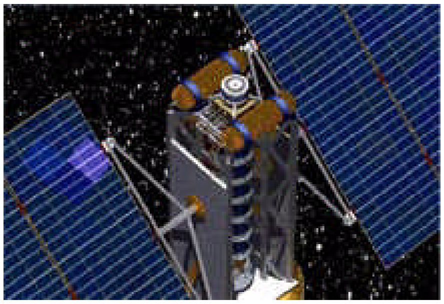
Power System Options Evaluated for the Radiation and Technology Demonstration Mission

The Radiation and Technology Demonstration (RTD) Mission is under joint study by three NASA Centers: the NASA Johnson Space Center, the NASA Goddard Space Flight Center, and the NASA Glenn Research Center at Lewis Field. This Earth-orbiting mission, which may launch on a space shuttle in the first half of the next decade, has the primary objective of demonstrating high-power electric thruster technologies. Secondary objectives include better characterization of Earth's Van Allen trapped-radiation belts, measurement of the effectiveness of the radiation shielding for human protection, measurement of radiation effects on advanced solar cells, and demonstration of radiation-tolerant microelectronics.

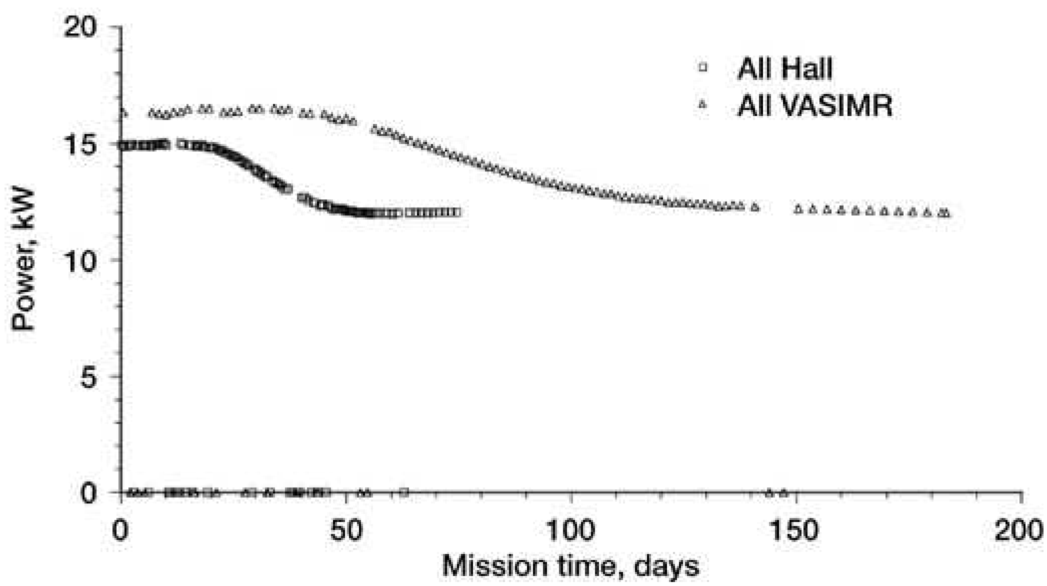
During the mission, which may continue up to 1 year, the 2000-kg RTD spacecraft will first spiral outward from the shuttle-deployed, medium-inclination, low Earth orbit. By the phased operation of a 10-kW Hall thruster and a 10-kW Variable Specific Impulse Magneto-Plasma Rocket, the RTD spacecraft will reach a low-inclination Earth orbit with a radius greater than five Earth radii. This will be followed by an inward spiraling orbit phase when the spacecraft deploys 8 to 12 microsatellites to map the Van Allen belts. The mission will conclude in low Earth orbit with the possible retrieval of the spacecraft by the space shuttle.



Radiation and Technology Demonstration spacecraft.

The preceding figure illustrates a conceptual RTD spacecraft design showing two photovoltaic (PV) array wings, the Hall thruster with propellant tanks, and stowed microsatellites. Early power system studies assessed five different PV array design options coupled with a 120-Vdc power management and distribution system (PMAD) and secondary lithium battery energy storage. Array options include (1) state-of-the-art 10-percent efficient three-junction amorphous SiGe thin-film cells on thin polymer panels deployed with an inflatable (or articulated) truss, (2) SCARLET array panels, (3) commercial state-of-the-art, planar PV array rigid panels with 25-percent efficient, three-junction $GaInP_2$/GaAs/Ge solar cells, (4) rigid panels with 25-percent efficient, three-junction $GaInP_2$/GaAs/Ge solar cells, in a 2×-concentrator trough configuration, and (5) thin polymer panels with 25-percent efficient, three-junction $GaInP_2/GaAs/Ge$ solar cells deployed with an inflatable (or articulated) truss.

To assess the relative merits of these PV array design options, the study group developed a dedicated Fortran code to predict power system performance and estimate system mass. This code also modeled Earth orbital environments important for accurately predicting PV array performance. The most important environmental effect, solar cell radiation degradation, was calculated from electron-proton fluence input from the industry standard AE8/AP8 trapped radiation models and the concept of damage equivalence (ref. 1). Power systems were sized to provide 10 kW of thruster power and approximately 1 kW of spacecraft power at end of life. Of the five PV array design options, the option 1 (thin-film cells) power system was the most massive—590 kg, whereas the option 4 (trough concentrator) power system was the lightest—260 kg. Arguably, the lowest cost would come from the option 3 (commercial array panels) power system with an acceptable, albeit greater, system mass of 320 kg.



Power to thruster and spacecraft for RTD mission.

Predicted power system performance during the spiral-out mission phase is shown the preceding graph for the option 5 (flexible-panel) array. From the results, the radiation-induced power loss over time is evident as the spacecraft slowly spirals outward through the trapped proton belt. The importance of the spiral trip time is also evident in the two curves representing 74-day and 182-day spiral-out periods. The longer spiral time introduces a beginning-of-life power oversizing penalty greater than 1 kW. Future studies will analyze power system performance and mass with a 50-Vdc power management and distribution architecture favorable to the VASIMR thruster and longer missions.

References

1. Anspaugh, B.E.: GaAs Solar Cell Radiation Handbook. NASA CR–203421, 1996.

Glenn contact: Thomas W. Kerslake, (216) 433–5373, Thomas.W.Kerslake@grc.nasa.gov

Authors: Thomas W. Kerslake and Scott W. Benson

Headquarters program office: OSF

Programs/Projects: HEDS