SPACE LIFE SCIENCES SYMPOSIUM (A1)
Interactive Presentations (IP)

Author: Mr. Matthew Lund
University of Utah, United States

Dr. Tatjana Jevremovic
University of Utah, United States

SIMULATING CHARGED PARTICLES IN A MAGNETIC FIELD FOR RADIATION SHIELDING USING ACTIVE SHIELDING PARTICLE PUSHER CODE IN HIGH-PERFORMANCE COMPUTING ENVIRONMENT

Abstract

A significant problem with deep space mission beyond Cislunar space is the space radiation environment, which includes high energy Galactic Cosmic Rays that pose a significant danger to astronaut health. Thus, there is a need to reduce astronaut radiation dose to enable these long duration space flights by development of improved shielding techniques, which use either passive or active systems. Traditional passive systems use materials and a large amount of mass to reduce particle fluence, adding a prohibitive amount of mass to the spacecraft; whereas, active systems use a magnetic or electric fields to deflect the charged particle away from the spacecraft and potentially could be lighter. In the past, potential active shielding configurations were analyzed using theoretical models for different magnetic field configurations; however, this is limited to basic calculations of particle reduction. Presented here is a newly developed code to calculate the path of charged particles within a magnetic and electric field, using high-performance Computing to quickly prototype many different types of fields. The developed code, Active Shielding Particle Pusher (ASPP), is built in C++ to run on multiple computer architectures, including optimized to run on Graphical Processor Units (GPUs) and high-performance computing clusters using OpenMP protocol for multithreading and Message Passing Interface (MPI) for running on multiple nodes. ASPP generates particles of different charges and energy, which it then propagates through several different types of magnetic and electric fields, including Helmholz, azimuthal, Earth's dipole field, a user-defined field, et cetera. The code implements several new methods to solve the partial differential equation for particle propagation, including the Boris Particle Pusher methods.

ASPP was verified, analyzing the simulation results against theoretical models by comparing the closest approach for a large number of particles. In Earth's magnetic field, Euler's, Leap Frog, and Velocity Verlet methods poorly approximated movement of a particle in a magnetic field; whereas, Runge-Kutta 4th Order Method and Gear Predictor method correctly predicted the exclusion zone but with anomalous closest approach for some particles surrounding the exclusion zone due to poor energy conservation. The Boris propagation method correctly calculated the exclusion zone with no anomalous particles with minimal runtime, thus it provides the best method for studying motion of charged particles in a magnetic field. Furthermore, ASPP was then integrated with an optimization code, RAVEN, to prototype and optimize an ideal magnetic field to shield a spacecraft capsule in interplanetary space, during a Mars mission.