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Author: Mr. Jordan Houri
StemRad, United States, jordan@stemrad.com

Dr. Oren Milstein
StemRad, Israel, oren@stemrad.com
Dr. Thomas Berger
Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR), Germany, thomas.berger@dlr.de
Dr. Ramona Gaza
NASA, United States, ramona.gaza-1@nasa.gov
Mr. Hesham Hussein
Lockheed Martin Space Systems, United States, hesham.hussein@lmco.com
Mrs. Shirit Schwarz
StemRad, Israel, shirit@stemrad.com
Dr. Gideon Waterman
StemRad, Israel, info@stemrad.com
Dr. Karel Marsalek
German Aerospace Center (DLR), Germany, Karel.Marsalek@dlr.de
Dr. Daniel Matthiae
Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR), Germany, Daniel.Matthiae@dlr.de
Dr. Bartos Przybyla
Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR), Germany, Bartos.Przybyla@dlr.de
Mr. Joachim Aeckerlein
German Aerospace Center (DLR), Germany, Joachim.Aeckerlein@dlr.de
Ms. Kathleen Coderre
Lockheed Martin (Space Systems Company), United States, kathleen.m.coderre@lmco.com
Dr. W Paul Segars
Duke University, United States, paul.segars@duke.edu
Dr. Ehsan Samei
Duke University, United States, ehsan.samei@duke.edu
Dr. Anuj Kapadia
Oak Ridge National Laboratory, United States, kapadiaaj@ornl.gov

FIRST DATA-BASED EVALUATION OF THE RADIATION PROTECTION CAPABILITIES OF THE ASTRORAD VEST AS FLOWN ONBOARD ARTEMIS I

Abstract

The degree of protection provided by the AstroRad vest, a novel radiation shielding garment for astronauts to wear during solar particle events (SPEs), was evaluated in deep space for the first time during the Matroshka AstroRad Radiation Experiment (MARE) onboard NASA's Artemis I lunar mission. In lieu of human crew, the Orion spacecraft carried two identical female radiation dosimetry phantoms, "Helga", who remained unshielded, and "Zohar", who wore a prototype AstroRad vest. The AstroRad vest

maximizes the solid angle of coverage with a proprietary selective shielding design, optimizing protection for specific radiosensitive organs, tissues, and stem cell concentrations. Helga and Zohar were equipped with a multitude of active radiation detectors provided by DLR (M-42 detectors) and NASA (Crew Active Dosimeters, or CADs). These detectors were placed at key locations on the surfaces of each phantom as well as on the outside surface of the AstroRad vest for Zohar. Additional M-42 detectors were placed inside of each lung, the stomach, uterus, and spine for both Helga and Zohar. Although no major SPEs occurred during Artemis I, the Orion spacecraft traversed the inner Van Allen belt, exposing the phantoms to a similar radiation environment that could serve as a baseline for extrapolating the AstroRad vest's performance during an SPE using Monte Carlo simulations. The simulation framework was first validated by modeling the MARE experimental setup during the Artemis I inner Van Allen belt transit. This validation model agreed strongly with experimental detector data; the percent difference between the simulated and measured dose values was $-2.2 \pm 12.5\%$ for the M-42s (N=16) and $-3.1 \pm 14.9\%$ for the CADs (N=18). Modifying the simulation to generate solar energetic protons, it was found that wearing AstroRad in the vicinity of seats 3 and 4 inside Orion would be expected to reduce effective dose from 233.6 to 89.4 mSv (-61.8%) for the August 1972 SPE and from 249.9 to 149.4 mSv (-40.2%) for the October 1989 SPE. Based on Artemis I GCR dose rate data and NASA's 600 mSv career dose limit, it can be extrapolated that AstroRad may enable astronauts to spend up to an additional 209 days in space if exposed to an August 1972-like SPE and 146 days if exposed to an October 1989-like SPE. In line with the principle of reducing radiation exposure As Low As Reasonably Achievable (ALARA), MARE has demonstrated that the AstroRad vest can provide significant protection while minimizing impacts on mission operations.