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ENHANCED MONTE CARLO SIMULATIONS OF THE SPACE RADIATION ENVIRONMENT USING GEANT4 IN A HIGH PERFORMANCE COMPUTING ENVIRONMENT FOR THE INTERNATIONAL SPACE STATION AND APOLLO MISSIONS

Abstract

A significant danger to future manned and unmanned space travel is the space radiation environment, which will require accurate models of radiation transport through spacecraft to predict dose to protect astronauts, predict energy deposition within sensitive electronics, and analyze radiation shielding for future missions. The International Space Station provides an invaluable resource for long-term measurements of the radiation environment in Low Earth Orbit (LEO); however, the only manned missions with dosimetry beyond LEO are the Apollo Missions. Thus the physiological effects and dosimetry for deep space missions are scare and not understood for extended missions requiring further investigation and simulating.

GEANT4 provides a powerful toolkit in C++ for simulation of radiation transport through spacecraft based on the Monte Carlo method. The newest version of GEANT4 supports multithreading and MPI allowing for much faster distributive processing of simulations across a high performance computing environment. In this study we introduce a new application that greatly reduces computational time using high performance computing to simulate radiation transport through full spacecraft geometry reducing computational time to hours instead of weeks without any post simulation processing. We also introduce a new set of detectors besides the historically used International Commission of Radiation Units (ICRU) spheres for calculating dose distribution including a Thermoluminescent Detector (TLD), Tissue Equivalent Proportional Counter (TEPC), and human phantom along with a series of new primitive scorers in GEANT4 to calculate dose equivalence based on the International Commission of Radiation Protection (ICRP) standards.

This study presents Monte Carlo simulation of the dose deposition in the International Space Station and during the Apollo missions in agreement with experimental measurements. In this study, the greatest contributor to radiation dose for the Apollo missions was from Galactic Cosmic Rays because of the short time within the radiation belts. The Apollo 14 dose measurements were an order of magnitude higher compared to other Apollo missions. The GEANT4 model of the Apollo Command Module shows consistent doses from Galactic Cosmic Rays and Radiation Belts for all missions with a small variation in dose distribution across the capsule. The study also shows dose deposition and equivalent dose for various organs within a human phantom in the International Space Station or Apollo Command Module.