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Standard

Low Earth Orbit Spacecraft Charging Design Standard Requirement and Associated Handbook

American National Standard

Approved American National Standard ANSI

AIAA

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Low Earth Orbit Spacecraft Charging Design Standard Requirement and Associated Handbook

Sponsored by

American Institute of Aeronautics and Astronautics

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Abstract

This standard presents an overview of the current understanding of the various plasma interactions that can result when a high-voltage system is operated in the Earth's ionosphere, references common design practices that have exacerbated plasma interactions in the past, and recommends standard practices to eliminate or mitigate such reactions.

American National Standard

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Foreword

This document is based on the low Earth orbit (LEO) Spacecraft Charging Design Guidelines (Ferguson and Hillard, 2003), and the National Aeronautics and Space Administration (NASA) Low Earth Orbit Spacecraft Charging Design Standard [NASA-STD-(I)-4005 (2006) and NASA-STD-4005 and NASA-HDBK-4006 (2007)] and has the same authors, Ferguson and Hillard, as those documents. It is the first American National Standard in its subject area and thus does not cancel or replace any other American National Standard in whole or in part. Only minor technical changes and updates distinguish the present standard from NASA-STD-(I)-4005. The present standard deals only with surface charging in LEO environments. In particular, this standard is not intended to replace NASA TP-2361, which is applicable to geosynchronous Earth orbit (GEO) plasma environments, or NASA-HDBK-4002, which deals only with deep dielectric charging. NASA-HDBK-4002A, which covers only charging environments outside of equatorial LEO and deep-dielectric charging, is also not to be replaced by this document. In this document, all of the Annexes are only informative. The only requirements in this standard are in Section 5 (Requirements).

At the time of approval, the members of the AIAA Atmospheric and Space Environment Committee on Standards Working Group for Low Earth Orbit were:

Henry Garrett, Chair	Jet Propulsion Laboratory
Michael Bodeau	Northrop Grumman Aerospace Systems
Dale Ferguson	NASA Marshall Space Flight Center
Dale Johnson	Retired
Justin Likar	Lockheed Martin Space Systems
Kent Tobiska	Space Environment Technologies
William Vaughan	University of Alabama, Huntsville
Albert Whittlesey	Jet Propulsion Laboratory
John Wise	Air Force Research Laboratory

The above consensus body approved this document in July 2013.

The AIAA Standards Executive Council (VP-Standards Laura McGill, Chairperson) accepted the document for publication in August 2013.

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Introduction

The purpose of this document and information handbook is to provide design standard requirements for high-voltage space power systems (>55 V) that operate in the plasma environment associated with LEO (altitude between 200 km and 1000 km, and latitude between -50 degrees and +50 degrees). Such power systems, particularly solar arrays, are the proximate cause of spacecraft charging in LEO, and these systems can interact with this environment in a number of ways that are potentially destructive to themselves and to the platform or vehicle that has deployed them. This document is also applicable to satellites during the lower latitude portion of polar orbits and to GEO satellites during the initial low altitude portion of their geostationary transfer orbit.

This document represents the technical consensus of the spacecraft charging community. Systems designers need a standard to show them how to mitigate the spacecraft charging effects of using high voltages in LEO. In addition to system designers, this document should be useful to project managers, solar array designers, system engineers, etc.

This document is intended as a standard for design applications and can be used as a requirements-specification instrument.

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1 Scope

This document and information handbook presents an overview of the current understanding of the various plasma interactions that can result when a high-voltage system is operated in the Earth's ionosphere. This document is also applicable to satellites during the lower latitude portion of polar orbits and to GEO satellites during the initial low altitude portion of their geostationary transfer orbit.

It references common design practices that have exacerbated plasma interactions in the past, and recommends standard requirements and practices to eliminate or mitigate such reactions.

1.1 Purpose

The purpose of this standard is to provide the requirements for a design standard for high-voltage space power systems (>55 V) that operate in the plasma environment associated with LEO (altitude between 200 km and 1000 km and latitude between -50 degrees and +50 degrees). Such power systems, particularly solar arrays, are the proximate cause of spacecraft charging in LEO. These systems can interact with this environment in a number of ways that are potentially destructive to themselves and to the platform or vehicle that has deployed them.

High-voltage systems are used in space for two reasons. The first is to save launch weight. High-voltage systems are often used as a means to reduce mass and increase efficiencies by reducing power line I^2R losses. High-voltage systems are also used in space because some spacecraft functions require high voltages. For example, electric propulsion uses voltages from about 300 V (Hall thrusters) to about 1000 V (ion thrusters). For low-voltage power systems, conversion of substantial power to high voltages is required for these spacecraft functions to operate. The weight of the power conversion systems, power management and distribution (PMAD), can be a substantial fraction of the total power system weight in these cases. It is more efficient, and can save weight, if the high-voltage functions can be directly powered from a high-voltage solar array, for instance. If the high-voltage function is electric propulsion, then we call such a system a direct-drive electric propulsion system.

These two reasons and others are causing spacecraft designers and manufacturers to use high voltages more and more. However, doing so entails risk: in particular, spacecraft charging in LEO, in contrast to that in GEO, is caused by exposed high voltages and can lead to arcing, power drains, power disruptions, and loss of spacecraft coatings. Thus, system designers need a standard to show them how to mitigate the spacecraft-charging effects of using high voltages in LEO. In addition to system designers, this document should be useful to project managers, solar array designers, system engineers, etc.

This document is intended to provide requirements and associated best practices for design applications and can be used as a requirements-specification instrument.

1.2 Applicability

The contents of this document are applicable to high-voltage space power systems that operate in the plasma environment associated with LEO. This standard is intended for space systems that spend the majority of their time at altitudes between 200 km and 1000 km (usually known as LEO applications) and at latitudes between about –50 degrees and +50 degrees—that is, space systems that do not encounter GEO charging conditions, that do not (often) encounter the auroral ovals of electron streams, and that do not fly through the Van Allen belts. For the extreme radiation protection that is necessary for orbits in the Van Allen belts, exterior spacecraft charging will likely be a secondary concern. However, internal charging will be very important. It is not in the purview of this document to deal with internal charging.

Some of the design standards for LEO are at variance with good design practice for GEO spacecraft. If your spacecraft will fly in both LEO and GEO conditions, then be careful to use design solutions that are applicable in both environmental regimes.

Table 1 (Ferguson and Brandhorst, 2012) illustrates some of the differences between good GEO and LEO design practices.