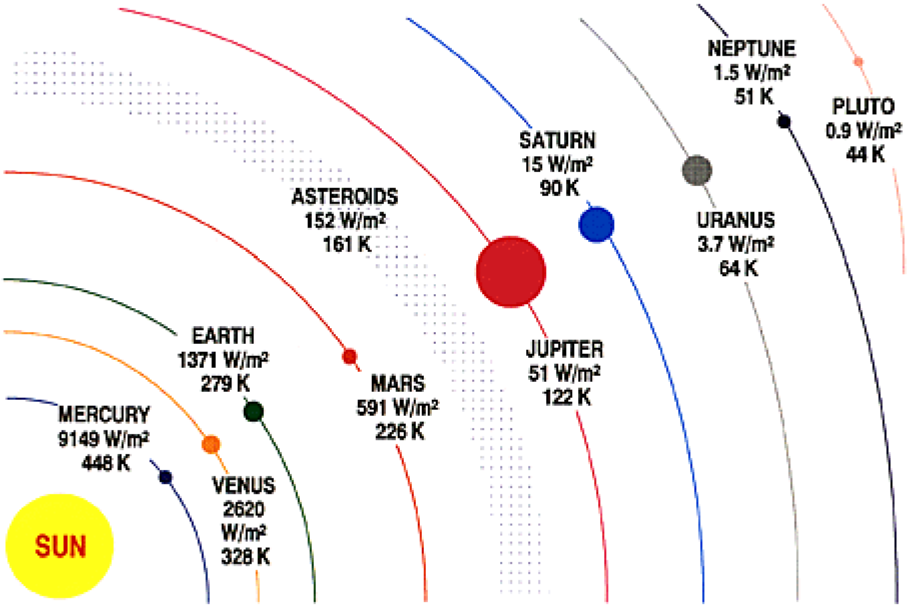
Cryogenic Electronics in Support of Deep-Space Missions

Beyond the orbit of Mars, the average temperature seen by a spacecraft falls below the normal operating temperature range of the spacecraft's electronics. Presently, spacecraft operating in the cold environment of deep space carry onboard a large number of Radioisotope Heating Units to maintain an operating temperature for the electronics of approximately 300 K. This is not an ideal solution because the Radioisotope Heating Units are always producing heat, even when the spacecraft is already too hot, thus requiring an active thermal control system for the spacecraft. Those spacecraft with sufficient power reserves to use electrical heaters experience problems restarting after a hibernation period during which the electronics cool significantly below 70 K.



Solar intensity and space probe temperature.

Another approach to problems associated with the cold operating environment of deep space is to use cryogenic electronics to operate the spacecraft at the ambient temperature. This approach has several advantages: semiconductor devices are more efficient at lower temperatures than at room temperature; high-temperature superconductors can be integrated with semiconductors to reduce losses; and a simpler (lighter and cheaper), passive, heat-rejection system can be employed. It has one significant challenge: cryogenic power generation and storage.

NASA Lewis Research Center is developing the enabling technologies for a cryogenic power system in conjunction with the NASA Jet Propulsion Laboratory (JPL) and universities. In addition, creative processes that could expand industrial participation in this program are being explored, such as the Small Business Innovation Research Program.

Through a National Research Council Fellowship and a NASA Graduate Student Research Fellowship, demonstrations of two key technologies have been performed: high-temperature superconductor components and cryogenic compound semiconductor switch technology. A dc-dc converter for low-temperature operation was designed, built, and characterized with commercial, off-the-shelf components and a custom-built superconducting inductor. A High Electron Mobility Transistor switch was designed, fabricated, and characterized at low temperatures. High Electron Mobility Transistor structures have the potential to handle high current loads at cryogenic temperatures. Although many silicon power devices that operate from room temperature to liquid nitrogen temperature (77 K) were used at NASA Lewis to build dc-dc converters which successfully operated over that temperature range, none of the commercial silicon or germanium transistors tested operated successfully significantly below 77 K. Therefore, compound semiconductor devices with the potential to operate over the temperature range of interest to deep-space missions (30 to 60 K) are being investigated by NASA Lewis.

Find out more about this research.

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