Evaluation of Spacecraft Shielding Effectiveness for Radiation Protection

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Summary

The potential for serious health risks from solar particle events (SPE) and galactic cosmic rays (GCR) is a critical issue in the NASA strategic plan for the Human Exploration and Development of Space (HEDS). The excess cost to protect against the GCR and SPE due to current uncertainties in radiation transmission properties and cancer biology could be exceedingly large based on the excess launch costs to shield against uncertainties. The development of advanced shielding concepts is an important risk mitigation area with the potential to significantly reduce risk below conventional mission designs. A key issue in spacecraft material selection is the understanding of nuclear reactions in determining the transmission properties of materials. High-energy nuclear particles undergo nuclear reactions in passing through materials and tissue altering their composition and producing new radiation types. Spacecraft and planetary habitat designers can utilize radiation transport codes not only to identify optimal materials for lowering exposures, but also to optimize configuration design to reduce astronaut exposures. To reach this objective will require providing design engineers with accurate data bases and computationally efficient software for describing the transmission properties of space radiation in materials. Our program will reduce the uncertainty in the transmission properties of space radiation by improving the theoretical description of nuclear reactions and radiation transport and will enhance new approaches to risk assessment.

Spacecraft shielding composed of low Z materials is known to be advantageous because of reduction of high energy and charge ions (HZE), and target fragments, especially neutrons, in comparison to higher Z materials such as aluminum. Projectile fragmentation is advantageous because lower charged ions of equal velocity are less biologically damaging than the projectile ion. Materials composed of lower atomic mass atoms are more efficient per unit mass in producing projectile fragmentation. Target fragmentation events are highly dependent on material type. These events are the major nuclear reaction effect for SPE's and are an important contributor to GCR transmission. Quantitative evaluations for material selection must rely on physical descriptions of radiation transmission properties and the accuracy of such descriptions are a critical issue. An important factor in the development of nuclear cross section databases is the ability to describe nuclear structure and clustering aspects of specific materials constituents and GCR components. The quantum-based QMSFRG model has been shown in previous limited studies to provide this capability. Source terms for nuclear fragments will be included in the state-of-the-art, radiation transport codes, GRNTRN/BRYNTRN, and extended to space applications. We are developing improved theoretical descriptions of nuclear interactions and radiation transport, and fast computational methods including software that will provide accurate predictive capability and an engineering design tool in support of the HEDS enterprises. The quantum multiple scattering model of nuclear fragmentation (QMSFRG) and the GRNTRN code will be developed into a data base for GCR and SPE studies. Radiation transport codes and associated data bases will be optimized for use by spacecraft and planetary habitat design engineers.

An objective of the HEDS Strategic Plan is to understand the effects of space radiation on humans including possible unique effects from heavy ions. The relationship between the transmitted radiation fields at organ sites and biological risk is poorly understood and awaits fundamental understanding in molecular and radiation biology. Two areas of risk mitigation using biological approaches are the development of genetic markers of radiation predisposition and of biological counter-measures. Determination of the impact of these approaches will be dependent on knowledge of transmitted radiation for specific materials and the microscopic energy deposition events of heavy ions. Radiobiology experiments to understand biological risks and potential countermeasures are supported by the Code UL Office of Life and Microgravity Sciences and Applications. Our research program will support these efforts by providing tools to study the combined effects of several risk mitigation areas, including the relationship between shielding properties and biological counter-measures. We will test the effectiveness of shielding material candidates using conventional risk assessment, and track structure models of biological response that quantitatively represent proton and heavy ion biological response data. The track structure models will be used to represent proton and heavy ion experiments supported by Code UL Sciences and by others. These findings will be used to develop a Handbook of Radiation Attenuation Properties of Spacecraft and *In-situ* Materials that will describe shielding transmission properties of a wide range of materials using physical descriptors such as particle flux and absorbed dose, dose equivalent, and biophysics models of health risks and their potential counter-measures.