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The Deep Space Solar Array: A Power-Source Technology for Missions to Saturn and Beyond

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Space solar arrays have provided electrical power for the vast majority of space missions since the start of space exploration. As missions reach farther into deep space, away from the sun, the conditions of low irradiance and low temperature (LILT) create challenges for both the efficiency of solar cells and the overall mass effectiveness of the array. However, space solar array technology has developed continuously over the past several decades and solar-powered missions have flown successfully at increasingly greater distances from the sun. For example the Juno spacecraft[1], currently orbiting Jupiter, has successfully demonstrated solar power at 5.5 AU.

Recently, technology has been developed that could enable many solar-powered missions to Saturn, its moons and beyond. This technology can be implemented on mission concepts such as the Enceladus Orbilander, Titan Orbiter, Enceladus Multiple Flyby, Saturn Probe, Centaur Orbiter and Lander, and Rideshare for Outer Planets. It could also significantly enhance potential new missions to the Jovian system, such as the Jupiter System Observatory and Prometheus.

Key performance projections for deep space solar arrays can be found in reference 2. To summarize, specific power at Saturn could reach 2.9 W/kg at end-of-mission[2]. In this case, the mass of a solar array for a 200 W mission to Saturn would be 69 kg.

Two key technology development efforts, conducted by JPL and its partners over the past seven years, have made this capability possible[3,4]. One was the development of a photovoltaic device, or solar cell, that is optimized for operation with very little sunlight and at the low temperatures expected during a mission to Saturn. The optimized solar cell is based on the inverted metamorphic (IMM) III-V solar cell technology used on many space missions, only in this case optimized for LILT conditions[3]. The second was the integration of these solar cells with a structure and electrical assembly that is optimized for the lowest mass possible at the solar array level, i.e. at the higher level of assembly representing a deployable power source. This design is based on the UltraFlex solar array, which is also common in the space industry, only in this case optimized for deep space missions[4].

The resulting solar array technology has undergone extensive testing at the Jet Propulsion Laboratory and the results were submitted to a JPL review board for technology readiness assessment (TRA) in 2021. The conclusion of the board was that the Deep Space Solar Array has reached a technology readiness level (TRL) of 5 and, as a result, is now ready for infusion into space flight projects.

References

[1] www.nasa.gov/mission_pages/juno/main/index.html

[2] T. Hendricks et al., Solar Power System and Radioisotope Thermoelectric Generation Technologies at Jupiter-Saturn-Uranus Environments: New Insights and Paradigms”, 70th International Astronautical Congress (IAC), October 2019.

[3] A. Boca, C. MacFarland and R. Kowalczyk, “Solar Power for Deep-Space Applications: State of the Art and Development”, AIAA Propulsion and Energy Forum, August 2019.

[4] A. Boca et al., “The Deep Space Solar Array: a Power Source for Missions to Saturn and Beyond”, 2022 Conference on Advanced Power Systems for Deep Space Exploration, August 2022.