NASA Facts

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Powering the Future

NASA Glenn Contributions to the International Space Station (ISS) Electrical Power System

The International Space Station, the largest scientific cooperative program in history

What's in a Space Power System?

Electrical power is the most critical resource for the International Space Station (ISS) because it allows the crew to live comfortably, to safely operate the station, and to perform scientific experiments. So, whether it is used to power the life support system, run a furnace that makes crystals, manage a computerized data network, or operate a centrifuge, electricity is essential.

Since the only readily available source of energy for spacecraft is sunlight, NASA Glenn Research Center has pioneered, and continues to develop, technologies to efficiently convert solar energy to electrical power. One method of harnessing this energy, called *photo-voltaics*, uses purified silicon solar cells to directly convert light to electricity. Large numbers of cells are assembled in arrays to produce high power levels.

However, a spacecraft orbiting the Earth is not always in direct sunlight. Therefore, the ISS relies on nickel-hydrogen rechargeable batteries to provide continuous power during the “eclipse” part of the orbit. The batteries ensure that the station is never without power to sustain life-support systems and experiments. During the sunlit part of the orbit, the batteries are recharged.

The process of collecting sunlight, converting it to electricity, and managing and distributing this electricity builds up excess heat that can damage spacecraft equipment. This heat must be eliminated for reliable operation of the Space Station in orbit. The ISS power system uses radiators to dissipate the heat away from the spacecraft. The radiators are shaded from sunlight and aligned toward the cold void of deep space.

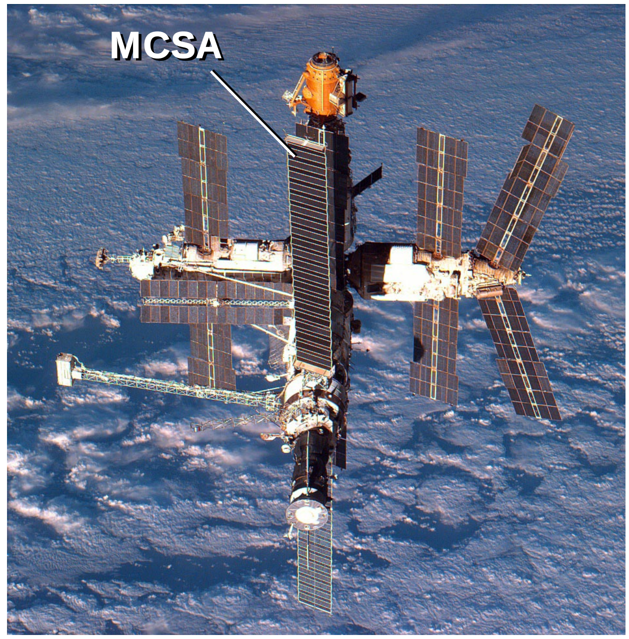
The power management and distribution subsystem disburses power at 160 volts of direct current (abbreviated as “dc”) around the station through a series of switches. These switches have built-in microprocessors that are controlled by software and are connected to a computer network running throughout the station. To meet operational requirements, dc-to-dc converter units step down and condition the voltage from 160 to 120 volts dc to form a secondary power system to service the loads. The converters also isolate the secondary system from the primary system and maintain uniform power quality throughout the station.

The NASA Glenn Research Center has decades of experience in designing, building, and testing space power systems. Therefore, it became the NASA Center initially responsible for designing the Space Station power system—the largest power system ever constructed in space. Engineers at Glenn combined state-of-the-art electrical designs with complex computer-aided analyses.

Mir Cooperative Solar Array

In cooperation with Russia, NASA Glenn managed a program to develop a solar array to increase the Mir Space Station’s power capability, extend its life, and support U.S. experiments conducted aboard the Russian station. Known as the Mir Cooperative Solar Array (MCSA), it was delivered to Mir during the second Shuttle/Mir docking mission (STS–74) in November 1995.

Data on array performance were recorded by the Russians and sent to NASA Glenn to be compared with computer-based predictions. These data will help to validate the performance of the International Space Station’s solar arrays, which will use the same U.S.-made silicon solar cells.



Mir Cooperative Solar Array (MCSA) in operation aboard Russia's Mir

Performance Analyses

The **S**ystem **P**ower **A**nalysis for **C**apability **E**valuation (SPACE) computer code was developed as a tool to predict the maximum power level that the Space Station power system could produce and sustain throughout the sunlight and shade portions of a specific orbit. The code includes mathematical models of the solar array, batteries, and power management and distribution equipment. Using SPACE, NASA Glenn supports the Space Station program by answering questions such as

- How is the power level affected by station on-orbit configurations, flight attitudes and orbits, and solar array shadowing?
- How does the power system respond when equipment is turned on and off?

A detailed mission profile is constructed and assessed with the SPACE code to ensure that the power system design can support the planned mission.

Array Design

The International Space Station’s electrical power system (EPS) will use eight photovoltaic solar arrays to convert sunlight to electricity. Each of the eight solar arrays will be 112 ft long by 39 ft wide. With all eight arrays installed, the complete Space Station is large enough to cover a football field. Because the Space Station needs very high power levels, the solar arrays will require more than 250,000 silicon solar cells. NASA has developed a method of mounting the solar arrays on a "blanket" that can be folded like an accordion for delivery to space. Once in orbit, astronauts will deploy the blankets to their full size. Gimbals will be used to rotate the arrays so that they face the Sun to provide maximum power to the Space Station.

The complete power system, consisting of U.S. and Russian hardware, will generate 110 kW (kilowatts) total power, about as much as 55 houses would typically use. Approximately 46 kW will be available for research activities.

Hardware Development

NASA Glenn's expertise and facilities were used in the development and testing of the electrical power system and its components. The electronics were evaluated in the EPS testbed, and gimbal testing was performed to demonstrate that the gimbal design met the electrical performance and lifetime requirements.

NASA Glenn also coordinated and participated in testing the assembly operations for the ISS power system hardware in a special pool dubbed a Neutral Buoyancy Simulator, which is located at the NASA Marshall Space Flight Center. Here, the procedures used to assemble the power system were tested underwater by attaching weights to divers and equipment so they neither sank nor floated, thus providing a realistic simulation of working in space. NASA Glenn engineers suited up as divers and tested equipment designs and tool use and worked through portions of actual mission timelines that would be followed to assemble the power system components in space.

A team of NASA Glenn engineers and technicians recently designed and built a small version of the over 100-ft-long ISS solar array, a solar array electrical simulator (SAES) about the size of a large walk-in closet. The SAES is used to test other power system flight hardware.

NASA Glenn expertise continues to be used extensively throughout the station power system for components such as switches and converter units. NASA Glenn led the design and development of all EPS hardware early in the Space Station program. Because of this comprehensive background, the NASA Johnson Space Center has asked NASA Glenn to oversee and manage the development and testing of EPS flight hardware in preparation for launch to the Space Station. This effort includes monitoring tests and inspecting hardware at both subcontractor sites where the hardware is manufactured and at the NASA Kennedy Space Center prior to launch. In addition to managing hardware built elsewhere, NASA Glenn is also manufacturing EPS component flight hardware like manually activated switches called circuit interrupt devices.

The remote power control modules (RPCM's) that are contained in the Unity node were also designed and developed by NASA Glenn. Each of the 12 small metal containers is filled with "circuit breakers" that provide switching and protection in case of a short circuit during construction of the ISS or during operation of the completed station. They can be controlled by astronauts via laptop computers or by ground personnel.

Keeping Cool

The ISS radiator system maintains the temperatures of systems and components. It was tested at the NASA Glenn Space Power Facility (SPF) at Glenn's Plum Brook Station in Sandusky, Ohio. This facility is the world's largest space environment simulation chamber (100 ft in diameter by 122 ft in height) and is used to ground-test large space-bound hardware. It can simulate the severe conditions of space such as vacuum, low temperatures, and unfiltered sunlight.

The radiator system consists of seven panels (each about 6 by 12 ft) designed to deploy in orbit from a 2-ft-high stowed position to a 50-ft-long extended position. The first round of tests confirmed that the deployment mechanism would operate properly in the cold void of space. The next phase of tests used a NASA Glenn-designed and assembled ammonia flow system to evaluate radiator performance. The ammonia collects heat from the Space Station's electronic equipment and module cooling components and transfers it to the radiator panels to be dissipated into space. Ammonia was selected because it was found to be the best heat transport fluid that meets all of NASA's thermal performance and safety requirements

Radiator testing in Space Power Facility

(i.e., toxicity, flammability, freeze temperature, stability, cost, and successful commercial and industrial use).

“Batteries Included”

The station is in an orbit with an altitude of 250 statute miles with an inclination of 51.6 degrees. As the station travels, the Earth will shadow the ISS solar arrays from the Sun for up to 36 minutes of each 92-minute orbit. To avoid an interruption in the power supply, NASA Glenn developed rechargeable nickel-hydrogen batteries that can store electrical energy gathered during the sunlit portion of the orbit and discharge electrical energy for use during the eclipse portion.

Thirty-eight cells are packaged together in series with monitoring instrumentation (temperature and pressure) inside an enclosure called an orbital replacement unit or “ORU.” The enclosure is designed to allow simple removal and replacement while in orbit. Since the ISS will never return to the ground, all repairs must be made in orbit. The batteries are not the only ORU’s on the ISS; in fact, every item of ISS hardware that will require maintenance or replacement has been designed as an ORU. The batteries are expected to last 5 to 6 years, life projections that have been verified by extensive testing at NASA Glenn.

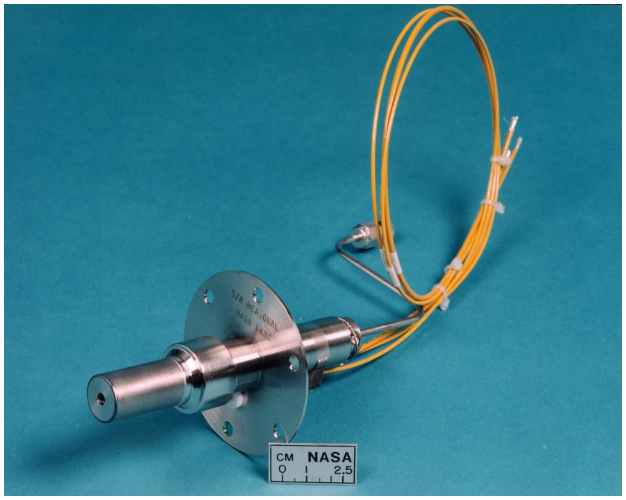
Plasma Contactor

The Space Station arrays operate at 160 volts dc. When the arrays are producing power, the station structure will also tend to float to a voltage close to the array voltage. Under these conditions, the Space Station could be subjected to problems like arcing from its surface to the surrounding environment. To avoid these problems, the structure has been “grounded” with a plasma contactor.

The plasma contactor unit acts as an electrical ground rod to connect the Space Station structure to the local environment and harmlessly dissipate the structure charges. NASA Glenn engineers designed, manufactured and tested the hollow cathode assembly, which is the critical component of the plasma contactor unit. The hollow cathode assembly performs this function by converting a small supply of gas into ions and electrons and discharging this stream to space. The stream carries with it the excess electrons that created the surface charge.

Circuit Isolation Devices

Circuit isolation devices, or CID’s, enable a spacewalking crewmember working on the station to remove power from selected loads so that the ISS



Plasma contactor that will protect the structure of the Space Station

power system cables, called “umbilicals,” can be mated or detached safely. Without the CID’s, large portions of the station would have to be powered down during some spacewalk activities, increasing both operational complexity and risk. The CID’s eliminate this problem without major software or hardware changes to the Space Station design.

The CID’s are rotary switches that mate to the Space Station with standard ISS electrical connectors and are installed and operated during spacewalks. Glenn Research Center designed, built, and delivered the CID’s to the Kennedy Space Center for integration into the ISS system in just 18 months. In total, eight CID’s will be installed on ISS. The first six were delivered by a space shuttle mission to ISS in October 2000. The final two CID’s will be launched by a later mission.

A Bright Future

At the dawn of this new era of discovery, the NASA Glenn Research Center continues its vital role of powering future space missions. As people from around the world continue their exploration and development of space aboard the International Space Station, they will rely upon the NASA Glenn-designed power system to harness the Sun’s energy. Even as researchers at NASA Glenn monitor the performance of this system, they will be working to address the challenges of future space exploration missions.

For more information, visit the NASA Glenn Space Power Web Site at http://space-power.grc.nasa.gov
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