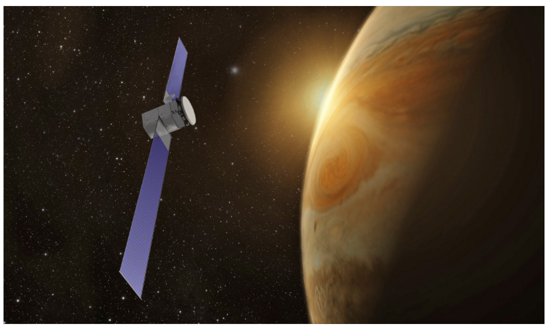
National Aeronautics and Space Administration

NASAfacts

# Space Technology

## Game Changing Development

## Solar Power Generation in Extreme Space Environments

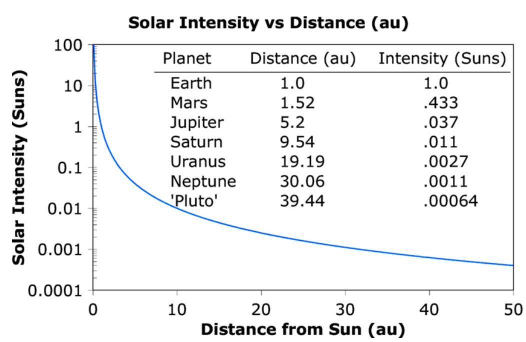


The exploration of space requires power for guidance, navigation, and control; instrumentation; thermal control; communications and data handling; and many subsystems and activities. Generating sufficient and reliable power in deep space through the use of solar arrays becomes more challenging as solar intensity decreases and high radiation levels degrade the performance of photovoltaic devices. The Extreme Environments Solar Power (EESP) project's goal is to develop advanced photovoltaic technology to address these challenges.

### LILT and Radiation Effects

The majority of NASA missions utilize solar cells that are designed and qualified for long-term operation within an Earth-orbit environment, air mass zero (AM0). Deep space NASA missions, however, subject solar arrays to stresses well beyond those experienced by commercial space and military satellites. Spacecraft sent to explore planets and other bodies farther from the sun encounter reduced light intensity levels and very low temperatures. Some of these missions may encounter low-intensity, low temperature (LILT) environments that can cause performance degradation in the power output of the solar cell. This degradation at LILT has been noted and verified through ground-based testing.The degradation at LILT occurs in some cells but not others. The existing method of addressing this problem is to screen all solar cells for the mission. This adds considerable cost and development time to the spacecraft power system. In addition, some methods of screening are imperfect. This affects the ability to accurately predict solar array performance throughout mission life as some cells may suffer power degradation. The issue becomes more pronounced when one cell with this degradation characteristic is added in a series string with well-behaved, predictable cells.

Space solar cells degrade over time due to exposure to the space environment with most effects being small and predictable; however, the largest power loss is due to particulate radiation. Electrons and protons released by the sun and trapped within various planetary orbits (such as Earth's Van Allen radiation belts) create defects within the semiconductor crystalline structure and reduce solar cell power output. The easiest way to protect the solar cell from these damaging effects is by shielding the front of the solar cell with glass. The thicker the glass, the more protection the cell receives, but this adds mass and cost to the solar array. On typical solar arrays, a few mils of ceria-doped microsheet protect the cell sufficiently to achieve the power output necessary at the end of the mission. Missions in very high radiation environments, such as those to Jupiter, must use novel approaches to limit these degradation effects.




### EESP Technology Solutions

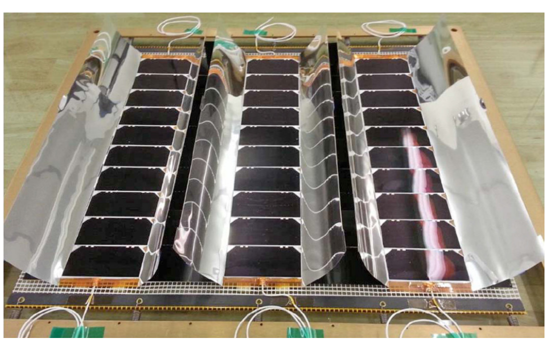
Various methods can be used to accomplish the goals to increase end-of-life solar array performance for missions exposed to severe radiation environments and to increase overall efficiency when operating in LILT-type environments. One method involves a redesign of the solar cell. The choice of appropriate semiconductor materials, cell designs, and precise attention to cell fabrication processes could be used to develop a high efficiency device that is both radiation tolerant and exhibits minimal LILT-type degradation effects.

Another approach is the use of concentrator optics to shield the solar cell and minimize the amount of solar cell area needed. Concentrator concepts have been successfully used for both space and terrestrial photovoltaic systems. This approach utilizes either reflective or refractive elements to focus the sunlight onto a much smaller solar cell area. Designs vary greatly in terms of complexity and solar concentration, from simple two sun trough reflectors to 100+ sun point-focus designs. Issues such as degradation/contamination of the concentrator optics and sun-pointing requirements for the solar array exist; however, concentrator concepts address EESP goals by providing added protection from the radiation environment for the solar cells and by operating at higher solar intensity and temperature conditions than one-sun planar arrays.

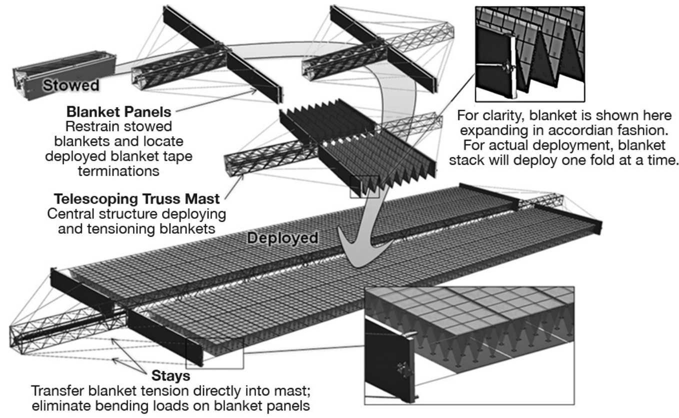
The EESP project currently has two technology development contracts in place that address these very NASA-unique mission requirements for solar array power systems. Johns Hopkins University-Applied Physics Laboratory (Laurel, MD) and Orbital ATK (Goleta, CA) are working on advanced photovoltaic concepts that address radiation damage and LILT degradation effects. The array designs being considered differ, but use varying degrees of the technology solutions summarized above. The technology developed under these contracts is expected to extend NASA's use of solar array technology as it continues to explore the reaches of space.

**APL Transformational Solar Array**

The Transformational Solar Array, being developed by the Johns Hopkins University Applied Physics Laboratory (APL), consists of a Deployable Space Systems (DSS) Roll Out Solar Array (ROSA), Flexible Array Concentrator Technology (FACT), and SolAero Inverted Metamorphic (IMM) solar cells. This array is designed to develop over 240 W/kg (at AM0, 25kW power level) compared with 60 W/kg that spacecraft arrays typically produce. Work on the transformational array concentrators includes a redesigned coating for higher reliability and reduction of outgassing from solar cell assemblies. The latter reduction will prevent concentrator darkening from outgassing product. Finally, efforts are underway to obtain IMM solar cell efficiency greater than 34 percent under LILT and radiation conditions. Development of the transformational array will notably improve array performance for spacecraft operation at almost any solar distance from the sun but especially for arrays operating at Jupiter and beyond.



*A small ROSA blanket equipped with FACT.*




*Orbital ATK's PFC-CTA Concept.*

**Orbital ATK — Point Focus Concentrator-Compact Telescoping Array (PFC-CTA)**

Orbital ATK is developing a novel solar array platform, PFC-CTA, which promises to provide a significant advance in performance and cost reduction compared to currently available space solar array systems, especially suited to deep space, low-intensity operation. "PFC" refers to the Point Focus Concentration of light provided by thin, flat Fresnel optics. These lenses focus light to a small bright spot onto solar cells of approximately one-twenty-fifth the size of the lenses. "CTA" stands for Compact Telescoping Array, which is the solar array blanket structural platform originally devised by NASA, and currently being advanced by Orbital ATK (and partners) under NASA and Air Force Research Lab funding. Key performance metrics currently projected include: scalability from <5 kW to >300 kW per wing (at AM0); specific power > 500 W/kg (at AM0, for wings >15kW); stowage efficiency >100 kW/$m^3$ (at AM0); 5-to-1 margin on pointing tolerance; >50 percent launched cost savings; wide range of operability between Venus and Saturn by active and/or passive thermal management.

**More Information**

The Game Changing Development (GCD) Program investigates ideas and approaches that could solve significant technological problems and revolutionize future space endeavors. GCD projects develop technologies through component and subsystem testing on Earth to prepare them for future use in space. GCD is part of NASA's Space Technology Mission Directorate.

For more information about GCD, please visit http://gameon.nasa.gov/

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