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NASA'S GALACTIC COSMIC RAY SIMULATOR AT BROOKHAVEN NATIONAL LABORATORY: ENABLING HUMAN EXPLORATION MISSIONS TO THE MOON AND MARS

Abstract

With exciting new Agency plans for a sustainable return to the moon, astronauts will once again leave earth's protective magnetosphere only to endure higher levels of radiation from galactic cosmic rays (GCR) and the possibility of large solar particle events (SPE). Gateway, lunar landers, and surface habitats will be designed to protect crew against SPE's with vehicle optimization, storm shelter concepts, and/or active dosimetry; however, the ever-penetrating GCR will continue to pose the most significant health risks especially as lunar missions increase in duration and as NASA sets its aspirations on Mars. The primary risks of concern include epithelial carcinogenesis and leukemia, central nervous system effects resulting in potential in-mission cognitive or behavioral impairment and/or late neurological disorders, degenerative tissue effects including circulatory and heart disease, as well as, potential immune system decrements. Characterization and mitigation of these risks requires a significant reduction in the large biological uncertainties of chronic (low-dose rate) heavy ion exposures and the validation of countermeasures in a relevant space environment. NASA has developed the "GCR Simulator" at Brookhaven National Laboratory to generate a spectrum of ion beams that approximates the primary and secondary GCR field experienced at human organ locations within a deep-space vehicle. The majority of the dose is delivered from protons (60-70%) and alpha particles (10-20%) with heavier ions ($Z>2$) contributing the remainder. The "GCR Simulator" exposes state-of-the art cellular and animal model systems to 33 sequential beams including 4 proton energies plus degrader, 4 helium energies plus degrader, and the five heavy ions of C, O, Si, Ti, and Fe. A polyethylene degrader is used with the 100 MeV/n H and He beams to provide a distribution of low energy particles. A 500 mGy exposure, delivering doses from each of the 33 beams, requires 75-90 minutes. To more closely simulate the low dose rates found in space, sequential field exposures are divided into daily fractions over 2-4 weeks, with individual fractions as low as 0.1-0.2 mGy. In the large beam, 54 special housing cages can accommodate 2-3 mice each for a 90 min duration or 15 individually housed rats. Emerging research results from our 2018 runs utilizing mixed heavy-ion fields and protracted space exposures are forthcoming and deepen our understanding of the health risks faced by our astronauts. This talk will discuss NASA's innovative technology solution for a ground-based GCR simulator at the NASA Space Radiation Laboratory to enable future exploration missions.