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ESTIMATING ACUTE RADIATION SICKNESS INCIDENCE FOR EXPLORATION MISSIONS OUTSIDE OF LOW EARTH ORBIT

Abstract

Solar particle event (SPE) incidence and dose rate estimates have been determined from data on past SPEs. However, estimates of the probability of an operationally significant exposure during future exploration missions is lacking. The Integrated Medical Model (IMM) is a probabilistic risk analysis based model approved by NASA for use as a decision support tool to evaluate the likelihood of mission specific incidence of medical events and their impact on mission outcomes. To conduct the analysis, input data including incidence and probability of clinical outcomes for pre-specified medical conditions is required. Towards this end, predicted acute radiation syndrome (ARS) incidence for missions outside low earth orbit (LEO) was estimated. Radiation exposures between 1 to < 2 Gray are considered mild ARS while those ≥ 2 Gray are considered severe and associated with an increasing probability of fatality proportional to radiation exposure. Therefore SPEs were distinguished as best case or worst case based on fluence sufficient to exceed threshold for fatal doses. For a spacecraft of 5 gm per cm^2 of aluminum shielding outside of LEO, SPE with omnidirectional fluence between $10^9 - 10^{10}$ protons per cm^2 of protons exceeding 30 MeV is expected to produce a whole-body dose of 1 to < 2 Gray while an SPE with a fluence of $\geq 10^{10}$ protons per cm^2 of protons exceeding 30 MeV is expected to produce a whole body dose ≥ 2 Gray. A yearly incidence for SPE with fluence of $10^9 - 10^{10}$ protons per cm^2 and $\geq 10^{10}$ protons per cm^2 of protons exceeding 30 Mev was estimated from published data to be 26.4% and 0.167%, respectively.

Probability of functional impairment (FI), need for evacuation (EVAC) and loss of crew life (LOCL) was assigned for best and worst case scenarios based on published data on clinical outcomes from terrestrial radiation exposures. Using these parameters, the likelihood of FI, EVAC, and LOCL for the Apollo missions was estimated to be 0.044 per mission (1 in 22 missions), 0.0011 per mission (1 in 909 missions), and $1.9 * 10^{-5}$ per mission (1 in 53200 missions), respectively.

Albeit limited, this approach enables estimation of ARS incidence from published data and suggests that incidence of operationally significant ARS endangering crew or mission outcomes may be low despite moderate shielding. Iterative modeling of ARS risk by incorporating additional parameters and revising current estimates may improve accuracy and applicability of these findings and offer insights into optimizing resource allocation for protection against SPEs during exploration missions.