FOUNDATION REPORT:

ADVANCES IN COMMERCIAL AND GENERAL SPACE DEVELOPMENTS

EARTHPORT LAUNCH SITE PROPOSAL DRAWS INTERNATIONAL ATTENTION

Several Nations Respond to Initial Inquiry; Project Expands with New Concepts, Services

by *Mark Frazier, Earthport Bulletin*

With commercial launch providers at the verge of doubling in number within five years, a total of eight nations have so far expressed interest in the creation of a new international launching center for peaceful uses of space.

Five of the countries—Liberia, Sudan, Panama, Rwanda, and Sierra Leone—say they welcome the concept of an equatorial launching facility within their borders. The Earthport launch site would be established as an international free trade zone to generate income for space activities and for the host country.

Three other countries, Indonesia, the Cook Islands, and the Pacific island nation of Nauru, have requested further information about the project. Approaches are now under way to a variety of other nations near the equator, which has been chosen as the primary area for study because of the intrinsic economics of equatorial launch.

The study is being sponsored by the Sabre Foundation, a California-based public policy research group. Among the advisors are Dr. Nelson de Jesus Parada, director of the Brazilian space effort; Professor Marcel Barrere, president of the International Astronautical Federation; Buckminster Fuller, the noted designer and futurist; Frank J. Malina, cofounder of the Jet Propulsion Laboratory; and former Apollo astronaut Philip K. Chapman.

"We are very pleased with the interest of equatorial countries to date," said Mark Frazier, director of Earthport feasibility study. "As the commercial uses of space grow, we believe an international launching facility will help people around the world to enjoy the benefits."

Recent studies funded by the National Aeronautics and Space Administration, as well as private groups, have described impressive commercial prospects in space for the next two decades. Present $2 billion-a-year communications satellite revenues are expected to multiply several times. Tens of billions of dollars may also be spent on solar-powered satellites, beaming an inexhaustible supply of energy to earth.

Increases in space activity promise to make launch economics important in the future. In contrast to ranges at higher latitudes, an equatorial site could offer several inherent advantages for launch into orbit:

- Additional momentum for launch vehicles. At the equator, the spin of the earth amounts to almost 1000 miles an hour in an easterly direction. Satellite launches into equatorial orbit from low latitudes thus are more efficient than from other locations, where the boosters have less momentum from the earth's rotation.
- Simplified orbital paths. To enter an equatorial orbital plane, most satellites now launched must make wasteful "dogleg" maneuvers. An equatorial launch site can render doglegging unnecessary, and simplify tracking procedures. A launch area near the equator, moreover, permits insertion of a satellite into any orbital plane with relative ease.
- More frequent "windows." Because satellites launched from the equator can pass overhead on each circuit, launch opportunities open up with each orbit for a minimum energy/fuel rendezvous. If a space vehicle in equatorial orbit is to return to earth, landing procedures are simplified by the recovery site's position in the orbital plane.

These benefits have already been instrumental in persuading two commercial launch organizations to establish equatorial sites. A private West German company, OTRAG, has spent approximately $30 million to date to develop a range in Zaire, which is scheduled to become fully operational within three years. The European Space Agency will begin offering launch services by 1980 from a base in Kourou, French Guiana. In addition to these sites, equatorial ranges for suborbital "sounding" rockets—used for atmospheric tests—exist in Kenya and India. An Earthport might be established at one of these existing locations, or at an area yet to be determined.

Earthport researchers believe that the international status of the spaceport would help to further reduce cost barriers for launches. Rather than having to build duplicative facilities near the equator, launch organizations in the future could benefit from the savings of shared ground support services at Earthport.

To draw in a range of investment and build an economic infrastructure at the site, Earthport is planned as an international free trade zone of approximately 200 square miles. The host country would retain sovereignty and ownership over the zone, leasing it to an international Earthport Authority for administration. Exempting commercial activities at the site from tariffs and taxes would raise land values substantially, to the point where annual lease revenues could generate large sums for launch services and

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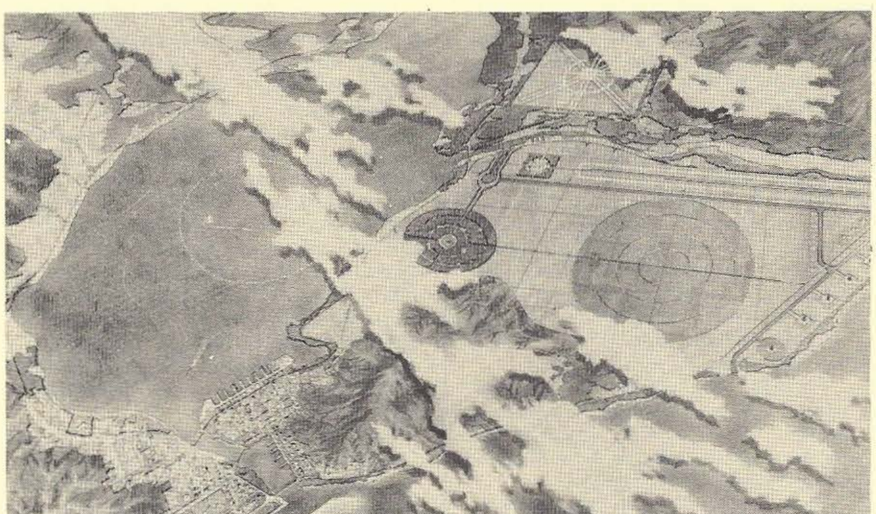


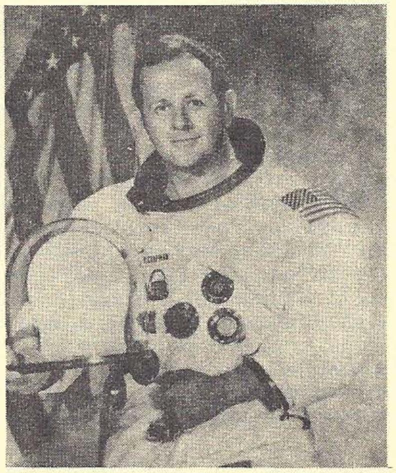
An artist's rendering of possible Earthport design shows dry and wet landing zones for future spacecraft and vehicles, as well as launching areas linked by canals for transport of large boosters and payloads. *Artwork by James McMenamin, copyright Earthport Project 1978.*

Astronaut to Lead Site Visit Group

Dr. Philip K. Chapman, a former Apollo astronaut, has been chosen by the Earthport Project to head a group to identify the most attractive locations for the establishment of an international space launching area.

As head of the Site Choice Committee, Chapman will supervise initial screening of potential sites for Earthport, and then visits to areas for first-hand analysis. Recommendations by his committee will be presented to the Earthport advisory board upon conclusion of the site visits.

Among the considerations of Chapman's study group will be the latitudes, launch azimuth limits, accessibility, altitude, economic potential, geology, climate, proximity to oil or natural gas, and political conditions at the sites.



An Australian-born scientist, Chapman received a degree in physics in 1956 from Sydney University. After spending time in Antarctica upon graduating, he came to the United States for studies in physics, astronautics and aeronautics, and experimental astronomy. He received a PhD from MIT in 1967.

While at MIT, Chapman became interested in the possibility of creating a new international, equatorial launching facility. He helped prepare a proposal that New Ireland in the Pacific be considered as a world launch site at a time when the French government was moving to establish a national launch center near the equator in French Guiana.

Chapman became a scientist astronaut in 1967, and flew on the Apollo 14 mission in 1970. His responsibilities on the flight included crew training and coordination experimentation.

Since leaving NASA in 1972, Chapman has studied the feasibility of laser spacecraft propulsion for AVCO, and Solar Power Satellite prospects for Arthur D. Little, Inc. He has been an active advisor to the Earthport project since early 1977.

SATELLITE CENTERS FOR INTERNATIONAL USE TO BE STUDIED

by Mark Frazier, Earthport Bulletin

Benefits from space, which have long gone to developed countries, may spread to new nations in coming years via centers for receiving and interpreting satellite data.

To encourage the establishment of such centers, the Earthport project in April formed a research team to assist nations in acquiring space-related technologies and expertise. The group will work under the chairmanship of Bert Cowlan, codirector of the New York-based Public Interest Satellite Association.

The principal objective of the research will be to determine requirements for ground stations and training centers, from the standpoint of developing countries. Special attention will be given to new equipment and building techniques for the facilities, as well as to means of assisting their financing in more nations than at present.

Two subcommittees will examine aspects of the subject. One study group will investigate alternative types of receiving stations, and their economic, technical, and manpower requirements. An Iranian authority in remote sensing, Siamak Khorram, has been selected as principal investigator for this area.

Another study group, on creation of training centers along with the ground stations, will have as its principal researcher Leonard David, program director of the Forum for the Advancement of Students in Science and Technology. The group will study methods of transferring skills in use of computers, telemetry equipment, and remote sensing images.

Reports from the two groups will be reviewed by experts in aerospace research and applications, including Krafft Ehricke, former chief scientist at Rockwell International; Raymond Bisplinghoff, a past dean of engineering at MIT and research director of NASA; and David Simonett, an Australian with world consulting experience in remote sensing who is now based at the University of California, Santa Barbara.

Financing for the ground stations and training centers will be explored jointly by the study teams. International aid or lending programs will be among the possible funding sources investigated, as will the potential for free zone lease arrangements.

While new ground stations could help bring more nations hardware of the space age, economic benefits would probably be more important. Among the possible benefits to developing countries would be an improved position relative to would-be users of their resources. Ground stations and training centers could equip nations with knowledge of valuable resources that might otherwise have gone unnoticed.

Resource sensing satellites, such as NASA's Landsat, at present send clues about mineral and energy deposits around the world to a relative handful of ground stations, most of which are located in developed countries. Corporations there generally receive the data long before a developing nation does, and possess more refined techniques of interpretation.

This imbalance may grow worse in coming years. Beyond the two Landsats now in use, it is expected that as many as 30 new source sensing satellites will be launched during the 1980s. These satellites will carry sophisticated new scanners, increasing the abilities of commercial enterprises to detect

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for the host country. Some developing nations, offering limited exemptions to commercial users, now reap from $2-4 million in rentals per square mile each year at free zones.

A portion of Earthport leasing income would be set aside to finance a World Space Center, which would help developing nations make greater use of space services. Besides offering independent consulting services to nations on technical issues in the short run, the Center might establish a network of training centers for nations desiring to acquire space-related skills. An international research institute, a space resources clearinghouse, and a fund to help finance launch activities would also be desirable.

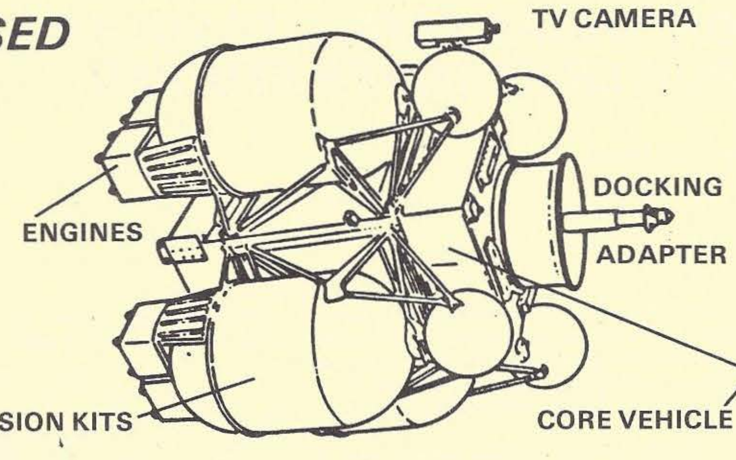
As an area in which nations could conduct space efforts at substantial savings, Earthport might play a role in reducing the proliferation of potential weapons delivery systems within countries. In coming years, nations will increasingly desire to begin launch programs of their own. Cost savings at Earthport could help persuade them to undertake peaceful space activities at a world site, rather than to attempt establishing far more expensive launch operations within their borders, where they would invite use for military ends.

The degree of investment in Earthport launch facilities would be decided by space-going organizations leasing land at the site. While rudimentary launch facilities can be constructed at low cost for suborbital rockets—and for launchers such as the OTRAG vehicle or Boeing's original, now demilitarized, Minutemen boosters—a full-scale space launch site would cost far more. Earthport leasing revenues might be applied towards some of the capital requirements, estimated by launch consultant Richard Gompertz to be at least $200 million.

For the first stage in creating a world spaceport, the Earthport project is conducting a feasibility study under the guidance of an international advisory board. Any developing nations may appoint representatives to the project to see that their interests are presented. If located in tropical regions, nations may also decide to explore, as eight countries are now doing, the potential benefits of hosting an international space launch center. □

TELEOPERATOR TO BE USED FOR SKYLAB REVISIT

Other Tasks Could Include Satellite Recovery, Repair



A Teleoperator Retrieval System (TRS) is being developed by NASA for first use in late 1979. Ordered by the NASA administrator in late October 1977, the retrieval system's first assignment will be either to re-boost the Skylab orbiting space laboratory to a higher orbit or to de-orbit it to a remote ocean area. The decision to re-boost or de-orbit is expected early in 1979.

NASA's Marshall Space Flight Center, Huntsville, Ala., was assigned management responsibility for TRS development in October 1977.

The design concept has evolved from teleoperator supporting research and development that has been underway since the mid-1960s. Hardware fabricated by the Marshall Center as part of this development has been used to validate subsystem design and to develop control and operation techniques.

Anticipated long-range usefulness of the TRS for payload survey, stabilization, retrieval and delivery missions. Its recovery and re-use capability; and its adaptability led to its selection for the Skylab re-boost/de-orbit mission.

The TRS has a central core with its own propulsion system. It is designed to accommodate strap-on kits for additional propulsion.

The core is equipped with a 24-nozzle attitude control system that provides six degrees of freedom in controlling the vehicle during rendezvous, docking and initial orientation. Its thrusters originally were designed for cold gas propulsion, but designers are now studying the possibility of using a lower cost hydrazine (hot gas) adaptation.

The strap-on propulsion kits contain a propulsion fuel tank and pressurant supply and eight hydrazine rocket engines.

Guidance and attitude control maneuvers can be controlled either through pre-programmed instruction in the core communication and data management computer, or through manual control by a Shuttle crew member, using support equipment in the orbiter. Rendezvous maneuvering and docking with the Skylab or any other objects in space would be accomplished remotely by the crew member, who can view the area around the docking adapter on a TV monitor.

A schedule allowing less than two years for development, plus the low cost objective, dictated maximum use of developed hardware. While the TRS structure and orbiter structure will be new designs, all other systems are designed almost completely with components that are either off-the-shelf qualified hardware from other programs, or are under contract and will be available, qualified and flown before the TRS is used.

The basic TRS core vehicle is box-like, 1.2 by 1.2 by 1.5 meters (4 by 4 by 5 feet), with a triad of attitude control thrusters on each of its eight corners. The thrusters, in the 2.25 to 4.5-kilograms (5 to 10-pound) range, will provide three-axis attitude control and backward and forward maneuverability.

The core houses a guidance, navigation and control system, a communications and data management system and a propellant tank. A docking system is mounted on the forward end of the core, together with two TV cameras.

A Skylab re-boost or de-orbit mission will require four strap-on propulsion kits. One kit, 3 ft. in diameter and 5 ft. long, will be attached to each of the four long sides of TRS core. Each kit will carry 1,500 lb. of hydrazine and each of its eight rocket engines will have a minimum of 25 lb. of thrust, providing a total of at least 800 lb. of thrust for the Skylab re-boost/de-orbit mission.

Many payload delivery missions will require only two strap-on kits.

Orbiter Command Station

The TRS communications and data management hardware in the orbiter will be located on the aft flight deck. Special hand controls, a TV monitor and other controls and displays are required here so that a crew member can remotely control or monitor the teleoperator through all phases of the mission.

The command station will be used for transmitting, receiving and processing telemetry to and from the TRS and to issue commands and receive TV pictures.

Skylab Re-Boost/De-Orbit Mission

The TRS will be mounted on a special support structure in the Shuttle's cargo bay for launch from NASA's Kennedy Space Center, Fla. The Shuttle will park in orbit in the vicinity of the Skylab's position.

The TRS will self-eject from the cargo bay and, using the core thrusters for propulsion, the orbiter crew member will accomplish the Skylab rendezvous and docking maneuver through the command station control system.

The TRS system is designed for docking with payloads having moderate dynamic motions, such as tumble, rolling and coning.

When docking is completed, the core thrusters will be used again to maneuver the Skylab into the proper attitude for re-boost or de-orbit. At this point, rockets of the four strap-on kits will be fired. Two burns of about 13.5 minutes each will be required for the re-boost mission, and one long burn of about 27 minutes will accomplish the de-orbit mission.

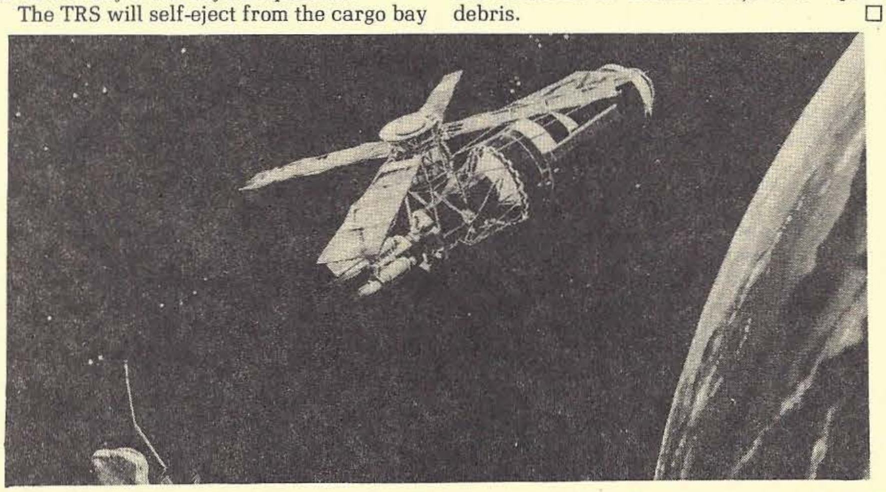
Following re-boost or de-orbit, the TRS will be separated from the Skylab and will be placed in an orbital storage mode for retrieval on a subsequent Shuttle flight.

Future TRS Uses

The TRS core vehicle will complement Shuttle orbiter capabilities for safe payload inspection and retrieval operations. Its compact, small size offers minimal cargo bay encroachment, as well as propellant savings for on-orbit maneuvering of payloads.

The core system is designed with a built-in versatility for growth applications. Growth kits, such as manipulators and steerable high gain antennas, can be added with minimum integration cost.

Typical of the growth applications are: payload retrieval at higher orbits than Shuttle is designed to achieve; large structure assembly; emergency payload repairs; and retrieval of unstable objects or space debris. □



OFFSHORE SATELLITE SOLAR POWER RECEIVER STUDIED

by Tom Brosz

An offshore structures division of a major Texas corporation is studying a proposal suggesting the possibility of constructing an offshore antenna to receive energy from solar power satellites and deliver it to coastal cities.

The solar power satellite system uses a large satellite placed in an orbit which makes it appear to remain over a single position on the earth's surface. This satellite collects energy from the sun night and day, and transmits the energy in the form of a tight microwave beam to a point below it on the earth.

The microwaves are collected by a large receiving antenna on the ground, and converted into electricity for use.

The ground receiving antenna is a flat surfaced array which is spread over several square miles to intercept as much of the microwave beam as possible. Some designs cover a roughly circular area 7 kilometers across.

Despite the enormous size of the antenna, it is actually quite lightweight. The antenna surface is made up of receiving elements placed half a wavelength of microwaves apart (about 10 cm.). This grid of elements receives the microwaves, converts it to electricity, rectifies it to DC power, and funnels it into transmission lines. This grid intercepts almost all of the microwaves, allowing very little to strike the ground below the antenna. However, the grid allows most of the normal sunlight and rainfall through its chickenwire-like structure.

The efficiency of the system can approach nearly 100% in conversion, and the large area of the antenna permits leftover heat to be slowly released into the air around it. Hence, very little thermal pollution results.

The major problem with the antenna system has been locating the system far enough from major useful areas so as not to use up valuable landscape, yet have it close enough to the electrical customers to reduce the length of energy-wasting transmission lines.

The offshore structures division feels that one answer may be to locate the receiving antenna in shallow water offshore from coastal cities. Landspace would then be preserved, yet the antenna would be located close to the users of the electrical power.

Since most coastal cities are major shipping ports, the antenna would either have to be placed out of shipping lanes (difficult with such a large object) or built on high supporting towers to allow ships to pass along underneath. The height and width of the largest ship required to pass under the structure's "roof" would dictate the major dimensions of the antenna. This extra height would also keep the antenna clear of high waves and most spray, although the operation of the antenna is only slightly hampered by rain and moisture.

Initial designs show the flat antenna array supported on a field of towers resembling those used in oil well platforms, and using similar structural techniques to anchor them to the shallow bottom of the coastal sea. Heavy structure is required to protect the antenna from damage during high winds, common in southern and eastern U.S. coastal waters.

Studies will need to be made to research effects, if any, on shallow water wildlife and fishing. The antenna itself would seem to

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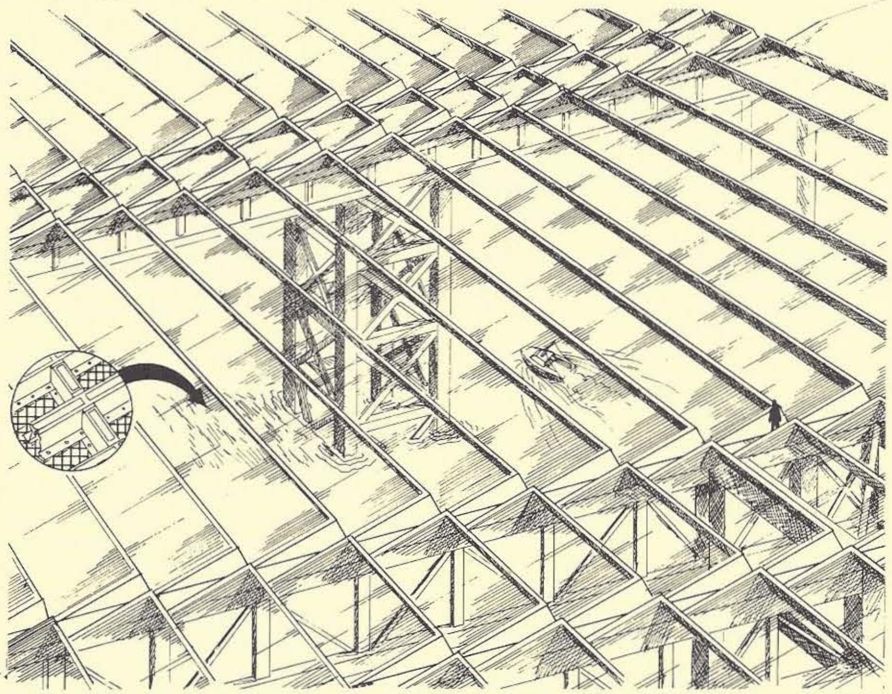
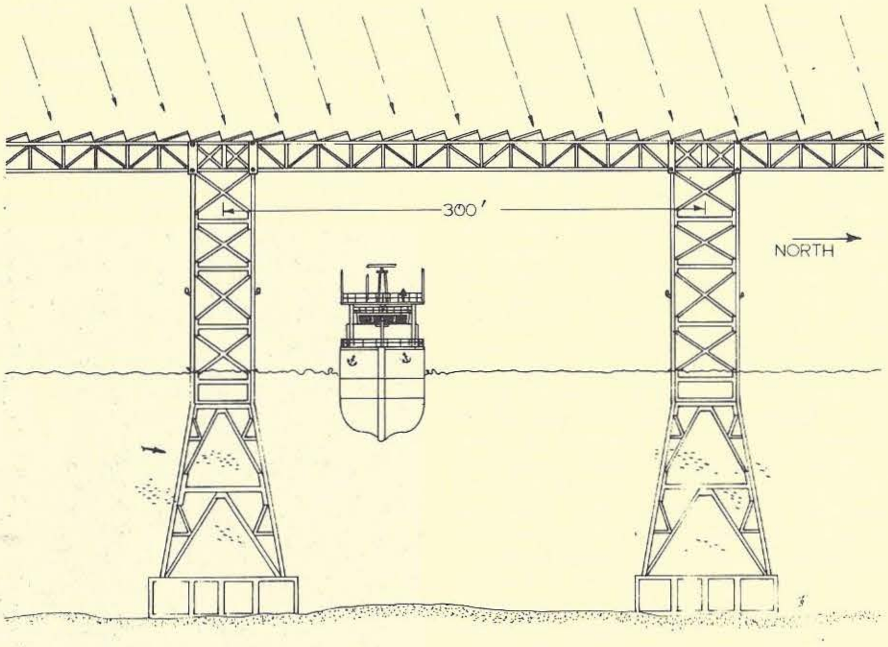


(Above) A bird's-eye view of an offshore receiving antenna for a satellite solar power system. Detail shows enclosure for electronic components which turn microwaves into electrical energy. "Chickenwire" grid prevents microwaves from passing through the rectenna. (Below) Offshore rectenna would be built on pylons to permit ships to pass underneath to reach coastal ports. *Artwork by Tom Brosz, copyright Foundation 1978.*



Another Business Opportunity—

LATEX MICROSPHERES HAVE DIVERSE MEDICAL POTENTIAL

One of the first prospects for a product which may be manufactured in space has been proposed for a near-term Space Shuttle flight by Dr. John W. Vanderhoff of Lehigh University. Dr. Vanderhoff proposes the development of a chemical reactor which would produce monodisperse latex particles in orbit.

Monodisperse latex particles are polystyrene latex microspheres with diameters of a few microns (1 micron equals 1000th of a millimeter). At the present time, ground based processes make available monodisperse (i.e., uniform diameter) particles between 0.1 microns to 2 microns. These particles are used as calibration standards for electron microscopes and in diagnostic kits for the detection of rheumatoid arthritis. The annual sales of the kits in 1973 was $30 million.

Particles larger than 2 microns are not available in production quantities however, due to problems with "growing" them in a strong gravitational field such as we have on earth. Sizes larger than 2 microns would command high prices for research and clinical applications. (Present prices for monodisperse latex particles in the under 2 micron size is $30,000/pound, with prices of $6 million/pound applicable to the larger sizes spheres.)

Three primary questions have been raised concerning the proposal to prepare monodisperse latex spheres in space.

First, what are the potential uses of these large particle size monodisperse latexes? The near-term use is as a standard to calibrate various instruments and for research work to determine pore sizes in the body. A possibility in the future is to use the spheres to deliver medication or x-ray opaque materials to very specific sites in the human body, such as tumors.

Most hospitals and clinics employ blood cell counters, for which calibration standards are often not completely satisfactory. Each of these institutions are potential customers for the larger size latexes. Simple estimates of the probable demand for the large monodisperse latexes indicate that as much as 1000 pounds of latex/year will be required to satisfy the needs of 50,000 worldwide facilities. (One small bottle of 7 micron spheres, with 5 grams of solid polymer, per year.) Assuming that these estimates are twice as high as would really be needed, the total market value is about $15 million/year based on the present market value of $30,000/pound for the latex.

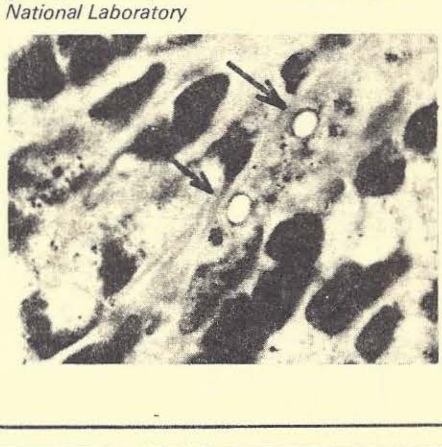
Use of the spheres for diagnostic purposes is also under consideration. For example, it is known that 2 micron spheres are irreversibly retained in the body, but since larger sizes are not available, there is no way to measure their retention rate. Different sized particles collect in specific locations in living tissue, and by choosing the exact size required for any organ, it may be possible to administer medication to highly specific sites. Also, research into cancer-causing substances would be aided, since carcinogenic materials can be incorporated onto the spheres before they collect at a select body site. If such experiments were performed in experimental animals, they would aid our understanding of the mode of action of cancer in the human body.

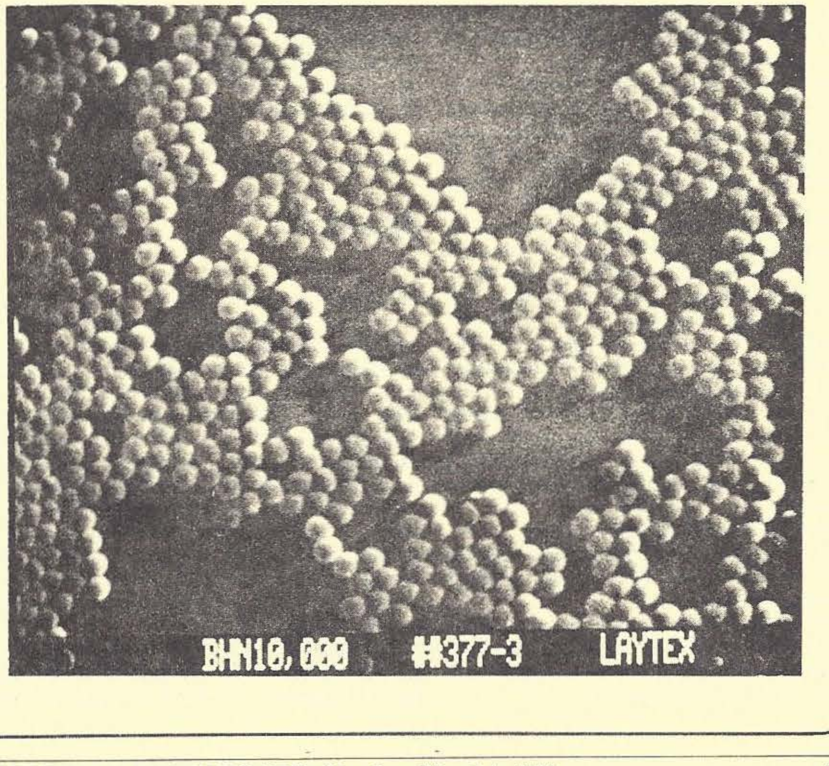
A second question is: why is it necessary for the spheres to be of a precise, uniform size? The simple answer is that the spheres are a "yardstick" used to calibrate and measure other objects. Its size must be carefully controlled if it is to have any value.

Third, why must these spheres be made in space? To understand the need for the microgravity of the space environment in the preparation of the latex spheres, we first need to understand the simple process by which the large size spheres form. First, a monodisperse latex of small particle size is prepared (this is relatively easy to do on earth). Next an amount of monomer and emulsifier is added to this seed crop, and the polymerization is carried out under controlled conditions of temperature. On earth, gravitational effects lead to settling and creaming of the mixture which is unavoidable if the polymerization process is to proceed properly. Large scale commercial batch quantities of the 2 micron plus size spheres cannot be made with well controlled diameters. The preparation of these latexes in space would obviate the settling and creaming problems, and open a promising new market for medical research and clinical applications. □

(Right) Photograph of 0.4 micron diameter monodisperse latex spheres prepared in the NASA Marshall Space Flight Center's Space Sciences Laboratory. Such particles could serve as the "seed" for the preparation of medically useful larger latex spheres. *NASA*

(Below) Micrograph of 2 micron particles (arrows) within a macrophage (white cell) in mouse tissue. Distribution of such particles at specific body sites for research and clinical purposes could become practical with larger perfect spheres manufactured in the microgravity of the space environment. *Brookhaven National Laboratory*





news notes...

SPACE INDUSTRIALIZATION STUDY...A NASA-funded study on space industry has been completed by Rockwell International Space Division and by Science Applications, Inc., a California consulting firm. Final reports are just now being distributed, including a Rockwell Space Division document titled: "Industries in Space to Benefit Mankind; A View Over the Next 30 Years". It is available by writing Rockwell International, Space Division, 12214 Lakewood Boulevard, Downey, CA 90241 and requesting a copy of document SD 77-AP-0094.

BROADCAST SATELLITE...Japan...At presstime, launch of the Direct Broadcast Japanese communications satellite was imminent. Built by General Electric, the satellite can communicate with rooftop antennas as small as one meter in diameter. While other experiments with direct broadcast have been tried (most notably the US/Indian ATS project in 1972 and the US/Canadian CTS project), none have involved planned broadcasts into people's homes like the Japanese experiment. Yoh Ichikawa, project manager for the Japan Broadcasting Corp., says the color-transmission project will last three years.

SOVIET POWER SATELLITE...USSR...The Soviet Union is studying the feasibility of Satellite Solar Power, according to a note in the April 24 Aviation Week.

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have little effect, as mentioned earlier, and the tower structures may even enhance sea life by providing shelter for fish and plants in the manner of natural reefs. If the structure is placed so as to be between the coastal cities and the prevailing direction of storm activity, it may even be possible that wind and wave action could be reduced by the maze of towers and antenna structure. This could result in reduced damage from frequent tropical storms.

The flaw in the offshore system would appear to be costs. A land-based antenna would have to be placed in remote areas of little used land, but would require much smaller supporting structures since it need be placed only a few feet off the ground.

Ships do not need to pass underneath (though automobiles might), and it does not need to resist oceanic winds and waves. A land-based structure would be built on the much cheaper principle of a chain-link fence rather than an oil-well platform. This cost must be balanced against the increased costs of the land-based system's need for much longer transmission lines to the power users. Transmission costs may be reduced somewhat by using DC transmission, though installation costs would not be greatly improved.

Other cost factors to be examined:

- increased fishing production due to "artificial reefs" of offshore antenna support towers
- possible use of support towers for oil drilling structures beneath the antenna's shielding effect, saving money on platform construction
- increased shipping costs due to having to pass through the rows of towers parallel to the rows instead of making a passage along a possibly shorter route through the area.
- Decreases in efficiency of microwave transmission due to passage through moister ocean air rather than dry, clear air over land-based system (usually assumed to be in some type of desert area due to criteria of low land value)

It is likely that costs not involving the antenna, such as launch costs and construction costs for the power satellite itself, will be nearly identical for both offshore and land antenna systems. □

CENTERS

valuable resources.

Ground stations and attendant training centers could prove invaluable in enabling developing nations to close much of the gap with rich nations as such uses of space unfold. Among the additional advantages of new stations and centers would be creation of more indigenous expertise in such areas as communications, computer operations, and astronautics. As envisaged by the Earthport project, countries hosting a ground station and training center would have the option of affiliating with American, Soviet, French, or any future international remote sensing systems.

Besides helping to locate new resources, present satellite sensors offer tools for protection of people and their livelihoods. Satellite images are extraordinarily promising as means for safeguarding countries from pollution, and for warning of ravages by advancing deserts, crop diseases, and even fires. Following floods or droughts, the Landsat system, as an example, can make detailed inventories of the areas affected.

With more earth-sensing satellites soon to become available, nations will have at their disposal increasingly sophisticated informations about their countries. Whether the information is made use of to its full extent will depend upon moves taken by developing countries today. The Earthport project believes that increasing the number of ground stations may help nations establish a firm base for developing space skills. □

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