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Radiation Fields, Effects and Risks in Human Space Missions (4)

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GALACTIC COSMIC RADIATION RISK IN HUMAN SPACE MISSIONS

Abstract

Since 1973, no human has traveled beyond low-Earth orbit (LEO). While the exploration of space began as a "giant leap" forward, it has subsequently taken a step back, whereby humans have not ventured past LEO in four decades. Recently, there have been a growing number of initiatives to return to the Moon, visit asteroids, and even to go to Mars. Among the many challenges facing such missions, ionizing radiation exposure is one of the most poorly understood and dangerous. Despite technological improvements, ionizing radiation exposure continues to threaten the safety and success of human space missions beyond LEO. Galactic cosmic radiation (GCR) is particularly challenging and is reviewed in this report.

The characteristics and measurements of GCR are collated from numerous reports providing a collected understanding of GCR prevalence in LEO, interplanetary space, and on Mars. Next, the biological effects of GCR are analysed for various space environments and mission durations. Finally, the effectiveness of shielding is discussed with respect to traditional and alternative designs.

The results are not encouraging for human space exploration. Beyond the protection of Earth's atmosphere and geomagnetic field, GCR exposure threatens to exceed NASA's annual (50 cSv) and career limits (100 cSv) imposed on astronauts. There remain many uncertainties concerning the biological effects due to exposure to GCR, resulting in a variety of estimates and models. These models are analyzed and presented demonstrating the range of GCR exposure effects.

Traditional shielding is shown to be rather ineffective at hindering GCR. Various materials and designs are analysed leading to the conclusion that only high density materials, specifically high hydrogen-density materials, will reduce astronaut exposure to acceptable limits. Additionally, these high-mass solutions would pose considerable engineering challenges to mission designers.

Alternative designs, such as active radiation shielding and the use of lunar and Martian regolith are also reviewed. While some reports support the use of regolith, others suggest it is ineffective as a radiation shield. Active radiation shielding is a developing field with many engineering challenges. However, shielding effectiveness models suggest that active radiation shielding may prove not only viable but necessary for the design and success of human space exploration missions.