MILITARY STANDARD FOR SPACECRAFT CHARGING STATUS REPORT

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SUMMARY

The Air Force Space Division, with technical support from Science Applications, Inc. and Aerospace Corporation have structured a Military Standard for Spacecraft Charging in the format of an appendix to MIL-STD-1541, Electromagnetic Compatibility Requirements for Space Systems. The document is one of the key products of the Cooperative NASA/AF Spacecraft Charging Investigation. This paper presents the status of the development of the Spacecraft Charging Requirements Appendix and provides an opportunity for a community review of the current document structure and content.

INTRODUCTION

The development of a military standard for spacecraft charging requirements is an essential product of the Cooperative NASA/AF Spacecraft Charging Investigation. Figure 1 presents a timeline of the history of this development over the past 4 years of the NASA/AF program. The current goal is the incorporation of S/C charging requirements into an update of MIL-STD-1541 by the end of Air Force FY82. Over the time period shown, the S/C Charging Standard has evolved from an initial identification of a need for an environmental and test specification, through a potential stand-alone military standard requirements document, to the now planned MIL-STD-1541 revision. The intent is to serve the community of system program offices, NASA labs, and space vehicle contractors with a document which provides a consensus of practical requirements for design, test, and analysis to minimize the effects of the S/C charging phenomena.

The military standard requirements for spacecraft charging will take the structure of an appendix to the MIL-STD-1541 document. Elements within the main body of the current MIL-STD-1541 relating uniquely to S/C charging will be deleted in the formal revision by Aerospace Corporation. The following section of this report provides the Science Applications, Inc. (SAI) recommended inputs for the Spacecraft Charging Requirements Appendix, following a prescribed format. The main sections of the appendix are:

10. SCOPE

20. REFERENCED DOCUMENTS

30. DEFINITIONS

40. GENERAL STATEMENT OF REQUIREMENTS

50. DETAILED STATEMENT OF REQUIREMENTS

This document does not have the formal approval of AF Space Division/ Aerospace Corporation at this time. It is a preliminary document intended to undergo a community review. An attempt has been made to quantify as much information as possible based on the current data available. Material with a high degree of uncertainty is flagged or left TBD at this time, with "best available information" in parentheses. The information contained in this version of the Appendix is inclusive of more material than will reside in the final document. Some of the information is more appropriate for a Statement of Work (SOW) than for the MIL-STD Appendix. All of the information, however, has been included here for completeness and for review. Comments from the community will be welcomed.

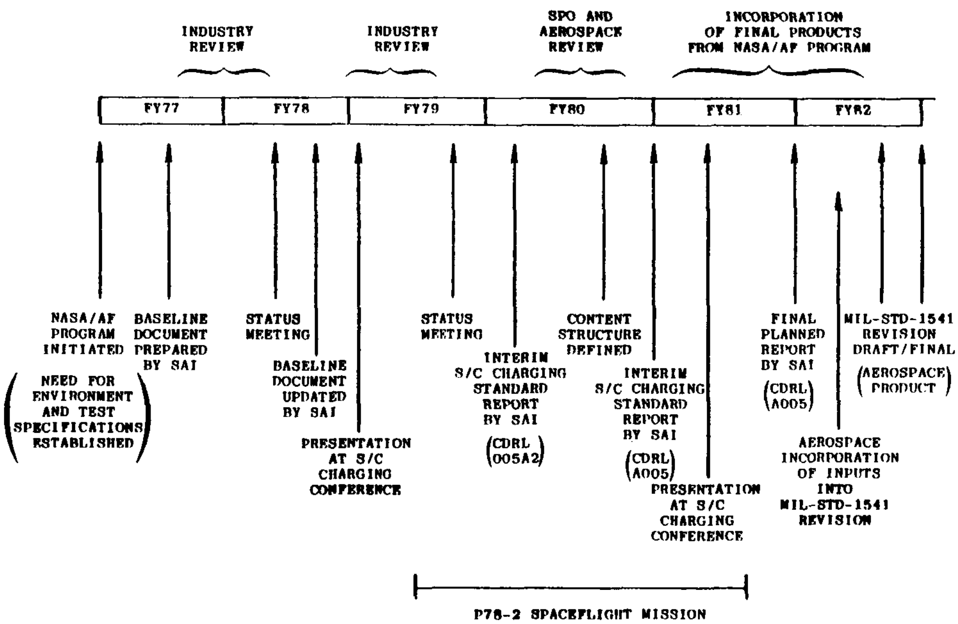

Figure 1. Timeline of S/C Charging Standard Development Activities

PROPOSED MIL-STD-1541 REVISION

APPENDIX: SPACECRAFT CHARGING REQUIREMENTS

This appendix includes mandatory material to be considered as part of this standard as prescribed in paragraph TBD of this standard. (Paragraph TBD is an applicability statement within body of MIL-STD-1541).

10. SCOPE

10.1 Scope. This appendix establishes the spacecraft charging (SCC) protection requirements for space vehicles which are to operate in the magnetospheric plasma environment as specified in TBD (AFGL Final Environmental Atlas definition of applicable region of space). This Appendix contains design requirements, analysis requirements, and test requirements and test methods to ensure space vehicle performance will not be degraded below specified levels when subjected to the magnetospheric plasma environment. (Analysis requirements may be transferred to the contractor Statement of Work (SOW)).

10.2 Application. This appendix shall be applicable only to space systems which might enter, during the course of their mission, the region of space containing the plasma environment which can cause spacecraft charging effects. This region is defined in TBD (Final AFGL Atlas). (Regions of space in the vicinity of the earth with L shell values of between 4.0 and 9.0 are representative of the regions of the SCC hazard). This appendix shall apply generally to all space systems exposed to the SCC hazard. Certain requirements may, however, be specifically tailored to individual program specifications with the approval of the procuring agency.

20. REFERENCED DOCUMENTS

20.1 Issues of Documents. The following documents of the issue in effect on the date of invitation for bids or request for proposal, form a part of this Appendix to the extent specified herein:

STANDARDS

Military

MIL-STD-1541 (USAF) - Electromagnetic Compatibility Requirements for Space Systems

20.2 Other Publications. The following documents form a part of this appendix to the extent specified herein. Unless otherwise indicated, the issue in effect on the date of invitation for bids or request for proposal shall apply.

NASA TM X-73446 - Provisional Specification For Satellite Time in a Geomagnetic Substorm Environment (to be updated)

AFML-TR-76-233 - Conductive Coatings for Satellites

AFML-TR-77-174	- Transparent Antistatic Satellite Materials
AFML-TR-77-105	- Spacecraft Static Charge Control Materials
AFML-TR-78-15	- Satellite Contamination
AFGL-TR-77-0288	- Modeling of the Geosynchronous Orbit Plasma Environment - Part I
AFGL-TR-78-0304	- Modeling of the Geosynchronous Orbit Plasma Environment - Part II
AFGL-TR-79-0015	- Modeling of the Geosynchronous Orbit Plasma Environment - Part III
NASA (to be published)	- Design Guidelines for Spacecraft Charging Monograph
NASA CR-135259	- NASCAP User's Manual
AFGL (to be published)	- Final Environmental Atlas, Preliminary version: P78-2 SCATHA Preliminary Data Atlas
AFWAL-TR-80-4029	- Satellite Spacecraft Charging Control Materials

30. DEFINITIONS

30.1 Definitions That Apply To This Appendix. The terms used in this appendix are either defined in MIL-STD-1541 (USAF) or listed in the following paragraphs.

30.1.1 Arc Discharge (Vacuum Arc Discharge). A discharge taking place in a vacuum region with initially high potential gradients. The electric field may exist within a dielectric or in the vacuum region surrounding the charge retaining material. In the latter case, the gradients are between the electrode and either the vacuum chamber walls or an equivalent space charge surrounding the electrode. In these cases, the potential gradients must be sufficiently high to ionize and vaporize the charge retaining material. There are different types of important vacuum arc discharges, each classified by the configuration of the electrodes or the characteristics of the current path at the spark gap. These are the dielectric-to-metal discharge and the metal-to-metal discharge, each with a spark gap path that is classified as a punch-through, a flash-over, or a blow-off discharge.

3.1.2 Blow-off Discharge (Space Emission Discharge). A vacuum discharge characterized by the ejection of current (blow-off of charge) into space surrounding an electrode. To produce a space emission discharge, the electric field must be suffiently high to cause ionization and vaporization at the electrode.

30.1.3 Backscattering. The deflection of particles by scattering processes in matter such that particles emerge through the same planar surface as they entered.

30.1.4 Capacitive Direct Injection (CDI). A method of inducing a space vehicle response that simulates that response to a blow-off discharge. The method involves driving the space vehicle with a current injection into a given point, with charge return accomplished through a drive plate serving as a capacitor.

30.1.5 Dielectric-To-Metal Discharge. A discharge between two electrodes, one of which is a dielectric charge retaining material and the other is a conductive (metal) electrode in the vicinity of the dielectric. A dielectric material will typically accumulate charge when irradiated by electrons or ions or under certain conditions when placed in a plasma environment.

30.1.6 Differential Charging. The charging of neighboring space vehicle surfaces to differing potentials by the combined effects of space plasma charging, photoemission, secondary emission, and backscatter.

30.1.7 Faraday Cage. An electromagnetically shielded enclosure. The term generally refers to a conductive metallic structure, package, or mesh which attenuates external electromagnetic energy to specified levels in the interior.

30.1.8 Flash-Over Discharge. A discharge characterized by a current path that travels along a surface of the material (and sometimes around an edge) to close the path between the electrodes.

30.1.9 Geomagnetic Substorm Activity. The conditions near geosynchronous altitude during the injection of substorm particles into the earth's magnetic field, including disturbances in the dipole field and increased plasma energies and current densities.

3.1.10 Magnetospheric Plasma. The space plasma environment constituent in the magnetosphere. This is an electrically neutral collection of electrons and positive ions (primarily protons) with densities near geosynchronous altitude on the order of one particle/cm^3.

30.1.11 Metal-To-Metal Discharge. A discharge between two conducting electrodes.

30.1.12 Photoemission. An effect whereby radiation of sufficiently short wavelength impinging on substances causes electrons to be emitted with an energy that varies with the frequency of the radiation.

3.1.13 Punch-Through Discharge. A discharge through the bulk of a dielectric material coupled with a bulk breakdown of the insulating strength of the dielectric separating two electrodes. The current path is through the bulk of the material, with surfaces on opposite sides of the dielectric acting as electrodes. The punch-through discharge may occur in vacuum or in air.

3.1.14 Replacement Current. Current that flows to the electrodes in response to a discharge but not as part of the discharge.

3.1.15 Secondary Emission. An effect whereby low energy electrons or ions, called secondary electrons or ions, are emitted from a material as a result of the interaction of higher energy electrons or ions with the material. The ratio of secondary particles to primary particles can be greater than unity.

30.1.16 Spacecraft Charging (SCC). The phenomenon where space vehicle elements and surfaces can become differentially charged to a level sufficient to cause discharges and resulting EMI. The primary effects of SCC are electrical transients and upsets, material degradation, and enhanced contamination.

30.2 Acronyms Used in This Appendix.

CDI - Capacitive Direct Injection
EMI - Electromagnetic Interference
ESD - Electrostatic Discharge
MLI-- Multi-Layer Insulation
S/C - Spacecraft
SCC - Spacecraft Charging

40. GENERAL STATEMENT OF REQUIREMENTS

40.1 Spacecraft Charging Protection Program. The contractor's spacecraft charging protection program shall include (a) the preparation and maintenance of an analytical plan and (b) the preparation and maintenance of a test plan. The intent of the program shall be to assure that the space vehicle is capable of operating in the specified space plasma charging environment (Section 40.1.1) without degradation of the specified space vehicle capability and reliability and without changes in operational modes, location, or orientation. This performance must be accomplished without the benefit of external control such as commands from a ground station. The spacecraft charging protection program, the analytical plan, and the test plan shall be subject to approval by the procuring agency. (The requirements for plans will be transferred to the contractor SOW).

40.1.1 Specified Environment. The space plasma charging environment shall be that as specified in TBD (AFGL Final Environmental Atlas). Other AFGL documents useful to model the plasma environment include: AFGL-TR-77-0288, AFGL-TR-78-0304, and AFGL-TR-79-0015. A "worst case" engineering specification for that environment follows.

A "worst case" substorm is described as a plasma environment composed of electrons (e) and protons (p) with the following temperature and density for the given time intervals (see Figure 2).

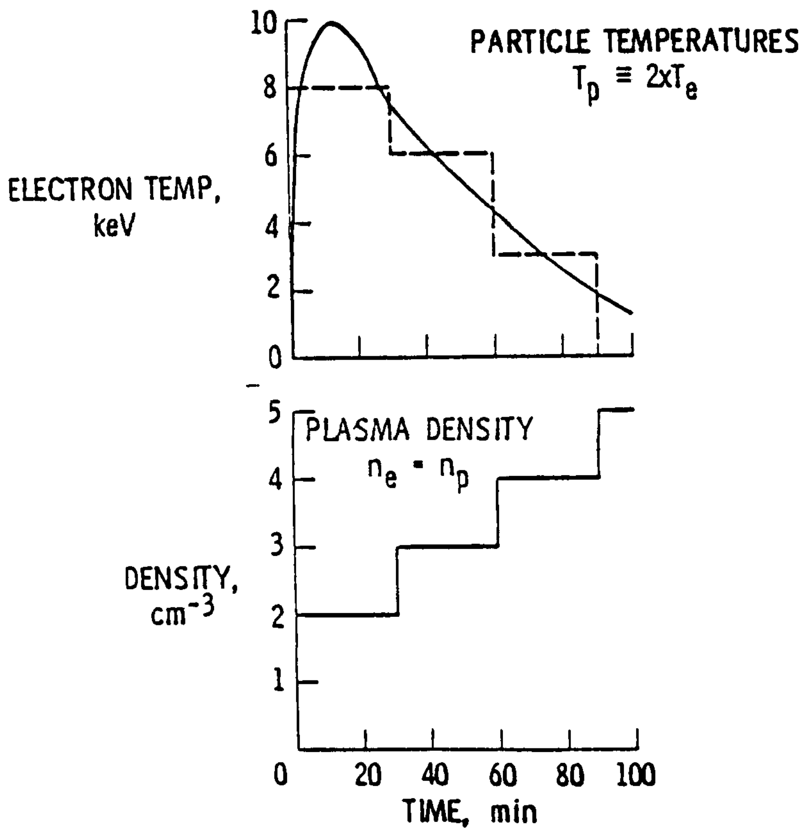

Figure 2. "Worst Case" Substorm Parameters

40.1.2 Performance. Analysis and test shall be used to assure that all space vehicle electrical systems perform to specified capabilities in the specified environment. Specified capabilities and levels of performance shall be established by the procuring agency. (The contractor SOW will call out this requirement).

40.1.3 Design. Protective design measures should be compatible with MIL-STD-1541 (USAF) and TBD (NASA Design Guidelines) to limit the susceptibility of electrical systems and spacecraft materials to the SCC hazard. Materials used in the space vehicle design shall perform to specified capabilities in the specified environment. The space vehicle design shall limit contamination enhanced by electrostatic effects induced by the specified environment to contamination levels that will not reduce the performance of space vehicle surfaces or systems below specified capabilities. Any protective features incorporated in the space vehicle design to reduce the SCC hazard must not reduce space vehicle performance below specified levels.

50. DETAILED STATEMENT OF REQUIREMENTS

50.1 Performance.

50.1.1 Electrical Subsystems and Systems. Space vehicle electrical subsystem and system outage shall be permissable during an arc discharge if operation and performance returns to specified levels within a telemetry main frame period after onset of the discharge or within some other period as defined by the procuring agency. A command to the space vehicle from an external source such as a ground station is not required to be completed if an arc discharge occurs during transmission of the command, provided that an unintended action does not result and that the space vehicle is capable of receiving and executing subsequent commands and meeting specified performance within a time period as defined by the procuring agency. Space plasma-induced electrical transients shall not affect on-board digital data beyond the specified design limits.

50.1.2 Materials. Thermal control materials and their surfaces, second surface mirrors, solar cells and coverslides, and other critical materials, structures, and components shall not degrade in thermal or optical properties or structural integrity in the specified space plasma environment below the level required to perform to specified capabilities.

50.2 Design. The following design requirements (50.2.1 through 50.2.5) shall be implemented for protection against the SCC hazard. Additionally, the design guidelines in TBD (NASA Design Guidelines Monograph) should be followed wherever reasonable and applicable. Where it is impractical or undesirable to implement the following design requirements, the contractor shall show by analysis or test that non-concurrence with the requirement will not degrade space vehicle performance below specified capabilities.

50.2.1 Grounding of conducting elements. All space vehicle conducting elements shall be tied by an electrical grounding system so that the DC resistance between any two points is $\leq$ 0.1 ohm. The grounding shall be applicable to all conducting elements with external surfaces exposed directly to the specified plasma environment and for all elements with surface areas $\geq$ 25 cm^2. DC resistance levels of grounds shall be verified by standard ohm-meter measurements. The grounding does not apply directly to thin (< 10μ) conducting surfaces on dielectric materials. These are treated separately in Section 50.2.2.

50.2.2 Grounding of thin conducting surfaces. All thin (< 10μ) conducting surfaces on dielectric materials shall be electrically grounded to the common space vehicle structural ground so that the DC resistance between the surface and the structure is $\leq$ 10 ohms. DC resistance levels of ground and bonds shall be verified by standard ohm-meter and bond-meter measurements. Thicker surfaces shall be grounded as described in Section 50.2.1. Thin conducting surfaces shall be inclusive of, but not limited to, all metallized surfaces of multi-layer insulation (MLI) thermal blankets, metalized dielectric materials in form of sheets, strips, tapes, or tiles, conductive coatings, conductive paints, conductive adhesives, and metallic grids or meshs. The number of ground points on each conducting surface should following the following prescription:

Surface Area	Number of Ground Points
< 1.0 m^2	2 or more
1.0 to 4.0 m^2	3 or more
> 4.0 m^2	1 per m^2

Additionally, any point on a conducting surface should be within 1 meter of a grounding point.

50.2.3 Shielding of EMI. All electronic cables, circuits, and components shall be provided with EMI shielding to attenuate radiated fields from discharges (100 kHz to 1 GHz) by at least 40 db. Attenuation levels of radiated fields shall be verified by standard measurement techniques or by analysis for representative locations internal to shielding enclosures. The method of verification shall be subject to approval by the procuring agency. The shielding may be provided by the basic space vehicle structure designed as a "Faraday cage" with a minimum of openings or penetrations, by enclosures of electronics boxes, by separate cable shielding, or by combinations of the preceding shields. Electronics units and cables external to the basic space vehicle structure shall have individual shields providing the 40 db attenuation of EMI.

50.2.4 Design against electrical discharges. The spacecraft shall be designed to perform to specified capabilities when subjected to discharges with the following characteristics:

TBD. The preliminary format for the characterization of typical "worst case" SCC associated discharges includes the following parameters:

1. Blow-off and arc current time history (probably monopolar, with rise time of 5 to 100 nanoseconds, dependent on sample linear dimensions; decay times to several μseconds, dependent on RC time constant of the sample; total charge in blow-off or integral of blow-off current is probably proportional to sample area; see Figure 3).

2. Electrical and magnetic fields (described as functions of distance and time; dependent on motion of blow-off charge; configuration dependent).

3. Total energy content (stored, radiated, and dissipated energies; probably in range of 1 mjoule to 1 joule).

4. Breakdown conditions (extrapolations of ground test data to space conditions)

Additionally, scaling relationships and functional dependencies for the above parameters will be included here or referenced in a supporting document. The discharge characterization is dependent on type of material, sample area, thickness, configuration, charging current density and energy distribution, and irradiation history. Discharges will be described for materials which are commonly used on spacecraft and known to exhibit charging/ discharging effects. Parameters listed above and in the following figure will be quantified as information becomes available.

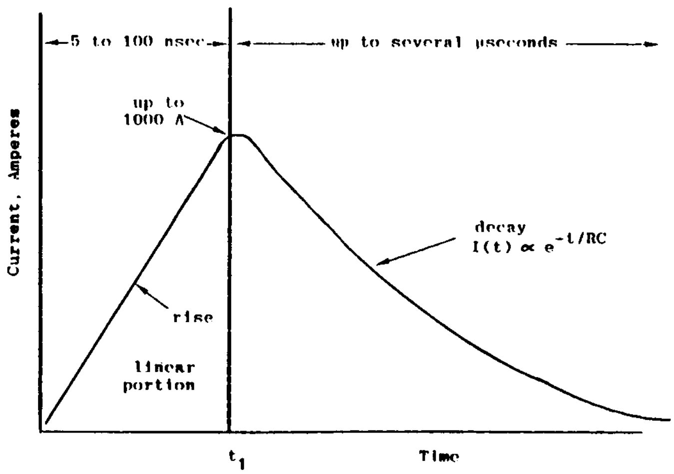

Figure 3. Discharge Current Pulse Shape

50.2.5 Materials selection. Materials used in the space vehicle design shall be selected to minimize differential charging (see Section 50.2.5.1) and discharging (see Section 50.2.4) effects from the specified environment while maintaining specified performance capabilities. All materials used on exposed surfaces should be tested or analyzed to determine their charging and discharging characteristics in the specified environment. The method of test or analysis is subject to the approval of the procuring agency. Surfaces located internal to the outer space vehicle structure should be shielded from the space plasma environment by eliminating openings in the structure. Material selection should additionally be based on minimizing outgassing and other sources of contamination. Exposed surfaces which are susceptible to effects of enhanced contamination due to SCC should be identified and protected where necessary to assure performance to specified capabilities. References useful to spacecraft material selection include AFML reports: AFML-TR-76-233, AFML-TR-77-174, AFML-TR-77-105, and AFML-TR-78-15.

50.2.5.1 SCC associated differential potentials.

TBD. Tables of "worst case" magnitudes of differential potentials and potential gradients expected for selected S/C materials and material configurations on generic S/C designs will be provided. Potentials will be those derived from analysis using the "worst case" substorm environment (Figure 2) and compared to P78-2 data.

To date, representative extreme levels as measured on the P78-2 SC1-3 (shadowed samples) SSPM include:

SAMPLE	POTENTIAL (with respect to S/C ground)
Aluminized Kapton	- 2.0 kV
Silvered Teflon	- 4.0 kV
Astroquartz	- 3.7 kV

50.3 Analysis. As part of the SCC protection program, an analytical plan for SCC shall be prepared and maintained. The SCC analytical plan shall be a detailed plan specifying the SCC analysis program that will be used to achieve conformance with the requirements in this appendix. The plan shall be subject to approval by the procuring agency. The plan shall be implemented to analyze the space vehicle design for susceptibility to SCC. The analysis plan should complement the test plan (see Section 50.4) and the analysis should generate data useful to identify susceptible design areas and locations for testing and to quantify representative test levels. (The requirement for an Analytical Plan will be transferred to the contractor SOW).

50.3.1 Analysis approach. The analysis should be inclusive of a modeling of the charging of the space vehicle by the specified environment as well as the competing effects of photoemission, backscatter, and secondary emission. Extremes in differential charging levels of the space vehicle and susceptible locations for discharges should be identified. Estimates of discharge characteristics (see Section 50.2.4) should be made for the specific space vehicle design of interest, including the actual materials and mounting configuration used in the design. A coupling analysis should be performed relating the EMI and structural replacement currents resulting from the discharges to electrical transients in internal space vehicle cables. In all cases, estimates should be made of the extremes ("worst case") magnitudes of charging levels, discharges, and electrical transients characteristics for the space vehicle design of interest. The analytical program should be made to complement the test program (see Section 50.4) for SCC effects on the space vehicle. In this manner, test levels and test locations should be an accurate representation of SCC effects on the actual space vehicle design.

50.3.2 Analysis procedure. The following procedure should be followed in analyzing the space vehicle for effects from electrical transients induced by SCC. Any analytical tools or computer codes used shall be described in the analytical plan and subject to approval by the procuring agency.

50.3.2.1 Charging analysis. The specified environment shall be used with space vehicle design features as primary inputs into analytical calculations of the extremes of differential charging for the spacecraft of interest. As a minimum, the analysis should determine:

1. the frequency of occurrence and duration of periods of high charging levels TBD (> 1000 volts)

2. the maximum differential potentials and potential gradients expected

3. the locations of large differential potentials and potential gradients on the space vehicle (candidate spacecraft locations for ESD tests)

(The NASCAP computer code, when validated, will be useful to this analysis).

50.3.2.2 Discharge characterization analysis. The characteristics of discharges caused by SCC are provided in Section 50.2.4 for selected material samples and configurations. These shall be used along with associated analysis of the specific space vehicle design of interest and with the charging analysis (Section 50.3.2.1) to estimate extremes of discharge characteristics expected. As a minimum, the analysis should determine:

1. discharge parameters (amplitudes, pulse shape, frequency content)

2. radiated electric and magnetic fields

3. energy content of discharge pulse

4. potential discharge site locations (candidate spacecraft locations for ESD tests)

50.3.2.3 Coupling analysis. The results of the discharge characterization analysis should be used as source terms in an electromagnetic coupling analysis specific to the space vehicle design of interest. Estimates should be made of extremes in magnitude of radiated EMI and structural replacement currents resulting from the expected or specified discharges. The coupling analysis should then determine as a minimum:

1. electromagnetic fields generated interior to the space vehicle due to ESD

2. induced transient pulse characteristics (amplitude, pulse shape, frequency content) for wiring harnesses and sensitive circuits and electronic components

3. identification of susceptible elements in electronic subsystems

Note: The entire section on analysis requirements, approach, and procedures may be compressed and called out in the contractor SOW.

50.4 Testing. As part of the SCC protection program, a test plan for SCC shall be prepared and maintained. The SCC test plan shall be a detailed plan specifying the SCC test program that will be used to achieve conformance with the requirements in this appendix. The plan shall be subject to approval by the procuring agency. The plan shall address the test requirements and test methods for subsystems and systems as presented in the following sections. The test plan should be complementary to the SCC analysis plan (see Section 50.3). The plan shall be implemented to test the space vehicle susceptibility to the effects of SCC. Test procedures as presented in the NASA document, TBD (Design Guidelines Monograph), should be followed where applicable. With the approval of the procuring agency, specific test requirements may be modified to be consistent with the contractor's space vehicle design. Supportive analysis is required to justify the reduction of any test levels below those specified in this appendix. (The requirement for a test plan will be called out in the contractor SOW).

50.4.1 Test Requirements. The following SCC test requirements are applicable to prototype and flight model space vehicle subsystems and systems.

50.4.1.1 Subsystem Test Requirements. All spacecraft subsystems, components, and their interconnecting cabling shall be subject to the following test requirements.

50.4.1.1.1 Direct Injection. All space vehicle subsystems shall be tested for SCC susceptibility by the direct injection of electrical pulses. The test level shall be TBD (amplitude level) or a level 6 dB greater than the threat level as determined by analysis. The test level shall be subject to approval by the procuring agency. Pulse rise times and pulse widths are TBD (10 nsec rise, 2 μsec width), and the number of test pulses shall be TBD (30 pulses) at a rate of TBD (one per second) or may be established by analysis and subject to approval by the procuring agency.

50.4.1.1.2 Critical Test Points. Injection points may be selected from subsystem box input cables or specific pin locations. The test must drive all subsystem electronic components. Injection test locations shall be subject to approval by the procuring agency.

50.4.1.2 System Test Requirements. The space vehicle system shall be subject to the following test requirements.

50.4.1.2.1 Capacitive Direct Injection (CDI). The space vehicle system shall be subject to the CDI of electrical pulses to the space vehicle structure. The test level shall be TBD (amplitude level) or a level 6 dB greater than the threat level for a blow-off discharge as determined by analysis and consistent with the specified discharge characterization (Section 50.2.4). The test level shall be subject to approval by the procuring agency. Pulse rise times and pulse widths are TBD (10 nsec rise, 2 μsec width) and the number of test pulses shall be TBD (30 pulses) at a rate of TBD (one per second) or may be established by analysis and subject to approval by the procuring agency.

50.4.1.2.2 Arc Injection. The space vehicle system shall additionally be subject to the arc injection of electrical pulses to the space vehicle structure. The test level shall be TBD (up to 200 amperes) or a level 6 dB greater than the threat level for a flashover discharge as determined by analysis and consistent with the specified discharge characterization (50.2.4). The test level shall be subject to approval by the procuring agency. Pulse rise times and pulse widths are TBD (10 nsec rise, 200 nsec width), and the number of test pulses shall be TBD (30 pulses) at a rate of TBD (one per second) or may be established by analysis and subject to approval by the procuring agency.

50.4.1.2.3 Critical Test Points. CDI test locations and arc injection points shall be selected based on an analysis of the space vehicle design for locations considered the most likely sites for SCC associated discharges. The CDI test must include at least one pulse injection to the S/C common ground structure, and the arc injection must include at least one pulse injection at the solar arrays (if applicable). All test locations must be approved by the procuring agency.

50.4.2 Test Methods. The following SCC test methods are applicable to prototype and flight model space vehicle subsystems and systems.

50.4.2.1 Subsystem Test Methods. All spacecraft subsystems, components, and their interconnecting cabling shall be tested using the following methods.

50.4.2.1.1 Test Setup. Direct injection tests on subsystems shall be accomplished in a bench test. The contractor shall assemble all units and interconnecting cabling of a subsystem as closely as possible to a flight configuration. Each subsystem shall be tested independently..

50.4.2.1.2 Test Conditions. Ambient environment testing is adequate. The subsystem should be powered by batteries and operated in representative modes subject to approval by the procuring agency.

50.4.2.1.3 Test Equipment. A pulse generator capable of delivering the specified test levels and pulse shape (Section 50.4.1.1.1) shall be utilized for the direct injection tests. The pulse generator shall be approved by the procuring agency. Tests may take the form of single injection or common mode pin tests, or direct drive of box input cables. All subsystem response and circuit monitoring instrumentation and other test equipment shall be subject to approval by the procuring agency.

50.4.2.1.4 Test Parameters and Susceptibility Analysis. Crucial subsystem test parameters shall be identified by the contractor as measures of subsystem performance and as measures of susceptibility to the direct injection test. The subsystem shall perform to specified capabilities during and after the test. Test parameters and measures of subsystem performance and measure of susceptibility shall be subject to the approval of the procuring agency.

50.4.2.2 System Test Methods. The space vehicle system shall be tested using the following methods.

50.4.2.2.1 Test Setup. CDI and arc injection tests on the space vehicle system shall be performed with the system dielectrically isolated from the ground and removed TBD (several) spacecraft diameters from any metallic walls or large metallic structures. Space vehicle telemetry monitoring instrumentation and other test monitoring equipment should be located in an electromagnetic shielded enclosure. The space vehicle shall be fully assembled and set up as closely as possible to its flight configuration.

50.4.2.2.2 Test Conditions. Ambient environment testing is adequate. The space vehicle system should be powered by batteries and operated in representative modes subject to approval by the procuring agency.

50.4.2.2.3 Test Equipment. Pulse generators capable of delivering the specified test levels and pulse shape (Section 50.4.1.2.1 and 50.4.1.2.2) shall be utilized for the CDI and arc injection tests. The pulse generators shall be subject to approval by the procuring agency. (Figures 4 and 5 represent preliminary schematics for performing the tests.) Test equipment shall be inclusive of system response monitoring instrumentation (all subsystem response monitored via spacecraft telemetry) as well as pulse injection instrumentation. All test equipment shall be subject to approval by the procuring agency.

50.4.2.2.4 Test Parameters and Susceptibility Analysis. Crucial system test parameters shall be identified by the contractor as measures of system performance and as measures of susceptibility to the CDI and arc injection tests. The system shall perform to specified capabilities during and after the test. Test parameters and measures of system performance and susceptibility shall be subject to the approval of the procuring agency.

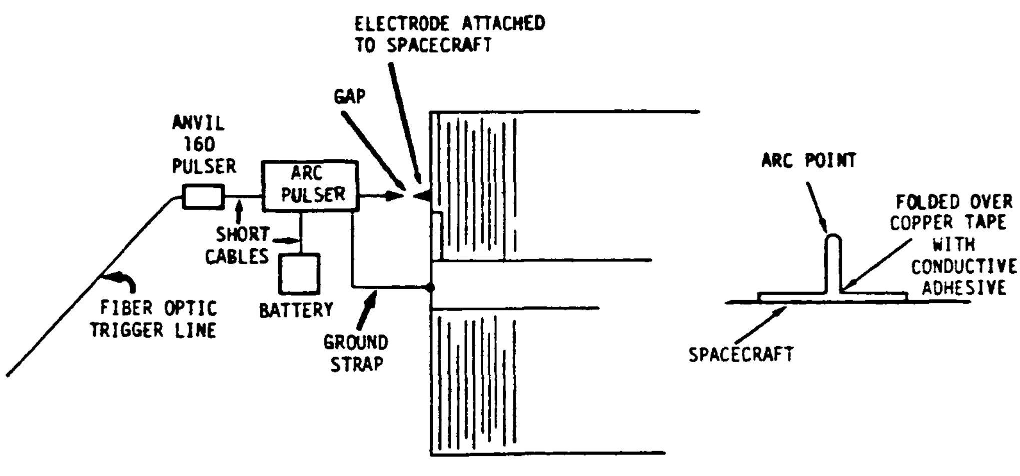

Figure 4. Arc Injection Schematic

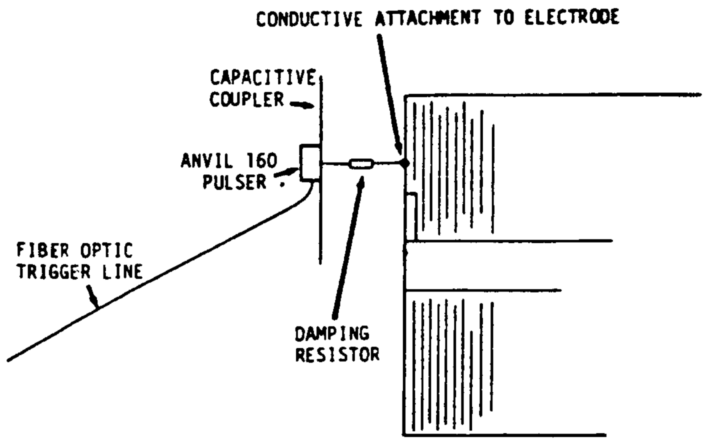

Figure 5. CDI Schematic