



# The Space Station Power System

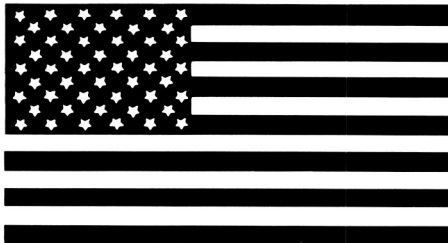
(NASA-TM-101245) THE SPACE STATION POWER  
SYSTEM (NASA) 12 p CSCL 22B

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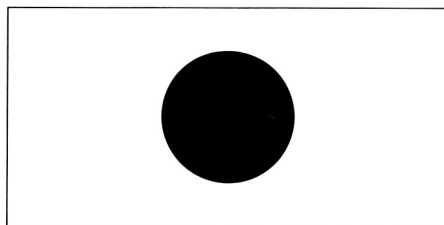
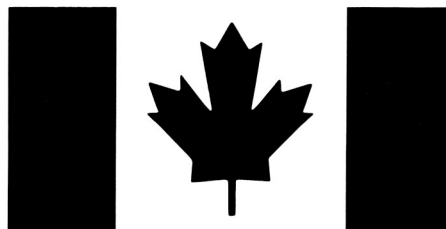
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The Space Station represents the commitment of the United States to a lasting future in space. This future will be ripe with intellectual and technical challenges. It will hold vast opportunity for commercial profit and preservation of the nation's economic vitality. It will be both a research facility in space and a stepping-stone to long-term human



space exploration and discovery. The Space Station demonstrates that America's significant achievements in space lie ahead of us, not behind us. The Station also symbolizes our nation's desire to cooperate with others in mutually beneficial civil space activities. Canada, the European Space Agency, and Japan have already responded positively to the U.S. invitation to participate in the development of the Station. Formal agreements are being negotiated and are near completion. If the negotiations are successful, their involvement will lead to unprecedented international cooperation, toward the peaceful exploration and utilization of the space environment.

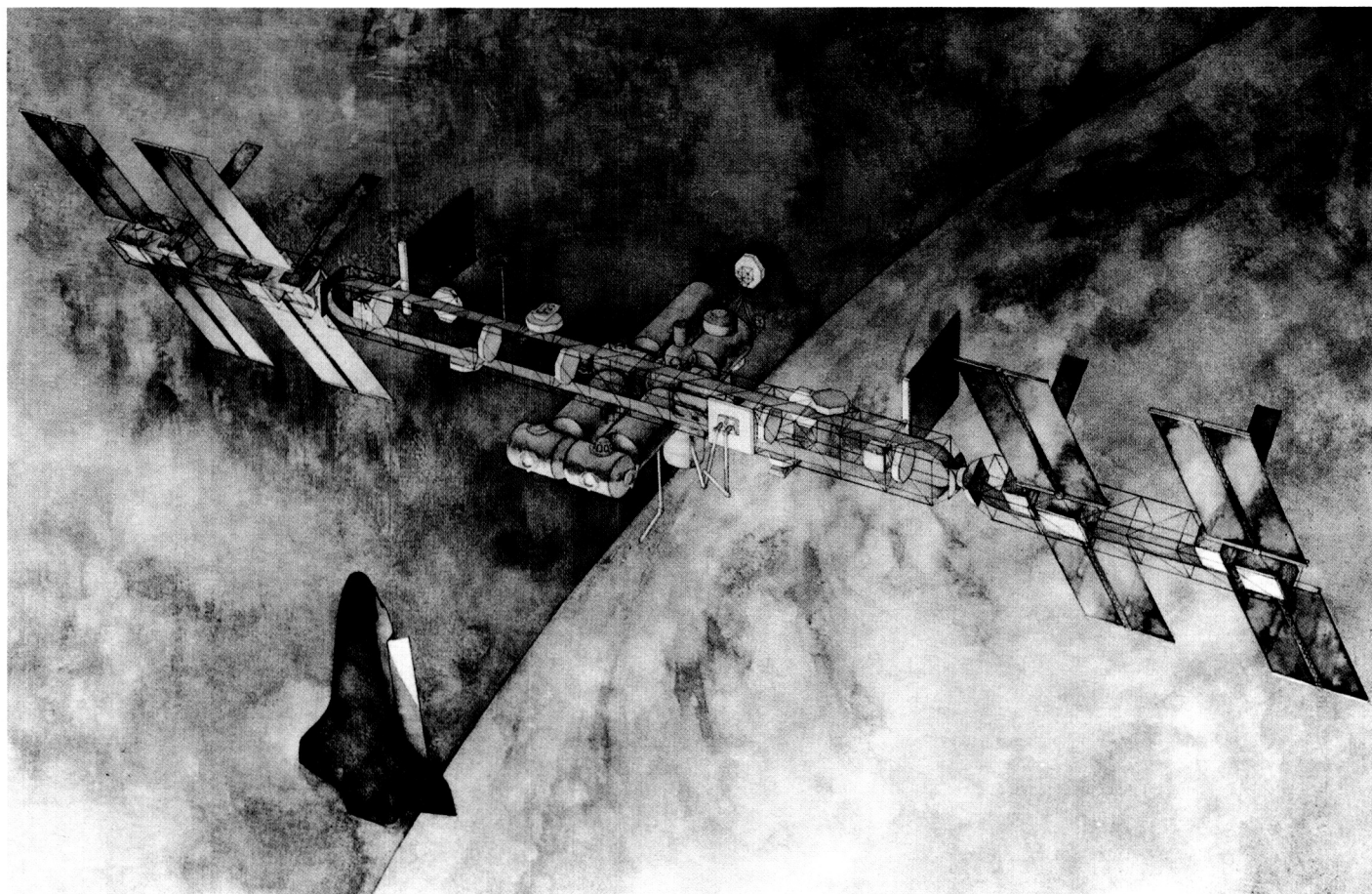


The Baseline Configuration of the Space Station, depicted in this brochure, is a result of several years of analysis and definition by NASA and industry. This configuration has been endorsed by the Administration, consistently supported by Congress, and independently validated by outside experts. It represents this nation's determination to continue a vigorous exploration and utilization of the frontiers of space for peaceful purposes.



## Background

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During the early planning stages of the Space Station Program, before the first engineer was allowed to set pencil to paper, two major questions had to be answered:

Who will use the Space Station?

What resources will have to be provided to those users?

A detailed survey of the technical community showed that five types of experiments would most likely be performed on the Space Station:

1. Observational sciences (astronomy and Earth observations),
2. Life sciences,
3. Materials sciences,
4. Servicing/repair, and
5. Technology development/testing

The major resources those potential users demanded were found to be:

Power  
Volume  
Crew time

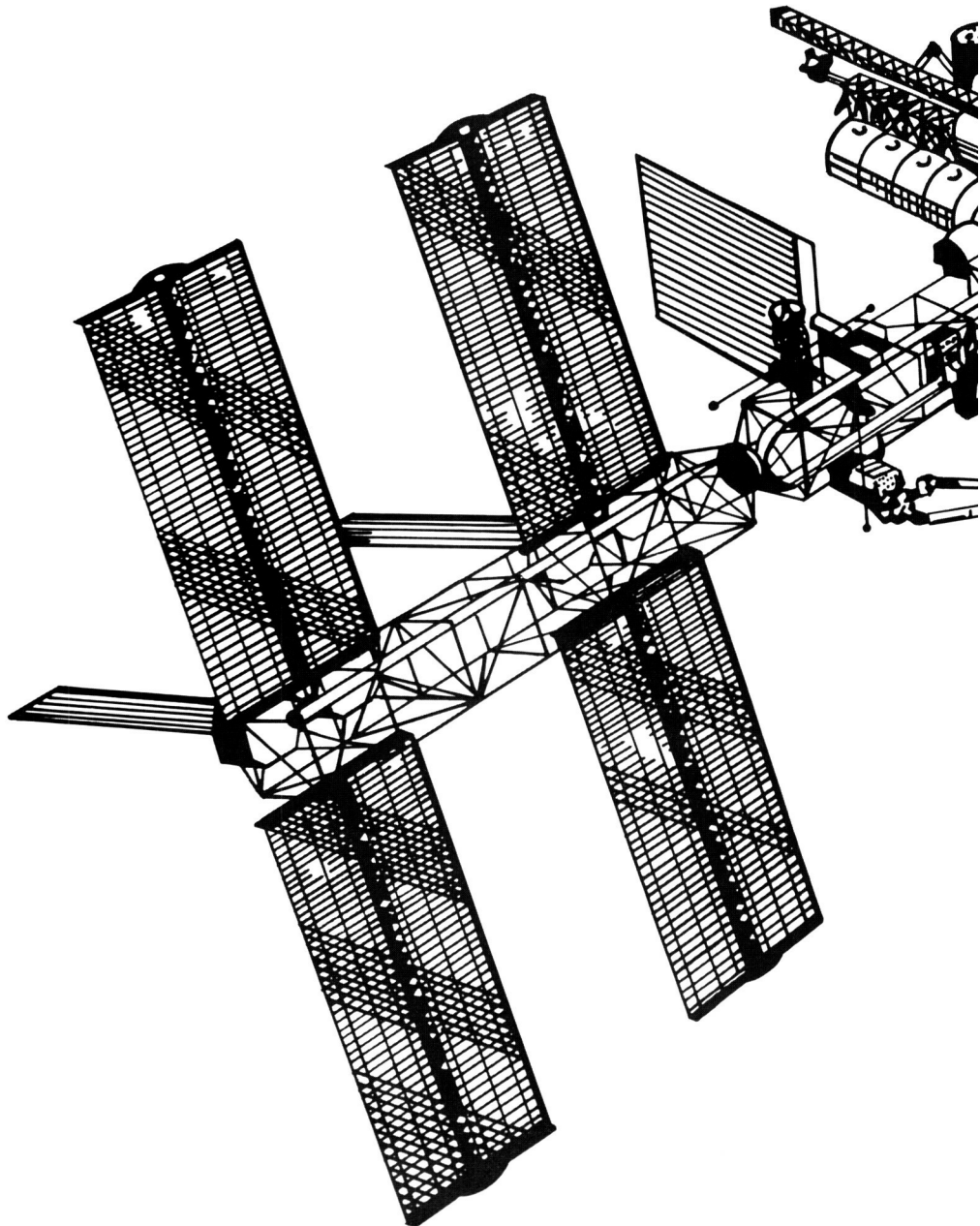
The quantitative evaluation of these user requirements defined the ground rules for the engineering studies that led to the system definition and preliminary design of the Space Station baseline configuration.

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## The Space Station Power Level

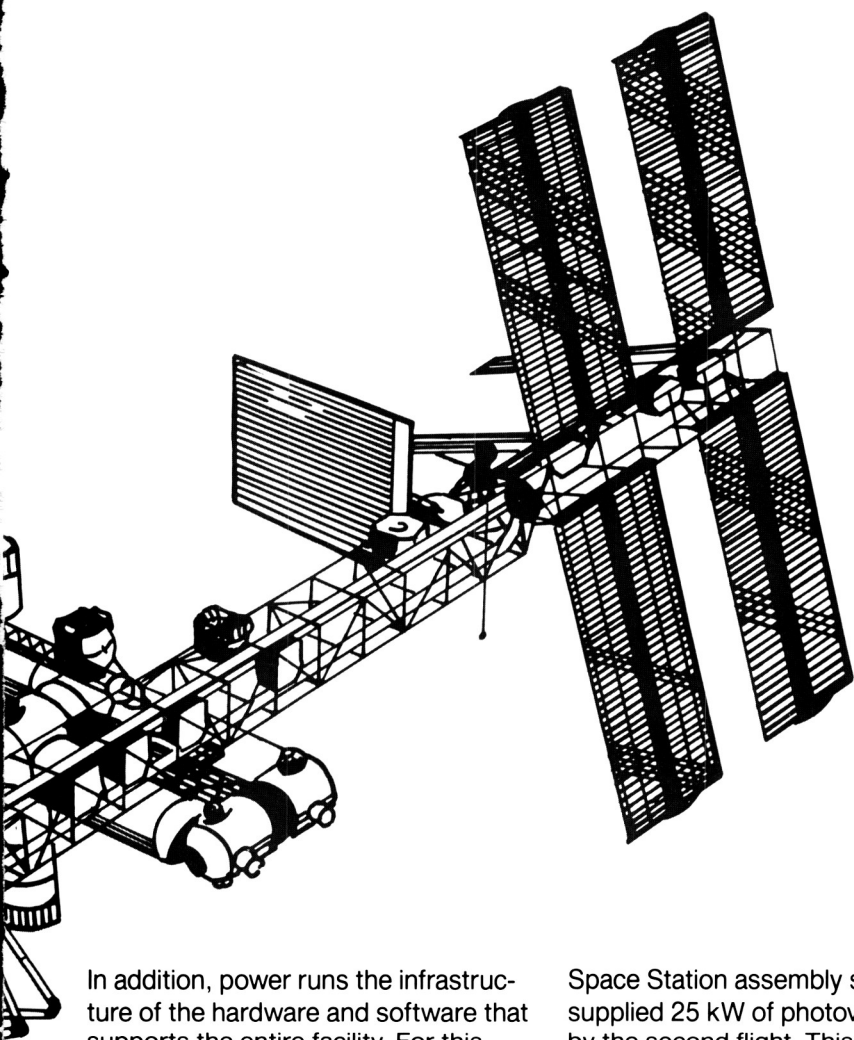
Electrical power, in many respects, is the most critical resource aboard the Space Station. Electricity is essential to supporting human life in space. It also allows a multitude of systems on board Space Station to operate, support, and produce. Whether electricity is used to power life support systems, to run a furnace making crystals, to manage a computerized data distribution system, or to operate a centrifuge, electricity is the key.

The more electricity available, the more work possible, and the more flexible the entire array of Space Station activities becomes. A comfortable amount of power allows men and women to utilize their own most precious resources: observation and innovation. Adequate power allows a crew, in orbit, and a variety of researchers, using telescience capabilities from the ground, the opportunity to make instantaneous observations and responses. In a severely power-constrained environment, flexibility and spontaneity are diminished. This, in turn, limits the invaluable utility of a permanent human presence in space.





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In addition, power runs the infrastructure of the hardware and software that supports the entire facility. For this reason, Space Station power systems and power-level projections have been an important focus of attention during Phase A and Phase B definition and design stages.

The power level given as the ground rule in the "reference configuration," the starting point for analytical studies during the Space Station Concept Definition and Preliminary Design Phase (Phase B), was 75 kW with growth capability to 300 kW. The

Space Station assembly sequence supplied 25 kW of photovoltaic power by the second flight. This 25 kW of power would support general station-keeping requirements and early payloads that would be provided during the assembly phase of the program. An additional 50 kW of solar dynamic power was planned downstream in the assembly sequence, raising the total power supply to 75 kW, the baseline level for the permanently manned phase. This figure was based on the projected needs of the future Space Station user community and early estimates of the housekeeping power.

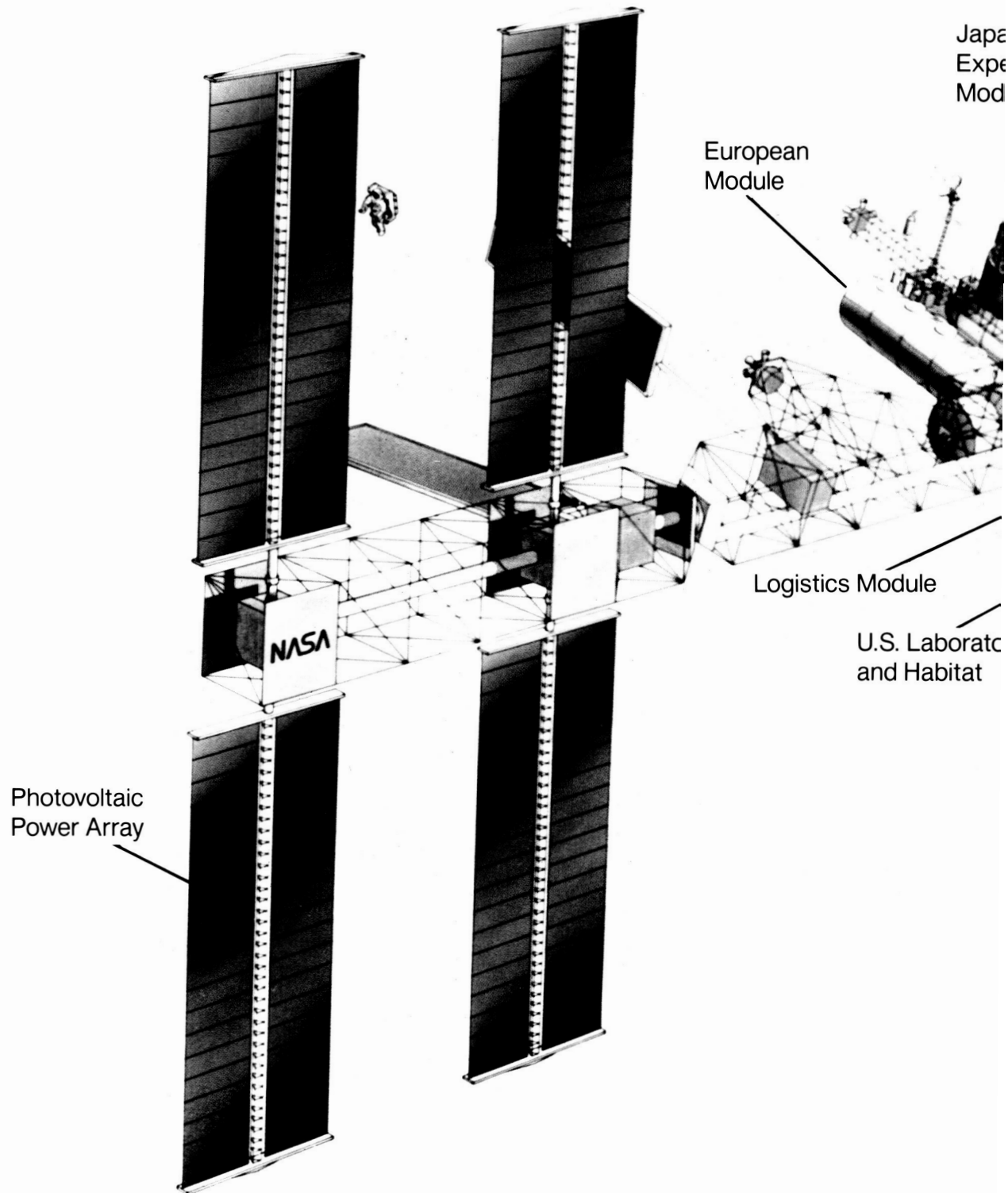
A review by Congress of Space Station concluded that the preliminary power level of 25 kW was insufficient to adequately support early payloads. As a result, the initial power level was increased to 37.5 kW of photovoltaic power. With the addition of the 50 kW of solar dynamic power intended for the later stage of the Station development, the total power level for the program climbed to 87.5 kW. It should be noted that the absence of a permanent crew in such a configuration makes crew time the most critical parameter and severely limits the kind of experiments that can be performed.

The Space Station review ordered by the NASA Administrator at the end of Phase B resulted in several changes to the Phase B results, including a reordering of the assembly sequence to allow for early user operation and confirming power at 87.5 kW.

A subsequent cost review resulted in the "phased" approach to construction of the Space Station. Early calculations of power needed in this approach yielded 50 kW. Further examination of user and housekeeping requirements, however, resulted in an increase of that figure to 75 kW for Phase I and an additional 50 kW (125 kW total) for a future Phase II.

## Baseline Configuration

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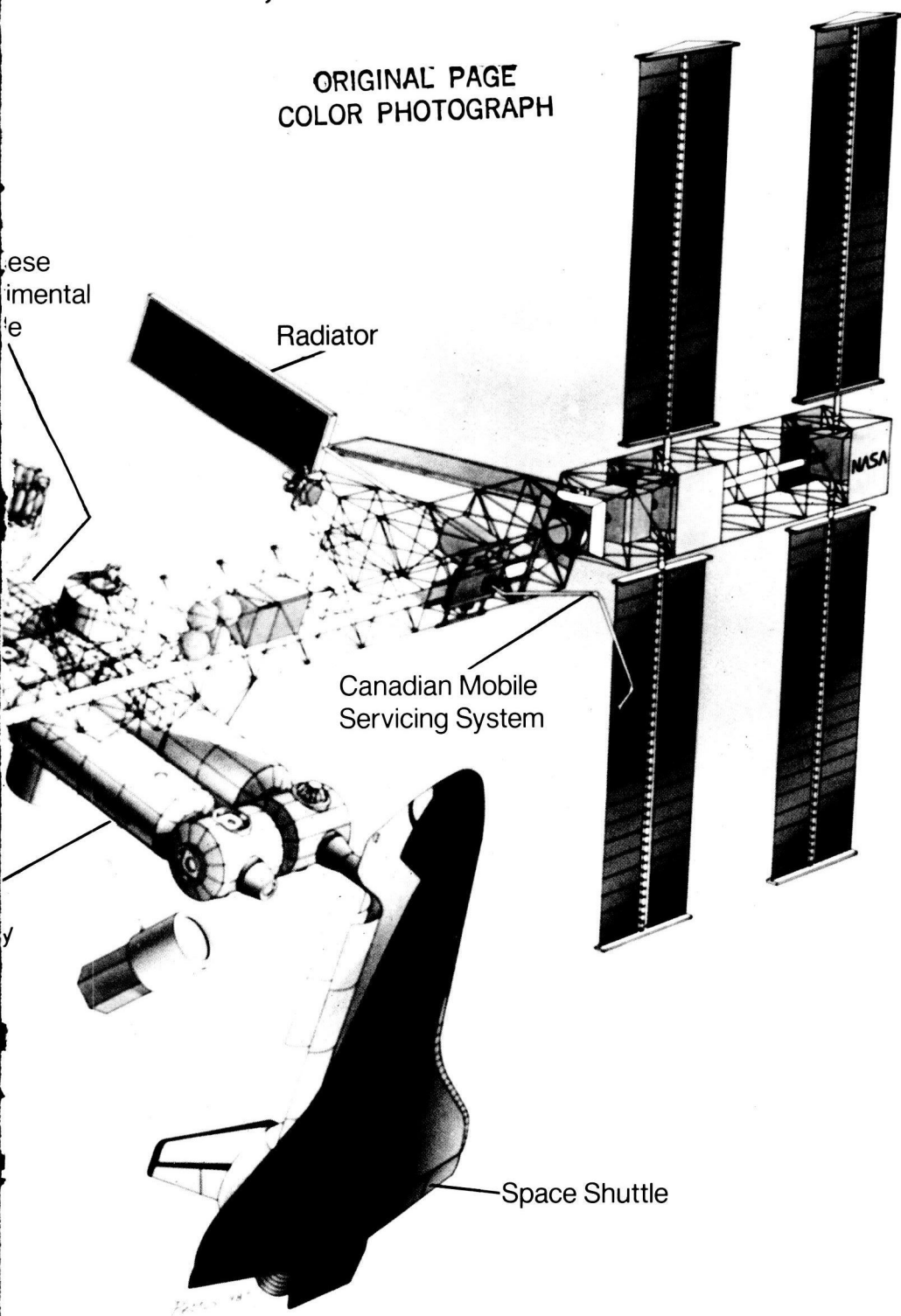
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Radiator

Canadian Mobile  
Servicing System

Space Shuttle



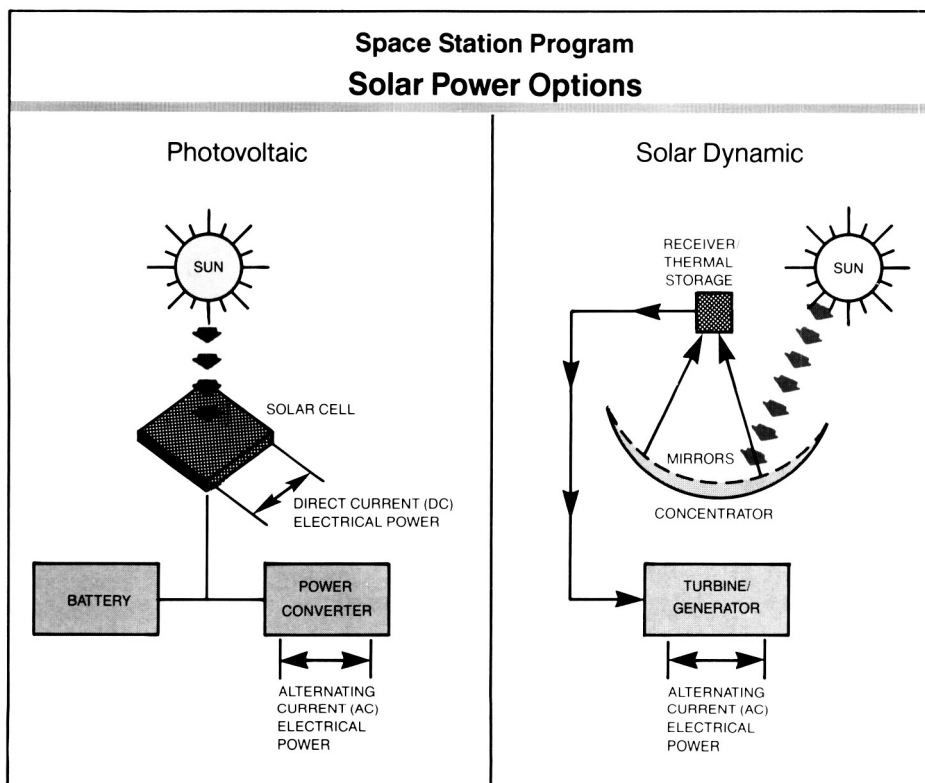
## The Space Station Power System

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The only continuously available source of energy in this solar system is the Sun. The Sun's energy is available in the form of light and heat; however, spacecraft need electricity. Accordingly, NASA has pioneered and is continuing to develop technologies to efficiently convert the Sun's energy (light and heat) into electrical power.

Some materials, such as silicon and gallium arsenide, can directly convert light to electricity. Hence, "solar cells" can be made from these materials. The efficiency of energy conversion by this method is not very high; it ranges from 5 to 10 percent. The cells, however, can be assembled into "arrays" and these can be used to generate high power levels. In fact, the 75 kW required for the Space Station Manned Base and the power for the Polar Platform will be generated entirely by solar arrays.

A spacecraft in orbit around Earth is not always in direct sunlight. Thus, energy has to be stored to provide a continuous source of electricity. Storage is usually accomplished by using batteries, which is the method of choice for Space Station. The Space Station "photovoltaic power module" contains both the solar arrays and the batteries.



The photovoltaic power system is well understood and has the advantage of being off-the-shelf technology. Its disadvantage is the large size of the arrays required to generate sufficient power. In addition, the large weight and relatively short lifetime (about five years) of the batteries is a disadvantage.

The Space Station will operate in low Earth orbit (about 220 nautical miles). In this, or any other near-earth orbit, there is a certain amount of "drag," i.e., resistance to the progression of the spacecraft. As a consequence, the spacecraft tends to slow down. This results in a loss of altitude, a gradual progression towards an ultimate de-orbit. To prevent the Station from eventually reentering the atmosphere, periodic reboost of the spacecraft is necessary. This requires a resupply of propellant: the larger the area, the larger the drag, and the more reboost propellant is needed. Resupply of the propellant is part of the life-cycle cost.

Decreasing the area of the spacecraft minimizes drag. The largest area of the Space Station is the solar arrays. Early design concepts indicated that a reduction in the area of solar arrays represented life-cycle cost reduction.

However a newer design concept has mitigated the increased life-cycle costs associated with reboosting, by using a hydrogen fuel obtained from surplus supplies of water. Therefore, the size of the solar array no longer drives life-cycle costs as directly. Another source of life-cycle cost is the need to replace the batteries after five years. The use of a long-life energy storage system represents life-cycle cost savings.

A solar dynamic power system might provide a solution for these problems. This technology, far different from the photovoltaic system, utilizes the Sun's heat instead of its light for the production of power. Heat is collected in the focal point of a mirror. Power is then generated exactly the same way as on an earthbound power station: by heating a fluid, which in turn rotates a turbine. Since a heat/gas-driven turbine is a much more efficient power converter than a sunlight-driven solar cell, the mirror (the largest part of the solar dynamic system) would have to be only one-fourth the area of a solar array to generate the same amount of power from the Sun's light.

There are several different engines that can be used for the generation of power within the solar dynamic system. They are similar in that they are "closed cycle," i.e., they recycle the working fluid. These engines are usually known by the names of their inventor. For use on Space Station, the Brayton Cycle engine has been selected.

The energy storage device used for a solar dynamic power system is superior to a photovoltaic system because heat is stored rather than electricity. Heat is cheaper and far more simple to store for subsequent use. Storage can be accomplished by taking advantage of the heating, or fusion, of inorganic salts. On the sunny side of the Earth, heat is absorbed by the salt and it melts. On the dark (cold) side the salt freezes and gives up its heat to the working fluid of the engine, ensuring continuous operation.



## Summary

An abundant supply of power is one of the top priorities for users of the Space Station and, therefore, of highest priority for the Space Station Program. It was for this reason that the original "hybrid" power system was chosen: it provided early power to the user by using off-the-shelf photo-

voltaic/battery technology, then adding the more "growable," but higher risk, solar dynamic system later. This concept was revised in light of budget realities. By using only photovoltaic modules in Phase I, NASA will be able to meet budget restrictions without sacrificing the needs of the users. The

ability to utilize solar dynamic systems with lower life-cycle cost will be added in the future as the Space Station evolves.

Solar Power Options:	Advantages	Disadvantages
PHOTOVOLTAIC	<ul style="list-style-type: none"> <li>• Large Data Base for Small Rigid Arrays with Batteries</li> <li>• Tolerant of Pointing Errors</li> <li>• Flexible Array Demonstrated</li> <li>• Technology Well Understood</li> </ul>	<ul style="list-style-type: none"> <li>• Limited Data on High Voltage Arrays</li> <li>• High Life Cycle Cost</li> <li>• Development Risks on Large Array and Energy Storage</li> <li>• Large Drag Area</li> </ul>
SOLAR DYNAMIC	<ul style="list-style-type: none"> <li>• High Efficiency</li> <li>• Terrestrial Data Base</li> <li>• Low Life Cycle Cost <ul style="list-style-type: none"> <li>— Low Drag Area</li> <li>— Low Production Cost</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>• Limited Phase Change Salt Data</li> <li>• Higher Development Cost Than Photovoltaic</li> <li>• More Sensitive to Pointing Error than PV</li> <li>• Not Demonstrated in Space</li> </ul>
HYBRID	<ul style="list-style-type: none"> <li>• PV Power for Early Station Buildup</li> <li>• SD Low Cost Power as Requirements Increase</li> <li>• Low Life Cycle Cost</li> <li>• Diverse Power Sources</li> </ul>	<ul style="list-style-type: none"> <li>• Requires Development and Logistics Support of Both Systems</li> </ul>

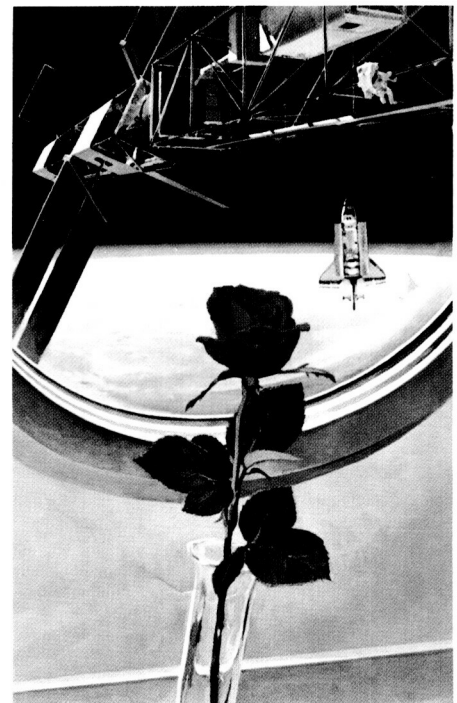
## Other Publications About the Space Station

The Office of Space Station produces documents describing different aspects of its program.

For more information, please  
contact the Space Station Public  
Affairs Office at:

NASA Headquarters  
Code SF

Office of Space Station  
Washington, DC 20546



National  
Aeronautics  
and Space  
Administration

**NASA**

A black and white photograph showing a satellite antenna structure in the foreground, with a view of Earth from space in the background. The antenna is a complex of metal beams and cables, with a prominent vertical mast. The Earth is visible as a curved horizon with clouds and landmasses. The lighting is dramatic, with strong highlights and deep shadows.

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