CRaTER Observations and Permissible Mission Duration for Human Operations in Deep Space.

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Introduction: Prolonged exposure to the galactic cosmic ray (GCR) environment is a potentially limiting factor for manned missions in deep space. Evaluating the risk associated with the expected GCR environment is an essential step in planning a deep space mission. This requires an understanding of both how the local interstellar spectrum is modulated by the heliospheric magnetic field (HMF), and how observed solar activity is manifested in the HMF over time. While current GCR models agree reasonably well with measured observations of GCR flux on the first matter, they must rely on imperfect correlations to describe the latter. It is more accurate to use dose rates directly measured by instruments in deep space to quantify the GCR condition at any given time.

Permissible mission duration: In this work, dose rates observed by the Cosmic Ray Telescope for the Effects of Radiation (CRaTER) instrument are used to obtain the local GCR condition as a function of time. A response function is constructed that relates observed dose rates (see Figure 1) to solar modulation potential using a series of Monte Carlo radiation transport calculations.

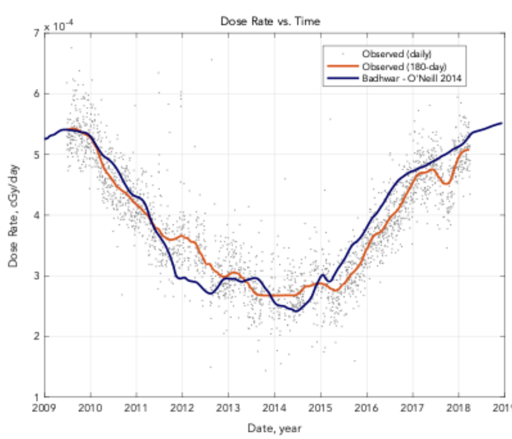

Figure 1. Dose Rate vs. Time. The daily (points) and 180-day average (orange) absorbed dose rates observed by CRaTER in the third detector pair (D5, D6) with a coincidence requirement in the first pair (D1, D2) compared with expected dose rate calculated using the Badhwar-O'Neill 2014 model.

This record of observed solar modulation potential vs. time is then used to calculate a recent historical record of permissible mission duration (PMD) according to NASA's permissible exposure limits (PEL). Tables are provided for extreme values of PMD. Additional tables provided include risk of exposure-induced death (at upper 95% confidence interval) accrual rates and effective dose rates as a function of solar modulation potential, astronaut age, sex, and shielding thickness (see Figure 2).

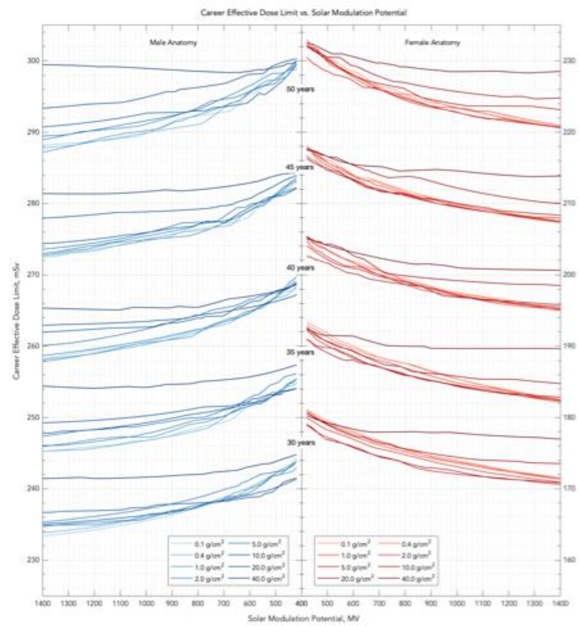

Figure 2. Career Effective Dose Limit vs. Solar Modulation Potential. Values are presented as a function of Al shield thickness, solar modulation potential, and astronaut age at exposure. The male (left) and female (right) sexes are represented by blue and red shades.

The significance of the PMD values reported in relation to likely transit duration requirements for future exploration missions is discussed. There is general agreement between CRaTER observations and the prescription of solar modulation vs. time given by the Badhwar-O'Neill 2014 GCR model. However, CRaTER observations do capture the effects of significant heliospheric transients, among other features, that are missing from the prescription of solar modulation potential vs. time.

Acknowledgments:
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