Appendix J
Key Spacecraft Charging Documents

This Appendix is a sampling of the many possible information sources relevant to this field. It is heavily colored by the principal authors’ knowledge, experience, and prejudices; and it has omitted many worthy references to keep it to a manageable size. The curious reader may dig deeper by following references in these documents. Additional, more specific, sources are referenced in the text following each chapter or appendix. The various charging conference records themselves contain a wealth of technical papers.

J.1 United States Government Documents

J.1.1 DoD

AFGL-TR-77-0288

AFGL-TR-78-0304

AFGL-TR-79-0015
AFRL-VS-TR-20001578  


This conference is documented on one or more CDs, one of which is contained in SEE Publication SEE/TP-2005-600 (J. Minor, compiler, NASA MSFC). The CD contains photo images of electronic files for the 1st through the 8th Spacecraft Charging Conferences.

AFWAL-TR-88-4143, Vol. II  


Contains good design ideas.

MIL-STD-461  

*Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment*. Various versions; version F is the latest as of 2007. 

Generally, a good EMC design will be helpful at mitigating space charging and ESD effects.

MIL-STD-462  


MIL-STD-883G  


This describes Vzap tests for measuring ESD response of electronic parts to the human body model for ESD.
MIL-STD-1541A  
*Electromagnetic Compatibility Requirements for Space Systems.*  
Appendix E.9 of this Handbook has a “Schematic Diagram of Arc Source” as copied from MIL-STD-1541A (30 December 1987).

MIL-STD-1686  
*Electrostatic Discharge Control Program for Protection of Electrical and Electronic Parts, Assemblies, and Equipment (Excluding Electrically Initiated Explosive Devices),* October 25, 1995.

MIL-STD-1809  
This includes some electron spectra that can be used in the electron transport codes. It has good information that supplements Earth environmental information in this version of NASA-HDBK-4002A.

PL-TR-93-2027(I)  
More detailed explanations of the space environment and its interactions with spacecraft.

**J.1.2 NASA**

NASA-CP-2004-213091  
More detailed explanations of the space environment and its interactions with spacecraft.
NASA-CP-2071  
More detailed explanations of the space environment and its interactions with spacecraft.

NASA-CP-2182  
More detailed explanations of the space environment and its interactions with spacecraft.

NASA-CP-2359  
More detailed explanations of the space environment and its interactions with spacecraft.

NASA-HDBK-4001  
This is a handy general document. Notice that the grounding diagrams show that the circuit grounds exit the boxes and apparently connect to a remote ground; this is a schematic and not a physical diagram. The grounds should be contained within the box for the EMC reason that it should not act as a radiator (antenna) of noise into or out of the box.

NASA-HDBK-4002  
One of the two base documents for NASA-HDBK-4002A along with NASA TP-2361.
NASA-HDBK-4002A


NASA-HDBK-4006


This document is written by two of NASA’s senior researchers in spacecraft charging, recognized experts on charging (and discharging) of solar arrays in space plasmas. It is a fine reference to have on your bookshelf for spacecraft charging. See also NASA-STD-4005.

NASA-RP-1354


NASA-RP-1375

R. D. Leach and M. B. Alexander, Failures and AnomaliesAttributed to Space Charging, August 1995.

NASA-STD-4005


The NASA standard for LEO charging, it gives mitigation techniques for LEO, some of which are also applicable to GEO and polar environments. See also NASA-HDBK-4006.

NASA TMX-73537


Design Guidelines for Assessing and Controlling Spacecraft Charging Effects, 1984. One of the two base documents for NASA-HDBK-4002A. Listed as historical reference; some of the deleted sections can provide more background information and illustrations. Its Section 2.3 describes charge loss in a discharge. Its Section 3.1.2.3 describes retarding potentials on large portions of dielectrics.

### J.2 Non-US Government Documents

#### J.2.1 American Society for Testing Materials (ASTM)

**ASTM D-257-61** Standard Test Methods for DC Resistance or Conductance of Insulating Materials, 1961. Uses test methods appropriate for normally dielectric materials. For measurement of highly resistive materials often used for space charging applications, special measurement methods should be used. (See ASTM D 257-91.)


J.2.2 European Cooperation for Space Standardization (ECSS)/European Handbooks

These documents are available via the ESA-ESTEC website, including unpublished drafts. The website is http://www.ecss.nl. Accessing documents requires registration on the website, but the only requirements for a user are to supply an ID and the users e-mail address to:

ECSS Secretariat
ESA-ESTEC
Noordwijk, The Netherlands

ECSS-20-06 Spacecraft Charging-Environment-induced Effects on the Electrostatic Behaviour of Space Systems. Unpublished draft that should be published because of its useful content.

ECSS-E-ST-20-06C Space Engineering, Spacecraft Charging Standard, July 31, 2008. This is intended to be a set of design rules but is far more than that. It contains the background physics and provides a wealth of space-charging information, both scientifically and practically oriented. The standard is a very good educational reference. Sometimes, however, it is not explicit in that it may provide two or more answers to the same question (e.g., what environment to use).

J.2.3 European Space Research and Technology Centre


J.2.4 Japan Aerospace Exploration Agency (JAXA)

J.2.5 Other

QinetiQ/KI/SPACE/HB042617


SD 71-770