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

QD01

MSFC TECHNICAL STANDARD

REQUIREMENTS FOR ELECTROSTATIC DISCHARGE CONTROL

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DOCUMENT HISTORY LOG

Status (Baseline/ Revision/ Canceled)	Document Revision	Effective Date	Description
Baseline		05-FEB-1999	Initial Release.
Revision	A	01-SEP-2000	Converted document to new template. Revised document to delete references to previous "MSFC-P" documents. Changed "Quality Assurance" to "Safety and Mission Assurance (SMA)".
Revision	B	21-JUN-2006	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.
Revision	C	18-OCT-2012	Revision C release; document is authorized through MPDMS. Major rewrite. This document was updated using NASA-HDBK-8739.21 to provide standardized guidance based on Agency-level best practices.
Revision	D	10-JUL-2014	Revision D release was authorized by the MSFC Technical Standards Document Control Board (DCB) through the Multiprogram Document Management System (MPDMS). Updated the "Foreword" section of the document by changing "shall be" to "is" within the second sentence. Updated the Table of Content based on changes made throughout the document. Throughout the entire document, changed the acronym "S&MA" to "SMA" as needed. Updated the "Applicability" section of the document by adding a new header and separating its text from the "Scope" section; Also, revised the second sentence for clarity and added a new paragraph with definitions for the words "shall", "may", "can", "should", and "will". Added "ANSI/ESDA/JEDED JS-001" titled "Human Body Model (HBM) Component Level" to the Applicable Document section.

			Updated the Section 5.0 "General Requirements" by adding the prohibition against using "pink-polyethylene" products for ESD protection within subparagraph "a"; by adding information about the Human Body Model Component Classifications within subparagraph "b"; by revising the initial setup and compliance verification requirements for ESD protected areas and work stations within subparagraph "c"; by revising subparagraph "d" for clarity; and by renumbering the remaining subparagraphs. Updated paragraph 6.1 (Handling) for clarity. Updated paragraph 6.1.1 (Packaging) for clarity and deleted the extra space between the word "or" and "static" within the fourth sentence. Updated paragraph 6.2.1 (Access) for clarity. Updated paragraph 6.2.2 for clarity and changed "Figures 2 and 3" to "Figures 1 and 2" within the second sentence. Updated paragraph 6.2.4 (Air Ionizers) for clarity and deleted the extra space between the words "When" and "the" within the first sentence. Updated paragraph 6.4 (ESD Grounding System Verification) by changing "Figure 4" to "Figure 3" within the last sentence. Updated paragraph 6.4.1 (AC Equipment Ground) by changing "Figure 5" to "Figure 4" within the third sentence. Updated paragraph 6.4.2 (ESD Technical Elements) by changing "Figures 2 and 3" to "Figures 1 and 2" within the last sentence. Updated paragraph 6.4.3 (Facilities with AC Equipment Ground and Auxiliary Ground) by changing "5.4" to "6.4" within the second sentence and by changing "Figures 2 and 3" to "Figures 1 and 2" within the fifth sentence. Updated paragraph 6.6 (Humidity) for clarity. Updated paragraph 6.8.1 for clarity and by adding the word "the minimum" and changing "Table 1" to "Table II" within the first sentence; by adding a new second sentence addressing information about the setups and compliance verification requirements; and by changing "Table 1" to "Table II" within the last sentence. Added a new paragraph 6.8.3 (Soldering Systems). Updated paragraph 6.8.4 (Audits) for clarity. Deleted the last paragraph in Section 7.0 (Notes). Updated paragraph 8.1for clarity by changing "hazard" to "concern" and by changing "high" to "hazardous"; Also, a second sentence stating the following: "Ground Fault Circuit Interrupters (GFCIs) and other safety protection should be considered wherever personnel might come into contact with electrical sources". Updated Section 10.0 (Records) for clarity to be consistent with other changes made within the document. Updated paragraph 11.2 by changing "Cold chamber" to "Environmental test chamber". Deleted the last sentence in paragraph 11.3. Updated paragraphs 11.4 and 11.5 for clarity. Updated Section 12.0 (Personnel Training and Certification) by adding requirements for the new SATERN SHE 413 ESD certification training course; by addressing the use of the CERTRAK database system within the fourth sentence; and by deleting the "Figure 1: ESD Certification Badge". Added a new Section 13.0 and a new Table I addressing "Component Classifications". Updated the "ESD Compliance Verification Schedule and Measurements" table by changing it from "Table I" to "Table II"; by deleting the "Weekly" column, and revising the "Verification Intervals" entries and application notes within the

			table; and by deleting the Note 4 and Note 5 located at the bottom of the table. Updated Table III (Recommendations Applicable to HBM Class 0 ESD Devices) by changing "Figure 2" to "Figure 1" within the third row entry, and by changing "Table 1" to "Table II" for the "Soldering irons" entry.
Revision	E	17-DEC-2015	This is a major rewrite of the document due to significant changes per ANSI/ESD S20.20-2014 which are flowed down to all NASA Centers in accordance with NASA Policy Directive (NPD) 8730.5 titled "NASA Quality Assurance Program Policy". Updated Section 3.1 Applicable Document, specifically document numbers ANSI/ESD 'STM7'.1; 'TR53-01' that were inadvertently typed incorrectly in the previous Revisions. Updated title for document number 'ANSI/ESD STM97.1' and added 'MWI 3410.5 in Section 3.1. Added APPENDIX A - Acronyms.

FOREWORD

This document provides requirements for prevention of electrostatic discharge (ESD) events and for protection of hardware from ESD. The document is applicable to MSFC in-house activities for flight and flight-associated hardware, mission essential or critical ground support equipment and elements thereof, or as specified per program or project requirements for in-house activities. This document has been developed to comply with the requirements of ANSI/ESD S20.20 as specified per NASA Policy Directive (NPD) 8730.5, NASA Quality Assurance Program Policy. The NASA-HBDK-8739.21 was also used to provide standardized guidance based on Agency-level best practices.

CONTENTS

1. SCOPE

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

2. APPLICABILITY

This document shall be for use internally at MSFC and shall not be invoked or specified on contracts. Use ANSI/ESD S20.20 or other approved ESD control procedures for contracts. The Electrostatic Discharge Association (ESDA) is the custodial organization of ANSI/ESD S20.20. It is required that each organization (i.e., NASA Headquarters and Centers, including Component Facilities and the Jet Propulsion Laboratory) prepare an ESD Control Program Plan that addresses the requirements of ANSI/ESD S20.20. This document has been developed to comply with ANSI/ESD S20.20 requirements. This document shall apply to all MSFC organizational elements involved in the design, procurement, receiving, inspection, fabrication, test, handling, storage, and operation of flight and flight associated hardware, mission essential or critical ground support equipment and elements thereof containing ESD sensitive items for which MSFC-RQMT-2918 has been made mandatory. 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.

This document applies to the Michoud Assembly Facility (MAF) as well.

This document applies the following: all mandatory actions (i.e., requirements) are denoted by statements containing the term “shall.” The following terms also apply: “may” or “can” denote discretionary privilege or permission, “should” denotes a good practice and is recommended, but not required; “will” denotes expected outcome, and “are/is” denotes descriptive material.

Due to significant changes imposed by the latest revision of ANSI/ESD S20.20 (i.e., the NASA agency-level/parent ESD standard), the effective date for full implementation of this document shall be six (6) months after its release. This will establish a "grace period" for the responsible organizations (users/operators) to continue using their existing ESD work areas and equipment without penalty, and allowing ample time to finalize the logistics of implementing the new requirements of this document.

3. APPLICABLE AND REFERENCE DOCUMENTS

3.1 APPLICABLE DOCUMENTS

Document Number	Title
ANSI/ESDA/JEDEC JS-001 ANSI/ESD S1.1 ANSI/ESD S4.1 ANSI/ESD S6.1 ANSI/ESD S20.20 ANSI/ESD STM3.1 ANSI/ESD STM7.1 ANSI/ESD STM12.1 ANSI/ESD STM13.1 ANSI/ESD STM97.1	Human Body Model (HBM) Component Level Wrist Straps Worksurfaces-Resistance Measurements Grounding Electrostatic Discharge Control Program for – Protection of Electrical and Electronic Parts, Assemblies, and Equipment (Excluding Electrically Initiated Explosive Devices) Ionization Floor Materials Characterization of Materials Seating-Resistive Measurement Electrical Soldering/Desoldering Hand Tools Footwear/Flooring System-Resistance Measurement in Combination with a Person
ANSI/ESD TR20.20 ANSI/ESD TR53-01 MIL-STD-129	Handbook for the Development of an Electrostatic Discharge Control Program for the Protection of Electronic Parts, Assemblies and Equipment Compliance Verification of ESD Protective Equipment and Materials Standard Practice Military Marking For Shipment And Storage
MWI 3410.5 NASA-HDBK-8739.21 NPD 8730.5 National Fire Protection Association (NFPA) 70	Marshall Work Instructions (MWI), Personnel Certification Program For Skills Workmanship Manual for Electrostatic Discharge Control (Excluding Electrically Initiated Explosive Devices) NASA Quality Assurance Program Policy National Electrical Code (NEC)

3.2 REFERENCE DOCUMENTS

MSFC-STD-1800	Electrostatic Discharge (ESD) Control For Propellant and Explosive Devices

4. DEFINITIONS

a. Antistatic . 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, Resistance. A material that has a surface resistance of less than 1×10^4 ohms or a volume resistance less than 1×10^4 ohms.

c. Conductive Material, Resistivity. A material that has a surface resistivity less than 1×10^5 ohms/square or a volume resistivity less than 1×10^4 ohm-cm.

d. Electrostatic Discharge (ESD). The rapid, spontaneous transfer of electrostatic charge induced by a high electrostatic field. Note: Usually, the charge flows through a spark between two bodies at different electrostatic potentials as they approach one another. Details of such processes, such as the rate of the charge transfer, are described in specific electrostatic discharge models.

e. Electrostatic Discharge Sensitive (ESDS). The ESD level that causes component failure.

f. Electrostatic Field. An attractive or repulsive force in space due to the presence of electric charge.

g. 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.

h. ESD Protected Area (EPA). A defined location with the necessary materials, tools and equipment capable of controlling static electricity to a level that minimizes damage to ESD susceptible items. An EPA can consist of a workstation, workbench, grounded protective mat, or grounded protective worksurface (i.e., laminated, painted, epoxied, or covered with other types of ESD protective coatings), an entire room, building or other designated area.

i. 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.

j. Groundable Point (G_p). Any point with low impedance to ground where grounding may be attached. Usually, it is the common point ground (CPG).

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

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

m. 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.

n. 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.

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

p. Human Body Model (HBM). The most commonly used model for ESD sensitivity levels of electronic devices. This model reflects the discharge effects when a person touches an electronic device. The HBM classifications are specified in accordance with the requirements of ANSI/ESD S20.20 and other approved ESD documents.

q. 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.

r. Mission Essential or Critical Ground Support Equipment. Ground support equipment whose operation is essential to successful mission performance, or whose problem can cause a safety hazard adversely affecting mission performance, or cause flight hardware malfunction/damage, or inability to detect flight hardware or software problem.

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

t. 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.

u. Static Dissipative Materials. A property of a material having a surface resistivity of at least 1 x 10^5 ohms/square or 1 x 10^4 ohm-cm volume resistivity but less than 1 x 10^{12} ohms/square surface resistivity or 1 x 10^{11} ohm-cm volume resistivity.

v. Surface Resistance. The ratio of direct current (DC) voltage to the current flowing between two electrodes of specified configuration that contact the same side of a material. This measurement is expressed in ohms.

w. Surface (Sheet) Resistivity. For electric current flowing across a surface, the ratio of DC voltage drop per unit length to the surface current per unit width. In effect, the surface resistivity is the resistance between two opposite sides of a square and is independent of the size of the square or its dimensional units. Surface resistivity is expressed in ohms/square.

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

5. GENERAL REQUIREMENTS

For ESD controls, as a minimum, the following prevention and control program requirements apply:

a. The use of pink-polyethylene (pink-poly) bags, film, bubble-wrap or foam near any ESDS item or within an ESD protected area shall be prohibited. Pink-poly provides little protection against ESD events and voltage fields and is a contamination source. The preferred alternative is the metallized static-shielding bag.

b. The minimum protection for ESDS designs shall be as specified per the engineering documentation. The HBM is commonly used to assist with the establishment of minimum protection levels for ESDS components. See Table I for HBM Component Classifications. ESD sensitive components are classified according to their HBM withstand voltage, regardless of polarity, as defined in Table I. A component can be classified based on testing per Section 8 of ANSI/ESDA/JEDEC JS-001, or data can be provided by the component manufacturer.

TABLE I. HBM ESD Component Classification Levels

Classification	Voltage Range (Volts)
0A	< 125
0B	125 to < 250
1A	250 to < 500
1B	500 to < 1000
1C	1000 to < 2000
2	2000 to < 4000
3A	4000 to < 8000
3B	≥ 8000

c. All ESD protected areas (i.e., a workstations, workbenches, or grounded protective mats) shall be designated as being acceptable for handling ESD sensitive components rated HBM Class 1A or less sensitive, unless specified otherwise for Class 0 items. For HBM Class 0 ESDS components, several recommendations are specified within Table II.

TABLE II. Recommendations Applicable to HBM Class 0 ESD Items

Topic	Recommendations
Chairs and Stools	Ground and periodically verify ESD protective properties. Increase compliance verification testing intervals based on actual usage.
Wrist Straps	All personnel should use wrist straps connected to a continuous monitoring system (CMS).
Conductive or Dissipative Floors or Floor mats	Use these items in the floor space directly in front of the protected area, workstation, workbench (See Figure 1), or in the floor space of other designated protected areas.
Relative Humidity	Keep relative humidity (RH) over 40%; monitor and record just before work is started. Additional precautions must be used to operate below 40% RH.
Ionizers	Ionizers should be located at each workstation designated for handling Class 0 items. The ionizers should be balanced to take into account the most sensitive device handled. The ionizers should be monitored frequently. Check the manufacturer's instructions.
Smocks	Must be grounded to the Common Point Ground or through the wrist strap. However, if a CMS is used at the EPA, it must not interfere with grounding of the smock or vice versa.
Mating and Demating Cables and Harnesses	Must be discharged to ground through an approved method prior to mating and demating to and from ESD sensitive assemblies.
Soldering Irons	Check for proper ESD operation before usage. See the soldering iron tip to ground resistance test parameter in Table IV.
Signage	Display signage identifying designated protected area or workstation for handling Class 0 items.

d. The initial setup of ESD protected areas (i.e., workstations, workbenches, or grounded protective mats) shall be performed and verified as adequate by Safety and Mission Assurance (SMA) personnel prior to use. Afterwards, the compliance verification requirements per Section 6.8 shall apply.

e. Proper personnel grounding devices (i.e., wrist straps, toe straps, ESD shoes), or a combination of these items shall be used at all necessary points where unprotected or unpacked ESDS items are handled. As appropriate to the application, ESD protective personnel clothing (i.e., smocks, gloves, finger cots, etc.) may also be used in conjunction with the personnel grounding devices listed above. Wearing an ESD smock is preferred, but not mandatory. If smocks are not available, wearing clothing made of cotton is another option to help reduce the risk of damage to ESDS items. Avoid wearing clothing made of wool or synthetic materials when working within ESD protected areas or handling ESDS items. Finally, avoid wearing loose fitting clothing or badges that drapes down and may come in contact with ESDS items.

f. A certification program shall be developed and implemented to ensure that all personnel handling ESDS items have received the necessary training and have been certified.

g. Initial certification training shall be obtained before personnel handle ESDS items. ESD recertification training shall be required every two (2) years.

h. SMA shall perform internal audits to ensure the integrity of the ESD protected areas and ESD operating equipment.

i. On-going verification of the ESD control requirements shall include inspection of documentation for ESD markings, precautionary signs, handling procedures, and compliance verification records (i.e., test measurement results), as applicable.

j. ESD testing, monitoring, and operating equipment used in protected areas or at workstations shall be calibrated in accordance with the manufacturer's instructions.

6. DETAILED REQUIREMENTS

6.1 Product Qualification Plan. The responsible organizations (users/operators) shall ensure that the ESD control items, used in their facilities, have been selected to meet the requirements of Table III herein. The test methods and required limits within Table III are as specified per ANSI/ESD S20.20-2014. Product qualification is normally conducted during the initial selection of ESD Control items (i.e., applies to new products to be purchased here). Any of the following methods can be used as evidence of qualification: 1) Product Specification Review (e.g., can use the manufacturing on-line data sheets as long as the proper standard is quoted), 2) Independent Laboratory Evaluation, or 3) Internal Laboratory evaluation. Each of the above methods must reference the ESD Association test method for that technical item and the limits must comply with those listed in Table III herein. Product qualification data shall be compiled, maintained, and readily available upon request by the responsible organizations (users/operators). For ESD control items (i.e., applies to existing products already on-hand here) that were selected and installed by the responsible organizations (users/operators) before the establishment of this new requirement, on-going compliance verification records can be used as evidence of product qualification.

TABLE III. Product Qualification Plan

Technical Requirement	ESD Control Item	Product Qualification	
		Test Methods	**Required Limit(s)**
Wrist Strap System	Wrist Strap System	ANSI/ESD S1.1 (Section 6.11)	< 3.5 x 10^7 ohms
Footwear/Flooring System (Both limits must be met)	Footwear/Flooring System	ANSI/ESD STM97.1 ANSI/ESD STM97.2	< 1.0 x 10^9 ohms < 100 volts Peak
EPA	Worksurface (Qualification can be done by either Test Method)	ANSI/ESD S4.1	Point to Point < 1 x 10^9 ohms Point to Groundable Point < 1 x 10^9 ohms
		ANSI/ESD STM 4.2	< 200 volts
EPA	Wrist Strap	ANSI/ESD S1.1	0.8 x 10^6 to 1.2 x 10^6 ohms
EPA	Wristband	ANSI/ESD S1.1	Interior: < 1 x 10^5 ohms
			Exterior: > 1 x 10^7 ohms
EPA	Personnel Ground wrist strap Connection (non-monitored)	ANSI/ESD S6.1	Point to Ground < 2 ohms
EPA	Footwear	ANSI/ESD STM9.1	Point to Groundable Point < 1 x 10^9 ohms
EPA	Foot Grounders	ANSI/ESD SP9.2	Point to Groundable Point < 1 x 10^9 ohms
EPA	Flooring	ANSI/ESD STM7.1	Point to Point < 1 x 10^9 ohms
			Point to Groundable Point < 1 x 10^9 ohms
EPA	Ionization	ANSI/ESD STM3.1	Discharge Time User defined Offset Voltage $-35 < V_{offset} < 35$
EPA	Shelving (When used to store unprotected ESDS items)	ANSI/ESD S4.1	Point to Groundable Point < 1 x 10^9 ohms
EPA	Mobile Equipment (Working Surfaces)	ANSI/ESD S4.1	Point to Point < 1 x 10^9 ohms
			Point to Groundable Point < 1 x 10^9 ohms
EPA	Electrical Soldering/Desoldering Hand Tools	ANSI/ESD S13.1	Tip to Ground < 2.0 ohms
			Tip < 20 millivolts
			Tip Leakage < 10 milliamps
EPA	Continuous Monitors	User defined	User defined
EPA	Static Control Garment	ANSI/ESD S2.1	Point to Point < 1 x 10^{11} ohms
EPA	Groundable Static Control Garment	ANSI/ESD S2.1	Point to Groundable Point < 1 x 10^9 ohms
EPA	Groundable Static Control Garment System	ANSI/ESD S2.1	< 3.5 x 10^7 ohms

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

6.1.2 Packaging. Electrostatic protective packaging shall protect ESDS devices through all phases of production, transport, and storage. Materials used in protective bags and pouches shall be constructed from a single folded piece of material and the surface resistance of any material shall be at least 1×10^4 ohms and not exceed 1×10^{11} ohms. 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. ESD-compliant packaging (i.e., Non-metallic conductive or static dissipative magazines, chutes and dip-tubes) shall be used for shipping integrated circuits. Where discrepancies or noncompliances are found in the shipping of integrated circuits, it is recommended that integrated circuits that are shipped in non-compliant packaging should not be used in flight hardware. ESD-safe 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 (e.g., unprotected gate oxide devices), double bagging (a static dissipative bag inside a metal foil bag) shall be required.

It has been revealed that packaging materials have been inadvertently used as worksurfaces and there has been confusion on the requirements. The ESD Association now specifies that the following requirements be added to address this issue:

When ESDS items are place on packaging materials and the ESDS items have work performed on them, then the packaging materials becomes worksurfaces. The worksurface requirements for resistance to ground shall apply.

6.1.3 Receiving. All ESDS items received shall be examined for proper ESD precautionary marking and for ESD protective packaging. 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.

6.1.4 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 (i.e., paperwork) shall identify the kit as ESDS. Paperwork (e.g., QA records, routing slips, travelers, instructions, etc.) accompanying an ESDS item shall be contained in static dissipative bags or envelopes, or packaged separately from the packaging used to protect ESDS items. Paperwork shall not come in physical contact with an ESDS item. ESDS items packaged for shipping shall be packaged and marked as required by the contract, or as specified per the requirements of paragraph 6.1.2 herein.

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

determined as needed by the responsible organizations (users/operators). When used during component testing, the wrist straps shall be tested prior to connecting cables to boxes. A logbook shall be required to document and maintain the wrist strap testing results. The logbook test results shall be available for review upon request.

6.2 ESD Protective Areas (EPAs). All EPAs (i.e., workstations, workbenches, or grounded protective mats) shall be maintained in a clean and orderly condition. Smoking, eating and drinking shall not be permitted.

6.2.1 Access. EPAs 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 (smock, gloves, finger cots, etc.), personnel grounding devices (i.e., wrist strap, toe strap, or ESD shoes), or a combination of these items as instructed by personnel of the responsible organizations (users/operators). See paragraph 6.3 herein for personnel grounding devices.

6.2.2 Worksurfaces. Worksurfaces of EPAs define the perimeters of localized ESD work areas in which unprotected (i.e., removed from protective packaging) sensitive items can be handled safely. The worksurface of an EPA shall be static dissipative and electrically connected to a common point ground. Refer to Figures 1 and 2 to see a typical ESD grounded workstation layout and workstation common point ground connections, respectively. As referenced per Figures 1 and 2, the ESD protective worksurface of a workbench, table mat, floor mat (walking surface), or any combination of these items shall be acceptable for the setup of an EPA. The ESD worksurface materials (e.g., table mats, floor coverings, floor mats, field service mats, etc.) shall have surface resistance (or surface resistivity) in the range of 1×10^5 to 1×10^9 ohms (or ohms/square). Note that the ESD Association (ESDA) allows the 1×10^5 to 1×10^9 range to be acceptable limits for either the surface resistance or surface resistivity measurements.

The worksurfaces of EPAs, where unprotected sensitive devices are being handled, shall be kept free of nonessential (i.e., static generating) insulators (e.g., common plastics, Styrofoam, bubble pack, tape, personal items such as radios, pictures, hair combs or brushes, coffee mugs, cell phones, iPADs, etc.). Tack boards attached as an integral part of ESD workstations are intended to be used for placing drawings, notes, memos, and other paperwork. Personal pictures securely attached to the tack boards of ESD workstations are allowed. If a radio is present within a room, it shall be in a location where unprotected sensitive devices are not being handled. It is acceptable to use the overhead shelves for storage provided the items placed on the shelves are positioned to prevent them from falling onto the EPA worksurface below.

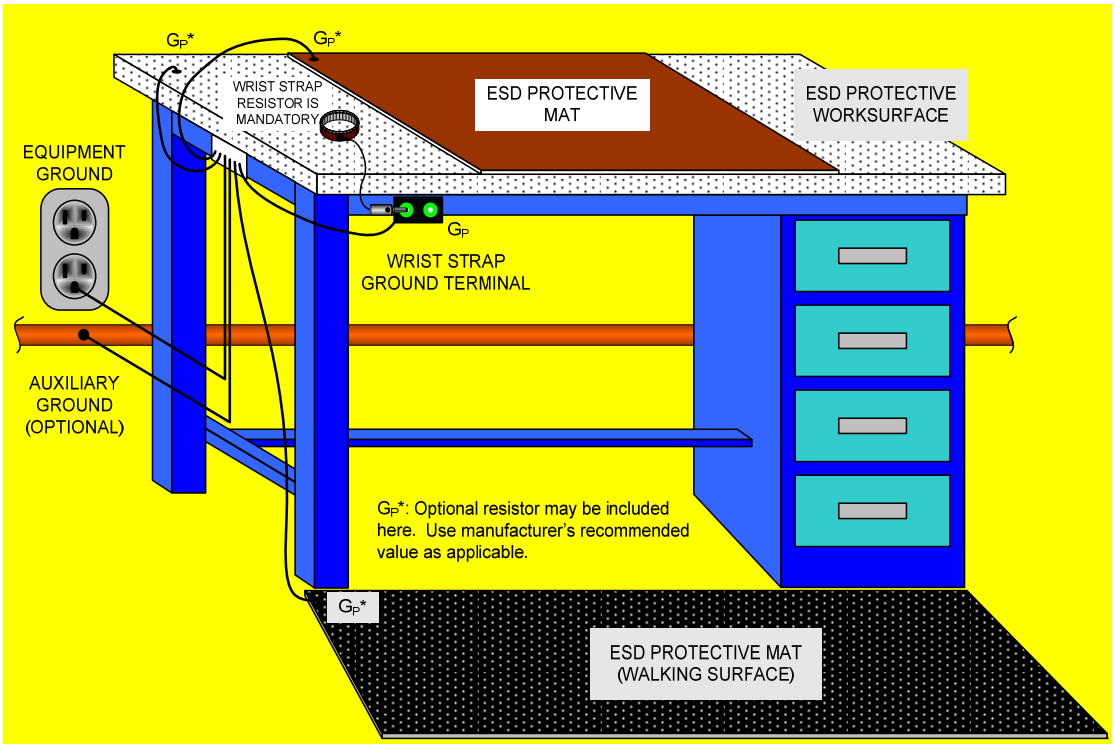

FIGURE 1: Typical ESD Grounded Workstation Layout

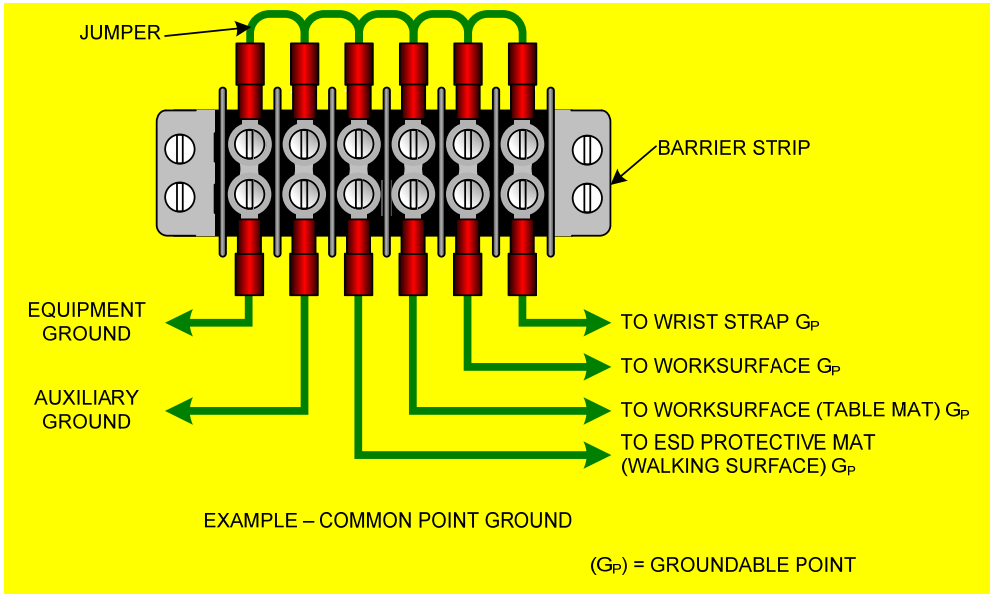

FIGURE 2: Workstation Common Point Ground Connections

When process-essential insulators (e.g., some tools and jigs) are required at the EPA or during any operation where unprotected ESD item are handled the following shall apply:

If the electrostatic field exceeds 2000 volt/inch, steps shall be taken to either:

a. Separate the insulators from the ESD-sensitive device by a minimum distance of 12 inches (for Class 0 devices increase the minimum distance to 18 inches), or

b. Use ionization or other charge mitigating techniques to neutralize the charge.

The electrostatic field can be measured using an electrostatic field meter in accordance with the manufacturer's instructions.

Cathode ray tubes used in monitors and various test equipment generate significant static charges on their glass surfaces and electromagnetic fields in their vicinity. Both of these issues shall be addressed in local procedures when they are necessary at the EPA.

6.2.3 Flooring. ESD protective floors or grounded ESD protective floor mats shall be mandatory in areas where personnel are working at standup operations and wearing wrist strap is not practical. Under these conditions the use of conductive or static dissipative leg straps, heel straps, or shoes shall be mandatory. ESD protective floors or mats shall be kept free of dust, dirt, and other contaminants. After each cleaning, the floor resistivity of ESD protective floors or mats shall be verified and the results shall be recorded. ESD protective floors shall not be waxed or buffed unless the flooring manufacturer's instructions are followed and the materials used do not inhibit the conductive or static dissipative properties of the flooring.

6.2.4 Air Ionizers. When the use of air ionizers is necessary, they shall incorporate a visual status indicator that illuminates to indicate proper operation per the manufacturer's instructions. All air ionizers shall be currently in calibration at time of use, unless specified otherwise per the manufacturer's instructions. Some air ionizers are designed to be maintenance free, and there are no calibration adjustments that can be made from the initial factory settings. The compliance verification requirements per Table IV (i.e., Discharge time and Offset voltage) shall still apply to all air ionizers as specified in accordance with the manufacturer's instructions.

6.3 Personnel Grounding Devices. Grounding devices shall be supplied to all personnel working with or handling ESDS items to prevent electrostatic charge buildup. A grounding device shall be worn continuously by all personnel while working with unprotected ESDS items.

6.3.1 Wrist Straps. Wrist straps shall ensure conductive contact with the wearer's skin. The safety resistor shall measure 1 mega-ohm (+/- 20%). Wrist straps used in conjunction with ESD continuous monitors that alarm when the connection to ground is compromised are preferred. When individuals are seated at ESD-protective workstations, they shall be connected to the ESD ground using a wrist strap.

6.3.2 Foot Grounding Devices. Conductive or static dissipative foot grounding devices, such as leg, toe, heel straps, or shoes worn in conjunction with ESD protective flooring and/or ESD protective 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.

6.4 ESD Grounding System Verification. 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. Grounding procedures must remain consistent with the National Electrical Code (NFPA 70). Prior to performing ESD grounding system verification, check for proper wiring within the AC wall outlet containing the equipment grounding conductor to be used for the ESD ground. Verify the following wiring conditions:

a. Neutral and equipment grounding conductor wires are present and not connected to each other at the wall outlet.

b. Hot and neutral conductors are not reversed at the wall outlet.

c. Hot and equipment grounding conductors are not reversed at the wall outlet.

The equipment grounding conductor will, hereafter, be referred to as the AC equipment/facility ground. Refer to Figure 3 for identification of AC wall outlet conductors and preferred connections.

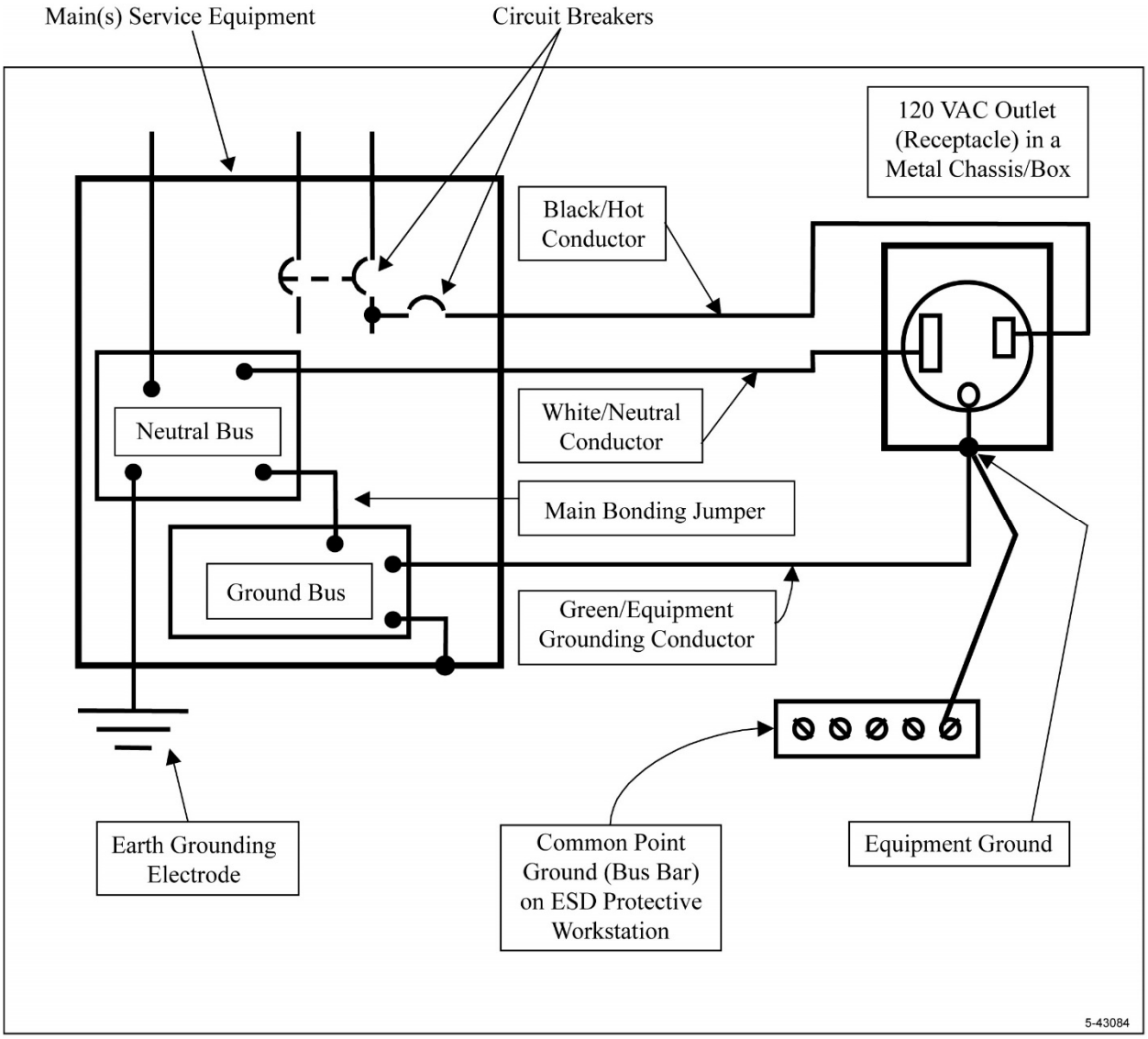

FIGURE 3: Preferred Ground Connection and Main(s) Service Equipment

6.4.1 AC Equipment/Facility Ground. Using an ohmmeter measure the resistance between the common point ground and the previously tested AC equipment/facility ground. The measurement probes shall be placed to include the resistance of all interconnecting and securing devices at the ESD-protected workstation. Refer to Figure 4 which shows the measurement test points. The total resistance shall not be greater than 1 ohm.

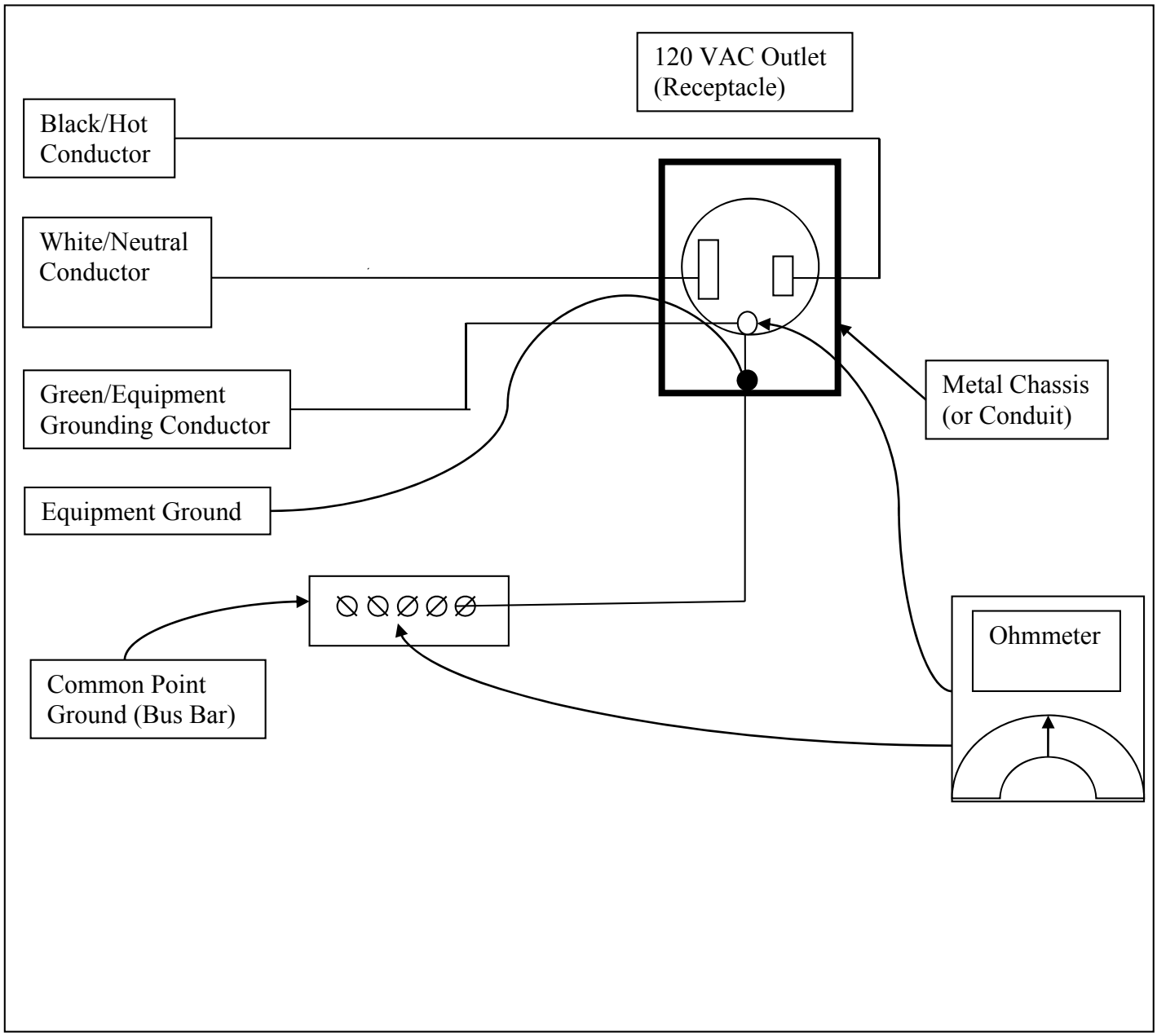

Figure 4: AC Equipment Ground Resistance Measurement Test Points

6.4.2 Facilities with AC Equipment/Facility Ground and Auxiliary Ground. When both the AC equipment/facility ground and an auxiliary ground (i.e., metal underground water pipe, metal frame of building, ground ring, etc.) are present and electrically bonded together within the facility, the following measurement shall be conducted. First, verify the wiring conditions of the AC equipment/facility ground as specified per paragraph 6.4. Next, using an ohmmeter, measure the resistance between the AC equipment/facility ground and any auxiliary ground. The measurement probes shall be placed to include the resistance of all interconnecting and securing devices. Refer to Figures 1 and 2 to show examples of interconnecting and securing devices to be included in the measurement. The total resistance shall not be greater than 25 ohms.

6.4.3 Field Service/Equipotential Bonding (Applications without AC Equipment/Facility Ground). This electrically interconnecting method applies to remote, temporary, or field service applications (e.g., Electromagnetic Interference (EMI) Copper Table, Environmental Testing Chambers, Shock or Vibration Testing Equipment, etc.) where an AC equipment/facility ground is not present. Equipotential bonding is established when all items are bonded together at a common connection point so that there is no potential difference between the items. Once the equipotential bonding process has been completed, it safe to handle ESDS items without inducing damage. Refer to ANSI/ESD S6.1 for the ESD requirements applicable to this method.

6.5 Accessories. ESD protective furniture (e.g., chairs or stools) can be used at workstations or in protected areas, but it is not required. The wrist strap system shall serve as the primary means of protection. If used, the ESD protective furniture 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 ESD protective floors are utilized, positive electrical contact shall be made between the floor and conductive structure of the vehicle. If non-ESD protective floors are present, the vehicle shall be grounded before ESDS items are loaded or removed from the vehicle. The vehicle having a permanently attached ground snap or common point ground connector for grounding the vehicle when docked at an EPA (i.e., workstation or workbench) is highly recommended.

6.6 Humidity. Unless other precautions (see below) are utilized, the relative humidity shall be maintained in ESD-protected work areas at 30 percent to 70 percent. Likewise for highly sensitive ESD (e.g., HBM Class 0) items, the humidity level shall be in the range of 40 percent to 70 percent. At levels below 30 percent (< 40 percent for Class 0 items), additional precautions shall be employed (e.g., air ionizers, humidifiers). If other cautionary methods are not available or if all attempted mitigation techniques are not successful, work shall be halted until the required humidity level is obtained. Electrostatic charge build-up problems increase at low humidity, especially at levels below 30 percent. At high humidity levels (i.e., greater than 70 percent), corrosion of electrical/electronic components (including ESDS items) becomes an issue. When ESDS items are not being actively processed (i.e., fabrication, troubleshooting, testing, repair, or any type of handling), the item may be stored inside of a desiccant dry cabinet or dry box, covered with static dissipative packaging materials, or may be fully enclosed within ESD protective packages (i.e., shielded, static dissipative, or antistatic bags, totes, etc.).

6.7 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 precautionary notes.

a. 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, or a similar cautionary warning message.

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

c. The ESDS cautionary marking 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.

6.8 Compliance Verification Plan/Monitoring

6.8.1 Compliance Verification Testing. The responsible organizations (users/operators) shall comply with the minimum compliance verification testing, as specified per Table IV herein or other approved methods, of equipment and materials used in their EPAs (i.e., workstations, workbenches, or grounded protective mats).

a. The MSFC responsible organizations (users/operators) shall contact the SMA Office to request the initial setup and initial verification of their EPAs.

b. Prior to use, the initial verification and reverification (i.e., follow-on) testing of ESD protected areas (i.e., workstations, workbenches, or grounded protective mats) shall be performed by Safety and Mission Assurance (SMA) personnel or by the responsible organization (user/operator) with a SMA employee witnessing the testing.

c. The SMA employee shall fill out the MSFC Form 4294 (either electronically or legible printing is acceptable), or use the SMA electronic records database to document the initial verification and reverification test results of ESD protected areas. The SMA employee shall use the assigned QA stamp or their signature for final approval of an ESD protected area. The SMA employee shall post the appropriate “Sign” using either MSFC Form 4633, MSFC Form 4654, or MSFC Form 4662 based on the results of the completed MSFC Form 4294. All “Signs” shall be filled out electronically or using legible printing.

d. Reverification of all ESD protected areas, where unprotected or unpacked ESDS items are handled, shall be required at a minimum of every six (6) months with an additional 7-day grace period.

e. A "Not In Service" sign (i.e., MSFC Form 4662) shall only apply and be posted at ESD protected areas when a nonconformance or EPA compliance verification testing failure occurs.

f. For locations where mission hardware is not being processed, signage is not required.

g. The SMA Office also shall maintain configuration control of verification test data for the EPAs at MSFC. The completed MSFC Form 4294 shall be an official record for the SMA organization.

h. Note that each item listed in Table IV may not apply to every EPA.

6.8.2 ESD Operating Equipment. The responsible organizations (users/operators) shall be responsible for both the initial and reverification (i.e., follow-on) testing, including the documentation and maintenance of test results, of their own ESD operating equipment (i.e., air ionizers, soldering iron tips, humidity monitoring devices, continuous monitor systems, ESD stools and chairs, etc.) as specified per Table IV herein. ESD garments (e.g., smocks) shall be tested prior to initial use and after each washing in accordance with the manufacturer's instructions or ANSI/ESD STM2.1. The requirements per paragraph 10.5 shall apply when ESD garments are used. Note that each item listed in Table IV may not apply to every EPA.

TABLE IV. ESD Compliance Verification Schedule and Measurements

Test #	ITEM	Test Method Ref.	Test Parameters	Verification Intervals				
				Continuous	Daily	Quarterly	Semiannually	Annual
1	[2] Worksurface Resistance (or Resistivity) from point to point (RTT)	ESD TR53; and ANSI ESD S4.1	> 1 x 10^5 and < 1x 10^9 ohms (or ohms/square) measured between two points 10 inches apart in the most commonly used portion of the worksurface, or perform testing per manufacturer's instructions.				X	
2	Worksurface Resistance to groundable point (RTG)	ESD TR53; and ANSI ESD S4.1	> 1 x 10^6 and < 1x 10^9 ohms from the center of the worksurface to the equipment ground, or perform testing per manufacturer's instructions.				X	
3	[1,2] Protective Floor Resistance	ESD TR53; and ANSI ESD S7.1	< 1 x 10^9 ohms. After cleaning the floor shall be checked and the data recorded.				X	
4	[1,2] Protective Floor Grounding	ESD TR53; and ANSI ESD S7.1	< 1x 10^9 ohms from the floor surface to the equipment ground.				X	
5	[3] Wrist Strap Check Resistance	ESD TR53; and ANSI ESD S1.1	1 x 10^6 ohms ± 20% or user defined value. Use approved Wrist Strap checker and log daily. Daily testing may be omitted if a Continuous Monitoring System (CMS) is used, which is the preferred method.		X			
6	[3] Foot Grounding Device Integrity	ESD TR53; and ANSI ESD STM97.1	< 3.5x10^7 ohms between the floor and person. Also, use approved footwear checker & log test results each time you enter the area.		X			
7	[2] ESD Continuous Monitoring System	ESD TR53	Verify functionality before handling ESDS items. Check alarm limits annually per Manufacturer's instructions.	X				X

8	[2] Stool / Chair Grounding.	ESD TR53; and ANSI ESD STM 12.1	< 1 x 10^9 ohms point to ground.					X
9	[2] Mobile Equipment (Working Surfaces)	ESD TR53; and ANSI ESD S4.1	< 1 x 10^9 ohms point to ground.					X
10	Relative Humidity (RH)	N/A	30 to 70% RH continuous for work area. For Class 0 Work Areas RH shall be > 40%. Calibrate humidity monitoring devices annually per the manufacturer's instructions.	X				X
11	[2] Ionizers	ESD TR53; and ANSI ESD STM3.1	Discharge time: User defined per manufacturer's instructions Offset voltage: < ± 35 Volts				X	
12	Soldering Iron Tip to Ground Resistance	ESD STM13.1; and ESD TR20.20	Verify that the tip to ground resistance is < 10 ohms. Also, see paragraph 6.8.4.			X		
13	AC Equipment Ground	ESD TR53; and ANSI ESD S6.1	< 1 ohm total resistance.				X	
14	Auxiliary Ground	ESD TR53; and ANSI ESD S6.1	< 25 ohms total resistance.				X	

[1] Additionally, the Protective Flooring resistances are checked and documented after the floor or floor mats have been cleaned. The area does not need to be checked after vacuuming.

[2] These items require proof of verification. (i.e. sticker or log entry)

[3] Automatic data loggers may be used for wrist strap and foot grounding daily checks.

6.8.3 Daily Test Measurements. The resistance of all personnel grounding devices that do not use an audible alarm shall be verified and recorded daily by the responsible organizations (users/operators).

a. Daily testing of ESD wrist straps may be omitted if a Continuous Monitor System (CMS) is used. The use of a CMS is the preferred method, and is also highly recommended for Class 0 EPAs. CMS equipment with both audible and visual alarms is recommended. Both alarms should activate when the wrist strap is temporarily removed, or when the grounding integrity is compromised (e.g., loose ground connection, defective wrist strap or cord, loose contact between the wrist strap and the wearer's skin, etc.). The users/operators shall verify proper functionality, per the manufacturer's instructions, of the CMS before handling ESDS items. The functional verification of a CMS is typically a self-check to ensure that both the visual and audible alarms are still working properly in the event the grounding integrity has been compromised. The self-check verification of the visual and audible alarms do not need to be documented. The compliance verification requirements per Table IV shall still apply for a CMS as specified in accordance with the manufacturer's instructions.

b. Note that if foot grounding devices are used in an ESD protected area, daily testing shall be required and the test results recorded by the responsible organization. Foot grounding devices must be worn on both feet and tested one foot at a time. Foot grounding devices shall be tested each time an individual enters an ESD protected area.

6.8.4 Soldering Systems. Soldering systems that incorporate sensing circuits to verify connections to ground and power down the system when out of range are exempt from calibration. There are no adjustments to be made, so these systems cannot be changed from their initial factory settings. Therefore, no calibration is required. The compliance verification requirements per Table IV shall still apply for soldering iron tip to ground resistance measurements.

6.8.5 Audits. Initial verification audits of EPAs (i.e., workstations, work benches, or grounded protective mats) shall be performed by the SMA personnel using MSFC Form 4294. Verification of current status shall be accomplished by the following:

a. During MSFC internal audits, organizations with EPAs and ESD testing, monitoring, or operating equipment shall be periodically audited for compliance with this document.

b. The reverification (i.e., follow-on) tests performed by SMA personnel using MSFC Form 4294 can be considered as additional audits of the EPAs (i.e., workstations, work benches, or grounded protective mats) to further assure compliance with this document.

7. SAFETY PRECAUTIONS AND WARNINGS NOTES

7.1 Worksurfaces of EPAs should be soft grounded to eliminate the safety hazard of touching a hazardous voltage (i.e., between 110 to 250 volts) circuit with one hand and a hard ground with the other. Ground Fault Circuit Interrupters (GFCIs) and other safety protection should be considered wherever personnel might come into contact with electrical sources.

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 representative. The bond connection and lines must be able to carry fault and lightning strike currents.

8. DATA, REPORTS, AND FORMS

- MSFC Form 4294 - ESD PROTECTED AREA/WORKSTATION AUDIT
- MSFC Form 4633 - MSFC FORM for ELECTROSTATIC DISCHARGE (ESD) CONTROL AREA for HUMAN BODY MODEL (HBM) CLASS 1A or LESS SENSITIVE ITEMS
- MSFC Form 4654 - ELECTROSTATIC DISCHARGE CONTROL AREA for HUMAN BODY MODEL (HBM) CLASS ZERO ITEMS
- MSFC FORM 4662 - FORM for AREA NOT IN SERVICE FOR ELECTROSTATIC DISCHARGE (ESD) CONTROL

9. RECORDS

9.1 The completed MSFC Form 4294 shall be maintained by the SMA Office for a minimum of 3 years from the initial audit date or as long as the EPA is in existence. Records for compliance verification testing of workstations, workbenches, or grounded protective mats required by paragraph 6.8.1, shall be maintained by a SMA Quality Assurance Branch designee. Posting the up-to-date information at each EPA shall be required using either MSFC Form 4633, MSFC Form 4654, or MSFC Form 4662 based on the results of the completed MSFC Form 4294.

9.2 The designee of the responsible organization (user/operator) shall maintain records for compliance verification testing, daily test measurements, and soldering systems per paragraphs 6.8.2, 6.8.3, and 6.8.4 respectively, for their ESD operating equipment.

9.3 All results [i.e., initial verification and reverification (i.e., follow-on) test data] shall be available for review upon request.

9.4 Logbooks used to document daily testing of wrist straps, foot grounding devices (e.g., toe or heel straps, ESD shoes, etc.), or ESD smocks after washings shall be available for review upon request.

10. 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, and the area making contact with the work piece shall be grounded with a measured resistance not to exceed 10.0 ohms.

10.2 Environmental test 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 insulating residues. Cleaning agents shall be chosen for low electrostatic charging propensity.

10.4 For areas not utilizing a CMS, wrist strap testers shall be available in all areas where ESDS items are handled. Footwear testers also shall be available in all ESD protected areas where foot grounding devices are used.

10.5 Wearing an ESD smock is preferred, but not mandatory. When used, an ESD protective smocks shall be constructed such that their static dissipative or conductive properties are continuous and consistent throughout the material. 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. It is also important that the ESD protective smock sleeves cover the end of the inner garment sleeves. When an ESD smock is worn while handling static sensitive items, the user/operator shall be grounded by wearing a properly tested wrist strap, or by using a ground cord from the hip connection of the smock to a groundable point when working at a stationary location. Either of these options will help ground the smock, and prevent it from becoming an isolated charged conductor. A charged garment (smock) can cause damage if it come into contact with ESDS items. Either the disposable-type or washable ESD smocks are acceptable, as preferred by the user/operator. The manufacturer's instructions shall be followed for installation, testing, maintenance, and washing in order to gain effectiveness and use from the smocks. The ESD protective properties of smocks/protective garments shall be verified by testing after each washing. The test results after each washing of the smocks/protective garments shall be recorded and maintained. Any ESD smocks/protective garments that fail testing shall be removed from service. Torn or damaged smocks shall not be used in ESD protected areas. 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.

11. PERSONNEL TRAINING AND CERTIFICATION

Certification of personnel shall be based on successful completion of an approved ESD Awareness and Prevention training program. The required training shall be per the SATERN SHE 413 course titled "Certification Training for Electrostatic Discharge (ESD) Control". This training is for those individuals who are involved in the handling of ESD sensitive parts, assemblies, and equipment. These individuals include, but are not limited to, 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 workstations, monitoring of the work place, handling ESDS items, packaging, marking and shipping of ESDS items. After successful completion of training, personnel shall receive an email notification from the Quality Assurance Branch (QD11) providing instructions to finalize the certification process prior to updating their records within the CERTRAK database system. The electronic records within CERTRAK, or a copy of the SATERN SHE 413 certificate of completion shall serve as objective evidence of certification. Support contractors shall be responsible for documenting and maintaining objective evidence for their personnel. In order to maintain ESD certifications, recurrent training and recertification shall be required every two (2) years. Reference Chapter 3 of MWI 3410.5, Personnel Certification Program for Skills, to obtain the requirements associated with training and certifications.

APPENDIX A
Acronyms

(AC)	Alternating Current
(ANSI)	American National Standards Institute
(CMS)	Continuous Monitoring System
(CPG)	Common Point Ground
(DC)	Direct Current
(EMI)	Electromagnetic Interference
(EPA)	ESD Protected Area
(ESD)	Electrostatic Discharge
(ESDA)	Electrostatic Discharge Association
(ESDS)	Electrostatic Discharge Sensitive
(G_p)	Groundable Point
(HBM)	Human Body Model
(JEDEC)	Joint Electron Device Engineering Council
(MAF)	Michoud Assembly Facility
(MSFC)	Marshall Space Flight Center
(MWI)	Marshall Work Instructions
(NASA)	National Aeronautic and Space Administration
(NEC)	National Electrical Code
(NFPA)	National Fire Protection Association
(NPD)	NASA Policy Directive
(QA)	Quality Assurance
(RH)	Relative Humidity
(RTG)	Resistance Top to Ground (or) Resistance To Ground
(RTT)	Resistance Top to Top (or) Resistance Point to Point
(SMA)	Safety and Mission Assurance