.

If by chance you are contacted by a debator (an example: during the Redlands University Debate Institution, over the summer ourselves and a friend, Paul Munch of Pomona, California, attempted desperately to arrange a phone call to Professor O'Neill) they would appreciate your cooperation in helping them develop a better knowledge of space power concept through acquiring **printed** and **published** documentation that you as "insiders" on the progression of the effort might have available.

Most debate teams have chosen to use the O'Neill plan as the basis for their proposals in debate rounds. Some of the problems that need to be addressed to make advocacy of space colonization easier for debators are:

1.) Are we really ready to progress in a development program within the time scale that O'Neill provides? Or should we opt to only study the problem some more and then go ahead with a development effort without making any commitment to space at the present time?

2.) Would an international plan be better than the national plan discussed in this year's debate resolution? What do the proponents think? Would Professor O'Neill would want his concept adopted through the structure of the debate resolution or would he prefer an international development scheme? (Needless to say, because of the insistence of most debate teams using space plans to defend the specifics of the O'Neill plan to the letter, it would be most useful if the professor himself could make statements concerning the applicability of his concept to the high school debate topic.)

3.) Is there a distinction made by experts between ground launched satellites and colony manufactured ones? Too many times teams advocating the O'Neill concept are losing rounds because of evidence read that only applies to ground-launched SPS, (i.e. that SPS would create climatic disturbance from launches, that SPS costs 1/2 trillion dollars, etc. . .)

Many L-5 members will hear from us this year and we look forward to our earnest effort to sincerely advance the space colonization movement through the medium available to us . . . debate. Inquiries on the subject, helpful offerings of evidence showing colonization's effectiveness under the debate resolution, and other members of the society who are debators and would like to correspond with your forensic comrades can write to us at: 465 Riviera, Turlock, Cal, 95380.

Matt George & Michelle Richardson
Captains of Debate, Turlock High School

P.S. We were just informed that the collegiate debate topic also has space colonies as an option, (their topic deals with providing employment opportunities) and that further inquiries and info on the subject should be obtained and sent to: Cindy Fraliegh, 9021 Sutters Gold Drive, Sacramento, Ca., 95826.

Slide Recall

No, you don't *have* to return any of your slides. However, if you bought slide A36, you can trade it in at no charge for a better version of that slide.

Nova Scotia L-5

We would like to inform the Society that we have recently formed the Nova Scotia chapter of the L-5 Society. Officers for 1978 are as follows:

President: Dr. Hugh A. Millward
Secretary: Mr. Michael Oja
Treasurer: Mr. Dennis Doof
Our address for correspondence is:
Nova Scotia L-5 Society
c/o Department of Geography
Saint Mary's University
Halifax, N.S.
B3H 3C3
Canada

Please note the new address for Houston L-5: Box 10161, Houston, TX 77206.

Virginia Tech Speakers' Bureau

If you live in the Blacksburg, Roanoke and Richmond, Virgina areas and need a speaker on space settlements, contact David Jones, VA Tech information officer, 711-9 Townside Rd., Roanoke, VA 24014.

Space Futures Newsletter

The Philadelphia based Space Futures Society has inaugurated the **Space Futures Newsletter** with a twelve page November issue. It contains news items on Landsat, O'Neill's Space Studies Institute, the Soviet space shuttle, Venus probes and more. The newsletter is free to Space Futures Society members. Dues are $10 per year, $5 for students. Send them to 1627 Spruce Street, Philadelphia, PA 19103.

Canadian Lecturer

Alan R. Hildebrand, of the Royal Astronomical Society of Canada, is available to give lectures on space settlements. He can be contacted at RR 7, Fredericton, NB Canada E3B4X8, 506/363-2050.

Errata

We've piled up a few lately — is our face red over listing a UCLA L-5 (**L-5 News,** October 1978). It's at arch-rival *USC*, care of John Blanton, Box 77206, Los Angeles, CA 90007.

In "Careers In Space" (**L-5 News,** August 1978) we tell Houston area students to contact the Physics Dept. of Rice University. That's the *Space Physics Dept. and Astronomy Dept.*

SPACE - ORIENTED INDIVIDUALS are invited to send resumes for eventual consideration for employment with wide ranging project. We anticipate several job openings in the coming year. No aerospace or technical background required. All fields welcome. Send to: Sabre Foundation, Earthport Project, 221 W. Carillo St., Santa Barbara, CA 93101.

So You Want to Write for the L-5 News?

We welcome articles for the **L-5 News**. Pay is rotten: two extra copies of the issue carrying your opus, and your own personal press card.

However, indirectly your L-5 press card can be worth a great deal. It will get you free admission to almost anything, free photos, papers, press releases, you name it. It's up to your discretion where you go and how you use it.

If you have ever written for the **L-5 News**, or sent us photographs or artwork we've used, you can get a free personalized press card by writing in and requesting it. If you haven't written for the **News** yet but know of an event where you could obtain useful information, we can also supply you with a card.

If you need "freebies" to butter up someone for an interview or to obtain free admission or photos and artwork, let us know and we will help you out.

If you've never written for the **L-5 News** before, but would like to, here are some tips:

1) Fill the article with *facts*. If you're a rotten writer but can dig out the *facts*, we'll sweat over your article until its ready to print. If you send in an opinion piece, however, you've got to write like an angel.

2) Don't use no double negative.

3) Make each pronoun agree with their antecedent.

4) Join clauses good, like a conjunction should.

5) About them sentence fragments.

6) When dangling, watch your participles.

7) Verbs has to agree with their subject.

8) Just between you and I, case is important to.

9) Don't write run-on sentences they are hard to read.

10) Don't use commas, which aren't necessary.

11) Try to not oversplit infinitives.

12) Its important to use your apostrophe's correctly.

13) Proofread your writing to see if any words out.

14) Correct spelling is esential.

Happy writing—CH

Editor Wanted

Do you cringe at the choice of articles, writing style, layout and artwork in the **L-5 News**? Could you do any better? Yes? Well, then we have a job for you. You can become the editor of the **L-5 News**—if you can stand to start at $500/month and can convince me you can handle the job.

Would you print an article about a heat machine with no cold sink? A reactionless drive? Can you turn a well researched but hideously written article into a literary gem—without offending the author? Can you turn 15 different items that came in the mail into a coherent news item? Can you check facts, and, if you later discover a boo-boo, tell everyone about it in the **L-5 News**? Would you be willing to go out of your way to solicit news, articles, photos and artwork?

What would you do if the printer said they're too busy and the **News** will be printed a week late? If the typesetter suddenly goes out of business? If the paper company is on strike?

If none of these questions faze you, write or call Carolyn Henson, 1620 N. Park, Tucson, AZ 85719 or 602/622-6351.

Letters

Skyhook Reply

The observations about rotating skyhooks made in Dr. Brakke's letter to **L-5 News** are correct, but not all his assumptions are the same as mine.

My analytical calculations assumed the skyhook remained straight to keep the problem tractable, but I never expected it to remain perfectly so in actuality. Not mentioned in the L-5 article were a series of digital simulations of both graphite terrestrial and Kevlar lunar skyhooks. These modelled the hooks as a string of a few hundred point masses separated by springs, to reflect the density and modulus of elasticity of the materials. The simulations showed that the cable did bow when it was horizontal (the ends dipped below the middle), but the angle was less than 5 degrees. There was also a 1 percent change in elongation between the horizontal and vertical orientations. These effects don't impair the skyhook's utility and lateral stiffening is unnecessary.

Damping is necessary. My simulations included both undamped and heavily damped cases. Captures or releases in undamped skyhooks inevitably launched tension/compression waves which travelled to the other end of the hook over

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several minutes, where they reflected and reinforced themselves and snapped off a piece of cable. In the damped cases the waves were sufficiently attenuated to be negligible when they got to the other end. Surprisingly, undamped skyhooks didn't run into trouble as long as the masses at their ends were not altered (i.e. no captures or releases).

Your observation about varying rotation rates is correct, but the situation is even more complicated, because the extended skyhook does not orbit exactly like a point at its mass center, as the analytical derivations assumed. At touchdowns the downward half of a symmetrical cable pulls down more than the upward half pulls up, and thus the mass center momentarily falls. This is actually an advantage because it lowers the takeoff acceleration, and thus the force on the cable in this maximum stress orientation. The elongation changes add yet more complication, and adding and removing masses really screws things up.

By experimentation I've managed to tweak skyhook lengths and initial conditions so that they nearly touch down six times per orbit, if you don't spoil things by adding payloads. The parameters are different from the analytic initial approximation in about the third decimal place.

Operating a skyhook transportation system will obviously keep several computers pretty busy calculating either the minor corrections needed to keep the skyhook in place and on time, or else predicting where it will show up so that a small rocket ferry can rendevous with it.

Regarding your and Carolyn's comments on metallic hydrogen, I don't think the evidence is in yet. It may be metastable like diamond or nitroglycerin. The linear theories that apply to normal pressures and densities can't be trusted at the 2 million atmospheres needed to make metallic hydrogen. Nobody is willing to guess about its stability, and you couldn't believe them if they did.

Hans Moravec
Artificial Intelligence Lab
Stanford University
Stanford, CA

SPS Pro & Con

You should try to show antinuclear people the potential of space power stations. I don't agree with Woodcock that nuclear foes are "irrational". I live where they mine it — it isn't safe or clean.

Anonymous
Niwot, CO

I would like to make a comment about Ken McCormick's article on the Solar Power Satellite Hearings.

It seems to me that Senator Abourezk should immediately be taken to the nearest hospital in the attempt to save himself from an almost sure to be fatal dose of Foot-in-Mouth disease. His comment about the 'Sunsat' group is direct evidence of a well advanced case. He says that 'Sunsat' is controlled by General Electric, McDonnell Douglas, Grumman, et al, and that if they get control of the SPS then they will, in effect, control our energy resources. He finished by saying: "Massive government regulation would be necessary to protect the consumer."

Now maybe I've missed some of his logic somewhere, but if I recall correctly, all of these companies are American run organizations and this would seem to be much more preferential over the Middle Eastern control that we now have. In fact isn't this return to American control exactly what we have been preaching about? At least then we would have that option of government controls if it were needed, whereas this control is not possible now as we can see everytime we pull into a gas station.

Larry D. Evans
Fairchild, WA

I am one of those who joined L-5 after the **Playboy** publicity, somewhat out of curiosity but mainly out of concern for our energy situation. Colonies and industry in space might work out, but the solar power satellite won't.

At one time I believed the solar power satellite was a good idea, but that was before I discovered what it *really* is: a multi-billion dollar corporate scam that affords the multinationals traditional objectives: monopoly and big, big profits.

Not to mention the radiation hazard (we'll cook more than geese), and other environmental problems (the incredible influx of energy will ultimately result in waste heat, and we're already warming the planet frighteningly fast).

The solutions to the energy problem must be economical, safe, decentralized, and democratically controlled. Solar power satellites are none of these.

Kevin Gillooly
Columbia, MO

Space Colony Course

I was disappointed not to find my courses on space colonies among those listed in **L-5 News** (page 9, August 1978). I suggest that I have taught about the colonization of space longer than anyone other than Professor O'Neill, since I was teaching a course called The Space Venture when O'Neill's Physics Today article was published, and I incorporated the topic in my course that fall. A brief discussion of my experience was published in **L-5 News** (page 6, December 1975). A full article describing my experiences in teaching about space colonies will be published in the American Journal of Physics this spring. I shall send the reprints (gratis) to the L-5 Society for distribution.

Jay S. Huebner
Department of Natural Sciences
University of North Florida

Pipefitters Passé?

I must say that I find Jack's advice for our editor's daughter (Sept. L-5) typical of him but, in this case, totally wrong. Let her become multi-disciplined—a generalist. For it will be the generalists who will live in the space habitats; not the specialists who will be needed only on a temporary basis. It will be the generalists who will be able to adapt to a new and constantly changing environment where the unexpected will happen daily and makeshift will be the password.

David Jones
Va. Tech Chapter
Blacksburg, VA

Feel What Can't Be Said

It's not enough to just live, on a minimal survival level. We have to ensure that more than abundant life that we are promised, in God's word, and to do that we have to have faith, and to look up. There may be, one day, nowhere to go but up.

Leora E. Morey
Medford, OR

Look Up

We need colonies for the same reasons the Egyptians created the pyramids: for the jobs, the feeling of togetherness and creativity, and so that others may look back thousands of years and feel what can't be said.

Michael C. Emmert
San Antonio, Texas