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Active Magnetic Radiation Shielding System Analysis and Key Technologies

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Abstract

Many active magnetic shielding designs have been proposed in order to reduce the radiation exposure received by astronauts on long duration, deep space missions. While these designs are promising, they pose significant engineering challenges. This work presents a survey of the major systems required for such unconfined magnetic field design, allowing the identification of key technologies for future development. Basic mass calculations are developed for each system and are used to determine the resulting galactic cosmic radiation exposure for a generic solenoid design, using a range of magnetic field strength and thickness values, allowing some of the basic characteristics of such a design to be observed. This study focuses on a solenoid shaped, active magnetic shield design; however, many of the principles discussed are applicable regardless of the exact design configuration, particularly the key technologies cited.

Keywords: Space Radiation; Radiation Exposure; Dose Equivalent; Active Radiation Shielding; Magnetic Shielding; GCR

1. Introduction

Providing adequate radiation protection is one of the most difficult problems facing long duration, deep space, human exploration missions. Chronic radiation exposure from Galactic Cosmic Radiation (GCR) and acute exposure from Solar Particle Events (SPEs) pose serious health threats to astronauts as they venture away from the protection of the near-Earth environment (Durante and Cucinotta, 2011; Townsend, 2005a). Current exploration goals seek to enable mission durations of a year or more in order to reach high interest destinations, and adequate radiation protection must be provided to ensure the safety of the crew (ISECG, 2013). Unfortunately, because of the nature of the space radiation environment, providing this protection using passive shielding requires a significant amount of mass to achieve reasonable radiation exposure values (Singleterry, 2013).

Over the last several decades, many shielding designs that actively deflect the incoming charged particle radiation have been proposed (Sussingham et. al, 1999; Spillantini, 2010). These active shields have the potential to reduce radiation exposure to acceptable levels at a lower mass penalty than the equivalent amount of passive shielding. There are several general classes of active shielding (Townsend, 2005b), some of which include the use of magnetic fields to divert harmful radiation away from the crew, and a variety of different ways in which these designs may be configured. This analysis focuses on a solenoidal magnetic configuration, in which large magnetic fields are generated around the protected habitat such that the field lines run parallel to the central axis of the habitat; however, the general principles involved in the study may also be applied to other magnetic configurations.

This paper explores the major systems which compose an active magnetic shielding design: superconductor, structure, thermal, and power. These systems are highly interdependent and significant mass drivers of the overall system design. A survey is conducted for each major system, and a study of the major design options is presented. This allows a narrowing in scope of possible system solutions and

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