LATEST DEVELOPMENTS IN SPACE INDUSTRIALIZATION, SATELLITE SOLAR POWER, AND SPACE HABITATS

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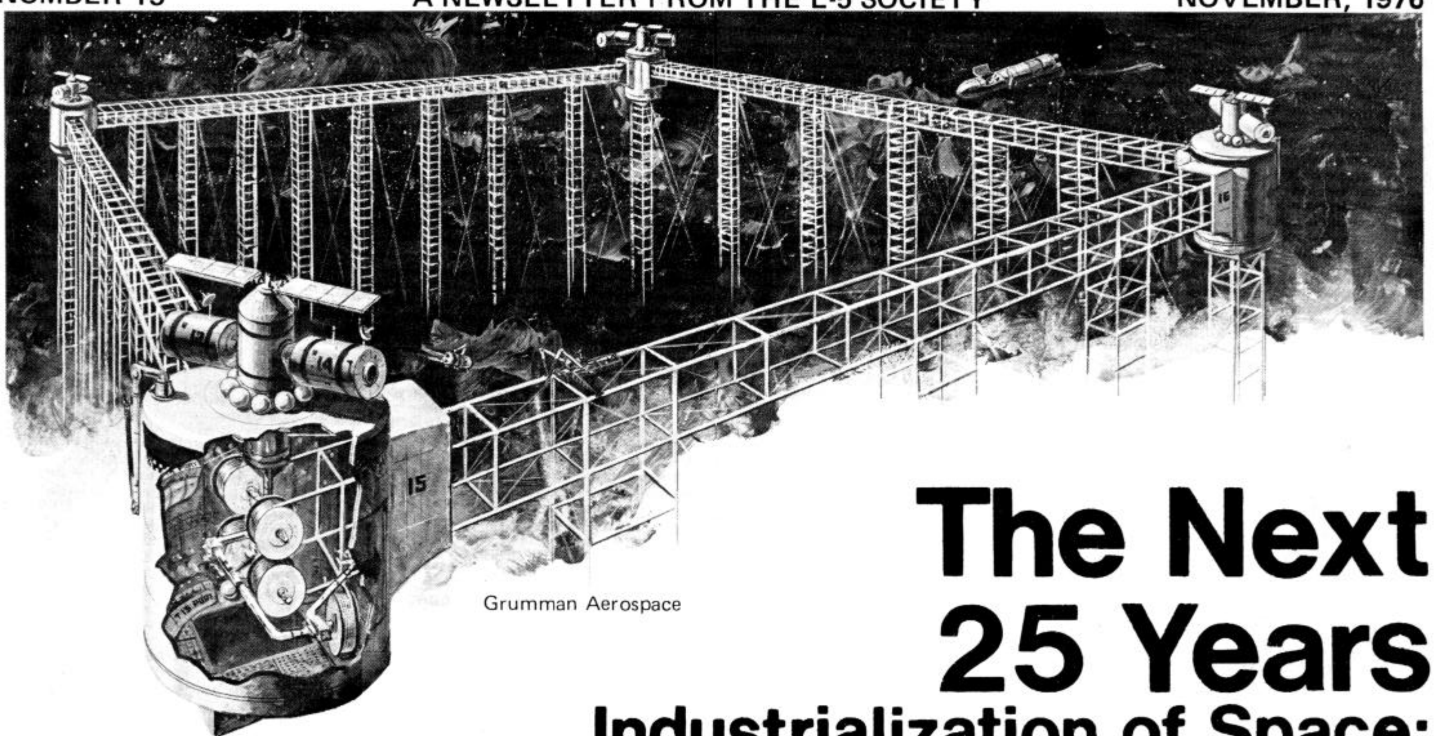

Grumman Aerospace

The Next 25 Years
Industrialization of Space: Rationale for Planning

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1. Humanizing Space

Dreams about Humanity emigrating into space are as old as science fiction. Concepts of permanently occupied and self-sufficient extraterrestrial outposts, bases, habitats, and colonies for settling space have long been envisioned in earth orbits, on the Moon, and on other celestial bodies such as Mars or larger asteroids. More recently, serious writers have suggested that such goals are possible within the foreseeable future. e.g., O'Neill in 1974 [1]. Results from recent NASA studies are generally in support of this work [2]. Some of these projections have included the suggestion that space colonies would be the answer to the "population explosion" on Earth.

Should our next major goal in space, then, be to establish a colony in space, -- say -- 10,000 people as proposed by recent studies?

The industrially advanced nations are no longer threatened by overpopulation as are many developing nations. Thus, by not answering a demographic or social need for that part of the world that would have to underwrite the effort, space colonization *per* se is unable to contribute to a lessening of population pressures in the relevant future.

While space colonization as initial objective and dominant program thrust is clearly not the answer, humanity's expansion into space will be unavoidable in the long run for sheer survival. There can be little doubt that permanent settlements in space will be in humanity's future, and it is one of our most important obligations to future generations to keep these and other growth options open at this time where we are only at the threshold of new frontiers. As the uncertainty about these new frontiers and the possibility of future crisis conditions rise, "safety" lies in maximizing the option potential open in the future, to avoid foreseeable and reduce unforeseeable problems.

At the same time, planning of the next steps must be responsive to our near-term needs and wants, while building a solid foundation of ethical responsibility and technological capability from which an open, choiceful long-term future (or futures) become accessible. That alone

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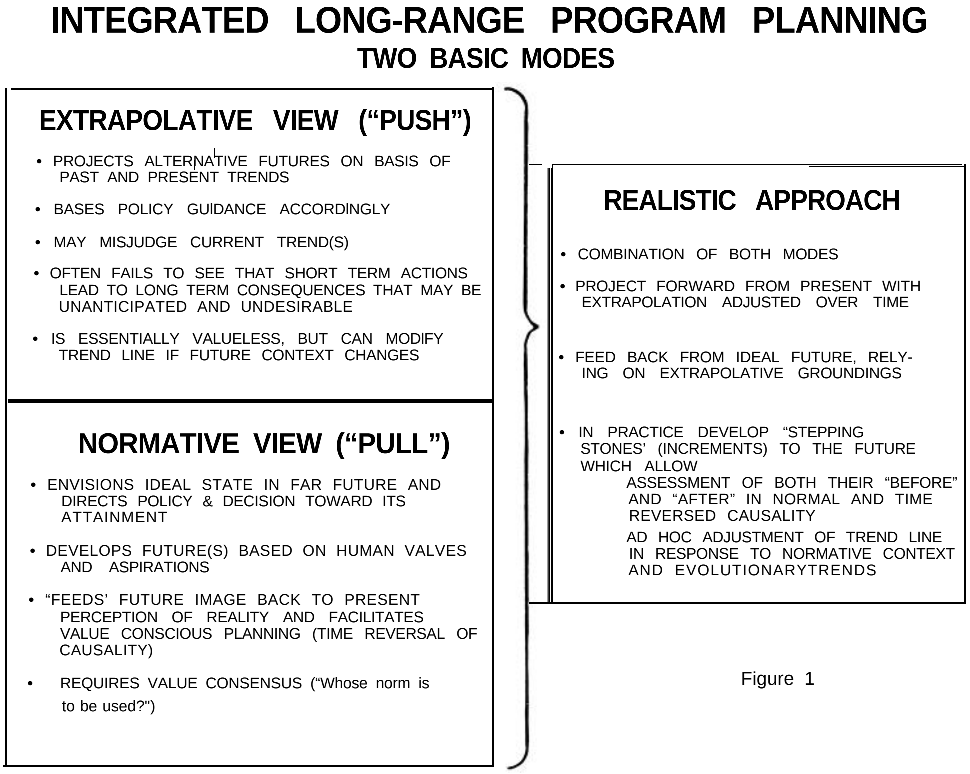

Figure 1

will provide validity to the Space Program.

In planning the long-range space program based on essentially utilitarian near-term aspects without losing sight of the more humanistically significant long-term, and to forecast associated technology requirements, a planning methodology was developed which has recourse to a combination of two basic modes of planning [Fig. 1], extrapolative and normative [3]. In the extrapolative view, responding to the "Push," alternative futures are projected on the basis of past and current trends and tendencies. In the normative view, establishing a "Pull," some ideal state in the future is envisioned or postulated, and policies and decisions are directed toward its attainment. While the extrapolative view is strictly rational, "cold," and without value statement, the normative planning is truly idealistic, by basing its futures on human values and aspirations, and it would therefore require a value consensus ("Whose norm?"). By not limiting the norms under investigation and keeping all those future options open that appear to be supported by *some* consensus at present, the problem of deciding whose norm should be baselined can be avoided. A combination of both modes can then yield a more realistic approach to integrated long-range planning by tying time-reversed vectors of the future to extrapolated, trend-oriented vectors of the quasi-present in a "tree of relevance." By defining development plateaus, common stepping stones can be identified. The "Push/Pull" planning approach, for the first time, appears to offer a useful relationship between utilitarian and humanistic goals of space flight [Fig. 2].

In thus aiming at long-range goals of humanizing space through colonization, Space Industrialization must first generate an open world that would -- through its "re-started" growth processes -- make space colonization tenable, supportable and practical. Once established in space, permanent settlements will tap the energy and resources of space, thus easing the mounting human pressure on Earth's dwindling resources, helping remove much industrial activity from the fragile biosphere of Earth, and providing new frontier challenge and new worlds for humankind.

2. Opening the Closed World

In our present world, both the industrialized and industrializing countries are facing monumental problems. But even more alarming is the dilemma of the nonindustrialized, undereducated, undernourished and undercapitalized nations. Rapidly approaching or already faced with excess population levels, they must undergo social changes at a considerably higher rates than all other countries in history. Their combined growth, based on current rates, will result in well over a billion new people in the next 20-25 years. Extrapolations of this type have led concerned people to seriously consider the Unspeakable -- namely, the imposing of "Limits to Growth.

There are no longer empty continents with lush vegetation into which excess populations could migrate. Space colonization, as stated before, is not (yet) an answer. Population control is an important near-term response, but the inertia-like time lag between birth-rate decline and slowdown in population growth and population stabilization will be many decades (typically 100 years to level off assuming the net reproduction rate reduced to 1.0 by 2025) during which population will continue to grow vigorously (to 10 - 12 billion at level-off point). Higher productivity through industry, generation of more capital in the undercapitalized world, and creation of new values and jobs will have to go hand-in-hand with population control to bring the standard-of-living -- and the natural acceptance of lower birth rates -- of the "developed," highly industralized countries to both the developing but raw-material-rich and the developing and raw-material-poor nations, in terms of gross national product (GNP), per capita income, energy, food and material consumption, and population index [4].

3. Goals of Space Industrialization

The intensification and expansion of Earth-based industrialization to support such a global-wide standard-of-living increase at the population levels predicted for the next 30-40 years (requiring an increase of industrialization above current levels by an estimated factor of 35-40) has given cause for serious concern of energy and raw materials availability as well as environmental burden due to waste products, waste heat, and pollutants,, supporting the simple fact that in a limited world -- as in a shrinking droplet of water -- growth is limited. For humans living in such a no-growth world, there will be only one choice: to organize scarcity. As a result, their future will quite likely be characterized by scarcities, deficiencies, shortfalls, defensive Earth resources policies, regression to intensified battle for survival, and new fragmentation of humanity. Thus, in a closed world, a fourth complex of problems joins the dilemma of population increase vs. living standard vs. environment: social strife and warfare.

For an effective opening of the essentially two-dimensional world with its "flat", closed surface limited in resources, energy and human real estate, to the three-dimensional environment of space, space must contribute to remove the limits to growth by not only generating new products and services but, in fact, by "shunting" energy- and pollution-intensive components of Earth industry into space where both energy and waste reservoirs are plentiful [5]. In addition to organizing scarcity to preserve, recycle, and substitute for limited resources, a second choice becomes viable: the creation of wealth for all humanity without detrimental environmental impact.

Foremost among the problems faced by the large majority of humanity (over 70%) are industrial development and diversification, unemployment, population growth rate, agricultural

PROGRESS IN SPACE

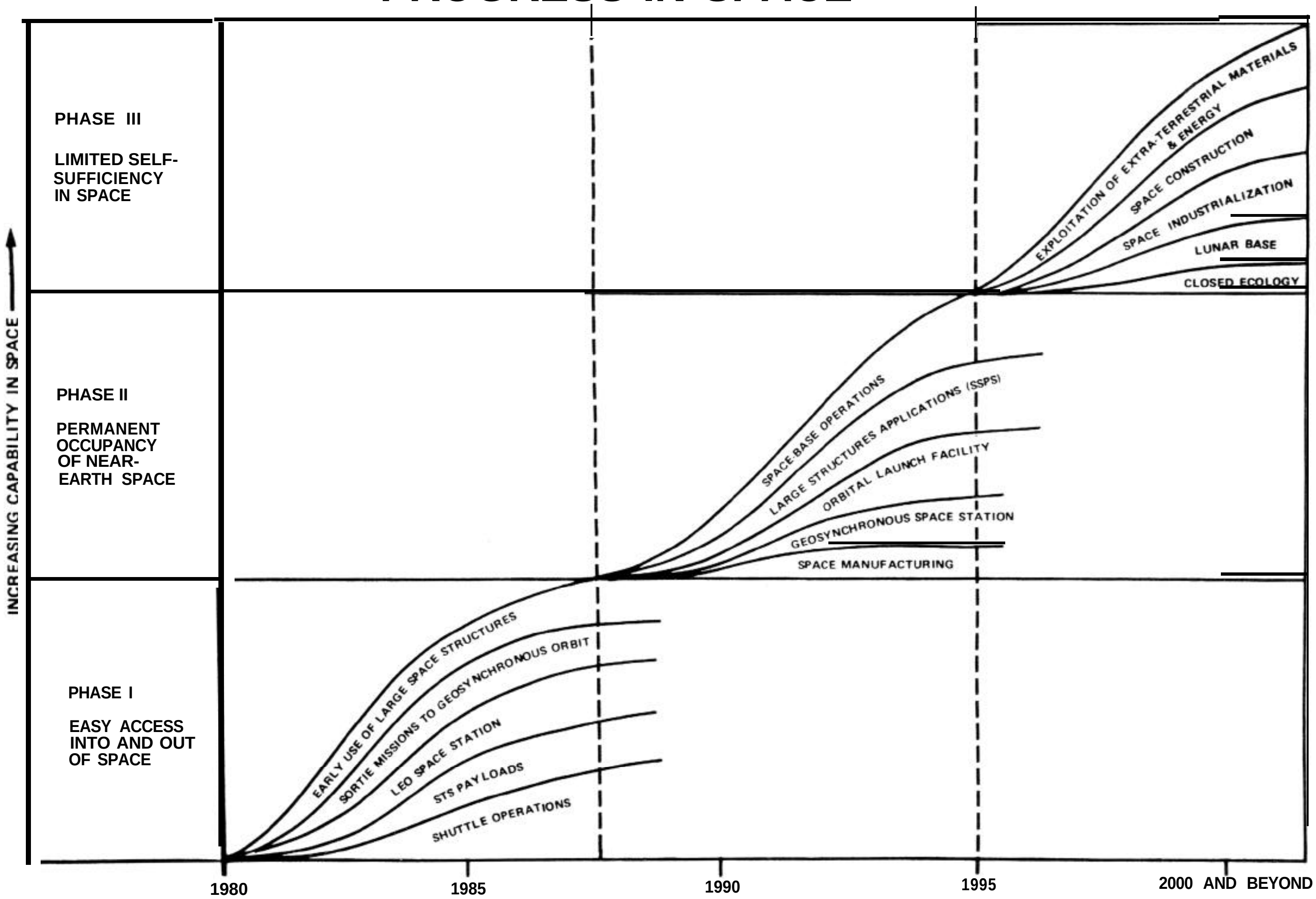

Figure 2

development and food supply, rural and urban development, health, and education. For the industrialized nations, additional concerns pertain to energy shortage and independence, raw materials depletion, environmental burden, and inflation/recession. Clearly, to be morally supportable, Space Industrialization must contribute to the solution of these problems, both on a national (U.S.) level and -- eventually -- on a global scale.

The goals of NASA's Space Industrialization program, thus, include making a major contribution to increased productivity on Earth without taxing the environment, generating new values through extraterrestrial productivity, and providing new growth options for the future which would include permanent settlement of space and long-range colonization and exploration projects.

The task of balancing the needs of humanity with the requirements of maintaining Earth's biosphere through the industrialization of space will -- by necessity -- be approached through a step-by-step evolution.

4. Stepping Stones

Space Industrialization, by developing the permanent and productive use of environments beyond Earth, must be based on the economic principles of cost effectiveness and commercial competition! This in itself presupposes the introduction of "stepping stones" to the overarching concept of Space Industrialization in order to facilitate the transfer of the investment capitalization from the public (Federal Government) sector to private industry. Since capital cost and interest rates are significantly affected, as is inflation, by the length of time and the extent to which investment capital is tied down unproductively in development (requiring discounting), return (pay-back) times on investment and the time until breakeven must be minimized. In addition, the higher the confidence level that influential features of the future Space Industrialization systems/programs can be maintained within acceptable tolerances, the lower the risk to the investor. Both arguments stipulate a stepping-stone approach that provides "manageable" increments within the "Push/Pull" force field of the long-range concept.

In addition to providing reduced investment steps and shorter pay-back times, the pre-planned plateau approach (Reference 3) or "technique of small steps" allows

- Goal-oriented program planning and management,
- Built-in "holds" for successive re-evaluation of subsequent goals and objectives,
- Built-in "holds" for introduction of new technologies, both improvements and replacements/breakthroughs, and
- Better assimilation of space progress in Earth's culture and concurrent consolidation of technological progress with (slower) humanistic/cultural development.

By expanding the biosphere to include the space dimension, access is obtained. to functionally infinite materials and practically infinite energy supplies. Some of the attributes and resources of space that are of relevance are listed in Table 1.

Based on this wealth of potentially attractive features, the guiding principles of Space Industrialization must therefore be to (a) exploit the availability of virtually unlimited energy, (b) exploit the excellent transmission characteristics for energy and information, (c) exploit the large geometrical coverage, and (d) exploit the benign (except for radiation belts) environment. A summary of

- Easy gravity control from ambient zero-g (or micro-g) to any desired rotationally induced multi-g-level
- Absence of atmosphere-
  - --unhampered viewing of space for astronomy, astrophysics, etc.
  - --perfect vacuum and freedom from seismic, acoustic, and convection disturbances
- Comprehensive overview of Earth surface and atmosphere
- Isolation from Earth's biosphere (for hazardous processes)
- Freely available light, heat, and power
- Infinite natural reservoir for
  - --unlimited disposal of waste products
  - --safe storage of radioactive products
- Super-cold temperatures (heat sink)
- Large, three-dimensional volumes (storage, structures)
- Variety of non-diffuse (directed) radiation
- Magnetic field
- Extraterrestrial raw materials

Table 1

candidate activities is given in Figs. 3a and 3b [4]. As a logical consequence, Space Industrialization introduces several new and interlinked commonality features that will become characteristic of future space activities, viz.,

- Large structures in space
- *Complex* systems in space
- Long flight durations
- *People* for orbital service and maintenance.

While the long-range motivation of Space Industrialization, the "Pull," is physical and humanistic expansion-and thus survival-of humanity, the nearer-term goals of Space Industrialization are three-fold: provide energy from space, provide space-derived products or goods that are salable and profitable, and furnish space-derived services for which agencies, industries and the public are willing to pay.

5. Applications

Energy. The problem of satisfying the energy demand of the industrialized world, as currently perceived, will reach near-critical proportions over the next 25 years. The electric power capacity of the U.S. alone is expected to triple (from 500 GW to 1500 GW) before the year 2000, requiring investments on the order of a trillion dollars, and to continue to grow. There is no obvious single source to supply this demand growth: oil, gas and conventional nuclear power generation use depleting, irreplaceable resources (i.e., living off "capital"); nuclear fusion development is uncertain at this time, and its costs are unknown; solar-terrestrial power (photovoltaic, thermal, wind, etc.) appears to be penalized by high cost and the problem of energy storage.

Without Space industrialization, prospects for power sources by 2000 appear to be limited to coal, using existing technology, and breeder reactors, requiring development. (First breeder reactor is expected to come on line about 1992-93, with doubling time (for fuel) of 30-60 years, improving to 20 years thereafter.) For both options, there exist problems of environmental burden and potentially high cost. An additional problem, pointed out by K. Ehricke, is the high cost of electrical power transmission, requiring presently more than 400,000 miles of high-voltage lines in the U.S., with 11,000 square miles of right-of-way real estate.

The potential benefits of Space Industrialization to the energy problem can be three-fold:

- by providing technology useful for generating and/or transmitting power on the ground,
- by providing RF power reflectors in space for passively relaying electrical power from ground power plants to ground users, and
- by generating power in space for transmission to the ground.

Replacing the current 64 kV transmission lines with higher-voltage cables is one answer to the power transmission problem. Switching from AC to DC power may be a better, more economic solution, according to Rockwell International, but it would require high-voltage AC/DC rectifiers and inverters. Such devices use terrestrially produced silicon crystals of 4-7 cm diameter (where size determines

SPACE INDUSTRIALIZATION
Examples of Opportunities–1

INFORMATION TRANSMISSION FOR PUBLIC SERVICES
- COMMUNICATION: person-to-person, Voting/polling, etc.
- DATA TRANSMISSION: Electronic mail, Package tracking, Surveillance
- INFORMATION STORAGE: For Recall from Earth or Space, Computer in Space
- PUBLIC INFORMATION SERVICE: Education, Cultural/entertainment programs.

DATA ACQUISITION/TRANSMISSION
- METEOROLOGY: Accurate Weather Predictions
- PROBING OF ATMOSPHERIC LAYERS: Ozone layer, Ionosphere
- LAND MONITORING: Resources, Fault zones, Earthquake areas, coasts.
- OCEAN MONITORING: Currents, Wave conditions, Icebergs, Marine life
- COLLECTION/TRANSMISSION FROM SURFACE BUOYS AND BALLOONS
- SOLAR ACTIVITY MONITORING: Flare warning, etc.

EARTH-ORIENTED TELEOPERATION AND TELEMONITORING
- LONG PIPELINES AND POWER LINES
- REMOTE INDUSTRIAL FACILITIES: Desert Solar Power Stations, etc.
- REMOTE AGRICULTURAL FACILITIES
- REMOTE HUMAN ACTIVITIES: Expeditions, Search/Rescue, etc.

NUCLEAR WASTE DISPOSAL
- FROM EARTH SURFACE: To long-lifetime orbits or Sun
- FROM VICINITY OF ORBITING INDUSTRIAL FACILITIES

Figure 3a

SPACE INDUSTRIALIZATION
Examples of Opportunities–2

MANUFACTURING IN LOW EARTH ORBIT
- HIGH-COST LOW-WEIGHT/VOLUME PRODUCTS: from Earth-supplied Materials
- STRUCTURES & STRUCTURAL ELEMENTS FOR SPACE FACILITIES: from Earth- or Moon-supplied Materials

SPACE LIGHT (ILLUMINATION FROM SPACE)
- INDUSTRIAL/AGRICULTURAL OPERATIONS, COMMERCIAL TRAFFIC, URBAN AREAS
- FOOD PRODUCTION: Plankton growth, etc.
- WEATHER MODIFICATION: Cropdamage prevention.

SPACE MICROWAVE POWER (ENERGY FROM SPACE)
- LONG-DISTANCE RELAY OF POWER FROM SOURCE TO USER CENTER
- SPACE-GENERATED POWER TO TERRESTRIAL USER CENTER
- SPACE-GENERATED POWER TO SPACE INDUSTRIAL FACILITIES

LUNAR INDUSTRIALIZATION
- SUPPLY OF OXYGEN FOR ROCKET PROPULSION/LIFE SUPPORT: Transportation
- STRUCTURAL & MANUFACTURED GOODS TO ORBITING FACILITIES
- PRIMARY COMMODITIES & MANUFACTURED GOODS TO EARTH

HUMAN ACTIVITIES
- MEDICAL/THERAPEUTIC SERVICES/OPPORTUNITIES: Curative & Alleviative
- RECREATION: Space Tourism Facilities

SOLAR SYSTEM INDUSTRIALIZATION
- MARS: STAGING & SUPPLY BASE FOR ASTEROID UTILIZATION
- ASTEROIDAL METALS FOR EARTH
- HELIOCENTRIC EXPLORATION

Figure 3b

maximum power level). By producing these crystals in space, a choice of sizes up to 15 cm could be provided, allowing a reduction in number of crystals needed for a given power level to 7% of the number of 4 cm crystals. Potential cost savings due to reduced construction requirements at-e estimated at $76.5 billion by the year 2000 (assuming 1000 GW generating capacity).

Even more significant may be the impact of "clean" power generated from solar energy from space. For solar-terrestrial (ground) collectors, availability of the Sun is roughly 17% of the time in Arizona and 6% average nation-wide [6]. By relocating the solar collector array from the day/night cycle and atmospheric environment of the ground to a suitable Earth orbit, solar radiation would be available more than 99% of the time, limited only by occasional passes through Earth's shadow. This means that a power collector in space (11,800 kWh/m^2 per year) would intercept almost 6 times as much as one in Arizona (2000 kWh/m^2 annually), and almost 17 times as much as the U.S. ground average (700 kWh/m^2-year).

After collection of the energy in geosynchronous orbit, electricity would be generated in space through one of a number of possible conversion techniques, listed below. For subsequent transmission to Earth (or to a space-based industrial facility complex), the DC electricity would be converted to microwave RF through amplitrons (vacuum-tube type amplifiers such as klystrons are unnecessary in the vacuum of space), and beamed to a receiver antenna (rectenna) on Earth. Atmospheric transmission losses for microwave energy at the 2.45 GHz level would amount to no more than 2-8%. The entire DC-to-DC transmission chain itself is expected to achieve a level of about 58% efficiency [7].

Conversion techniques, presently under investigation by NASA and its contractors, may be photovoltaic (light energy) or solar-thermal (heat energy). The latter category includes thermionic, Brayton-cycle, thermionic Brayton-cycle, and Rankine-cycle systems. The former uses vast arrays of solar cells (silicon). Overall efficiencies of solar power satellites (from interception to AC ground power busbar) are estimated at 4-8% for photovoltaic, 6-17% for thermal systems.

To make the solar power satellite system economically viable, a considerable amount of power must be delivered, requiring very large collector arrays. For a ground power output of 10 GW, a photovoltaic array would cover an area of 129 km^2 and have a mass of 34,000 metric tons. Its development costs are estimated at $50 billion, its energy production-cost at 27 mils/kWh. For comparison, a Brayton-cycle thermal satellite system would require only 70 km^2 of size, but 151,000 tons of mass, $59 billion of development cost, and 50 mils/kWh of energy production cost [7].

If sold "at cost" of $.027 per kilowatt-hour, the power output of a photovoltaic satellite would yield an annual revenue of $2 billion, i.e., a square kilometer space would return more than $15,500,000 each year.

Goods and Services. Exploitation of the unique environment of space for processing of commercial inorganic and biological/pharmaceutical materials as well as manufacturing of new products designed to enhance productivity on Earth are expected to develop very high industrial potential. Not only would such activities affect world trade and lead to lower costs, thus benefitting national and global economy, but they would also be of importance to human health by benefitting disease prevention and more effective treatment.

At present, we know of five basic types of industrial processes that require a zero-g environment for improved material quality, more efficient material utilization, commercially significant production volume, and lower cost:

1. Crystal growth, including growth from a melt, growth in solution, and growth from the vapor phase.
2. Purification/separation.
3. Mixing.
4. Solidifications.
5. Processes in fluids.

Other processes require high vacuum, such as vapor deposition techniques:

The possible evolution of Space Processing and Manufacturing of Goods along plateaus or stepping stones of immediate and contemporary benefit toward far-future goals of Space Colonization are highlighted in Fig. 4. Again, the stepping-stone approach would allow sponsorship by the Government during the high-risk concept formulation phase, with subsequent shift of emphasis to private/commercial investment. The detailed plans for government/industry interaction have yet to be constructed and are presently under early study; however, they can be expected to vary with the product or service produced.

Top candidates on NASA's list of inorganic commercial products made in space are semiconductor materials such as silicon or gallium-arsenide ribbons for wafers and chips, vapor-deposited solar cells, and niobate crystals for lasers and memories. For example [8], producing crystal chips in the gravity field on Earth from cylindrical boules yields 37% of useable wafers which in turn are processed into 21% of tiny electronic chips for integrated circuit (IC) substrates, resulting in an overall yield of 8%. For comparison, processing of the semiconductor material in zero-g in ribbon-form would bypass the wafer stage and lead directly to chips, with an overall yield of 35%. There would thus be an improvement ratio, i.e., profit margin, of 4% to 1 over ground-processed chips.

According to Western Electric Manufacturers Association (WEMA), the market for ICs in the free world was on the order of $5 billion in 1975, with $6 billion predicted for 1977. Extrapolation leads to an annual average of $19 billion between 1985 and 1989. The share of silicon, as raw material, in this market is estimated at about 10%.

Among the space-manufactured metals of interest are materials for high-strength permanent magnets, turbine blades, and X-ray targets.

Even more important will be separation and culture-growth processes of biological products such as pancreatic cells (insulin), pituitary cells, endothelial cells (macrophages), bone marrow, blood cells (lymphocytes, granulocytes), sperm cells (control of sex in farm animals),

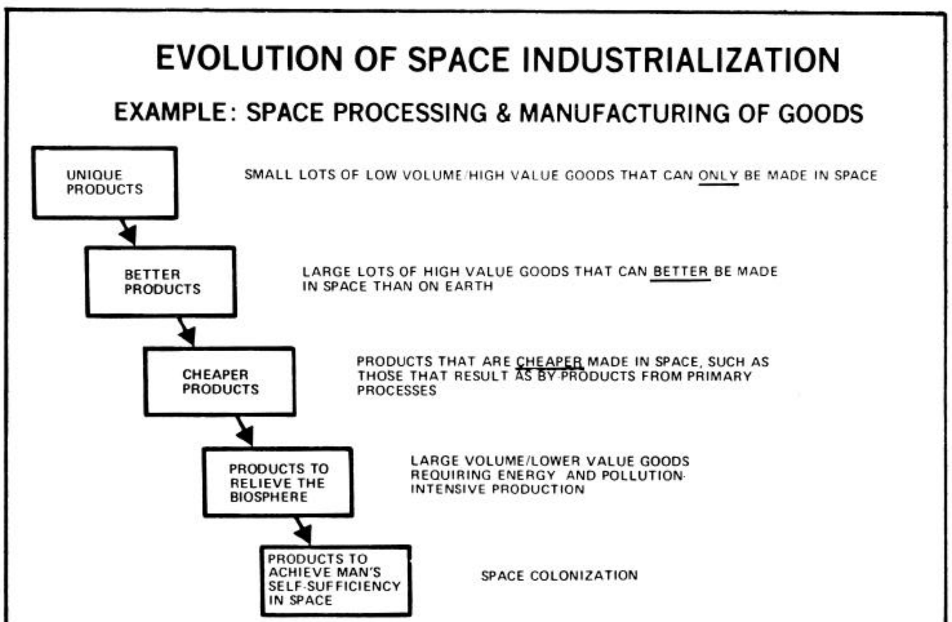

Figure 4

and enzymes. Space-processed biologicals include the enzyme urokinase with the potential of preventing up to 50,000 deaths per year in the U.S. due to thromboembolisms (blood clots), and erythropoietin for the treatment of kidney failure and anemia. In the U.S. alone, the annual requirements for urokinase are 500,000 doses at an Earth-produced cost of $2.5 billion. If produced from space-enriched material, the cost would amount to only $400 million [9].

Similar considerations apply to space-processed lymphocytes (for prevention of organ transplant rejection) and macrophages (for early detection of immunological reaction).

Public Services. Basic concepts of making space useful and directly relevant in the everyday life of large numbers of ordinary citizens involve the placing of very large satellites and antenna structures into orbit.

In a reversal of a previous space flight principle which required that spacecraft be kept as simple, lightweight and reliable as possible by relegating functions associated with complexity and weight to ground stations, the achievement of easy access to and from space and permanent occupancy of space by people will permit us to develop and operate large and complex satellites.

NASA studies indicate that in many applications of information transfer minimum total system cost might be achieved by deliberately making satellites large and highly capable, accepting their expense in order to allow the user equipment to be tiny, highly portable, and inexpensive. Because of the vantage point of geosynchronous altitude, millions of Earth-based users can be serviced by one or only a few satellites, and the cost of even very large and capable satellites and antennas could be expected to be less than that of the terminals, resulting in minimum total cost while simultaneously performing functions of unprecedented system utility not possible with simpler and smaller satellites. By using people in space for assembling, maintaining and servicing advanced systems of this type, these satellites can reach very large size. Due to the weightlessness of space, however, the erection and assembly of large antennas and reflector structures will not be subject to the constraints of weight deflections. Typical active multi-beam antennas for RF and microwave output identified to date would measure 200 to 600 feet in diameter and operate at power levels of 20 to 150 kW. Passive space reflectors for beaming light to Earth or relaying energy can reach diameters of 1000 to 3000 feet [10]. Space power collectors may measure miles in length and width, as stated before.

The new, almost unlimited opportunities offered by space communications using these advanced systems have the potential to answer many serious needs of humanity in numerous personal, civic, government, industrial, and international applications in the next 25 years and beyond.

For *improved personal communications,* for example, a single 200-ft satellite could service 2,500,000 people with two-way voice and data communications, using ground-user radio sets no larger than a “Dick Tracy” wristwatch radio. For *improved mail communications,* a multi-beam satellite with total U.S. coverage may relay up to 30% of U.S. mail electronically (100 billion pieces per year) and accrue cost savings on the order of $1 billion/year. *Improved educational opportunities* would become available with a large, high-power TV direct-broadcast satellite bringing televised programs to mountainous, rural and remote areas of the world. Multi-beam satellites that provide citizens via wrist radio with around-the-clock access to police headquarters, and police with jam-proof communications from any location, will *reduce crime rates. Improved public and governmental services* could be obtained by using multi-beam satellites for direct and immediate communications to disaster areas as well as direct, instantaneous individual voting and polling. Intrusion detection of ships, personnel and goods across borders and coasts by large RF arrays in space, global communications with ocean vessels via space-based low-frequency loop antennas, and 24 hour, all-weather monitoring of global air and ocean traffic with a large microwave antenna satellite could improve *national security and international air/sea traffic lines* [10].

To achieve these long-range goals in a practicable step-by-step “Push/Pull” development, Space Industrialization would make use of a Space Construction Base [Fig. 5] in the early 1980s to (a) develop and demonstrate concept technology, (b) erect, assemble and test large structures in space, and (c) develop the first operational communications systems by transferring complexity from ground to space.

Early NASA studies of a Public Service Platform (PSP) indicate that integrated platform concepts with multiple functions may be superior to non-integrated separate satellites with dedicated antennas. A typical first stepping stone, by 1985, may be a demonstration antenna of about 2400 m^2 area and 7 kW of RF power in a 500 km orbit, with four different voice/data transmission functions. Subsequent growth to a 3-antenna platform with 13 functions (voice/data transmission functions, voice/video/imaging functions, and security/safety detection and control functions) and relocation from low Earth orbit to geosynchronous altitude could be achieved as next step in 1986/87 [11].

SPACE CONSTRUCTION BASE
EARLY SYSTEM OBJECTIVES

- **CONSTRUCTION RELATED**
  - SATELLITE POWER SYSTEM
  - NUCLEAR ENERGY
  - EARTH SERVICES
  - SPACE COSMOLOGICAL R&D
- **SPACE MANUFACTURING**
  - SPACE PROCESSING
- **SUPPORT OBJECTIVES**
  - CLUSTER SUPPORTSYSTEM
  - DEPOT
  - MULTIDISCIPLINE SCIENCE LAB
  - SENSOR DEVELOPMENT
  - LIVING AND WORKING IN SPACE

Figure 5

6. NASA Studies

The total, overarching concept of Space Industrialization is currently becoming a subject of intense study. These efforts, contracted with Rockwell International and Science Applications, Inc. [12], are primarily a planning activity intended to lay the necessary groundwork for subsequent implementation phases of a Space Industrialization program and the required support programs, including space transportation systems, domiciliary facilities in space, and space assembly/manufacturing facilities. Prime objective of these efforts is to develop an evolutionary Space Industrialization program which leads from Shuttle/Spacelab and early Space Station/Space Construction Base experiments to the permanent, practical and commercial utilization of space.

7. Summary

Space Industrialization has joined science and exploration as a major concept of space activity that introduces new themes of human space flight (Fig. 6).

In humanity’s long-range drive to humanize space and achieve eventual space colonization, the industrialization of space can offer a realistic approach to developing a progressive program to provide permanent, practical and commercial utilization/tools of space through products and services that create-in the long run-new values, jobs, and better quality of life for all.

The planning of such massive space endeavors as space colonization in the far future is quite helpful since it enables us to trace possible pathways of “Push/Pull”-type development through Space Industrialization back to the present. In thus establishing a “relevance tree” (Fig. 7) between far-future “dreams” and near-term realities and “pragmatisms,” we are in a better position to identify major stepping stones which are useful in terms of contemporary benefits (short-term returns) while at the same time being relevant to future growth-type needs. Once these vectors are established, we do not have to be too specific about the actual far-future goals and can leave their selection up to future generations.

This approach brings "dreams" into the realm of "strategic" thinking. It allows us to (1) give a larger purpose to our near-term "tactical" and pragmatic activities and thus reintroduce the "dream" in our "Now''-orientation, and (2) improve our ability to avoid dead-end "branches" in our major planning decisions for Space Industrialization.

The merits of Space Industrialization lie in the fact that it encompasses all human beings. This is a new fundamental premise, untenable without highly developed industrial foundations. Knowledge, health care, and the satisfaction of other existential and higher needs no longer are privileges of a few but fundamental rights of all. While space colonization, if taken as initial goal and prime objective, would probably "benefit" only a relatively small group of people living in a space colony, Space Industrialization can benefit *all* people on Earth. Moreover, it would not preclude but in fact validate the option that the industrialization of space may subsequently grow into space colonization as full self-sufficiency in space is reached. By being basically non-elitist, Space Industrialization will thus introduce the true humanization of space.

NEW THEMES FOR SPACE FLIGHT

- **ON-ORBIT EXPERIMENTATION, INSTRUMENT DEVELOPMENT, SERVICING & MAINTENANCE**
  - Production and Management of Food and Forestry Resources
  - Prediction and Protection of the Environment
  - Protection of Life and Property
  - Energy and Mineral Exploration
  - Transfer of Information
- **SPACE ASSEMBLY, CHECKOUT, EMPLACEMENT, AND SERVICING OF LARGE STRUCTURES**
  - Solar Power Conversion and Transmission
  - Terrestrial Power Relay
  - Space Light Illumination
  - Radio-Astronomy
  - Aid to Civil Problems (Observations, Communications, Support Services)
- **SCIENTIFIC AND COMMERCIAL UTILIZATION OF SPACE**
  - Basic Physics and Chemistry
  - Material Science
  - Commercial Inorganic Processing and Manufacturing
  - Production/Isolation of Biologicals (e.g., Blood Cells, Vaccines, Insecticides)
  - Effects of Gravity on Terrestrial Life
  - Living and Working in Space
  - Physiology and Disease Processes
- **STEPPING STONES FOR FUTURE HUMAN NEEDS AND OBJECTIVES**
  - Improvement of Technology/Capability (Transportation, Habitation, Operation)
  - Development of Closed Ecology Systems (Space-based Agriculture, Atmospheres)
  - Development of Human Physiological Adaptation to Space
  - Access to Extraterrestrial Raw Materials and Energy

--Space Industrialization	--Exploration of Mars
--Occupation and Settlement of the Moon	--Exploration of the Solar System
--Colonies in Space	--Interstellar Flight

Figure 6

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EVOLUTIONARY PATHS TO FAR-FUTURE SPACE ENDEAVORS [Relevance Tree]

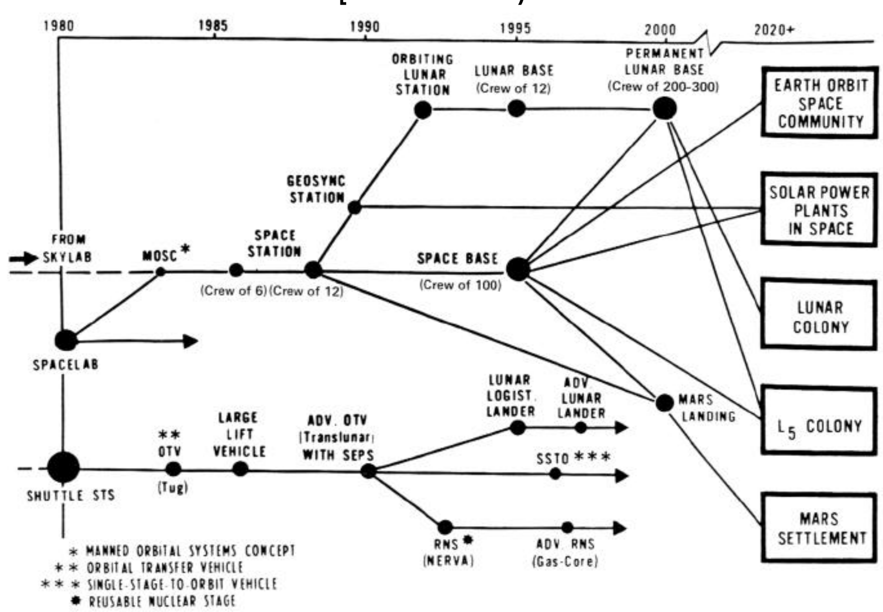
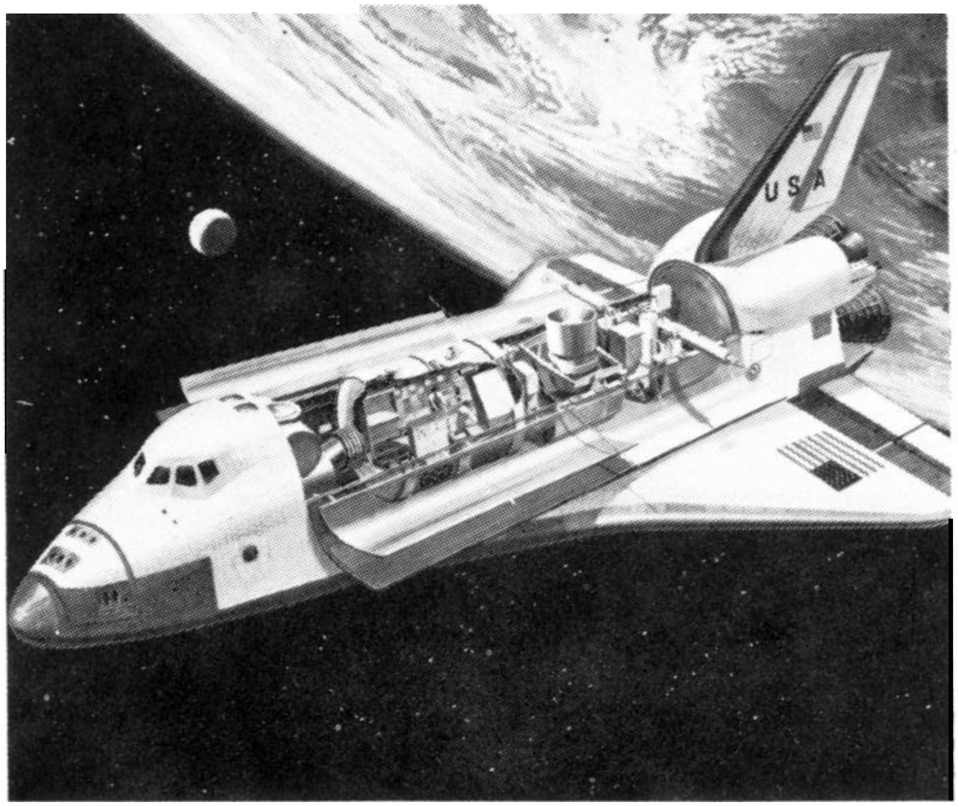


Figure 7

SPACE INDUSTRIALIZATION
Rationales & Key Technologies

David R. Criswell. Lunar Science Institute, Houston, Texas

Reprinted from **Lunar Utilization, Abstracts of Papers Presented at a Special Session of the Seventh Annual Lunar Science Conference,** 16 March, 1976, with permission.



Industrialization describes the broad range of activities by which humanity gathers and manipulates materials, using energy to produce the thousands of goods and devices necessary to the support of civilizations on Earth. The continuing development of our skill in the manipulation of matter, and especially recently in our ability to make matter manipulate information (for example, computers and communication networks) is the physical foundation upon which advanced civilizations rest. In the broadest context "space industrialization" must also create a new extraterrestrial economy and culture in space. It is not reasonable at this point in time to attempt a detailed description of the myriad of specific products, devices, and human activities which are necessary to constitute a space industry. Rather, I wish to focus on three primary facets -- *matter, energy,* and *skill.*

Figure 1 presents one way of grasping the role of matter in an industrial society. This is a qualitative distribution of cost of *goods or end-use-material* on a dollars per kilogram basis (horizontal axis) versus the total output of goods in billions of dollars at a given dollars per kilogram value. It must be noted that this is a qualitative curve based on a general awareness of the features of the United States economy. Mathematically the curve represents the equation

$$y(x) = I/(x^2 e^{1/x})$$

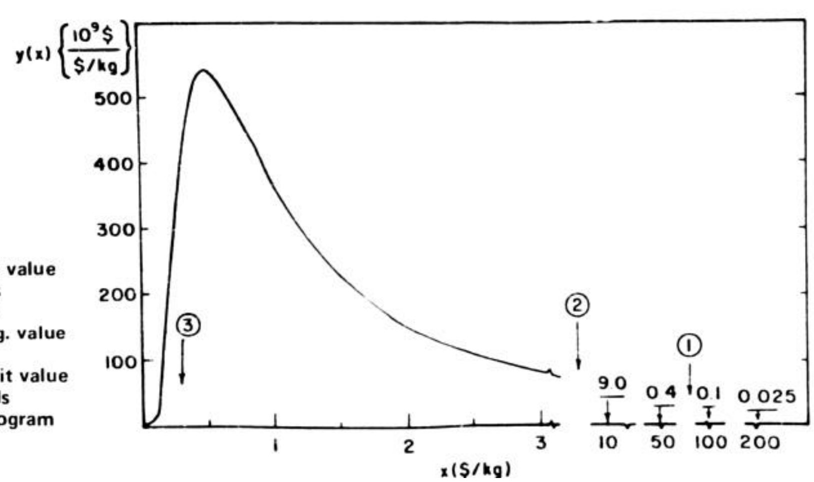
where x corresponds to dollars per kilogram of end products and y corresponds to billions of dollars of goods at a given dollars per kilogram value. The equation is normalized to an economy with I equals ten billion dollars annual output of goods. Services are not included. The form of the equation is not qualitatively correct for x less than about $20 per kilogram (left of "3") because water supplies, pollution control and other processes are present in the national economy which account for ten billion dollars per year, but handle such vast quantities of materials that the dollars per kilogram value is very low.

The high dollars per kilogram section (right of "2") of the curve (x is greater than ten dollars per kilogram) is in rough qualitative agreement with a similar analysis by Woodcock (1973). The numbers on the right side (i.e., 9.0, 0.4, 0.1, and 0.0025) indicate the total dollar value of goods with worth greater than 10, 50, 100, and 200 dollars per kilogram respectively in billion dollars.

Notice that most of the industrial goods are restricted to a very small range of dollars per kilogram values. Probably 99% of the products output of a nation such as the U.S. is restricted to items selling for less than ten dollars per kilogram. The majority of goods (examples-food, cars, gasoline, houses) fall between ten cents per kilogram and two dollars per kilogram. The cost of final products will always be more than the weighted costs of the materials which compose them. Thus, if the raw materials which go into a product average one dollar per kilogram, then the potential market for the final product is restricted to the portion of Figure 1 with x greater than one dollar per kilogram.

This relates to the possibility of producing items in space. If the space shuttle is used to carry the raw materials into low Earth orbit, then the raw materials acquire a value in excess of $50 per kilogram and thus any products derived in low Earth orbit from this material must be worth several times $50 per kilogram to be saleable. However, the total value of goods with x greater

Figure 1
Differential value of all goods in billion $ per $ per kg. value vs. intrinsic unit value of the goods in $ per kilogram



than $50 per kilogram is rather small when compared to the national economy or even compared to the cost of the shuttle program.

Woodcock (1973) estimated the *maximum* possible market for such goods to be only a fraction of a billion dollars per year (i.e., the integral of the curve from x equals $50 per kilogram to infinity). Even the most advanced schemes for Earth to orbit transportation do not forecast launch costs less than $3 to $10 per kilogram by the year 2000. A lower limit on the cost for which material could conceivably be transported up to Earth orbit is set by the cost of the energy-required.

Let us imagine a device exists which converts electrical energy with 100% efficiency into kinetic and potential energy and that 100% of the mass lifted is payload. Then, at a 25 mills per kilowatt-hour electrical rate, one would require approximately $.30 per kilogram to eject material into orbit from the Earth. Such an achievement would open a vast potential for space industrialization (all the area under the curve to the right of arrow 3). However, no such scheme has even been proposed at this point in time. However, several schemes have been suggested by which material could be ejected from the moon into deep space, or possibly to low earth orbit at low costs.

Thus, lunar materials may be able to supply a large fraction of the raw materials necessary to create economically attractive products for use in space and on the Earth.

Approximate cost analyses have been done on one of the processes involving the use of magnetically levitated buckets containing slugs of lunar materials weighing in the tens of kilograms (O'Neill, 1974). The buckets are accelerated to escape velocity along a lunar track by linear induction motors. Upon reaching escape velocity, the material is kicked out and travels to a collection point in deep space. The bucket is decelerated and then circled to the return portion of the track and refilled for subsequent runs.

It is conceivable that such a system could deliver lunar material to deep space for a few cents per kilogram following development of the "mature" launch and catching system. This low figure is made possible by the low escape velocity of the moon and the fact that the moon does not have an atmosphere. Only 1/22 of the energy is required to eject material from the moon as from the Earth. Absence of a lunar atmosphere means that payloads traveling at lunar escape velocity (about 5700 Km per hour) do not require protection from the atmosphere such as being in a spacecraft. More than 70% of the ejection energy can go directly into the payload.

Holbrow and Driggers have suggested the use of gas cannons (closed to the escape of the working gas) which could eject 10-100 kiloton payloads. This last approach offers the possibility of placing a small reaction control system and heat shield on these large payloads. The payloads could be targeted to perform a grazing reentry through the Earth's upper atmosphere, undergo a subsequent apogee orbit correction and then be in Earth orbit. This may be a manner by which to deliver inexpensively a source of raw materials (particularly oxygen) to low Earth orbit.

If one or more of these schemes can be demonstrated and implemented, then a large fraction (cf Driggers) of the materials necessary for particular space industrialization efforts could be available and many of the economic processes encompassed by Figure 1 would become conceivable. It should be remembered that one is after the raw materials at a low cost. The production machines can be far more expensive because such machines process many times their own mass of materials. One could generally afford to ship such processing machinery to orbit in the Space Shuttle.

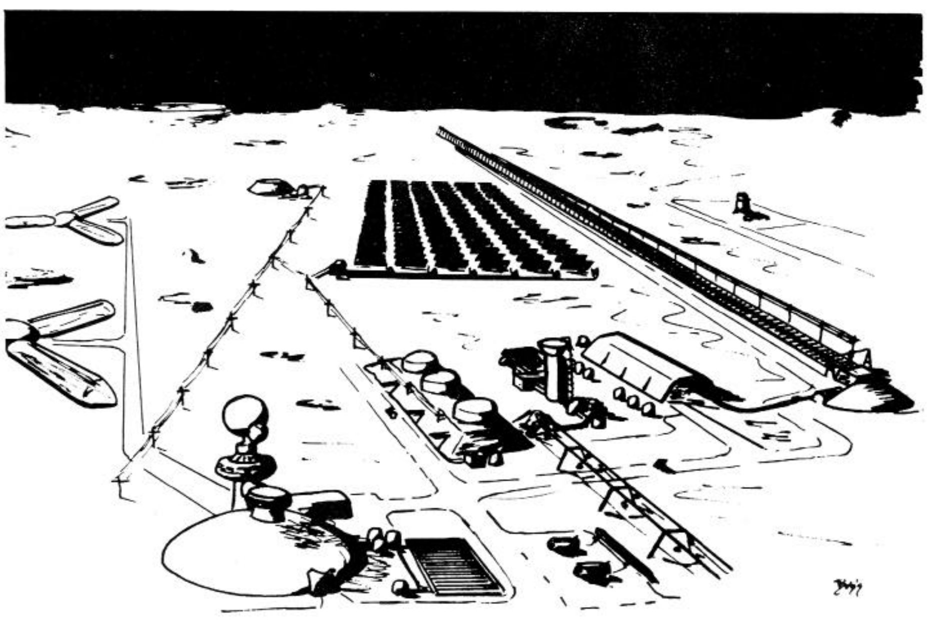
Energy is a major factor which encourages us to consider space industrialization. Terrestrial energy needs have increased to such huge levels that serious consideration can be given to constructing large power stations in space which convert solar energy into microwave power and then beam microwaves to the Earth for reconversion to terrestrial electricity.

Investments of hundreds of billions of dollars would be required. Such enormous expenditures are comparable with the trillion dollars of capital investment which U.S. utilities expect to make by the year 2000 (O'Neill 1975). In addition, the techniques for concentrating sunlight to run boilers (i.e., for electrical turbines) or producing electricity by photoconversion insure a source of cheap, clean and inexhaustible energy for industrial operations in space. The basic resources of materials (lunar, asteroidal, etc.) and energy are abundant in the solar system for development of space industrialization. The critical resource, and the one which probably needs the greatest development, is the skill to utilize these inanimate resources.

Several types of skills will be required. This special session concentrated on the technical aspects-how to get the materials, how to process the materials, implications of lunar or asteroidal supplies and many others. Technically, we appear able to rationally plan how to go again to the Moon and start tapping its resources. This confidence is a direct legacy of the Apollo program. The immediate problem is to define an approach whereby such a program can gather support. NASA faces an extremely difficult problem in this respect. Table 1 is useful in understanding the difficulties.

In 1965 (Table 1a) NASA was the significant economic power in the United States with respect to research and development and also was very significant nationally with respect to cash flow or people employed (directly or through contracts). NASA ranked in terms of cash flow as the fourth largest industrial economic entity in the United States. In 1965 NASA could and did firmly guide the major research and development directions of the United States simply by buying the resources necessary to accomplish its appointed goals. This dominant approach is no longer possible or even conceivable in the future.

A glance at Table 1b reveals the fundamental changes that have taken place in the national economy and NASA's status in this economy. In 1974 the total NASA cash flow of $3.3 billion



Bob Parkinson

TABLE 1a
1965 FORTUNE 500 INDUSTRIALS

Rank	Company	Gross Sales (10^9\$)	Net (10^9\$)	Employees (10^3 people)
1.	GM	17.0	1.7	661
2.	Standard Oil	10.8	1.1	147
3.	Ford Motor	6.9	0.51	337
	NASA			411*
4.	General Electric	4.9	0.24	262
50.	Dow Chemical	1.1	0.09	33

*NASA SP-4012 (government and primary and subcontractors)

TABLE 1b
1974 FORTUNE 500 INDUSTRIALS

Rank	Company	Gross Sales (10^9\$)	Net (10^9\$)	Employees (10^3 people)
1.	Exxon	42.0	3.1	133
2.	GM	31.5	0.95	734
47.	Borden Milk (N.Y.)	3.3	0.08	47
	NASA	3.3		120*
48.	Reynolds Tobacco	3.2	0.3	32

*NASA historical pocket statistics -- January 1975, P. D-12 (government and primary and subcontractors)

placed it between the Borden Milk Company (New York) and Reynolds Tobacco or approximately 47½ on the scale of the Fortune 500. *Business Week* (28 June 1976) presented a detailed report of private research and development expenditures for 1975. Total private R & D expenditures in the U.S. exceeded $15 billion or approximately five times that available to NASA. The U.S. government expended approximately $9 billion on private contractors and $11 billion in government facilities for a total R & D expenditure of $35 billion.

Most of the priorities which dictate how these funds are spent are set by non-NASA considerations, such as environmental protection, engineering development, or consumer product development. For the private R & D approximately 3.5% went to basic science, 20% to applied science projects and 76.5% to development work. This is far from an unhealthy situation for NASA. The point is simply that NASA may not again buy dominance in the R & D market place.

Rather, if NASA is to have a significant long term effect on the direction of the nation's technological development it must adopt new strategies. If NASA is to successfully guide the nation into a new capability of space industrialization, it must somehow make the potential gains and risks of industrial operations in space clear to the many private sectors and aid the interested entrepreneurial organizations in establishing real operations in space. Reiterating this point, present efforts by NASA to develop space industrialization in the new context of the Space Shuttle continue to attempt to buy industrial participation on contract to identify potential products, develop at NASA's expense possible specific industrial processes to manufacture the products and then publicize (i.e., sell concepts) these possible products to industry.

The markets for very expensive goods (greater than $50 per kilogram) are very limited and, therefore, there are very few entrepreneurs interested in the available possibilities. NASA must reverse the situation. It must be demonstrated that a cheap source of materials (less than $1 per kilogram) can be available in space. Thus, a far larger fraction of the nation's entrepreneurs can reasonably consider initiating their operations in space at their own expense. Then NASA can provide the guidance on technical matters necessary to judge the reasonableness of the many schemes. In this manner, far larger economic resources can be attracted to space industrialization than can be provided by NASA

For space industrialization the goal is the identification of realistic economic functions and their attendant risks rather than specific products. This point is more understandable by referring again to Figure 1. Suppose a source of materials is made available in low Earth orbit at a cost of $1 per kilogram. Figure 1 indicates that approximately $500 billion of goods might be considered for production from this material. However, the figure gives no aid in identifying *what* to make or the possible functions and associated costs to produce those goods. One very small, but useful, task would be to identify the products which compose this overall curve and how the curve and mix of goods changes with time. This would allow entrepreneurs to quickly grasp whether or not space production is of any conceivable interest to them for the goods with which they are familiar.

A general strategy should encompass these functions: (1) a clear theoretical exploration of space industrialization; (2) demonstration of the key gathering and processing functions in space; and (3) maximum involvement of private and governmental interests through all stages of these processes. This is a very different strategy than that involved in the development of Apollo or even the Space Shuttle. In those efforts there was a clear singular technical goal to be achieved. Consider each of the three strategy elements in turn:

(1) A major effort is needed to establish a new field of economics. "Physical Economics" seems an appropriate designation. In this field one considers in detail the many functions that control economic processes and asks the question: "What happens if these processes are conducted in space?" This is not simply an examination of the effect of zero-gravity easing the movement of large structures, or even the reconsideration of many industrial processes adapted to space. Rather, it is essentially a new field of study or inquiry which addresses humanity's demonstrated and projected ability to organize matter, energy, and society in the three dimensional context of space. It is likely that a variety of new permanent institutions could be formed to address this question and be structured so as to continually involve private, academic and governmental organizations. This effort must be long term and very large, probably involving tens of thousands of people over the next 20 years. The product would be a clear understanding of new and realistic growth directions for industry and society into space, the identification of critical problems, and the creation of a new technocracy capable of managing space industry.

(2) There is an established pattern of government/industry cooperation in the development of new technological hardware. Technical feasibility is by the government or under government funding and then industry establishes the economically viable industrial operations. Nuclear reactor and aircraft developments are prime examples. This pattern will persist in space industrialization. It seems reasonable that NASA should concentrate on identifying and bringing to fruition the minimum number of key-systems which demonstrate that supplying material, energy, and initial working facilities to the new industrial activities in space is possible. A major problem and necessary planning constraint is the continuous identification and implementation of short term goals and pay-offs, rather than concentrating exclusively on super programs of 15 to 30 years duration, such as satellite solar power stations. An example of a shorter term goal could be a source of oxygen in Earth orbit (derived from lunar materials) for partial refueling of space vehicles.

(3) The programs must actively involve the maximum number of people so as to shorten the learning period for the development of this new widespread expertise in space industrialization, to promote widespread support for the program and to develop the widest range of new concepts to be developed in space.

We face an interesting and exciting problem in the promotion of space industrialization. The expertise in science and engineering clearly exists to create near-Earth and deep space habitats from lunar materials and eventually from the asteroidal material. Undoubtedly, the physical, engineering and economic factors of habitat construction and power station fabrication can be clearly defined **and then judged as to their worth to us.** The immediate and very challenging task is to organize the resources of society now external to the space program to support space industrialization as active participants.

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CEA and life in Space

John M. Phillips, Environmental Research Laboratory

Indications are that life support systems for long-term space exploration and similar activities, including the establishment of space manufacturing facilities, will require the development of closed ecological systems for food production, waste recycling, and gaseous exchange. NASA scientists have stated that building a closed ecosystem in space to 99.99% reliability, a design factor which aerospace engineers commonly insist upon, will require 25-75 years, although research on plants in space and supplementation of astronaut diets with green vegetables may be possible in the near future. However, an already existing technology may contribute significant information which may help to minimize development costs for food production in space. This technology is known as controlled-environment agriculture (CEA).

For many years scientists at the Environmental Research Laboratory at the University of Arizona have been working on controlled-environment agriculture systems for food production in adverse environments such as coastal deserts and similar arid regions. Through a program of basic and applied research using a multidisciplinary staff, ERL has developed integrated systems for power, water, and food production. An example of a power/water/food production facility is the five-acre Arid Lands Research Center in Abu Dhabi which the laboratory designed and built. Research and production experience with this facility has amply demonstrated that yields of vegetables from CEA systems exceed those from conventional agricultural systems by several orders of magnitude.

In addition to the project in Abu Dhabi the laboratory has participated in the design and operation of several other large-scale controlled-environment agriculture systems in the U.S. and abroad. These include the ten-acre Superior Farms, Inc., facility in Tucson, Arizona, a nine-acre project on the Quechan Indian reservation near Yuma, Arizona and the two-acre Kharg Environment Farms in Iran. All these projects are concrete examples of working CEA systems.

At Puerto Penasco, Mexico, ERL scientists are working to develop a semi-closed controlled-environment mariculture system for the cultivation of penaeid shrimp. ERL's principal research facilities at Tucson International Airport, work is underway to develop CEA systems using a tropical aquatic plant, the water hyacinth, for sewage effluent recycling and biomass production for bioconversion to methane gas for fuel. In some of the pools, the herbivorous fish *Tilapia* is being raised to determine if this source of high quality protein can be grown as a by-product. In the phytocell complex at Tucson, experiments are underway to monitor plant responses in closed systems with combinations of high and low humidity and carbon dioxide.

Presently the laboratory is contributing technical advice to a technology assessment of the potential contribution of controlled-environment agriculture to solving U.S. and world food problems as part of the National Science Foundation study on food production being conducted for President Ford.

The director of the Environmental Research Laboratory, Carl N. Hodges, feels that much of its experience with controlled-environment agriculture would benefit efforts to develop closed ecological life support systems for space travel. The laboratory plans to participate in the forthcoming AIAA Conference on Space Manufacturing Facilities and hopes to make contact with interested individuals in NASA and other organizations. Additional information on the laboratory's work in controlled-environment agriculture may be obtained by writing: Environmental Research Laboratory, Tucson International Airport, Tucson, AZ 85706.

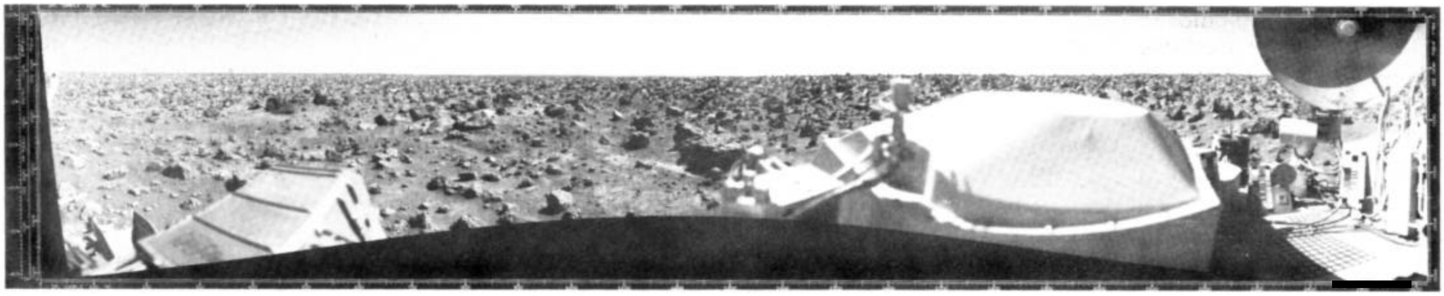
BIBLIOGRAPHY UPDATE

Lunar Utilization: Abstracts of Papers Presented at the Seventh Annual Lunar Sciences Conference, edited and organized by David R. Criswell, available through Lunar Sciences Institute, Houston, TX 77058, $1.OO domestic, $7.00 foreign. Thirty-nine short papers on what's on the Moon (or might be there), what we might do with it, how to get it off the Moon, and many other topics.

The lead paper by D. Criswell is reprinted in this *L-5 News.*

"Designing A Space Community," Magoroh Maryuma, *The Futurist,* October, 1976, pp. 273-281.

The Extraterrestrial communities that may be built in the future present an opportunity to develop new cultural patterns and social philosophies. In this article, anthropologist Maruyama considers some social and philosophical issues that may arise as people create settlements beyond the Earth.



XXVII CONGRESS International Astronautical Federation

An interview conducted on November Ist, 1976, with the Hon. Edward R. Finch, Jr., Chairman of the American Bar Association Aerospace Law Committee, former U.S. Special Ambassador and U.S. Delegate to the Fourth and Fifth U.N. Congresses, by Elaine Meinel.

We are fortunate that Edward R. Finch, a member of the L-5 Society Board, was invited to both the opening ceremonies of the Space Hall of Fame and the 27th IAF Congress.

The Space Hall of Fame was dedicated on October 5th in Alamogordo, New Mexico. The building is set on the side of a low mountain with a beautiful view and below, on the plain, sit various relics left over from the thirty year struggle to get into outer space. Afterward, the International Academy of Astronautics held a symposium until October 9, during which the future of space shuttles, tugs, laboratories, and solar stations were discussed. The results of this gathering will be published in March by Dr. Steinhof of White Sands, New Mexico.

Beginning the next day the XXVI I IAF Congress was held October 10-16 in Anaheim, California. Leonard Jaffe presided. Participants came from 34 different countries and represented 30 organizations. Forty-five sessions were held covering nearly every aspect of space usage and law. A partial list includes astrodynamics, bioastronautics, communication with extraterrestrial intelligence, materials processing in space, spacecraft power systems, flight in planetary atmospheres, space rescue and safety, microwave observations, propulsion systems, etc.

On October 13th, the participants were invited by the U.S. Government to view either the Space Shuttle at Rockwell in Palmdale, California, or visit the Jet Propulsion Laboratory in Pasadena to see the third Viking Mars Lander.

Edward R. Finch's main concern at the IAF Congress was, naturally, legal. He had presented a paper titled, "Energy-Ecospace," at the 19th colloquium of the International Institute of Space Law (IISL). In this paper he demonstrated how outer space law related to national policies on energy, environment, economics, and ethics. Like International Ocean Treaties, the space laws are drawn up by the United Nations. As of today, the only space treaty in effect is the 1967 Space Treaty which, in Article I, states that "the use of outer space shall be for the benefit of all nations, irrespective to the stage of their economic development and shall be the province of all mankind." It goes on to say that there shall be no orbital military activity, nor shall any nation engage in environmentally detrimental activity, and that all participating nations should keep the UN Secretary General informed as to all space activities and plans.

This treaty has its limitations, especially in the light of the development of Satellite Solar Power Stations, and Edward R. Finch pointed out that "first we must solve the cost-benefit problems relating to sharing space resources since the launching nations should first be able to recover the initial costs." He added that, "It is possible there will be a full outer space conference under UN auspices by 1980."

Right now a new Moon Treaty is being drawn up by the UN. With the possibility of Lunar mining if permanent orbital space colonies are to be established, then such a treaty is imperative. The USSR and the USA have locked horns over certain issues such as the delineation between sovereign airspace and free outer space; also, as the Soviet Lawyer, R.V. Dekanozov writes, "It is necessary to distinguish between the status of the Moon's surface and sub-surface and that of the exploitation of Lunar natural resources" (IAF-ISL-76-04).

Edward R. Finch is optimistic, saying, "These conflicts are being resolved right now and I expect the treaty to go into effect by early 1977." Indeed, both the Soviet Russian and American governments have shown a desire to co-operate in space, as with the unprecedented Apollo-Soyuz project in 1975. Even Brezhnev has said, ". . . we are supporters of international co-operation in space research" (Novosti Press Agency Publishing House, Moscow, 1975). But difficulties arise when exploitation of space resources are brought up. Still, Edward R. Finch says, "The U.S. strongly supports the free exchange of SSPS and other outer space information."

At the same session, a paper was submitted by Stephen Gorove, Chairman of the Graduate Program in Law, University of Mississippi titled, "The Future of Space Law: A Legal Regime for Space Colonies" (IAF-ISL-76-08). in which he looked into future legal complications in the light of shortcomings in present laws. He suggested alterations, especially in the fields of sovereignty, jurisdiction, and property rights. So be forewarned; even though we shall be pioneering in the New Frontier, it won't be quite so rowdy and lawless as the legendary Old West.

FLETCHER ON SHUTTLE

At the International Astronautical Federation Congress in Anaheim, California, James C. Fletcher, administrator of NASA, discussed the Space Shuttle, which is expected to make its first orbital flight in February, 1979.

Three landing sites are planned for the Shuttle: Kennedy Space Center in Florida and Vandenberg Air Force Base and Edwards Air Force Base, near Los Angeles. The Shuttle will glide in through the atmosphere and roll to a stop on a runway, in contrast to the heart-stopping plummet of the Apollo capsules. Another contrast to Apollo is that the Shuttle will be reusable.

Shuttle flights can last up to 30 days and can reach orbits as high as 500 miles. Countries other than the U.S. are keenly interested in these flights. The European Space Agency has been developing Spacelab, a facility which will be boosted into orbit in the Shuttle's hold. "We have already received flight requests from twelve countries to conduct 58 experiments," Fletcher reported. "They are under review."

NASA doesn't plan to rest on its laurels after the Shuttle has begun operation. The Shuttle's activities, according to Fletcher, are intended to pave the way for the "eventual colonization of space."

A DAY SPENT ON MARS

Bill Weigle

The plan called for 120 participants, but over 200 attended a symposium, "The Search for Life in the Solar System," organized by Forum for the Advancement of Students in Science and Technology (FASST) and American Institute of Aeronautics and Astronautics (AIAA) on Friday, October 8, 1976, at Jet Propulsion Laboratory (JPL).

The folks at JPL, while handling things

pretty smoothly, still did some scrambling to accomodate the overflow, which was another example of the high and continuing public interest in Viking.

The conference got off to a great start with the appealing optimism of Ray Bradbury as he inspired us to a "madness" of commitment "to be" and to carry out our dreams.

Then James Martin, Viking Project Head, introduced speakers on the experiments in geology and biology, followed by a discussion of JPL's future project possibilities. They include lunar, out-of-ecliptic, and planetary probes.

A rather dissapointing discussion of "Manned Exploration of Mars" by scientist/astronaut Dr. Karl Henize dealt only with Von Braun's 1969 concept to send 12 men to Mars at a cost of $100 billion. Perhaps Dr. Henize has not kept abreast of the implications of space colonization. Launching of a Mars mission from a space manufacturing facility could reduce the cost to a few billion.

I couldn't help but imagine the time when a habitat highliner carrying thousands of people slips into Martian orbit after a journey from L-5. There, with family, fellow scientists, and friends, the mysteries of Mars could be studied only a short shuttle hop away.

It was an exciting and informative conference. Congratulations go to FASST, AIAA, and JPL.

CARTER CALLS FOR SOLAR POWER SATELLITES

In a recent letter to the American Institute of Aeronautics and Astronautics, Jimmy Carter praised earth resources and communications satellites, adding that "other areas which appear promising include space medicine and manufacturing and space generated solar power, all of which will be more feasible through use of the Space Shuttle." Carter promised that NASA budgets would receive "close attention" under his administration.

NASA officials, who have been concerned by Carter's choice of veteran shuttle foe Mondale as a running mate, have welcomed Carter's statement.

A member of Carter's energy task force told the *L-5 News* that student and citizens groups from all over the country had sent them information on the Space Colonization/Space Industrialization approach to the solar power satellite concept.

SPS RESEARCH FUNDS
Carter Plans ERDA Reorganization

NASA has been appropriated $2.5 million for solar power satellite (SPS) research in fiscal 1977 (which began this October). Another $2.5 million has been included in the Energy Research and Development Administration (ERDA) appropriation for FY '77; however, a filibuster threat by Senator Gravel (D-Alaska) only minutes before the Senate was to adjourn for the year prevented a final vote on the ERDA funds. As a result, ERDA will be unable to fund SPS research until its authorization bill is passed after Congress reconvenes in January.

With at least 4 years of Carter on the horizon, supporters of the SPS concept may wonder about his energy R & D plans. In his campaign he promised to abolish ERDA, the Federal Power Commission (FPC), Federal Energy Administration (FEA) and the White House advisory group, the Energy Resources Council (ERC).

In their place Carter plans to create a Department of Energy and Natural Resources (DENR). It would, Carter has explained, "eliminate the overlap, duplication and inconsistency of the present structure." Given the difficulties of getting ERDA's FY '77 appropriations passed this year, however, SPS researchers have reason to be thankful that this research program is being funded by two agencies.

MOSS CALLS FOR OFFICE OF EARTH RESOURCES POLICY

Senator Moss, (D-Utah) Chairman of the Senate Aeronautical and Space Sciences Committee has introduced legislation calling for the establishment of an Office of Earth Resources Policy within the Executive Office of the President. This Office would coordinate the Federal activities associated with an Earth Resources Information System (ERIS) which is also proposed in Moss's bill. ERIS would coordinate NASA with the private organizations which will wish to use earth resources satellite data.

These proposed activities will be financed through the sale of information collected from satellites to industries which will then, in turn, sell the data to interested customers.

"The private sector involvement in receiving, processing and disseminating data is seen as a means of expanding and marketing new uses of the data," says Senator Moss, adding that the goal of his bill is to assure that "government funding will be minimized."

For more information, contact Gilbert W. Keyes, Aeronautical and Space Sciences Committee, U.S. Senate, Washington DC 20510, 202-224-6477.

STEWART BRAND JOINS JERRY BROWN'S STAFF

Stewart Brand of *CoEvolution Quarter/y* will be working on California Governor Jerry Brown's staff for two months. He is planning a festival, "California Celebrates the Whales," scheduled for November 20, a soft technology fair and exposition, and is working on the California Conservation Corps, which is being developed along the lines of the Civilian Conservation Corps.

Some L-5 members have asked about an article, "Star Trekker Jerry Brown and Outer Space," which appeared in the Village Voice, October 27, 1976. It states that "Prompted by his guru-consultant Stewart Brand, he (Brown) is taking a keen interest in Space Colonies. . . . Brown, after initially exploring the idea at the Greengulch Zentagon, has arranged for Gerard O'Neill to present his ideas to the California State Energy Commission. The Commission is now considering giving O'Neill a grant. Brand, incidentally, has been given a two-month state job as temporary special consultant on energy and environmental issues."

Brand, in response to the article, told *L-5 News* that he and Brown hadn't discussed space colonies once since his arrival at Sacramento. He added that if his job was in any way related to O'Neill's work, "It would be news to both of us."

ASTRONAUT ELECTED TO U.S. SENATE

Astronaut Harrison "Jack" Schmitt is the new Republican Senator from New Mexico, displacing Democratic Senator Joseph M. Montoya.

Schmitt, who went to the moon on the Apollo 17 flight in 1972, unseated the incumbent with a campaign which promoted Schmitt as "a man for the future."

Astronauts now comprise 2% of the U.S. Senate. John Glenn (D-Ohio) was the first to win a place in the Senate.

LEARY LECTURE TOUR

We are informed that psychologist Timothy Leary is traveling across the country lecturing on space settlements and longevity research. He is interested in meeting L-5 members wherever possible. Dr. Leary also encourages the distribution of L-5 membership fliers at his lectures. If you plan to attend, please let us know and we will send some flyers to you.

The following is a listing of Dr. Timothy Leary's current tour:

Dec. 1	University of Wyoming, Laramie
Jan. 11	University of California, Berkeley
Jan. 12	University of Santa Clara, Calif.
Jan. 14	Church of Naturalism, Hollywood, Calif.
Jan. 18	University of California, Santa Barbara
Jan. 25	Missouri Southern, Joplin
Jan. 26-28	University of Houston-NASA Conference
Feb. 10	University of South Carolina, Columbia
Feb. 14	University of North Carolina, Chapel Hill
Feb. 15	Fairmont State College, West Virginia
Feb. 17	University of Arizona, Tucson
Feb. 21	Montclair State College, New Jersey
Feb. 23	Bridgewater State College, Massachusetts

Leary's lectures are being arranged by New Line Presentations. They can be contacted, toll free, at 800-221-5150.

PRINCETON CONFERENCE DATE CHANGE

The Third Princeton/AIAA Conference on Space Manufacturing Facilities has had its date changed from May 10-13, 1977, to May 9-12.

inside the L5 Society

SLIDE ORDERS

The volume of slide orders being processed by the L-5 Society has tripled in the last two months..This has resulted in a constant out-of-stock situation, and it has taken up to one month to process orders. We wish to thank our members for their patience in waiting for their slides to arrive.

The increase in slide sales has forced us to analyze more closely the financial aspects of this whole slide business, and we have come to the realization that we losing money with each order we process.

Therefore we are increasing the price of slides. Effective December 1, slides will cost 50¢ per slide plus $2 per order. (The $2 handling charge will also cover handling on other items ordered together with the slides, such as copies of papers offered by the Society.)

Next month's *L-5 News* will include, it is planned, a catalog of slides available, and it will be possible to pick and choose individual slides.

Until then, slides are available in sets; Non-Technical Set (16 slides), $8; Technical Set (16 slides), $8; Supplemental Supplemental Set (8 slides), $4 -- plus *$2 handling.* (All slides together will cost *$22).*

For the lecture information packet, add $1.83, (a new, lower price).

SPACE ~~COLONIES~~ SETTLEMENTS

Our spies within NASA inform us that after months of brainstorming sessions and consultations with public thought shapers it has been decreed (via a NASA Policy Directive) that the term "space colonies" has been terminated with extreme prejudice.

Henceforth the term shall be "Space Settlements."

CREDITS

The *L-5 Society's* growth rate has increased to 15% per month, and letters inquiring about membership have been coming in at a rate of 10 to 15 per day.

People who have been responsible for this include Harlan Smith, Director of McDonald Observatory, who has been lecturing on Texas college campuses; science writers Isaac Asimov and Joel Strasser; Carol Motts, editor of *Speculative Anthropology;* and psychologist Timothy Leary, who is lecturing on college campuses across the country. Anthropologist Magoroh Maruyama and planetary scientist Brian O'Leary also gave a well-received lecture at Urbana, Illinois, November 9, (we apologize for losing the announcement of the lecture which was to have been run in the October *L-5 News.)*

Quite a few people helped organize a lecture tour this October for L-5 Director Keith Henson. They include Jim Martin, Mike Sebahar, pastors Joel Nickel and Raymond Eissfeldt, Scott Hodgson, Mark Laman, Rose Lucas and fellow Director Magoroh Maruyama of Urbana, Illinois; Steve Harris, Norton Salvin and Luke McGuff of Chicago, Illinois; Dr. Sharma of Greenbay, Wisconsin; Mike Cahill of West Bend, Wisconsin; Victor Wrigley of Waukeska, Wisconsin; and Joe Sodd of Minneapolis, Minnesota. Our apologies to anyone whose name we missed!

Staffer Lisa Coan has been keeping records of who is responsible for new members. Top people this month were Timothy Leary and Keith Henson. Currently, however, the person responsible responsible for the most recent surge of inquiries about memberships is Isaac Asimov! If you would like to help bring in new members, write us and we will send you some membership application flyers.

Aerospace engineer Gregory Bennett and meteorology graduate student Paul Walter Greiman are organizing a major educational event on the L-5 concept at Seacon, November 28, in Seattle, Washington. Seacon is a science fiction convention. Some people have questioned the wisdom of involving science fiction fans in the space program, especially in the wake of the successful campaign of Star Trek fans to have the first Space Shuttle renamed "Enterprise."

Jesco von Puttkamer, a NASA official' (in Advanced Programs) who frequently lectures to audiences at Star Trek conventions, found that some NASA officials "were kind of caught by surprise and didn't quite see the connection between us and Star Trek." But von Puttkamer praised the Trekkies for helping to establish a better awareness of the space program in the public mind. Von Puttkamer's answer to those who turn up their noses at science fiction fans : "I would say to them that after all, we are using public money, and why shouldn't we establish a dialogue with the public to find out what they are thinking?"

BITS AND PIECES

Next issue is planned to contain interviews with Captain Freitag of NASA, Peter Glaser of Arthur D. Little, Inc., and Dr. Timothy Leary: a wide range of viewpoints, to say the least.

We invite comment on articles in the *L-5 News.* We don't agree with all we print, but if no one replies to a position taken by some author, perhaps it wins by default.

You may have noticed the odd price on the lecture information packet. This is a clue to the fact that we are nearly ready to offer a wide range of materials, including reprints of most of the major space habitation articles.

These materials will be available for 7¢ per page plus 50¢ per title: this covers xerography and file maintenance.

A list of titles available will appear in a future issue of *L-5 News;* members will also receive, in the next month, a separate mailing on this subject.

letters

In most cases, editors have been careful to make only minor changes in articles printed with my signature, and to offer ample opportunity to review any such changes. These cases include:

"The Colonization of Space," *Physics Today,* September, 1974.

"Settlers in Space," *Science Year '76,* September, 1975.

"Space Colonies and Energy Supply to the Earth," *Science,* December 5, 1975.

"The High Frontier," *New York Times Magazine,* January 18, 1976.

Recently, there have been instances, unfortunately, in which editors have printed over my signature articles which were heavily rewritten and "sensationalized." In these cases, involving articles in English and in German, large amounts of material which I never wrote have been inserted without my approval. Readers interested in having an accurate knowledge of the work at Princeton might be well served by the occasional printing, in *L-5 News,* of an updated list of articles in which adequate editorial standards have been maintained.

For a review of the most recent technical work, an article of mine in the October, 1976, issue of *Aeronautics and Astronautics* may be of interest.

Also, from time to time, our small group at Princeton sends out a free newsletter summarizing our most recent activities and publications. Persons who may wish to receive such newsletters can do so by writing to me at Physics Dept., Princeton University, Box 708, Princeton, NJ 08540.

Gerard K. O'Neill

I'd like to reply to your "Reply to 'Access to Energy': L-5 Activists Beware" article, which you printed in the August 1976 *L-5 News.* As the author of the original "Access to Energy" article, I feel obligated to justify phrases which I used which seemed to cause some discomfiture.

I'll cover three of your main points:

1) ". . . there has been nothing in print proposing that solar power in space is the *only* energy source that will be competitive. . . ."

2) *". . .* we do have to take issue with the

assertion of the *Earth/Space* News that with a price of 15 mils/kWh that it would take over 35 years to break even. . ."
3) In the follow-on article "Fusion Woes," the author stated "compared with the problems fusion engineering faces, construction of solar power plants from L-5 colonies seems simple. . . ."

To begin-a point of philosophy and intent:

I'm all for the colonization and commercialization of space. My company-Earth/Space-has been formed to take advantage of the commercial opportunities which lie ahead in the domain of space, and at the same time to make space economically accessible to large numbers of businesses and individuals. When I point out potential barriers to the success of extremely large programs such as L-5/SSPS, it's not so much to say that it can't be done (that's not my style; in fact, I tend to enjoy doing things which the experts say "can't be done"), but more to caution against an imbalance of optimism in a singular approach.

I've tried to show, both in *Earth/Space* News and in talks at conferences, that it's unwise to rely on a single large operation (such as solar power satellites) to economically justify such a gigantic project as L-5. When you rely on a single economic justifier, you face the threat of that justifier being put out of business because of competition or other unforeseen factors-especially when the project takes tens of years before payback. The business world moves too rapidly (and non-linearly at that) to let any one component of an industry retain a position of economic favor for very long. In the "Access to Energy" article, I was saying that you shouldn't discount competitive moves from future energy sources (such as migma fusion) in the time period in which SSPS needs to make great inroads to achieve subsequent breakeven.

In the "Access to Energy" article, I used as my source of L-5 economic analysis a well-documented study by Dr. J. Peter Vajk: *The Impact of Space Colonization on World Dynamics* (November 1975). I recognize that Mark Hopkins has done most of your analyses, and that there have been other studies as. well. But the soundness of Vajk's study, the reasonableness of his methodology, -- and the fact that he didn't seem to be contradicting any of the other studies -- all made this a good reference source. Since Vajk's study had been recommended by L-5, and since there didn't seem to be a universally agreed-upon analysis which would preclude the use of his numbers, I went ahead and used them.

1) One of Vajk's assessments was that "a 40-year transition is assumed for 90% conversion (of other energy sources) to SSPS power." This amounts to solar power becoming virtually the only energy source. Given the low cost assumed, it makes sense-with a historical parallel (conversion from wood to coal to petroleum in the U.S.) to back it up. If the cost can be kept as low as promised (less than 15 mils) and if there were to be no competition, it would make eminent sense that this could happen. On the other hand, a hidden assumption is that SSPS must take over a very large share of the energy market if it is to break even: any economically competitive energy techniques which make SSPS undesirable after 1 or 3 or 5 power satellites have been made operational would seem to deny the system breakeven at any time in the future.

2) To arrive at a figure of 35 years, I needed to take some assumptions and rework the original analysis. The analysis to which I refer is on pages 11 and 12 of Vajk's original study.

Like many of the studies I've seen, Vajk assumed constant (1975) dollars. This assumption covered both expenses and revenues. It seems to be a reasonable approach if everything inflates at the same rate. However, if expenses inflate at one rate, and revenues (or price to the user per unit) inflate at a lower rate or remain constant, then it might be better to take the expense side and the revenue side, and analyze them as individual components.

To begin this process, I looked at long-term trends of the overall economy in the U.S., and noted a general trend to inflation. That is-yes, as time goes by, things general have been getting more and more expensive. This has been particularly true of wage rates and costs of construction (on Earth).

However, on looking at the long-term trend of energy costs (reference *Energy in the American Economy 1850 - 1975: Its History and Prospects* by Schurr and Netschert), I found that quite the opposite process was taking place: energy costs have been generally declining since 1900 (with some brief exceptions). Decline in the cost of energy has followed an almost classic learning curve-going from 7.5¢ per kWh (busbar rate) in 1900, to 1.8¢ per kWh in 1955, to roughly 1.5¢-1.8¢ in 1965 for the average cost of busbar energy in the U.S. There have been some unpleasant discontinuities: 1920-1925, when the energy industry had to recover from a severe coal strike and energy prices skyrocketed; and 1970-1975, when cartel-impelled oil prices shot the cost of all forms of energy through the ceiling. But like most commodities, you have to look at the long term trend to see what's really happening before you take an atypical pricing situation and trend it linearly into the future.

We're now caught up in an inflationary energy spiral. Viewed close up, it appears that energy costs will always rise at an uncomfortable rate, and that we need a crash program to save us. This is the alarmist point of view. The optimist, on the other hand, sees this as an opportunity: as long as oil prices were low, it made little sense for private capital to flow to other energy techniques which at the going prices promised only a modicum of return on investment. But with the discrete jump in oil prices comes a simultaneous jump in private investor enthusiasm-to catch some of that extra profit floating around. And when private capital begins to flow to alternate forms of energy-motivated purely by greed, you understand-an efficient energy source will be found to take the place of the artificially high-priced commodity . . . and which itself will subsequently take the price of the commodity (energy) back to "steady-state" level. Historically that's been the case. It's held on a theoretical basis, and it appears to be holding on a real-life basis, as alternate forms such as migma fusion (privately funded) appear to be succeeding (more on this later).

The analysis, then, had to differentiate between a general societal inflationary trend (overall cost of goods and services, which affects expenses of your colony/SSPS), and a particular commodity trend (cost of energy). This means you have to differentiate between constant dollars-which take a base year as the standard; and current dollars-which take the real value in any given year. Inflation notwithstanding, cost of energy has been declining over the long term, in real, current dollars.

Thus I took two possible long-term societal inflation rates which seemed reasonable (5% and 7%) and added up costs as they might appear in real year to year dollars over the time period given by Vajk for large-scale construction and implementation. I then took revenues as being derived from a non-inflationary (in fact, declining) price from the SSPS, also as defined by Vajk. In other words, *costs* as given increased at a 5% to 7% rate per year (compounded), while *revenues* were assumed to remain uninflated.

In light of this, I determined that with a 5% inflation, at the end of 25 years, the entire project would still be in debt by $430 billion *real* dollars (just coming down from a peak debt of $610 billion). With a 7% inflation, debt would still be $769 billion at 25 years (coming down from a peak debt of $810 billion). The 5% rate would indeed see a positive return in 31 years, but the 7% rate would take 35 years for payback. Any competitive energy source which drove prices below the (beginning) level of 15 mils would imply an even longer time for breakeven to occur. Further, the magnitude of the numbers seemed to imply massive stretchouts somewhere along the line just as a matter of common sense. Otherwise the very large debt incurred to support this one project could bankrupt entire nations.

3) The closest competitor to SSPS now

appears to be migma fusion. Readers of *Earth/Space* News are familiar with the concept of migma fusion, and know that it approaches the problem of fusion in a manner quite different from the plasma techniques used in most other laboratories. Suffice it to say that Fusion Energy Corporation of Princeton, N.J., appears to have the fusion problem licked. The company hopes to have an operational fusion plant by 1981, at a total cost to private investors of less than $65 million.

The point? The unseen hand of profit-motive has once again given impetus to new technologies which promise to radically undercut currently inflated energy prices, and make a bundle for its investors to boot, well before the first SSPS gets off the ground.

As I said in the article-it may not happen that way. And SSPS may turn out to be much cheaper. But the important point seems to be that L-5 (or any) colonies would be well advised to address a large number of economic justifiers for the colonies. The justifiers should be easy to implement, and should allow rapid payback to investors (less than 10 years -- even better if less than 5). A broad, diverse mix of industries justifying your colonies will set it up to withstand the economic failure of one or several industries without catastrophe to the colony system as a whole.

When you get the design cost of L-5 down to a level at which private industry can participate on a non-guaranteed basis, and when you open the system to a multitude of user industries-that's when you have a winner.

And that's essentially what I've been trying to say.

Paul L. Siegler, President
EARTH/SPACE, Inc.

(1) L-5 Society does not consider the SSPS power to be the only justification for space colonies. Many of us, in fact, consider SSPS power as an excuse rather than a primary justification for what may be the next major step in the evolution of life.

(2) We report on alternate energy technologies when appropriate and have an article on migma fusion planned. We also discuss alternate economic justifications for space settlements as they come to light.

(3) Our sources are not so optimistic about Fusion Energy Corporation's success as Mr. Siegler seems to be. Time will tell. --DL

Let me pay a complement which I've. long had in mind to pay: you can take it that I highly approve the way the L-5 Society has conducted itself so far. At the Princeton Conference a year and a half ago, somebody voiced the apprehension that we would launch another lunatic fringe cult. Well, it's been nothing-of the sort. As matters have worked out, the Society has been a model of maturity and professionalism -- *and* it's got the innocent, old-fashioned verve of a grassroots campaign. No rarer combination -- congratulations on a job well done.

Dick Frederickson
White Plains, New York

I subscribe to the idea that nothing ever will be done if taxpayers are not interested; they must be *reached* thru the most illogical of avenues: pure excitement. I think, while I am not certain, we are moving into a new era of supreme boredom. Nothing is going on. What could be more dull than economic problems? Therefore, I believe the space colony concept has a marvelous chance of working NOW, simply because it is the first space project which offers a chance of *personal participation* to the "ordinary " individual. The first such opportunity. Every other space venture has involved a selected and highly trained elite. But I think we can sell this most important project if we present the idea to a weary public, weary with federal boondoggles, inflation, high unemployment, etc., that this is a way but, an escape into adventure -- aside from the probability that it just might save our species and our planet from virtually certain extinction.

John E. Dyer
Collinsville, Oklahoma

Just a brief note on Heppenheimer's story ("Home, Home on Lagrange," part 2) in relation to the part that says: "Some of our *chemists* rigged equipment to turn soybeans into TVP -- textured vegetable protein -- and they tried to make artificial steaks and things from the TVP, using artificial flavors."

Perhaps chemists, metallurgists and chemical engineers will be mainly responsible for the construction of solar power stations as well as the space colony by itself, but when we arrive to the point of food products and their development, leave that to the *food technologists,* and give them their proper place, because if we are going to be fair in a space colony program, we have to give equal opportunities to skilled professionals in different areas, and not only to concentrate in a "petite elite" of chemists. Although at present the ratio is perhaps of 100 (chemists, metallurgists, chemical engineers, etc.) to just 1 (food technologist), I am certainly sure that it is possible to find candidates to become "outer space food technologists." And if you need some, I know at least of one who is ready to work on that. Me!

Congratulations to T.A. Heppenheimer for his thoughtful story, that I really hope will be true soon.

Aldo J. Pontecorvo
Food Technologist/
Nutritionist
Cornell University

POSTCARDS!

We had hoped to include two sample postcards in this issue, but discovered, as we were going to press, that such enclosures are not permitted in second-class mail.

So it will have to suffice that we now announce the publication of two color postcards of the Bernal Sphere space settlement, which are available to members for 15¢ each, 50 (of one kind) for $3.00. The postcards are of the interior and exterior of the Sphere, the same photographs we published on the cover and inside cover of the September *L-5 News,* only in color. Remember that we have a $2 handling charge on all orders -- in addition to the amount for goods.