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SOLAR POWER SYSTEM AND RADIOISOTOPE THERMOELECTRIC GENERATION TECHNOLOGIES AT JUPITER-SATURN-URANUS ENVIRONMENTS: NEW INSIGHTS AND PARADIGMS

Abstract

Power system selection at outer planet destinations, such as Jupiter, Saturn, and Uranus and beyond, is complex, involving and dependent on many interdisciplinary factors such as power system mass, specific power, cost, mechanical and electrical integration and orbital mechanics issues. Low solar irradiance at Jupiter-Saturn-Uranus systems (i.e., 50, 15, and 4 W/m2, respectively) make solar power systems challenging in mechanical / electrical integration and orbital mechanics demands, but not impossible. More costly radioisotope thermoelectric generator (RTG) systems can overcome orbital mechanics constraints and spacecraft control challenges at Jupiter-Saturn. NASA's Jet Propulsion Laboratory (JPL) has recently made significant strides in demonstrating high-efficiency, radiation-hard solar cell technologies for low-irradiance, low-temperature (LILT) applications, and high-efficiency thermoelectric (TE) materials and modules for higher-specific-power RTGs. State-of-art multi-junction solar cells now routinely demonstrate high efficiencies at LILT (30-34% at 9.5AU and -165C), making solar arrays a viable option for near-term Saturn mission concepts. In addition, emerging technologies such as LILT-optimized solar cells have recently demonstrated even higher efficiencies (37% at 9.5AU and -165C) and 30% lower mass than the state-of-art, offering the prospect of 3W/kg array-level, end-of-life specific powers under Saturn conditions. Having already demonstrated the tremendous utility of RTGs on Mars and in deep-space missions (i.e., Jupiter, Pluto), NASA is now developing and demonstrating new TE materials and modules (i.e., Skutterudites, Lanthanum Tellurides, ZINTLs) for increasing RTG specific power (up to >8.5 W/kg), which strongly impacts their mass, fuel availability issues, and modularity in the power system trade domain. The new accomplishments in both areas highlight the renewed requisite for updated comparisons and tradeoffs in power output, specific power and mass, cost, mechanical and electrical integration, new technology timelines, and orbital mechanics impacts between the new LILT-optimized photovoltaic technologies and next-generation RTG technologies. This paper will discuss and demonstrate how new LILT-based technologies are now allowing one to consider and design solar power systems for Saturn orbit and beyond, and are changing the potential cost-mass tradeoffs between emerging solar power technologies and newly-envisioned RTG technologies. This work will show and discuss key tradeoffs in the above mentioned interdisciplinary factors between these two complementary power technologies. It will crystallize different potential uses of high-performance LILT and RTG technologies, and reinforce power

selection criteria in support of possible future NASA deep-space science and exploration missions to Mars, the Jupiter system (Europa, Ganymede), the Saturn system (Titan, Enceladus), Uranus, and beyond.