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Radiation Fields, Effects and Risks in Human Space Missions (5)

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ADDRESSING CRITICAL GAPS IN SPACE RADIATION MODELS FOR IMPROVED SPACE RADIATION RISK ESTIMATION

Abstract

Radiation-induced health effects stand as one of the primary risks confronting manned exploration of the Moon. As human space exploration progresses, understanding these effects of space radiation on astronauts becomes increasingly crucial (1). Despite advancements in this domain, uncertainties persist when developing accurate risk estimates from past studies. These uncertainties arise due to both radiation data gaps and radiation model gaps (2). While data gaps involve deficiencies in empirical information, model gaps induce limitations in the theoretical or computational frameworks used for interpretating and extrapolating this data. This paper identifies and addresses the three most critical gaps in current radiation models for developing accurate space radiation risk estimates.

One of the gaps in radiation models arises from the uncertainties in current galactic cosmic ray environmental models beyond Low Earth Orbit, which provide the inputs for radiation transport models in space environment. Existing models, such as Badhwar O'Neill 2014 (3), DLR (4), and Nymmik (5) exhibit uncertainties in the range of 20

Another gap in radiation models arises from uncertainties in space radiation transportation codes (7). Most of the transportation codes rely on different semi-empirical total reaction models, yet these lack sufficient benchmarking due to a scarcity of particle track structure calculations (8) and experimental biological impact data (9). Addressing this uncertainty would require more accurate Monte Carlo calculations of particle track structure and energy deposition distributions in 3D.

The third and last gap addressed in this paper is in regards to the absence of a standardized risk assessment framework. Even when equipped with sufficient galactic cosmic ray environmental models and space radiation transport models, various approaches are observed across space agencies in determining total allowable radiation limits (10). This work therefore highlights the imperative need for a unified framework to guarantee consistency in the best practices of risk assessment methodologies.

In conclusion, this paper highlights critical gaps in models addressing the effects of space radiation on humans and emphasizes the importance of reducing these gaps for safer human spaceflight missions. Recommendations include prioritizing continued measurements for model benchmarking, advancing validation efforts, and fostering collaboration towards a unified risk assessment framework. These efforts are essential for ensuring astronaut health in space.