



**NASA HANDBOOK**

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8739.21**

National Aeronautics and Space Administration  
Washington, DC 20546

**Approved: 2010-06-18**

**WORKMANSHIP MANUAL FOR  
ELECTROSTATIC DISCHARGE  
CONTROL**

**(EXCLUDING ELECTRICALLY INITIATED  
EXPLOSIVE DEVICES)**

**Measurement System Identification:  
Metric**

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## DOCUMENT HISTORY LOG

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## FOREWORD

This NASA-HANDBOOK is published by the National Aeronautics and Space Administration (NASA) to provide standardized guidance for implementing ANSI/ESD S20.20 requirements. This document:

- a. Describes basic considerations necessary to ensure ESD protection in work areas to be used with ESD-sensitive items.
- b. Reinforces rigorous operator training best practice.
- c. May be used by suppliers performing work for NASA to satisfy ANSI/ESD S20.20 ESD implementation plan requirements.

*NOTE: For the purpose of this document, the term "supplier" is defined as civil servants and contractors who are building and delivering ESD-sensitive hardware for NASA Projects.*

This manual addresses ESD Control Program Plan (CPP) <sup>[1] Note 1</sup>, Compliance Verification, and ESD Administrative and Technical Requirements specified in ANSI/ESD S20.20 paragraphs 6.0, 7.0 and 8.0. Guidance materials used for the development of this manual include ESD TR20.20 Handbook for the Development of an Electrostatic Discharge Control Program for the Protection of Electronic Parts, Assemblies and Equipment and ESD TR53-01-06 Compliance Verification of ESD Protective Equipment and Materials, published by the ESD Association.

Several drawings, tables and paragraphs in this manual have been adopted, with permission from the associated NASA Center, from pre-existing NASA Center-level ESD implementation plans. The intent is to facilitate NASA's and industry's use of a common baseline in order to maximize the success of ESD programs implemented during the manufacture, test and handling of ESD-sensitive NASA hardware. This document is not intended to prescribe specific technical procedures and/or software tools.

This document is controlled and maintained by the NASA Office of Safety and Mission Assurance (OSMA). Comments and questions concerning the contents of this publication should be referred to the National Aeronautics and Space Administration, Director, Safety and Assurance Requirements Division, Office of Safety and Mission Assurance, Washington, DC 20546.



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Approval Date

*Note 1: See Section 11 for the list of references. References are noted throughout in superscripted brackets [ ].*

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## Acronyms

AC	Alternating Current
ATL	Area Test Log
CDM	Charged Device Model [for electrostatic discharge].
CMS	Continuous Monitoring System
CPG	Common Point Ground
EPA	ESD Protected Area
ESD	Electrostatic Discharge
ESDA	Electrostatic Discharge Association
ESD ADV	Advisory Document
ESDS	Electrostatic Discharge Sensitive
ESD DS	Draft standards
ESD S	Standards
ESD SP	Standard Practices
ESD STM	Standard Test Methods
ESD TR	Technical Report
GFCI	Ground Fault Circuit Interrupter
GPR	Goddard Procedural Requirement
HBM	Human Body Model [for electrostatic discharge].
MM	Machine Model [for electrostatic discharge].
NASA	National Aeronautics and Space Administration
NMTTC	NASA Manufacturing Technology Transfer Center
QA	Quality Assurance
RH	Relative Humidity
RMS	Root Mean Square
SAM	Systems Assurance Manager
WM	Workmanship Manual

# 1 SCOPE

## 1.1 PURPOSE

1.1.1 The Agency-level quality requirements for ESD safety and control are defined by NPD 8730.5, NASA Quality Assurance Policy Requirements, and are wholly contained in ANSI/ESD S20.20, 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). The purpose of this document is to present a standardized administrative and technical baseline for development of an organization’s ESD Control Program Plan which is required by ANSI/ESD S20.20.

Note: While providing a recommended ESD Control Program Plan in a format that facilitates direct use of its text (starting at paragraph 4.3) by authors of supplier-level ESD Control Program Plans, this document also summarizes the recommendations from ESD TR20.20. Supplier-level ESD Control Program Plan authors who choose to use the text herein, in their own Plan, are encouraged to examine each use of the words “should”, “will”, “is”, and “are” herein and, when using those clauses, change those to “shall” or “must” as needed to establish the local requirements. Uses of the word “shall” herein indicate a requirement that is traceable to ANSI/ESD S20.20.

## 1.2 APPLICABILITY

1.2.1 This publication is provided as a resource for all organizations that handle ESD-sensitive (ESDS) items for NASA projects and are subject to the requirements of ANSI/ESD S20.20.

1.2.2 Agency-level ESD safety and control requirements are intended to apply to all ESDS devices applied on projects where NASA high reliability aircraft or space flight hardware will be processed. This baseline should also be applied to hardware production where the end item may not be mission-critical yet is expensive to replace, or is a long-lead item.

1.2.3 The practices described herein are generally suitable for the ESD sensitivity levels of the Human Body Model (HBM) Classes 0 and 1A and Machine Model (MM) Class M1. For special instances where the Charge Device Model (CDM) applies, additional precautions and practices beyond those described herein may be necessary. See paragraph 8.2.

## 2 APPLICABLE DOCUMENTS

ANSI/ESD S20.20	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) NOTE: all references herein to ANSI/ESD S20.20 shall be to the 2007 version unless otherwise specified.
ANSI/ESD S541	Packaging Classification & Technical Requirements
ANSI/ESD S6.1	Grounding
ANSI/ESD TR20.20	Control Program Handbook, Technical Requirements
ESD ADV1.0	ESDA Glossary of Terms
ESD SP3.3	Periodic Verification of Air Ionizers
ESD S4.1-1997	Worksurfaces–Resistance Measurements
ESD STM2.1	Protection of ESD Sensitive Items – Garments
ESD STM5.1	Human Body Model (HBM) – Component Level
ESD STM5.2	Machine Model (MM) – Component Level
ESD STM5.3-1	Charged Device Model (CDM) – Component Level
ESD STM7.1	Resistive Characterization of Materials – Floor Materials
ESD STM12.1	Seating Resistive Measurements
ESD STM13.1	Electrical Soldering/De-soldering Hand Tools
ESD TR53-01-06	Compliance Verification of ESD Protective Equipment and Materials
NPD 8739.5	NASA Quality Policy

### 3 DEFINITIONS

The following definitions apply to terms used in this manual:

Assembly	A functional subdivision of a component, consisting of parts or subassemblies, which perform functions necessary for the operation of the component as a whole. Examples: regulator assembly, power amplifier assembly, gyro assembly, etc.
Certificate of Completion of Training	The actual certificate issued or the wallet-sized card given to the trainee after successful completion of training.
Certification	The act of verifying and documenting that personnel, facilities, equipment, processes, or materials comply with the requirements of this document.
Certification of Competence	The act of verifying and documenting that personnel are competent to perform work in an ESD-protected area as required by this document.
Certification of Training	The act of verifying and documenting that personnel have successfully completed training. The Certification of Completion of Training documents this certification.
Charged Device Model	A specified circuit characterizing an electrostatic discharge, which results when a device isolated from ground is first charged and then subsequently grounded.
Cheater Plug	An AC plug adapter used to connect a three-pronged plug to a two-pronged AC socket. It can be used to separate the ground wire from the socket for testing purposes.
Component	A functional subdivision of a system, generally a self-contained combination of assemblies performing a function necessary for the system's operation. Examples: power supply, transmitter, gyro package, etc.
Contractor	The individual(s) or concern(s) who enter into a prime contract with the Government.
Conductive Material	A material that has a surface resistivity of $<10^5$ ohms per square or a volume resistivity $<10^4$ ohms-cm.
Equipotential Bonding	A connection between two points with a maximum resistance between them of $< 10^9$ ohms [with no current flow].
Electrostatic Discharge (ESD)	A transfer of electrostatic charge between bodies at different electrostatic potentials caused by direct contact or induced by an electrostatic field.
ESD ADV...	ESDA Advisory Document. Advisory Documents are not standards, but provide general information for the industry or additional information to aid in better understanding of ESD Association standards.
ESD DS...	ESDA Draft Standard. Draft standards, test methods and standard practices are subject to revision before being issued as full standards.

ESD S...	ESDA Standard. Standards have completed the industry comment and review process, and have been approved by the ESD Association Standards Committee as final standards documents.
ESD SP...	ESDA Standard Practice. Standard practices have completed the industry comment and review process, and have been approved by the ESD Association Standards Committee as final standards documents
ESD STM...	ESDA Standard Test Methods. Standard test methods have completed the industry comment and review process, and have been approved by the ESD Association Standards Committee as final standards documents.
ESD TR...	ESDA Technical Report. A technical report is a collection of technical data or test results published as an informational reference on a specific material, product, system or process. The opinions expressed in a technical report are the opinions of the author(s) and may or may not be endorsed by the ESD Association.
ESD Program Monitor	An individual who is trained and certified who are responsible for the day-to-day maintenance of the certification status of an ESD protected area.
ESD Protected Area	An area that is constructed and equipped with the necessary ESD-protective materials and equipment to limit ESD voltage below the sensitivity level of ESDS items handled therein. This may include benches, rooms or buildings.
ESD-Protective Material	Material capable of one or more of the following functions: limiting the generation of static electricity; safely dissipating electrostatic charges over its surface or volume; or providing shielding from ESD spark discharge or electrostatic fields.
ESD-Protective Packaging	Packaging with ESD-protective materials to prevent damage to ESDS items during storage or transport.
ESD Protected Workstation	See ESD Protected Area.
ESD Sensitive (ESDS) Items	Electrical and electronic parts, assemblies and equipment which are sensitive to ESD voltages or electrostatic fields.
Electrostatic Field	A voltage gradient between an electrostatically charged surface and another surface of a different electrostatic potential.
Ground	A mass such as earth, a ship, or a vehicle hull, capable of supplying or accepting a large electrical charge.
Groundable Point	Any point with low impedance to ground where grounding may be attached. Usually it is the common point ground.
Hard Ground	A connection to earth ground either directly or through low impedance.
Human Body Model	An electrostatic discharge circuit that meets the set model values by conforming to waveform criteria specified in ESD-STM 5.1, characterizing the discharge from the fingertip of a typical human being.

Insulative Material	A material having a surface resistivity $\geq 10^{12}$ ohms/square or a volume resistivity $\geq 10^{11}$ ohms-cm.
Kit	A prepared package of parts with instructions for assembly and/or wiring a component or chassis.
Level B Instructor	An individual who is certified to train operators and ESD program monitors. Certified Level B Instructors are qualified to perform the duties of an ESD program monitor.
Machine Model	An electrostatic discharge simulation test based on a discharge network consisting of a charged 200 Pico farad capacitor at (nominally) zero ohms of series resistance. Actual series resistance and inductance are specified in terms of the current waveform through a shorting wire. The simulation test approximates the electrostatic discharge from a machine. (See ESD STM 5.2)
Operator	An individual who is trained and certified to perform tasks in an ESD protected area.
Organization	A NASA center, support contractor, supplier, department, group or team.
Part	An element of a component, assembly, or subassembly which is not normally subject to further subdivision or disassembly without destruction of its designed use, e.g., a module, IC, resistor, etc.
Soft Ground	A connection to ground through impedance sufficiently high to limit current flow to safe levels for personnel (normally 5 milliamperes). Impedance needed for a soft ground is dependent upon the voltage levels which could be contacted by personnel near the ground. By this definition a hard ground protected by a functional GFCI is considered a soft ground.
Static Dissipative	A property of a material having surface resistivity $\geq 10^5$ but $< 10^{12}$ ohms per square or a volume resistivity $\geq 10^4$ but $< 10^{11}$ ohms-cm
Subcontractor	An individual or concern that enters into a purchase agreement under a Government prime contract.
Surface Resistivity.	The surface resistivity is an inverse measure of the conductivity of a material. Surface resistivity of a material 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 surfaces and materials with constant volume conductivity and has the value of ohms per square.
System	A system is a functional subdivision of a spacecraft generally composed of two or more components designed to perform an operation. An instrument is considered a system.
Verification	The act of performing the tests and/or inspections required in Table 7-1 and reviewing ESD protected areas for compliance to the requirements of this Manual.
Triboelectric	Pertaining to electricity generated by friction.

## 4 GENERAL

### 4.1 CONFIGURATION CONTROL

4.1.1 This document is a controlled document and is controlled by NASA Headquarters OSMA configuration management procedures.

4.1.2 Requests for technical changes are processed in accordance with NASA Headquarters OSMA configuration management procedures.

### 4.2 IMPLEMENTATION

4.2.1 ESD Control Program Plans which conform to the recommendations in this handbook include requirements related to facility preparation and certification, records management, assignment of responsible personnel, manager and operator training, assessment of the sensitivity of the hardware to be handled, and declaration and use of special processes and criteria as applicable. It is intended that recommendations herein, made using language such as “is”, “are”, “should”, and “will”, will be converted to “shall” statements in the local ESD Control Program Plans.

4.2.2 Suppliers should provide a central ESD Point of Contact (POC) that can advise and assist operators, Program Monitors, contractors, subcontractors and other authorized personnel in the proper and effective implementation of the provisions of this handbook. This person can be the ESD Control Program Manager that is required by ANSI/ESDA S20.20-2007<sup>[2]</sup>.

4.2.3 The methods described in this handbook for developing an ESD Control Program Plan are implemented directly by operators, Program Monitors, Audit Teams, Audit Coordinators, and Program Managers.

4.2.4 The needed ESD Protected Area (EPA) certification level and associated ESD event model are determined by the hardware designer based on the most sensitive piece-part to be handled. The recommended default EPA certification level is HBM Class 1A (See Table 5-1). Where the Human Body Model (HBM) does not provide sufficient protection for the hardware, the Machine Model (MM) or the Charged Device Model (CDM) should be considered when designing the ESD protected area. (See 5.7). For areas required to protect extremely sensitive devices see paragraph 8.2.

4.2.5 Use of the guidelines herein facilitates compliance to NASA Agency-level ESD requirements however it does not supersede or preclude Project review and approval of suppliers' ANSI/ESD S20.20-compliant ESD Control Program Plans. It is the Project's responsibility for assuring that local ESD Control Program Plans meet the requirements of ANSI/ESD S20.20 as well as Project-specific requirements. However, it is recommended that Projects utilize this document as a benchmark against which suppliers' plans are evaluated.



### 4.3 RECORDS

Records required by the processes described herein should be retained per Table 4-1 below.

**Table 4-1: Record Retention**

<b>Record Title</b>	<b>Record Custodian</b>	<b>Retention</b>
Training records	Office of Human Resources and/or Supervisor.	NRRS 3/33G1* -- Destroy 5 years after employee discontinues or completes training.
ESD workstation records	Laboratory Manager or owning project manager when there is no Program Manager	NRRS 8/109* -Temporary- Destroy/delete when between 2 & 15 years old. Do not retain longer than life of program/project plus 5 years.
Temporary/Intermittent Workstation records	Project Manager	NRRS 8/109*

\*NRRS – NASA Records Retention Schedules (NPR 1441.1)

## **5 ESD CONTROL PROGRAM**

### **5.1 GENERAL**

5.1.1 The intent of this ESD Control Program Guide meets or exceeds the requirements of ANSI/ESD S20.20 as well as the NASA ESD Workmanship requirements for processing ESD sensitive equipment.

5.1.2 Proper control of ESD is critical at every process step that an electronic part may see, from part manufacturing through testing and shipment, to incorporation on printed wiring boards, electronic modules, and directly into boxes.

### **5.2 ELECTROSTATIC DISCHARGE (ESD) TECHNICAL OVERVIEW <sup>[15]</sup>**

5.2.1 ESD is the sudden transfer of electrical charge between two objects at different potentials. Almost everyone has experienced ESD. One example occurs when you, wearing shoes, walk across a carpet and touch a conductive object, such as a metal doorknob. The “zap” that you feel and hear is a form of ESD.

5.2.2 The human body or other conductive objects can become electrostatically charged if not properly grounded. If this charge comes in contact with or passes near an ESD sensitive (ESDS) device, ESD damage can occur. Charge is not localized on the surface of a conductor, but is spread out uniformly over the conductor’s surface. Thus, very low voltages are capable of damaging ESDS devices.

5.2.3 Cathode ray tubes and other high voltage electric devices can create high electrical field potentials. Moving an ESDS device through such a field can induce current to flow through the device, thus causing damage even if the device does not come into contact with the charged surface. In addition, grounding a device that has become charged in an external electrostatic field can cause damage.

5.2.4 The physical structures on modern devices are extremely small and continue to shrink in size as technology advances. Very small charges accumulated on conductive elements of a device can exceed the breakdown potential of the insulating layers or the air gaps between them, causing the device to destroy itself. The presence of mechanical damage, such as fine scratches or contaminants within and on the surface of the device, tends to increase its ESD sensitivity.

5.2.5 Conductive, static dissipative, and insulative materials in the work place can become charged due to the triboelectric effect. These must be controlled to below damaging potentials through the use of grounding in the case of conductive and dissipative materials, or through the use of air ionization for insulative materials.

5.2.6 Where the static safe work place is in a clean room, the requirements of contamination control may place restrictions on the approaches that might ordinarily be available for controlling ESD.

5.2.7 The smallest ESD event most people can detect is about 2,000 volts. This same voltage, when applied to an ESDS device, can result in catastrophic failure. Some parts are severely damaged by ESD events of tens of volts. Thus, many damaging ESD events are not noticeable by human detection alone.

5.2.8 Three general ESD damage failure modes can be defined:

a. Catastrophic failure: When a catastrophic failure occurs, the device does not function at all. The consequence can be increased cost and delayed production milestones while replacement hardware is located, installed, and retested. The fact that the failure could be detected during testing reduces the risks of carrying a latent failure and of more costly consequences from failures found at higher levels of assembly and schedule points closer to the launch date.

b. Parametric failure: A parametric performance failure occurs when the device has been slightly damaged so that it still performs, but not to specification. For example, the device may not oscillate at the correct frequency, may exhibit intermittent performance, or may be unstable. The device still works when tested, but some performance parameters may be out of the acceptable tolerance limits. Again, this type of failure results in increased cost and schedule delay, but the fact that the failure could be detected during testing is positive.

c. Latent failure: A latent failure occurs when a device has been damaged so slightly that it does not fail but performs within its parametric tolerance limits. The damage remains hidden for a period of time until the device fails or the performance degrades earlier than its designed life. Parts with latent damage are sometimes referred to as the “walking wounded.”

Both catastrophic and parametric failures are usually found during product testing, where isolation and replacement are possible. Correcting these failures often results in increased costs and schedule delays.

Latent failures remain undetected during routine system testing and product development. However, after time and use, the damage leads to early failure. Depending upon the type and location of the products, the repair of a latent failed part may be impossible. This is the case for the majority of electrical systems built for NASA which are ultimately installed in spacecraft. A latent failure on a launched spacecraft could reduce mission effectiveness or lead to possible loss of a mission. Thus, the need to control ESD to prevent catastrophic, parametric, and latent ESD failures is crucial to the success of all NASA projects

### 5.3 ESD SENSITIVITY LEVELS

5.3.1 The ESD sensitivity of devices is determined using three different electrical models: the Human Body Model, the Machine Model, and the Charged Device Model. Device classification using any of the electrical model Classes in Table 5-1, 5-2, or 5-3 indicates that the device will not be damaged by that type of discharge, with an energy level that relates to the voltage level shown for that Class level.

a. Human Body Model (HBM): This simulates the discharge from the fingertip of an operator to an electronic component. In the HBM, a 100-pF capacitor is discharged through a 1500-ohm resistor to ground.

**Table 5-1: ESDS Component Sensitivity Classifications – HBM<sup>[3]</sup>**

Class	Voltage Range
0	<250 V
1A	250 to <500 V
1B	500 to <1000 V
1C	1000 to < 2000 V
2	2000 to <4000 V
3A	4000 to <8000 V
3B	≥8000 V

b. Machine Model (MM): This model originated in Japan as a worst-case HBM. It is a faster discharge model, designed to simulate ESD events in automatic handling and testing equipment. In this model, a 200-pF capacitor is discharged directly to ground.

**Table 5-2: ESDS Component Sensitivity Classifications – MM<sup>[4]</sup>**

Class	Voltage Range
M1	<100 V
M2	100 to <200 V
M3	200 to <400 V
M4	≥400 V

c. Charged Device Model (CDM): This model considers the situation where a device is charged and then discharged to ground through one pin or connector. The CDM sensitivity of a given device may be package dependent.

**Table 5-3: ESDS Component Sensitivity Classifications – CDM<sup>[5]</sup>**

Class	Voltage Range
C1	<125 V
C2	125 to <250 V
C3	250 to <500 V
C4	500 to <1000 V
C5	1000 to <1500 V
C6	1500 to <2000 V
C7	≥2000 V

## 5.4 DECLARING THE MODEL AND CLASS REQUIRED

5.4.1 The applicable ESD model and Class level is specified in the engineering documentation, ensuring that they are accurately communicated to the ESD program monitor who designs and verifies the EPA.

5.4.2 The ESD program manager certifies the EPA based on the ESD model and Class level reported by the ESD program monitor.

5.4.3 The most sensitive device to be handled during processing dictates the minimum protection afforded by the EPA. Note that parts mounted in high level assemblies are usually less sensitive. The recommended default EPA certification level is HBM Class 1A (See 4.2.4 and 5.8).

5.4.4 Design, maintenance, and certification of HBM Class 0 EPAs can be costly. Use of the HBM Class 0 level should only be done as dictated by the sensitivity of the hardware being processed

## **5.5 PERSONNEL SAFETY <sup>[15]</sup>**

5.5.1 The procedures and equipment described in this document may expose personnel to hazardous electrical conditions. Users of this document are responsible for complying with applicable laws, regulatory codes, and both external and internal safety policy. Users are cautioned that this document cannot replace or supersede any requirements for personnel safety.

5.5.2 Ground fault circuit interrupters (GFCI) and other safety protection should be considered whenever personnel might come into contact with electrical sources.

5.5.3 Electrical hazard reduction practices should be exercised and proper grounding must be followed.

## **5.6 ESD CONTROL PROGRAM MANAGER/COORDINATOR (REQUIRED BY ANSI/ESDA20.20)**

5.6.1 An ESD Control Program Manager or Coordinator <sup>[2]</sup> acts as the primary point of contact and responsible party for ESD plan implementation.

5.6.2 The Program Manager duties are:

- a. Issue and control the ESD Control plan that is traceable to the applicable requirements of ANSI/ESD S20.20 and utilizes this guideline to the greatest extent possible.
- b. Verify the organization's compliance with the published ESD Control plan.
- c. Certify new ESD Protected Areas (EPAs).
- d. Recertify expired or failed EPAs.
- e. Maintain Records of EPA certification.
- f. Periodically audit certified EPAs.
- g. Maintain a record of audits performed.
- h. Report results of certifications and audits to the proper ESD Program Monitors.
- i. Report results of certifications and audits to upper management.

## **5.7 ESD PROGRAM MONITOR**

5.7.1 The organization responsible for an ESD Protected Area (EPA) shall designate an ESD Program Monitor for that area. ESD Program Monitors may be responsible for more than one EPA.

5.7.2 The ESD Program Monitor is responsible for:

- a. ESD Protected Area (EPA) maintenance.

- b. ESD signage in the area.
- c. Scheduled EPA verifications.
- d. Random inspections and audits of EPAs.
- e. Up-to-date verification records (logs) and maintenance records.
- f. Reactivation of EPAs with less than six months of inactivity.
- g. Transfer of records during projects transitions.
- h. Monitoring and maintenance of additional protective measures when needed meet specialty certification requirements for handling highly sensitive devices.
- i. Authorization to use EPAs (except Class 0 rated EPAs) for non-ESD sensitive work.
- j. Verification and reactivation of EPA after it was used for non-ESD sensitive work.
- k. Notifying ESD Program Manager of any deviations sought against the organization's ESD Control plan.

## **5.8 ESD PROTECTED AREAS (EPA)**

5.8.1 An EPA may be a single workstation, laboratory, room, or building, or any area with pre-defined boundaries, that is designed to limit damage to electrical hardware by electrostatic discharge events. EPAs may be permanent or temporary.

5.8.2 When an EPA is not maintained, the ESD Program Monitor decommissions it by marking the area as not approved for use (see Appendix C). If the area is not maintained for a period not to exceed six months, the ESD program monitor can reactivate the area by verifying that the area passes the tests in Table 7-1, by affixing a verification sticker per Appendix C, and by initiating an area test log (ATL) per Appendix B2.

5.8.3 When an EPA is not maintained for a period exceeding six months it is considered "Abandoned". Activation of an abandoned area is accomplished via certification by the ESD Control Program Manager. The ESD Program Monitor is responsible for properly marking the status of abandoned workstations if they may be mistaken for active EPAs.

5.8.4 Certified EPAs can protect ESD sensitive parts, assemblies and equipment that are without ESD-protective covering or packaging however transport away from the EPA, or between EPAs, without using ESD-safe packaging or carriers risks ESD damage to the parts.

5.8.5 The ESD Control Program Manager initially certifies all EPAs and recertifies them as needed (see Para. 5.6 and Appendix C). The following are prerequisites for EPA certification:

- a. Personnel carry current certification.
- b. A control program for verification records is instituted.
- c. EPA environment measurements are up to date and meet Class level requirement (see 7.12.1).
- d. ESD workstation measurements are up to date and meet Class level requirement (see Table 7.1).

#### 5.8.6 Causes which require EPA recertification:

- a. Rewiring of the area has occurred.
- b. New work areas are added or moved.
- c. New features are added (e.g., new conductive floor, upgrade to CMSs, etc.).
- d. An abandoned EPA is reactivated.
- e. An ESD failure is traced to the particular ESD protected Workstation.

5.8.7 The ESD Control Program Certification Log in Appendix B1 may be used to record the certification data. It is recommended that identification stickers be used to indicate the compliance of all benches, chairs, and stools. For shelving, microscopes, wrist straps, foot straps, etc., the recorded data may serve as proof of compliance.

5.8.8 Once certified by the ESD Control Program Manager, certification of an ESD protected area (EPA) is maintained via scheduled inspections which are performed by the assigned ESD Program Monitor. See Table 7-1. EPA certification is voided if the scheduled verification is not performed for more than six (6) consecutive months, or if any of the conditions in Paragraph 5.8.6 above have been encountered. Also see paragraph 9.2.2.

5.8.9 Proper calibration of verification equipment is essential to a properly executed EPA certification.

### **5.9 TEMPORARY, PROVISIONAL AND INTERMITTENT-USE EPAS**

5.9.1 Temporary EPAs are areas which are created for use while working on a specific project for a continuous period of less than three months (one month if they are Class 0). These areas are certified by the ESD Program Manager for a specific period of time and the verification records are stored with the Project's I&T records. A long-term verification schedule requirement is not applicable to these types of EPAs, however all other requirements would apply if the temporary EPA were converted to a permanent EPA.

5.9.2 Provisional EPAs are areas created for a one-time use only and where it is not practical to set up a temporary EPA. Provisional EPAs are the responsibility of the Project's Chief Safety and Mission Assurance Officer (CSO) and are not certified by the ESD Program Manager.

5.9.3 The lack of certification and oversight associated with provisional EPAs makes them incompatible with applications that require handling items which require tighter controls and lower ESD voltage levels than the default HBM 1B (see Table 5-1).

5.9.4 Intermittent-Use of EPAs is defined as the use of a permanent EPA for periods lasting less than one month at a time, with longer periods of idle time. When not in use, intermittent-use EPAs are considered temporarily Out-of-Service and are marked as such. Following the idle period and prior to use, the ESD Program Monitor re-commissions the EPA using standard verification methods (see Appendix A). These EPAs are not required to be recertified by the ESD Control Program Manager as long as the idle period does not exceed six (6) months. During idle periods, the ESD Program Monitor ensures that intermittent-use HBM Class 0 EPAs are not used for any other purpose and they are kept clean.

## 5.10 ESD CONTROL PROGRAM

5.10.1 An effective ANSI/ESD S20.20-traceable ESD Control implementation plan requires internal procedures to accomplish the following:

- a. Verification that EPAs conform to the limits described in Table 7-1 prior to use.
- b. Use of protective personnel clothing and proper personnel grounding at all necessary points where ESDS items will be handled.
- c. All personnel handling ESDS items have received the necessary training to the appropriate working level (Operator, ESD Program Monitor or Level B Instructor) and have current certification.
- d. Performance of audits and inspections to ensure the integrity of the ESD protected areas and equipment in accordance with the requirements listed in Table 7-1. See paragraph 5.11.
- e. Inspection of documentation for ESD markings, precautions and handling procedures, as applicable.
- f. Proper identification of ESDS items. This can consist of labels, stamps, etc.
- g. Handling of ESDS items only at approved EPAs.
- h. Description of field operations and precautionary procedures, when applicable, to prevent ESD damage.
- i. Maintenance of auditable records and documentation for all measurements required in Table 7-1. When several projects share an ESD protected area, the original records are kept at the ESD protected area and copies are distributed to each project as needed.
- j. Use within EPAs only of materials recognized by the ESD Association as ESD-protective materials (i.e. the material complies with ESD Association-recommended practices). A record of each material should be kept with other records for ESD stations using it.

## 5.11 AUDITS AND INSPECTIONS

5.11.1 General: The ESD Program Monitor is responsible for the following activities related to records:

- a. Maintain records regarding the ESD protected area at the site.
- b. For creating the area test log (see B-2) and recording data related to deficiencies, corrective actions and related verification and validation.

5.11.2 Audits: EPA certifications are achieved through audits which are performed by the ESD Program Manager or on their behalf by an Audit Team or Audit Coordinator. Certification is based on yearly EPA audits. The ESD Program Monitor may perform a self-audit of an EPA and provide the data to the ESD Program Manager to meet this requirement.

5.11.3 Inspections/Verifications: Inspections are the responsibility of the EPA Program Monitors. The inspections consist of a general review of the area and records, as well as the verification described in Appendix A. These inspections may be carried out any time the ESD Program Monitor deems them necessary to ensure continuous compliance of the EPA to the ESD assigned safety level. As a minimum, it is recommended that inspections be done concurrently with the verification tests (see Table 7.1).



5.11.4 New Projects: If a new Project takes over the EPA and the old records are not available, the ESD Lab Monitor is responsible for performing a re-verification of the EPA in accordance with Appendix A and for attaching new stickers to the applicable workstations.

## **6 TRAINING AND CERTIFICATION PROGRAM**

### **6.1 GENERAL**

6.1.1 Training and certification is applicable to all personnel who perform or supervise any of the following ESD-related functions:

- Design.
- Production.
- Inspection and test.
- Procurement (only if handling, purchasing or specifying ESDS materials).
- Storage, shipping and receiving.

6.1.2 Handling, and/or Installation, maintenance and repair.

6.1.3 The ESD Control plan will document the prerequisites for personnel certification and will identify the certifying authority or authorities.

6.1.4 EPAs provide protection to sensitive items not only through the use of approved and verified equipment, furniture, fixtures, tools and materials, but also by limiting access to only trained and certified personnel. Therefore, certification audits of ESD protected areas (EPAs) include confirmation of the certification status of the personnel operating therein. Personnel are eligible for ESD Safety certification when they have successfully completed training or retraining (one or more training levels apply) and are determined by the certifying authority to be competent. Training is performed on a biennial basis (see 6.2). The certifying authority acts as the guarantor that certified individuals will correctly implement the organization's ESD Control plan. The evidence of ESD Safety certification, which is requested during an EPA audit, is provided by the certifying authority. The training organization will provide evidence of completion of training (and may call this evidence "certification of training"), however, a completion of training card or completion of training certificate is usually not a substitute for final certification because trainers typically do not have the ability or authority to vouch for the competency of individuals working on final hardware. Certification is more appropriately awarded by the operator's, program monitor's, or trainer's supervisor.

6.1.5 ESD training instructors are certified based on their competency as instructors and their knowledge of the ESD Control Plan they are teaching.

6.1.6 A "Train the trainer" system can be used where one or a few "Master" or "Level A" instructors train larger number of "Level B" trainers, who in turn train operators and program monitors. "Master" or "Level A" instructors are certified by the assignee who has overall responsibility for the organization's ESD Control program. Level B instructors may also be certified in the same way or may be certified by the Master or Level A instructor.

### **6.2 TRAINING PROGRAM**

6.2.1 The local ESD Control implementation plan requires the organization to define and document the following training requirements, rules, and procedures:

- a. Procedures for training.

- b. Training levels.
- c. Lesson plan(s)/student manuals.
- d. Special topics and local rules beyond the scope of ANSI/ESD S20.20.
- e. Hours of instruction.
- f. Procedures for recording of training, recertification and methods of identifying/recalling trained personnel.

6.2.2 The training shall include the following, as a minimum:

- a. ESD Control Program policies, procedures and practices.
- b. Principles of static electricity and methods of ESD control.
- c. Identification of ESD-sensitive (ESDS) items.
- d. Protective materials and equipment.
- e. Protected areas and workstations.
- f. Handling of ESDS items.
- g. Packaging, marking and shipping of ESDS items.
- h. Performance of ESD audits.
- i. Administration and record keeping.
- j. Class preparation, presentation and test administration.
- k. Demonstration of ability to teach a class.

6.2.3 Training programs will instruct students how to fully implement the local ESD Control plan. Therefore, use of outside or generic commercially available ANSI/ESD S20.20 training programs will not meet the ESD control plan's training requirements.

6.2.4 NASA Centers who are maintaining their own ANSI/ESD S20.20-traceable implementation plans also have associated ESD training programs. Civil servant personnel or personnel performing work in a NASA facility should contact their local ESD specialist for information about their local ESD Control implementation plan and availability of the required training.

6.2.5 Organizations who choose to model their ESD Control Plan after this handbook may use training available at the NASA Manufacturing Technology Transfer Center (NMTTC) Eastern Region (Ref: <http://workmanship.nasa.gov/index.jsp> . Select "Workmanship Training", then "GSFC School", then scroll down and select the class for GSFC-WM-001 ANSI/ESD S20.20.).

### **6.3 CERTIFICATION OF TRAINING LEVELS**

6.3.1 A four-level training program can be used to address training needs: Level A or Master Instructor, Level B Instructor, ESD program monitor, and operator. Level B instructors, ESD program monitors, and operators should be tested to ascertain comprehension of the material covered for each level. (See 6.1.4).

6.3.2 Instructor Level A: Level A instructors have the authority to train Level B instructors, ESD program monitors, and operators who work in ESD controlled areas.

6.3.3 Instructor Level B: Level B instructors have the authority to train ESD program monitors and operators who work in ESD controlled areas.

6.3.4 ESD program monitor: This training is for those who are directly responsible for compliance of ESD safe areas (EPAs) to the ESD Control plan. ESD program monitor training includes the scope described in 6.2.2.a. through 6.2.2.i above, with particular emphasis and detail provided on:

- a. Grounding and charge retention verification methods.
- b. Sources of electrical charge.
- c. EPA design.
- d. Compliant equipment, furniture, fixtures, tools and materials.
- e. Monitoring responsibilities and associated record-keeping.
- f. EPA certification process.

6.3.5 Operator Level: This training is for technical personnel performing work on or with ESDS items, such as assembly, soldering, conformal coating, cleaning, inspections, testing, packaging, and shipping. It is also intended for any other personnel dealing with ESDS items or administratively responsible for proper implementation of the ESD Control plan in EPAs under their jurisdiction. ESD operator training includes the scope described in 6.2.2.a. through 6.2.2.i above.

## **6.4 RECORD MAINTENANCE**

6.4.1 Records retention requirements apply to training records. A retention duration of 5 years minimum is recommended, however, Federal Acquisition Regulations and/or other Project-level requirements may specify longer retention periods. Training records include the following information:

- a. The applicable standard (ANSI/ESD S20.20) and ESD Control plan.
- b. Name of the trainee.
- c. Name of the organization which employs the trainee.
- d. Level of training completed.
- e. Date of completion of training.
- f. Name of the instructor and organization providing the training.
- g. Traceability number of the completion record or training certificate.
- h. Test score.

6.4.2 Evidence of the successful completion of training is provided to students for submission to the personnel certifying authority. A Certificate of Completion of Training is an example and is provided in Appendix C.

## **6.5 MAINTENANCE OF TRAINING AND CERTIFICATION**

6.5.1 Level B instructors, ESD program monitors, and operators will require periodic retraining and recertification under the following conditions:

- a. New ESD control techniques have been approved that require different skills.
- b. Two years have elapsed since last certification (biennial retraining schedule is recommended).
- c. Job performance indicates inadequate understanding of ESD controls.
- d. Evidence of successful completion of training (to the applicable standards, see 6.4.1.a) is not available to the certifying authority.

6.5.2 Evidence of successful training is valid for the certification process regardless of the employee's department within the larger organization. However, certification authorities are required to certify or recertify all personnel under their jurisdiction regardless of prior ESD certifications issued by other departments.

## **7 ESD CONTROL REQUIREMENTS FOR FACILITIES**

### **7.1 GENERAL**

7.1.1 This section pertains to EPAs, including facilities, equipment, tools and materials. The instructions and recommendations in this section include specific facility inspection methods used by ESD program monitors and ESD program managers in periodic verifications and certification audits.

7.1.2 The recommended default EPA certification level is HBM Class 1A. HBM Class 0 applies when handling parts sensitive to lower than 250 volts. Additional protective measures may also be required when protecting items to which the protection level HBM Class 0 applies.

7.1.3 Where an ESD protection level applies that is more restrictive than HBM Class 1A (i.e., protects more highly sensitive items), signage is used to clearly mark and communicate to personnel the boundaries and class level of the ESD protected area (EPA).

7.1.4 The measurements of Table 7-1 are performed as follows:

- a. Operators at the EPA perform tests numbers 5, 7, 8 (continuous), 11, and 13 as they apply to their area. For an example of the Test Log, see appendix D.
- b. The area ESD program monitor is responsible for verification of tests numbers 1, 2, 3, 4, 6, 8(annual), 9, 10, 11, and 12. See example of the ESD Protected Area Test Log, Appendix B2.
- c. The ESD program monitor for the area is responsible for ensuring that the logs are up to date.

### **7.2 COMPLIANCE**

The ESD program monitor is responsible for identifying non-conformances, for implementing corrective actions, and for ensuring that “unusable” areas and equipment are not used with ESDS items. A work bench or work area cannot be certified or treated as active until all non-conformances relative to Table 7-1 are corrected. This may involve repair or replacement of equipment and marking the equipment and/or space “unusable” in the interim. Use of a corrective action system to identify and track all non-conformances will ensure that all findings are addressed before the work area is used again for handling or processing ESD sensitive items. See Appendix C for an example of a Failed Area sign.

### **7.3 TRACEABILITY**

ESD program monitor verification records, especially those related to Table 7-1, are kept in the proximity of the associated EPA. These records pass between program monitors if benches or spaces transfer between departments or projects. The recommended record retention period is five (5) year minimum.

### **7.4 IDENTIFICATION AND ACCESS - ESD AREAS**

Clear demarcation of the presence and boundaries of EPAs, where ESDS items are to be processed, is achieved using prominently placed signs and a partition, rope guards, or similar barrier. The boundary defining method is intended to prevent unauthorized and untrained personnel from entering the EPA. Personnel who are not ESD-certified that must enter the EPA can do so with an ESD-certified escort (e.g., visitors or maintenance personnel).

**Table 7-1: ESD Control Program Verification Schedule and Measurements**

Test #	ITEM	Para. Ref.	Test Parameters	Verification Intervals				
				Continuous	Daily	Weekly	4	
							Monthly	Annual
1	<sup>2</sup> Work Surface Resistance	7.7.50	$< 10^9 \Omega$ Between two points 10" apart on the Work Surface and 2" from the edge in the commonly used area.				X	
2	Work Surface Grounding	7.7.6	$10^6$ to $10^9 \Omega$ from the center of the work surface to the equipment ground or $< 1$ ohm if a GFCI is used.				X	
3	<sup>1,2</sup> Protective Floor Resistance	7.8.2 7.8.3	$< 10^9 \Omega$ . After cleaning the floor shall be checked and the data recorded. See restrictions on paragraph 7.8.2 (This is a Class 0 requirement)				X	
4	<sup>1,2</sup> Protective Floor Grounding	7.8.2	$10^6$ to $10^9 \Omega$ from the floor surface to the equipment ground or $< 1$ ohm if a GFCI is used. (This is a Class 0 requirement)				X	
5	<sup>3</sup> Wrist Strap Check	7.9.2 7.10.4	Use approved Wrist Strap checker and log daily. The use of CMS is preferred.		X			
6	Wrist Strap Ground Point Resistance	7.9.2d.	$< 1$ ohm impedance from Groundable Point (Gp) to the Equipment Ground. ( $< 1.2 \times 10^6$ ohms if measured through a Continuous Monitoring System).				X	
7	<sup>3</sup> Foot Grounding Device Integrity	7.9.3 7.10.3	$< 35 \times 10^6 \Omega$ or use approved (calibrated) footwear checker & log each time you enter the area.		X			
8	<sup>2</sup> ESD Continuous Monitoring System	7.10.4	Verify functionality before handling ESDS items. Check alarm limits per Mfr. Instructions yearly.	X				X
9	<sup>2</sup> Stool / Chair Grounding.	7.11.2.a	$< 10^9$ ohms to the chair's groundable point. [For Class 0 Work only, verify monthly].				[X]	X
10	<sup>2</sup> Carts	7.11.3	$< 1$ ohm if tied directly to equipment ground. $< 10^9$ when grounded thru conductive flooring, referenced to CPG.					X
11	Humidity (RH)	7.11.4a.	30 to 70% RH continuous for work area. For Class 0 Work Area certification RH should be $> 40\%$ .	X				
12	<sup>2</sup> Ionizers	7.11.5a.	See Table 7-2 for test parameters.				X	
13	Soldering Iron Tip to Ground Resistance	7.12.5c.	Soldering Stations with self-contained checkers shall use them per schedule. Otherwise check to $< 20$ . Ohms and $< 2.0$ mVAC. <sup>[6]</sup>			X		

<sup>1</sup> Additionally, the Protective Floors resistance are checked and documented at least 2 hours after the floor has been cleaned but before the room is used. The area does not need to be checked after vacuuming.

<sup>2</sup> These items require proof of verification. (i.e. sticker or log entry)

<sup>3</sup> Automatic data loggers may be used for wrist strap and foot grounding daily checks.

<sup>4</sup> For workstations with sensitivities of HBM Class 1A ONLY, this interval may be done quarterly as a minimum.

## **7.5 TEMPORARY USE OF ESD BENCHES FOR NON-ESDS WORK**

7.5.1 The ESD program monitor is responsible for ensuring that non-ESDS work performed at EPAs does not cause ESD Control plan non-conformances or lead to damage to ESDS items. The following recommendations apply:

- a. Permission from the cognizant ESD program monitor is obtained before work is started.
- b. The ESD program monitor clearly marks the affected area as a “Non-ESD Protected Area” during the period it is used for non-ESDS work. (See Appendix C2)
- c. The ESD program monitor verifies the ESD protected area before ESDS items are again handled in that area.

7.5.2 ESD workstations designated as Class 0 or higher sensitivity are never used for Non-ESDS work. If any of these areas are used for non-allowed material handling, recertification by the ESD program manager is necessary.

## **7.6 PROHIBITED MATERIALS AND ACTIVITIES**

7.6.1 The following housekeeping practices are critical for continuous EPA compliance:

- a. Smoking, eating and drinking in EPAs is not allowed.
- b. Materials unessential to the work being done in the EPA are not allowed.
- c. Clipboards, books, notebooks, loose sheets of paper, etc., used to read or record data or follow instructions (this manual included), are kept at least 1 meter (3.3 ft.) from ESDS items or placed in ESD-safe bags or totes. Materials specifically made and verified to be safe in an ESD area are exempt from this requirement.
- d. Floors or mats are kept free of dust, dirt and other contaminants.

7.6.2 A 1-meter minimum separation is recommended between the location where ESDS items are handled and “tacky mats” which are used at the entrance to Clean rooms, CRT displays, and other equipment, and which generate a static charge.

7.6.3 The risk of damaging an item by an ESD event is heightened when the item is left exposed and/or unattended at a workstation or elsewhere. This risk is mitigated by placing ESDS items on an ESD protective surface and wrapping or covering them with static shielding material when they must be left unattended for short periods of time, such as a lunch break.



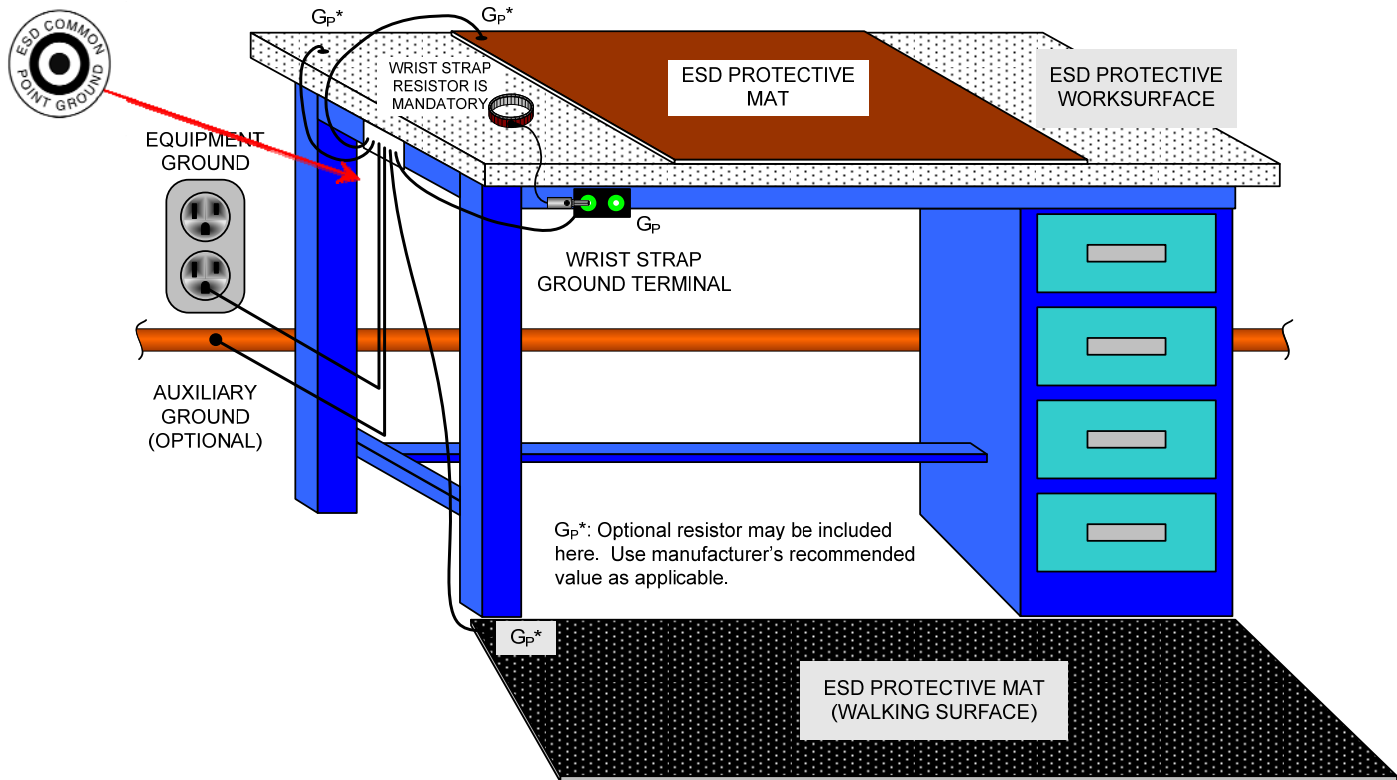


Figure 7-1: Typical ESD Grounded Workstations

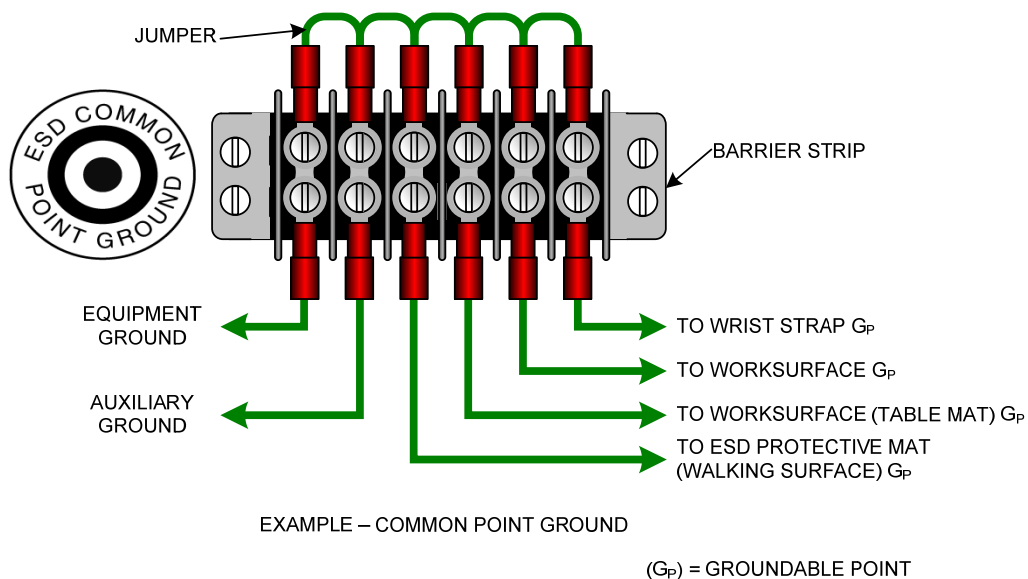


Figure 7-2: Workstation Common Point Ground

## 7.7 ESD-PROTECTIVE WORK SURFACES

7.7.1 The recommended default for the conductivity level for all work surfaces in an ESD-protected area is static dissipative ( $>10^5$  to  $<10^9 \Omega$  for surface resistance). Some work in EPAs requires conductive surfaces ( $<10^5 \Omega$ ) (e.g., optical benches).

7.7.2 ESD-safe surfaces shall be electrically connected to the Common Point Ground. The common point ground may be a terminal strip, bus bar, or any other convenient configuration that is, within itself, electrically continuous to no greater than 1 ohm measured from point to point with an ohmmeter [7].

7.7.3 When conductive surfaces are used, a one megohm (1 M $\Omega$ ) optional resistor may be needed to provide a soft ground between the work surface and the common point ground. See Figure 7-1 above.

7.7.4 **Extreme care is required when using conductive work surfaces.** To eliminate the safety hazard associated a high current event that results from touching a high voltage circuit with one hand and a hard ground with the other hand, work surfaces must either be soft grounded by installing a resistor in series with the ground (> 800 k $\Omega$ ) or a Ground Fault Circuit Interrupter (GFCI) must be used (GFCI, disconnects the circuit when an unsafe current event is detected, usually  $\approx$  5 ma). The use of the 1 megohm (1 M $\Omega$   $\pm$ 20%) optional resistors in Fig. 7-1 is acceptable in lieu of the GFCI. Conductive work surfaces also generate a CDM hazard for very sensitive devices.

7.7.5 Selection of the protective work surface will ensure that:

- a. It does not release particle contaminants.
- b. It will resist attack by common solvents or cleaners (see Section 7.15.1).
- c. It is sufficiently large to accommodate the resting of common hand tools on the protective surface rather than on adjacent non-protected surfaces.

7.7.6 Soft grounding of dissipative work surfaces shall measure < 10<sup>9</sup> ohms [9]. When highly conductive work surfaces (e.g., stainless steel or copper) are used, and they need to be connected directly to the equipment or auxiliary ground without the optional resistor (see Figure 7-1), GFCIs shall be used in the ESD-protected workstation. [10] Type "A" GFCIs are preferred. GFCIs shall be tested at least once a month using their self-test feature (see Appendix A, paragraph A5.2.2.b). The GFCI manufacturer's web site usually has a preferred/recommended method to check their particular model.

## 7.8 ESD-PROTECTIVE FLOOR SURFACES

7.8.1 Conductive or dissipative floors and/or grounded conductive/dissipative floor mats are used in EPAs where personnel are not wearing wrist straps. To provide the intended ESD protection under these conditions, the use of leg straps, heel straps or conductive shoes is required (see 7.9.4). Conductive/dissipative flooring combined with ESD chairs are strongly recommended in HBM Class 0 EPAs to provide equipotential ground.

7.8.2 ESD protective flooring is not affective if it is not grounded. It may be connected directly to equipment or auxiliary ground without the optional resistor (see Figure 7-1). For testing purposes, the dissipative floor-to-system ground resistance target is < 10<sup>9</sup> ohms. [9] ESD TR20.20-2008 [11] recommends 10<sup>6</sup> to 10<sup>9</sup> ohms for floor resistance for safety reasons. On highly conductive floors the option to include the resistor (see Fig 7-1) or use GFCI if available. Measure the floor resistance between the equipment ground and a point on the floor at least 12 inches away from the floor-to-ground connection.

7.8.3 After each cleaning, floor resistance is verified per paragraph 7.8.2 above and the results are recorded. Vacuuming or dry sweeping the floor does not require a subsequent check.

7.8.4 Proper use of conductive waxes requires compliance with manufacturer recommendations. Floor resistance is always verified after application and the results are recorded.

NOTE: Some conductive waxes may be a source of contaminating volatiles. Make sure the type used has been approved for use around flight hardware.

7.8.5 A conductive wax on non-conductive floors is not considered an effective method of ESD control.

7.8.6 At this time, no carpeting, including products advertised as "conductive" or "static-eliminating," is considered suitable for use in an EPA.

## 7.9 PERSONAL GROUNDING DEVICES

7.9.1 ESD Control plans will include specific policies for issuance and use of Personal Grounding Devices. It is recommended that, as a minimum, the plan require that all personnel working with or handling ESDS items are issued and use Personal Grounding Devices to prevent the accumulation of dangerous electrostatic charge levels. **It is strongly recommended that all personnel coming within 1 meter (3.3 feet) of any ESDS item be required to wear a personal grounding device.**

7.9.2 Wrist Strap: The wrist strap is the preferred means for ESD protection. It is the "first line of defense." See 7.10.2. for recommendations on checking wrist straps. The wrist strap system consists of four major components:

- a. Lead: Only the lead supplied with the wrist strap should be used, as it may contain the safety resistor.
- b. Cuff: The design of the wrist strap cuff ensures conductive contact with the wearer's skin. Metallic cuffs are preferred over plastic or fabric cuffs. Bead type chains are not effective and are normally prohibited. ESD S1.1. dictates that the wrist strap shall have a cuff connector, which breaks away with a force between 1 and 5 pounds. This property is verified as part of incoming inspection of at least the first delivery lot, for each type of wrist strap used.
- c. Safety Resistor: All wrist strap systems are expected to contain an integral current-limiting safety resistor (1 megohm  $\pm$  20%). This resistor may be an integral part of the lead (see 7.9.3.a).
- d. Ground Termination: The wrist strap ground termination must ensure a positive and durable connection between the lead and the Common Point Ground (CPG). The resistance between CPG and the equipment ground, for testing purposes, shall be  $<1.0$  ohm.<sup>[7]</sup> For wrist straps ground, protected through a CMS, the value shall be  $<3.5 \times 10^7$  ohms.<sup>[9]</sup>

7.9.3 Foot Grounding: Foot grounding devices such as leg, toe or heel straps, or conductive shoes worn in conjunction with a conductive floor and/or conductive floor mats, are acceptable alternatives to a wrist strap in those situations where the operator needs to be mobile and the use of a wrist strap is impractical or unsafe. When used, foot grounding devices are worn on both feet and are not to be worn outside the ESD protected area. The total resistance of these devices shall be  $< 3.5 \times 10^7$  ohms.<sup>[9]</sup> When employing foot grounding devices, it is the responsibility of the ESD program monitor to set up a footwear checker and log to monitor the continued performance of the personal grounding device system.

*NOTE: Foot grounding devices which are not kept clean will have reduced effectiveness from contaminants inhibiting their conductive interface with the floor.*

## 7.10 INTEGRITY TESTING OF PERSONAL GROUNDING DEVICES

7.10.1 The integrity of the connection between the operator, the personal grounding device, and the ground connection is critical to proper ESD protection. Periodic, scheduled verification of personal grounding device performance will identify non-compliant units. Typically, damaged or worn units are not repairable and must be replaced.

7.10.2 Wrist straps are expected to be either continuously monitored or checked each time the wearer enters the ESD protected area using an approved wrist strap tester. The first daily check should be logged. Logging wrist strap checks is not needed for EPAs that use Continuous Monitoring Systems (CMS). If a CMS is used at a workstation, it is recommended that all wrist strap connection points be enabled through the CMS. Exceptions should be made for instances where the voltage-sensing from the CMS may damage very sensitive components.

7.10.3 Foot grounding devices are checked and logged each time the wearer enters the ESD protected area. Foot grounding devices are worn on both feet and are checked one foot at a time.

7.10.4 Workstation Real Time Continuous Monitoring Devices are checked to ensure functionality just before handling ESDS items. (The monitor's alarm should sound and the appropriate red light should light when the lead is temporarily removed from the cuff. Paragraph A5.2.6, Table 7-1 recommends a yearly verification of the trip limits.)

7.10.5 If one of the checks in 7.10.2 through 7.10.4 fails, corrective action is taken before work is performed and a subsequent re-check is used before work resumes. Appropriate corrective actions include:

- a. Replace cord.
- b. Replace complete system.
- c. Use a conductive lotion designed for use with ESD wrist straps (if acceptable in the area of use).
- d. Wrist band cleaning.

7.10.6 If it is found that an ESDS item was handled in an EPA with faulty ESD protection (e.g., wrist straps, grounding, etc.), that item will carry a risk lien that must be retired by the affected Project. The failure of the ESD protection is recorded by the ESD program monitor.

## 7.11 EQUIPMENT AND FACILITIES

7.11.1 Facilities Grounding: The preferred practice is to use the third wire AC line ground for grounding all items at the ESD protected area (EPA). When a separate grounding line is present or used in addition to the equipment ground, it should be electrically bonded to the equipment ground at each ESD protected work station to minimize the difference in potential.<sup>[7]</sup> The resistance of the conductor from the Common Point Ground to the equipment ground (AC ground) should be less than 1 ohm. The impedance from the area Common Point Ground to the neutral bond at the main service box should be less than 2 ohms. See Figure 7-2. Daisy chaining is not permitted.

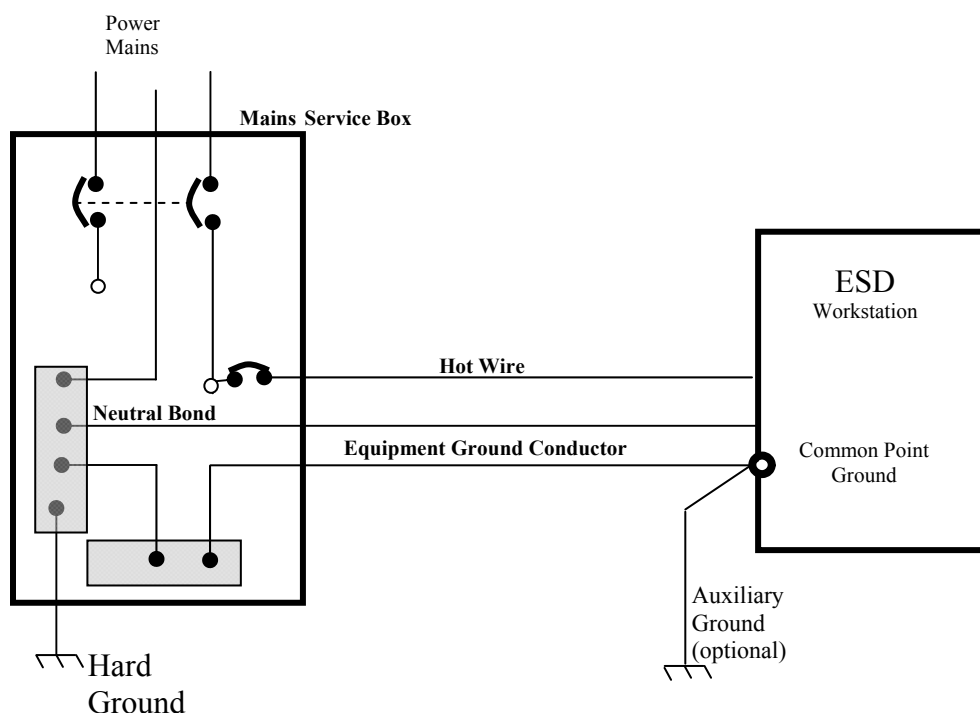


Figure 7-3: Main Service Box

### 7.11.2 Stool, Chairs and Carts

a. The ESD program monitor is responsible for the certification and proper use of stools, chairs and carts in EPAs. Marking certified chairs, stools, and carts with identifying stickers facilitates their proper use and certification maintenance. Local ESD Safety procedures will address EPA-specific uses of chairs, stools and carts relative to the employed grounding scheme.

Note: Carts do not usually carry a certifying sticker but they should be groundable to carry ESDS equipment. Also see paragraph 7.11.3 Mobile Equipment Carts.

b. Certification: The recommended verification levels and verification intervals for chairs and stools are shown in Table 7-1. The resistance shown in Table 7-1 applies to measurements between any part of the chair and a groundable point. The resistance for any part of the chair to a groundable point shall be  $< 10^9$  ohms<sup>[9]</sup>.

c. Grounding: For handling Class 0 sensitive items a positive electrical contact between the Common Point Ground and the chair or stool is recommended. This contact may be achieved through an ESD protective floor or ESD protective floor mat.

### 7.11.3 Mobile Equipment Carts

a. Where carts, wagons, trams, or other mobile equipment are used, they are required to be grounded while in use in the EPA. When conductive floors are being utilized, it is recommended that positive electrical contact be made between the floor and conductive structure of the mobile equipment. The required resistance used for verification from the equipment to the Common Point Ground is shown in Table 7-1.<sup>[9]</sup> If the floor is non-conductive, the vehicle will have to be grounded before ESDS items are loaded or removed from the vehicle. The use of protective packaging applies (ESD approved

wrap material, totes, etc.) when moving ESDS items for transport away from the EPA, even if a certified-safe cart is employed.

b. Other Mobile Equipment: When other tabletop equipment such as microscopes or lead bending equipment is used within an EPA, it should be ESD grounded. Note that such equipment may have a large capacitance and present a hazard to components susceptible CDM type pulses. To avoid damage, the equipment and the component must be at the same potential before they contact each other. This can be done by using dissipative materials to make first contact to both the component and the equipment.

#### 7.11.4 Humidity

a. The relative humidity (RH) target range for ESD-protected areas (EPAs) is 30% to 70% when monitored near the ESDS item (40% to 70% for Class 0). At levels below 30%, ESD risk increases, requiring the use of additional precautions, such as turning on a humidifier to achieve the required humidity or using an air ionizer (See paragraph 7.11.6a). If additional precautionary methods are not available (e.g., the use of an ionizer), it be recommended that work is halted until the required humidity level is obtained (See paragraph 7.3 on records retention).

b. A check of the RH level in each EPA is performed at the start of the workday and the result is logged. Continuous compliance is verified with periodic observations and recording of the results. If the RH level is close to 30% or is seen to be dropping rapidly, extra vigilance is recommended. Data loggers with an integral alarm system are suitable substitutes for the daily check.

c. Maximum RH depends on the equipment and device under test (DUT) to be protected as condensation due to temperature variations can cause corrosion, short circuits or moisture contamination.

d. Sealed ESD bags which have been stored in “dry boxes” or may have desiccant gel bags to prevent high humidity problems are easily charged when rubbed against the ESD protective bag. Care should be taken when removing ESDS items from them to prevent ESD events from triboelectric charging.

NOTE: Surface resistivity changes exponentially with humidity changes.

#### 7.11.5 Air Ionizers

a. Air ionization is a technique used to neutralize charges on insulators and ungrounded conductors. Air Ionizers are considered necessary when handling Class 0 sensitive parts or when the relative humidity falls below 30% in the work area. See Table 7-2.

b. Air ionizers are designed to work where unrestricted airflow exists between the ionizer and the ESDS item. Their design also requires sufficient distance between the ionizer and the ESDS items to ensure proper ion balance in that airflow. Consult the ionizer manufacturer’s documentation for detailed ionizer operating instructions.

c. Careful selection of the ionizer is needed in order to realize the benefits of ionizers in the EPA and may be application dependent. Ionizers require routine maintenance and testing in accordance with manufacturer’s recommendations to ensure acceptable continued performance.

d. The presence of ionized air creates an increased risk for corona discharge in the presence of “powered-up” high-voltage or RF-sensitive equipment, therefore, the use of ionizers is not recommended in those environments. To avoid fire hazards from corona discharge, keep flammable materials away from air ionizers.

e. Electrostatic survey meters in conjunction with a charging plate may be used to verify the effectiveness of ionizers in extremely sensitive work areas (e.g., Class 0, Class M1) before work is started. It is important that the meter used has sufficient resolution and time response to detect values beyond the minimum performance limits required. To avoid meter saturation or generating false data, the meter should be slowly moved into the area being measured while watching for readings close to the limits of the meter.

f. Though the use of ionizers is recommended for Class 0 EPAs, it is important that the ESD program monitor ensure that the ionizer is not the source of unacceptable charge deposition into the ESDS items. In these cases, the ESD program monitor will ensure in advance that the ionizer peak balance potential is less than one half the susceptibility of the most sensitive part ( $\leq 50\%$  of item sensitivity level) (See 5.3.2).

*CAUTION: An improperly adjusted air ionizer can actually charge ESDS devices and lead to possible damage to the device. Only use calibrated air ionization systems.*

**Table 7-2: ESD Sensitivity for Selection and Performance of Air Ionizers**

Class	ESD Sensitivity	Air Ionization	Discharge time	Float Potential
1A +	$\geq 250$ volts	Optional	$\pm 1000$ to $< \pm 100$ V in $< 45$ sec.	$< \pm 100$ V
0 <sup>1</sup>	$> 100$ V to $< 250$ V	Required	$\pm 1000$ to $< \pm 50$ V in $< 20$ sec.	$< \pm 50$ V
0 <sup>2</sup>	$\leq 100$ V	Required	$\pm 1000$ to $< \pm 20$ V in $< 20$ sec.	See below 2
M1 <sup>3</sup>	$< 100$ volts	Required	$\pm 1000$ to $< \pm 20$ V in $< 20$ sec.	$< \pm 20$ V

<sup>1</sup> Class 0 covers all HBM  $< 250$  V but it is not sensitive enough to protect some newer parts.

<sup>2</sup> Class 0 with sensitivities at or below 100 V the ionizer peak balance potential shall be less than one half the susceptibility of the most sensitive part in the assembly.

<sup>3</sup> This level is intended for use with automatic equipment therefore it uses MM vs. HBM

## 7.12 HAND TOOLS, EQUIPMENT, AND FIXTURES

7.12.1 The ESD program monitor is responsible for approving the use of all tools in the EPA.

7.12.2 Tools designed for ESD areas, such as static dissipative cushioned tools or un-insulated metal hand tools such as pliers, cutters, tweezers and wire strippers, are preferred in ESD-protected areas.

7.12.3 Hand tools should be kept on the grounded work surface when not in use.

7.12.4 It is recommended that only antistatic solder extractors made of metal, or having a metalized plastic barrel and tip, be used in an ESD-protected area (EPA).

7.12.5 The following criteria are recommended for electrical tools used in EPAs:

- a. They employ a three-wire grounded power cord.
- b. They have static dissipative handle grips.
- c. That the tool's contact point (e.g., soldering iron tip) which touches the work piece has a resistance of less than 20 ohms ( $< 1 \Omega$  when new)<sup>[6]</sup> and the potential difference does not exceed 2 millivolts



RMS using methods indicated in the supplier's process documentation. See Appendix A, paragraph A5.2.10.

d. Motor driven tools are not recommended for use near ESDS items due to inductive charging in the ESDS devices.

*Caution: GFCI systems can indicate a faulty soldering station but do not prevent damage to hardware from damaged soldering tips. Soldering stations are easily moved to the workbench however their records are not usually kept by lab monitors and the tips cannot be easily identified as verified ESD-safe.*

7.12.6 Digital Multimeters (DMMs) may introduce voltage spikes when changing scales and/or have high voltages when measuring resistance. Make sure that the measuring equipment is compatible with the hardware being measured.

7.12.7 Fixtures used while working at an ESD protected area must be ESD safe and ground bonded to the Common Ground Point.

7.12.8 Measuring equipment, breakout boxes, harnesses, etc. must be properly discharged (grounded) before making connection to flight hardware. Consult with the designer to ensure that work instructions clearly document hardware limitations and procedural considerations relative to the equipment normally used in the laboratory.

Note: During testing of the Astro-E satellite, several J-FETs were damaged due to discharging of the DMM leads while touching a charged breakout box.

## 7.13 PROTECTIVE PACKAGING

7.13.1 Electrostatic protective packaging must prevent charge generation (e.g., triboelectric contact and separation) and protect from external electrostatic fields. Static dissipative materials used in packaging are considered to provide both properties. Static dissipative materials in intimate contact with devices shall have a surface resistance of  $\geq 10^4$  &  $< 10^{11}$  ohms<sup>[12]</sup>.

7.13.2 Protective bags and packaging are considered ESD protective based on the following application methods:

a. Materials used in protective bags and pouches shall satisfy the resistance requirements to avoid triboelectric charge buildup.<sup>[12]</sup>

b. Acceptable bags and pouches used for electrostatic shielding are constructed from a single folded piece of material. Two-piece construction is not considered ESD-safe. If bags or pouches are not transparent, allowing identification of contents without removal, a label stating contents shall be placed on the outside of the bag or pouch.

c. Materials in contact with the protected hardware shall have a dissipative surface.

d. Neither static dissipative impregnated nor topically treated plastics provide electrostatic shielding. Both types need to be enclosed in an outer container which will provide shielding to the contents during shipping. For acceptable electric field shielding, the package must be electrically conductive with a surface resistance of  $< 10^4$  ohms.

7.13.3 Compliant shipping packaging for all integrated circuits used by NASA is non-metallic conductive or static dissipative magazines, chutes and dip tubes. It is recommended that integrated circuits that are shipped in non-compliant packaging should not be used in flight hardware.



7.13.4 ESD-safe tote boxes shall be made of conductive or static dissipative material. Compliant tote boxes shall be fitted with covers of the same conductivity as the bottom sections that fit tightly enough to ensure conductivity across this interface.

## **7.14 TEMPERATURE CHAMBERS AND COOLING AGENTS**

7.14.1 ESD program monitors are responsible for taking appropriate precautions when gas flow is utilized in the area of ESDS items. Particles in the gas flow can be a significant generator of electrostatic charges.

7.14.2 To ensure the safety of ESDS items in cold chambers, conductive baffles and shelves within the chamber must be grounded. ESDS items contained within those chambers must have a path to ground by mounting them or placing them on conductive material (preferably a dissipative surface) which is in contact with the grounded shelves.

7.14.3 ESD program monitors are responsible for taking appropriate ESD precautions when pressurized cryogenic cooling agents are used for localized cooling, such as in troubleshooting. "Mist Freeze" has proven to be a very good ESD generator.

7.14.4 The stability of ESD-protective materials which are used in temperature chambers must be suitable for the test temperature and humidity ranges present in those chambers to ensure the test and measurements are properly achieved, to prevent damage to the equipment, and to prevent contamination of the chamber.

7.14.5 Resistance checks should be sufficient for normal test chamber environments. For extremely sensitive parts, the use of electrostatic survey meters may be required (see paragraph 7.16.2). Survey meters can provide information on stray fields harmful to the hardware being tested. Consult the meter manufacturer's documentation for additional cautions.

## **7.15 CLEANING AND CLEANING AGENTS**

7.15.1 Cleaning agents and methods used on ESD-protective items (e.g., work surfaces and floor coverings) should be selected and applied so that they do not reduce the effectiveness of these items, cause leaching, or leave insulating residues.

7.15.2 In addition to other required properties (e.g., solvency), cleaning agents used directly on ESDS items should be selected for low electrostatic charging propensity and must be approved for use in flight hardware.

7.15.3 Only natural bristle or static dissipative brush materials are considered safe for use on ESDS items.

## **7.16 ELECTROSTATIC SURVEY METERS, VOLTMETERS, AND MONITORS**

7.16.1 Electrostatic survey meters are used to detect the presence of electrostatic charges. The types which read the electrostatic charge on a surface area without requiring contact should be used in NASA EPAs. These instruments should be capable of measuring the voltage on a sample not more than 8 inches in diameter with a minimum resolution of 100 volts and a range of at least 1 kilovolt (kV). For areas handling highly sensitive parts, other methods may be needed. Always follow the manufacturer's recommendations.

7.16.2 Use of electrostatic monitors designed to actuate an alarm when an electrostatic field reaches a preset level is recommended in an EPA handling ultra sensitive hardware. It should be noted that

these monitors are very sensitive and require a lot of trial-and-error to properly position them to avoid false alarms.

7.16.3 Wrist strap testers and recording logs must be made available in all areas where ESDS items are handled, unless the ESD protective area exclusively uses a Continuous Monitoring System.

## 7.17 CLOTHING REQUIREMENTS

7.17.1 Static dissipative outer garments (smocks) must be worn at all times when in EPAs. A compliant smock will cover all personal garments above the wrist except at the neck area and make intimate contact with the skin. Smocks must be fully zipped/buttoned all the time they are worn.

7.17.2 The garments must be properly checked after laundering. This requirement may be met by using an approved cleaning facility for ESD garments which provide this service.

7.17.3 When handling ESD Class 0 sensitive parts, the ESD smock must be connected to the common point ground or wrist strap lead. Otherwise, it becomes an isolated ungrounded conductor. Some garments have the provision for attachment to the wrist strap coil cord snap. Some configurations also allow for continuous monitoring.

7.17.4 When cuff-to-cuff resistance of the garment is  $< 3.5 \times 10^7 \Omega$ , the garment can be grounded using a single wire wrist strap cord<sup>[13]</sup>. This arrangement, when used with the corresponding continuous monitor device meets the requirements of section 7.9 and can be used in lieu of the wrist strap or foot grounding systems. This setup does not work with the dual wire Continuous Monitoring Systems.

7.17.5 For less sensitive areas (Class 1A and above), smocks may be used over cotton shirts or short-sleeved shirts without the extra ground connection. This configuration permits slow static dissipation of the charge acquired by the garment (wrist straps shall be worn<sup>[9]</sup>).

7.17.6 ESD program monitors are responsible for ensuring that finger cots and gloves, when worn in an ESD-protected area, are made of static dissipative materials.

## 7.18 ORBIT REPLACEABLE UNITS (ORU) REQUIREMENTS<sup>[16]</sup>

7.18.1 An electronic assembly manufactured with a conductive outer enclosure is expected to be ESD sensitive only through exposed connector pins. If conductive or static dissipative caps cover the connectors, the box forms a Faraday cage around the internal ESDS components. A charge on the box should not cause damage to the internal components as long as the Faraday cage is intact and the charge is removed prior to mating any connectors. All ORUs installed in their normal flight configuration, with all connectors mated and/or covered, whether in a launch vehicle or in a test configuration simulating flight conditions, are not considered ESDS unless analysis or testing has shown otherwise.

7.18.2 ESD precautions are implemented just prior to the connector or connector caps being removed. Exposed connector pins can be touched or tested only after the operator and the box are at the same ground potential (equipotentially bonded ground).

7.18.3 Interconnecting Cables: Tests conducted on cables have shown that a charge of several hundred volts can be generated on the conductor of a cable as the cable is flexed, unwrapped, and handled in a similar manner as would occur during cable installation in a vehicle. This charge, which is generated by the triboelectric effects of the wire and its insulation, can potentially damage sensitive devices that would ultimately be connected to the cable.

- a. Prior to the initial mating of newly installed cables, the connector pins and cable shield are grounded to discharge any electrostatic potential. An existing cable that is connected to another ORU does not require shorting prior to mating.
- b. When installing test equipment to flight hardware, the cables are to be installed to the non-flight equipment prior to the flight equipment.

7.18.4 Operator Grounding During ORU Installation: As noted in the previous paragraph, an ORU with protective connector caps is not considered ESDS, but it is highly recommended that personnel be grounded throughout the installation or removal process. The use of a wrist strap in a spacecraft shall be regulated by the need to protect metal surfaces from scratches caused by alligator clips on soft metals and the need to preclude conductive debris generated by the teeth of the clips. In addition, the working space may be too constrained to wear a wrist strap. In these cases, the operator will use some other means to equipotentially bond (ground) themselves with the ORU and connector prior to mating and de-mating.

7.18.5 Procedures for ESD-safe handling of ORUs will include the follow practices:

- a. Upon arrival at the equipment rack with the ORU, the mobile cart is to be tied to ground. If the ORU cannot be grounded through connection to the grounded cart, it is acceptable to momentarily ground the ORU by touching it with one hand and touching a grounded conductive surface with the other hand.
- b. Conductive or dissipative covers and those covers are to be installed securely in place.
- c. Prior to moving the ORU from the cart, all personnel will momentarily ground themselves by touching a grounded object.
- d. The ORU may be moved to the equipment rack without the use of a grounded wrist strap, however, a wrist strap or other grounding method must be used by the technician/operator prior to removing any connector covers.
- e. The procedure for removing an ORU from the equipment rack is the reverse of items a-d above. A grounded wrist strap shall be worn prior to removing a connector from the rack and reinstalling the connector cover.
- f. When removing a connector from a non-ESDS ORU that is directly wired to a known ESDS ORU, the technician shall comply with the requirements of section 7.18.3 of this manual.
- g. When a patch-panel/breakout box has been installed into the wiring harness of an ESDS ORU, all operations performed using the breakout box require the operator to be grounded and a sign to be placed at the worksite warning of the ESD damage concern.

7.18.6 Determination of an ORU's ESD Sensitivity: For all new flight hardware designs, it is the responsibility of the hardware design activity to determine if an assembly is ESDS. The hardware shall be properly marked and documented as to the HBM sensitivity Class (0, 1A, 1B, etc.) or non-ESDS and the proper procedures for handling and packing shall be provided. All ORUs with an unknown ESD sensitivity shall be handled as HBM Class 1A. Note that the requirements above imply ESD susceptibilities of above 1 kV and below (HBM 1C).

7.18.7 Hardware handled by the crew during flight should not be ESDS. It is highly recommended that even for a flight item known to be ESD immune, these items are transported in ESDS packaging. Static generating materials are a hazard if they come in close proximity to ESDS hardware.

## **8 ESDS ITEM HANDLING**

### **8.1 GENERAL**

8.1.1 ESDS items must be handled only in ESD protected areas (EPAs). When outside of EPAs, ESDS items must be completely enclosed inside ESD-protective packaging in a ESD protective container (Tote or box).

8.1.2 Paperwork accompanying an ESDS item (e.g., QA records, routings, and instructions) must be contained in static dissipative bags or envelopes. This paperwork must never come in physical contact with an ESDS item. Materials specifically made and verified to be safe in an EPA are exempt from this requirement.

8.1.3 Shunts, such as bars, clips, or conductive coverings, are used to protect an ESDS item when it is not being tested or worked on. However an ESD event may occur if extreme care is not exercised to ensure that both items are at the same potential when attaching any conductive material to an ESDS device. Process-essential insulators (e.g., Kapton tape) must be neutralized with an ionizer before they are moved within 12 inches of ESDS items.

8.1.4 All containers, tools, test equipment, and fixtures used in ESD protected areas must be grounded before and during use. Before connecting or disconnecting test cables, a common soft ground between an ESDS item and any test equipment is to be established.

8.1.5 While in the vicinity of ESDS items, personnel handling ESDS items must avoid physical activities that produce static charges (e.g., wiping feet, or adding or removing items of clothing).

### **8.2 SPECIAL REQUIREMENTS FOR HIGHLY SENSITIVE ITEMS**

8.2.1 Table 8-1 summarizes the recommendations made throughout this document which are particular to HBM Class 0 and MM Class M1 only. For higher sensitivity levels, for devices sensitive to CDM events, or for other special cases, the Project engineers should partner with the ESD Program Manager to determine suitable ESD Control Program requirements.

8.2.2 When assembling parts sensitive to low voltage and low energy pulses, the measures prescribed for HBM and MM models do not provide sufficient component protection. This section provides guidance for handling components sensitive to breakdown voltages as low as 2 volts and energies as low as 0.3  $\mu$ J. Electromagnetic interference (EMI) signals can inductively charge components with these low level sensitivities and put them at risk from an ESD event that is so rapid that it evades HBM and MM safety methods. Parts in this category include detectors, some high-frequency low-voltage differential signal (LVDS) transceivers, low noise amplifiers (LNAs), Noise diodes, and integrated circuit radio frequency (IC RF) switches.

#### **a. Equipment**

- (i) All ports in the flight hardware should use shorting plugs/ESD caps when not in use, including when inside their ESD bags. RF ports may use a metal dust cap to form a faraday cage.
- (ii) Operators should use ESD finger cots instead of ESD gloves.

**Table 8-1: Summary of Recommendations Applicable to HBM Class 0 and MM Class M1**

Topic	Recommendation
Chairs & stools	Ground and periodically verify as ESD protective. See Table 7-1 for intervals
Conductive or dissipative floors or floor mats	Use them in the area in front of the protected area or in the designated EPA floor space
Relative Humidity	Kept over 40%, monitor and record just before work is started. Additional precautions must be used to operate below 40% RH.
Ionizers	Keep them in place and working properly. See Table 7-2. It is recommended that an ESD survey meter be used to check the area before work is begun.
Smocks	Must be grounded to the Common Point Ground or through the wrist strap. However, the CMS, if used, must not interfere with grounding of the smock or vice versa.
Mating and De-mating cables and harnesses	Must be discharged to ground through an approved method prior to mating and de-mating to ESD sensitive assemblies
Soldering irons	Check for proper ESD operation before start of operation.
Signage	Display them, describing the Class sensitivity level for the area

(iii) The DUT should be placed on metal which in turn is placed on a certified ESD workbench. This plate should be permanently grounded to the power supply in the test setup using a separate ground braid and connected in the same fashion as the chassis connection called out in the test procedure setup.

*Caution: This step may compromise components with low voltage CDM sensitivity. For CDM protection below 100V one should avoid metal-to-metal contact.*

(iv) ESD garments should have conductive elastic cuffs or have means by which they can be grounded.

(v) Avoid highly triboelectric materials under the ESD garment (e.g., silk, wool). Cotton or cotton blends are recommended.

(vi) Continue to use wrist straps per the current requirements.

(vii) If a Continuous Monitoring System (CMS) is used, the sensing voltage of the system is to be lower than the most sensitive component to be handled. If CMS cannot be used, the operator/garment combination needs to be checked and recorded at least once a day. The operator should check himself every time he/she enters the area.

(viii) A voltmeter check of all powered equipment grounding (including soldering irons, power supplies, spectrum analyzers, etc.) is to be performed before removing the shorting plugs and making contact with the DUT.

(ix) Cleaning procedures around sensitive parts should be performed using ethyl or isopropyl alcohol and a small horsehair brush (not Q-tips). Hot air guns are not to be used.

#### b. Handling and Operational Procedures

(i) An ESD checklist should be created as part of the production traveler which includes a relative humidity check (40-60%RH), possible EMI sources, static survey, and ionizer "sweet spot" as a

minimum. This checklist should be filled out before the start of each operation and when the physical configuration of the test area is changed.

- (ii) No pagers, cell phones, or RF transmission devices can be powered ON in the room/area. Setting devices to “vibrate” does not eliminate the inductive charging risk from the EMI source originating from the wireless device.
- (iii) The test setup is to be completed before the flight hardware is taken out of the ESD bag.
- (iv) The ionizer is to be run during the operation and the sensitive device(s) need to be within the “sweet spot” of the ionizer. It should be noted that some nearby electrostatic generators may change the “sweet spot” of the ionizer.
- (v) Test equipment with cathode ray tubes (CRTs) are to be turned on before the DUT is taken out of the ESD bag and kept as far as practical away from the DUT.
- (vi) Once the setup is completed, the DUT is to be removed from the ESD bag, the grounds are to be equalized by touching with finger cots both the DUT and metal plate and then the DUT is to be placed on the metal plate.
- (vii) Before power is applied to any RF device in the DUT, the ionizer is to be turned off.
- (viii) Every tool is to be discharged by placing it on the ESD mat (or any dissipative surface). Test leads are discharged by touching the ESD mat with the lead for at least 1 second. This instruction applies to screwdrivers, tweezers, and special tools.
- (ix) The proper ionizer discharge time and float potential are to be selected per Table 8-2.

**Table 8-2: ESD Sensitivity for Selection and Performance of Air Ionizers**

<b>Class</b>	<b>ESD Sensitivity</b>	<b>Air Ionization</b>	<b>Discharge time</b>	<b>Float Potential</b>
1A	≥250 volts	Optional	± 1000 to < ± 100 V in < 45 sec.	< ± 100 V
0	< 250 V to >50 V	Required	± 1000 to < ± 50 V in < 20 sec.	< ± 25 V
0	≤50 V to ≥20 V	Required	± 1000 to < ± 20 V in < 20 sec.	< ± 10 V
0	<20 volts	Required	± 1000 to < ± 5 V in < 10 sec.	< ± 5 V

### 8.3 RECEIVING, INTERNAL HANDLING, AND SHIPPING

8.3.1 Incoming inspection includes examining all ESDS items for proper ESDS precautionary marking and ESD-protective packaging. See paragraph 8.4.3. Inadequate precautionary markings must be corrected and handling history investigated prior to further processing.

8.3.2 When an item is received that has not been protected during shipment or internal transfer, it should be:

- a. Rejected as defective
- b. Processed as non-conforming material

Additionally the package should be labeled as failed ESDS material and the incident reported



8.3.3 When a kit is assembled that includes an ESDS item, the entire kit and the accompanying documentation used to identify the kit must be packaged and marked as ESDS.

8.3.4 ESDS items packaged for shipping must be packaged and marked as required by the contract and in accordance with special instructions defined in these ESD implementation plan.

#### **8.4 EQUIPMENT LEVEL TEST, MAINTENANCE, AND INSTALLATION**

8.4.1 The following practices apply both within a facility and in the field when the equipment being serviced contains ESDS items:

- a. Personnel must be properly grounded (e.g., using a wrist strap) before each maintenance action. Maintenance actions include adjustments, restoring covers, and tightening fasteners.
- b. Protective packaging of a replacement ESDS item is to be grounded to the equipment to dissipate any static charge before the package is opened.
- c. As an ESDS item is installed, contact with parts, electrical terminals, and circuitry is to be kept to a minimum.
- d. Failed ESDS items are placed in protective packaging after removal from the equipment to facilitate root cause analysis.
- e. Probing ESDS items with test leads is to be conducted only within a certified ESD protected area.

8.4.2 ESD-protective covering or protective caps on external terminals, interconnecting cables, and connector assemblies are never removed until it is necessary to permit the installation.

8.4.3 The cable connector pins and cable shield (connector outer shell) must be grounded prior to engaging a de-energized connector and cable with a mating receptacle which is connected to an ESDS item. Soft grounding is used to avoid rapid discharge.

#### **8.5 IDENTIFICATION AND MARKING**

8.5.1 ESDS items, equipment, and assemblies must be identified in order to warn personnel before any potentially ESD-damaging procedure can be performed. For this purpose, packing lists, inspection reports, travelers, and other paperwork accompanying the hardware must contain ESDS labels and cautionary notes.

8.5.2 Alternative identification is applied when the prescribed marking is not available. ANSI/ESD S8.1-2007 provides the approved identification methods.

8.5.3 The standard ESD Protective Item Symbol is to be used to identify items which are specifically designed to provide ESD protection for ESDS assemblies and devices. This symbol is illustrated in Figures 8-1 and 8-2.



Figure 8-1: Sensitive Electronic Device Caution Symbol (with & without sensitivity class level)

*Note: If the Class sensitivity level is not specified within the symbol, or is other than Classes 0, M1, or C1, it will default to Class 1A. Refer to paragraph 5.3.1*



Figure 8-2: ESD Protective Item Symbol

8.5.4 The standard ESD common point ground symbol is used to indicate the location of an acceptable Common Point Ground.



Figure 8-3: ESD Common Point Ground Symbol

8.5.5 The standard ESD common point ground symbol is to be used to indicate the location of an acceptable Common Point Ground.



## **9 ASSURANCE PROVISIONS**

### **9.1 SURVEILLANCE**

9.1.1 Project Chief Systems Assurance Officers (CSOs) have the responsibility to ensure that processes used for their project are properly controlled and meet requirements. Therefore, CSOs or their designated representatives are to audit ESD controlled areas prior to beginning work on their flight hardware and ensure compliance to the ANSI/ESD S20.20 requirements.

9.1.2 The area's ESD program monitor is to periodically verify EPAs (See Table 7-1).

9.1.3 The ESD Control program manager (see paragraph 5.6) is responsible for the initial certification of all ESD Protected Areas. This task may be delegated to an audit team who represents the program manager.

9.1.4 The ESD Control program manager is to perform random audits where deemed necessary. This task may also be performed by any assigned auditor.

### **9.2 ESD PROTECTED AREA "PASS" CERTIFICATION REQUIREMENTS**

9.2.1 If the ESD protected area meets the requirements of the ESD Control plan, it is to be certified as approved for use. The certifier is to initial, date, and record "Approved" on the ESD Protected Area Test Log (see Appendix A).

9.2.2 The certifier may also affix a Certification Sticker (Appendix C) to the work area in a conspicuous location, but not in an area where ESDS items will be processed (e.g., workstation riser, front edge of work surface). For ESD workstations inside clean rooms or other restricted areas, sticker placement must comply with the clean room management requirements and positioned for clear visual access.

9.2.3 The ESD protected area remains certified for use until a discrepancy is found during its use (e.g., broken ground wire, workstation was moved, or rewired) or the verification has not been performed in over 6 months. See abandoned EPAs in paragraph 5.8.3.

### **9.3 ESD PROTECTED AREA "FAIL" REQUIREMENTS**

9.3.1 If an ESD protected area fails to meet the requirements of the ESD Control plan, an "OUT OF SERVICE Not Approved for ESDS Work" sign is to be placed in an obvious location. For an example of an out-of-service sign see Appendix C2. The person certifying the EPA is then to initial, date, and post the "Not Approved for Use" sign, and provide a brief description of the problem on the ESD Protected Area Test Log. The area will remain out of service until the discrepant item(s) have been corrected and the ESD Protected Area Test Log has been updated to show the area acceptable for use. When ESDS hardware has been handled in the area since the last passing verification the hardware is handled as non-conforming material.

9.3.2 The verifying organization and the department responsible for the area will address discrepancies in a team environment in order to restore the area for use in as little time as practical. Disposition of ESDS items affected by the discrepancy is the responsibility of the organization that owns the items and the organization responsible for the area.

## 10 FORMS

The following forms are recommended for use as part of an ESD Control program. Organizations are encouraged to modify these forms to be area-specific.

- a. ESD Control Program Certification Log (Appendix B1)
- b. ESD Protected Area Test Log (Appendix B2)
- c. Certification Sticker (Appendix C)
- d. Verification Sticker (Appendix C, has expiration date)
- e. Failed ESD Protected Area Sign (Appendix C)
- f. Wrist Straps/Footwear/Hand Tools Logs (Appendix D)
- g. Other area-specific logs as required by each particular ESD protected area (e.g., humidity log).
- h. If electronic data logging is used, a soft copy of the data is to be made available at the ESD protected area for the verifier to review.

## 11 REFERENCES

- |   |   |
|---|---|
| [1] ANSI/ESD S20.20-2007 paragraph 6.1                    | Requirements for ESD Control Plan   |
| [2] ANSI/ESD S20.20-2007 paragraph 6.2                    | Requirement for ESD Manager/Monitor   |
| [3] ESD STM5.1-2001                                       | HBM Test Model  |
| [4] ESD STM5.2-1999                                       | MM Test Model   |
| [5] ESD STM5.3.1-1999                                     | CDM Test Model  |
| [6] ANSI/ESD TR20.20-2008 paragraph 5.5.2,<br>Page 130    | Electrical Hand Tools   |
| [7] ANSI/ESD S6.1-2005 paragraphs 5.2.1 & 5.1.2           | Common Point Ground Requirements  |
| [8] ANSI/ESD S6.1-2005 Foreword                           | ESD vs. EMI Grounding.  |
| [9] ANSI/ESD S20.20-2007 Tables 2 & 3                     | Limits  |
| [10] ESD TR20.20-2008 paragraph 5.1.3, Page 47,<br>Note 3 | Recommendation for GFCI   |
| [11] ESD TR20.20-2008 paragraph 5.3.4, Page 74            | Floor Properties, Electrical Resistance   |
| [12] ANSI/ESD S541-2008 paragraphs 7 and 8                | Packaging Classification & Technical<br>Requirements  |
| [13] ANSI/ESD S20.20-2007 paragraph 8.2 Note              | Requirement to wear garments  |
| [14] ANSI/ESD S20.20-2007 Table 1                         | Auxiliary ground resistance   |
| [15] JPL D-1348   | JPL Standard for Electrostatic Discharge<br>(ESD) Control   |
| [16] JPR 8730.1   | Electrostatic Discharge Control<br>Requirements for the Protection of<br>Electronic Components and Assemblies |

## **APPENDIX A    ESD PROTECTED AREA VERIFICATION TEST PROCEDURE**

### **A.1    Purpose**

This appendix provides an example of a procedure that a ESD Control program monitor can use to support verification checks in accordance with the ESD Control plan.

### **A.2    Scope**

This document applies to personnel performing ESD protected area tests or other ESD-related support for organizations who request such support.

### **A.3    Requirements**

#### **A.3.1 Personnel Requirements**

The organization shall ensure that:

- a. Their ESD program monitor has the appropriate resources and knowledge to implement this procedure (e.g., correct level of training, certification to act as a program monitor for the organization, proper equipment, calibrated equipment). The monitor shall ensure that the verifications they perform are within specified time frames, records are current, and reports are issued as specified herein.
- b. Personnel providing ESD support have the appropriate level of training to perform the assigned task and are certified to work with ESDS items.
- c. Personnel assigned to this task verify calibration status of test and measuring equipment, make all necessary measurements and observations, and complete all appropriate forms and records as identified in this procedure (e.g., ESD Protected Area Test Log sheets, internal records).

#### **A.3.2 Equipment Calibration**

All test and measuring equipment used to perform the ESD Protected Area Verification Test shall be in a current state of calibration.

### **A.4    Equipment List**

The following equipment, or equivalent, shall be used:

- a. 3M Model 701 Test Kit for Static Control Surfaces
- b. 3M Model 718 Static Sensor
- c. Monroe Electronics Model 287 Ionizer Performance Analyzer
- d. Fluke 77 DMM

### **A.5    Procedure**

#### **A.5.1 Verifications and Results**

- a. The applicable elements of ESD protected areas shall be verified by personnel currently certified in accordance with paragraph A.3.1 of this appendix. See Section 9 of this manual for personnel responsibilities. The frequency of verifications, conditions of tests, and limits shall be in accordance with Table 7-1 of this manual.

- b. Area verifications shall be documented on the ESD Protected Area Test Log (ATL) (see Appendix B2). The EPA ATL shall be used for data entry.
- c. Measurements shall be compared to previous data for the relevant area in order to identify trends toward a noncompliant condition. If a trend is noted, the organization responsible for the ESD protected area shall be notified so correction can be implemented before failure occurs.

## **A.5.2 Test Procedures**

### **Test 1: Work Surface Resistance**

This test shall be performed by measuring the resistance between two 5 pound, 2.5 inches diameter electrodes. The electrodes shall be positioned 10 inches (25 cm) apart and at least 2 inches (5 cm) from the edge of the work surface. Set the megohmmeter voltage to 100 V, measure the resistance after 15 seconds, and record the value in the ATL. The area shall be clean and dry prior to performing this test. For older surfaces, the measurement shall be made on the most worn area.

### **Test 2: Work Surface Grounding**

- a. Measure the resistance between the equipment ground (the nearest permanent electrical outlet ground) and the center of the work surface. Use a 5 pound, 2.5 inches diameter electrode at the work surface. Set the megohmmeter voltage to 100 V, measure the resistance after 15 seconds, and record the value in the ATL.
- b. When checking highly conductive surfaces, a ground fault circuit interrupter (GFCI) outlet shall be used to protect personnel. Check the GFCI using the self-test feature in the outlet. Plug a lamp in the receptacle and press the TEST button in the GFCI. The light must go out. Unplug the lamp, press RESET, and record the result in the ATL.

*Note: Since this is a special test for ground check, when performed, the ATL example must be modified to accommodate it.*

### **Test 3: Floor Resistance**

Measure the resistance between two points on the “High Transit” area of the floor at least 12 inches apart. Use a 5 pound, 2.5 inches diameter electrode at the work surface. Set the megohmmeter voltage to 100 V, measure the resistance after 15 seconds, and record the value in the ATL. This is a minimum test for recertification only and can be used for either floor mats or conductive floors. For initial certification of a newly installed conductive floor, follow the test procedure in ESD STM7.1-2001.

### **Test 4: Floor Grounding**

Measure the resistance between the facility ground (the outlet ground) and a point on the floor at least 12 inches away from the floor-to-ground connection. Use a 5 pound, 2.5 inches diameter electrode at the work surface. Set the megohmmeter voltage to 100 V, measure the resistance after 15 seconds, and record the value in the ATL. This is a minimum test for verification only and can be used for either floor mats or ESD protective floors. For initial certification of a newly installed ESD protective floor, follow the test procedure in ESD STM7.1-2001).

**Test 6: Wrist Strap Grounding**

Resistance shall be measured using an ohmmeter. The measurement shall be made from the wrist strap groundable point to a facility ground in the nearest permanent electrical outlet. Record resistance value in ATL.

**Test 7: Continuous Monitoring Systems**

Check that the CMS alarm activates when the ground is removed by using a “Cheater Plug,” and again by physically removing the cord from the wrist strap while wearing it. This test shall be performed when the CMS is being tested for functionality or when there is doubt about the reliability of the CMS. For a complete calibration of the CMS, use the manufacturer’s recommended fixture and test procedure.

**Test 8: Stool & Chair Grounding**

Qualification tests for any seating used in an ESD protected area shall be in accordance with ESD STM12.1-1997. For verification tests, position a 5-pound, 2.5 inch diameter electrode at the center of the seating surface and measure the resistance to the chair’s groundable point (a caster or grounding chain shall rest on a conductive surface; use of a metal plate may be necessary on non-conductive floors). The test shall be repeated for the back and arms of the chair, if present. Set the megohmmeter voltage to 100 V, measure after 15 seconds. Record the largest resistance measured.

**Test 9: Humidity**

Relative Humidity shall be constantly monitored using a calibrated hygrometer. The hygrometer shall be in the same room and as close as possible to the work area. Continuously recording chart recorders or automatic logging are recommended. For places where there is no continuous record, a log shall be maintained by the organization responsible for the ESD protected area. The log shall document that the humidity levels are within the acceptable limits. Daily entries shall be made each time the ESD protected area is in use. The verifier shall record the current relative humidity in the ATL and review the humidity charts/log for large variations in humidity, which indicate that more frequent checks may be necessary.

**Test 10: Ionizers**

- a. For most applications, ionizer performance is considered acceptable as long as the ionizer is in a current status of calibration. Ionizer average decay rate and ion balance shall be measured in accordance with ESD Association Standard Practice ESD SP3.3-2000.
- b. The limits for decay and balance measurements are determined by the ESD classification of the ESD protected area being verified. See Table 7-2.
- c. Since some ionizers tend to collect dust and lose their effectiveness, periodic cleaning and verification of all air ionizers is recommended.
- d. The verification tests can be done using a Monroe Electronics Ionizer Performance Analyzer Model 287 or equivalent instrument(s) capable of making the measurements contained in ESD SP3.3-2000. Follow the instrument manufacturer’s operating instructions. Record decay time and balance on the ATL.

**Test 11: Soldering Iron Tip to Ground**

- a. Soldering iron tips may be checked using a Digital Multimeter (DMM) and a FR-4 copper-clad PC Board of size 2" x 0.5".
- b. Attach one lead of the DMM to the AC outlet common ground and the other lead to the PC Board. Set the meter to measure AC voltage.
- c. After the iron is at operating temperature, melt a small pool of solder with the tip of the iron on the far end of the PC Board and monitor the AC voltage on DMM. It should measure < 2.0 mV AC.

*Caution: If this test fails, STOP the following tests and replace the soldering iron.*

- d. Set the DMM to read ohms, then melt the solder pool using the soldering iron and check the resistance value on the DMM. The resistance should be < 1 ohms when certifying a new soldering station and < 20 ohms during periodic verification.<sup>[6]</sup>
- e. For soldering irons with integral protection, use the manufacturer's recommended procedures to check proper circuit operation.

**Test 12: Equipment & Facility Grounding**

Measure the resistance between the main service box neutral bond and the ESD protected area common point ground (CPG). This test may require the assistance of the maintenance department to access the neutral bond at the main service box. A quick check can be done using a commercial socket tester.

*Note: This test is only required during initial certification of an ESD protected area or if the electrical system in the area has been serviced or modified.*

When an auxiliary ground (e.g., quiet ground) is used, resistance between the equipment ground and the auxiliary ground shall not exceed 25 ohms.<sup>[14]</sup>

**A.5.3 Reporting**

The verification activity, if not performed by the ESD program monitor, will provide a summary report to the ESD program monitor responsible for the area. These reports shall be retained as described in paragraph 4.3.

**A.5.4 Out of Calibration Test Equipment**

Only test and measuring equipment in a current state of calibration shall be used.

If a piece of test or measuring equipment is returned from the calibration contractor providing indicating it was received in an "out of tolerance" condition, records shall be reviewed to determine which ESD protected areas were verified using that piece of equipment since its last known "good" status. A Nonconformance Report shall be prepared documenting the impact of the out-of-tolerance condition on all products or services processed in the areas in question since the last acceptable assessment of calibration. The ESD Program Monitor shall notify all affected organization(s) and supply them with as much information as possible for them to use in their impact analysis (e.g., dates of prior verifications, how far out of tolerance the equipment was found to be).

## APPENDIX B EXAMPLE OF AN ESD CONTROL PROGRAM CERTIFICATION LOG

		Measurement Date:	HBM Class:			
Bldg. #	Room #	Workstation ID #	ESD Mon.		Program Mgr.	
Test Item		Test Parameters	Pass	Fail	Measurement Data	Comments
1. Work Surface Resistance		$< 10^9 \Omega$				
2. Work Surface Grounding		$10^6$ to $10^9 \Omega$ from the center work surface to Common Point Ground or $< 1$ ohm w/GFCI. (Conductive plate use)				
3. Floor (or mat) Resistance*		$< 10^9 \Omega$ (*Floor mat required for Class 0)				
4. Floor (or mat) Grounding*		$10^6$ to $10^9 \Omega$ from the floor surface to Common Point Ground or $< 1$ ohm w/GFCI.				
5. Wrist Strap Check		Check wrist straps for signs of damage or wear. Use approved wrist strap checker and log daily if CMS is not used. Use of CMS is preferred.				
6. Wrist Strap Receptacle to Ground		$\leq 1 M\Omega$				
8. ESD Continuous Monitoring System Alarm		Verify alarm functionality.				
9. Stool/Chair Grounding		$10^5$ to $10^9 \Omega$				
10. Mobile equipment resistance to groundable point.		$< 1 \Omega$ if tied directly to equipment ground. $< 10^9 \Omega$ when grounded thru conductive flooring, referenced to CPG.				
11. Work Area Relative Humidity (%RH)		30% to 70% RH Continuous for work area. *Class 0 work areas RH $> 40\%$ to 70%.				
11. Hygrometer Log Status		Verify RH readings are recorded.				
12. Ionizer Average Decay Rate*		Decay +1050V to +100V/-1050V to -100V in $< 45$ sec. Class 0 See Table 7-2 for limits				
12. Ionizer Balance*		$\pm 100$ V. Class 0 See Table 7-2 for limits.				
13. Soldering Iron Tip to Ground		Solder stations with self-contained checkers shall use it. Otherwise $< 20 \Omega$ and log.				
ESD Control Program's Test/Measuring Equipment ID and Calibration Due Date		Hygrometer (located in area)	ID		Cal Due	
		Megohmmeter	ID		Cal Due	
		CMS Checker	ID		Cal Due	
		Ionizer P.A.	ID		Cal Due	
		Fluke Meter	ID		Cal Due	
Comments: Enter "Approved" if tests PASS Otherwise; describe problem and any relevant remarks pertinent to the certification.						
*Required for Class 0 work			Certifier's Signature			



## APPENDIX C EXAMPLE OF AN ESD PROTECTED AREA TEST LOG

Building #		Room #		Work Stn ID #		HBM Class		ESD Mon.		Program Mgr				
Test Item			Date:			Date:			Date:					
Test #			Pass	Fail	Data	Pass	Fail	Data	Pass	Fail	Data			
1. Work Surface Resistance														
2. Work Surface Grounding														
3. Floor (or mat) Resistance **														
4. Floor (or mat) Grounding **														
6. Wrist Strap Receptacle To Ground*														
8. ESD Continuous Monitoring System Alarm resistance threshold level. **														
9. Stool & Chair Grounding **														
10. Mobile equipment resistance to groundable point. **														
11. Work Area Relative Humidity (%RH)														
11. Hygrometer Log Status**														
12. Ionizer Average Decay Rate +1050V to +100V/-1050V to -100V														
12. Ionizer Balance ± 50 Volts														
13 Soldering Iron Tip to Ground														
Test/Measuring Equipment ID and Cal. Due Date	Area Hygrometer		ID		Cal Due		ID		Cal Due		ID		Cal Due	
	Megohmmeter		ID		Cal Due		ID		Cal Due		ID		Cal Due	
	CMS Checker		ID		Cal Due		ID		Cal Due		ID		Cal Due	
	Ionizer P.A.		ID		Cal Due		ID		Cal Due		ID		Cal Due	
	Multimeter		ID		Cal Due		ID		Cal Due		ID		Cal Due	
Comments: Enter "Approved" if tests PASS Otherwise describe problem and any relevant remarks pertinent to the verification. Use back of sheet if needed.														
			Verifier's Signature			Verifier's Signature			Verifier's Signature					

\*Measurement not required if a continuous wrist strap monitoring system is used.

\*\*Fill when Applicable

## APPENDIX D EXAMPLE OF CERTIFICATION/VERIFICATION STICKER

This ESD protective workstation is verified compliant to: GSFC-WM-001 HBM Class____ Workstation ID: _____ Verified by: _____ Verification date: _____ Due _____
--

This ESD protective workstation is certified compliant to: GSFC-WM-001 HBM Class____ Workstation ID: _____ Certified by: _____ Certification date: _____
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## APPENDIX E EXAMPLE OF FAILED ESD PROTECTED AREA SIGN

<p>This ESD Protected Area is</p> <p><b><u>OUT OF SERVICE</u></b></p> <p>It is</p> <p><b>NOT APPROVED FOR ESD WORK</b></p> <p>Failed by: _____ On (date): _____</p> <p>For more information contact the area ESD Monitor</p>
--

## APPENDIX F EXAMPLE OF COMPLETION OF TRAINING CERTIFICATE



*Note: Replace "GSFC-WM-001" with the name of the local ESD implementation plan*

