SPACE RADIATION AND PLASMA SCIENCE ENABLED BY THE DEEP SPACE GATEWAY.

Joseph I. Minow[1] and Linda Neergaard Parker[2], [1]NASA Marshall Space Flight Center, EE04L, Huntsville, AL 35812, joseph.minow@nasa.gov, [2] Universities Space Research Association, Huntsville, AL 35812

Introduction: Lunar orbit is a unique location for studies of space radiation and plasma environments. NASA plans for constructing a Deep Space Gateway (DSG) space station for human operations in cislunar space will provide an important first step for a sustained human presence beyond low Earth orbit and opportunities for routine studies of space radiaton and plasma environments at lunar distances. Travel times from the Earth to lunar orbit are on the order of four days, allowing relatively easy logistics for resupply and operational support. The DSG in orbit about the Moon will therefore provide opportunities for sustained monitoring of the interplanetary space environment outside of the Earth's magnetosphere and the Earth's magnetotheath and magnetotail at lunar distances and experiments focused on specific aspects of those environments of interest to basic and applied science.

This paper considers candidate opportunities for investigating space radiation and space plasma environments from the DSG vehicle in lunar orbit, DSG logistics vehicles used to support Gateway, and subsatellites supported by the DSG.

Space Radiation and Plasma Science Opportunities: The mean radius of the Moon's orbit is ~60 Earth radii (R_E), well outside of the strong dipolar magnetic field configuration of the Earth's central magnetosphere. Galactic cosmic rays (GCR) and solar energetic particles (SEP) at energies of importance to both human health and avionics components have free access to the Moon over its entire orbit [1]. At low energies, lunar orbit is immersed in the free flowing solar wind thermal plasma over ~75% of an orbit with the remaining 25% of the orbit divided between shocked solar wind in the magnetosheath and the low density plasma of the Earth's magnetotail.

DSG Opportunities. Routine operation of the DSG in lunar orbit provides opportunities to investigate a variety of aspects of the space radiation and plasma environments including:

- Moon-plasma interactions in the solar wind, magnetosheath, and magnetotail,
- Magnetotail dynamics at lunar distances,
- Backscattered and sputtered ions from the lunar surface,
- Energetic ions upstream of Earth's bow shock,
- Monitoring quiescent and storm-time GCR and SEP ions of importance to human health and avionics,
- Human central nervous system response to GCR and SPE heavy ions,
- Testing space weather monitoring systems for protecting crew from extreme space radiation environments.

Opportunities from DSG Logistics Vehicles.

DSG will need to be serviced with logistics vehicles providing cargo, supplies, and transfer of crews between Earth and the DSG throughout the operational lifetime of the station. These vehicles provide a secondary opportunity for routine measurements of radiation and plasma environments within the Earth's radiation belts including opportunities to obtain:

- Measurements of trapped energetic particles as a function of flux and energy in the inner and outer radiation belts over a wide range of L-values from low Earth orbit to beyond the outer trapping boundaries. While enabled by the DSG logistics vehicles, these measurements may be useful for routine space weather monitoring of the Earth's radiation belts for terrestrial applications,
- Spacecraft charging investigations using surface potential monitors and charged particle environment measurements in the inner and outer radiation belts.

Use of solar electric propulsion is often discussed as one method for supporting a DSG architecture with routine, low cost logistics flights. One option for these vehicles is a slow spiral out through the radiation belts offering the opportunity to sample multiple local times over a seris of slowing increasing L-values. Another option is to establish a highly elliptical orbit immediately following lauch with apogee well beyond the boundaries of the radiation belt and perigee in low Earth orbit. Perigee is then slowly raised over a period of time until the solar electric support vehicle as climbed out of Earth's gravity well. Spacecraft in these orbits provide an opportunity for sampling the radiation belts over a wide range of L-values in a restricted range of local times over a period of time.

DSG Subsatellite Opportunities. A third set of opportunities my be supported by small satellites operating independently from the DSG but utilizing DSG as a communictions relay or other required support. Examples include studies of:

- Charged particle dynamics in the lunar wake,
- Lunar surface charging from a lunar lander,
- Spacecraft charging in the deep lunar wake,

- Lunar secondary particle (neutron) environments.

Investigations in this category greatly benefit from, or require, orbits relative close to the lunar surface. While the Deep Space Gateway may approach within a few hundred kilometers of the lunar surface during some operations to support lunar landings, it is likely a much higher orbit will be used on a routine basis to avoid the complexitites and fuel needs required to maintain the unstable low altitude orbits in the lunar gravity field. Therefore, options to periodically deploy single, or possibly a constellation, of small spacecraft from the DSG that will operate at low lunar altitudes will provide additional opportunities to study features of the lunar plasma and radiation environments.

DSG Flexibility Opportunities. Hardware response to SPE and GCR is well understood from many decades of satellite operations in GEO. However, new electronics technologies are always being developed that must be tested to characterize their failure modes due to single event effects before they can be used for space applications. Access to terrestrial test facilities is becoming more difficult due to closure of a number of accelerator facilities. An option for electronics single event testing would be to rotate new technologies for extended exposure periods of months to years in the full deep space heavy ion environment at DSG which is the same environment that exploration vehicles will be exposed to on future missions to Mars. Routine changeover of flight crews allows deployment of new and different candidate technologies that can be exposed to the unprotected GCR and SPE flux during periods between human changeover flights.

Summary: NASA's DSG offers a number of new and exciting opportunities for the space physics and applied space science community. Which opportuniites ultimately are successful will depend on the flexibility of DSG operations and the final orbital parameters chosen for the Gateway itself and the logistics vehicles used to support the DSG.

References: [1] Huang, C.-H. et al. (2009) Geophys. Res. Lett., 36, L09109.