Introduction to special section on the Earth-Moon-Mars Radiation Environment Module

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[1] The United States is preparing to return humans to the Moon and is setting the stage for exploration to Mars and beyond. However, it is unclear if long missions outside of low-Earth orbit (LEO) can be accomplished with acceptable risk. The central objective of the NASA Living With a Star Earth-Moon-Mars Radiation Environment Module (EMMREM) is to develop and validate a numerical module for completely characterizing time-dependent radiation exposure in the Earth-Moon-Mars and interplanetary space environments. EMMREM currently provides the capability to predict radiation exposure in the interplanetary environment outside of Earth's protective atmosphere and magnetosphere and at various heights of a nominal Mars atmosphere. Ongoing and future efforts will fold in the effects of Earth's atmosphere and the geomagnetic field so that the radiation environment can be predicted near the Earth's surface, at LEO, and at various geomagnetic latitudes. EMMREM is being designed for broad use by researchers to predict radiation exposure by integrating over time-evolving incident particle distributions from interplanetary space. The EMMREM represents a growing and developing system of coupled models that describe particle acceleration and transport in interplanetary space and secondary transport through shielding materials, atmospheres, and various parts of the human body to determine doses, dose rates, and linear energy transfer spectra. Thus, EMMREM makes the explicit connection from observations and simulations of solar energetic particles and galactic cosmic rays to characterization of the potential hazards of the radiation environment and to acute radiation risks. The papers in this special section will describe the following.

[2] 1. Observations near 1 AU from ACE, GOES, and IMP 5 for the historic August 1972 event to characterize the near-Earth radiation environment are used as time-dependent boundary conditions near 1 AU in an energetic particle propagation and acceleration module (the Energetic Particle Radiation Environment Module (EPREM)) to predict the radiation environment throughout the inner heliosphere. Observations at Ulysses (near 5 AU) are then used to validate the EPREM predictions.

[3] 2. Event-based simulations in the inner heliosphere predict time-dependent estimates of organ exposures for human crews in deep space.

[4] 3. A paper provides a risk assessment approaches for solar particle events.

[5] 4. Several papers describe a model for prompt solar energetic particle (SEP) dose rate forecasting for the Earth-Moon system.

[6] 5. The transmission of SEPs and galactic cosmic rays (GCRs) through the Mars atmosphere predicts the radiation environment at Mars.

[7] 6. The coupling between the Energetic Particle Radiation Environment Module and magnetohydrodynamic models improves the predictions of the radiation environment in the inner heliosphere.

[8] 7. Ulysses observations and a model of GCRs are used to improve our understanding of recent GCR fluxes and associated GCR dose rates throughout the inner heliosphere.

[9] 8. A paper provides predictions of the linear energy transfer spectrum for the Cosmic Ray Telescope for the Effects of Radiation detector during the Lunar Reconnaissance Orbiter mission.

[10] 9. Several papers describe predictions of the space radiation environment during gradual solar energetic particle events using physics-based particle acceleration models.

[11] Thus, the papers in this special section of *Space Weather* introduce the EMMREM project and provide a baseline for current understanding of the space environment beyond Earth's protective atmosphere and magnetosphere.

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