NASA Langley Research Center
Center Innovation Fund (CIF) - First Year Report
Project Title: Crystal Shielding for Space Radiation
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Space radiation is a critical limiting factor in long duration spaceflight, especially on a three year Mars mission, and with present technologies, astronauts would receive unacceptable radiation doses. Space radiation shielding technologies are based on passive methods, whereby the spacecraft structure and habitat walls provide the shielding, but this is insufficient to reduce radiation to safe levels. Active methods, using external electric or magnetic fields remain unproven technologies. A shield which can reduce radiation dose to acceptable levels would revolutionize long duration space travel and enable a three year mission to Mars. Crystals have a periodic lattice structure that incorporates very strong, periodic electric fields which are capable of controlling the trajectories of incoming charged particles. Bent crystals made from silicon, germanium, and other materials have long been used in particle accelerator applications for beam extraction, focusing, and steering. When light is incident on water, the light can either be refracted (i.e. bent) or reflected. Similarly, charged particles can be refracted or reflected by steering magnets. Bent crystals have analogous properties and can be used to refract or reflect or absorb incident charged particle beams. Accelerator technology applications most often deal with charged particle beams coming from a single direction, with a single energy (monoenergetic), and with a single charge. (For crystal applications, refraction is often called channeling, reflection is often called volume reflection, and absorption is often called volume capture). The major hazard to long duration space flight is due to radiation produced from galactic cosmic rays, which come from all directions, with a wide range of energies, and a wide range of charges. Dealing with this multi-energy, multi-charge, and multi-angle aspect of space radiation represents the principal difficult technical challenge in developing radiation shielding using crystals. The long term aim of the present work is to design a crystal space radiation shield which is capable of shielding astronauts from the galactic cosmic ray environment. Crystal shielding would therefore be a combination of active and passive shielding methods, whereby a passive crystal shield material would be used as spacecraft structure, and the internal electric fields would actively deflect charged radiation particles. There are three design modes that are being investigated based on refraction, reflection and absorption of galactic cosmic ray particles. Both refraction (channeling) and reflection (volume reflection) might address the multi-energy, multi-charge, and multi-angle aspects. A computer code is being developed to visualize how the crystal shield changes the trajectories of galactic cosmic rays. Three tasks were accomplished in the first year of this work. Firstly, a computer code was written that includes both channeling and volume reflection, and follows trajectories of galactic cosmic ray particles when incident on a simple crystal configuration. Secondly, a code was developed for following galactic cosmic ray trajectories from a more complex crystal configuration, such as a bent two-dimensional crystal. Thirdly, a code was developed for a more complicated crystal configuration completely surrounding a spacecraft. The computer codes enabled the discovery of new trajectory modes in addition to channeling and volume reflection, and also allowed one to visualize galactic cosmic rays trajectories passing through crystal shielding configurations surrounding a spacecraft. The aim of future work is to make the computer codes apply more directly to realistic scales and to incorporate more realistic quantum atomic structure effects within a crystal material.