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ENERGY CRISES:

a history lesson

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In the past, humanity has confronted repeated energy crises. Each time, creative use of technology constituted a response that redefined by means of new technology what constituted energy resources. Such redefinition helped propel civilization's onward march. Thus, the coming depletion of fossil fuels does have its bright side by providing for us a stimulus to seek substitutes. The withdrawal symptoms may, however, be painful and result in the creation of a new form of civilization.

The Changing Nature of Energy Crises

Suppose this were the year 1776 and that a conference were meeting in Britain to discuss the energy situation. The country was then industrializing rapidly. What would be our assessment of the situation and what would be the nature of the energy crisis? The consensus of experts would be that Britain was running out of adequate sites for water wheels that were providing power for the rising number of factories. Such a development would lead to a curtailment of the growth of the economy, just like lack of timber (the timber famine) was curtailing the use of wood as fuel, construction material, and even the production of iron (you need wood to produce charcoal to smelt iron ore). Projection of trends, if made, bode nothing good for the year 1800; a limit to growth was being approached rapidly.

A response to the crisis would come in the form of calls for energy conservation. Furthermore, the consensus of experts would be that massive efforts should be made to improve the efficiency of water wheels. Improve the familiar rather than gamble on the unfamiliar. This was on the

minds of most engineers of the time. Part of this trend was the experimental work of John Smeaton, one of the leading British engineers of the eighteenth century¹. He performed numerous experiments, varying a single factor at a time and came up with a design that

doubled the efficiency of water wheels.

Yet when the year 1800 came along none of the dire prophecies about limits to growth materialized*. The growth in power demand was taken up by a new technology, namely, steam engines. Indeed, they already existed in 1776, and already then a totally different approach to the energy crisis was

possible. James Watt had patented his invention, produced a prototype that worked, and by 1776 was in the steam engine business. The firm did not show a profit until the 1780s, but by 1800 (when his patent monopoly expired) Boulton and Watt had produced approximately 500 steam engines, while probably twice that number were made by various competitors who were evading his patents³. The growth of canals had provided an effective network of transportation that had lowered the



price of coal dramatically, and made steam engines profitable not just at the coal mines. They began to complement water wheels, at first. They could operate in all seasons, while water wheels often stood idle for lack of water in the summer or could not operate when streams froze in the winter.

The great flexibility that steam engines provided did not, however, result in the outright desertion of good water wheels and favorable sites. Their great disadvantage was the impossibility of locating them in urban centers where labor and markets were placed. Steam engines invaded the power market sector by sector, and gradually other uses of power emerged. Steam engines began to do things that water wheels could not, such as railroads. But in some industries the changeover was slow. In textiles, as late as 1830, about 25% of motive power was still provided by water⁴. But meanwhile the use of coal had expanded rapidly. It was displacing wood as fuel, and the expanding production of iron was made possible by smelting iron ore with coke rather than charcoal. The full transition to steam took approximately sixty years in Britain⁵.

In the wake of this transition, the energy crisis had been redefined completely by 1876. Running out of coal became a national concern in the 1860s, spurred by an economist, W. Stanley Jevons. In his book⁶, published in 1865, he once more talked of an energy crisis and once more posed the limits to growth issue. If the rate of growth in coal consumption continued unabated, Britain would be within a century checked in its economic growth. He arrived at this conclusion by plotting on semi-logarithmic graph paper the consumption of coal since the late eighteenth century and by extrapolating he showed that long term growth was impossible. Although during the years following the publication of his book the rate of growth settled to a lower value, still the implications were serious. Another imaginary British commission set up in 1876 could hardly avoid this conclusion. Again, the proposed solution would call for conservation and for the increasing of steam engine efficiency⁷.

Like in the previous episode, the people and the new technology already existed and, by the year 1900, a very different energy scenario was developing. Steam technology continued to improve but what was fueling the steam engines and turbines was increasingly oil rather than coal. And new technology, internal combustion engines of various types were displacing steam engines. In 1867 and 1878, N. A. Otto had taken important patents, and the superiority of his engine was so apparent that his firm sold more than 35,000 engines. In 1892 Rudolf Diesel took out his first patent, and there were many others*. But the main

thing about the displacement of the steam engine by the internal combustion engine is that it had been already on the horizon in 1876, only the experts did not notice it. A century ago John D. Rockefeller was already making millions from oil at the Standard Oil Company, while in 1900 he was well on his way to becoming the first oil billionaire⁹. The internal combustion engine could perform where steam engines could not. The aviation industry, and in part the automobile industry are prime examples of the kinds of factors that accelerated the displacement of coal by oil. Electrical power generation slowly began to convert and was followed by the use of oil or gas for domestic heating. By 1930 coal had retreated on a broad front so that the transition to oil also took approximately sixty years¹⁰.

These two episodes provide valuable case studies from which some lessons can be drawn because of the historical analogy with our present energy crisis. First, both the water wheel and the steam

“Yes, there is an energy crisis today, but it is a fossil fuel energy crisis.”

engine experienced a flurry of technological innovations some time prior to the time that they began to confront the new technology. This flurry occurs quite often without an awareness of which technology will displace the older one. This phenomenon, called “technological backlash,” seems to come about from the emotional involvement or even commitment to older technology on the part of its practitioners. They may have contributed towards its development, been trained in it, or maybe their livelihood can be threatened by the new technology. Watt opposed high pressure engines; Edison opposed alternating currents.

Second, it is, therefore, not surprising that experts miss forecasting our way out from an energy crisis. Consulting the eminent experts or forecasting based on trends usually miss even those things that are already on the horizon. The new technology does not yet form part of trends, and they often are not incorporated into middle range or long range forecasts. But of one thing we can be certain about the future-it will not be like the experts think it is going to be. In forecasting we often ask the expert to forecast his own demise or that of the field of his expertise. This unpleasant activity seldom is carried out well. Both transitions were comparatively rapid, where a new technology went from

nothing to a significant role in twenty-five years and full transition occurred in about sixty years.

Third, the technology that experiences backlash has powerful economic backing, while the challenging technology develops without major expenditure and by single individuals or small groups of devotees. Thus, many engineers worked on improving the water wheel; James Watt worked alone with the financial backing of two individuals. When the steam engine became the predominant technology it was the concern of many individuals; Otto, Diesel, Daimler worked with their own meager resources.

The Fossil Fuel Energy Crisis

This brings us to 1976, and to our present energy crisis. The first signs became visible to a few during the 1960s¹¹, but its full impact exploded on the public during the early 1970s. Today we import 50% of our oil requirements with no relief in sight. Our internal oil production will decline, according to the predictions of M. King Hubbert¹². His main assumption is that given the nature of conventional oil resources, what goes up must come down again. He derived his method of projection from straightforward statistical analysis of past records and production of oil. Oil production in the United States would come down again roughly along a bell-shaped curve whose span would be an almost insignificant blip in the span of human history. This blip has been called Hubbert's pimple, and it tells us that between 1940 and 2000, United States will use up 80% of its oil.

Conservation efforts will stretch our oil resources a little. Washington demands by legislative fiat that by 1980 automobiles deliver an average of twenty miles per gallon. Insulation of homes, more efficient appliances, and new or higher efficiency industrial practices will certainly help. ERDA's budget has over a billion dollars for nuclear fission, and hundreds of millions for various fossil fuel energy projects. There is much activity to solve “the energy crisis.” Yet I can hardly escape the feeling that we are going about it in the 1776 or 1876 fashion. Are we not “improving the water wheel?” Are we not losing track of the broader trends? Does not a crisis present an opportunity to take bold steps in new directions?

Yes, there is an energy crisis today, *but it is a fossil fuel energy crisis*. Crises have their bright side in that they force us to question our old ways. The water power crisis propelled the agricultural society in Britain to the wealth of the industrial society today. And even though the wealth of our industrial societies is based on fossil fuel technology, a crisis does not entail the end of our civilization. The coming depletion of fossil fuel reserves will result in technology that will propel us into a new age. Living standards

can increase even higher once we tap non-fossil energy sources. Unfortunately, ERDA's plan is based on fossil fuels and nuclear fission technology. They have no plans for "other energy sources." But if past history is any guide, under that category lies the story of energy developments of the next thirty to sixty years. It is very likely that when the year 2000 comes along new technology will begin displacing our present fossil sources.

Technology Defines Natural Resources

Technology has often defined what constitutes a natural resource at a given time in history. When the appropriate technology was produced, waterfalls became a valuable, and even scarce, resource. Whenever we said that something was useless, we really meant that we had not yet had a technology to turn it into a resource. At one point, oil seeping from the ground was useless-and actually a nuisance that ruined good agricultural land in Pennsylvania. Technology transformed it into black gold. Uranium, bauxite, and many others are further examples of the role that technology plays in defining natural resources. The Sahara and other arid tropical or semi-tropical areas were considered useless. Now they suddenly are perceived as solar energy intensive fields. Now that we seem to be developing a technology to exploit the bottom of the sea, we are beginning to discuss the fascinating question, "Who owns the oceans?"

Space, until now, was also thought of as useless, empty. But not any more. It is emerging as technology's next frontier, and with it, a clean, abundant, renewable energy frontier. The technology that will accomplish this is already here. But solar power has to overcome vested interests and other technical aspects before it can become competitive with other fossil energy sources. Fossil energy advocates see only a small role for solar energy. Their most optimistic forecasts give only 25% of the energy budget in 2020 to solar power¹³. For the advocates of solar power that same year could well reverse the situation-only 25% still produced by fossil sources.

The flurry of technological innovation in the fossil fuel energy sources antedates by more than a decade Project Independence, which, launched by President Nixon, was supposed to provide us with energy self-sufficiency in ten years at a cost of 600 billion dollars. By going into nuclear technology and using known coal transformation technologies, some dating as far back as WW II, we could become independent of oil imports. We would turn coal into gas and synthetic gasoline. We would extract oil from shale rock and tar sands. We would still further improve the efficiency of the internal combustion engine. Huge sums would be devoted to research in these areas. So far the plan

has been an absolute failure, and we have reached the 50% mark for our imports of oil. And notice that the plan would not make us independent from fossil fuels, just independent from foreign oil imports. If we do nothing at all we will spend even more money, importing some 35 billion dollars a year of oil. These imports may well amount to one trillion dollars over the thirty years, and more if we import more oil due to increased energy consumption or if the price goes up.

Space technology can provide a novel and inexpensive resolution of our present energy crisis. For a small fraction of the money that we shall spend on self-sufficiency or fossil energy imports, some 120 billion dollars, space technology could make us independent of fossil fuels altogether¹⁴. Our energy costs can become inflation-proof, because in solar energy the fuel is free. Solar energy would give us back a clean ecology; its great abundance would eliminate the gap between rich and poor nations. But like previous modes of technology, solar energy at present has some major difficulties.

"Placing solar collectors in geosynchronous orbit would allow the same surface area to capture up to twenty times more energy."

Solar power comes in a very diffuse form, and this requires huge areas for solar collectors. The atmosphere absorbs a large portion of energy, the day-night cycle requires complex storage systems, and the seasons and cloudy days complicate this picture further. Simply put, solar energy collected on the surface of the Earth is not competitive with other forms of fossil energy at current prices¹⁵. There is some hope that as fossil energy prices rise, and the costs of mass-produced solar collectors goes down, that the picture for solar energy will improve in some special cases. No doubt the efficiency of photovoltaic cells will see further increases, and there is high expectation that their cost will drop from the current one of \$20 per watt to \$0.50 per watt by 1985¹⁶.

This economic scenario changes for the better if we can collect solar energy above the atmosphere and outside the shadow of the Earth. Placing solar collectors in geosynchronous orbit would allow the same surface area to capture up to twenty times more energy in the same interval of time. The idea of a Satellite Solar Power Station (SSPS) was

conceived by Peter Glaser almost ten years ago¹⁷. He proposed that huge solar collectors be set up, convert electrical power to microwaves and beam this energy down to Earth. Rectennas would pick up the microwaves and the energy would be reconverted to electrical power. The surface area devoted to solar energy would be much reduced. But this idea remained impractical because it takes large amounts of energy to put an SSPS into geosynchronous orbit.

But what may tip the balance in favor of solar power is a further reduction in costs in the manufacturing and positioning of an SSPS. If these huge structures must be built in space, why build them here on Earth? This novel approach was made public in 1974 by Gerard O'Neill who suggested that we use lunar materials, process them with solar energy, and manufacture Satellite Solar Power Stations in space directly¹⁸. Samples of lunar rock that were brought back have been analyzed and shown to contain all the necessary materials, except for hydrogen. This in itself constitutes a breakthrough and a discovery that justifies our space program of the 1960s.

Instead of carting an SSPS from Earth, working against its gravitational field and incurring heavy energy penalties, an SSPS can be built in space for a fraction of the energy costs and then slowly shuttled across space to its geosynchronous orbit. The savings, amounting to a factor of ten, will provide us with the first major instance of space as a valuable resource. The technology to do all this is already available. It comes at the peak of a mounting feeling that the future of the human race is once more confronting a limits to growth situation. Among the problems most frequently mentioned are, in addition to the energy crisis, the resource depletion crisis, overpopulation, breakdown of the ecology, and widespread shortages of food. The solution to all of those problems is to reach out into space for energy, raw materials and living room for our expanding population.

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3. John Lord, **Capital and Steam Power 1750-1800** (1966) based on papers of the firm Boulton and Watt. Singer, op. cit., Volume 4, p. 163.
4. Singer, op. cit., Volume 4, p. 156. Water power had reached its peak some forty years earlier, so that its declining share of the market was due to the rapid growth of steam. By 1850, it dropped to 19.4%, while in 1870, it was down to 5.3% when an absolute decline in water power began. See **Miscellaneous Statistics of the United Kingdom**, part III, (1870). p. 370.
5. A better measure of market penetration is to consider that displacement has occurred when 50% of the power is provided by steam. Shipping was a sector where the transition was one of the longest, especially for long distance shipping. Displacement occurred in 1890. Charles K. Harley, "The shift from sailing ships to steamships, 1850-1890: a study in technological change and its diffusion," in Donald N. McCloskey, **Essays on a Mature Economy: Britain after 1840** (1971), 215-237.
6. W. Stanelly Jevons, **The Coal Question. An Inquiry Concerning the Progress of the Nation, and the Probable Exhaustion of our Coal-mines** (1865).
7. According to W. M. McFarland, **Engineering Magazine** (1902), p. 215, efficiency of steam engines doubled between 1876 and 1900. Slightly different figures are given by Singer, op. cit., p. 164.
8. Singer, **op. cit.**, Volume 5, Chapter 8, "Internal Combustion Engines," pp. 175-176.
9. Standard Oil Company's net worth on the books in 1900 was two hundred million dollars according to Albert Z. Carr, **John D. Rockefeller's Secret Weapon** (1962). p. 122, while a figure of 660 million dollars is quoted for 1911 by Jules Abels, **The Rockefeller Billions. The Story of the World's Most Stupendous Fortune** (1965). p. 272.
10. In 1970 coal provided about 2% of the US energy budget, and hydroelectric power contributed only 3%, Lawrence Rocks and Richard P. Runyon, **The Energy Crisis** (1972). p. 8. Since then coal decreased to about 20% as the Clean Air Act (1970) forced some utilities to abandon coal and go to gas or oil.
11. M. King Hubbert started the dispute in 1956 and throughout the 1960s clashed with the constant upgrading of estimates of reserves made by the oil industry. Oil production in the US has been declining since 1970, while gas production reached a peak in 1974. M. King Hubbert, **US Energy Resources: a Review as of 1972** (June 1974) has been vindicated by the latest study of the National Academy of Sciences, **Mineral Resources and the Environment** (1975).
12. **Science** (28 February, 1975). pp. 725-6.
13. This is an ERDA estimate published in 1975. But recently their priorities have drawn heavy fire for its reliance on nuclear and traditional fossil sources, and for not looking into solar energy possibilities.
14. Economic estimates vary from an initial one of 30 billion dollars to 200 billion. But at the same time, estimates for Project Independence go from 600 billion to 2,000 billion.
15. In the pre-embargo days fossil fuels ranged from 1.5 to 5.0 mills per kilowatt-hour, while mass produced solar equipment would cost from 5 to 10 mills per kilowatt-hour. Today, solar energy from a SSPS will be competitive at 15 mills.
16. **Aviation Week & Space Technology** (18 August, 1975). p. 21.
17. Peter E. Glaser, "Power from the Sun : Its Future," **Science** (22 November 1968), pp. 857-860.
18. Gerard K. O'Neill, "The Colonization of Space," **Physics Today** (September 1974). pp. 32-40. Revised economic figures were provided in his "Space Colonies and Energy Supply to the Earth," **Science** (5 December 1975), pp. 943-947.

Non-Terrestrial Resources

Cheap transportation costs for raw materials from the Moon and the asteroids may be the key to large-scale space manufacturing. And there might be some surprises tucked away out there.

Eric Drexler (research assistant to Gerard K. O'Neill)

The goal of using non-terrestrial resources motivates the idea of space colonization. Use of non-terrestrial resources may be essential for the economic viability of power satellites and other proposed space industries. Non-terrestrial resources may eventually provide the substance of life for most of humanity during the greater part of its history. Their use in the future will depend on availability, economics, and goals.

Proposals under study by O'Neill and others involve fabricating the high mass components of power satellites, their construction facilities, and habitats for the construction workforce, from non-terrestrial resources. While some materials and intricate components would still come from Earth, such proposals aim to avoid the cost of lifting massive components into space. The activities of this period, which runs from the late 1980s to the late 1990s in many scenarios, have been the subject of considerable engineering analysis. A later period has been examined involving a reduction in the number of materials required from Earth and possibly involving the return of raw materials to markets on the Earth. Beyond these Earth-centered activities lies a period in which non-terrestrial resources would supply the primarily non-terrestrial markets of a space-based civilization. In this period, which has not yet been subjected to rigorous engineering analysis, the major resource-related questions are whether independence from Earth is possible, and whether limits to growth exist in the foreseeable future.

A number of factors determine whether a non-terrestrial resource will be used at a given time. These include not only demand, cost of alternatives, and the quality of the resource, but end-use point and transportation cost. The following will examine various potential resources with reference to the various periods mentioned above, and will use ideal energy costs as a handle on the dollar costs of transportation. These energy costs will be given assuming 100% efficiency of application and a unit cost of 2¢/kwh.

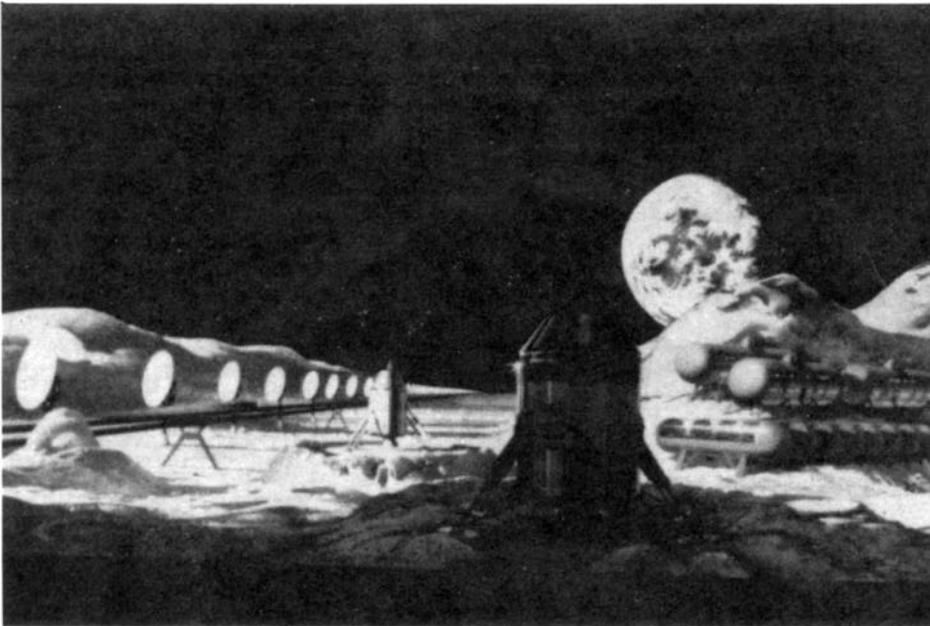
For those of us born on Earth, planets seem a natural source of materials. Ideal energy costs for transportation from other planets to a high Earth orbit range from 9¢/kg. Mars, to \$10.17/kg, Jupiter. This would be fine, at least in the case of

Mars, if ideal energy costs resembled dollar costs for rockets escaping atmosphere-covered planets. A comparison of Shuttle costs for reaching high orbit, roughly \$1000/kg, or advanced vehicle costs, roughly \$200/kg, to ideal energy costs, roughly 37¢/kg, shows the magnitude of the discrepancy for Earth. One might add that it shows the room for improvement in launch methods. Barring vast improvements, however, transportation costs suggest that most materials used in space are unlikely to come from planets.

Earth's Moon, around which most non-terrestrial resource utilization scenarios have been built, has the advantages of being closer to the Earth, of being a previously explored body, and of having an ideal energy cost for transportation to a high Earth orbit of only 2¢/kg. In addition, the Moon's lack of an atmosphere permits materials to be launched by linear electric motor (mass driver) rather than by rocket. Estimates of the dollar cost of transportation by a space constructed mass driver, roughly 10¢/kg, fall within a factor of five of the ideal energy costs. Surface mining of lunar soil provides a material containing roughly 45% oxygen, 20% silicon, 8% calcium, 4% magnesium, 5 to 15% aluminum, 5 to 15% iron, and 0.5 to 7% titanium. These elements, if recovered, suffice to construct over 90% of the mass of a power satellite based on silicon solar cell technology, together with a comparable fraction of the construction facilities and workforce habitats.

Lunar soil resembles volcanic ash in composition. Volcanic ash is not notable as an ore for metals or anything else. With the incentive provided by the ready availability of lunar soil in space, however, a number of terrestrial processes seem capable, upon modification, of recovering metals, silicon, and oxygen at reasonable cost. Study of a carbothermic reduction process resulted in the design of a plant able to produce its own mass in metals, silicon and oxygen, starting with lunar soil and sunlight, in only six days. The difficulty of landing equipment on the Moon (landing cannot be accomplished with mass drivers), and the lack of sunlight during the lunar night favor locating the processing plants in free space.

Materials other than those mentioned above may be hard to come by because the Moon appears to lack ore bodies. No hint of the unusual element concentrations relied on by terrestrial



Artist's conception of the Lunar Mass Driver, key to the economics of large-scale manufacturing in space.

civilization was found among the rock fragments returned by Apollo, nor does the Moon show evidence of the geological processes by which such concentrations form. Other processes exist on the Moon, however. Magnetic equipment can separate grains of meteoritic iron (rich in nickel, cobalt, and copper) from the lunar soil. There is the possibility that meteoroids may have injected massive veins of this iron in the walls of some lunar craters. The Earth's largest nickel deposit, in Sudbury, Ontario, appears to be the weathered remains of just such a crater. The lunar surface appears to have been baked until its content of the bio-elements carbon, hydrogen, and nitrogen has virtually vanished. At the Moon's poles, however, crater floors may not have seen sunlight for billions of years. They may be cold enough to store ice in vacuum for geological times. Calculations suggest that the Moon may have produced or accreted enough water since the baking event to have formed substantial deposits in these craters. Such ice may even be contaminated by compounds containing usable amounts of carbon and nitrogen. A final answer on whether ice exists awaits a thorough orbital survey of the Moon.

The asteroids have also been considered as a near-term resource base, either in competition with the Moon as the initial source of materials, or, as seems more probable, as a later source of materials scarce on the Moon. Ideal energies for transportation of materials from asteroids to a high Earth orbit vary from 3¢/kg, comparable to the lunar transportation cost, to 28¢/kg, comparable to the terrestrial transportation cost. This spread results from the wide range of asteroidal orbits, some having average distances from the Sun similar to Earth's while most

asteroidal orbits remain between Mars and Jupiter. As with the Moon, efficient transportation techniques exist. Either use of the mass driver as a rocket or use of solar sails may yield dollar costs comparable to ideal energy costs.

Asteroidal compositions are diverse. Where the Moon offers only a narrow range of rock compositions and possible deposits of iron and ice, the asteroids offer an extended range of rock compositions, cubic kilometers of meteoritic iron, and water-rich material resembling low-grade oil shale. Even without assuming the presence of ore-like concentrations, a comparison of US material needs to asteroidal resources suggests that a technological civilization could support itself on asteroidal resources alone.

The main barriers to early use of the high-quality, low-cost asteroidal resources are initial costs, distance, and risk. Despite the expected similarity of transportation costs, transportation times jump from days for lunar flights to months for asteroidal flights. Logistics considerations seem to require either a large expedition or an intelligent automated device to return asteroidal materials, rather than a gradually built system like a lunar base. This may require higher initial costs of development to answer questions of reliability. Finally, while a synthesis to meteoritic and spectroscopic data provides high confidence in our knowledge of the compositions of various asteroids, it does not match the certainty of documented samples. Although this last problem can be rectified, lunar materials may still prove the materials of first resort. Some time after this first beachhead in space is established, asteroidal materials are likely to be used to supply steel (meteoritic iron is a good alloy steel in

its natural state) and organic compounds to space facilities. Use of mass driver engines or solar sails constructed in space may make meteoritic iron recovery cheap enough to permit profitable sale on Earth. If so, the potential market is large.

As was stated above, the asteroids seem capable of supplying the material needs of a technological civilization. Their apparent compositions and masses, taken together, suggest that they could support, at a high standard of living, a total population some thousands of times that of the Earth. Hence independence from Earth seems possible in the long run, and while the limits to growth (considering only asteroidal materials) are foreseeable, they lie far beyond the present horizons of our civilization.

LONG-TERM ENERGY CHOICES: BEYOND 2000

This article is excerpted from ERDA's Energy Policy brochure, "Creating Energy Choices for the Future." It shows the current perceptions by this government agency of energy options that appear to be viable.

After the turn of the century, the U.S. should rely primarily on energy sources that essentially inexhaustible. But the technological development of these sources must be actively pursued now so that they will be available when urgently required.

The energy resources and conservation measures that are the mainstay of energy planning throughout the near-term and midterm diminish in their capacity to support further energy growth in the long-term. Thus, some time after 2000, the Nation will have to depend on essentially inexhaustible sources of solar electricity, uranium breeding, or hydrogen fusion.

The breeding concept has been shown to be feasible, although the total system concept must yet be demonstrated. Fusion and solar-electricity are unproven. All three require long lead times to develop. Any of the three could conceivably meet a major portion long-term energy needs, and one or more will be critical during the 21st century. All have some serious technical, environmental, or cost problems. Because of a vital need for success in long-term energy technology, all three must be developed on a high priority basis.

Electricity generated from inexhaustible solar, bred uranium, and fusion sources should eventually, some time beyond 2000, make us much less dependent on imported and dwindling supplies of domestic petroleum and on liquid fuels synthesized from coal. Urban transportation could be based primarily on electric-powered cars and mass transit vehicles.

Vapor Phase Fabrication of Structures in Space

A technology, limited on Earth to making hardware no larger than integrated circuits, will be used in space to manufacture structures bigger than any ever seen on the planet.

Keith Henson and Eric Drexler

An economical approach to large scale metal processing and fabrication in space may be a vapor deposition method which uses to advantage the sunlight, vacuum, and zero gravity elements of the space environment. It may even be possible to process and fabricate simultaneously.

The physics of vapor deposited metals is a well understood subject, partly because vapor deposited coatings are widely produced by industry. Integrated circuits, for example, depend on vapor deposited aluminum for interconnections. The method is rarely, if ever, used for fabricating thick sections because other methods are available and the cost of energy and capital equipment to provide vacuum and vapor sources is high. In the space environment, conditions are just the reverse. Vacuum costs less than pressure, energy in the form of sunlight is almost free, and liquid metal corrosion, a high cost factor for vapor sources on Earth, seems to be avoidable in zero gravity.

The apparatus proposed for heating metal to the vaporization temperature (-2500K for steel or aluminum) consists of a two cavity solar furnace where the metal vapor filled cavity is isolated from

the optical path by a conductive diaphragm (Figure 2). Sunlight, concentrated on the diaphragm, raises its temperature to -2700K. At this temperature, even graphite, the proposed structural material, sublimates at a substantial rate (tens of centimeters per year) into a vacuum and would rapidly degrade the concentrating mirror (see Figure 1). Sublimation of the diaphragm can be retarded by the presence of an inert gas at a slight pressure, stagnant in the proximity of the diaphragm. The gas would be restrained from loss into space by a window dome. Slowly flowing gas (shown by the arrows in Figure 2) protects the window from deposition of material evaporated from the diaphragm. Thermal and optical considerations favor sapphire for the window material. Synthetic sapphire is currently produced at an acceptable cost for fighter aircraft windows.

Liquid metal within the evaporation cavity in the absence of gravity is restrained by electromagnetic fields, surface tension, and/or adhesion to cooled metal tabs to prevent contact and chemical reactions with the graphite walls of the cavity. Chemical reactions between the metal vapor and the cavity walls

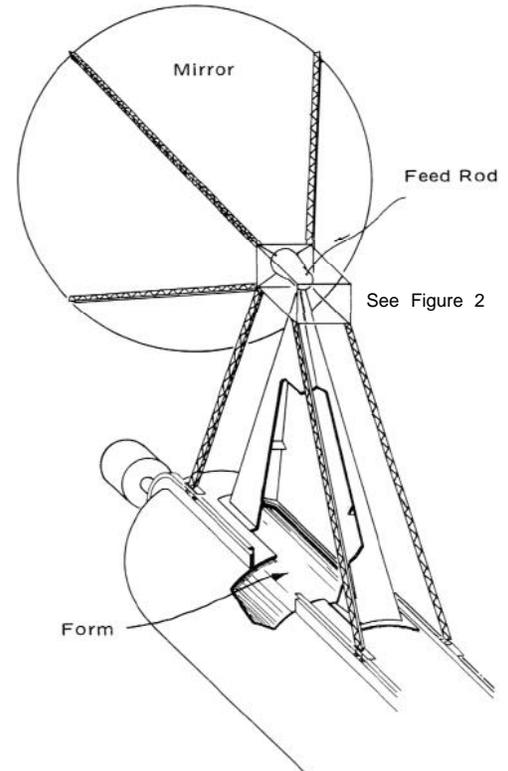


Figure 1

appear to be energetically unfavorable (i.e., metal carbides are less stable than carbon and metal vapor at the operating temperature)'.
Metal vapor at a pressure of -10 torr and a temperature of -2600K escapes through a slot-shaped orifice and forms a fan-shaped beam perpendicular to the slot axis. The metal vapor beam is directed toward a rotating inflated form which may be of any desired size (see Figure 1). Spheres and cylinders with spherical end caps are particularly convenient shapes. Alternately, an endless belt may be used for the form, producing flat stock or sheet metal. To control the metal grain structure and thereby many of the physical characteristics of the metal, such as yield point and elongation at rupture, the temperature of the form must be controlled. To produce physical properties ranging from work-hardened to fully annealed requires deposition temperatures from .30 to .45 of the melting point of the metal². For aluminum the optimal temperature is close to 300K, permitting the use of ordinary plastic film for the form.

Purification of metals by vacuum distillation may be accomplished by the same type of equipment if provision is made for continuous removal of the less volatile fraction.

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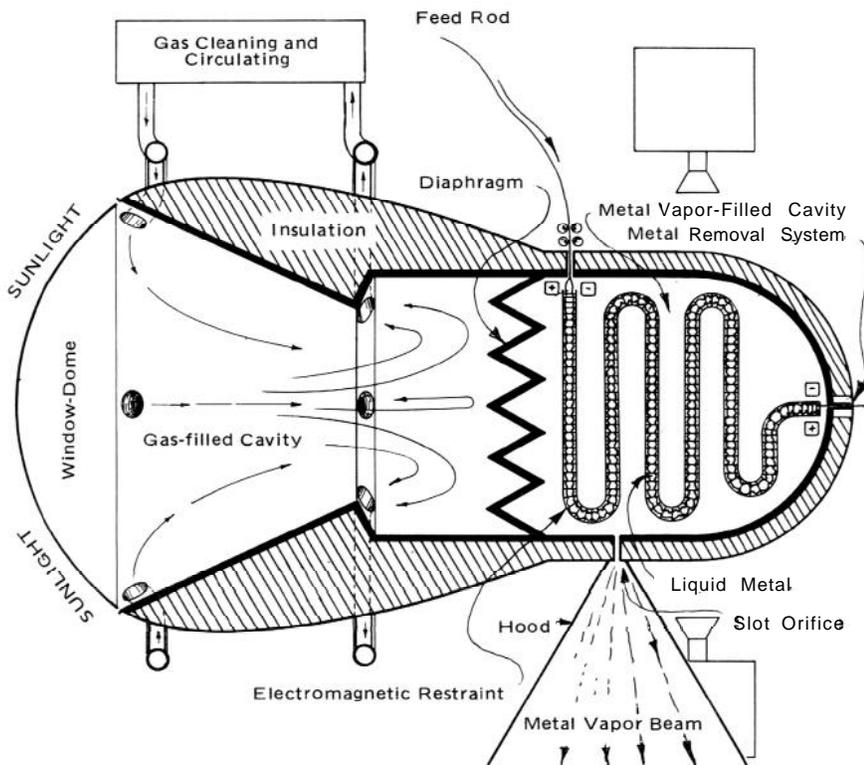


Figure 2 Two-Cavity Solar Furnace/Metal Evaporation (Section View)

Homogeneous metal structures formed by methods including vapor deposition are subject to catastrophic fracture failure unless the material is stressed to only a small fraction of its yield strength. Several methods may be used to control this highly undesirable attribute. Aircraft designs control crack propagation by using discontinuous structures (crack stopping holes and layers), methods to keep the surfaces in compression (shot peening) and fiber reinforcement. This last seems to be very promising for use in conjunction with vapor deposition. Strong (500,000 pound per square inch) fracture resistant, silica and aluminum composites have already been produced and tested³. An adaptation of this method suitable for operation in conjunction with the vapor phase fabrication might be to wind metal vapor-coated silica fibers on the form at the same time the vapor is being deposited.

One way to evaluate the economics of production equipment in space is to compute the mass payback time (i.e., how long does the system under consideration take to process its own mass?). The mass of the system shown in the figures was calculated for a throughput of 10kg/sec and found to be 250 metric tons⁴. Such a system processes its own mass in eight hours or more than 1000 times its own mass in a year. The high throughput per unit mass together with the low labor requirement normally associated with the movement of liquids and gasses makes vapor deposition an attractive possibility for the economical fabrication of massive structures in space.

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O'NEILL AT AIAA

Princeton professor Gerard K. O'Neill, speaking January 13 at the annual American Institute of Aeronautics and Astronautics meeting in Washington, introduced yet another concept to decrease the cost and shorten the time scale for large scale space exploitation. His latest proposal is to use the external shuttle tank as reaction mass to "fuel" an orbital mass driver. The shuttle tank is almost taken into orbit anyway, and with

a small reduction in payload 37 tons of tank can be made available for reaction mass, more than enough for a high performance mass driver to push shuttle payloads (65,000 lbs. maximum) to geosynchronous or higher orbits. Lifting the mass driver, shuttle tank grinder and power plant to orbit would take five to seven shuttle flights, but once operational would cut the cost of transportation to high orbits by a factor of about four.

Reworking earlier studies with the improved transportation gets a lunar base and minimum mass driver there for about one hundred shuttle flights, and a Solar Power Satellite factory with cramped but shielded quarters for an additional four hundred flights. Considering one hundred shuttle flights to be only slightly over the projected eighty flights per year originally used to justify the shuttle, a time span of six to seven years from first shuttle payloads in space to the first SPS (and a 10-20 billion dollars per year revenue stream) isn't out of the question.

O'Neill's current best guess on the cost is around twenty-four billion dollars, and that is not the lowest being quoted (Brian O'Leary thinks an asteroid capture would be less expensive). If this gets some of you free enterprise buffs stirred up, the L-5 News will sell space for a prospectus announcement.

U. S. SENATE PLANS REORGANIZATION

The Temporary Select Committee to Study the Senate Committee System has revamped the U.S. Senate committee system, which was last updated in 1946.

The Aeronautical and Space Sciences Committee has been abolished under the reorganization. Nasa now has its funding split between the jurisdiction of at least two other committees: the Committee on Commerce, Science and Transportation Transportation, and the Committee on Energy and Natural Resources.

Following is a statement by the ranking minority member of Aeronautical and Space Sciences, Barry Goldwater (R-Arizona):

"The main reason I refused to sign the Majority Report is its failure to recommend the creation of a Senate Committee on Science and Technology. Under the proposed S. Res. 586, research and development, science, and engineering would be scattered among a number of committees.

"Energy is the best example of the need for a science committee. With all due respect to the committees now having jurisdiction on energy matters, we have done practically nothing in Congress towards solving our energy crisis. Energy has become politically attractive. Accordingly, there is a natural tendency

for committees to try for a portion of the energy pie. I suggest that as long as this situation obtains, science will suffer and so will the prospects for a solution to our energy problems.

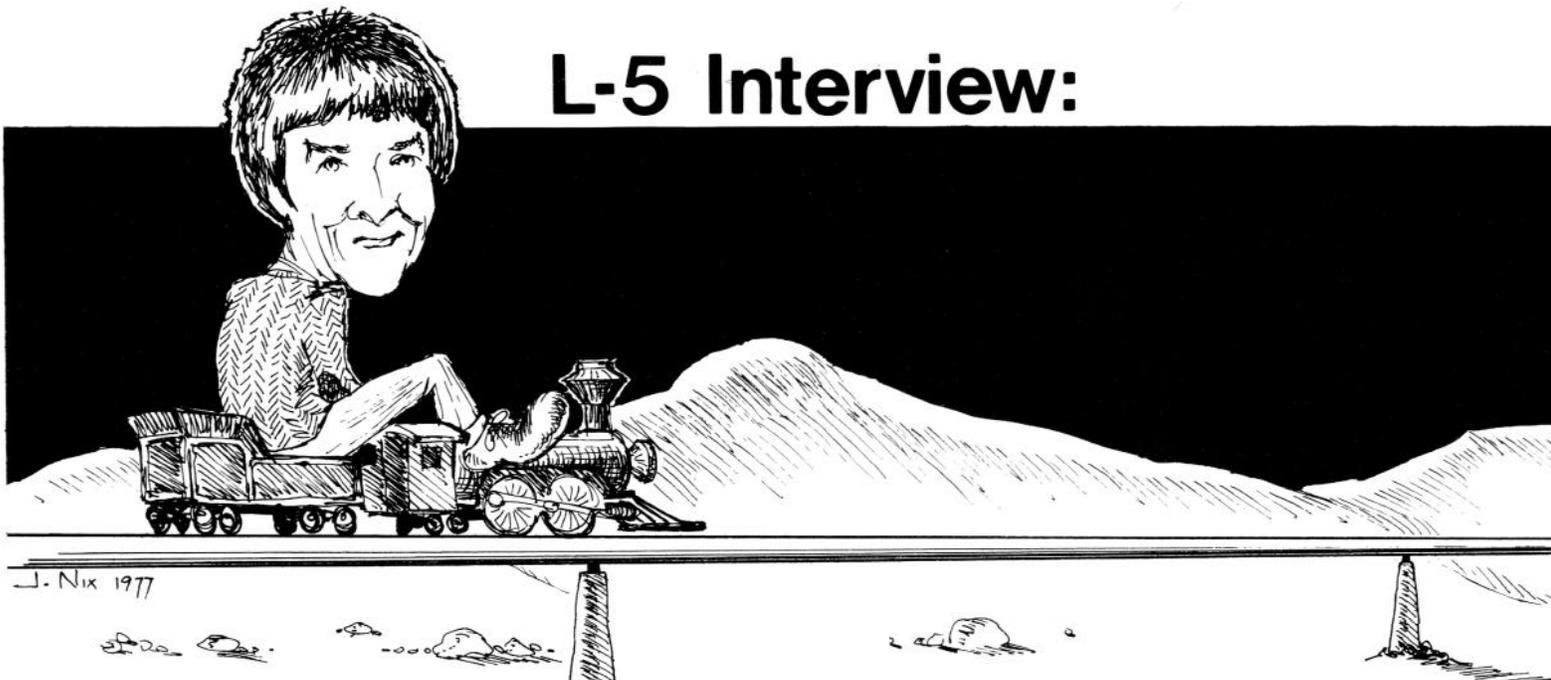
"Our nation has no higher priority than the development of new sources of socially acceptable energy. If we are to achieve energy self-sufficiency, many disciplines and technologies must be harnessed and work in unison. The Select Committee, for example, confers jurisdiction over 'non-military aeronautical and space sciences,' and 'science, engineering and technology policy' to the Committee on Commerce, Science, and Transportation. On the other hand 'energy research and development' are given to the Committee on Energy and Natural Resources. While the committee's report stresses the need to reduce overlapping jurisdictions, I submit the separation of energy R & D from science, engineering and technology policy not only creates an overlap, but it also creates a division where there should be unity. ERDA, DOT, NASA and NSF, just to mention a few, possess assets that can lead to solving the energy problem. Shouldn't they be under one legislative hat?

"Since 1964, each year has seen a fall-off in federally funded research and development as a portion of the Gross National Product. Moreover, the percentage of the federal budget devoted to research and development has gone down from 12.4% in 1964 to an estimated 6.3% in 1976. During the same period, in terms of actual dollars, there has been an increase from slightly over \$14 billion to nearly \$22 billion. However, when inflation is taken into account, there is a net reduction in the real purchasing power of federal R & D funds.

"The industrialized countries of the world recognize the relationship between R & D and their standard of living. Yet, here in the Senate, we seem to be acting as though the Industrial Revolution had never occurred. I see the future of our country resting largely on developments in science, engineering, and technology, but the above-mentioned statistics tend to prove that we have forgotten the lesson learned by every modern industrial nation. If America is to maintain a strong scientific, engineering, and technical base this trend must be reversed. Should federally funded research and development continue to decline, inevitably there will be fall-off in the export of high technology wares which could adversely affect the relatively free trade system in existence today.

"Finally, the creation of a Senate Committee on Science and Technology would recognize the importance of the nation's 900,000 scientists, 1,000,000 engineers, and technicians too numerous to count."

L-5 Interview:



In which the simple high-energy physicist discusses the travails of an outfielder, and the work that continues after crossing home-plate.

*An interview with Gerard K. O'Neill,
by Keith and Carolyn Henson*

Dr. O'Neill, the readers of the L-5 News are constantly deluged with technical details. What I'd like to hear is some of the personal side to the story. For example, one of the things that isn't covered in your book is, how did you first get interested in space? Was it a fascination ever since you were a kid?

For a very long time I'd been aware that space represented a possible new frontier, though it was not until 1969 that I began to realize the way in which that frontier could best be reached. When I was in college, in the late 1940s, I recall doing calculations on rocket equations and such-things that many people do. In the same period I used to talk with my parents about possible activities in space. My mother used to counter with questions and then interrupt herself and say, "No-I'm afraid you'll tell me the answer." (That was out of non-comprehension of mathematical things rather than any fear of future shock on her part, by the way; it's some commentary on her that years later, when she was 80, she volunteered for her first glider ride.)

But of course, thirty years ago the whole subject of space research was in its infancy, and the utilization of space unheard-of; it was just too early to form any sort of scientific career around it. (A very few people did, but they were far outside the mainstream at that time.) As I mentioned in *The High Frontier*, I was involved in the 1966 "Olympiad" for scientist-astronauts. It seemed to me a unique opportunity. It wasn't that the scientific work to be carried out was all that deep or rewarding from the

astronauts' viewpoint. It just seemed to me that to be alive at that time, and not to try to take part in that unique event in human history-the first breakout from the planetary surface-would be something I would regret forever afterward. If you look at the long development of human history, humankind has been genetically indistinguishable from ourselves, very nearly, for many thousands of years. But looking back on this time from perhaps a hundred thousand years later (still a short time on the scale of natural evolution) our era will surely be looked on as unique.

That partially answers one of the questions I was going to ask. Some of my friends who are physicists at the University of Arizona are really scratching their heads, wondering why someone like you, who is so respected in the incredibly competitive world of high energy physics, would run off in a completely different direction.

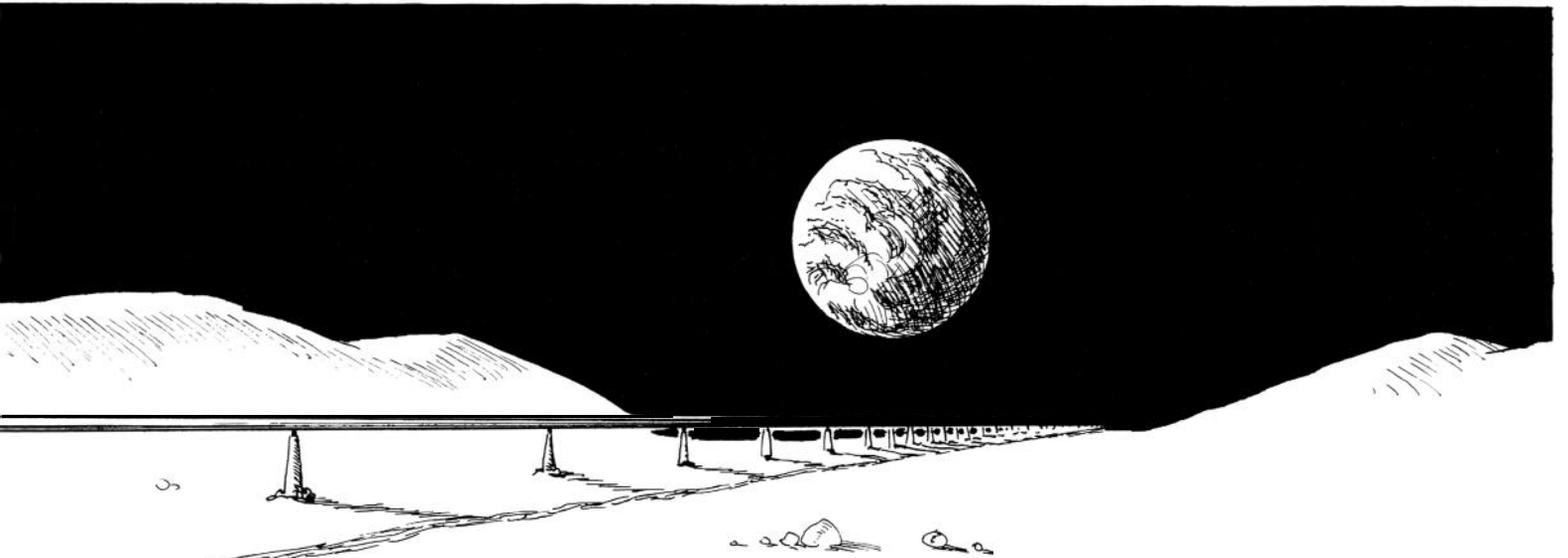
Of course, high energy physics is a very exciting field also, and has a much longer, distinguished history of its own. I continue to do work in it, and am proud of the work that has been done by our little Princeton group particularly during the past few years, when we have reached something like adequate size. But from a personal viewpoint, I seem to have a need to create new things rather than to concentrate on continuing a static situation. In 1956 and for a few years afterward, I had that pleasure of creation during the time in which I was working on the storage-ring concept, at first, for several years, alone, and afterward with larger numbers of co-workers. In the late 1960s. though, I

found that work much less satisfying.

I had never wanted to continue as a storage-ring designer forever, but rather wanted to use storage-rings in order to do good physics experiments of a unique kind. By that time, I found that as the number and size of storage-ring facilities grew rapidly, the whole field became heavily political, and a number of people who were excellent politicians managed to put themselves in positions of control of the facilities. My opportunities were much reduced, and that was a time of considerable frustration for me. Perhaps it is no accident that I began the speculations about human habitation of space within a year after an especially unpleasant series of events, in which I saw the largest of all the storage rings, whose design had come straight out of a paper I had published many years before, taken over by people who succeeded in minimizing my opportunities to continue the creative process in a useful way. Events of that kind are something of a test of mental health, I think. Someone who is of a pessimistic turn of mind can brood on such situations, begin to get paranoid, and spend the rest of his life in an embittered series of attempts to "get even." In my case, despite a good deal of temporary unhappiness I eventually laughed it off and looked for fresher fields. Oddly enough, although the situation in high energy physics is still not greatly changed from the 1960s, at least now, after many years of careful negotiations and perhaps a little bit of learning something of the political process, my high energy work is going very well.

I recommend to readers, by the way, a favorite book of mine, Nevil Shute

O'Neill on O'Neill



Norway's autobiography *Slide Rule*, written about events of forty to fifty years ago. It points out the universality of such experiences.

Although the potential for rapid change in space is far greater than it is now in the field of high energy physics, I don't think that our opportunity for the human habitation of space falls into a small window in time. It is more that the window is just now opening, and if we don't take advantage of the opportunity now, later on someone else will. On the time-scale of human history, a decade or two is only an instant, and by now, after a little over two years of public discussion, the discrepancy in the estimates between the optimists and pessimists is only a matter of decades at most.

There is a more serious kind of danger, though. If, as a result of increasing tension and the threat of conflict, brought about by shortages of energy and materials, the world enters a period of even greater hostility, or even a period of large-scale warfare, it seems all too likely that the opening of a new frontier will be caught up in that conflict, and will either be prevented or be militarized. The history of the Caribbean area during the years 1500-1900 is an unfortunate but very real example.

Then you feel a sense of urgency with space that you don't feel with high energy physics?

Yes. And, after all, each of us lives only once (presumably!) and so each of us has only a limited time to contribute something to the world in which we live. As I look back on the past decade in high energy physics, although there have been many important discoveries, the opportunities for creation—that is to design new and unique kinds of experiments or types of experimental

apparatus—have been very limited. The instrumentation has become relatively predictable and fairly static, changing mainly in scale and cost, with relatively minor innovations. In space, on the other hand, it seemed to me in 1969 that there was a tremendous opportunity which no one else was grasping. I felt then, and still do, that in trying to contribute something to developments in space I was doing something that no one else was working on; something that might be delayed many years past its proper time unless I made the effort to advance it. I felt much the same way about the storage-ring concept in 1956, but of course the space work has far wider human implications.

When you were first trying to bring your message to the public, did you have any assistance from the aerospace community?

I didn't even know anyone in the aerospace community at that time. As I mentioned in the appendix to *The High Frontier*, within a year or two of my earliest work on that subject I had a talk with John Tukey, of Princeton, and asked him for the names of some people to whom I might talk about it. He did give me a number of names, of very interesting people, but they had no more connection with the aerospace field than I did—because John didn't know any such people either.

So you were really isolated, then, when you started?

Very much so, and the first positive response I got was from students.

A little more open minded?

Yes, and the students of the early 1970s had grown up to accept the events of the space age as a matter of course; also, they had come to regard rapid change as normal and routine, rather than threatening. But we must recognize that

“youth” in the sense of mental attitudes can be entirely disconnected from chronological age. There are people who are old in years, but still mentally quite youthful. And, sadly, there are people young in years whose minds have already set. On the average, though, it seems that being for many years in a position of great prestige and authority may be the poorest way to retain mental flexibility. Some people manage to have secure and prestigious positions and still keep open minds, but it's an uphill struggle.

Who was the first one in NASA to notice your existence?

Back in '74, when I was trying to set up the first Princeton Conference, I got a few names of people in NASA from acquaintances of mine in the Engineering School at Princeton; then I called those people and found out where in the chain of command was the best “point of entry.” It was as a result of those conversations that Gerald Sharp and Bob Wilson of NASA came to the conference. Joe Allen came by a different route: he had talked to someone who had heard one of my lectures on the West Coast, and Joe wrote to me.

What did it feel like, coming out of left field as a physics professor—for you to go to NASA and ask them to take on a project several times bigger than anything they'd ever done before?

(Laughing) Well, I didn't try to tell them all of it in one go! Now, when this whole field of activity is exploding so rapidly, it's very hard to get across how frustrating it was, in the years from 1969 to about 1972, to be so sure that I was on the right track, and yet to have almost no one to talk to. By late 1972 I was beginning to give lectures, so Freeman Dyson and others whom I respected were starting to react to these ideas and engage in a dialog, but I still

didn't know anyone at NASA, nor in the aerospace industry. As you know, I avoided the "easy way out" which would have been to publish in a science-fiction magazine. The temptation was there, but I felt that if I followed that route it would be the kiss of death for the realization of the ideas. That's no criticism of science fiction writing or publications, by the way-it's just that I felt it was very important to maintain a clear separation between speculation and an achievable reality. The most difficult years were those from 1969 to 1972. By early '74, when we were planning our conference and I was beginning to talk to people at NASA, already the *Physics Today* article had been accepted for publication. Without that, I would probably not have tried to talk to NASA. In effect, I'm saying that by 1974 the situation was already so much better than in the early years that I didn't worry about the fact that I was coming, as you say, from far left field.

Well, it certainly looks as if you're getting into the establishment now, with the AIAA [American Institute of Aeronautics and Astronautics] having you speak two years in a row -- 1976 and 1977 - at their annual meeting!

We still have a long way to go. I'm encouraged by a number of indications, though. I was very pleased with the solid technical results of the 1976 Ames Study, and most gratified when it was accepted as a volume in the AIAA series "Progress in Aeronautics and Astronautics." The escalation in the Princeton Conferences between 1974 and 1977 is also rather spectacular. As you know, this year it will be a national AIAA conference, and will also have support from both NASA and ERDA. That is a far cry from 1974, when it was all I could do (as I detailed in the appendix to my book) to drum up \$600 from the Point Foundation, and we met as a band of daring radicals.

What do you see as the next moves that we ought to make on this?

My own interests tend to concentrate on looking for routes by which we could achieve what I call the "ignition point" in space manufacturing, by a series of stepping-stones each of which is within the "real world" of the transportation system that will actually exist-the Space Shuttle. Although I'm certainly interested in the long-term philosophical and historical significance of the work we're doing, I'm putting nearly all of my own effort into very direct and specific technical fields. During this year while I'm on sabbatical visiting MIT, I'm concentrating on the "mass-driver" device. As you may know, a group of student volunteers together with Prof. H.H. Kolm and myself are building a working model of a mass-driver, full-scale in cross-section but only eight feet in acceleration length. We hope to demonstrate it at the Princeton Conference. Also, I just completed an

article for *Astronautics and Aeronautics*, which will probably be published around April or May. In it I work out the ways in which we could reach the "ignition point" within the Shuttle era which starts around the early 1980s.

Would you like to comment on Dave Criswell's work [see L-5 News, No. 15] -- that is, there is a very small market for the very valuable stuff that can be done using Earth resources, but the big market for low value products can't be tapped until you go to lunar resources- I'm talking about things such as power satellites. I call it the "Panama Canal Syndrome"-there's no revenue until you cut the canal all the way through.

Certainly that's a serious problem, and that's why I'm concentrating on it. From a fundamental viewpoint, one of the ways that one can attack it is to minimize both the energy-input and the degree of complexity required to reach the ignition point. That's the main point of the most recent article.

Cut the narrowest canal possible?

Yes, that's a good way to put it.

Like, go for lunar oxygen early.

Not necessarily. There are even more primitive stages which represent vital stepping-stones. From an R & D viewpoint, any sort of chemical processing seems to be a relatively sophisticated stage of development, I think we must avoid getting locked into a fixed plan which has to be realized as a complete package, or not at all. We should always be exploring ways in which we can get a large return in energy, materials, or technical certainty, with a minimum input of research and development funding. Also, we should be looking for items of commonality. A great deal of the work I am involved with now, for example, relates to a method by which we could upgrade the Shuttle to geosynchronous capability. If that continues to prove out, we will have contributed to all the economically important space development opportunities, whether or not using lunar materials.

I understand that Rene Miller, chairman of the MIT Department of Aeronautics and Astronautics [where O'Neill is a visiting professor] is hoping to develop a space industrialization program which can conduct research and train students.

It's very good that efforts of that kind are being made. We are attempting something of that kind at Princeton also, and there is far more interest in it than there would have been even a year or two ago. But we must recognize that completing the Shuttle is putting an enormous strain on NASA, and while the Shuttle is in the peak development years there will be few resources left over for other activities. Every time some minor crisis arises in the Shuttle program-the sort of thing that happens in every large technical program, and that there is no

way to avoid-the cost-accountants have to sweep through the Agency, picking up every piece of loose change they can find. Even an 0.1 percent change in the cost of the Shuttle program is eight million dollars-and that is almost three times as much as the combined total of advanced-planning money in both the OSF and OAST divisions of NASA. It will be a while yet before NASA will be able to begin any new program, but I think that from a practical viewpoint the best approach will be a coordinated plan, with as much commonality as possible, which makes maximum use of the Shuttle, and draws in the space-development community, the aerospace community and the space science community in a coherent and mutually reinforcing way. I think we're making excellent progress in forging such an alliance, even though it will necessarily be a "shadow organization" for a period of time.

How are you doing with your TLA model project?

In addition to the model I just described, we are building a magnetic-lift demonstration model. That is being done by a Princeton student, as a junior paper project.

When did you first become aware of the "planetary chauvinism" syndrome?

Rather quickly, in the course of the little seminar-series that I carried out in 1969. All you have to do is ask a few basic questions: what are the essentials for human life-air, water, gravity (probably), energy, and so on. Then you start asking what is the most efficient way, from a physical viewpoint, to provide those essentials. Very quickly you find that you want to work with the relatively strong electromagnetic interaction, which binds solid objects together, rather than with the gravitational interaction, which is extraordinarily weak.

Then it was ultimately theoretical physics that gave you a handle on the idea?

A very simple-minded kind of "theoretical physics."

Well, it didn't occur to anybody else. Don't call it "simple-minded," call it "profound."

(Laughing) That's very kind of you. I'll go on with my own label, but you're welcome to call it what you like.

Dr. O'Neill's book, *The High Frontier: Human Colonies in Space*, is available from the L-5 Society (see page 14) or your local bookstore (\$8.95).

MOBILE HABITATS AS STARSHIPS

What kind of star drive is possible for habitats, and is it realistic?

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Edited by E. Meinel and J. Matloff

With the growth of science fiction in the twentieth century, the fantasy of humans constructing both mobile and orbital space Arks that faithfully mimic Earth's familiar environments has stimulated many writers. Some imagined what result if an Ark built by an alien life-form came into contact with an Earthling vessel. Others, particularly since the Atomic Age, imagined the deterioration of an interstellar Ark's populace after centuries of travel or the escape of nonconformist individuals from the confines of their particular space habitat. Some of the more daring scientists published papers speculating on the possibility of constructing space habitats as early as the turn of the century, although it wasn't until the advent of rocket and atomic technology in the mid 1940s that scientists began to give the subject serious consideration.

One of the founders of astronautics, the Russian Konstantin Tsiolkowsky, writing at the turn of the century, hypothesized that greenhouse-equipped space stations would first proliferate in the Venus-Mars region before expanding into darker, cooler regions as the inner solar system became congested. The American, Robert Goddard, just before the atomic age, thought these stations could, through the use of atomic energy, easily operate far from the sun and could eventually accelerate to a high enough velocity to bridge the 4.3 light year gap between the Sun and Alpha Centauri during the expected life-time of these stations. For a flight lasting 1000 years a cruise velocity of 1200 km/sec would be needed. Realizing this extreme velocity would surely subject him to considerable ridicule, Goddard did not allow publication of his stat-flight analysis until well after his death in 1945. So not until 1952, the year L.R. Shepherd's paper describing "The 600 Year Ark," appeared in *JBIS*, did the scientific community at large begin to seriously entertain the idea of interstellar flight.¹

Perhaps because of the sudden progress in the evolution of space propulsion systems after Sputnik, the paths of space habitation and interstellar flight diverged in the early 1960s. Of the hypothetical star drives then proposed, the antimatter proton drive by E. Saenger was the most sophisticated.² He suggested that equal masses of matter and antimatter could be combined in a reaction chamber and then the gamma-ray photon reaction products would be directed by an electron-gas reflector out the rear of the craft. Although a small

fuel/ship mass ratio is sufficient to achieve near-relativistic velocities, the antimatter-photon drive seems well beyond our foreseeable technology.

At any rate both current and projected accelerators are notably inefficient when applied to the problem of antimatter production.³ If antimatter production could be greatly enhanced or an accessible cosmic source were found, we would still face storage problems. Indeed, if the smallest defect in the magnetic field storage container let any antimatter come into contact with the normal matter of the container walls, then the fuel, the ship, and the crew would disappear in a spectacular chain reaction, visible in the night sky on planets light years away.

Another exotic drive is the "Warp Drive." Imagine a starship falling into a highly collapsed star (Black Hole); it could emerge via "White Hole" into a completely different region of space and/or time. Carl Sagan has suggested that we might search the vicinity near such Black Holes for signs of technological activity indicating a cosmic "switch-board" set up by a galactic supercivilization. Yet even a very advanced technology might not be able to use this hypothetical Black-White Hole faster-than-light travel, for tidal stresses could fatally stretch the ship and its inhabitants in the instant before it enters or exits.⁵ Thus, although it isn't completely impossible, this mode of travel belongs to the very distant future, if anywhere.

The only method of reaching high relativistic velocities that has merit for the foreseeable future is the interstellar Ramjet. But as we shall see, even this approach will probably not be able to achieve its full theoretical potential.⁷ The ideal Ramjet would use some form of electric or magnetic scoop to absorb ionized interstellar matter over a radius of hundreds or thousands of kilometers. In an advanced reactor system, hydrogen would be converted to helium and the reaction products would be ejected out the rear of the ship. For deceleration, the

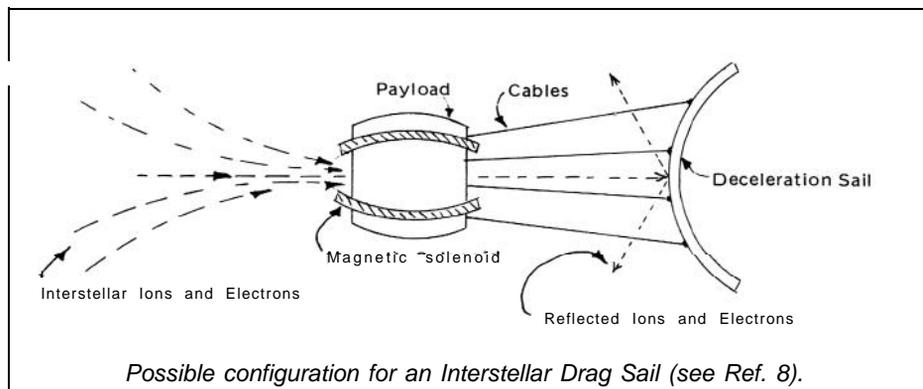
scoop field would be used to reflect the interstellar ions, thereby slowing the ship.⁸

Although field-deceleration seems quite reasonable,⁹ it is apparent that the ideal fusion drive for the Ramjet that could propel a starship to the edge of our galaxy during the lifespan of its human crew is well beyond our capability.

Although the direct fusion of hydrogen seems impossible, the catalytic carbon-hydrogen cycle may seem reasonable after 50 years or so of fusion experience.¹⁰ A Ramjet utilizing interstellar ions fused with projected 21st century technology (deuterium and helium-3) would require a much larger scoop radius than a hydrogen-fusing Ramjet since these isotopes are very tenuous in the interstellar medium. It is probably impossible to construct pure magnetic scoops with radii 10,000 to 100,000 km; therefore some form of electrostatic scoop must be utilized. As it collects positive ions, it would reflect the electrons, thereby severely limiting the ship's maximum velocity.¹¹

To alleviate electron drag a Ramjet designer might project a very thin, light array of charged cables in front of the craft as suggested by Robert Forward.¹² A 106 km length of cable need weigh no more than a few thousand kilograms. Although this can reduce electron drag by radially reflecting electrons before they are forward-reflected by the scoop field, the cables would require some sort of support during spacecraft acceleration. Some sort of electric drive on the end of the cable array farthest from the scoop should work, but electric drive technology may limit acceleration to less than 10^{-3} g.¹³ Therefore it would take at least a lifetime for these Ramjets to reach the nearest stars.

A possible Ramjet derivative is the Ram-augmented Interstellar Rocket (RAIR).¹⁴ RAIR uses a laser- or electron-beam-induced fusion reactor which burns deuterium, deuterium-tritium, deuterium-helium 3, lithium-hydrogen, or one of several other possible combinations of light nuclei. All or most of the fusion fuel is supplied by resources in the solar system. A portion of the fusion energy is transferred to ionized interstellar



Possible configuration for an Interstellar Drag Sail (see Ref. 8).

hydrogen scooped up over a radius of about 10,000 km. If no such energy transfer took place, a mass ratio of 150 would be required for a peak velocity of 0.13c. A similar mass ratio would allow an ideal RAIR to transport reasonable payloads within a few decades of flight time at peak velocities of 0.5c or greater. The system must be highly efficient and the mass/power ratio for the interstellar-ion thruster must be improved at least by a factor of 10 over current ion drive technology.

So, although Ramjet, RAIR, and field-induced deceleration seem to be capable of reducing fuel requirements, it is doubtful that even after a century of research and development travel time to Alpha Centauri or to Barnard's star (six light years away) would be under 50 years. Tau Ceti and Epsilon Eridani, the nearest stars believed to have a high probability of an Earth-like planet, are at least 100 years away.¹⁵

Barring an unexpected biological discovery, such as suspended animation, it seems that early starships will be small-scale, mobile versions of the space habitats in Earth's orbit.¹⁶ A systems analysis indicates that the population of a mobile habitat or Interstellar Ark depends upon the amount of radiation shielding (ship's mass) necessary to restrict the level of cosmic-ray radiation to a safe level.¹⁷ An Ark with the same mass as O'Neill's Model I Colony (5×10^{11} gm, not including fuel) could carry 1000 persons at Earth-normal radiation levels, although much smaller craft are likely.

By considering the mass necessary to establish a human settlement in another solar system and ship component masses, it is possible to estimate that the smallest starship would have a fuelless mass of about 2×10^{10} gm. If all payload and structure is applied to shielding then, a population from 50 to 120 seems reasonable, if we use O'Neill's figure for population density, especially since a mere handful of people would be necessary to establish a self-sufficient lunar base for 200 people.¹⁸

Let us imagine an interstellar expeditionary program for the 21st century. With the aid of a large space telescope or one of its multi-mirrored descendants, we search the nearby stars for planets of Jupiter's size or larger.¹⁹ As the targets are evaluated, one or more interstellar probes such as the BIS "Daedalus" would be constructed by the orbital space colonies.²⁰ The first probe would then set out for Barnard's star, (the only star known as yet to have a confirmed planetary companion).²¹ With a fuelless mass of 5×10^8 gm and a mass ratio of 100 or higher, construction of thermonuclear-rocket robots will be expensive. Fuel for the initial probe can be shuttled from Earth, mined from the moon, the asteroids, or Jupiter's atmosphere, bred in lunar reactors, or collected from the solar wind. The cost,

complexity, and duration of the fuelling process will depend to a large degree upon the reactants selected. Thus we shall probably not send out probes to each star we wish to visit in person, although several probes would be required to test engines and deceleration devices and to sample the interstellar medium.

If the first unpowered probe is launched in 2010 and its terminal velocity is 0.1c, then the first inhabited star ship could leave by 2060. Even if the schedule could be accelerated, it would be better to allow for time for us to improve space habitat technology before taking such an ambitious course.

Depending upon the reactants chosen and the efficiency of RAIR techniques and assuming ship mass of 2×10^{10} gm plus 10^{11} gm of fusion fuel, the terminal velocity would be about 0.05 to 0.1c. Projected costs for one interstellar ship could top \$100 billion. Of course, co-operation among the terrestrial nations and the assistance of the inhabitants of cis-lunar space is essential for this vast enterprise.

Now that the work is completed and a star chosen, let us imagine the departure of a star ship from earth orbit. The fusion of the pellets or microbombs will light up the night, but the ship continues to accelerate and disappears from sight, just as a comet. After ten to fifty years, the motor will disengage and the ship would coast. Now it will be possible to tap the interstellar magnetic field to supply on-board power at the rate of up to 100 kw per person, without plundering the ship of too much of its kinetic energy.²³ This way, life runs as usual as the ship travels serenely for a century or two.

During this time the lives of the people aboard the star ship may seem unbearably restricted and introverted, but it would seem quite natural to the next generation. Indeed, it is logical that the voyagers would probably be space colonizers already and the starships would simply be scaled-down versions of their own homes.

When the solar winds from the target star become detectable the ship will begin to decelerate. This, like the acceleration process, may require some decades to complete. The final deceleration might also be provided by giant-planet "rebounds" within the new solar system.

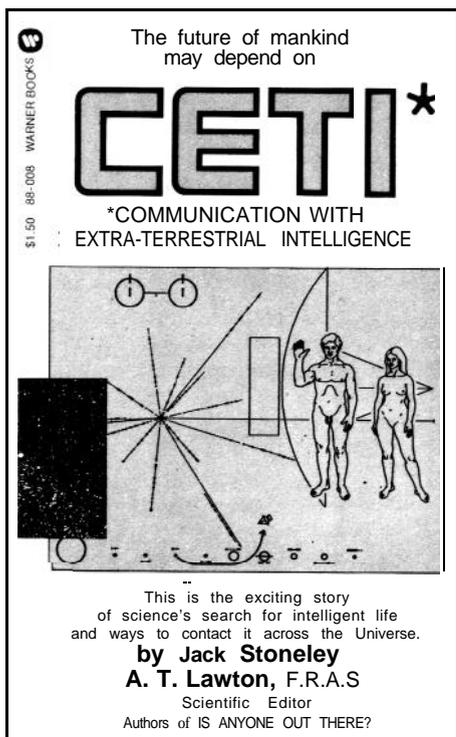
The voyagers examine the unfamiliar solar system by telescope and other devices, radioing the results to Earth. If, to their dismay, the place proves to be unsuitable for terrestrial life, the colonizers can refuel, drawing on the target solar system's resources. But by this time we will probably have the tools and knowledge for establishing a home on various types of planets or can simply establish yet another large space habitat. If the ideal planet miraculously like Earth is found, the colonizers would set

up an interim base capable of supporting the bulk of the colonizers. According to Robert Parkinson, an independent technology and culture can begin to flower after the population level tops one to two thousand people.²³ The more Earth-like the planet, the faster the colony would grow.

In this fashion, by 2300, the first interstellar colonies will be established and humanity will be stepping into the vastness of Eternity. That is, if we manage to not destroy ourselves before then!

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BOOK REVIEW

Communication with Extra-Terrestrial Intelligence, Jack Stoneley and A.T. Lawton, Science Editor, Warner Books, New York, N.Y. 10019, 1976.

It has been said that communication with extra-terrestrial intelligence (CETI) is the first science without a subject, and this book certainly contributes little toward making CETI a respectable topic for study. In fact, except for a short, poorly written section on some work done at the Radio Institute of Gorky in the U.S.S.R., the book is hardly about CETI at all. Rather, it covers a broad range of topics, most easily classified as "fictional science" (as opposed to science fiction)-everything from the ESP research of Puthoff and Tarqat at the Stanford Research Institute, to the Bermuda Triangle, which Stoneley thankfully concludes is just another couple hundred square miles of ocean with particularly nasty weather.

L-5 and Dr. O'Neill's space colonies are covered very quickly, in just under a chapter. Little detail is included and that which is tends to be garbled. The subject matter is probably familiar to regular readers of the *L-5 News*. Stoneley manages to link the utilization of extra-terrestrial materials, in the form of comets, to ancient legends about comets as harbingers of doom-no mean feat.

The best information in the book is its description of "Project Daedalus," the British Interplanetary Society's design for a hydrogen fusion pulse jet interstellar probe. The Daedalus starship was designed, by a team of British scientists, to make an undecelerated flyby of Barnard's Star, after a 47 year cruise at about 14% the speed of light. Anthony

Lawton, the book's scientific editor, was on the team which designed the electronics for Daedalus, and predictably, Stoneley includes considerable detail on the communications and computer systems for the starship.

However one might feel about the practicality of Daedalus, the BIS has a fairly good track record as far as prototype designs go. The BIS design for a moon rocket in 1936 has been acknowledged by NASA as being the grandfather of the Apollo project, which Stoneley indicates. And, as Bob Parkinson of the BIS points out in the book, "part of the problem is trying to predict third generation techniques while we remain in the first generation of space flight. So whether or not Daedalus is ever built, the design remains an historical achievement"-the first attempt to engineer a starship based on existing or realizable technology.

By taking a 'gee whiz' approach to some of the exciting, new ideas which are beginning to emerge in the space sciences, Stoneley runs the risk of severely alienating the general public. Most people are willing to credit a certain amount of truthfulness to what they read, and the mixture of half facts and speculation which Stoneley presents as truth is sure to cause skepticism when visitors from Alpha Centauri aren't walking on the White House lawn next week. Carl Sagan's book, *The Cosmic Connection*, manages to convey some of the promise and wonder of space without talking down to the reader. Those who are interested in general reading about CETI and humanity's possible future in space would do better to check out Sagan.--JK

WHERE ARE THOSE SUMMER STUDY PAPERS?

Keith Henson

One of the most serious problems of the space habitat/industrialization is delay of publication. The '74 and '75 Princeton conference papers are still unpublished (though rumor has it they will be by the '77 conference). And if NASA has published the '75 Summer Study, word hasn't reached us yet.

Hopefully the '76 study, to be published as a volume of progress in aeronautics and astronautics by the AIAA, will escape this fate and be available before it is obsolete. Already advances-particularly the concept introduced by O'Neill in January of using the external Shuttle tank for mass driver "fuel"-are beginning to outdate this study.

The '76 study went into detail on chemical processing, packaging lunar soil, design and operation of mass drivers, trajectory analysis, establishment of lunar facilities and habitat design. If you can understand the mathematics, it is fascinating reading.

To cite a few points, if the mass driver is located at 33.1 ° west longitude on the lunar equator, dispersion of the mass stream as a function of velocity approaches zero.

A 1,000 ton (exclusive of power plant) mass driver was calculated to accelerate 600,000 tons per year off the lunar surface at an electrical efficiency of 92%.

The chemical processing of lunar soil for metals, silicon and oxygen has close analogs in Earth-based systems tested to at least pilot plant scale.

Good news to eager space settlers is that the initial habitat ("construction shack") could be built by 1986.

For those of you who wonder what "log cabins" in space might look like there is an excellent article on shielded minimum mass structures by Gerard K. O'Neill, which we will print soon in the *L-5 News*.

The L-5 Society has a draft copy of the '76 study (240 pages) for those who can't wait for the printed version and are willing to part with \$15 for copying plus our ubiquitous \$2 handling and postage fee.

L-5 NOVELS BEING WRITTEN

Science fiction author Mack Reynolds is currently working on two novels based on the L-5 project, according to *The Section G Report*, a fanzine published by The Reynolds Circle, P.O. Box 721, Hillside, NJ 07205.

The *Report* continues, "*Lagrange Five* and *The Lagrangists*, as they will be called, will deal with the socioeconomic ramifications of the space colonization program. Frederick Pohl, . . . editing SF for Bantam Books, contracted for the first of the two and plans to rush into print since the whole project is mushrooming so fast."

NEW LEARY BOOK OUT

Exo-Psychology: A Manual on the Use of the Human Nervous System According to the Instructions of the Manufacturers, by Timothy Leary, available from Starseed/Peace Press, Box 188, Culver City, CA 90230 for \$8.00.

L-5ers who are interested in Dr. Timothy Leary's S.M.I.²L.E. concept (standing for Space Migration, Intelligence Increase and Life Extension), which incorporates the space colonization concept into what is described as "a new philosophy of human evolution," may find this new book of interest. We have not received a review copy yet, but from the comments in the announcement flyer, Leary seems to concentrate on developing an evolutionary approach to human psychology, with emphasis on future possibilities. A sample quote: "Here is the first attempt to prepare humanity for the outward journey, for extraterrestrial union, for extra-terrestrial migration."



VISITING L-5 STAFF

We would like to thank visiting L-5 volunteer staffers Jim Bennett of Ann Arbor, Michigan, Dick Fredrickson of White Plains, N.Y., Dick Mesce of Los Angeles, California, and Elaine Meinel of New York, N.Y., for their hours of toil. Tucson volunteers this month included Chuck Barnard (who has recently joined the paid staff), Stewart Nozette, Bill Weigle, Jim Kempf and Keith and Carolyn Henson.

In the last month we also had a number of fascinating visitors who wanted to see our famed headquarters at first hand. They included medical science writer Saul Kent; sculptor Susan Kaiser; NASA artist Don Davis; opera librettist Ron Giteck; stage manager Barbara Giteck; lecturer Timothy Leary and his business manager, Jay Levey. We encourage visitors, especially if you donate money or labor while visiting!

The work load at the office is insatiable! Tucson members are urged to drop in and help. Out of town members are invited to try out the Henson's hospitality-free room and board in exchange for work on the L-5 staff. Vacation coming up? Try Tucson first! Please write Carolyn Henson, c/o the L-5 News, 1620 N. Park Ave., Tucson, AZ 85719, first and warn her so that she can arrange schedules.

Those of you who ordered posters should be receiving them soon. We appreciate your patience and hope you will find them worth the wait.

Robert Anton Wilson's letter in the Playboy Forum (February '77) generated a flood of mail which still continues. Better publicity for the L-5 concept (and the Society) than a letter to the editor in a major magazine is hard to imagine (hint!).

Dr. Timothy Leary is lecturing all over the country on space migration and cites the L-5 Society as an information source (another flood of mail). His lecture is nothing short of inspiring-but get your ticket or go early, they usually sell out.

In spite of highly appreciated volunteers, we got behind at one point by almost 600 letters in processing requests for information. Our hats are off to Wilson and Leary.

NORTHWEST L-5 SOCIETY

The Northwest L-5 Society will hold a meeting March 31 at 7:30 PM at Gregory Bennett's home, 13001 79th Place NE, Kirkland, Washington.

PUBLICITY

The San Marcos L-5 chapter made the front page of their local newspaper, the *San Marcos Daily Record*, recently. How did Troy Welch manage it? We suggest writing him c/o Physics Department, Southwest Texas State University, San Marcos, TX 78666 for hints on local publicity.

Another red hot Society publicist is Mike Shields, who has arranged two major lectures and at least two television appearances for L-5 spokespeople in San Diego this March. For details on how he does it, write to 695 Nardo Avenue, No. G-8, Solana Beach, CA 92075.

LOCAL CHAPTERS

If your local chapter has an announcement to make in the *L-5 News*, please write it up as *you would like it to appear* in this section. Rambling, chatty letters which mention planned meetings and request that the news be published are hard to handle as we must find a volunteer to convert it into a news item. Have pity on the overworked Tucson volunteers!

THE L-5 SYNERGY COALITION

The membership of the L-5 Society encompasses an extremely wide variety of skills and talents, all of which will undoubtedly be needed to help put humanity into orbit at L-5. Currently this multi-talented membership lacks a viable method of developing ideas. The need for a better communications system is apparent.

In order to fill these needs, Shirley Varughese announces the formation of the L-5 Synergy Coalition. The Synergy Coalition will perform three interrelated functions intent on improving communications among members and local chapters of the Society.

The three functions of the Synergy Coalition are: (1) to catalog and act as a repository for information on space colonization and to make this information available on request; (2) to catalog the various skills, talents, and interests of the members of the L-5 Synergy Coalition and to coordinate these skills, transfer ideas and information and to generally act as a liaison between disciplines; and (3) to co-ordinate group efforts, innovate ideas and locate and solve problems using the resources of the L-5 Synergy Coalition.

Not only can the Coalition provide a forum for discussion, but it can also take care of specific information requests on space settlement. Information can be provided by referring to function 1 (the data file) or function 2 (the skills file) when a specific person is directed to another individual who has that information.

Functions 2 and 3 may prove extremely useful in mobilizing the human resources of the L-5 Society, producing

some very solid research work, developing ideas, and in locating and solving problems.

People with related skills, interests, and ideas will be put into contact with each other and provided with a "suggested topic" for discussion and development. (The first topics will most likely be defining topics for the Synergy Coalition.)

Be aware that the Synergy Coalition will be able to provide an important link between disciplines as well as between individuals.

In order to set the Coalition into motion, the Coalition needs *members*. If your skills fall into any category between astrophysicist and artist or tinker and technician, send your name and address to: Shirley Ann Varughese, The L-5 Synergy Coalition, 272 Route No. 206 (So), Somerville, NJ 08876.

We will send you more information and a data sheet. The data sheet will supply us with the information we need for functions 1 and 2. Once these are in working order, the third function, (communications) can get to work.

The Synergy Coalition needs YOU!

WHAT'S AVAILABLE FROM THE L-5 SOCIETY?

- Xerographic reproductions of articles from other publications (please ask for list).
- *The Hunger of Eve: A Woman's Odyssey Toward the Future*, Barbara Marx Hubbard, Stackpole Books, 1976. \$8.00.
- *The High Frontier: Human Colonies in Space*, Gerard K. O'Neill, Wm. Morrow and Co., 1977. \$8.00.
- *The Fourth Kingdom*, William J. Sauber, Aquari Corp., 1975. \$6.
- *L-5 News*, back issues \$1 each (Volume 1 included 16 issues).
- Bernal Sphere color postcards (interior, exterior). 15¢ each; 50 of one kind, \$3.
- Bernal Sphere 14" x 17" color posters (interior, exterior). \$3.50 for one, \$3 each for two or more, \$2.10 each for 10 or more, \$1.75 each for 50 or more.
- Introduction to the L-5 Concept, 18 slides, \$9.
- Space Industrialization, 28 slides, \$14.
- Satellite Solar Power Stations, 12 slides, \$6.
- Space Habitats, 18 slides, \$9.
- The L-5 Society Slide Show, all 76 slides, \$38.
- Individual slides, 50¢ each. Write for catalog.

Note: **Postage and handling per order, add \$2.**



Has anyone tried to prepare an environmental impact statement for the lunar surface mass driver? It will restrict certain circumlunar orbits used by transfer craft. Will it place a measurable torque on the moon in a decade or two?

I would like to see tradeoff studies of the effects of a 1 bar non-breathable atmosphere on the moon (it would have a half life measured in millennia). Sure, the mass driver would not work (or would it?); but landing on the moon, point to point transportation, and point to point communication (with an ionosphere) would be much easier. Does it matter? The atmosphere could come from an aimed comet or stolen Saturn ring, someday.

Jim Oberg
Dickinson, Texas

Space colonies are the first step in freeing ourselves from the bonds of this planet. The only hope for mankind's survival is to free himself from dependence on this planet and its dwindling resources, a reality made all too clear by the present natural gas crisis which all of us on the East Coast are currently suffering through.

Bob Yannes
Media, Pennsylvania

I'm fed up with politicians and publicists who call themselves journalists proclaiming our "limited" resources. Such shortsighted, planet-bound thinking can only discourage an atmosphere of exploration and discovery-an attitude sorely needed if we are to ever to expand mankind's base-line energy wealth foundations.

David C. Manchester
Springfield, Virginia

Those of us in the L-5 Society are well aware of the urgent needs the world has for clean efficient solar energy. We are also aware of the many programs and discussions being held around the country to lay the ground work for an effective energy policy. I'm afraid, however, that we are in the overwhelming minority of people that have any idea that such subjects as space space colonization and SSPS are being discussed seriously. It seems to me therefore, that it must be the intention of the L-5 Society to help make this message widely available to the public. The question is how.

One hope is that Gerard O'Neill's latest book, *The High Frontier*, will reach many interested readers. However, when I went to purchase the book at a local bookstore I bought the only copy (not the last copy, the only copy). I hope this was an isolated occurrence. A review of his book on the PBS television network would certainly be beneficial.

Several articles have been written and published but I still do not believe enough people have been exposed to this very necessary message. Another interesting possibility would be to arouse the interest of environmentalists like Jacques Cousteau in SSPS and space habitats in hope they would find the subjects suitable for a television production analyzing the effects of such an ambitious project. Another vehicle for publicity and a personal favorite of mine would be to see a full length motion picture produced using the space habitat of Gerard O'Neill as the setting.

Some people will consider these ideas absurd or useless and some may be (a little), but all of them would definitely help put a spotlight on the projects which all of us in the L-5 Society believe to be so important. And it follows that if these ideas are well known then wide public discussion cannot be far behind.

James D. Ryan
Indianapolis, Indiana

I would like to suggest "Extraterrestrial Settlement Society" as a new name for the organization as it lacks the rather starry-eyed fantasy connotation of "Space Colonization. . ." and would therefore be found more acceptable to those of the general public (to whom, it must be remembered, we must appeal).

Peter Blinn
Ann Arbor, Michigan

I agree with M. Ruth Minyard's letter in the January issue: how many children who began by reading science fiction have gone on to become scientists and engineers, to make the dreams they were inspired by come true? Anyone who thinks we'll downgrade our cause by enlisting supports from science fiction fans simply doesn't understand the historical fact that individuals interested in science fiction are more likely than most to have (or develop) an interest in science and its applications, and persons with science careers are more likely than most to respect science fiction (indeed, as I mentioned, in many cases science fiction helped steer them to those careers).

Robert Freitag's pessimism on probable time-tables for space exploitation reminds me of one of Arthur C. Clarke's dictums: "When a distinguished but elderly scientist says that something is possible, he is almost certainly right, and when he says that something is impossible, he is very probably wrong." I recall that back about 1955, I was one of the few people who believed we could -- and probably would -- have people on the Moon within twenty years of that time. And at that, I was too pessimistic. Predictions of technical capability more than 15 years ahead are almost always too pessimistic.

And if I may comment on the "Evolutionary Imperative" article, have you seen the editorial in the recent issue of *Galaxy*? The editor makes a convincing case that for those of us who follow the Jewish and Christian faiths, the Genesis injunction (to "subdue the Earth" and have dominion over it) demands that we

L-5 SOCIETY MEMBERSHIP FORM (please type or print)

NL 703

L-5 SOCIETY
1620 N. PARK AVE.
TUCSON, AZ 85718

NAME: _____

ADDRESS: _____

CITY/STATE/ZIP: _____

AFFILIATION/TITLE OR POSITION: _____

(OPTIONAL)

- I am interested in being active locally. Phone (optional) _____
- Please enroll me as a member of L-5 Society (\$20 per year regular, \$10 per year for students). A check or money order is enclosed. (Membership includes *L-5 News*, \$3 to members; the balance -- \$17 or \$7 -- is a tax-deductible donation.)
- Please enter the above as a nonmember *L-5 News* subscriber (\$20 per year). A check or purchase order is enclosed.
- Enclosed find a donation of \$ _____. (Donations to L-5 Society are tax-deductible.)

colonize space, for the word "Earth" could not have meant the "planet Earth," because at the time it was written, the concept of a planet in its present sense did not exist. He states that a more accurate rendering of the original sense of the term into modern English would be "ail available habitats," and then proceeds to cite O'Neill colonies as an example of such habitats.

Larry Friesen
Webster, Texas

I've noticed in recent issues of the L-5 News that some people are of the opinion that the L-5 Society should change its name to the "Space Colonization Society"; I would like to cast my vote in opposition.

Point 1: While space colonization, a /a O'Neill, was one of the prime movers behind the organization of the Society, it is no longer so. The Society has already officially broadened its horizons to include space industrialization, satellite solar power, and space habitats. I think it is further obvious to everyone that everything that happens in space is of concern and interest to us-not just colonies.

Point 2: The L-5 Society, with its simplicity, is something much easier to keep in the public's mind, memory, etc. (and to rally around for Society members) than the "Space Colonization Society."

Point 3: Even explaining the name of our society to an outsider can be a starting point for conversation, and explaining what L-5 is alone can keep a conversation going-and spark a person's interest. This in spite of the fact that L-5 as such has dropped in interest as a space colony/space manufacturing site.

The L-5 Society is something that I can identify with. The "Space Colonization Society" sounds more like a 6th grade organization that will die by next week. I vote against the proposed change.

Dave Huntsman
NASA/Houston

When I went home over Christmas vacation this year those kids in my little sister's crowd who didn't believe "we should fix up the ecology before we go into space" asked me "Will you go when they do it?" Then I had to gently explain that it wasn't clear that it would happen in my lifetime unless support kept growing.

Ray Sperber
Cambridge, Massachusetts

There is a point that I would like to raise; one that I think is very important. We should be organizing a grassroots movement to communicate a pro-space philosophy to Congress. We should be writing to our elected representatives in Washington, asking them where they stand on such things as the NASA budget, trying to get them to spend more of our tax dollars on worthwhile projects like keeping the Space Shuttle program going at full speed or launching a prototype SPS to check out the cost and any possible eco-hazards from microwave beams, etc. I understand Jimmy Carter is in favor of the SPS concept. Wouldn't it be nice to repeat the massive letter-writing campaign that resulted in a new name for the Shuttle, for a new space project? How does the L-5 Society feel about political action and lobbying efforts? Could we get any help from our natural allies, the big aerospace companies?

Do you (or anyone) have the following information for those of us who do want to write to our Congressperson: the names of the members of the House and Senate committees that deal with space and/or energy; the names of any pro-space Congressmen who might be interested in sponsoring pro-space bills; the names of any Congressmen and/or aerospace industry lobbyists in Washington who would be able to provide us with information on pending bills or committee hearings, so that we could write knowledgeable letters on the right subject at the right time to convince our

elected reps to vote the right way? The L-5 concept is not going to "get off the ground" until we have profit-making space industries to support it out there, and the Third Industrial Revolution is not going to get off the ground without a lot of preliminary work by NASA to cover the expensive up-front costs of capitalization involved in getting out into space, and that is not going to happen unless and until we, the voters and taxpayers, can convince our lawmakers to do it. So, why don't we write to them and grab their somewhat limited attention, and let them know that how we vote in the next election depends on how they vote on space appropriations in the next year or two? Would you like to comment on this in the L-5 News?

Robert Lovell
Shawnee, Kansas

First, by the requirements of its charter, as a non-profit corporation, the L-5 Society may not engage in lobbying efforts. However, we are happy to provide information about Congresspeople who support space settlements. These include Senators Mike Gravel (D-Alaska), Barry Goldwater (R-Arizona), and Wendell Ford (D-Kentucky), and Representatives Olin Teague (D-Texas), Don Fuqua (D-Florida), and Morris Udall (D-Arizona). It is probably no coincidence that the only state with two pro-space settlements Congresspeople is also home of a dedicated band of prospective space dwellers!

In the U.S. Senate, NASA's budget is considered by the Commerce Committee Subcommittee on Science and Space (Washington DC 20510) chaired by Adlai Stevenson. The ranking minority member is former astronaut Harrison Schmidt.

Over in the House, the most important committee is Science and Technology, U.S. House of Representatives, Wash., DC 20515. Olin Teague is Chairman. Another useful committee is Interior and Insular Affairs, chaired by Morris Udall. That committee considers natural resources and environmental issues.

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