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Space Administration

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MSFC-RQMT-2918
REVISION B
Effective Date: June 21, 2006

George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama 35812

QD01

MULTIPROGRAM/PROJECT COMMON-USE
DOCUMENT

REQUIREMENTS FOR
ELECTROSTATIC
DISCHARGE CONTROL

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MSFC - Form 454 (Rev. October 1992)

Multiprogram/Project Common-Use Document QD01		
Title: Requirements for Electrostatic Discharge Control	Document No.: MSFC-RQMT-2918	Revision: B
	Effective Date: June 21, 2006	Page 2 of 15

DOCUMENT HISTORY LOG

Status (Baseline/ Revision/ Canceled)	Document Revision	Effective Date	Description
Baseline		02/05/99	Initial Release.
Revision	A	09/01/00	Converted document to new template. Revised document to delete references to previous "MSFC-P" documents. Changed "Quality Assurance" to "Safety and Mission Assurance (S&MA)".
Revision	B	06/21/06	Updated document per NASA Headquarters Rules Review. Updated "SCOPE" to identify the applicable Electrostatic Discharge (ESD) standard for propellant and explosive devices, and replaced MIL-STD-1686 with ANSI/ESD S20.20-1999 in the second paragraph. Updated the "APPLICABLE DOCUMENTS" section to remove canceled, or add replacement documents. Replaced MIL-STD-1686 with ANSI/ESD S20.20-1999, and added MIL-STD-1800. Updated the "DEFINITIONS" section. Updated the "GENERAL REQUIREMENTS" section, item "a" with the following: "The minimum protection for ESDS design shall be as specified per the engineering documentation, or 2000 volts for assemblies and 4000 volts for components and equipment." Updated paragraph 5.1.1 titled "Packaging" changing 10^9 to 10^{12} in the second sentence. Updated paragraph 5.1.3 titled "Kitting and Shipping" adding the following to the last sentence: ", or as specified per the requirements of paragraph 5.1.1 herein." Updated the requirements for "Equipment and Facility Grounding" per paragraph 5.4. Replaced MSFC-RQMT-1493 with MSFC-RQMT-2918 in paragraph 6.4. Deleted the last sentence of paragraph 7.1. In the first sentence of paragraph 7.2, change "ground" to "grounding". Updated paragraph 10.5. Updated Figure 1. Added Figure 2.

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Multiprogram/Project Common-Use Document QD01		
Title: Requirements for Electrostatic Discharge Control	Document No.: MSFC-RQMT-2918	Revision: B
	Effective Date: June 21, 2006	Page 3 of 15

FOREWORD

This document provides requirements for prevention of electrostatic discharge (ESD) events and for protection of hardware from ESD. The document shall be applicable to MSFC in-house activities for flight hardware.

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Multiprogram/Project Common-Use Document QD01		
Title: Requirements for Electrostatic Discharge Control	Document No.: MSFC-RQMT-2918	Revision: B
	Effective Date: June 21, 2006	Page 4 of 15

CONTENTS

<u>PARAGRAPH</u>	<u>PAGE</u>
<u>DOCUMENT HISTORY LOG</u>	2
<u>FOREWORD</u>	3
1. <u>SCOPE</u>	6
2. <u>APPLICABLE DOCUMENTS</u>	6
3. <u>DEFINITIONS</u>	6
4. <u>GENERAL REQUIREMENTS</u>	8
5. <u>DETAILED REQUIREMENTS</u>	9
5.1 Handling	9
5.1.1 Packaging	9
5.1.2 Receiving	9
5.1.3 Kitting and Shipping	9
5.1.4 Component Testing (Black Box)	9
5.2 Protective Areas/Workstations	9
5.2.1 Access	9
5.2.2 Work Surfaces	9
5.2.3 Flooring	10
5.2.4 Air Ionizers	10
5.3 Personnel Grounding Devices	10
5.3.1 Wrist Straps	10
5.3.2 Other	10
5.4 Equipment and Facility Grounding	10
5.4.1 Accessories	10
5.5 Humidity	11
5.6 Identification and Marking	11

CHECK THE MASTER LIST - VERIFY THAT THIS IS THE CORRECT VERSION BEFORE USE

Administratively Controlled Information – TBD (remove marking if document is not designated as ACI)

Multiprogram/Project Common-Use Document QD01		
Title: Requirements for Electrostatic Discharge Control	Document No.: MSFC-RQMT-2918	Revision: B
	Effective Date: June 21, 2006	Page 5 of 15

5.7	Monitoring	11
5.7.1	Annual Measurements	11
5.7.2	Daily Measurements	12
5.7.3	Audits	12
6.	<u>NOTES</u>	12
7.	<u>SAFETY PRECAUTIONS AND WARNING NOTES</u>	12
8.	<u>APPENDICES, DATA, REPORTS, AND FORMS</u>	12
9	<u>RECORDS</u>	13
10.	<u>TOOLS, EQUIPMENT, AND MATERIALS</u>	13
11.	<u>PERSONNEL TRAINING AND CERTIFICATION</u>	14
<u>FIGURE</u>		
1.	ESD Certification Badge	14
2.	Preferred Ground Connection and Main(s) Service Equipment	15

CHECK THE MASTER LIST - VERIFY THAT THIS IS THE CORRECT VERSION BEFORE USE

Administratively Controlled Information – TBD (remove marking if document is not designated as ACI)

Multiprogram/Project Common-Use Document QD01		
Title: Requirements for Electrostatic Discharge Control	Document No.: MSFC-RQMT-2918	Revision: B
	Effective Date: June 21, 2006	Page 6 of 15

1.0 SCOPE

This document provides a consistent application of requirements for an electrostatic discharge (ESD) control program for electrical and electronic assemblies, and equipment, and their constituent parts susceptible to damage from ESD. This document shall not apply to ESD requirements for electrically initiated explosive devices. For propellant and explosive devices, reference MSFC-STD-1800 or other approved procedures.

This document shall be for use internally at MSFC and shall not be used on contracts. Use ANSI/ESD S20.20-1999 or other approved ESD control procedures for contracts. This document shall apply to all MSFC organizational elements involved in the design, procurement, fabrication, inspection, test, handling, storage, and operation of flight and flight associated hardware containing ESD sensitive items for MSFC projects. Specifically, these requirements shall apply to the following personnel as a minimum: electrical designers, engineers who troubleshoot electrical hardware, manufacturing personnel, quality assurance (QA) personnel, shipping/receiving personnel, kitting personnel, and electrical test personnel.

2.0 APPLICABLE DOCUMENTS

<u>Document Number</u>	<u>Title</u>
ANSI/ESD S20.20-1999	ESD Association Standard for the Development of an Electrostatic Discharge Control Program for – Protection of Electrical and Electronic Parts, Assemblies, and Equipment (Excluding Electrically Initiated Explosive Devices)
MIL-STD-129	Standard Practice Military Marking For Shipment And Storage
MSFC-STD-1800	Electrostatic Discharge (ESD) Control For Propellant and Explosive Devices

3.0 DEFINITIONS

a. Anti-static. Usually refers to the property of a material that inhibits triboelectric (friction) charging. NOTE: A material's antistatic characteristic is not necessarily co-relatable with its resistivity or resistance.

b. Conductive Material. A material that has a surface resistivity less than 10^5 ohms per square.

c. Electrostatic Discharge (ESD). Transfer of electrostatic charge between objects at different potential caused by direct contact or induced by an electrostatic field.

d. Electrostatic Discharge Sensitive (ESDS). Relative tendency of a device's performance to be affected or damaged by an ESD event.

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Administratively Controlled Information – TBD (remove marking if document is not designated as ACI)

Multiprogram/Project Common-Use Document QD01		
Title: Requirements for Electrostatic Discharge Control	Document No.: MSFC-RQMT-2918	Revision: B
	Effective Date: June 21, 2006	Page 7 of 15

e. Electrostatic Field. Voltage gradient between electrostatically charged surfaces.

f. Equipment Grounding Conductor. The conductor used to connect the non-current carrying metal parts of equipment, raceways, and other enclosures to the system grounded conductor, the grounding electrode conductor, or both at the service equipment.

g. ESD Protected Area/Workstation. Area or workstation constructed and equipped with necessary ESD protective materials, equipment and procedures to limit ESD voltages below the sensitivity level of handled ESDS items. A protected area differs from a workstation by accessibility. Access to protected areas is limited to certified personnel or personnel escorted by certified personnel.

h. Ground. 1) A conducting connection, whether intentional or accidental between an electrical circuit or equipment and the earth, or to some conducting body that serves in place of the earth. 2) The position or portion of an electrical circuit at zero potential with respect to earth. 3) A conducting body, such as the earth or the hull of a steel ship or vehicle, used as a return path for electric currents and as an arbitrary zero reference point.

i. Grounded. Connected to the earth or some conducting body that serves in place of the earth.

j. Grounded Conductor (i.e., the Neutral conductor). A system or circuit conductor that is intentionally grounded.

k. Grounding Electrode(s). A metal underground water pipe; metal frame of a building or structure; ground ring encircling a building or structure; or, an iron or steel rod/pipe/plate electrode in direct contact with the earth and electrically continuous to the points of connection of the grounding electrode conductor and bonding conductor/jumper.

l. Grounding Electrode Conductor. The conductor used to connect the grounding electrode(s) to the equipment grounding conductor, to the grounded conductor, or to both, at the service equipment.

m. Hard Ground. A connection to earth ground either directly or through low impedance.

n. Impedance. The total opposition (i.e., due to resistance and reactance) a circuit offers to the flow of alternating current. It is measured in ohms and the lower the ohmic value, the better the quality of the conductor.

o. Raceway. An enclosed channel of metal or nonmetallic materials designed expressly for holding wires, cables, or busbars.

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Administratively Controlled Information – TBD (remove marking if document is not designated as ACI)

Multiprogram/Project Common-Use Document QD01		
Title: Requirements for Electrostatic Discharge Control	Document No.: MSFC-RQMT-2918	Revision: B
	Effective Date: June 21, 2006	Page 8 of 15

q. Soft Ground. A connection to ground through an impedance sufficiently high to limit current flow to safe levels for personnel (normally 5 milli-Amperes). Impedance needed for a soft ground is dependent upon the voltage levels which could be contacted by personnel near the ground.

r. Static Dissipative Materials. ESD protective material having surface resistivities greater than 10^5 but not greater than 10^{12} ohms per square.

s. Surface (Sheet) Resistivity. The surface resistivity is an inverse measure of the conductivity of a material and equal to the ratio of the potential gradient to the current per unit width of the surface, where the potential gradient is measured in the direction of the current flow in the material. (Note: Surface resistivity is numerically equal to the surface resistance between two electrodes forming opposite sides of a square. The size of the square is immaterial. Surface resistivity applies to both surface and volume conductive materials and has the value of ohms per square.)

t. Triboelectric (friction) charging. The generation of electrostatic charges when two materials make contact or are rubbed together, then separated.

4.0 GENERAL REQUIREMENTS

ESD controls, as a minimum, shall be implemented to include the following ESD control program requirements:

- a. The minimum protection for ESDS design shall be as specified per the engineering documentation, or 2000 volts for assemblies and 4000 volts for components and equipment.
- b. Protected areas and work stations shall be established and verified as adequate by Safety and Mission Assurance (S&MA) personnel prior to their use.
- c. Use of protective personnel clothing and proper personnel grounding at all necessary points where unprotected or unpacked ESDS items are handled.
- d. Establish a certification program to ensure that all personnel handling electrostatic discharge sensitive (ESDS) items have received the necessary training and have been certified.
- e. Perform internal audits to ensure the integrity of the ESD protected areas and equipment.
- f. Inspection of documentation for ESD markings, precautions, and handling procedures as applicable.

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Administratively Controlled Information – TBD (remove marking if document is not designated as ACI)

Multiprogram/Project Common-Use Document QD01		
Title: Requirements for Electrostatic Discharge Control	Document No.: MSFC-RQMT-2918	Revision: B
	Effective Date: June 21, 2006	Page 9 of 15

5.0 DETAILED REQUIREMENTS

5.1 Handling. Handling and moving of ESDS items shall be accomplished using appropriate ground straps, grounding chains, and/or protective packaging. Detailed ESD procedures shall be developed to minimize occurrence of discharge when handling of ESDS items where ESD protection is not practicable.

5.1.1 Packaging. Electrostatic protective packaging shall require both the prevention of charge generation and protection from strong electrostatic fields. Materials used in protective bags and pouches shall be constructed from a single folded piece of material and the surface resistivity of any material shall not exceed 10^{12} ohms/square. If bags or pouches are not transparent to allow identification of contents without removal, a label shall be placed on the outside of the bag or pouch that identifies its contents. Non-metallic conductive and static dissipative magazines, chutes and dip-tubes shall be used for shipping integrated circuits. Tote boxes and covers shall be made of conductive or static dissipative material. For devices that are sensitive to damage from 100 volts or less (i.e., unprotected gate oxide devices), double bagging (a static dissipative bag inside a metal foil bag) shall be required.

5.1.2 Receiving. All ESDS items received shall be examined for proper ESD precautionary marking and for ESD protective packaging. Inadequate precautionary markings shall be corrected prior to further processing. When an item is received that has not been protected during shipment or internal transfer, it shall be rejected as defective and processed as nonconforming material.

5.1.3 Kitting and Shipping. When a kit is assembled that includes an ESDS item, the entire kit shall be packaged and marked as ESDS. The accompanying documentation shall identify the kit as ESDS. ESDS items packaged for shipping shall be packaged and marked as required by the contract, or as specified per the requirements of paragraph 5.1.1 herein.

5.1.4 Component Testing (Black Box). Wrist straps shall be used when cabling boxes unless the box design precludes ESD damage due to discharge into connector pins. Environmental controls during testing shall be in accordance with the test procedure.

5.2 Protective Areas/Workstations.

5.2.1 Access. Protective areas shall be clearly identified by prominently placed signs. Access to such areas shall be limited to certified personnel. All other personnel shall be escorted and equipped with protective clothing, as required.

5.2.2 Work Surfaces. All work surfaces in ESD protected areas and at protective workstations shall be static dissipative and electrically connected to a common ground. Homogeneous materials shall have surface resistivity in the range of 10^5 to 10^9 ohms/square.

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Administratively Controlled Information – TBD (remove marking if document is not designated as ACI)

Multiprogram/Project Common-Use Document QD01		
Title: Requirements for Electrostatic Discharge Control	Document No.: MSFC-RQMT-2918	Revision: B
	Effective Date: June 21, 2006	Page 10 of 15

Work surfaces shall be kept free of static generating materials (e.g., common plastics, Styrofoam, bubble pack, tape).

5.2.3 Flooring. Conductive floors and grounded conductive floor mats shall be mandatory in areas where personnel are not wearing wrist straps. Under these conditions the use of leg straps, heel straps, or conductive shoes shall be mandatory. Conductive floors or mats shall be kept free of dust, dirt, and other contaminants. After each cleaning, conductive floor resistivity shall be verified and the results shall be recorded. Conductive floors shall not be waxed or buffed unless the flooring manufacturer's recommendations are followed and the materials used do not inhibit flooring conductivity. Carpet in ESD protected areas shall be prohibited unless precautionary measures are documented and approved in writing.

5.2.4 Air Ionizers. If the use of air ionizers is necessary, then their design shall incorporate a continuous balance status indicator (alarm). Otherwise, the air ionizer shall be placed on category I calibration (recall) with the interval established by the calibration laboratory.

5.3 Personnel Grounding Devices. Grounding devices shall be supplied to all personnel working with or handling ESDS items to prevent the accumulation of ESD. A grounding device shall be worn by all personnel while working with unprotected or unpacked ESDS items.

5.3.1 Wrist Straps. Wrist straps shall ensure conductive contact with the wearer's skin. The safety resistor shall measure 1 mega-ohm (+/- 20%). Wrist strap monitors that alarm when the connection to ground is compromised are preferred.

5.3.2 Other. Foot grounding devices, such as leg, toe, heel straps, or conductive shoes worn in conjunction with a conductive floor and/or conductive mats, shall be acceptable alternatives to wrist straps in those situations where the operator needs to be mobile and the use of a wrist strap is impractical or unsafe.

5.4 Equipment and Facility Grounding. The preferred practice is to use the third wire (i.e., equipment grounding conductor) of an AC (alternating current) wall outlet to ground all items at the ESD-protected workstation. Reference Figure 2 for preferred connections. When a separate grounding electrode (auxiliary ground) is present or used in addition to the equipment grounding conductor, it shall be bonded (attached) to the equipment ground at each ESD protected work station to minimize the difference in potential. The resistance of the conductor from the common point ground to the equipment ground shall not be greater than 1.0 ohm. The impedance from the workstation common point ground to the neutral bus at the main service box shall not be greater than 2.0 ohms.

5.4.1 Accessories. Chairs and stools shall be constructed of conductive material and the cover material fabricated from static dissipative materials. Where carts, wagons, or trams are required to be grounded and approved conductive floors are utilized, positive electrical contact

CHECK THE MASTER LIST - VERIFY THAT THIS IS THE CORRECT VERSION BEFORE USE

Multiprogram/Project Common-Use Document QD01		
Title: Requirements for Electrostatic Discharge Control	Document No.: MSFC-RQMT-2918	Revision: B
	Effective Date: June 21, 2006	Page 11 of 15

shall be made between the floor and conductive structure of the vehicle. If the floor is non-conductive, the vehicle shall be grounded before ESDS items are loaded or removed from the vehicle.

5.5 Humidity. The relative humidity shall be maintained in ESD-protected work areas at 30 percent to 70 percent. At levels below 30 percent, additional precautions shall be employed (e.g., air ionizers, humidifiers). If other precautionary methods are not available, work shall be halted until the required humidity level is obtained.

5.6 Identification and Marking. ESDS items, equipment, and assemblies shall be identified in compliance with the following requirements. Identification shall be placed so as to warn personnel before any ESD damaging procedure can be performed. Packing lists, inspection reports, travelers, and other paperwork accompanying the hardware shall contain ESDS labels and cautionary notes.

5.6.1 Equipment containing ESDS items shall be identified internally with either the sensitive electronic device symbol from MIL-STD-129 or the Electronic Industries Association RS-471 symbol. The following caution statement shall be placed adjacent to the ESDS symbol if room is available: CAUTION - CONTAINS PARTS AND ASSEMBLIES SUSCEPTIBLE TO DAMAGE BY ESD.

5.6.2 Equipment having external sensitivity shall have ESDS symbols affixed to their exterior.

5.6.3 The ESDS cautionary mark on an assembly shall be visible when the assembly is installed in the next higher assembly. Alternative identification shall be used as approved by the NASA procuring organization when the prescribed marking is not possible.

5.7 Monitoring.

5.7.1 Annual Measurements. The following measurements/ verifications shall be recorded annually by the organization responsible for the protected area/workstation:

- a. resistivity of anti-static mats and floors (except floor resistivity shall be measured after each cleaning).
- b. resistance of all personnel protective devices connected to audible alarms.
- c. resistance of all power tools.
- d. all grounding points.

CHECK THE MASTER LIST - VERIFY THAT THIS IS THE CORRECT VERSION BEFORE USE

Administratively Controlled Information – TBD (remove marking if document is not designated as ACI)

Multiprogram/Project Common-Use Document QD01		
Title: Requirements for Electrostatic Discharge Control	Document No.: MSFC-RQMT-2918	Revision: B
	Effective Date: June 21, 2006	Page 12 of 15

5.7.2 Daily Measurements. The resistance of all personnel protective devices that do not use an audible alarm shall be verified and recorded daily by the responsible organization.

5.7.3 Audits. Initial verification audits shall be performed by the S&MA personnel upon request using MSFC Form 4294 as a guide. Verification of current status shall be accomplished by the following:

a. During MSFC internal audits, organizations with protected areas/workstations shall be audited for compliance with this document periodically.

b. Spot audits shall be performed by S&MA personnel on a random basis using MSFC Form 4294 as a guide to further assure compliance with this document.

6.0 NOTES

6.1 For the purpose of this document, parts assemblies and equipment susceptible to ESD voltages of 16,000 volts or higher are considered non-ESD sensitive.

6.2 Surface resistivity changes exponentially with humidity changes. Therefore, relative humidity levels maintained between 40 percent and 60 percent are recommended.

6.3 The S&MA Office will assist in performing annual resistivity measurements when requested.

6.4 This document replaces MSFC-RQMT-2918 dated September 1, 2000.

7.0 SAFETY PRECAUTIONS AND WARNINGS NOTES

7.1 Work surfaces should be soft grounded to eliminate the safety hazard of touching a high voltage circuit with one hand and a hard ground with the other.

7.2 Before altering or connecting any line from an additional ground rod to the equipment grounding conductor (EGC), consult with a qualified electrician or safety person. The bond connection and lines must be able to carry fault and lightning strike currents.

8.0 APPENDICES, DATA, REPORTS, AND FORMS

MSFC Form 4294 ESD PROTECTED AREA/WORKSTATION AUDIT

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Administratively Controlled Information – TBD (remove marking if document is not designated as ACI)

Multiprogram/Project Common-Use Document QD01		
Title: Requirements for Electrostatic Discharge Control	Document No.: MSFC-RQMT-2918	Revision: B
	Effective Date: June 21, 2006	Page 13 of 15

9.0 RECORDS

The completed MSFC Form 4294 shall be maintained by the S&MA Office for 10 years from the audit date or as long as the protected area/workstation is in existence. The measurement and verification records required by paragraphs 5.7.1 and 5.7.2 will be maintained by the organization responsible for the protected area/workstation for 3 years.

10.0 TOOLS, EQUIPMENT, AND MATERIALS

10.1 Insulated metal hand tools such as pliers, cutters, tweezers, and wire strippers are prohibited. Static dissipative solder extractors are preferred over anti-static solder extractors made of metal, or having a metallized plastic barrel and tip. Plastic solder extractors are not allowed unless fabricated from a static dissipative material. Electrical tools shall have a three-wire grounded power cord or be double insulated. The area making contact with the work piece shall be grounded with a measured resistance not to exceed 2.0 ohms. All electrical tools used in proximity of unprotected ESDS items shall be connected electrically through a ground fault interrupter circuit.

10.2 Cold chambers shall have the conductive baffles and shelves within the chamber grounded. The ESDS items shall be contained within or mounted on conductive material. The stability of ESD protective materials, which are used in temperature chambers, should be suited for the test temperature and humidity ranges.

10.3 Cleaning agents and methods used on ESDS protective items shall not reduce the effectiveness of these items. They shall not cause leaching or leave insulation residues. Cleaning agents shall be chosen for low electrostatic charging propensity. ESDS items shall only be cleaned with solvent wetted brushes.

10.4 A wrist strap tester shall be available in all areas where ESDS items are handled.

10.5 When worn, ESD protective smocks shall be constructed of lightweight dissipative material with conductive fibers. The conductive fibers shall be interwoven throughout the material, providing continuous and consistent charge dissipation. The ESD protective smocks shall be buttoned (except for the collar) whenever the wearer is at an ESD protective workstation or in a designated ESD protective area. The manufacturer's instructions for installation, testing, and maintenance/cleaning shall be followed to gain maximum effectiveness and use from the smocks. Finger cots and gloves, when worn in an ESD protective area, shall be made of static dissipative or conductive materials.

10.6 When spraying ESDS printed wiring assemblies with conformal coating, an anti-static spray nozzle shall be used.

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Administratively Controlled Information – TBD (remove marking if document is not designated as ACI)

Multiprogram/Project Common-Use Document QD01		
Title: Requirements for Electrostatic Discharge Control	Document No.: MSFC-RQMT-2918	Revision: B
	Effective Date: June 21, 2006	Page 14 of 15

11.0 PERSONNEL TRAINING AND CERTIFICATION

Certification of personnel shall be based on successful completion of an approved training program. This training is for those who play a major role in ESD damage prevention, i.e., electrical designers, engineers who troubleshoot electrical hardware, manufacturing personnel, QA personnel, shipping/receiving personnel, kitting personnel, and electrical test personnel. The training shall include the following: ESD control program, principles/control methods of static electricity, identification of ESDS items, protective materials and equipment, protected areas and work stations, monitoring of the work place, handling ESDS items, packaging, marking and shipping of ESDS items. After successful completion of training, personnel shall receive a badge shown in figure 1 as evidence of certification. Certification to previous versions of this document is equivalent and acceptable certification in lieu of certification to this revision/document number.



Figure 1. ESD Certification Badge

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Administratively Controlled Information – TBD (remove marking if document is not designated as ACI)

Multiprogram/Project Common-Use Document QD01		
Title: Requirements for Electrostatic Discharge Control	Document No.: MSFC-RQMT-2918	Revision: B
	Effective Date: June 21, 2006	Page 15 of 15

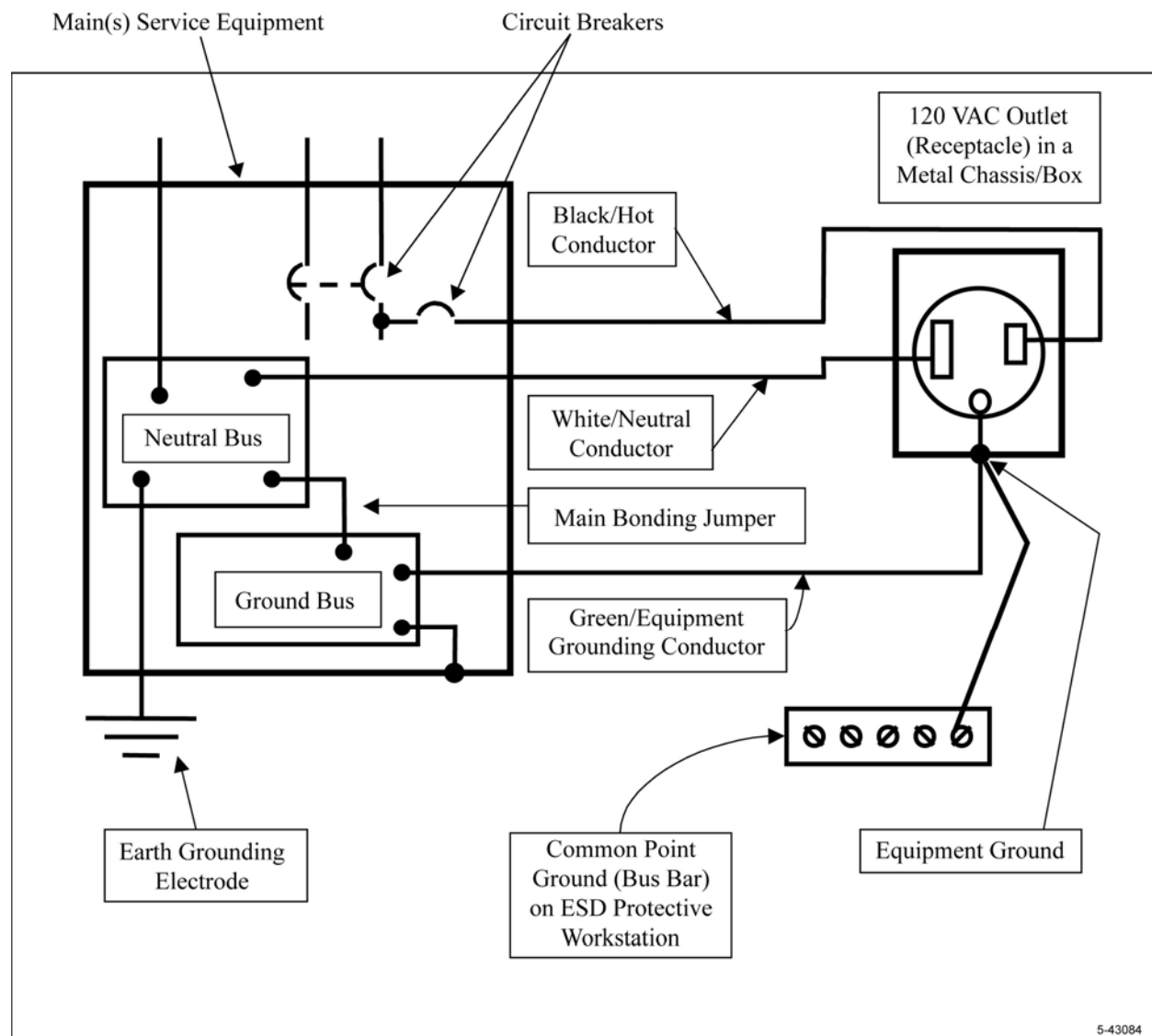


Figure 2. Preferred Ground Connection and Main(s) Service Equipment

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