Session VI:

Acute Effects and Space Physics

4:45 p.m. – 6:10 p.m.
Port Jefferson Village Center, 3rd Floor

Chairs:

Kathryn Held
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Precursor Measurements of the Mars Surface Radiation Environment with the Radiation Assessment Detector (RAD) on the Mars Science Laboratory (MSL)


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The Radiation Assessment Detector (RAD) is a compact, lightweight energetic particle analyzer that will fly on the NASA 2011 Mars Science Laboratory (MSL) Mission. RAD will detect and analyze energetic particle species (protons, neutrons, and ions with $2 \leq Z \leq 26$) relevant for dosimetry on the Martian surface. The Galactic Cosmic Rays and Solar Energetic Particles impinging on the Martian atmosphere produce a complex environment at the surface, with secondaries being created in both the atmosphere and the Martian regolith. Fully characterizing and understanding the surface radiation environment with a compact instrument such as RAD presents many technical challenges, but this characterization is an essential precursor measurement for future human missions to Mars. An extensive database to be used for the calibration of RAD has been obtained for a wide range of energetic charged particle beams at the NASA Space Radiation Laboratory (NSRL) and the Heavy Ion Medical Accelerator in Chiba (HIMAC). Neutron data at 5, 15, and 19 MeV were obtained at the Physikalisch-Technische Bundesanstalt (PTB) calibration facility. Most recently, data were taken with the flight spare RAD unit placed near the radioisotope thermal generator (RTG) that will be used on the MSL rover. In this talk we will describe the calibration campaign, showing results with protons, ions, and neutrons, and we will also discuss the data obtained in proximity to the RTG. The data demonstrate that RAD can meet all its scientific objectives for the MSL mission and is also a viable instrument for other missions where dosimetry in mixed fields of energetic charged and neutral particles is needed.

The design of the instrument and its functions are shown below in Figure 1. In the cutaway view on the right, the detector elements are identified. These include three silicon detectors (SSD’s A, B, and C), and three scintillators (D, E, and F). The three silicon detectors provide highly accurate energy loss measurements for charged particles within the viewing cone of the telescope (65º opening angle), and the cesium iodide calorimeter (D) serves both as a stopping detector for some charged particles and as an efficient γ-ray detector. The E detector is a piece of BC-432 plastic scintillator for neutron detection (E), and a larger, barrel-shaped piece of BC-432 (F) surrounds D and E and serves as a veto detector for neutral-particle events. Light from all scintillators is collected by p-i-n diodes so that only a single bias voltage is required to run RAD. The sensor head contains all detectors and front-end electronics, which produce a total of 17 output signals. These signals are input to a custom ASIC, the VIRENA, which provides discriminators and additional amplifiers. The VIRENA is controlled by an FPGA, which also performs first- and second-level data analysis. Additional analysis is performed to histogram the data, reducing the data volume to a size that fits within MSL’s very stringent telemetry allocation.
A major solar particle event (SPE) may place astronauts at significant risk for the acute radiation syndrome (ARS), which may be exacerbated when combined with other space flight stressors, such that the mission or crew health may be compromised. The National Space Biomedical Research Institute (NSBRI) has funded a Center of Acute Radiation Research (CARR), which is focused on assessing the risks of adverse biological effects related to the ARS in animal models exposed to space flight stressors combined with the types of radiation expected during an SPE. As part of this program, FDA-approved drugs that can be used as countermeasures for the prevention and/or mitigation of the ARS symptoms will be evaluated, if warranted.

The CARR has been established to determine whether there are adverse acute biological effects like those of the ARS, which are likely to occur in astronauts exposed to the types of radiation, at the appropriate energies, doses and dose-rates, present during an SPE. The ARS is a phased syndrome which often includes vomiting and fatigue. Other acute adverse biologic effects of concern are the loss of hematopoietic cells, which can result in compromised bone marrow and immune cell functions. There is also concern for skin damage from high SPE radiation doses, including burns, and resulting immune system dysfunction. Using 3 separate animal model systems (ferrets, mice and pigs), the major biologic endpoints associated with the ARS being evaluated are: 1) vomiting/retching and fatigue, 2) hematologic changes (with focus on white blood cells) and immune system changes, resulting from SPE radiation with and without reduced weightbearing conditions, and 3) skin injury and related immune system functions. In all of these areas of CARR research, statistically significant adverse health effects have been observed in animals exposed to SPE-like radiation.

Examples of a few of the results obtained from CARR research projects performed thus far are as follows: 1) Pig skin exposures to 6 MeV electron radiation have resulted in an enhanced delayed type hypersensitivity (DTH) response, 2) In the skin of mice, both high and low dose rate radiation exposures lead to a significant decrease in FoxP3 mRNA, a marker of T regulatory cells, in skin biopsies. It is concluded from these studies that radiation leads to a loss of Treg cells that results in an alteration in immune responsiveness, and 3) The combined effects of Cs-137 gamma radiation and reduced weightbearing (utilizing the hindlimb suspension or the Partial Weight Suspension (PWS) mouse model systems) have been evaluated in mice. Complete blood cell counts were performed on mice irradiated with doses of 50, 100 or 200 cGy and then were either hindlimb suspended or placed in the PWS system for 4 hrs, 24 hrs, 48 hrs or 4 days. Control mice were exposed to identical conditions without exposure to radiation, reduced weightbearing or both. Both radiation dose and reduced weightbearing were significant factors affecting the lymphocyte and total white blood cell (WBC) counts. Exposure to the combined effects of radiation and reduced weightbearing resulted in a more pronounced reduction in lymphocyte and WBC counts, which is characterized as a synergistic interaction in the high dose groups (100 and 200 cGy) for both the lymphocyte and WBC counts.

Acknowledgements: This research is supported by the NSBRI CARR grant; NSBRI is funded through NASA NCC 9-58.
NSRL Overview and Update*

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The NASA Space Radiation Laboratory (NSRL) at Brookhaven National Laboratory (BNL), an accelerator-based facility which provides ion beams for radiobiology, physics and instrumentation studies, is currently in its 8th year of operation. We will survey developments at NSRL since its commissioning in 2003, touching on developments in beam profiles, intensities, energies and time structure, beam imaging techniques, dose measurement methods, calibration and quality assurance. The large beam and Solar Particle Event (SPE) simulation capabilities will be described, and additions to the NSRL instruments and methods which grew out of interactions with individual users will be highlighted. We will then discuss near and not so near future activities and plans, including the commissioning and usage of the new Electron Beam Ion Source (EBIS), which will provide ions unavailable from the source currently used, and a Galactic Cosmic Ray (GCR) simulator which involves upgrading NSRL to 1.5 GeV/n.