THE FOUNDATION
COMMERCIAL SPACE REPORT

LASERS IN SPACE

The Commercial Uses Grow

Part Two of Two Parts

What would you do with a 20 meter diameter beam of coherent light with the power of 100 megawatts if you had one? That is the question which industrial planners may now ask themselves as the prospect of solar powered lasers inches towards commercial reality. In the last issue of the *Report*, we looked at a few of the many ways that solar photons may be "converted" into laser light. The most promising system for powersats seems to be the direct solar pumped laser, with other frequency specific applications best served by carbon dioxide or carbon monoxide lasers or the new variant, the free electron laser, being developed at Stanford University and elsewhere.

The obvious next step is: make steam. All of the electric generation plants in the world (with the minor exception

—Editorial

SYNFUELS AND SPACE

by Gary C. Hudson

Recently I had the pleasure of participating in an AAS/AIAA conference in San Francisco celebrating the tenth anniversary of the first manned landing on the moon. Entitled "Remember the Future", the papers presented at this meeting ran the gamut from planetary exploration to space humanization. In fact, the banquet speakers (Poul Anderson and Dr. Robert Bussard), spoke about the space options for humankind and the prospects for interstellar travel. The most significant event at this meeting, however, was a paper by Ken Billman on the SOLARES reflector concept that he and two associates (Bill Gilbreath and Stu Bowen) have been considering for several years now. This newsletter has reported on SOLARES before (March, 1977), but I can give a short

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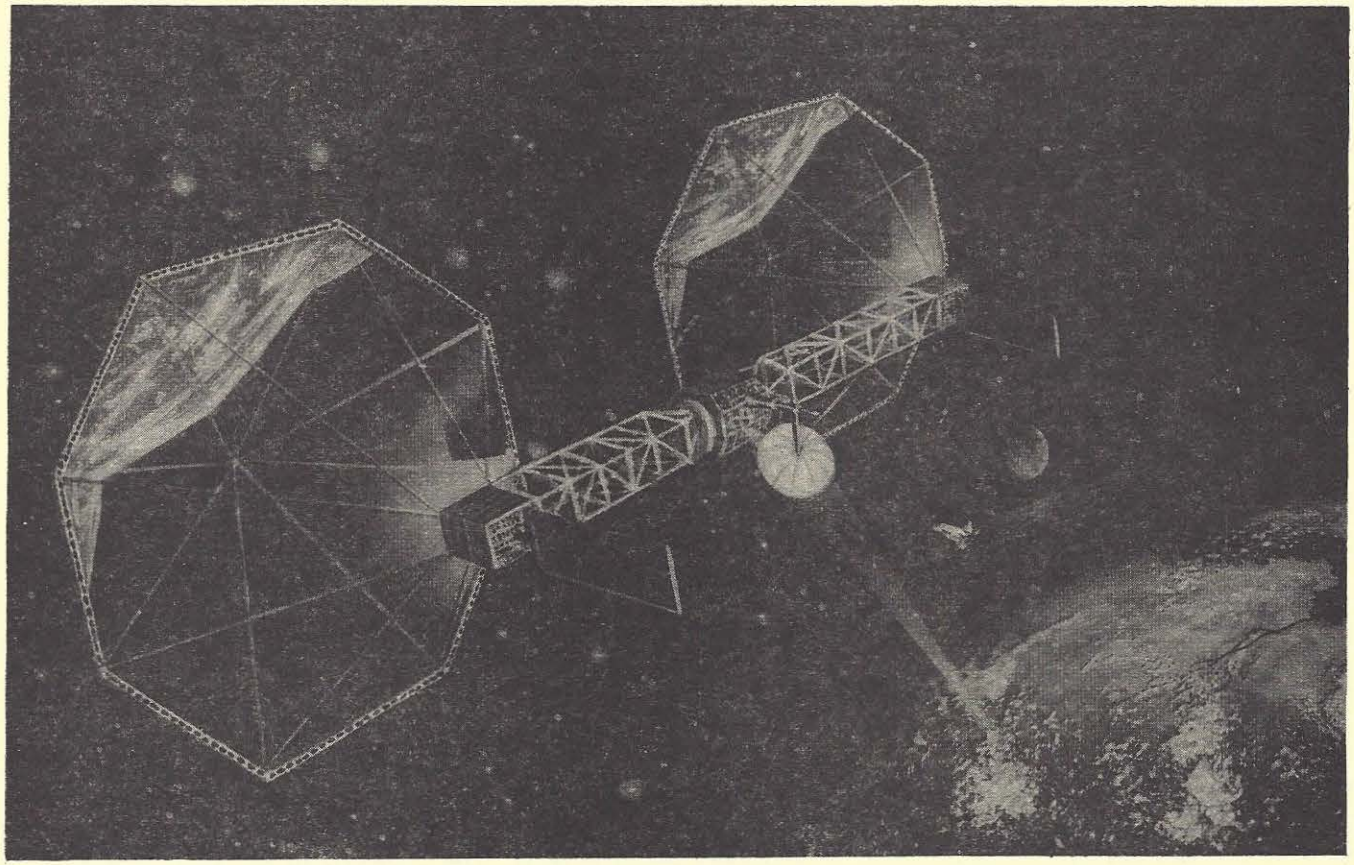
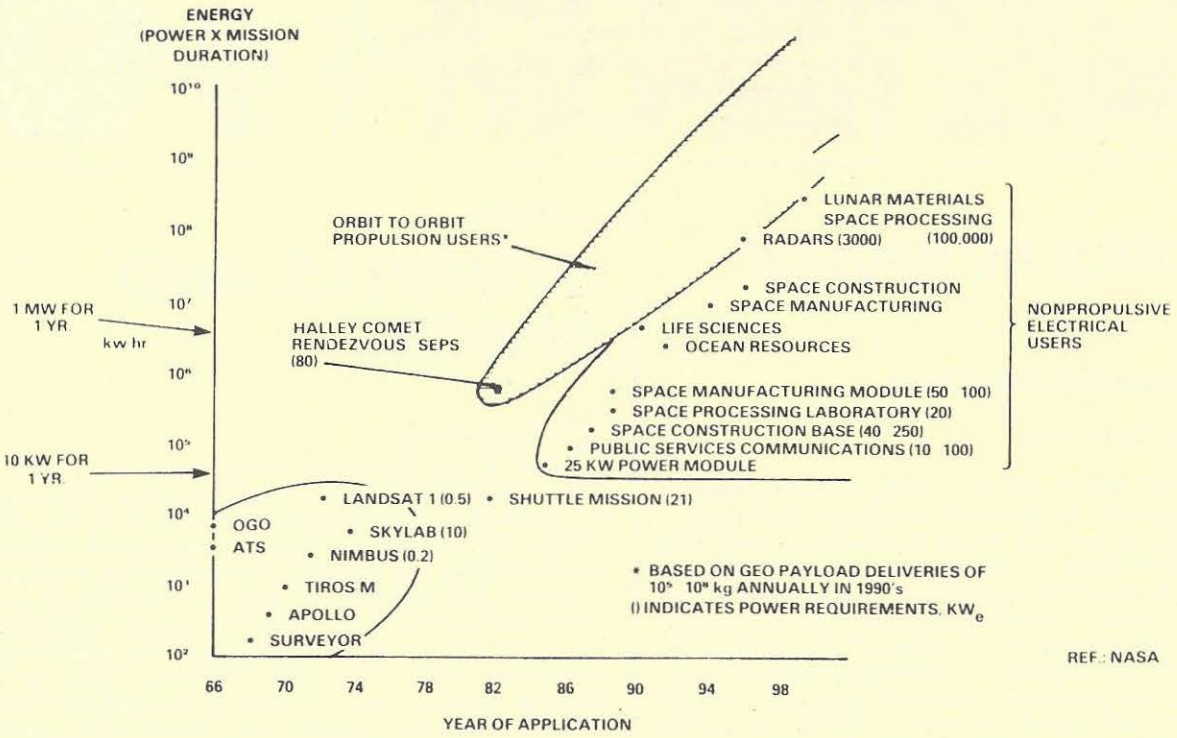


A conceptual sun-pumped laser powersat in earth orbit. Note Shuttle for scale. The powersats need not be located at geosynchronous altitudes, thus eliminating the present crowding problem in those orbits. *Original artwork for Foundation by David Egge.*

FUTURE NEAR EARTH SPACE ENERGY NEEDS



NASA data was used to compile this chart of future space energy requirements. Illustration copyright and courtesy of Dr. J. Rather and the BDM Corp.

of gas turbine systems) use some source of energy (coal, nuclear, oil) to heat water into steam and use that gas to spin a turbine connected to a generator. One could just as easily use the heat energy contained in the laser beam to do the same thing. One major advantage of the sun-pumped laser system as a powersat seems to be the ease of converting existing boilers in conventional ground based power plants to accept heating by the laser beam. Thus, the capital investment already partly amortized by the utilities has continuing value. Microwave powersats would directly obsolete the conventional plants. Using the existing equipment makes the prospect of solar power from space more economically attractive to the end user: the power companies.

While electricity from these power plants could be a major reason for the introduction of the laser powersat, it may be that the laser beam can be used directly to provide "process heat." This is heat energy which can be used for a variety of industrial applications, from boiling chemicals to melting steel. Heat is a valuable commodity in the industrial economies of the world, and the ease of delivering it via laser beam, with minimal pollution from the burning of coal and other fuels should be highly attractive.

The heating value of the laser beam also makes it useful for propulsion in space and on earth. By now, most observers of the space industrialization effort have been introduced to the laser boosted rocket concept of AVCO Corporation. Proposed many years ago, this idea would employ ground-based lasers, probably run off of nuclear power plants, to launch small (one ton) payloads into space regularly and economically. Useful more for higher tolerance cargo than human traffic, the launcher would cost many hundreds of millions of dollars to construct, and could only be used for the launch function. However, there is no reason why the laser need be on the ground consuming valuable earth-based fuels. By focusing the output of several "phase-locked" orbiting lasers on the ascending launch vehicle, it should be possible to employ energy from laser powersats for the whole mission. Relays into orbit may be needed, but such relays will be required for other commercial uses of the laser as well. The same orbiting lasers or some fraction of them might also be employed to boost cargo delivered into low earth orbit to higher orbits or to escape velocity. Similarly, the lasers could be useful in giving solar sails operating near the earth a welcome assist to sunlight alone.

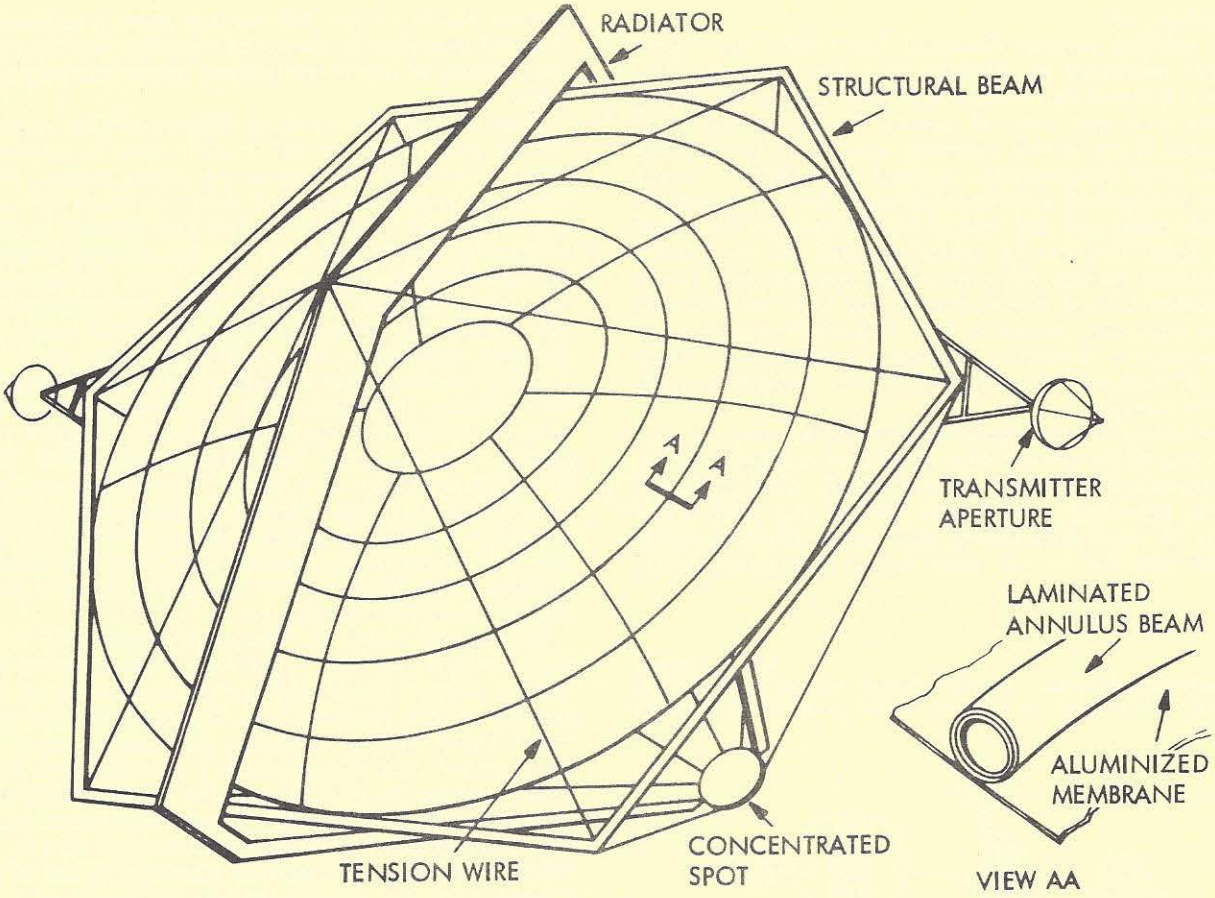
This suggests the possibility that after conventional launchers have orbited the first dozen or so lasers, those same lasers might be used to loft additional materials for subsequent powersats, thus relieving the burden on and the expense of using rockets. Orbital laser power will also be useful for mining operations conducted at asteroids near earth or on the surface of the moon. This in turn means that less material need be launched from earth for the laser powersats in the first place.

On earth, the laser powersat can help transportation in two major ways. While it may be too soon to suggest that trucks and automobiles be powered by laser beams from space, it is certainly practical to consider their use in aircraft. Hertzburg at the University of Washington and Sun and Jones of Lockheed have suggested that aircraft of the near future may be effectively powered by laser light. The beam would heat air in a special laser turbofan engine which would provide cruise power for the aircraft. Conventional kerosene engines will be used for takeoff, landing and emergency cruise. In an analysis done last year (see *Report*, March, 1977), they concluded that the system would become competitive with all kerosene planes when the cost of fuel reached a dollar per gallon. This analysis was based on the much more expensive carbon dioxide laser system in orbit, rather than the lower cost sun-pumped variety. One 100 MW sun-pumped powersat could handle two aircraft continuously.

Conceivably, airships hauling freight around the world might use lasers as well. Instead of scarce helium to provide lift, a airship might rely on laser heating of a semi-opaque gas which would be contained by the airship bag. Using laser light to warm this gas, the airship would rise. Smaller lasers could provide power to propeller engines which could drive the vehicle. Obviously the laser heating the gas bag need not be on continuously, so one laser could provide power to tens of airships.

Lasers might also provide power to ships at sea. By using a thermal storage system on board to capture the heat from the beam, ships would not have to be continuously irradiated by the orbiting platform.

The powersats have other uses as well. Local climate modification might be a prospect for lasers of specific frequencies. For example, frost destroys tens of millions of dollars worth of crops each year. Use of reflecting mirrors to warm an area could be very costly, and would provide unwanted light in some locales. The lasers could very precisely heat a small farm without exposing an adjoining ranch to stray infrared radia-



(Above) A Lockheed conception of the reflector powersat, with dual transmitter optics installations. Radiators would be required to cool the laser. Nominal size for the device is about 3 kilometers diameter. (Below) The new concept of a laser pipeline is illustrated below. Laser light could be transmitted across country in evacuated pipelines which would terminate at industrial parks specially equipped to use the beams in manufacturing and research. *Drawing by Tom Brosz.*

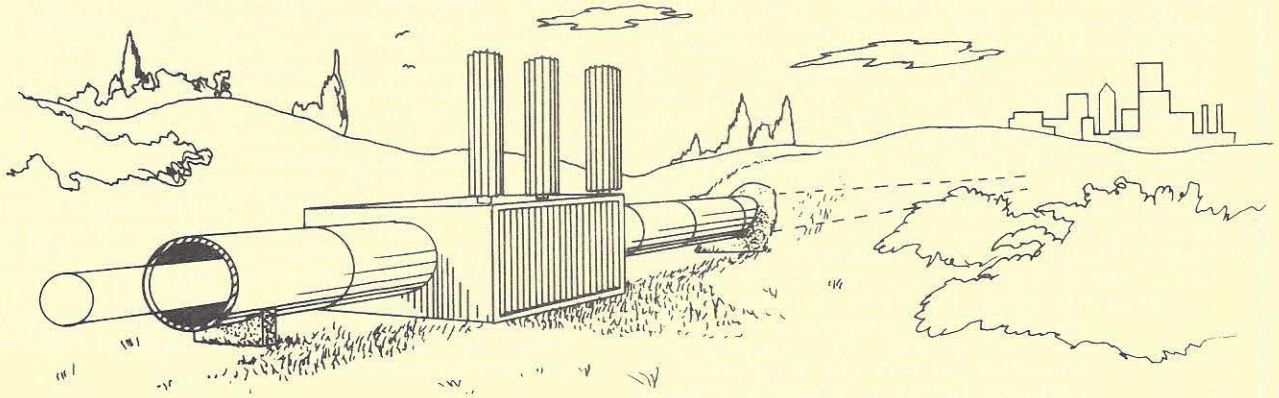
tion. The commercial application is straightforward: those who paid for the laser heating service would get it while those who did not want it would not.

Such lasers could also be focused to high temperature beams to cut firebreaks around areas imperiled by brush and forest fires. They could be used with ground-based refocusing equipment to cut rock and perform other mining tasks. Specialized photochemical reactions useful for the production of fuels and useful chemicals might also be initiated by space-based lasers.

Finally, there is the concept known as the "laser utility". Laser light would be captured by a ground station near an industrial park, and "pumped" through pipelines to the site. There it would be split into hundreds of separate beams of a few kilometers power each. The beams would be routed to end users in companies throughout the facility, where they would be piped to individual tools, such as drills, lathes, mills, welders and cutters. Not only would the laser light produce better finished goods, but the speed of production can be increased (by as much as 6 times in tests to date). The cost of such a system might also be measured in terms of safety and reduced noise in the workplace as well as the savings in tool wear.

Whatever is planned, however, must take into account safety in the transmission of the laser beam. Happily, this can be reduced to a problem of minor proportions if the beam is highly defocused as it transits the atmosphere.

Lasers seem to be with us to stay on earth. The question facing the industrialist now is Can we take them to space and reap the benefits back here on the planet? There is every reason to believe that we can and will.

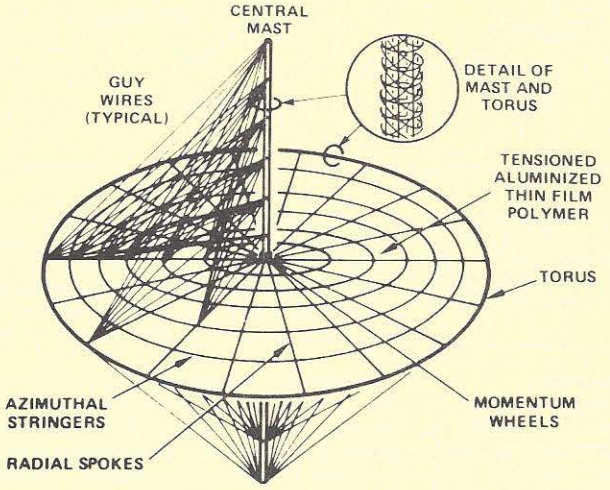


recapitulation.

By orbiting several thousand lightweight (and quite simple) reflectors at altitudes of a few thousand kilometers, it would be possible to reflect sunlight on ground targets with spot sizes of around ten kilometers or so diameter. If you located a ground-based solar power plant at this area, the insolation (amount of sunlight received) would increase by a factor of three to five . . . providing sunlight night and day, and of higher intensity than high noon light. This has an immediate and obvious benefit for making ground solar plants an economically viable competitor to fossil and nuclear power facilities. The cost of the electricity produced by a SOLARES/ground solar power plant is, according to Billman's calculations, about 12 to 30 mills per kilowatt hour or very competitive with present sources.

The capital cost of establishing the system and the very large size of the ground sites have been discussed as the reasons why SOLARES could not be built. (Cost of the full system, providing nearly 1000 GW, or the total world supply, is about $450 billion; each power plant would be around 100 GW or 100 times bigger than conventional nuclear plants.) While Billman can show a reduced cost of initial operation by designing a smaller startup system, the problem of highly centralized power production still exists.

(Below) One of the early designs for the individual reflectors needed by the system. In a full scale program, as many as 70,000 such mirrors would be required.



There the matter rested, as Billman and his coworkers refined their numbers and tried in vain to interest the powers that be in this alternative energy project. I maintained a passing interest, but didn't do much else. About two weeks ago I decided to visit Ken Billman to discuss whether or not he had done any calculations suggesting that SOLARES could be used on the moon. (I was attempting to study the near term use of lunar resources on earth, and needed the advantage that SOLARES could give.) But that application was quickly forgotten as I heard about a scheme to use a minimum SOLARES installation for synthetic fuel production. Following the interest in synfuels which has been generated by Carter's recent energy speech, some new calculations show that a SOLARES could be very useful in producing synfuel by two different processes: bioconversion and the production of methanol using atmospheric carbon dioxide and hydrogen from water. Both processes have the potential of providing a large fraction of the liquid fuel that the country (and ultimately the world) uses.

Billman still faced an important problem with the concept: startup cost due to the high transportation tariff. At that point, I introduced him to the Foundation Large Launch Vehicle (known as the Big Dumb Booster around here). Using the low operating and nearly non-existent development cost figures which I provided him, he was able to reduce the startup costs for the SOLARES system to less than $18 billion using conservative estimates, and this figure might be reasonably reduced to two or three billion by further analysis and planning. Either of these figures puts the projects within the reach of private funding.

Well, so what? We all know that synfuels will cost more than conventional petroleum, don't we? Therein lies a very pleasant surprise. Using his conservative costing estimates, Billman was able to compute the price per barrel of SOLARES synfuels as $12, or about half of the OPEC price at the present time. Using the more optimistic costing, the price goes down to about $2/barrel, or about half of the cost at the time of the first oil embargo in 1973. All this for an investment of about 10% of what the President plans to spend for synfuel production which will yield prices of $25/barrel and up, as well as potential environmental disruption.

Did I hear someone say that we have an energy crisis?

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NEWS NOTES:

PRIVATE ENTERPRISE THREATENED...United Nations...The United Nations Committee on the Peaceful Uses of Outer Space has sent a Soviet-inspired version of the Draft Lunar Treaty to the General Assembly for approval. Several space lawyers have commented to the Report that the document is in their opinion a "disaster for the United States". Reported out of the committee on July 3, 1979 for consideration in the 1979 session of the General Assembly, the document effectively prohibits the commercial exploitation of extraterrestrial resources by private organizations, and if strictly interpreted, may do likewise for governments. Article II of the the draft states: "The moon and its natural resources are the common heritage of mankind..." with Paragraph 3 stating: "Neither the surface or subsurface of the moon, nor any part thereof or natural resources in place, shall become the property of any state, international, intergovernmental or nongovernmental organization...or any natural person". Article V provides for the establishment of an "international regime" to govern exploitation of the moon and other celestial bodies with the proceeds of the sale of any resources being distributed among all nations. Since the use of the term "moon" is taken to mean not only earth's moon but all other bodies besides the earth in space according to the definition in the treaty, these provisions would effectively prohibit any private mining activity anywhere in space. The USSR has offered to host a Conference on Outer Space Law during the later half of 1982 for the purpose of reviewing the document following implementation of the accords. According to a knowledgeable observer, it appears that the US, which had opposed the original Soviet draft of the Treaty, collapsed in recent negotiations and gave the USSR nearly everything it had asked for. Among space industrialization advocates it was widely believed that the treaty would be stalled in committee for another five to ten years.

EARTHPORT UPDATE...Washington, D.C...The Earthport Project has opened a new office in Washington; the new address is 325 Pennsylvania Avenue, S.E., Washington, D.C., 20003. Among the recent developments has been a contribution received of a nearly new sport fishing boat with an estimated value of 86,000 dollars which has been donated to the project to advance its technology oriented programs. When sold, the funds from the boat will go in large part to support Neil Ruzic's Island for Science in the Bahamas. Another grant was received from the editor of Byte Magazine. The Project has been reorganized into three separate activities: Free Zone study groups, Space study groups and Ocean study groups. According to Mark Frazier, Earthport has "broadened the overall description of our goal to be the establishment of 'Technology Development Zones'. Earthport, a freeport devoted to space, remains the centerpiece of the project. But we are now offering potential host countries a wider range of programs that could be funded by free trade zones." Frazier went on to say that "despite very friendly communications with the Liberian government, and their endorsement of the

'space freeport' proposal at the United Nations last October, recent events in Monrovia--including civil upheaval-- have slowed progress on our proposal. Other countries continue to respond favorably. In recent months, representatives of the Project have had two meetings in Lagos with senior Nigerian officials, and extensive communications with Caribbean and Pacific island countries." New advisors have joined the Project in recent months, including Scott Carpenter, former astronaut, and Hugh Downs, president of the National Space Institute.

SHUTTLE ENGINE FIRE...A board of investigation has been appointed by the NASA Marshall Space Flight Center to investigate an accident which occured July 2 during the test firing of the Space Shuttle Main Propulsion Test Article. The Test Article consists of three Space Shuttle main engines mounted in an orbiter aft section and attached to an external tank. During a planned 520 second test firing, an automatic cutoff occured after 18.5 seconds due to a liquid hydrogen leak from one of the engines' main fuel valves. This was followed by a fire around the aft area of the Test Article. In related news, NASA has been forced to ask for an additional 150 million dollars to cover development costs on the engine due to the problems encountered in the last year. President Carter has asked NASA Administrator Robert Frosch to come to the White House October 15 to brief him on the Shuttle and its problems.

NEWSLETTER MAILING CHANGE... St. Paul...Due to new postal regulations, the Commercial Space Report will now be mailed in a business size envelope. This should provide better service for newsletter readers since the envelopes can be handled faster (according to Postal authorities).