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HIGH-TEMPERATURE PHOTOVOLTAIC CELLS FOR NEAR-SUN AND INTERSTELLAR PRECURSOR MISSIONS: STATE OF THE ART AND FUTURE DEVELOPMENTS

Abstract

Most current spacecraft use solar power to carry out their missions in deep space, especially when the main propulsion system is based on Electric Propulsion (EP). This means that their solar arrays are exposed to various extreme environments, with high temperature variations, radiation exposition, and power density. Developing new technologies capable of withstanding these conditions is crucial for the future of space sciences, to study celestial bodies such as Mercury and the Sun, and to explore concepts for reaching high velocities for interstellar precursor missions with Laser-powered Electric Propulsion (LEP). In all of these missions, we need to find different ways to maintain the efficiency and the integrity of those arrays as both degrade rapidly at high temperatures and under high light intensity, especially when temperatures reach more than 450°C around the orbit of Mercury and even higher closer to the Sun. This could also be an issue in spacecraft powered by high-power lasers; the photovoltaic array that converts the incoming laser power into electrical power for the EP system must withstand very high power densities; hence it must be based on photovoltaic cells that can operate at very high temperatures. This paper focuses on missions in which extreme environments are present for the solar arrays and gauges the readiness of current technologies. The missions consist of a Mercury orbiter, a solar probe to study the Sun from up close, and finally, an interstellar precursor mission to prepare for future missions on the outer Solar System and beyond. The first step is to provide an overview of the state of the art of different technologies corresponding to solar cells, thermal regulation of spacecraft at very high temperatures, power transmission using space-based lasers, and advanced EP propulsion systems. This review is then used to assess the Technology Readiness Levels of the different technologies using objective criteria and predict which technologies will evolve the fastest, and propose a reasonable roadmap for their development and evolution.