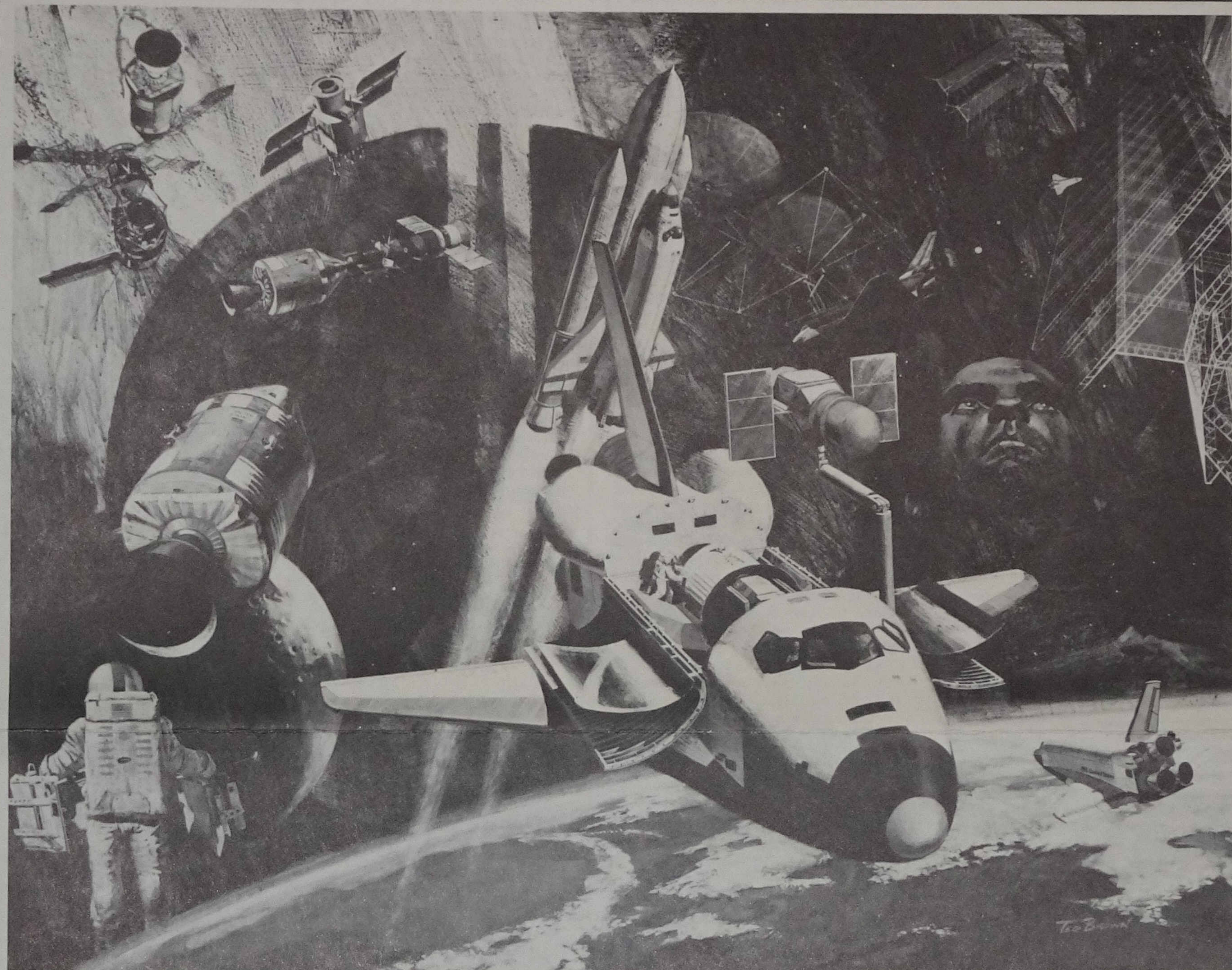
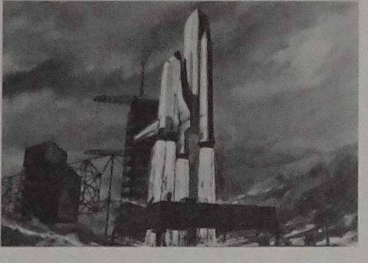


The next giant leap

Rockwell International
Space Division

INDUSTRIALIZA

Space Shuttle will become operational in 1980, and America will embark on a dramatic new course: the routine, practical use of space. One of the goals of that era is space industrialization, which simply is the expansion of our world by the incorporation of the space environment into our productive capacity. Here is a brief look at some of the remarkable benefits that can be foreseen for America and mankind from those industrial activities.



PROLOGUE

Since orbiting its first satellite in 1958, America has turned the "hostile" environment of space into an ally. We're learning to use space as a means of improving life on earth, and we're on the threshold of using it regularly. Following are a few examples of the direct benefits from our first two decades in space:

- It costs some $100,000 and requires thousands of aerial photos to cover 115 square miles of the earth's surface for geological mapping. At this rate, it would cost billions of dollars to survey the earth, but a satellite can send back the equivalent of a $100,000 picture every 25 seconds. Naturalists, oceanographers, ecologists, astronomers, geologists, urban planners, and a growing number of specialists are learning how to use these satellite photos.
- Satellite imagery has provided hydrologists with timely—sometimes critical—information. For example, legislators in Nebraska based their decision to allocate water on satellite-compiled inventories of the amount of water being drawn from drought-lowered water tables. Photos of the entire state, which were 95 percent accurate, were taken from space in about 150 hours.
- Observation satellites have given agricultural investigators valuable information about crop inventories, crop-destroying weeds, diseases, and insects, grazing land, and the amount of moisture retained in the soil.
- Nine years ago the first commercial communications satellite, Early Bird, was orbited to supplement telephone cable traffic between the United States and Europe. Early Bird could handle 240 simultaneous phone conversations. Today seven INTELSAT spacecraft are orbiting the earth, each with 4000 simultaneous circuits for voice and data communications and each serving to transmit television programs around the globe. In 1968, the cost of transmitting a one-hour television program between Europe and America was $22,350; the cost now is $5120. The monthly charge for a telephone circuit between New York and Europe dropped from $10,000 to $4625 during the same period.
- By keeping an eye on hurricanes and other weather systems, weather satellites are saving untold lives and property across the United States. It is virtually impossible for a hurricane to be spawned without being detected by weather satellites. Tracking the storm with pictures from space, meteorologists can predict its landfall with great accuracy. Moreover, they use satellite photos to determine whether the hurricane is "wet" or "dry," giving river forecast centers the information on which to base warnings of potential flooding.

These are substantial benefits, but they have been limited to what we can do working from earth. In a few years, Shuttle will give us a working capability in space. It will carry cargo and specialists into orbit routinely, enabling us to perform tasks ranging from the manufacture of products to the harnessing of solar energy. It is the next giant leap for mankind.

THE ROLES OF SPACE SHUTTLE

Among the features that make Space Shuttle unique are its ability to economically transport cargo to space, its longevity, and its versatility. No other spacecraft has flown more than once, but Shuttle will fly repeatedly. It will accommodate a variety of payloads, all devoted to using space to benefit earth. Following is a summary of what the manned Shuttle system can do:

- **Transport larger and heavier payloads than can be launched by expendable boosters. This not only will reduce the cost of carrying payloads to low earth orbit but will allow us more flexibility in what we take into space.**
- **Carry to space scientific labs and pilot manufacturing plants**—along with scientists, engineers, and technicians. This will enable specialists to make observations, conduct experiments, and develop manufacturing processes in a unique environment that cannot be duplicated on the ground.
- **Return payloads to earth. This will permit us to transport to earth products manufactured in space and to recover and renovate satellites that would otherwise be abandoned.**
- **Deploy, retrieve, and refurbish satellites** in orbit and replace or repair satellite systems. This will lower the cost and increase the orbital lives of these spacecraft.
- **Check out and launch spacecraft to high earth orbit and on deep-space missions.** This will reduce the risk of losing spacecraft from malfunctions during orbital launches.

SPACE IS OUR WORLD TOO

When commenting on the future a few years ago, space observers only conjectured about a self-sustaining space colony. Today they can describe one. The technology needed to build it is clearly within reach.

An essential part of that technology is the ability to transport building blocks to space. This is one of the roles Space Shuttle will play in the future, a future in which space could be used to benefit earth in extraordinary ways. For example: climate control, space hospitals, and permanent space habitats manned by engineers and technicians. Long before we take steps to colonize space, however, we will have done much to industrialize it—space manufacturing will create new materials and new products, personal communications via space will dramatically touch our lives with far-reaching social consequences, and satellite solar power stations will supply continuous energy to earth.

These and other promising possibilities challenge the imagination. Yet they represent barely the beginning of our long-range potential in space, a potential that will depend more and more on the Space Shuttle transportation system. The impact on mankind of these and other space uses can only be estimated. But this much is known: Space is now a very real part of our world, and, beginning in 1980, space benefits will be increasingly realized in our own lifetimes.

Space Promises Exciting New Products and Services; Shuttle Is the Key to Our Long-Range Space Goals

Industrialization is a long-term objective of America's space program, for a very important reason: many things can be produced better and more economically in space than on the ground. There are possibilities in space that simply don't exist on earth. Our goal in industrializing space is not to compete with earth but to complement it, not to duplicate the production here but to extend our capabilities.

A New National Theme: *Power From Space*

George W. Jeffs, President of North American Space Operations, in a recent statement presented to the U. S. House of Representatives, spoke of the importance of space industrialization. The following excerpts are from his speech.

"The compelling demands for moving out aggressively now in space industrialization fall into two categories: (1) pressing world and national problems and (2) the availability of routine, economical space transportation and machinery to operate in space.

"I view space industrialization as a potential means to help deal with the rapidly approaching crisis in energy. With the proper national resolve, we have the potential to achieve American energy self-sufficiency, become a major energy exporter, and arrest the contamination of our environment caused by the large-scale burning of fossil fuels. Space-based systems can become significant contributors to this objective. We can now proceed more rapidly with space industrialization, since the needed transportation system is nearly ready. . . .

"When Shuttle enters routine service in just a few years, launch costs will decline dramatically, and a wide range of new operating capabilities will become available. . . .

"Through its use, an order-of-magnitude expansion in space R&D participation by individuals, industry, and international groups will be possible. . . .

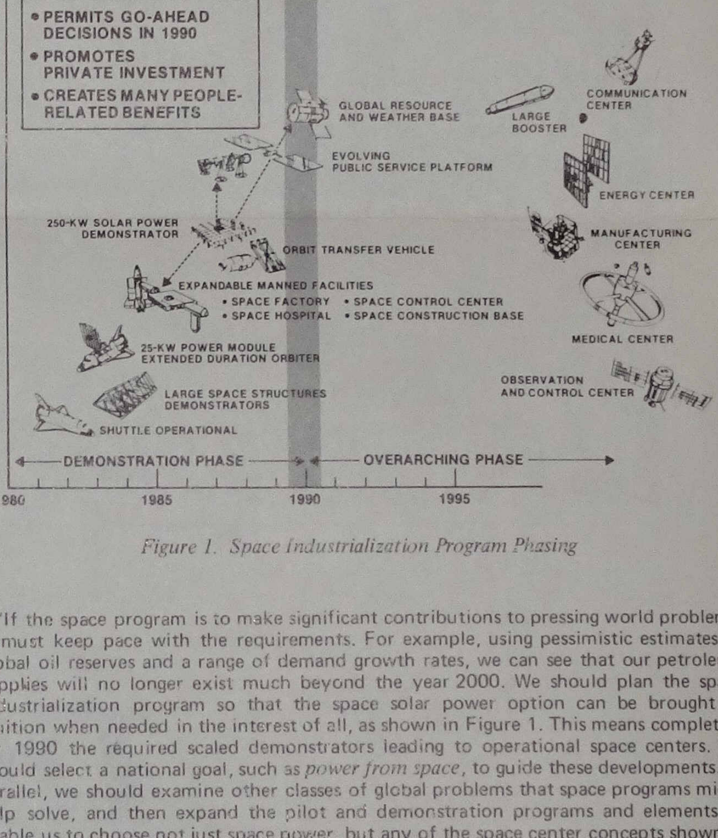


Figure 1. Space Industrialization Program Phasing

"If the space program is to make significant contributions to pressing world problems, it must keep pace with the requirements. For example, using pessimistic estimates of global oil reserves and a range of demand growth rates, we can see that our petroleum supplies will no longer exist much beyond the year 2000. We should plan the space industrialization program so that the space solar power option can be brought to fruition when needed in the interest of all, as shown in Figure 1. This means completing by 1990 the required scaled demonstrators leading to operational space centers. We should select a national goal, such as *power from space*, to guide these developments. In parallel, we should examine other classes of global problems that space programs might help solve, and then expand the pilot and demonstration programs and elements to enable us to choose not just space power, but any of the space center concepts shown in Figure 1. Such a program, starting with a *power from space*-aligned building-block *demonstration phase* now, will provide the foundation upon which a truly *overarching phase* space industrialization program can be structured."

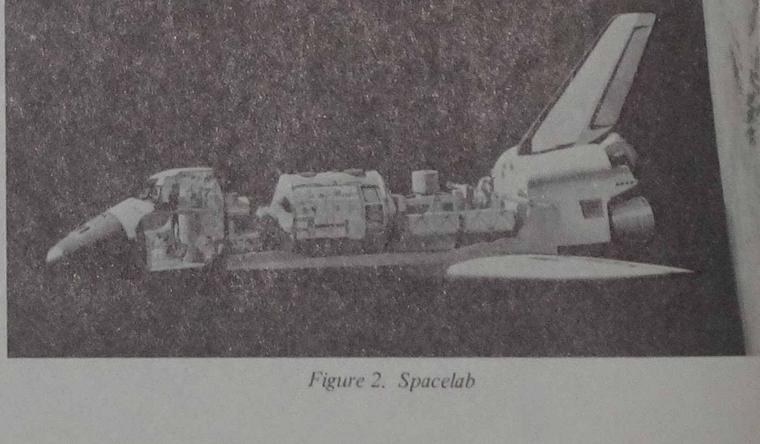


Figure 2. Spacelab

ATION OF SPACE

SPACE MANUFACTURING

Initial manufacturing research and development will be conducted on Spacelab missions in the early 1980's (Figure 2). By the mid-1980's, this work will have been gradually shifted to interim pilot manufacturing stations. The first products manufactured in space will be produced in relatively small facilities deployed from the Shuttle orbiter's cargo bay and serviced by the orbiter at regular intervals (Figure 3). Fully developed commercial production facilities, operated by private companies, are expected to be operational by the late 1980's.

Ball Bearings That Never Wear Out

Levitation melting in space (without benefit of a container) has several advantages: container contaminates are eliminated, perfect shapes can be formed, and alloys of immiscible materials can be developed. The melts will be heated by heating coils and handled by the orbiter's manipulator arm. By injecting gases into mixtures or metal melts, we could produce extraordinary materials—for example, steel as light as balsa wood. Glass and steel, impossible to combine on earth, also could be mixed in space. And a perfectly shaped ball bearing could be manufactured in orbit that might last indefinitely.

Crystals Without Flaws

Earth-formed crystals, widely used in electronic applications, are limited in size and seriously flawed by microcracks, dislocations, and contaminants. We know from the Apollo, Skylab, and Apollo-Soyuz programs that crystals approaching perfection can be made in space. There are no contaminants to migrate from container walls, and materials are uniformly distributed in the still, weightless environment. Moreover, in the absence of gravity, it is possible to form unusually large crystals.

The facility shown in Figure 3 is designed to process silicon crystals. It would be automated, operating on the energy supplied by its solar arrays. The Shuttle orbiter would periodically replenish the facility's raw material and pick up the finished crystals, eventually bringing them to earth.

Surface acoustic wave devices will benefit greatly from the flawless crystals produced in space. Some of the advantages that will accrue to electronic systems are high frequencies and large bandwidths, easily formed complex structures, integrated-circuit manufacturing techniques, and precise reproducibility and design predictability. Eventually, there will also be a cost advantage. According to a study conducted by General Electric for NASA, the break-even point for an investment in this space product would be reached in 12 years (Figure 4).

Electronic products and services are a multibillion-dollar industry in the United States, gross sales having reached $35.4 billion in 1974. It is conservatively estimated that space-related electronic products will gross $2 billion per year: the production of superpure and large crystals will lead to the opening of new fields in engineering and to the creation of new products and instruments; new types of bubble memory components will have a substantial impact on the computer industry; and additional capabilities in the microminiaturization of large-scale integrated circuitry will be a boon to medicine and communications.

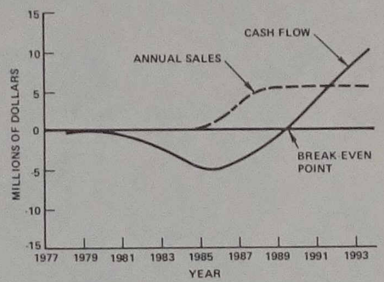


Figure 4. Return on Investment for Space-Produced Surface Acoustic Wave Devices

A New Dimension in Optics

Glasses with unique qualities can be manufactured in space. Since containers won't be required in the production process, no contamination will be present to cause crystallization; and higher temperatures can be used for making glass, thus introducing new materials for the optic designers.

Space-made glasses will add a new dimension to the world of optics. They will improve microscopes and telescopes, and lenses made from them will be a source of everlasting delight for camera buffs.

Better Products and Savings Too

The directional solidification experiment conducted on the Apollo-Soyuz mission was an outstanding success, producing 60- to 100-percent improvement in the coercive strength of permanent magnets. Space-made magnets exhibit a high degree of magnetic alignment, which means more magnet for less weight. These enhanced properties, leading to the development of smaller and more efficient components for products such as electric motors and transformers, will offset the higher cost of space production.

Directional solidification could benefit earth in many other ways. For example, turbine blades produced at higher temperatures in an orbiting factory would dramatically increase the efficiency of jet engines and thermal power plants. And greater efficiency would inevitably lead to cost savings. In a recent study, it was estimated that over a 10-year period the savings for airplanes alone could total $6.6 billion and 6.5 billion gallons of fuel.

Longer Lives Through Medical Advances

Medicine will benefit tremendously from the Shuttle era and space industrialization. Indeed, our lives should be longer and healthier because of the medical advances made possible by space. Here are several promising examples of these medical returns:

Long-chain organic molecules (such as proteins) have specific ionic charges. In solution, these ionic species move in response to an imposed electrical field (electrophoresis). After a period of time, because each species in a mixture has a unique charge, the various species will have separated by virtue of their differing drift rates. Unfortunately, the electrical field produces heat, which causes the solution to vary in density. On earth, gravity induces convective motion in the solution, mixing the ion species being separated. In the zero-g environment of an orbiting vehicle or a satellite, however, there is no convective motion. Thus the species separate unhindered, which results in much greater purity.

Electrophoresis is a powerful analytical tool in space. For example, it facilitates the separation of isozymes, which have ionic strengths of nearly equal value. Our metabolic processes are controlled by about 2000 enzymes, 100 of which have been found to be mixtures of isozymes. If these and other isozyme groups could be isolated and studied, we could predict body disorders and imbalances much earlier than can be done with present diagnostic techniques.

Electrophoresis can also be used to produce high-quality urokinase, a catalytic substance created by a small group of cells in the kidneys. Urokinase prevents blood clotting, and it is more precious than gold. Over a ton of urine must be processed to obtain just one dose, which costs $1200! Obviously, urokinase is not available in quantity and is used only for special clinical treatment and research.

In experiments performed aboard Apollo, Skylab, and Apollo-Soyuz, it was found that high-purity urokinase cells could be separated rapidly with electrophoretic techniques. A couple of Shuttle flights per year could supply the United States' urokinase needs.

Another candidate for space processing is insulin. In a normal person, insulin regulates the metabolism of sugars. Diabetes results when the pancreas produces an insufficient amount of insulin to serve that purpose.

Since human sources of insulin are limited, severe diabetes is treated by the daily injection of insulin extracted from the pancreas of animals. There are allergenic and immunologic hazards in this treatment, however. Moreover, the demand for insulin is increasing at such a rate that the supply is expected to be short by the end of the 1980's.

Electrophoretic production of human insulin in space offers a means to forestall this impending crisis. The projection for a plant making insulin in space shows that the cost per dose would drop as space processing replaces terrestrial production, with supply rising to meet demand in the late 1980's (Figure 5).

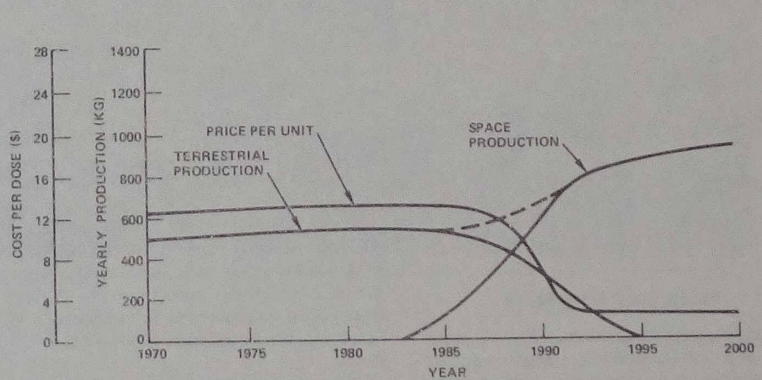


Figure 5. Production of Insulin

ERECTABLE STRUCTURES

The prefabricated structures to be erected in space will be huge, spidery assemblies ranging in diameter from 300 to 3000 feet. All structural elements will be fabricated on the ground and transported to low earth orbit by the Shuttle orbiter, which also will serve as the construction base (Figure 6). Low-thrust propulsion systems will transport the structures to their operational orbits.

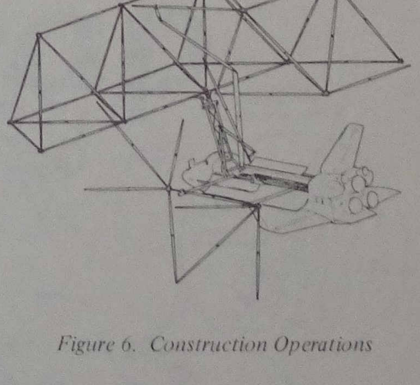


Figure 6. Construction Operations

Space Mail

While the mailman will continue to make his rounds through rain, sleet, and snow, space industrialization promises to give us a revolutionary new way of writing to Aunt Agnes. The letter would be "delivered" electronically by satellite through the use of facsimile scanning techniques. Among the advantages of electronic mail are faster delivery, lower costs, and greater reliability.

A 900-foot-diameter antenna platform suitable for transmitting electronic mail (Figure 7) would be assembled at an altitude of 300 nautical miles. The platform would be made entirely of identical struts and unions. A single strut would be 27 feet long; two would be coupled together to make a 54-foot assembly

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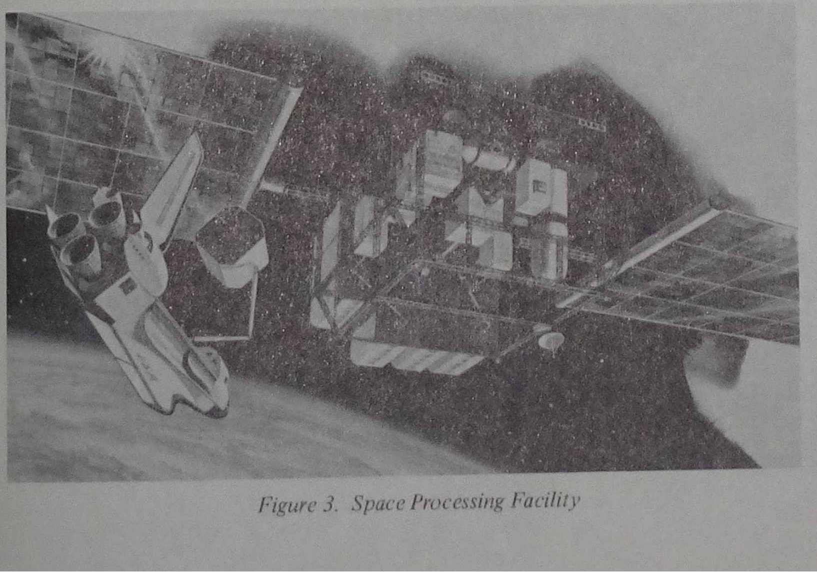

Figure 3. Space Processing Facility

Erectable Structures

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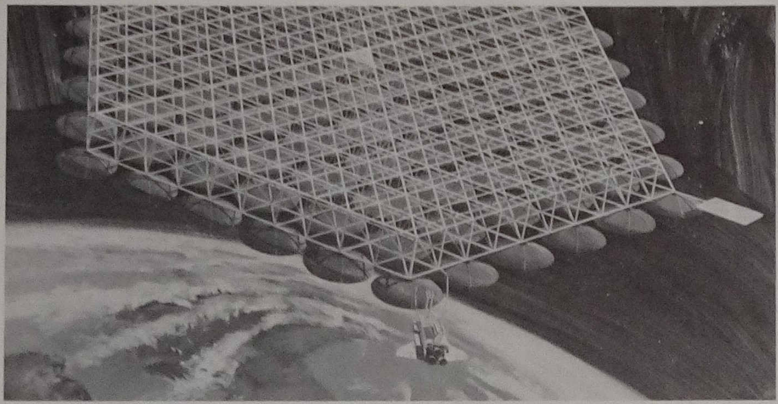

Figure 7. Antenna Platform

strut. Figure 8 shows how the struts would be nested in the orbiter's cargo bay. It would take 2670 54-foot struts and 631 9-point unions (Figure 9) to build the platform, whose weight is estimated to be 67,500 pounds.

Three Shuttle flights would be needed for the assembly of a 900-foot antenna structure, a third of the prime payloads plus adequate spares being taken up on each flight. The assembly operation, requiring orbiters with extended-mission capabilities, would take 6 to 12 months, including orbiter turnaround time.

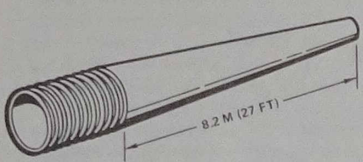

Figure 8. Struts Nested for Storing in Orbiter Cargo Bay

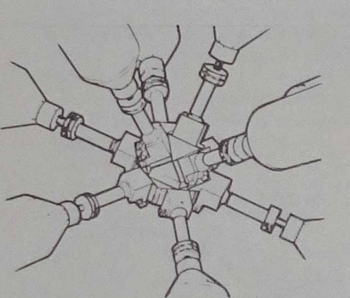

Figure 9. Ball-and-Socket Union

Phone Calls From Space

Space industrialization could revolutionize one of America's most popular institutions—the telephone call. In the not-too-distant future, a call to Europe or to the corner pharmacy may be completed through space. Instead of calling your friends at their homes, offices, or clubs, you would dial them directly; you wouldn't have to know their whereabouts. The telephone would be a small, hand-held communicator or a wrist radio. There would be little interference from adjacent users, and the signal-to-noise level would be 20 to 30 decibels (S/N for an FM radio is 30 decibels).

A personal communication satellite that would make this possible might be a much larger structure than that used for electronic mail. Its 66,000 square feet of solar collector area would provide the energy for the system's three 83-foot-diameter antennas, each with a 60-beam capacity. The orbiter would transport the structural elements to space, then function as the construction base for assembly of the 13-1/2-ton structure. The satellite could service approximately 2.4 million users, assuming a five-percent usage rate. Hardware elements of the system could be demonstrated initially in the orbiter (Figure 10).

Cost of service would be surprisingly low. A call from Los Angeles to Washington, D.C., would cost no more than one to your next-door neighbor. Moreover, we would save the enormous cost of developing and maintaining our present telephone system. (Provisions would have to be made, of course, for making calls to persons in buildings or cars and calling from within structures that interfere with signals to the satellite.)

The reduction in long-distance communication costs would open up a host of services for the individual user, services now enjoyed only by institutions, large organizations, and the wealthy. Instant stock market quotations would be available to the smallest investor, and information obtainable only in large municipal or university libraries could be expanded and categorized in the Library of Congress or the Smithsonian Institution. This centralizing of information would reduce the cost nationally and improve service. Data now available solely to experts would be at the fingertips of consumers at every level.

Crime prevention, safety, and first aid are other areas that would benefit from the personal communication system. Victims of crimes or persons being threatened could dial the police, and those who are lost could get directions or help, even though the callers don't know where they are. And the seriously ill or injured could be given first aid by paramedics or others under the direction of doctors until the victims could be taken to a hospital.

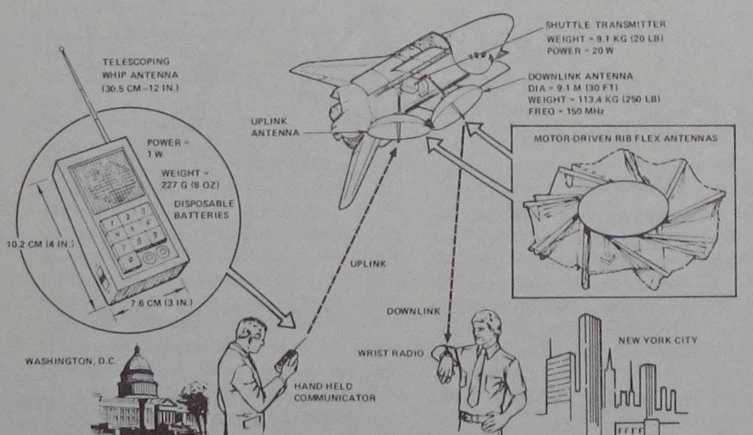

Figure 10. Concept for Demonstrating Personal Communication System Hardware

LARGE SPACE STRUCTURES

As stated previously, structures *erected* in space will be up to half a mile in diameter; but some of those *built* in space will be many miles long. The materials for these superlarge structures will have to meet several stringent criteria. Besides satisfying structural, thermal, and weight requirements, the materials must be compatible with high-speed, automatic machine processing, a low-energy atmosphere during processing, and high-density packaging. These are properties of graphite fibers.

Shuttle will deliver the fabrication machinery as well as the materials to space. A fabrication fixture, hinged to the cargo bay doors, could be rotated out of the cargo bay by the manipulator arm, and into a configuration for producing long trusses. A beam builder (Figure 11), mounted on the fabrication fixture, could manufacture four 656-foot beams in four operational positions. After being rotated, it would build the cross members (Figure 12).

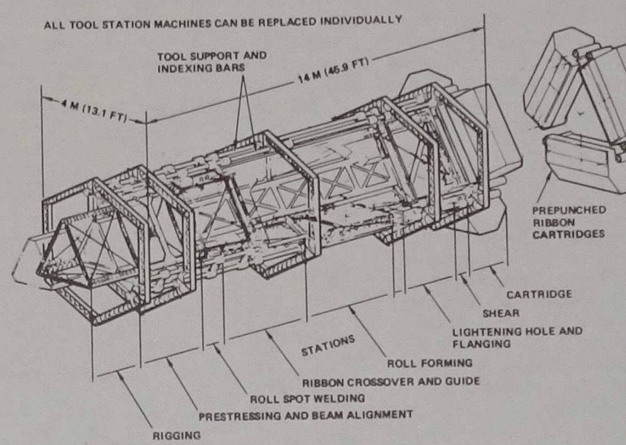

Figure 11. Beam Builder

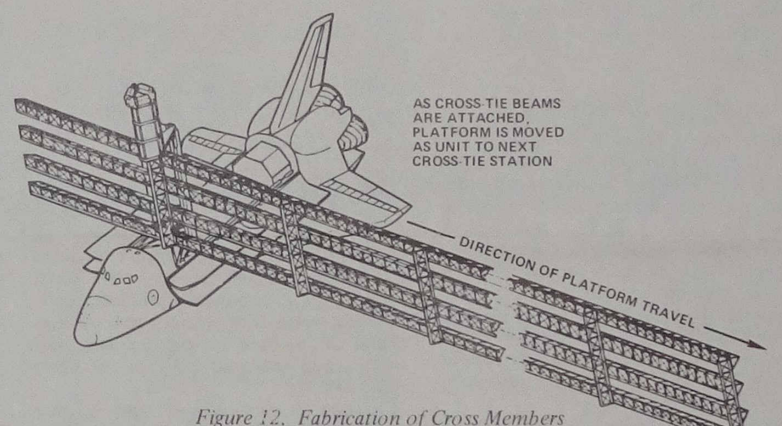

Figure 12. Fabrication of Cross Members

Energy for Earth

One of the most exciting prospects in space is energy. In space, solar radiation is both limitless and constant. To tap this unmatched source of energy is a major goal of space industrialization.

A satellite solar power station would be more than 20 square miles in area (Figure 13). After being fabricated and assembled in low earth orbit, it would be placed in geosynchronous orbit (about 22,000 miles out in space), where it would remain in the same relative position to earth. The trip to its operational orbit would take about six months.

Sunlight bathing the station would be converted to electricity by solar cells, and the resultant energy would be beamed to earth by microwave transmission. Huge ground receivers would convert the microwave energy back to pollution-free electricity. The station would generate 5 gigawatts of energy day and night, which is about the capacity of the Grand Coulee, Hoover, and St. Lawrence Dams combined. This amount of energy would almost meet the needs of the greater Los Angeles area.

In the first two decades of the 21st century, the energy capacity of the projected 180 solar power stations installed in space could supply as much as 25 percent of America's electrical requirements.

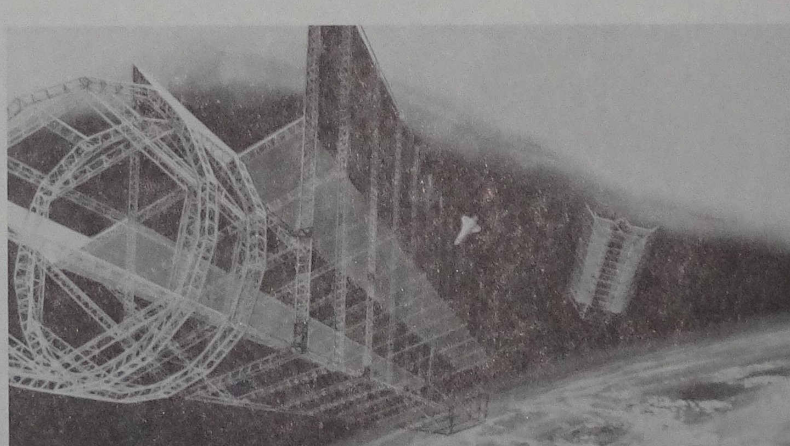

Figure 13. Satellite Solar Power Station