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Large Scale Human Benefits from the Industrialization of Space

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LARGE-SCALE HUMAN BENEFITS FROM THE INDUSTRIALIZATION OF SPACE

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ABSTRACT

This paper summarizes the results to date on an 18-month study on Space Industrialization performed for NASA-MSFC by Rockwell International. This study is in two parts. Part 1 addressed the "what" and "why" of Space Industrialization; Part 2 will address the "how". This paper highlights important future world needs and trends in which space can potentially play a part, and identifies the specific recommendations for the evolutionary industrialization of space. The space opportunities that are applicable to future national and world needs are listed, and these opportunities are assessed. They cover the broad areas of Space Industrialization: (1) information services, both transmission and data acquistion; (2) energy ... in the form of light or converted to microwaves and beamed to earth for conversion to electricity; (3) materials ... manufactured in orbit using terrestrial materials, materials from the moon, or materials from outside cislunar space; (4) weather, environment and climate monitoring, predicting, or controlling; and (5) other uses of space including human activities such as medical treatment and tourism. During the study several Space Industrialization program options were identified and the various viable opportunities were integrated into evolving programs, each with a step-by-step development of the required hardware and returning intermediate benefits leading toward longer range goals. The paper discusses an assessment of these program options, including the benefits incurred and the hardware items necessary to implement the overall recommended program.

As we look to the turn of the century and beyond, many people see an increasingly bleak future. The press of population continues on, particularly in the less-developed countries where their needs are not being met even with the current population. The average age in the world is young about 15—and these people will live (hopefully) for several generations. However, in the developed countries like ours, the average age is about 29 and getting older each day. We have reached that magic time when each pair has a pair. Worldwide, however, that is not the case and it is not likely to be soon. Therefore, no matter how you look at birth control success, the overwhelming percentage of the world population is not in the industrialized nations and will not be for many decades to come. Fig. 1 shows a projection to the year 2070, whereby the percentage of people in less-developed countries (LDC's) gets even larger compared to that in industrialized nations.

Although the last decade has seen much progress in world output growth, there is little doubt that the population growth will keep it very difficult to show year-by-year improvement on a per-capita basis. Unless we encounter a massive catastrophe, this world is committed to support a population at least double and most likely triple today's population. Most futurists believe that it is essential to make the changes in the next 30 years that will lead to population stability within the 21st century.

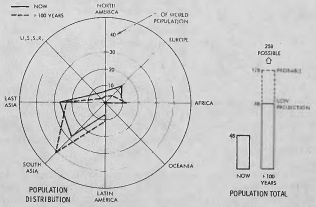


Figure 1. World Population Shifts

Many people also look with fear at the rate at which we are using known resources. Fig. 2 plots data from the "*Limits to Growth*" study which indicates that we will either run out of some important materials or pay much more for them in terms of energy, land spoiled, environmental degradation, etc. Although we would wish the good life for all, Figs. 1 and 2 seem to run counter to this wish. The trick to avoidance of the catastrophes indicated by trends like these is to use, again, the ingenuity of man, as Herman Kahn has pointed out. Our question, in the high technology business, is: "*Does space offer at least a partial solution and, if so, what is it?*" Krafft Ehricke, as Fig. 3 indicates, believes that in the long run, space offers the major solution. I personally believe that space is exceeded only by food and energy in long-range importance to mankind.

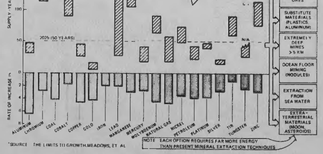


Figure 2. Potential Exhaustion of Selected Minerals

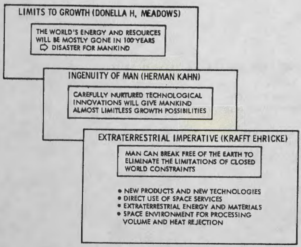


Figure 3. Views of the Future

Dr. Ehricke, in several publications, and using a theme he calls "the extraterrestrial imperative," points out that we can break free of thinking of the world as a limited and isolated unit. We can turn our thoughts and efforts toward the utilization of space in many ways. He suggests that this is certainly useful in the near term and mandatory in the long term.

As a practical matter, long-range solutions to overall world problems, however valid, do not have a handy marketplace. Our study was funded by the U.S. taxpayer who has a primary interest in the here and now. He is interested in jobs his and his standard of living. Government officials who promise to satisfy these interests tend to get elected. However, we must cope in the world marketplace to maintain our jobs and our standard of living. Keys to this are the vital areas of energy, productivity, and balance of trade. Energy is needed in increasing quantities for extraction and production of the things that make our lives more comfortable and more enjoyable. Productivity keeps our costs down even if our wages are high, so that we have something that can sell to other countries. We do have some things that we want to buy in the world marketplace, not the least of which is oil. Fig. 4 shows the main export products and the 20 top buyers of United States goods on the left; the main import products and the 20 top sellers to the United States on the right.

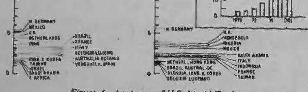


Figure 4. Anatomy of U.S. World Trade

The main export markets lie in rich countries. Import sources involve rich and poor countries. The economy of the latter rests on the purchases of the industrial countries. There can be no production without consumption (and vice versa). Increasing the consumption (purchasing rate) of a country moves it from the right to the left side of the chart and tends to turn it into a United States market.

The United States and the other industrial countries are giant markets for developing countries. The United States now relies (over 50 percent) on imports for 14 important materials or material groups. Quantities and costs of imported oil have risen dramatically since 1974. But the bottom line of economic health is trade—the combination and reasonable balance of import and export. In 1965-75, total United States trade more than quadrupled. After decades of surpluses before 1971, United States trade has been in the red for three of the last five years. We have now moved into a new situation. President Carter has the distinction (already) of exceeding the balance of payments deficits of all of his predecessors combined and there is good reason to believe that this major problem will continue.

World poverty deprives us of a market of two billion people (at least three billion by 2000); that is, of potentially several hundred billion dollars of exports. Presently, according to United States Department of Labor calculations, each billion dollars creates 47,000 jobs—about 10 million jobs for 200 billion dollars. If the United States could tap, for example, $200 per year of purchasing power of each of the two billion people that are now too poor to buy from us it would create a lot of jobs (almost 20 million) in our own country.

Therefore, it is of the greatest importance to the United States economy that United States investments (public and private) in the productive use of space contribute to the economic growth and purchasing power in as many developing countries as possible.

Fig. 5 shows a different view of world trade. The western block industrialized countries are not very self-contained and are, therefore, much more vulnerable to interruptions of imports or exports than the communist countries. The LDC's appear to have little to lose and much to gain. They can gain most from what we have to sell—technology and the products that go with it—if they have the buying power. Specifically, their needs are summarized in Fig. 6. To the extent that space can contribute to those needs, it creates a vast market for the things the developed countries have to sell. Therefore, the interrelationship between the top and bottom bars on the figure has a tremendous influence—one way or the other—on world future.

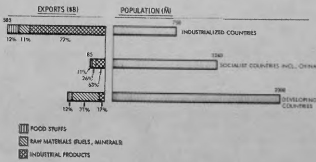


Figure 5. Economic–Industrial Anatomy of Mankind

ENERGY - INCLUDING GEOTHERMAL AND SOLAR. THEIR COSTS FOR FOSSIL FUELS ARE HIGHER THAN OURS

MANAGEMENT OF RESOURCES - OFTEN THEIR KEY SOURCE OF WEALTH. HOWEVER, THEY WANT TO DO MORE LOCAL PROCESSING

JOBS - TO HAVE A JOB IS THE EXCEPTION RATHER THAN THE RULE

FOOD - A CRITICAL PROBLEM FOR NEXT THIRTY YEARS, PARTICULARLY IN THE FACE OF POPULATION GROWTH, FERTILIZER COSTS, AND POTENTIAL CLIMATE WORSENING

WATER - MANY TIMES WATER IS ABUNDANT A FEW FEET DOWN, BUT THEY DON'T HAVE THE MEANS TO UTILIZE IT

EDUCATION - ALL KINDS, BUT COMPATIBLE WITH SOCIAL SYSTEM, MUST MAKE THEM EMPLOYABLE IN A POSITIVE FEEDBACK SENSE.

Figure 6. Key Needs of Developing Countries

The needs of humanity, world wide, are basically similar. We need to be productive and feel useful (i.e., to have a job). We need a standard of living that is acceptable to us and improves each year, and–along with that–a quality of life compatible with our individual heritage and reasonable expectations for an even better future. I think that the U.S. has the role of the leader, whether we like it or not. It is technological, economic, and also social. The key direction of this leadership should not only be good stewardship of what we have but the continued creation of wealth for ourselves and for the world. In the face of population growth, a more "just" organization of scarcity makes the future look even more bleak for the average world citizen (per-capita basis) and will inevitably lead to world conflict.

During the study we attempted to look 50 years into the future and interrelate world needs with space opportunities. We undertook the task with humility, and do not pretend that we have taken into account all the socio-economics, technology, and politics of worldwide earth and infinite space.

Fig. 7 summarizes the flow of Part 1 of the study. Our work started with two parallel paths, one looking into the future for trends and needs and the other searching for space opportunities that technological forecasting could foresee. Previous work on both subjects is voluminous and we read most of it. The problem was to get from the general to the specific, and from the infinite to a reasonable approach that could be understood and supported. Two kinds of screening were used, a narrowing process that identified the best of the opportunities and an integrating process that allowed a very few applications of hardware/technology to accomplish multiple opportunities and bring about their benefits.

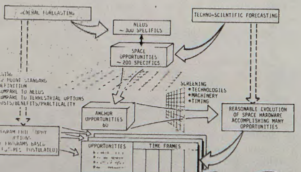


Figure 7. Rockwell Space Industrialization Study–Part 1

The direction we're heading and the pace at which we're proceeding are critical to the process of space industrialization. Fundamental to both is the age-old question of major attention to immediate needs versus the foresight to sacrifice some of today for a better tomorrow. Also fundamental is the possibility of a major event–like a war, climate change, end-of-aging drug, etc. We postulated six program options, one based on responses to immediate crisis, three on foresight, and one on climate change hurting the Northern Hemisphere. Another program option was based on commonality across the other five.

By the time you consider six program philosophies, 60 opportunities, three ratings of importance, and five ratings of rate–all divided into five time frames–you need to make about 5000 decisions. We made these and exposed at least 100 persons to the results in complicated reports and extended working group sessions. Their responses and our judgment led to the preliminary results summarized in this briefing. In addition, a preliminary hardware implementation scheme was derived, based heavily on full utilization of the Shuttle, minimum cost over the whole period considered, and driven heavily by the steps we need to take to make critical energy decisions in the next few years.

OPPORTUNITIES

During the study a list of more than 200 seemingly viable space opportunities was compiled. These were broken down into the general categories shown in Fig. 8.

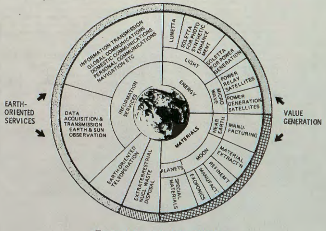


Figure 8. Space Industry Options

As we got into the study we found that it was easier (and more fun) to think up new things to do in space than it was to narrow the list down to a manageable few. We used the ideas that have been put forth by Ivan Beckey (Aerospace Corp), Outlook for Space (NASA), and any others we could find plus adding many new ones. The overall lists are shown in Figs. 9, 10, and 11. It is not possible to discuss each one individually in any reasonably sized paper, but it is reassuring to know that the known opportunities are quite numerous and respond to a major degree to the needs of mankind. This would suggest that space should always be considered in financial and social relation to the mainstream of world activities rather than being a matter of minor interest, benefitting only a few people.

A. COMMUNICATIONS

1. INFORMATION RELAY
   - DIRECT TV BROADCAST
   - ELECTRONIC MAIL
   - EDUCATION BROADCAST
   - RURAL TV
   - METEOROLOGICAL INFORMATION DISSEMINATION
   - INTERAGENCY DATA EXCHANGE
   - ELECTRONIC COTTAGE INDUSTRIES
   - WORLD MEDICAL ADVICE CENTER
   - CENTRALIZED "DISTRIBUTED" PRINTING SYSTEMS
   - ENVIRONMENTAL INFORMATION DISTRIBUTION
   - TIME AND FREQUENCY DISTRIBUTION
2. PERSONAL COMMUNICATIONS
   - NATIONAL INFORMATION SERVICES
   - PERSONAL COMMUNICATIONS WRIST RADIO
   - VOTING/POLLING WRIST SET
   - DIPLOMATIC U.N. HOT LINES
   - 3 D HOLOGRAPHIC TELECONFRENCING
   - MOBILE COMMUNICATIONS RELAY
   - AMATEUR RADIO RELAY
   - 'TELEGRAPHING' PERSONAL COMMUNICATIONS SYSTEMS
   - WORLDWIDE ELECTRONIC PING PONG TOURNAMENTS
   - CENTRAL COMPUTER SERVICE (FOR TRANSMITTING HAND HELD CALCULATORS)
   - URBAN/POLICE WRIST RADIO
3. DISASTER WARNING
   - DISASTER WARNING RELAY
   - PRE DISASTER DATA BASE (EARTHQUAKE)
   - EARTHQUAKE FAULT MEASUREMENTS
   - DISASTER COMMUNICATION SET

B. NAVIGATION, TRACKING, AND CONTROL

1. NAVIGATION
   - PUBLIC NAVIGATION SYSTEM
   - GLOBAL POSITION DETERMINATION
   - COASTAL NAVIGATION CONTROL
   - GLOBAL SEARCH AND RESCUE LOCATOR
2. TRACKING AND LOCATION
   - IMPLANTED SENSOR DATA COLLECTION
   - WILD ANIMAL/WATERFOWL SURVEILLANCE
   - MARINE ANIMAL MIGRATIONS
   - VEHICULAR SPEED LIMIT CONTROL
   - RAIL ANTI-COLLISION SYSTEM
   - NUCLEAR FUEL LOCATOR
   - VEHICLE/PACKAGE LOCATOR
3. TRAFFIC CONTROL
   - MULTINATIONAL AIR TRAFFIC CONTROL RADAR
   - SURFACE SHIP TRACKING
4. BORDER SURVEILLANCE
   - U.N. TRUCE OBSERVATION SATELLITE
   - BORDER SURVEILLANCE
   - COASTAL ANTI-COLLISION PASSIVE RADAR

Figure 9. Information Transmission

A. LAND DATA

1. AGRICULTURAL MEASUREMENTS
   - SOIL TYPE CLASSIFICATION
   - CROP MEASUREMENT
   - CROP DAMAGE ASSESSMENT
   - GLOBAL WHEAT SURVEY
   - CROP IDENTIFICATION/SURVEY
   - AGRICULTURAL LAND USE PATTERNS
   - CROP HARVEST MONITOR
   - RANGELAND EVALUATION
   - CROP STRESS DETECTION
   - SOIL EROSION MEASUREMENT
   - AGRICULTURAL ACREAGE SURVEY
   - SOIL MOISTURE MEASUREMENT
   - SOIL TEMPERATURE MONITOR
2. FOREST MANAGEMENT
   - TIMBER SITE MONITORING
   - LOGGING RESIDU INVENTORY
   - FOREST STRESS DETECTION
   - FOREST FIRE DETECTION
   - RURAL/FOREST ENVIRONMENT HAZARDS
   - LIGHTNING CONTACT PREDICTION/DETECTION
3. HYDROLOGICAL INFORMATION SYSTEM
   - SNOW MOISTURE DATA COLLECTOR
   - WETLANDS MONITOR
   - TIDAL PATTERNS/FLUSHING
   - WATER MANAGEMENT SURVEILLANCE
   - IRRIGATION FLOW RETURN
   - RUN OFF FORECASTING
   - INLAND WATER/ICE COVER
   - SUBSURFACE WATER MONITOR
   - WATER RESOURCE MAPPING
   - SOIL MOISTURE DATA COLLECTOR
   - IRRIGATION ACREAGE MEASUREMENT
   - AQUATIC VEGETATION MONITORING
   - SALINE INTRUSION
3. HYDROLOGICAL INFORMATION SYSTEM (CONT)
   - UNDERWATER VEGETATION SURVEY
   - LAKE/RIVER SUSPENDED SOLIDS
   - SEDIMENT MEASUREMENTS (RIVERS)
   - FLOODED AREA MONITORING
4. LAND MANAGEMENT
   - LAND CAPABILITY INVENTORY
   - LAND USE MAPPING
   - WILD LAND CLASSIFICATION
   - RANGE VEGETATION MAPPING
   - RANGELAND UTILIZATION/POPULATION
   - FLOOD DAMAGE ASSESSMENT
   - BEACH EROSION
5. POLLUTION DATA
   - ADVANCED RESOURCES/POLLUTION OBSERVATORY
   - SALT ACCUMULATIONS (IRRIGATION)
   - AGRICULTURAL POLLUTANT MONITORING
   - LAKE EUTROPHICATION MONITOR
   - GREAT LAKES THERMAL MAPPING
   - EFFLUENT DISCHARGE PATTERNS
   - TOXIC SPILL DETECTOR
   - AIR QUALITY PROFILOMETER
   - AIR POLLUTANT CHEMISTRY (FREON)
   - POLLUTION DETECTION AND DISTRIBUTION
   - MOSQUITO CONTROL (WETLANDS FLOODING)
6. RESOURCE MEASUREMENTS
   - OIL/MINERAL LOCATION
   - DRILLING/MINING OPERATIONS MONITOR
7. GEOGRAPHIC MAPPING
   - URBAN/SUBURBAN DENSITY
   - RECREATION SITE PLANNING
   - HIGH RESOLUTION EARTH MAPPING RADAR
   - WILDLAND VEGETATION MAPPING
   - OFFSHORE STRUCTURE MAPPING

B. WEATHER DATA

- ATMOSPHERIC TEMPERATURE PROFILE SOUNDER
- RAIN MONITOR

C. OCEAN DATA

- OCEAN RESOURCES AND DYNAMICS SYSTEM
- MARINE ENVIRONMENT MONITOR
- OIL SPILL
- SHORELINE OCEAN CURRENT MONITOR
- ALGAE BLOOM MEASUREMENT

D. GLOBAL ENVIRONMENT

- GLACIER MOVEMENT
- OZONE LAYER REPLENISHMENT/PROTECTION
- HIGHWAY/ROADWAY ENVIRONMENT IMPACT
- RADIATION BUDGET OBSERVATIONS
- ATMOSPHERIC COMPOSITION
- ENERGY MONITOR SOLAR TERRESTRIAL OBSERVATORY
- TECTONIC PLATE OBSERVATION

Figure 10. Data Acquisition

A. PRODUCTS (REPRESENTATIVE)

1. ORGANIC
   - ISOENZYMES
   - GENETIC ENGINEERING OF HYBRID PLANTS
   - UROKINASE
   - INSULIN
   - NEW ANTIBIOTICS VIA RAPID MUTATION
   - UTILIZATION OF BIORHYTHMS
2. INORGANIC
   - LARGE CRYSTALS
   - SUPER LARGE SCALE INTEGRATED CIRCUITS
   - TRANSPARENT OXIDE MATERIALS
   - SURFACE ACOUSTIC WAVE DEVICES
   - NEW GLASSES (INCLUDING FIBER OPTICS)
   - TUNGSTEN X-RAY TARGET MATERIAL
   - HOLLOW BALL BEARINGS
   - HIGH TEMPERATURE TURBINE BLADES
   - SEPARATION OF RADIO ISOTOPES
   - HIGH STRENGTH PERMANENT MAGNETS
   - MAGNETIC BUBBLE MEMORY CRYSTAL FILM
   - THIN FILM ELECTRONIC DEVICES
   - FILAMENTS FOR HIGH INTENSITY LAMPS
   - ALUMINUM-LEAD LUBRICATED ALLOYS
   - CONTINUOUS RIBBON CRYSTAL GROWTH

B. ENERGY

1. LUNETTA
   - NIGHT ILLUMINATION FOR URBAN AREAS
   - NIGHT ILLUMINATION FOR AGRI-CULTURE AND INDUSTRIAL OPERATIONS
   - NIGHT ILLUMINATION FOR DISASTER RELIEF OPERATIONS
2. SOLETTA
   - NIGHT FROST DAMAGE PROTECTION
   - LOCAL CLIMATE MANIPULATION
   - REFLECTED LIGHT FOR GROUND ELECTRICITY CONVERSION
   - OCEAN CELL WARMING FOR CLIMATE CONTROL
   - CONTROLLED SNOW-PACK MELTING
   - STIMULATION OF PHOTOSYNTHESIS PROCESS
3. OTHER
   - SATELLITE POWER SYSTEM (SOLAR)
   - FUSION IN SPACE
   - NUCLEAR WASTE DISPOSAL

Figure 11. Geospace Industries

In this presentation, I will briefly discuss one or two opportunities in the areas of products, services, and energy and then show an integrated picture of the plans that would put these and others into an evolutionary *space industrialization* program to meet certain objectives.

Products

We were especially interested in products that related to health, that improved the electronic services, that either saved energy or aided in producing or finding more energy or materials, or created a new product that might spawn a new industry. I'll discuss one—urokinase—as an example for space processing that could have a large impact on public health. Urokinase is a catalytic substance which is produced within a small group of specialized cells located in the kidney. Its function is to prevent blood clotting and it can dissolve a blood clot.

Unfortunately, urokinase is not available in mass quantity so it is used primarily for special treatment and research. The common mode of production involves its separation from urine. This process requires the collection of more than a ton of urine for processing one treatment. Therefore it is very expensive.

Recently, in experiments carried out onboard Apollo, ASTP, and Skylab, it was found that urokinase cells can be separated rapidly with high purity in the space environment using electrophoretic techniques. The cells are separated by virtue of a difference in molecular charge between it and other surrounding cells. Other space experiments indicated that the enzyme is produced by the specialized cells at a faster rate than experienced in terrestrial laboratories. This processing benefit is attributed to the absence of convection currents which obstruct separation in the presence of a gravitational field.

Since previous space processing experiments involving urokinase and related materials indicated the possibility of high production rates of pure urokinase in the zero-g environment of space, it seems possible that this substance can be made available to the public on a mass basis in the mid-1980's. As the production rate of space-processed urokinase rises in the mid-1980's, the cost will reduce substantially, and the enzyme's use will be more widespread. The total market could be satisfied by 1995.

This is only one product example. Many others—making large perfect crystals, metals with special properties, new glasses—have been studied. It's hard to determine winners from losers at this point, but once the Shuttle/Spacelab flies we'll surely find some winners that will spawn whole new industries and contribute to our economy and quality of life.

The evolution of space processing is shown in Fig. 12. Currently we are in a planning stage, both in a technical and in an institutional sense. The Space Shuttle orbiter, particularly with additional power and on-orbit time, will facilitate the operations necessary to prove out the processing concepts and actually make some marketable materials. Beyond that, small, Shuttle-tended free flyers and a space processing section of a space base will make large quantities of high-value products for earth markets. Recent studies, particularly that by Science Applications Inc., indicate that thousands of tons of glass, crystal, and metal items will be processed in space by the turn of the century. These will require major, dedicated factories that utilize hundreds of kilowatts of power. In the concept shown, this power is supplied by a solar array similar to but several orders of magnitude smaller than an SPS solar array.

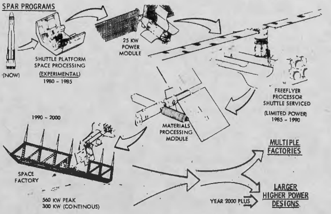


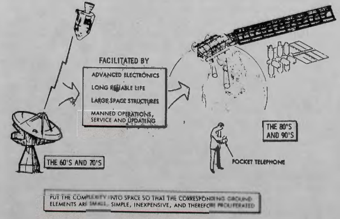
Figure 12. Space Processing Evolution (20-Year Span)

Services

The services area, using space, has the best chance of improving the lives of millions or even billions of people within the next two decades. *Space industrialization* is already a reality providing communications, observation, and weather services. A fundamental trend in this area is what I call *complexity inversion*, shown in Fig. 13.

Complexity inversion is a fundamental change in our approach to a space-ground system that has far-reaching potential. In the early days of the space program, every effort was made to keep the space segment of the system small and light. The corresponding ground segments had to be, therefore, massive and complex. Numerous examples can be found in both civil and military programs in which huge antennas and major computer installations processed raw data from a satellite in order to get useful information.

The reverse of this situation is now becoming feasible. The current trends in advanced electronics allow the space segment to be vastly more capable and complex but still stay within reasonable launch cost limitations—particularly considering the launch economics of the Space Shuttle. Further, we have developed and demonstrated the long, reliable life that is required of systems that are routinely used by millions of people who count on that service.



PUT THE COMPLEXITY INTO SPACE SO THAT THE CORRESPONDING GROUND ELEMENTS ARE SMALL, SIMPLE, INEXPENSIVE, AND THEREFORE PROLIFERATED

Figure 13. Complexity Inversion

By developing the capability to build extremely large structures in space and by eventually adding the presence of man to operate, service, and (perhaps most importantly) update the system to incorporate ever expanding technology, we can have space/ground systems in the 1980's and 1990's that interface directly with users with useful, processed information. Such things as wrist radio telephones, direct broadcast TV, global weather monitoring—the possibilities number in the hundreds—become feasible, practical, and cost-effective. Therefore, the tide of the future is to put the complexity into space so that the corresponding ground elements are small, simple, inexpensive and, therefore, proliferated worldwide.

Cars, trains, ships, and especially aircraft have done much to conquer geography. Space, however, can greatly reduce the importance of geography, primarily by providing easy and inexpensive access to data, computer power, other people, etc., regardless of where you are located at the moment or even where you live. This expands personal options in things such as education well beyond what happens to be taught near where you live to thousands of course options that could be brought into your home or into a remote village in India. From a business standpoint, the space segment of the system is a small part of the overall market; the big, worldwide market is in the production of the large number of inexpensive units used by millions of people.

Fig. 14 emphasizes the direct and personal effects that could occur with effective utilization of the telecommunications possibilities of space. Key points are shown, with the emphasis on the possibility that geography (your personal location at any given moment) could be largely de-coupled from the options you have to receive data, to access computer power, to take a specialized education course, or to communicate with other persons. The cities of the world largely reflect transportation situations of the past; with the diminishing of importance of location and transportation, a whole range of new options open up which may greatly affect where people live and what they do for a living.

- DIMINISHES THE IMPORTANCE OF YOUR GEOGRAPHICAL LOCATION
- PROVIDES EASY AND INEXPENSIVE ACCESS TO DATA, COMPUTATION, AND OTHER PEOPLE
- EXPANDS YOUR PERSONAL OPTIONS SUCH AS EDUCATION AND EMERGENCY SERVICES
- OPENS UP VAST NEW WORLD MARKETS

Figure 14. Benefits of Complexity Inversion

One of the near-term benefits of information transmission services is the construction of a high-capability satellite relay to provide linkages between the source of information (schools, universities, libraries) and the users (students, individuals, business and production plants). One of our consultants (Kerry Joels) provided a detailed evaluation of the needs, benefits, and comparative costs of delivering information via various media, and the effect that space-relayed information would have upon productivity, generating new job skills, improved life styles—all of which would improve dramatically (see Fig. 15).

In all cases, space industrialization would reduce the cost of delivery of instructional media: television for lectures, demonstrations; films; radio for lectures, audio laboratories, and

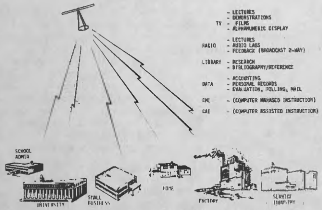


Figure 15. Space Industrialization Reduced Information Delivery Cost

feedback (two-way); library services for research, bibliography, or reference; data for accounting, personnel records, evaluations, polling, mail; computer-managed instruction for primary, secondary, college, trade schools; computer-aided instruction for the handicapped, the disadvantaged, or correspondence courses. Each of these has commercialization possibilities to prepare and sell specialized information.

The user's terminal would be inexpensive and readily available, and would require little training to use. This same user terminal would be also useful for other non-educational services, such as telecommuting, or "cottage industry" applications. Several billions of dollars, millions of gallons of gasoline, and millions of hours of individuals' time could be saved if electronics replaced some of the use of the automobile.

An especially worthy benefit would be to provide education and entertainment for the deaf. Multi-media transmission of programming with sign language on subtitles would enrich the lives of the estimated 15 million individuals in the U.S.A who suffer total or partial loss of hearing.

Electronic telecommuting is a concept in which workers would be linked to their offices electronically. Hence, rather than having to drive to work each day, the worker would operate from his home or from a small satellite office where he could interact electronically with machinery located at a central location. The fundamental advantage of such a system is that it would significantly reduce commuting. This would save fuel, transportation costs, and commuting time. It could allow a life-style trend whereby we again live, work, play, etc., in a small community, but still have most of the advantages of a big city.

Forty percent of all the urban population in the United States commutes by automobile. This commuting consumes about four percent of all the U.S. energy--or about $6 billion per year in fuel costs alone. If commuting costs are calculated at $0.10 per mile, it costs America's 86 million workers about $47 billion per year just to get to work. Moreover, if commuting time is figured at $5 per hour, there is an additional cost of about $90 billion in lost time. Of course this lost time could otherwise have been used to make a contribution to our productive capacity or our quality of life.

A recent experiment was conducted in Los Angeles with electronic telecommuting. Although this experiment did not utilize satellite relay links, it did provide some important information on the practicality of a satellite system and on its economic viability.

An insurance company in downtown Los Angeles employed 2500 workers, 1700 of whom did routine clerical work that did not require face-to-face contact. The primary job of these workers consisted of entering data into computer terminals. Because of high rental costs, the company officals decided to open two smaller offices in the San Fernando Valley. Then, rather than have all the workers report to the downtown headquarters, some of them (those who live in the local area) were permitted to drive to the San Fernando Valley locations and operate electronic terminals whose impulses were transmitted to the downtown location. Because of the success of this operation, the company now plans to open two additional electronic terminals in the Los Angeles area. Using this practical experience as a guide, they have employed special computer simulations to determine the savings that would be effected if they opened as many as 18 similar remote stations.

The major savings for the company consisted in reduced headquarters lease costs (because the satellite terminals were located in the lower-rent districts) and reduced salaries (premium salary rates were not necessary in the more desirable San Fernando Valley area). In addition, the employees saved about $1 million in reduced transportation costs, so that the total savings for this telecommuting experiment amounted to about $5 million per year, spread over about 2500 employees or about $2000 per employee.

If such a system using satellite relay links could be installed, the geography could be completely removed from commuting to work. In essence, workers could live anywhere they chose. Operations of this type would easily be conducted within the continental United States. Workers, for example, could live in rural areas and perform jobs that were essentially urban. An alternate use of the telecommuting concept would be to export jobs across international borders without moving the people.

Information acquisition is an equally important area to information transmission. It, too, has major benefits to LDC's and also ourselves. As we understand our weather and climate we can respond more productively, and as we know where our resources are we can use them more judiciously. Since no one paper can cover the entire area of space industrialization, I'll skip the details of the acquisition opportunities, but I do not intend for that to be construed as a non-endorsement.

Energy

Other papers at many conferences cover solar power satellites (SPS) in detail. As I see the stage we're now in, it is a technology development task to show either that we do indeed have the option of providing power from space that is economical, continuously renewable, and environmentally safe, or that we do not have that option, at least for 25-30 years. If the latter is the case, we should understand that fact and take appropriate steps in other energy directions.

There are alternatives to SPS, both terrestrial and space. I will briefly mention some of these and note that technology required for SPS is directly applicable to many other beneficial things both in the energy field and space industrialization in general.

Fundamentally, large space structure technology is a key to SPS and a wide variety of other things, civilian and military. One of these is Krafft Ehricke's Lunetta (Fig. 16). Light is a necessity to civilization and our eyes are wonderfully adaptive to the million-to-one ratio between daylight and a full moonlit night. As we learn to build very lightweight, large structures, we could make a family of Lunettas that illuminate large cities and/or large agriculture or industrial/construction areas. According to

Figure 16. Lunetta Concept

Dr. Ehricke, "...the system optimizes out at about 3-hour orbits rather than 12- or 24-hour ones, due to transportation, ground spot size, and shadows..." Imagine, if you will, living in a city, all parts of which are continously bathed in light from several bright stars, from several directions at once, each moving slowly (Fig. 17). It is light enough for Abe Lincoln to read and the places for criminals to hide are very scarce. As each satellite element of the system leaves one paying customer area, it either spills its reflected light back to space or illuminates another paying customer city or area.

A much larger system using reflected light for energy is Dr. Ehricke's Powersoletta, which would reflect sunlight down to a large desert area where it would be used in solar electric power generation. It would then put out full power 24 hours a day rather than 8 or 12. The space segment, although huge as the SPS, is relatively simple since it is only a set of reflectors. The RF bandwidths are then reserved for information services rather than used for hundreds of gigawatts of power. Most of the R&D and even the systems applicable to SPS could be used to make Powersolettas if, for whatever reason, SPS's do not work out. A 1987 decision point seems appropriate, but studies should proceed on both systems between now and then. For either one, lunar oxygen for interorbit transportation and, perhaps, other lunar materials would lower the cost when you are building tens or hundreds of units.

Science and Human Activities

Human activities in space have excited man's imagination for generations and still make the headlines far more frequently than the many other facets of space. Space colonization, as exciting as it seems to be, has many similarities to space industrialization, but with a fundamentally different motive. It is our opinion that a flourishing space industrialization program will do much to turn these dreams into reality, but in their own time. (The same is true of science and exploration; space industrialization in the long run is an ally, not a competitor.) The human spirit needs the promise of a better future and the challenge of a new frontier. The "high frontier" of space is the first time mankind has had a frontier that is only 200 miles from everybody, and he and she can actually see it. There is an emerging, uplifting spirit becoming widespread, especially among the young, and space (encompassing both pragmatic reality and fiction) is its focus.

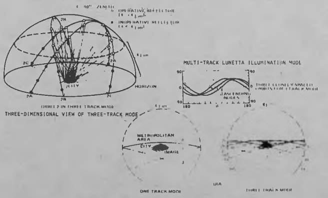


Figure 17. Space Light Illumination Concept

ROCKWELL'S PROGRAM OPTIONS

Our approach to developing an encompassing range of program options was to formulate a set of varying philosophies stemming from general future trends. Three futures were used: (1) near-term orientation decision-making, (2) long-term orientation decision-making, and (3) basic environmental change (35-year cold period).

From these futures, the six program options shown on Fig. 18 were derived. They are:

1. Immediate Crisis-Oriented Program—In accordance with this option the public views our country as having so many pressing problems that they do not feel they can justify sacrificing today for a better tomorrow. In general, the space program and other long-lead time opportunities will be postponed continually unless they have a crisis aura. Business will do what shows near-term payoff, and government will support what seems to be a near-term solution to a recognized immediate crisis. As the future evolves, new crises will precipitate various space program solutions, but in each case only those opportunities that can be accomplished quickly will be included.

2. Foresight Program—If this philosophy is followed, the United States government is willing to look ahead for two or more decades and support those investments that are clearly shown to be directly beneficial to national and international interests. The national feel is one of basic confidence in the future, but the necessity to cope with energy, productivity, and balance-of-payment needs are understood. In this future we seek also to develop a strong synergistic interrelationship between developed and developing countries for both humanitarian and

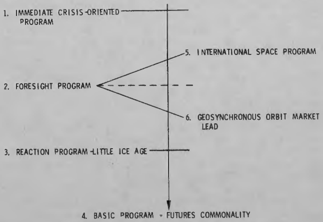


Figure 18. Space Industrialization Program Options

business reasons. We are dedicated to help worldwide industrialization on a progress curve that outpaces population growth, and to develop customers with buying power for our higher technology products and services.

3. Reaction Program (Little Ice Age)—This future assumes that data are available which clearly convince our population that a 30-year cooling-off period has begun such that a World War II-like national motivation becomes real, and approximately 10 percent of our GNP would be dedicated to terrestrial and space investments that are clearly beneficial in mitigating the bad effects upon the United States.

4. Basic Program (Futures Commonality)—This philosophy calls for a play-it-safe approach that warrants a reasonable investment in space activities common to the basic futures identified. It is not strictly nationalistic, but international assistance is secondary in priority since the crisis influences of futures 1 and 3 are strong.

5. International Space Program—The driving philosophy in this program option is that full world participation in space activities will tend to ease friction and foster world peace. A press to have all countries participate and share the benefits tends to override purely technical and business considerations.

6. Geosynchronous Market Leadership—The fundamental driver in this program is to recognize the value of world market leadership in the information business. A key to this market is the utilization of space, particularly geosynchronous orbit, for an ever-changing variety of services. We would aim to keep ahead of the competition in the space segment, the multiplicity of corresponding ground equipment, and the number and quality of benefits provided.

RANKING OF PROGRAM OPTIONS

During the course of the study, parallel efforts were conducted to extrapolate both mankind's needs and technical opportunities into the future. The needs were then used to trigger new ideas for space opportunities and as a background for evaluation of these opportunities, both relative to each other and relative to competitive terrestrial options. This process yielded some 300 specific needs (there could be many more) and some 200 space opportunities. By evaluation and combination, the 200 opportunities were pared to about 100, each of which was then written up to a specific 12-point format for more detailed evaluation. It was intended to pare the list to some 25 outstanding opportunities upon which an evoluationary space program could be firmly anchored. As the evaluation proceeded, however, we found it surprisingly difficult to throw out very many of the opportunities. The list still numbers about 50, each of which seems worthwhile and cost-effective to do sometime before the year 2025.

As we looked at the options and the opportunities, we talked to a lot of people, both within the company and outside, and in and out of the aerospace industry. About 100 evaluators, young and old and of various ethnic and technical backgrounds, helped us come to the conclusions discussed below.

Option 1 should surely be done. It is the least we should do and its implementation should be simply a matter of getting the facts understood to the Congress, OMB, and people.

However, we, in the aerospace community, should have an obligation to pursue the foresight options, at least in our own plans and getting as much support as we can. Knowing that the Administration, Congress, and the public, as a whole, are not future-oriented, this program option has little chance of full implementation but can be partially brought about.

The two oblique foresight options, one seeking the primary emphasis to be on international funding and participation (No. 5) and the other seeking to deliberately nourish a potential information systems market for the United States (No. 6) are not as viable as the middle route. True international cooperation is extremely difficult to turn into reality, but, on the other hand, too self-serving an approach implemented by any country is apt to meet strong resistance by most of the other countries. We do feel that a reasonable market leadership in this area is a "natural" for the United States and should be supported by government action.

Program Option 3 (Reaction Program - Little Ice Age) is really a specific kind of foresight (No. 2) that predicts an immediate crisis (No. 1) at a future time. This particular crisis, if it should appear to be coming (as the climate patterns are studied and experienced), has such an overriding influence that it is prudent foresight at least to develop long-lead precursors to the accelerated space activities indicated.

Finally, the Futures Commonality Program Option (No. 4) does not make as much sense as a commonality of opportunities as it does as a commonality of hardware and technology across the systems that implement these opportunities. These hardware commonalities will be determined at a later date when the characteristics of the system hardware items are better defined.

PROGRAMMATIC IMPLICATIONS

Services

The services opportunities are shown in Fig. 19 as we recommend their implementation. Within the timeframes, R stands for research, D for development, O for operational. An arrow following the O indicates a plateau of capability continuing to operate. An O' or O" indicates a step increase in capability—essentially a Block II or quantum jump increase.

One of the problems of space industrialization is that it is not monolithic and therefore difficult to communicate to the American (and world) public. Surely the 200 good things to do

ANCHOR OPPORTUNITIES	TIME FRAME 80-85	85-90	90-95	95-00	00-10
SERVICES					
TRANSMISSION					
DIRECT-BROADCAST EDUCATION - U.S.	D	O'	O"		
DIRECT-BROADCAST EDUCATION - DEVEL. COUNTRIES	D	O		O'	O"
BUSINESS SYSTEM DATA TRANSFER	O	O'	D"		
ELECTRONIC TELECOMMUTING	R	D	O		
ELECTRONIC TELECONFERENCING	D	O			D'
WORLD MEDICAL ADVICE CENTER	D	O	D'		
TIME AND NAVIGATION SERVICES	O				
IMPLANTED SENSOR DATA COLLECTOR	D	O	D'	O"	
NATIONAL INFORMATION SERVICES			D	O	
PERSONAL COMMUNICATIONS	D	O	D'		
ELECTRONIC MAIL (EXCL. PACKAGES)	D	O	O'	D"	
MEDICAL AID AND INFORMATION - U.S.	D	O			
TELEOPERATION FROM SPACE			R	D	O
OBSERVATION					
OIL/MINERAL LOCATION	D			D'	
CROP MEASUREMENT	D	O	O'		
OCEAN RESOURCES AND DYNAMIC SYSTEM	D	D			
WATER RESOURCE MAP AND RUNOFF FORECAST	O				
GLOBAL EFFECTS MONITORING (STO)	O	O	D'	O"	
LANDSAT D	O				
TOPOGRAPHIC MAPPING	D	O			
HIGH-RESOLUTION RESOURCE SURVEY	D	O			
HIGH-RESOLUTION RADAR MAPPING	R	D	O		

Figure 19. Anchor Opportunities–Services

in space would be perceived by the public as a hodge-podge. Sixty anchor opportunities also are too diffuse. Therefore we highlighted a very few whose impacts are very direct and whose motivies are clearly understandable and related to widespread and known needs. Prudent engineering allows us to do many services with the same basic machinery, but the most publicized reasons for the program would be the highlighted services opportunities. These relate directly to our need to reduce fuel consumption and to improve urban quality of life, to reduce the soaring costs of universal health care, to help feed a growing world population, and to understand and predict our weather and climate.

As the figure shows, reasonable foresight recognizes the tremendous returns in investment in job-related education, in a rapidly changing U.S., and a population-expanding world. Acceleration of the opportunities indicated will pay off, particlarly to developing countries. In the long run, the creation of customers (with buying power) in the developing and heavily populated countries is the most important overall world contribution that industrial countries can make, both for their own well-being and for a better world.

In addition, the full understanding of our climate and weather, both solar effects and man-made effects, should be accelerated to have major payoffs before the turn of the century.

Products and Energy

As stated previously, the specific winners in the products area (Fig. 20) are hard to predict until Shuttle/Spacelab flights have occurred. However, we are confident that space electrophoresis will work and that the cost of urokinase will come down to affordable levels. Since it's not really a new drug, the lengthy process of approval for use can be short-cut. Each one probably knows of a stroke or heart attack that this drug could have prevented by quickly dissolving the offending blood clot. When people understand the relevance of just this one product to their own life, they can probably accept the many other beneficial made-in-space possibilities.

Foresight adds emphasis to those products that relate to information management and the accelerated services discussed previously. In addition, other health-related products, such as the early diagnostic tool or isoenzymes, should be emphasized. Continuous ribbon crystal growth potentially lowers the cost of solar cells for both the terrestrial and space markets.

ANCHOR OPPORTUNITIES	TIME FRAME 80-85	85-90	90-95	95-00	00-10
PRODUCTS					
RGANIC					
ISOZYMES (ALSO MEDICAL DIAGNOSTIC)	R	O			
UROKINASE (ANTICOAGULANT)	D	O			
INSULIN (FROM HUMAN SOURCES)	O	O			
INORGANIC					
LARGE CRYSTALS (SIZE AND PERFECTION)	O				
SUPER-LARGE-SCALE INTEGRATED CIRCUITS	O	O'		O''	
NEW GLASSES (INCLUDING FIBER OPTICS)	D	O	O'	O''	
HIGH-TEMPERATURE TURBINE BLADES		D	O		
HIGH-STRENGTH PERMANENT MAGNETS	O				
UTTING TOOLS	D	O		O'	
THIN-FILM ELECTRONIC DEVICES	D	O	O'		
CONTINUOUS RIBBON CRYSTAL GROWTH	D	O			
ENERGY					
REFLECTED SOLAR ENERGY					
NIGHT ILLUMINATION FOR URBAN AREAS	R	D	O	O'	
NIGHT ILLUMINATION FOR AGR & INDUST OPERATIONS			O		
NIGHT FROST DAMAGE PROTECTION			R	D	O
REFLECTED LIGHT FOR GROUND-ELECT. CONV.		R	R/D	D	D
MICROWAVE TRANSMISSION					
SATELLITE POWER SYSTEM (SOLAR)	R	R/D	D	O	O'
FUSION IN SPACE	R	R	D	D	O

Figure 20. Anchor Opportunities–Products and Energy

In the area of energy, solar energy (either reflected to ground conversion units or converted to electricity and beamed to earth receivers) is easily understood and sorely needed. We are not yet sure of the technical practicality, environmental acceptability, or economic competitiveness of either system, but we do think that the U.S. high technology community has the obligation to either put this option within reach or else determine clearly that we do not have such an option and therefore must look elsewhere for turn-of-the-century energy solutions.

Fusion is of such tremendous importance that we should seriously investigate every serious breakthough potential. Space indeed offers such a breakthrough potential, by using the essentially infinite vacuum to allow movement of the container walls farther away from the reaction and also quickly restore the vacuum whenever impurities are introduced into the system.

Also in the energy area, the reflected light illumination of burgeoning cities. . . worldwide. . . brings a benefit of space capability directly to more people than any other opportunity of the list. It can be done reasonably quickly and at low cost. Down the same road of large structure technology, we recommend developments toward either reflected light for power (Powersoletta) or SPS; the decision of pursuit to operational status cannot be made now for either one. As part of the public communication, however, night frost damage protection as a byproduct of Powersoletta is readily understood and probably widely accepted.

Human Activities and Lunar Industry

These opportunities, shown in Fig. 21, are really support functions – primarily to energy programs. Therefore their timing and emphasis are based on the energy decisions. The earliest need is the development of facilities for in-space working personnel. Later, these facilities can be expanded to allow people to go into space for purely pleasure purposes. Although this sounds only remotely connected to space industrialization, the appeal of personally being in space is so strong and so universal that there is little doubt of space tourism becoming a reality (for some) during the lifetime of most of the people living on the earth today. This possibility–or dream–was dominant in most of those under 30 who participated in our program evaluation.

ANCHOR OPPORTUNITIES	TIME FRAME 80-85	85-90	90-95	95-00	00-10
HUMAN ACTIVITIES					
MEDICAL AND GENETIC RESEARCH	D	O			
SPACE VACATION CRUISES (SHUTTLE FLIGHTS)			D	O	
ORBITAL TOURISM (LEO HOTEL)			R	D	D
ORBITAL THERAPEUTICS				D	D
ENTERTAINMENT AND ARTS			D		
LUNAR					
UNMANNED EXPLORERS	D	O			
LUNAR ORBITER		O	O		
LUNAR BASE		R	D	O	
LUNAR INDUSTRY			R	O	O

Figure 21. Anchor Opportunities–Human Activities

The moon is of fundamental importance to the world in the long run, partly because of its relative (gravity) accessibility to geosynchronous orbit and partly because of its resources. Further exploration and eventually manned return is recommended, but this is not the program driver and not the main point of public communication. Therefore none of the opportunities are highlighted.

Program Summary

All in all, we suggest that the United States take the lead to develop a global space program responding to the energy crisis

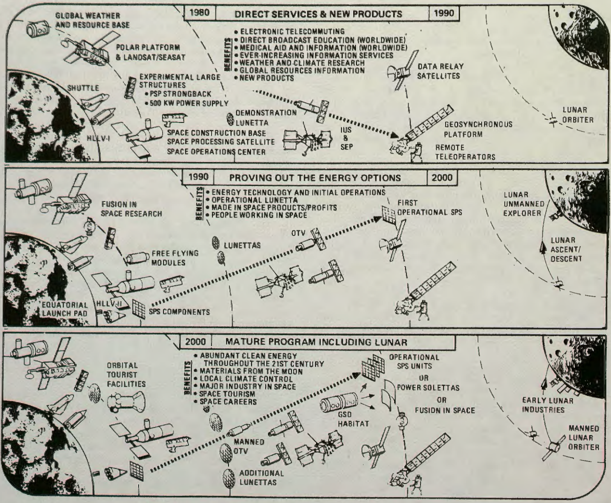


Figure 22. Space Industrialization Time Frame Summary Program Options

but balanced between near- and far-term objectives. It should be immediately and dramatically responsive to mankind's current needs but let longer-term objectives pull the program spirit and direction.

Fig. 22 is a summary chart of the Space Industrialization Program. It is divided into time frames as shown. On the chart we see the center of activity is in low earth orbit as we use the Shuttle to its fullest extent in the 80's including adding a 25-kw power module that can be left in orbit. We establish a public service platform and a global weather and resources base, both of which provide worldwide benefits. We eventually establish a facility in low earth orbit that is a construction base, a space factory, and space operations center. We learn to build large structures as a step toward SPS and put this to good use as we make multi-hundred kilowatt power modules, and build an operational Lunetta system.

In the 90's we increase the capabilities of the space factory, public service platform, and STO and also bring into initial operation a satellite power system (or fusion or Powersoletta). Beyond the year 2000 we utilize the moon to furnish oxygen and materials for massive energy-related projects in GSO.

The chart also shows transportation additions. The 1980's need only the Shuttle and modifications thereto. A low-thrust inter-orbit propulsion system also is needed. In the late 80's or early 90's we develop a large chemical upper stage, capable of transporting man to GSO but not initially used in that mode. The big investment, however, is a new HLLV, in the size range of an operational SPS, and its corresponding launch facilities. Beyond the 90's this becomes fully operational, and GSO-lunar transportation also is needed.

The mainstream of benefits in the 80's is service, both information and observation. The world clearly benefits in education, health, and conversation of resources, and productivity. Lunetta now serves many cities and is on call for special situations.

In the 90's we move to operational status a solution to the basic energy scarcity problem. Beyond the year 2000 we make energy from our space installations the major worldwide energy source. Throughout the entire program we continue to expand services, make new products, and move toward full understanding, prediction, and localized control of our weather and climate. Most importantly, people get increasingly involved with space, first by receiving directly benefits such as information and light but later on by direct participation in the space activity itself—even to space travel. A government/industry partnership-for-growth develops between developing and industrialized countries, between the scientific/academic community and commercial interests, and between space and terrestrial activities.

PROGRAM HARDWARE CONCEPTS

It was not the intent of this study to optimize hardware designs. However, we did want to get a feel for the year-by-year and total program costs, particularly the space segment of overall systems. Consequently, we developed hardware concepts and then used classical cost-estimating relationships (CER's) for cost estimates. These are primarily based on weight and complexity, although many other factors also are taken into account.

The most interesting hardware concept (Figs. 23 and 24) was a geosynchronous platform (GP). Our overall evaluation indicated that greatly expanded information transmission services from space was the most beneficial thing that could be done in a very early period. Although there is controversary in this area, we felt that a bold U.S. step to design and put into operation a platform of major capability with continuing reliable operation would represent a pull for an industrial quantum jump.

The initial RDT&E and first item would be from public funds (shared between NASA and other benefitting agencies) and the industrial firms could lease locations or "pads" and install mission-peculiar equipment on those pads. For an annual charge, the GP would provide the user abundant electrical power (deliberately designed to be a step in the direction of SPS), corresponding heat rejection, attitude control, maintenance of orbit location, and—most importantly—repair and updating capability. In our designs we used teleoperators that we think could be more productive at much lower cost than a man on a multi-mission sortie mission to GSO. The teleoperator would be always available, have more eyes, hands, legs, strength, reach, mobility, etc., than a suited astronaut, and be more radiation hardened. Eventually, as we move toward SPS's in GSO, the importance and amount of activity in that orbit will inevitably pull man to that location, and any intermediate hardware designs should take that natural evolution into account.

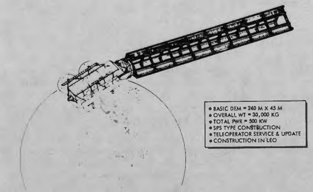
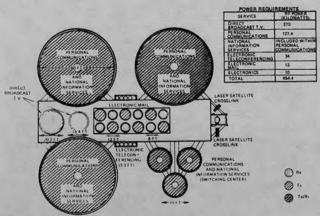


Figure 23. 500-kw Geosynchronous Platform



SERVICE	RF POWER (KILOWATTS)
DIRECT BROADCAST T.V.	270
PERSONAL COMMUNICATIONS	127.4
NATIONAL INFORMATION SERVICES	INCLUDED WITHIN PERSONAL COMMUNICATIONS
ELECTRONIC TELECONFERENCING	34
ELECTRONIC MAIL	13
ELECTRONICS	10
TOTAL	454.4

Figure 24. Antenna Locations for the Geosynchronous Platform

The envisioned 500-kw, 30,000-kg geosynchronous platform would provide five basic services for the entire U.S. These are:

1. Direct-Broadcast TV (five channels, 16 hours per day)—The consumer would need to buy a 1-meter antenna and a converter, the total cost of which would be about $100. Assuming that the programming is of good quality, of high educational content, and relevant to people's needs, I think virtually every family would spend the one-time $100. Maintenance of the on-orbit system (not the programming, etc.) would cost the average citizen 11 cents per year in taxes.

2. Pocket Telephones (45,000 channels that are portable and private, linked to our present telephone system)—The instrument would be of the size and cost of a good pocket calculator and each call would cost about 20 cents. This would be a moneymaker for industry and taxes would flow into state and federal governments accordingly.

3. National Information Services—With the cost of nationwide calls reduced (as satellite channels are installed) each of us has access to national rather than local data, people, calculating power, etc. Many small businesses could spring up and provide a national data bank or other specialized service.

4. Electronic Teleconferencing (150 two-way video, voice, and facimile channels)—Recent studies and demonstrations (PRELUDE, etc.) indicate that the market is much bigger than we thought when we sized this system.

5. Electronic Mail (40 million pages transferred among 800 sorting centers overnight)—Major companies would probably have fiber optics or microwave directly to and from an electronics sorting center. The mail would be automatically sorted per zip code or even per mail route, plant location, etc.

Other hardware concept designs were developed in order to estimate overall costs. These include an earth observation platform beyond LANDSAT (Figs. 25 and 26), a huge microwave radiometer (Fig. 27), the large space factory mentioned earlier (Fig. 28), and various other items shown in the overall program integration chart (Fig. 22). Designs and costs from other studies were used for space stations, transportation systems, lunar systems, and SPS.

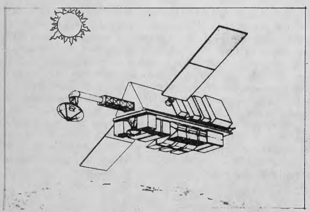


Figure 25. Earth Observation Platform

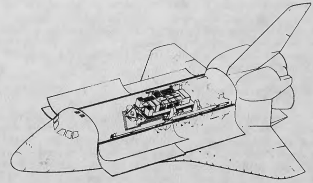


Figure 26. Earth Observation Platform in Launch Configuration

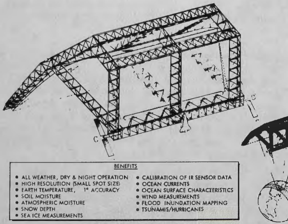


Figure 27. Orbital Microwave Radiometer

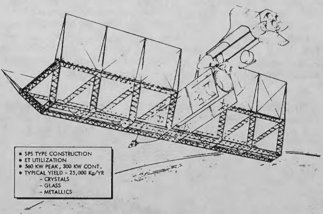


Figure 28. In-Space Factory

OVERALL CONCLUSIONS AND RECOMMENDATIONS

The overall conclusions and recommendations of the study are summarized on Figs. 29 and 30. Although forecasting to the year 2010 and beyond is always suspect, some trends are fundamental. One of these is the predictability of some degree of population growth and where the people will be located. Barring major catastrophies, the vast majority of the people of the world will be in developing countries. The relationship between the industrialized countries and developing countries is of paramount importance, because of the vast numbers of people and their major raw material resources. The evolution of this relationship is one of the major determinants shaping our national as well as global future. The industrial utilization of space is important to the nation, and facilitates the advancement of developing countries. It is both technologically feasible and economically rewarding on a need/market oriented basis.

The most immediate rewards and the most favorable investment conditions in the 1980's are indicated in the service area, both for information transmission and acquisition. In both cases the number of market opportunities is particularly large, while the capacity to realize them can be met by a relatively small number of systems due to a high degree of commonality made possible by the STS.

✓INDUSTRIALIZED COUNTRIES ⟷ DEVELOPING COUNTRIES

- TECHNICALLY FEASIBLE • • • INSTITUTIONALLY TROUBLESOME
- NEED/MARKET ORIENTED--NEW FUNDING POSSIBLE
- NEXT 30 YEARS ARE CRITICAL

✓LEAD WITH SERVICES

- LARGE MARKET • • • SMALL SPACE INVESTMENT
- COMMONALITY OF HARDWARE FOSTERS EXPONENTIAL GROWTH IN BENEFITS
- EVOLUTIONARY & SHUTTLE BASED
- U.S.A. SHOULD WORK FOR INFORMATION/OBSERVATION MARKET LEAD

✓PRODUCTS WILL COME

- SHUTTLE/SPACELAB EXPERIMENTS VITAL
- BIOCHEMICALS. CRYSTALS, GLASSES & DIRECTIONAL SOLIDIFICATION GOOD BETS
- GOVERNMENT SHOULD MOVE TO LOWER RISKS AND ALLOW PROFITS

Figure 29. Conclusions and Recommendations--1

✓ENERGY IS KEY

- SHORT RANGE HELP IN PRODUCTS AREA & POWER-IN-SPACE FOR SPACE
- FORESIGHT SAYS PURSUE ALL THREE, SPS, POWERSOLETTA, & FUSION-IN-SPACE BUT WATCH TERRESTRIAL COMPETITION & MAKE DECISION IN LATE 80'S
- THE SOLAR OPTIONS IN GENERAL HAVE MERIT, AND HAVE LESS TERRESTRIAL COMPETITION.
- LARGE SPACE STRUCTURES TECHNOLOGY IS COMMON TO BOTH ENERGY AND SERVICES
- PLASMA RESEARCH IN SPACE HAS ENORMOUS LONG-RANGE POTENTIAL

✓DON'T FORGET THE MOON

- RESOURCES FOR EARTH ARE LONGER-RANGE PROPOSITION
- LARGE SPACE INITIATIVE (e.g., SPS, SOLETTA) MAY PROVIDE TRIGGER
- FIRST OXYGEN, THEN OTHER MATERIALS

✓SPACE INDUSTRIALIZATION PAVES THE WAY

- VIGOROUS EXPLORATION PROGRAM CAN RIDE COAT-TAILS
- IT LAYS THE FOUNDATIONS FOR THE YOUNG PEOPLE'S DREAMS OF THE PERSONAL SPACE EXPERIENCE.

Figure 30. Conclusions and Recommendations–2

The Shuttle/Spacelab combination provides an early first step toward a general-purpose manufacturing R&D facility. The prospects for meaningful production levels of promising biochemical and directional solidification products by the mid-1980's are promising. Their development should be pursued vigorously, since these products are needed, contribute to U.S. pharmaceutical and technological leadership (and, hence, enhance U.S. export capability), and are potentially profitable to produce. Enlargement of an underlying data base to permit more accurate assessment of products and investment requirements is of paramount importance in the next 10 years.

The energy area offers three near-term benefits (1984-1990): (1) products for use on earth that help either conservation or the identification/exploitation of new deposits; (2) generation of solar-electric power for in-space use, especially services and manufacturing (25-250 kwe); and (3) use of reflectors for night lighting (Lunetta) of urban areas, agricultural and other applications, including illumination services for orbital operations in the earth's shadow.

Energy, of course, is the key to many aspects of the creation of wealth. Potential shortages in many things, including materials, can be related in the long run to the cost of energy. Space has enormous long-range benefits. These are in three categories: reflected light, intercepted light converted to microwave energy, and nuclear energy in space. The largest benefit potential is long-range (1990's). There is a strong competing terrestrial potential in the form of "clean" breeder reactors and fusion reactors which can mature in the same period of 1995-2010. For the use of solar energy for base load power, however, the space options face less competition and therefore are "safer" initiatives (the sun shines continuously in space). The SPS and Powersoletta represent two options to achieve virtually continuous generation of solar-electric power in the 1995-2010 time period.

The development of operational techniques in orbit for assembly, handling, and maintenance of large structures (beyond sizes needed for large antennas) should be undertaken early in the 1980's.

Because of its great potential for advancing and economizing space industrialization, plasma research in orbit should be initiated early with the objective of generating controlled fusion power in orbit and on the moon and/or aiding terrestrial fusion research.

Lunar material contains industrially valuable metallic materials. But technological advancements in economic exploitation of progressively poorer grades of metal-bearing ore enlarge terrestrial land reserves not counted on at present. Large mineral deposits, especially of manganese, can be mined on the ocean floor. Recycling and substitutions offer additional options for stretching terrestrial metal supplies. The initiation of lunar industrialization, therefore, is more likely to spring from needs associated with large space projects where advantage can be taken of the weak lunar gravity field. The largest potentials in this context are the SPS and Soletta structures. Associated with these are significant transportation requirements. If oxygen/hydrogen propulsion is used from near-earth space on out, large amounts of oxygen must be delivered from earth. In this case, lunar oxygen can be an attractive substitute.

Space industrialization should not be viewed as a competitor to science and exploration; rather, a vigorous space industrialization program can be the main impetus upon which an expanding science program can be carried. Likewise, space industrialization is not in conflict with the increasingly prevalent dream of young people to go into space themselves. That dream becomes more credible as the space industrialization program evolves.

BIOGRAPHY

Charles L. Gould is currently the Program Manager of the National Aeronautics and Space Administration (NASA) study on Space Industrialization, the prospect of using space to produce goods and services of major economic benefit throughout the next thirty years.

Mr. Gould's aerospace background dates back to 1956, when his responsibilities at Wright Air Development Center related to the B-52 and the F-100 through F-108 series aircraft. Later, he was Engineering Officer, U.S.A.F. at Ramstein Air Base, Germany. Since his Air Force active duty, he has had responsible assignments on many advanced projects, as a government employee and later in 1962 at Rockwell International. During the 1960's, he worked on both Apollo and Skylab and was Manager of Electrical/Electronic Systems for the Apollo modifications for Skylab. In the early 1970's, he was Assistant Chief Engineer for the Space Station and Advanced Logistics System studies performed for the NASA. Later he was Engineering Manager for several military projects and managed the Space Division internal research and development program.

He holds a BSME degree from Iowa State University, a Certificate of Business Management from the University of California at Los Angeles, and is a Certified Professional Manager.