THE FOUNDATION
COMMERCIAL SPACE REPORT

# LASER POWER SATELLITE STUDY SCHEDULED

## Atmospheric and Environmental Effects of Beam To Be Primary Study Objective

The NASA Marshall Space Flight Center and Rockwell International corporation are planning to evaluate use of a laser system as an alternative to microwaves for transferring power from a Solar Power Satellite to the earth. The study, which is an add-on contract to a major SPS project presently being completed by the Space Systems Division of Rockwell, will be completed by early spring, 1979.

One of the major concerns with the use of microwave power beaming is that the transmitting and receiving antennas size and mass are not particularly sensitive to the energy levels being processed. The result of this fundamental physical limit is that even early generation SPS test articles would require space-based antennas on the order of one kilometer in diameter. Another major concern is the unknown effect that microwave radiation will have upon biological life on the planet, especially following long term exposure.

To avoid bias in the study, Rockwell is suggesting that only two major guidelines be employed. First, the operational orbit for the system must be geosynchronous, and second, the individual power modules must be capable of being grouped in single location and operated as a single power source at levels up to that which is possible with photoelectric/microwave systems (5-10 gigawatts). However, the study will concentrate on electric discharge lasers (EDL's) of the carbon monoxide and carbon dioxide types. While it is suggested that other types of lasers might be used, the study has listed as an objective ". . . to prepare a preliminary definition of the CO or CO2 EDL type". By doing this, it appears that the study must come to the conclusion that lasers are inappropriate compared to microwaves for the power beaming task.

The reason for this is simple. Lasers are highly inefficient compared with microwave transmitters in turning electricity into beamed energy. (Microwaves are about 50-60% efficient, lasers less than 10%). If the laser is limited to an EDL type which is pumped by electricity from solar cells, it must be found to be inadequate compared with microwaves, almost irrespective of the environmental hazards associated with the latter system.

It is the hazards of microwave use that primarily motivated this study by NASA. A major portion of the time and funding of the add-on contract will be devoted to the environmental effects of lasers. Rockwell states "It will be the intent of this task (Environmental Assessment) to evaluate the impact of laser operations on the atmosphere and biology, as well as the adverse impact on laser system selection and operation." However, other issues such as beam pointing, technology growth and system reliability will be addressed.

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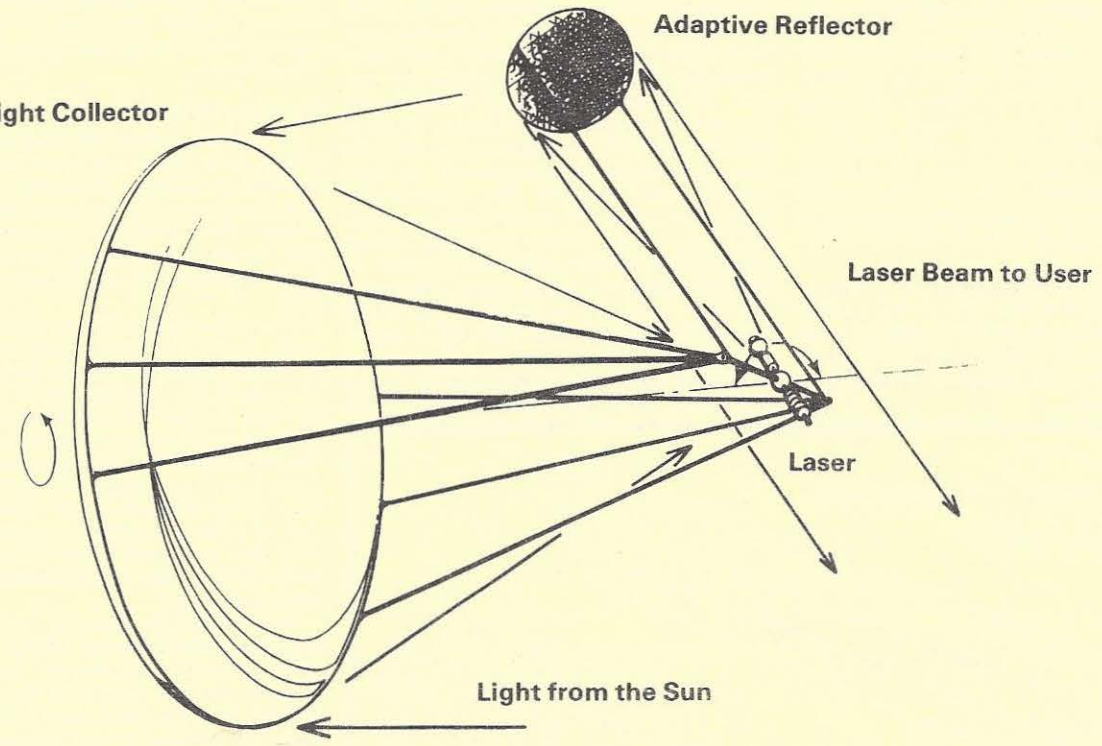


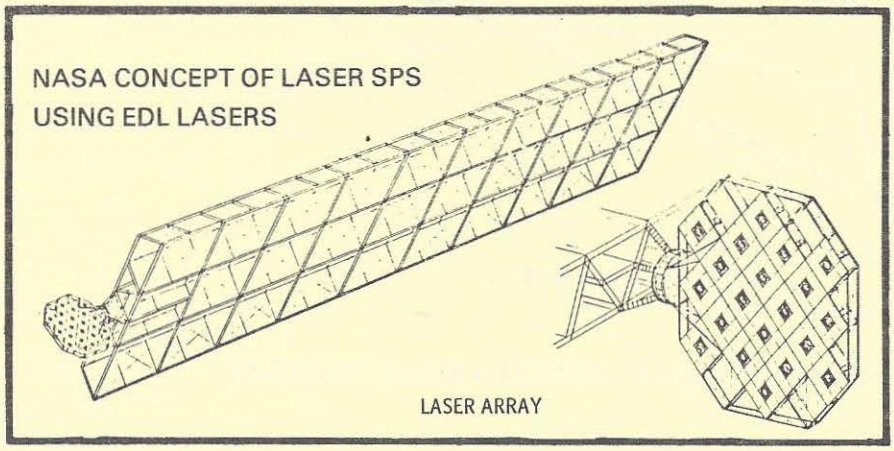

CONCEPTUAL VIEW OF A SUN-PUMPED LASER POWERSAT

The matter of environmental safety and the very large powerplant size has led some scientists to investigate the use of laser SPS systems in past years. The large size of the microwave SPS presents important problems with respect to the siting of the receiver on the ground and the integration of a powerplant which is five to ten times larger than a nominal nuclear reactor with the national power grid. Failure of a massive microwave SPS would strain the local power grids surrounding the receiver. Further, and perhaps more to the point, the microwave SPS would require massive capital investment . . . capital which is in short supply.

Dr. John Rather, formerly of Schafer Associates and now with BDM Corporation in McLean, Virginia, has been a pioneer in the study of laser SPS. With these concerns in mind, he has devised a scheme to both minimize the environmental effects of power transmission through the atmosphere and to limit the size of the SPS. Rather suggests using a sun-pumped laser, of a power level around 100 megawatts, as the basic size SPS. If more power is needed, it could be supplied by clustering modules of individuals laser SPS systems. The sun-pumped laser would operate at a frequency which would pass through the atmosphere without interaction or absorption, thus nearly eliminating any adverse atmospheric or biological effects. The power density of the beam could be controlled by focusing or defocusing a mirror attached to the satellite, meaning the laser SPS could be programmed to illuminate the ground "receiver" with the equivalent of one to a few tens of times normal solar insolation, depending on what is safest and most economic.

The ground reception apparatus could vary depending on the energy requirements of the user. For example, if process heat is needed by an industry, the receiver could be a boiler and focusing mirrors. If electricity is required, a solar cell system which has been designed to absorb light from the laser most efficiently could be employed. Existing powerplants might even be used, by pumping steam generated in a solar boiler receiver to the present turbines in coal and nuclear powerplants. This way the capital investment can be further minimized, as well as providing backup power in case of a laser SPS failure.

The laser SPS is highly resistant to failure, however, in that it has only a few moving parts, and the total power system is such that no failure of a single laser SPS could adversely affect the supply of energy in a given local area. □




# HIDDEN PERILS IN GOVERNMENT SUPPORT OF SPACE ACTIVITIES

## Part Two

*by Robert Poole, Jr.*

### Radio and Television

Commercial radio broadcasting began in 1920; and by 1922 there were 564 broadcasting stations in the United States. Because no law provided for assigning property rights in specific radio frequencies, this early period was soon characterized by chaos. Users of all types freely chose which frequencies to use, subject only to registering their use with the Secretary of Commerce under a 1912 law. Conflicts between users abounded, leading Commerce Secretary Hoover to call a series of radio conferences in 1922, 1923, 1924, and 1925. The general thrust of these conferences was that the federal government should be empowered to allocate frequency use, and at the same time *prevent* any user from establishing property rights in any spectrum allocation. Legislation embodying these principles finally emerged in 1927, bringing into being the Federal Radio Commission. At the price of giving up any property rights to radio frequencies, and conceding control over the essentials of their business to a federal agency, broadcasters achieved order in their industry.

The rest of the history is well known. In 1934 the Federal Communications Commission was created, superseding the FRC, and adding telephone and telegraph to its regulatory functions. Protected by the FCC, the radio broadcast industry became cautious, conservative, monopolistic, and very profitable. Television accentuated the pattern, with three powerful networks coming to dominate the industry. Growing adept at utilizing the FCC to their advantage, the networks successfully manipulated the Commission into retarding the development of pay and cable TV. Nationwide programming for a mass audience demanded lowest-common-denominator program content in order to maximize market share. The result was the cultural "wasteland" described by critics in the 1960s and still with us today, along with an FCC that continually engages in implicit and explicit censorship of a kind that would never be tolerated in the print media.

How might radio and TV have developed in the absence of the FCC? To be sure, *some* mechanism to prevent interference between spectrum users was necessary. But the normal mechanism for preventing such conflicts over the use of a limited resource—e.g. downtown land—is a legal system that provides for the protection of property rights. If, instead of creating the FRC, Congress had defined property rights in the electromagnetic spectrum, and made them fully transferable in the market and enforceable in the courts, there would have been no need for an administrative body with vast powers to control the shape of the industry.

Consequently, there would have been no way for the present monolithic network—if it even came into existence to begin with—to remain the dominant pattern in the industry. Cable TV technology and more aggressive development of UHF would have led to a vast expansion in the number of channels and the type and diversity of programming. Cable today would be in virtually every home in urban areas—offering specialized pay-TV programs—catering to hundreds of special-interest markets, much as magazines do today. Two-way, interactive cable would already be a reality. Many fortunes would have been made outside the narrow realm of mass-market broadcast TV. And consumers would be far and away the ultimate beneficiaries.

### Nuclear Power

In nuclear power we find an industry which, once again, has come to its present size and prominence primarily with government assistance. In this case, however, the industry itself is largely a government creation, rather than being an independent sector which sought out government protection.

After World War II the federal government, possibly reflecting guilt over the use of atomic weapons against Japan, decided to promote the development of the "peaceful atom." After the expenditure of billions of dollars, the government announced that the technology for nuclear electric power production was ready for commercialization. Congress passed the Atomic Energy Act of 1954, permitting private utilities to take part in atomic power development by giving them access to AEC's heretofore classified technology.

Unfortunately, despite extensive research-and-development efforts, the insurance industry considered the potential risks of nuclear accidents too great, and refused to write third-party liability insurance for nuclear power plants. Congress therefore passed the 1957 Price-Anderson Indemnity Act, making the *taxpayers* liable for any large-scale nuclear accident. With

this cushion, the insurance industry then made available 60 million dollars per reactor in conventional liability coverage.

Despite both the R&D subsidies and federal insurance coverage, the growth of commercial nuclear power has been halting and uncertain. A 1977 study by the Rand Corporation concluded that if it had not been for the quadrupling of oil prices by OPEC, nuclear power plants would still not be competitive with fossil fuel plants. What seems to have happened is that governmental efforts have pushed high-cost nuclear technology onto the marketplace before the market really called for it. Decades of AEC public relations efforts misled both the public and the power industry into expecting too much, too soon, of a very complex, costly (but nonetheless worthwhile) technology. Thus, for example, Westinghouse overextended itself by making commitments to supply reactor buyers with uranium. Utilities believed their own PR that minimized the cost and complexity, and maximized the ready availability of nuclear power plants. The AEC in the early years failed to appreciate the difficulties involved in such issues as nuclear waste disposal, and glossed over them in public. As a result of all these factors, a massive public opinion backlash set in during the 1970s, fanned and exploited by many with political or ideological axes to grind.

What if commercial nuclear power development had not been subsidized and its liability limited by the federal government—if, instead, the government had merely made available to the power industry the nonclassified results of its military reactor R&D programs? Some would say that we'd have *no* nuclear plants in operation today. And that might be true. More likely, I believe, industry would have conducted a lower-key R&D effort on its own, focusing far more attention on design and operational factors relating to reactor safety and waste disposal. Prototype reactors would have operated for many years; and commercialization might just about now be beginning—with enough operating experience and proven safety features to convince the insurance industry that reactors are insurable. Instead of a public backlash, there would likely be a wave of enthusiasm for nuclear power, which would now be viewed—along with solar power—as America's savior from the depredations of OPEC.

## Lessons

We have looked at five examples of new technology being commercialized. In each of these cases the government played a major role. In some cases it provided heavy subsidies, which made possible investment well beyond what would have occurred at that point in time through strictly private efforts. In the terminology of economists, such investments represent misallocations of resources. Funds were transferred away from sectors where the market signaled that they could be productively (profitably) used, to areas which were not—or not yet—productive. Such uneconomical investments are most evident in the cases of the railroads and nuclear power plants.

In other instances government involvement served to determine the shape and structure of the industry, distorting it from what free-market forces would have produced, and leading to its ultimate control by government. We saw this clearly in the case of the telephone and broadcasting industries. Government involvement has also led to serious social consequences, such as fuel-wasting transportation patterns, overdependence on the automobile, mind-numbing television programming, and a backlash against high-technology energy. In the case of the railroads, where government involvement has the longest history, we see an industry regulated into stagnation and decay.

Thus, possible perils of government intervention in the introduction of new technology include:

- Premature (and therefore inefficient) investment of capital,
- Eventual government control,
- Adverse social consequences,
- Stagnation of the industry;
- Popular backlash due to government sponsorship and subsidy.

Bear in mind that in no case did government involvement make possible the development of the industry. It may have speeded it up a little, or altered its course somewhat. But in each case, the industry developed because it made economic sense, in and of itself. And the same applies to space industrialization.

## Applications

Government involvement in space, except for military programs, has heretofore been focused mainly on two efforts: public relations (beating the Soviets to the moon), and scientific research. More than half of total NASA expenditures to date have been spent on Cold War PR efforts like the Apollo program. The bulk of its remaining funding has gone, not for commercial or industrial projects, but for scientific endeavors—astronomy, geophysics, planetary chemistry, etc. It is only within the last five years, with the development of the Space Shuttle, that NASA has begun to take commercial utilization of space seriously.

But even now there remains the question of whether NASA really understands the profit-and-loss world of business. The Shuttle program is funded at several billion dollars per year, and reflects NASA's Apollo-proven, gold-plated approach to system development. In sharp contrast is the modular launch-vehicle being developed by completely private OTRAG in West Germany. OTRAG, which made its first test launch last May, has invested 30 million dollars to date, and expects development costs to total only 400 million dollars by the time its 10,000 kg. to low-earth-orbit booster is qualified in 1981. OTRAG is relying heavily on mass-produced, commercially available, off-the-shelf components to keep costs down. It has minimized complexity by avoiding the use of cryogenic fuels. Its booster design is totally modular, even to having a separate microcomputer for each rocket motor. The only moving parts on the launch vehicle are the electromechanical valve-actuating units for each motor—the valves are normal industrial ball-valves used in the chemical industry; and the actuators are commercially available windshield wiper motors!

The contrast between OTRAG and NASA speaks volumes about the difference between private industry and government. OTRAG is making design decisions on the basis of true cost-effectiveness. Without access to the taxpayers' wallets, it must demonstrate to its 600 private investors that it can design and build a launch vehicle that is simple, cheap, and reliable. Engineers and cost analysts have the ear of OTRAG's management, not scientists used to living at public expense. And that difference makes all the difference.

What has happened with NASA is similar to what happened with railroads and nuclear power. Enthusiasts for the new technology grew impatient with the slow pace of commercialization, and turned to government to speed things up. But as in those prior examples, government has devoted huge efforts to misallocating resources—playing Cold War macho games and being a patron of science—instead of taking space exploitation seriously as a business prospect. The result, already, is a large group of vested interests dependent on ever-larger NASA budgets.

But the emergence of OTRAG indicates that a new era is about to begin. (OTRAG is the first, but by no means the only, private launch-vehicle effort; several others are already on the drawing boards.) For years the argument among space enthusiasts was that space industrialization is feasible; it's just that we need the government to fund the heavy start-up costs that private industry can't or won't cover. In other words, as with railroads and nuclear power, give the industry a push, beyond what the private-capital market views as justified. OTRAG's investors, however, reject the need for a governmental push. They expect to make a lot of money selling launch vehicle services in the 1980s; and they want no government interference in reaping those profits.

What this should be telling us—and the General Electrics, IBM's, TRW's, and Boeings—is that we are already very close to the point where commercial space activities can pay for themselves. The markets for communications satellites and Earth resources-sensing satellites are themselves already well developed. Orbital materials-processing and solar power-production show immense potential. Do we really need government involvement to push these things along? And do we want to pay the long-term price this involvement will very possibly entail?

No one can say for sure what these consequences may be. But based on the historical examples we've reviewed, we might anticipate:

- The emergence of government-franchised exclusive monopolies in solar power and communications satellites;
- Manufacturing cartels in space-processing activities, owning the limited number of facilities made available on government-owned space stations;
- Technological and economic stagnation in space transportation under the heavy hand of government regulation;
- Unanticipated, adverse social consequences such as total government control of land use, farming, and population movements, based on remote-sensing data;
- A popular backlash against space industrialization, as an elitist rip-off of tax money for the benefit of wealthy industrialists and technocrats.

Is government help really worth such costs? Should the taxpayers really be asked to underwrite a commercially viable endeavor? Frankly, I don't think so. And I think the historical precedents bear me out. □

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*—Editorial*

# POWERSATS, POLITICS, AND PEOPLE

*by Gary C. Hudson*

One of the most frequently asked questions which I am confronted with during space industrialization lectures to both professional and lay audiences is: What will be the first important product or service generated by orbital industry? Often among knowledgeable audiences that question can be rephrased: What do you think about powersats?

My answer has often incurred the wrath of the powersat proponents and the space settlement advocates. I have been categorical in my opposition to solar power satellites, not for any technical reasons (the development of the SPS would be fairly trivial) but rather for my concerns about the size and capital investment required. More recently, worries about the use of microwaves for power beaming have also bothered me.

The fantastically large capital investment required for SPS before payback has been a prime stumbling block to acceptance of the concept. While I feel that most estimates that I have heard from NASA and the aerospace industry have been naively *high*, the fact remains that only governments or oligarchical giant corporate consortiums could afford to pay the price. The resulting power base established by such a massive effort would be a centralizing technology of the worst nature.

Anthropologists talk of "water empires", where the use and control of water for irrigation is in the hands of a central government. Examples in the past include Egypt, the Indus valley and China. Let me point out the obvious: water empires are static, long term social institutions which have a generally stultifying effect on the culture and freedoms of their population. Do we want to establish a new water empire based on electrical power?

Several people have chided me for holding such a simplistic view of the way the world works. They point out that the powersats, while probably designed, built and operated by the Department of Energy, would no doubt be turned over to private enterprise once they had been completed and checked out. Myself, I find this just a bit difficult to believe. But even if it were the case, would the "private enterprise" owning the SPS really be private? It is foolish to believe so.

Well, what of it? Does this matter so? Some individuals have suggested to me that we already have a similar situation with the regulated public utilities. Will regulated powersats make a difference worth worrying about?

I think they will. Space, for all the cliches, is truly the last frontier. We have a great opportunity to establish a society based on human and economic freedoms in space. All of the factors needed are present . . . room, resources, and soon, people. Why start off on the wrong foot?

Having stated my position in brief, let me now say that I have changed my mind. Not about the negative implications of microwave powersats, nor about the hazards of energy regulation, or about the great opportunity for free societies in space. No, I have changed my mind about *powersats.*

The man who changed my mind was Dr. John Rather (see lead article, this issue). Concerned with the size and investment required for conventional microwave SPS, and also with the use of microwaves for power beaming, he has conceived a brilliant scheme for using sun-pumped laser powersats to provide baseload electrical power. The system would completely eliminate all the social/political concerns which I've had relating to SPS. It is small (about 100 MW compared to 10000 MW for the microwave system), integrates easily with existing powerplants and industry, and requires practically no investment in land. If you think the latter point is trivial, consider the problem that the U.S. Navy has had in locating their Very Low Frequency antenna (originally Project Sanguine) in a dozen or so states. If there was so much irrational opposition to Sanguine, can you imagine what it will take to locate 100 microwave receivers, each ten miles in diameter, across the country?

Rather has a system concept which is inexpensive, simple, useful, and it is as innovative as the original technical proposal for SPS was. Best of all, many different relatively small, competitive institutions around the world could offer to build and operate the laser powersats. The opportunity will be an entrepreneur's delight. (By the way, the concept will improve the already good economics of the Hertzburg/Sun laser-powered airplane. See *Report*, March, 1978. The laser system will also be useful for powering settlements in space or on planetary surfaces. It will make a great ABM system and will come in very handy for mining asteroids.)

The next time someone asks me what I think is going to be the most important product/service from space industry, have I got an answer for them! □

Further information on the Rather Powersat can be found in the AIAA book *Radiation Energy Conversion in Space* Edited by Ken Billman (1978).

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