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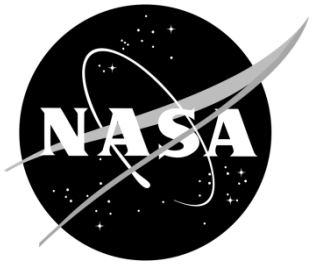

National Aeronautics and
Space Administration

Goddard Space Flight Center
Greenbelt, MD 20771

WORKMANSHIP MANUAL FOR

ELECTROSTATIC DISCHARGE CONTROL

(EXCLUDING ELECTRICALLY INITIATED EXPLOSIVE DEVICES)

NOT MEASUREMENT SENSITIVE

Code 300 / OFFICE OF SYSTEMS SAFETY AND MISSION ASSURANCE

Workmanship Manual for Electrostatic Discharge Control

Signature Page

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CHANGE HISTORY LOG

Revision	Effective Date	CCR No./Date	Description of Changes
-	04/11/2005	--	Initial Release
A	05/16/2006	05/16/2006	Numerous editorial and formatting changes. Clarified 5.5.4 for new programs. Clarified requirements and usage of Test Log. Minor changes to required measurements in Table 7-1. Clarified requirements throughout with proper use of "shall" and other verbiage consistent with NASA Directive requirements. Updated tailoring requirements in 7.20. and moved to 5.2 Added requirements throughout for documenting problems and non-conformances in accordance with GPR 5340.2. In section 9, clarified trending requirements and addressing of failed areas. Updated forms and labels in Section 10 and Appendix C. Minor updates to other appendices.
B	07/10/2008	CCR-D-0005 04/06/08	Reformat document to minimize styles Correct typos in Foreword Reformat Scope & General to remove redundant wording. Changed words to remove flow down of WM-001 to off-site contractors (primes and their subtiers). Added the PM new requirement per S20.20-2007 Para. 3.1.1.t Redefined EPA to include benches, rooms or buildings in accordance with ESD ADV1.0-2004 Clarified definition of Surface Resistivity. Changed SAM acronym use to CSO To 4. and 5. used language to reflect actual process re: process technical authority and delegation of

			authority for lab certifications. Added new Para. 4.1.4 to address separately deviations and waivers. Para. 4.1 Change title, also Record Custodian to match actual Practice at GSFC. 4.3, Changed NRRS record retention type from 8/109 to 8/107. 109 was assigned in error. Added section 4.4, ESD Overview and section 4.5, Safety sections from JPL D-1348 ESD Control Program. Moved Tailoring from Para. 7.20 to Para. 5.4 and clarified it. Added section 5.5 to define requirements for Temporary, Provisional and Intermittent-Use EPAs. Para. 5.4.1.i, 5.4.10, 5.5.3, 6.5.1, 7.1.2 & 7.1.3 reworded. Included a reference for the definition of a sensitive device. Added new paragraph 7.6.6 to clarify treatment of unattended ESDS items. Clarified Para. 7.7.1 Added CDM risk factor. Modified new Para. 7.7.2 Moved Para. 7.7.2 to 7.7.4 & Para. 7.7.6 to 7.7.3 Para 7.8 Clarify requirement for floors in Class 0 EPAs. Para 7.8.2 Clarified use of 1 Meg. Resistor. Modified Section 7.19 to include S20.20-2007 new garment requirements. Added new 7.20 ORU handling requirements from JSC JPR 8730.1 including handling of cable

			charging. Table 7-1 changed to allow different verification intervals for Class 1A workstations. Table 7-1 Test 13, added reference to S20.20-1999, the resistance measurement limit of 20 ohms on soldering irons since req. was removed from the S20.20-2007 version. This reference was also added to A5.2.10 Table 7-2 Modified to reflect new requirements for Class 0 EPAs under 100 V. Modified Fig. 7.1 and added Fig. 7.2 Para. 7.14.4 Reworded to clarify. Para. 7.14.5 Added Astro-E2 “Lesson Learned.” Corrected Indent on Para’s. 8.2.2.e & 8.3.1.a Added References section Revised A5.2.9 to account for ultra sensitive parts. & made compatible w/JPL. Added Area Certification Log Sheet to Appendix B Updated TOC

FOREWORD

This manual was created specifically for the use of the GSFC.

In order to comply with ANSI/ESD S20.20[1] and meet the standards of the GSFC Electrostatic Discharge (ESD) program, this publication:

a. Prescribes the plan to be followed when implementing ANSI/ESD S20.20. It replaces NASA–STD–8739.7 (cancelled) at GSFC.

b. Describes basic considerations necessary to ensure static free work areas.

c. Establishes the requirements for training and certifying personnel.

d. May be used in whole or in part by suppliers in the pursuit of creating their own ESD implementation plan in order to comply with the requirement of ANSI/ESD S20.20.

This document is controlled and maintained by Code 300, Office of Systems Safety and Mission Assurance. Questions concerning application of this publication shall be referred to Code 300 or its designated representative.

This Manual provides the ESD Control Program Plan (CPP), Compliance Verification and ESD Technical Requirements specified in ANSI/ESD S20.20 paragraph 6.1.

The guide for the development of this manual was the ESD TR20.20 HANDBOOK, published by the ESD Association. Technical Reports are normally not considered ESDA approved documents, but in the case of this Handbook it is a compiled reference and interpretation of the ESDA standards and guidance on how to create an ESD Control Program Plan for ANSI/ESD S20.20.

Several drawings, tables and paragraphs in this manual have been adopted, with permission, from the "ESD Control Plans" [documents] of other NASA Centers. The intent is to introduce, in this manual, the "lessons learned" of those centers.

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1 SCOPE

1.1 Purpose

The purpose of this document is to define the minimum requirements (per ANSI/ESD S20.20-2007) for protection against electrostatic discharge (ESD) damage to ESD sensitive (ESDS) devices, and to ensure reliable performance of GSFC spaceflight and ground support hardware.

This Workmanship Manual defines and implements the ESD Control Program at GSFC.

1.2 Applicability

As defined by GPR 8730.6, all applicable organizations within GSFC shall use this document. Applicable personnel in those organizations include both civil servants and contractors.

This publication sets forth an ESD control plan & technical requirements for items that are ESD Sensitive (ESDS) (excluding electrically initiated explosive devices) in accordance with ANSI/ESD S20.20-2007.)

The practices described here are generally suitable for the ESD sensitivity levels of the Human Body Model (HBM) Classes 0 and 1A and Machine Model (MM) Class M1. See paragraph 1.1.

In this document, a requirement is identified by “shall,” a good practice by “should,” permission by “may” or “can,” expectation by “will” and descriptive material by “is.”

2 APPLICABLE DOCUMENTS

ANSI/ESD S20.20-2007	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.
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
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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
GPR 8730.1	Calibration and Metrology
GPR 8730.6	Electrostatic Discharge (ESD) Control
GPR 5340.2	Control of Nonconformances

3 DEFINITIONS AND ACRONYMS

3.1 Definitions

The following definitions apply to terms used in this manual:

a. **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.

b. **Certificate of Completion of Training.** The actual certificate issued or the wallet size card given to the trainee at the time of training.

c. **Certification.** The act of verifying and documenting that personnel, facilities, equipment, processes, or materials comply with the requirements of this document.

d. **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.

e. **Certification of Training.** The act of verifying and documenting that personnel have completed training required by this document.

f. **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.

g. **Cheater Plug.** An AC plug adapter used to connect a three prong plug to a two prong AC socket. Can be used to separate the ground wire from the socket for testing purposes.

h. **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.

i. **Contractor.** The individual(s) or concern(s) who enter into a prime contract with the Government.

j. **Conductive Material.** A material that has a surface resistivity of $<10^5$ ohms per square or a volume resistivity $<10^4$ ohms-cm.

k. **Deviation.** A specific written authorization, granted before the fact, to depart from a particular requirement of specification or related document. A deviation is usually granted for a particular item, and/or a specific series of units, and/or a specified period of time.

l. **Equipotential Bonding.** A connection between two points with a maximum resistance between them of $< 10^9$ ohms.

m. **Electrostatic Discharge (ESD).** A transfer of electrostatic charge between bodies at different electrostatic potentials caused by direct contact or induced by an electrostatic field.

n. **ESD ADV... Advisory Documents** are not standards, but provide general information for the industry or additional information to aid in better understanding of ESD Association standards.

o. **ESD DS...** Draft standards, draft standard test methods, and draft standard practices are subject to revision before being issued as full standards.

p. **ESD S...** Standards have completed the industry comment and review process, and have been approved by the ESD Association Standards Committee as final standards documents.

q. **ESD SP... Standard Practices** have completed the industry comment and review process, and have been approved by the ESD Association Standards Committee as final standards documents

r. **ESD STM... 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.

s. **ESD TR... Technical Report,** 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.

t. **ESD Program Monitor.** An individual who is trained and certified to be in charge of an ESD protected area.

u. **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.

v. **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.

w. **ESD-Protective Packaging.** Packaging with ESD-protective materials to prevent damage to ESDS items.

x. **ESD Protected Workstation.** An area which is constructed and equipped with the necessary protective materials and equipment to limit damage to ESDS items handled within.

y. **ESD Sensitive (ESDS) Items.** Electrical and electronic parts, assemblies and equipment which are sensitive to ESD voltages or electrostatic fields.

z. **Electrostatic Field.** A voltage gradient between an electrostatically charged surface and another surface of a different electrostatic potential.

aa. **Ground.** A mass such as earth, a ship, or a vehicle hull, capable of supplying or accepting a large electrical charge.

bb. **Groundable Point.** Any point with low impedance to ground where grounding may be attached. Usually it is the common point ground.

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

dd. **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.

ee. **Insulative Material.** A material having a surface resistivity $\geq 10^{12}$ ohms/square or a volume resistivity $\geq 10^{11}$ ohms-cm.

ff. **Kit.** A prepared package of parts with instructions for assembly and/or wiring a component or chassis.

gg. **Level B Instructor.** An individual who is certified to train operators and ESD program monitors. They may be also in charge of an ESD protected area.

hh. **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)

ii. **Operator.** An individual who is trained and certified to perform tasks in an ESD protected area.

jj. **Organization.** A NASA center, contractor (the corporate entity), department, group or team.

kk. **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.

ll. 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.

mm. 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

nn. Subcontractor. An individual or concern that enters into a purchase agreement under a Government prime contract.

oo. Supplier. Commercial or academic organization supplying flight hardware, who are doing so using facilities and processes wholly under their own control, e.g. a prime contractor or a sub-tier contractor. On-site contractor personnel are not considered to be supplier personnel.

pp. 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.

qq. 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.

rr. 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.

ss. Triboelectric. Pertaining to electricity generated by friction.

tt. Waiver. A specific written authorization, granted after the fact, to depart from a particular requirement of specification or related document. A waiver is usually granted for a particular item, and/or a specific series of units, and/or a specified period of time.

3.2 Acronyms

The following acronyms apply to terms used in this standard:

AC	Alternating Current
ATL	ESD Protected Area Test Log
CDM	Charged Device Model [for electrostatic discharge].
CMS	Continuous Monitoring System
CPG	Common Point Ground
CSO	Chief Safety and Mission Assurance Officer
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
GSFC	Goddard Space Flight Center
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
WM	Workmanship Manual

4 GENERAL

4.1 Configuration Control

4.1.1 This document is a controlled document and shall be controlled by Code 300 in accordance with GPR 1410.2 and Code 300's configuration management procedures.

4.1.2 Requests for technical changes shall be processed by Code 300 as configuration changes in accordance with Code 300's configuration management procedures. Approval by the GSFC Workmanship Technical Lead is also required. Proposed changes to this Manual shall require review and approval by a Code 300 Configuration Control Board (CCB) that includes at least one ESD-knowledgeable individual from each of the following GSFC directorates: Codes 200, 300, 400, 500, 600 and 800.

4.1.3 All deviation and waiver requests shall be processed as Class I configuration changes. Deviations and waivers shall be supported by objective evidence and data substantiating that quality and reliability of the hardware will not be compromised.

4.2 Implementation

4.2.1 Code 300 shall advise and assist users of this plan in the proper and effective implementation of the provisions of this manual.

4.2.2 A supplier may exercise the option to adopt this implementation plan as their own or may duplicate in part or in entirety, the contents of this plan for use in their own plan. Requirements for ANSI/ESD S20.20 flow down to all contracts can be found in NPD 8730.5.

4.3 Records

Records required by the processes described herein shall be retained in accordance with GPR 1440.8. Records shall be as follows:

Record Title	Record Custodian	Retention
Training records	Civil Servants: Office of Human Resources and/or Supervisor, as described in GPR 3410.2 On-site Contractors: Company retains records.	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 lab manager	NRRS 8/107* -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 This ESD Control Program meets or exceeds the requirements of ANSI/ESD S20.20 and establishes the GSFC ESD Workmanship requirements for processing ESD sensitive equipment.

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

5.2 Electrostatic Discharge (ESD) Overview *(from JPL D-1348)*

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, surprisingly, 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 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 structures on modern devices are vanishingly small. 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.

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. This is bad because increased cost and time will be needed to locate, replace, and retest the failed components. But the fact that the failure could be detected during testing is good.

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 is bad because increased cost and time will be needed to locate, replace, and retest the failed components. But the fact that the failure could be detected during testing is good.

c. Latent failure. A latent failure occurs when a device has been damaged so slightly that it does not fail but continues to perform within its parametric tolerance limits. The damage remains latent (hidden) and the device continues to operate as designed. Parts with latent damage are sometimes referred to as the "walking wounded."

Both the 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.

The latent failure remains 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 the products developed at NASA, since these products are spacecraft. A latent failure on a launched spacecraft could reduce the mission accomplishments 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 Personnel Safety *(from JPL D-1348)*

5.3.1 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.

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

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

5.4 Tailoring

5.4.1 Project Managers and Lab Monitors may institute additional or stricter ESD safety requirements in their work spaces in order to manage situational ESD safety concerns, without use of a deviation or waiver. Exceptions to the requirements herein shall be documented and approved via a deviation or waiver (see 4.1.3).

5.4.2 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.

5.4.3 For areas required to protect extremely sensitive devices (HBM Class 0 and MM Class M1) see paragraph 8.2.

5.5 ESD Control Program Manager/Coordinator.

An ESD Control Program Manager or Coordinator [2] shall be assigned by GSFC Code 300 to oversee and verify the compliance of the GSFC Program with the requirements of ANSI/ESD S20.20.

5.6 ESD Protected Areas (EPA)

5.6.1 An ESD protected area may be a single workstation, laboratory, room, building, or any area with pre-defined boundaries that contains materials and equipment designed to limit damage by electrostatic discharge.

5.6.2 Temporary EPAs shall be certified by the ESD Control Program Manager and the records maintained by the responsible Project.

5.6.3 Each ESD protected area shall have a designated ESD program monitor responsible for that area.

5.6.4 When an ESD protected area is not maintained the workstation(s) shall be marked as "Out of Service" and the area ESD program monitor in charge of the area may reactivate them by verifying they pass the tests of Table 7-1. A new Verification Sticker (See Appendix C) shall be affixed to the workstation(s). Also filled-in ATLs (See appendix B2) shall be used to demonstrate that the area was inactive for less than six months.

5.6.5 An ESD protected area shall be considered "**Abandoned"** when it has not been verified for a period longer than six months. Abandoned workstations shall be clearly marked as a "**NON ESD PROTECTED AREA**" and shall be recertified by Code 300 or its delegate in Code 800 before use for ESDS work.

5.6.6 All handling of ESDS parts, assemblies and equipment without ESD-protective covering or packaging shall be done in certified ESD protected areas.

5.6.7 All GSFC ESD Protected Areas at Greenbelt and Wallops where ESDS hardware is handled shall be initially certified (and recertified if required) by the ESD Control Program Manager (see Para. 5.5) or their delegate. The following requirements shall be reviewed and approved as a condition of certification:

a. Training certification of personnel;

b. Record Control Program for verifications (how, where and for how long will the records be kept);

c. ESD Protected Work Area Environment and

d. ESD Workstation Measurements

5.6.8 Recertification of an ESD protected area is only required if:

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 ESD protected area is reactivated; or
e. An ESD failure is traced to the particular ESD protected Workstation.

5.6.9 Following initial certification and recertification, a Certification Sticker will be issued (See Appendix C). Certifications shall default to the HBM Class 1A (See Table 5-1) unless specified otherwise.

5.6.10 Areas and /or workstations shall be certified prior to use. The ESD Control Program Certification Log in Appendix B1 may be used to record the certification data.

5.6.11 Certifications shall be maintained by scheduled inspections for the area/workstation performed by the area ESD program monitor. See Table 7-1. The area/workstation certification shall be voided if the scheduled verification is not performed for more than 6 consecutive months, or if any of the conditions in Paragraph 5.6.8 above are met. Also see paragraph 9.2.3.

5.6.12 Certification shall be validated by the use of certification stickers that shall be applied to all compliant benches, chairs, stools or ESD protected areas (e.g. clean rooms). Equipment such as wrist straps, mats, etc. do not need to have their own sticker or proof of compliance.

5.6.13 All equipment used to perform an ESD Protected Area Certification shall be in a current state of calibration.

5.7 Temporary, Provisional and Intermittent-Use EPAs

5.7.1 **Temporary EPAs** are areas which are created for use while working on a specific project for a period of less than one month. These areas are certified by the ESD Program Manager, or their delegate, for a specific period of time. The records collected shall be part of the project's I&T records

5.7.2 **Provisional EPAs** are areas created for a one-time use only. Provisional EPAs are the responsibility of the project CSO and are **not** certified.

a. The use of Provisional EPAs should be limited to areas where it is not practical to set up a temporary EPA. This type of EPA shall not be used when handling items with sensitivities above HBM 1B, i.e., not to be used when handling items with sensitivities of < 500 volts HBM.

5.7.3 **Intermittent-Use** of EPAs is defined as: the use of a permanent EPA for periods lasting less than one month at the time, with longer periods of idle time. These EPAs shall be considered temporarily Out of Service and marked as such. They do not have to be recertified,but shall be verified by the area's ESD monitor before use. An intermittent HBM Class 0 EPA (see Table 5-1) shall not be used for any other purpose and it shall be kept clean. If a HMB Class 0 EPA is not kept in the verification schedule it shall be marked as Out of Service and it shall be verified before use. These EPAs shall be verified at least once every 6 months.

5.8 ESD Sensitivity Levels

5.8.1 The ESD sensitivity of devices is determined using three different models: the Human Body Model, the Machine Model, and the Charged Device Model.

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

Table 5-1: ESDS Component Sensitivity Classifications – HBM

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 equipment. In this model, a 200-pF capacitor is discharged directly to ground.

Table 5-2: ESDS Component Sensitivity Classifications – MM [4]

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 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 [5]

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

5.8.2 Assemblies, components and equipment shall be designed to provide ESD protection for the sensitivity level of the most sensitive ESDS parts chosen for the design. The minimum protection for each ESDS design shall be as specified by the engineering documentation. When no specific sensitivity level is given, the design sensitivity shall default to Class 1A **(**250 to <500 V HBM) for assemblies, components and equipment. This default limit was chosen to agree with current certification for most of the ESD workstations at GSFC.

5.9 ESD Control Program Requirements

Area ESD program monitors and certified operators shall follow the ESD control procedures detailed in this Manual and verify conformance. As a minimum, laboratory and project procedures shall include directly or by reference, the following ESD controls:

a. Conformance of protected areas and items listed in Table 7-1 to requirements set forth in this document. Verify the adequacy of these areas 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 shall have received the necessary training to the appropriate working level (Operator, area ESD Program Monitor or Level B Instructor) and shall have a current certification of training.
d. Performance of assessments 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 5.10.
e. Inspection of documentation for ESD markings, precautions and handling procedures as applicable.
f. Proper identification on ESDS items. This can consist of labels, stamps, etc., or in special cases a formal deviation may be granted against this requirement. (See 4.1.3).
g. Handling of ESDS items only at approved ESD protected work areas.
h. Description of field operations and precautionary procedures, when applicable, to prevent ESD damage.
i. Maintenance of records and documentation, reviewed during certification assessments, for all measurements required in Table 7-1. These records shall be available to the certifier upon request. When several projects share an ESD protected area, the original records shall be kept at the ESD protected area and copies distributed to each project as needed.
j. Materials approved for use within ESD protected areas shall be recognized by the ESD Association as ESD-protective materials (the material shall comply with ESD Association-recommended practices). Exceptions shall have prior approval. A record of each material should be kept with other records for ESD stations using it.

5.10 Assessments and Inspections

5.10.1 General. Records of deficiencies, corrective actions and corrective action validation and verification shall be maintained for assessments and inspections as described below. These records shall be available at the ESD area. Form and format of the records of deficiencies shall be coordinated through the GSFC Assessment Coordinator or their delegate.

5.10.2 Assessments. The applicable CSO or designee shall be responsible for the ESD areas under their accountability. Assessments shall be based on the requirements of this manual and shall be coordinated through the Greenbelt or Wallops Assessment Coordinator. EPAs shall be assessed at least once a year to remain active. The area ESD Program Monitor may perform a self-assessment of an EPA and provide the data to the ESD Program Manager, or their delegate, to meet this requirement. Special assessments may be conducted by ESD Control Program Manager or their delegate. See Para. 5.5.

5.10.3 Inspections. Inspections are the responsibility of the area ESD program monitors. The inspections shall consist of a general review of the area and records as well as verification to be performed in accordance with Appendix A. These inspections may be carried out any time the area ESD program monitor deems them necessary to ensure continuous compliance with the requirements of this manual. However, as a minimum, they shall be performed every time the verification tests in paragraph 7.1.4c are required.

5.10.4 New Projects. If a new GSFC Project takes over the EPA and the old records are not available, the area ESD program monitor shall perform a reverification in accordance with Appendix A and attach new stickers to the applicable workstations.

6 TRAINING AND CERTIFICATION PROGRAM

6.1 General

6.1.1 The area ESD Program Monitor shall ensure that all personnel who perform or supervise any of the following ESD-related functions have current certifications for either ESD training to this Manual or an equivalent ANSI/ESD S20.20 based system, and are familiar with the requirements of this document and any additional hardware-specific requirements.

a. Design,
b. Production,
c. Inspection and test,
d. Procurement (*Certification is required only if handling, purchasing or specifying ESDS materials*),
e. Storage, shipping and receiving,
f. Handling, and/or
g. Installation, maintenance and repair.
h. Evidence of training certification status shall be available in the work area.

6.2 Training Program

6.2.1 GSFC administers a training program that meets the requirements of this Manual and complies with ANSI/ESD S20.20. This training is available at the NMTTC Eastern Region Training Center at http://workmanship.nasa.gov/index.jsp . Select "Workmanship Training" and then "GSFC School."

6.2.2 Alternatively**,** on-site contractors may train personnel for certification or recertification utilizing a training program taught by a currently certified Level B Instructor. The on-site contractor's training program documentation (see paragraph 6.3.3) shall be available for review and shall be submitted to GSFC upon request. To assist with documentation, generic training materials are given to the Level B instructors. Other training information may be obtained from the NMTTC site given in 6.2.1.

6.2.3 If used, the on-site contractor's training documentation shall include, but not be limited to, the following:

a. Procedures for training,

b. Lesson plan(s)/student manuals,

c. Hours of instruction,

d. Procedures for establishing and maintaining student training records

e. Criteria for Certification of Training.

6.3 Certification of Training Levels

6.3.1 There are four training levels under this program: Level A Instructor, Level B Instructor, ESD Program Monitor, and Operator. Level B instructors, ESD program monitors, and operators shall be tested to ascertain comprehension of the material covered for each level.

6.3.2 Instructor Level A. Level A instructors are certified by the ESD control program manager. Level A instructors have the authority to train civil service and contractor Level B instructors, ESD program monitors, and operators.

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

a. Level B instructors may only train ESD program monitors and operators who work for their own company or its subcontractors.

b. Training of Level B instructors shall be provided by a Level A instructor at the NMTTC.

c. The training shall include the following, as a minimum:

(1) ESD Control Program (as described in this manual);
(2) Principles/control methods of static electricity;
(3) Identification of ESDS items;
(4) Protective materials and equipment;
(5) Protected areas and workstations;
(6) Handling of ESDS items;
(7) Packaging, marking and shipping of ESDS items;
(8) Performance of ESD assessments;
(9) Administration and record keeping;
(10) Class preparation, presentation and test administration; and
(11) Demonstration of ability to teach a class.

6.3.4 ESD Program Monitor. This training is for those who play a major role in ESD damage prevention. Training of ESD program monitors shall include the following, as a minimum:

a. ESD Control Program (as described in this manual);
b. Principles/control methods of static electricity;
c. Identification of 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 assessments; and
i. Administration and record keeping.

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

a. ESD Control Program (contents of this manual);
b. Principles/control methods of static electricity;
c. Identification of ESDS items;
d. Protective materials and equipment;
e. Protected areas and workstations;
f. Handling of ESDS items; and
g. Packaging, marking and shipping of ESDS items.

6.4 Record Maintenance.

6.4.1 Training records shall be retained for a minimum of 5 years or as required by contract. These records shall include the following information, as a minimum:

a. Standard & Control Plan used for the training;
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 certificate; and
h. Test Score.

6.4.2 The Certificate of Completion of Training shall contain, as a minimum, the information described above, except for the test score. See example in Appendix C.

6.4.3 Evidence of certification of training shall be available in the work area.

6.4.4 The training organization shall issue a wallet card version of the certificate for assessment purposes.

6.4.5 It is the line manager's responsibility to certify the competence of their Level B instructors, ESD program monitors and operators. Certification of competence requires a current Certificate of Completion of Training.

6.5 Maintenance of Certification of Training Status

6.5.1 Level B instructors, ESD program monitors, and operators require periodic retraining and recertification.

6.5.2 Recertification of training shall be required when:

a. New ESD control techniques have been approved that require different skills;

b. Two years have elapsed since last certification of training;

c. Job performance indicates inadequate understanding of ESD controls;

d. The Certificate of Completion of Training is not available at the NMTTC or is not in the employee's records; and/or

e. The line manager is not willing to issue Certification of Competence based on another contractor's training program.

6.5.3 The Certification of Training is completely portable as long as the employee can produce objective evidence of a current Certificate of Completion of Training.

6.5.4 The portability of Certification of Competence is at the discretion of the employer.

7 ESD CONTROL REQUIREMENTS FOR FACILITIES

7.1 General

7.1.1 This section contains requirements specific to ESD protected facilities including work areas, equipment, tools and materials.

7.1.2 The effectiveness of ESD protection in eliminating and/or dissipating electrostatic charges shall be demonstrated by inspection of facilities in accordance with and implementation of the requirements in Table 7-1 and specific requirements found throughout this section.

7.1.3 All EPAs are certified to HBM Class 1A. When handling parts sensitive to lower than 250 volts, the area shall be certified to HBM Class 0 with additional protective measures as required. Proper implementation of these protective measures shall be verified by the area ESD program monitor prior to starting work in these areas. No specific identification level is required for Class 1A areas. Where a different level classification is required the area shall be clearly marked with signage indicating the proper classification.

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

a. Operators at the EPA shall perform tests # 5, 7, 8(continuous), 11 & 13 as they apply to their area. For an example of the Test Log see appendix D.

b. The ESD program monitor for the area is responsible for ensuring that the logs are up to date.

c. The area ESD program monitor is also responsible for verification of tests # 1, 2, 3, 4, 6, 8(annual), 9, 10, 11 & 12. See example of the ESD Protected Area Test Log, Appendix B2.

7.2 Compliance

All items that are not in compliance with Table 7-1 shall be repaired or replaced and/or rendered unusable and clearly marked as unacceptable, until corrective actions are completed. See Appendix C for a Failed Area sign.

7.3 Traceability

All items listed in Table 7-1 shall require the maintenance of "on-the-premises" records for verification prior to use. The ESD program monitor shall maintain those records during the time the records are under his/her control. See paragraph 4.3 for record's Custodian and Retention.

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

Test #	ITEM	Para. Ref.	Test Parameters	Verification Intervals				
				Continuous	Daily	Weekly	4 Monthly	Annual
1	[2] Work Surface Resistance	7.7.2A5.2.1	< $10^9\Omega$ Between two points 10" apart on the Work Surface.				X	
2	Work Surface Grounding	7.7.6 A5.2.2	10^6 to 10^9 Ω from the center of the work surface to the equipment ground or <1 ohm with GFCI.				X	
3	[1,2] Protective Floor Resistance	7.8.2 7.8.4 A5.2.3	< $10^9\Omega$. 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	[1,2] Protective Floor Grounding	7.8.2 A5.2.4	10^6 to 10^9 Ω from the floor surface to the equipment ground or <1 ohm with GFCI. (This is a Class 0 requirement)				X	
5	[3] 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 A5.2.5	< 1 ohm impedance from Groundable Point (Gp) to the Equipment Ground. (< $1.2x10^6$ ohms if measured through a Continuous Monitoring System).				X	
7	[3] Foot Grounding Device Integrity	7.9.3 7.10.3	< $35x10^6$ Ω or use approved (calibrated) footwear checker & log each time you enter the area.		X			
8	[2] ESD Continuous Monitoring System	7.10.4 A5.2.6	Verify functionality before handling ESDS items. Check alarm limits per Mfr. Instructions yearly.	X				X
9	[2] Stool / Chair Grounding.	7.11.2.a A5.2.7	<10^9 ohms to the chair's groundable point. [For Class 0 Work only, verify monthly].				[X]	X
10	[2] Mobile Equipment	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)	7.12.1 A5.2.8	30 to 70% RH continuous for work area. For Class 0 Work Area certification RH shall be > 40%.	X				
12	[2] Ionizers	7.13.1 A5.2.9	See Table-2 for test parameters.				X	
13	Soldering Iron Tip to Ground Resistance	7.14.4 A5.2.10	Soldering Stations with self-contained checkers shall use them per schedule. Otherwise check to < 20. Ohms and < 2.0 mV_{AC}. [6]			X		

[1] Additionally, the Protective Floors resistance shall be 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.

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

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

[4] For workstations with sensitivities of HBM Class 1A ONLY, this interval may be done quarterly as a minimum.

7.4 Identification and Access - ESD Areas

EPAs, where ESDS items are to be processed, shall be clearly identified by prominently placed signs. Access to such areas shall be limited to trained and equipped personnel. A partition, rope guard, or similar barrier should be set up to assist in prohibiting unauthorized and untrained personnel from entering the EPA. All personnel not ESD-certified, e.g., visitors or maintenance personnel, shall be escorted and equipped with standard protective clothing as required.

7.5 Temporary Use of ESD benches for Non-ESDS Work.

7.5.1 EPAs may be used to perform non-ESDS work when approved by the ESD program monitor and under the following circumstances:

a. The area shall be clearly marked as a "Non-ESD Protected Area" during the period it is used for non-ESDS work.

b. The ESD program monitor shall verify 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 shall not be used for Non-ESDS work. If any of these areas are used for non-allowed material handling, the workstation shall be recertified by Code 300 before the area can be used to handle ESDS parts.

7.6 Prohibited Materials and Activities

7.6.1 The area shall be maintained in a clean and orderly condition.

7.6.2 Smoking, eating and drinking in EPAs shall not be permitted.

7.6.3 Materials unessential to the fabrication operation are prohibited in the EPA.

7.6.4 Clipboards, books, notebooks, loose sheets of paper, etc., used to read or record data or follow instructions (this manual included), shall be 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.

7.6.5 "Tacky Mats" usually used at the entrance to Clean rooms, CRT displays, and other equipment which generate a static charge shall be outside the EPA or placed at least 1 meter away from where ESDS parts are handled.

7.6.6 ESDS items shall not be left exposed and/or unattended at a workstation, or elsewhere. ESDS items, which must be left unattended for short periods of time, e.g., a lunch break, shall be placed on an ESD protective surface and wrapped or covered with static shielding material.

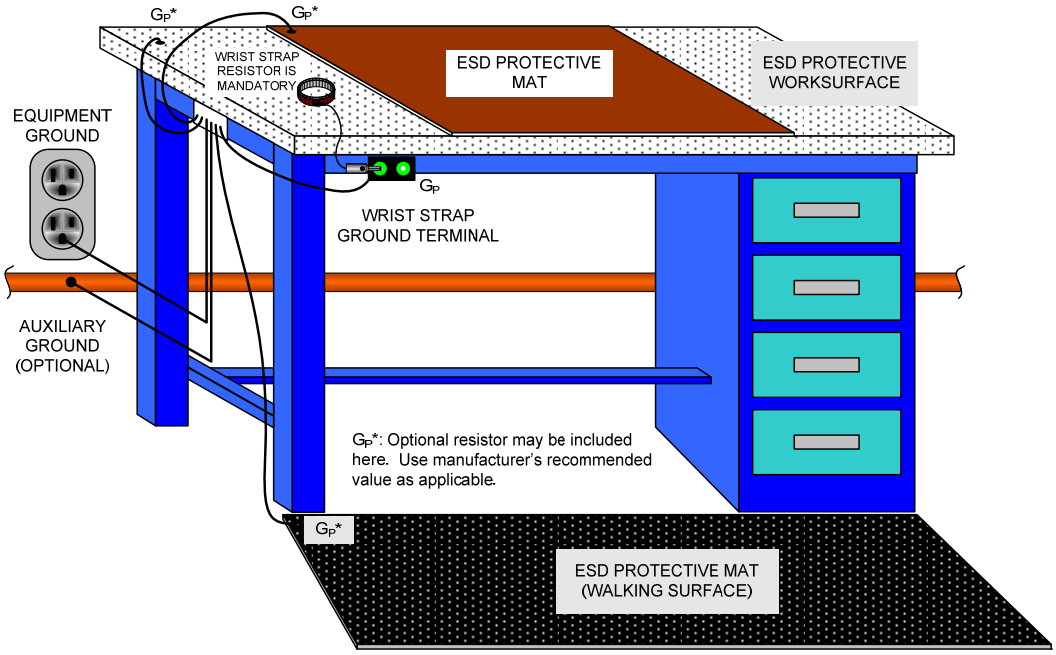


Figure 7-1: Typical ESD Grounded Workstations *(Courtesy of JSC)*

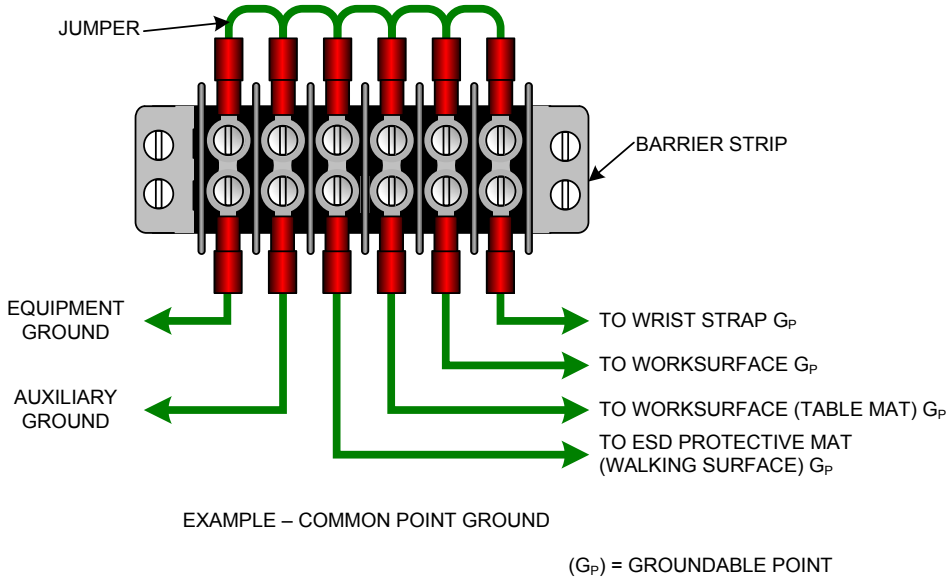


Figure 7-2: Workstation Common Point Ground *(Courtesy of JSC)*

7.7 ESD-Protective Work Surfaces

7.7.1 All work surfaces in an ESD-protected area shall be static dissipative (>10^5 to <10^9 Ω for surface resistance) if possible or conductive if necessary (e.g., optical benches). They shall be electrically connected to the Common Point Ground. When conductive (<10^5 Ω) surfaces are used, a one megohm optional resistor may be needed to provide a soft ground. See Figure 7-1 above.

NOTE: Work surfaces should be soft grounded (> 100 k ohms) to eliminate the safety hazard of touching a high voltage circuit with one hand and a hard ground with the other. A conductive work surface which is connected to hard ground requires that the electrical power line be protected with a ground fault circuit interrupter. The use of the 1 megohm optional resistors in Fig. 7-1 is acceptable in lieu of the GFCI. Conductive work surfaces may also generate a CDM hazard for sensitive devices.

7.7.2 For testing purposes, the resistance of the surface material shall be < 10^9 ohms [7] when measured at two points 10" (25.4 cm) apart and 2" (≈ 5 cm) from the edge, on the most commonly used portion of the work surface [8].

7.7.3 The resistance measurement from the center of the work surface to the Common Point Ground shall be < 10^9 Ω. [9].

7.7.4 The protective work surface shall not release particle contaminants and shall resist attack by common solvents or cleaners (see Section 7.17).

7.7.5 The protective work surface shall be 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 <1.2 x 10^6 ohms. 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), Ground Fault Circuit Interrupters (GFCIs) shall be used in the ESD-protected workstation. Type "A" GFCIs are preferred [10]. 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 the best 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 mandatory in areas where personnel are not wearing wrist straps. Under these conditions, the use of leg straps, heel straps or conductive shoes is mandatory. See paragraph 7.9.3 (Foot Grounding Devices). They are also required in HBM Class 0 EPAs to ground chairs.

7.8.2 Protective Floor Resistance. ESD protective flooring shall be 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 shall be between 10^6 and 10^9 ohms. ESD TR20.20-2000 [11] recommends 10^6 to 10^9 ohms for floor resistance for safety reasons. On highly conductive floors the option to include the resistor (see Fig 7-1) or use GFCI is 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 Floors or mats shall be kept free of dust, dirt and other contaminants.

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

7.8.5 The use of conductive waxes shall be in accordance with manufacturer recommendations. Floor resistance shall be verified after application. The results shall be recorded.

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

7.8.6 Conductive waxes on non-conductive floors shall not be considered an effective method of ESD control.

7.8.7 Use of carpeting in an ESD-protected area shall be prohibited. This includes carpeting advertised as "conductive" or "static-eliminating."

7.9 Personal Grounding Devices

7.9.1 Personal Grounding Devices shall be supplied to all personnel working with or handling ESDS items to prevent the accumulation of dangerous electrostatic charge levels. **All personnel coming within 1 meter (3.3 feet) of any ESDS item shall wear a grounding device**.

7.9.2 Wrist Strap. The wrist strap is the preferred means for ESD protection; it is the "first line of defense." Checking of wrist straps shall be done in accordance with paragraph 7.10.2.

The wrist strap system consists of four major components:

a. Lead. Only the lead supplied with the wrist strap shall be used, as it may contain the safety resistor.
b. Cuff. The design of the wrist strap cuff shall ensure conductive contact with the wearer's skin. Metallic cuffs are preferred over plastics or fabric cuffs. Bead type chains are prohibited. The wrist strap shall have a cuff connector, which breaks away with a force between 1 and 5 pounds per ESD S1.1. This property shall be tested each time a new manufacturer or type of wrist strap is approved for use.
c. Safety Resistor. All wrist strap systems shall contain an integral current-limiting safety resistor (1 megohm ± 20%). This resistor may be an integral part of the lead.
d. Ground Termination. The wrist strap ground termination shall ensure a positive and durable connection between the lead and the Common Point Ground. For testing purposes the resistance between CPG and the equipment ground shall be <1.0 ohm. For wrist straps ground, protected through a CMS, the value shall be $<1.2 \times 10^6$ ohms.

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. Foot grounding devices shall be worn on both feet and shall not be worn outside the ESD protected area. The total resistance of these devices shall be $< 35 \times 10^6$ ohms. Use an approved footwear checker and log every time the operator enters the ESD protected area. [12]

NOTE: FOOT GROUNDING DEVICES SHOULD BE KEPT CLEAN SO THAT CONTAMINANTS DO NOT INHIBIT 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. All personal grounding devices shall be periodically checked for signs of damage or wear, and replaced when needed.

7.10.2 Wrist straps shall be either continuously monitored or checked each time the wearer enters the ESD protected area (use an approved wrist strap tester). The first daily check shall be logged. Logging wrist strap checks is not required for areas that use Continuous Monitoring Systems (CMS) throughout the ESD protected area. If CMS is used at a workstation, all wrist strap connection points shall be enabled.

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

7.10.4 Workstation Real Time Continuous Monitors eliminate the need for users to test wrist straps and log the results. Personnel shall check Continuous Monitoring Devices 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. See Para. A5.2.6). These units shall be verified operational (within specification) per Table 7-1 or when a malfunction is encountered.

7.10.5 If a check fails, corrective action shall be taken before work is performed and a subsequent re-check shall pass 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); and/or

d. Wrist band cleaning.

7.10.6 If flight hardware has been handled while wearing a failed personal grounding device, a risk assessment of hardware failure shall be performed and the event shall be recorded.

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. 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. 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.

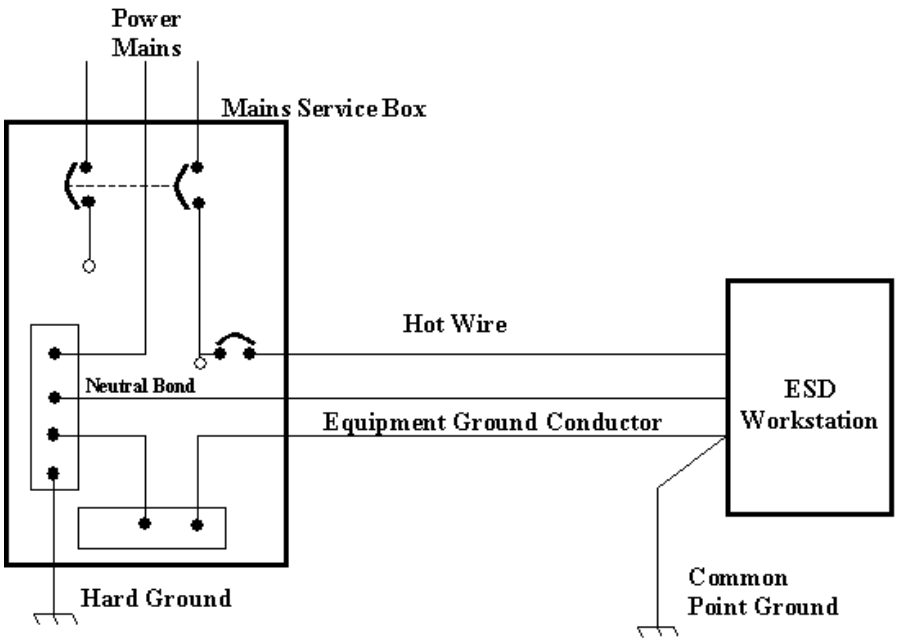


Figure 7-3: Main Service Box

7.11.2 Stool and Chairs.

a. Certification. Where chairs and stools are required, they shall carry a certification sticker. The resistance for any part of the chair to a groundable point shall be $< 10^9$ ohms [13]. For Class 0 work, the chairs and stools shall be verified periodically. See Table 7-1 for verification intervals.

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

7.11.3 Mobile Equipment. Where carts, wagons or trams are required to be grounded, and approved conductive floors are utilized, positive electrical contact shall be made between the floor and conductive structure of the cart, wagon or tram. For testing purposes the resistance from the equipment to the Common Point Ground shall be $< 10^9$ ohms. If the floor is non-conductive, the vehicle shall be grounded before ESDS items are loaded or removed from the vehicle. Flight hardware shall be protected with ESD approved wrap material, totes or other approved method. Consult the area ESD program monitor for the approved solution for the project involved.

7.12 Humidity

7.12.1 The relative humidity (RH) shall be maintained in ESD-protected work areas at 30% to 70% and monitored near the ESDS item. At levels below 30%, additional precautions shall be employed, such as turning on a humidifier to achieve the required humidity or using an air ionizer (See paragraph 7.13.1). If additional precautionary methods are not available, work shall be halted until the required humidity level is obtained. For handling Class 0 sensitive parts the relative humidity shall be between 40% and 70% (Best Industrial Practice).

7.12.2 A check of the RH level in each ESDS area shall be performed at the start of the workday and the result shall be logged. Periodic observations of the RH level should be made to ensure continuous compliance. 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 may dispense with the daily check.

7.12.3 The records of continuous RH monitoring (chart recorders, data loggers) shall be retained for 5 years or as required by contract.

***NOTE:* SURFACE RESISTIVITY CHANGES EXPONENTIALLY WITH HUMIDITY CHANGES. THEREFORE, RELATIVE HUMIDITY LEVELS MAINTAINED BETWEEN 40% AND 60% ARE RECOMMENDED.**

7.13 Air Ionizers

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

7.13.2 Unrestricted airflow between ionizer and the ESDS item is required for the ionizer to be effective. Sufficient distance between the ionizer and the ESDS items shall be maintained to ensure proper ion balance in the airflow. Consult the ionizer manufacturer.

7.13.3 Careful selection of the ionizer is needed to meet these requirements (see manufacturer's data sheet). Selection may also be application dependent. Ionizers shall be routinely maintained and tested in accordance with manufacturer's recommendations.

7.13.4 Electrostatic survey meters may be used to verify the effectiveness of ionizers in extremely sensitive work areas (Class 0, Class M1) before work is started. The meter used shall have enough resolution to detect values at the limits required.

7.13.5 For EPAs handling ESDS items with sensitivities below 100 V the ionizer peak balance potential shall be less than the one half the susceptibility of the most sensitive part. Note that parts mounted in an assembly are usually less sensitive. Engineering documentation should define the ESD sensitivity of an assembly to minimized the time and expenses of trying to protect sensitive hardware.

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

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

Class	ESD Sensitivity	Air Ionization	Discharge time	Float Potential
1A +	≥250 volts	Optional	± 1000 to < ± 100 V in < 45 sec.	< ± 100 V
0[1]	>100 V to < 250 V	Required	± 1000 to < ± 50 V in < 20 sec.	< ± 50 V
0[2]	≤100 V	Required	± 1000 to < ± 20 V in < 20 sec.	See below [2]
M1[3]	<100 volts	Required	± 1000 to < ± 20 V in < 20 sec.	< ± 20 V

[1] Class 0 covers all HBM <250 V but it is not sensitive enough to protect some newer parts.
[2] 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.
[3] This level is intended for use with automatic equipment therefore it uses MM vs. HBM

CAUTION: ***THE USE OF ANY TYPE OF AIR IONIZER IS PROHIBITED IN THE PRESENCE OF "POWERED-UP" HIGH-VOLTAGE OR RF SENSITIVE EQUIPMENT TO AVOID BREAKDOWN IN THE PRESENCE OF IONIZED AIR. ALSO KEEP FLAMMABLES AWAY FROM AIR IONIZER SINCE CORONA DISCHARGE COULD CREATE A FIRE HAZARD.***

7.14 Hand Tools, Equipment, and Fixtures

7.14.1 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.

7.14.2 Hand tools shall be kept on the grounded work surface when not in use.

7.14.3 Only antistatic solder extractors made of metal, or having a metallized plastic barrel and tip, shall be used in an ESD-protected area.

7.14.4 Electrical tools used in ESD-protected areas shall have a three-wire grounded power cord. Except were "double insulated" tools are used. They shall have static dissipative handle grips and be approved for use in those areas. The area making contact with the work piece shall be grounded (e.g., soldering iron tip). When measured from the work piece contact point to ground, the resistance shall be less than 20 ohms (< 1 ohms when new) and the potential difference shall not exceed 2 millivolts RMS using methods indicated in the tool vendor's process documentation. See Appendix A paragraph A5.2.10. Some soldering stations have an integral GFCI which will trip the unit if the tip is not grounded. These units are considered Continuous Monitoring Systems (CMS) and are exempt from the logging requirements of Table 7-1, but the proper operation of the system shall be periodically checked depending on the usage. See Table 7-1 Test # 2.

7.14.5 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. Measuring equipment, breakout boxes, harnesses, etc. shall be properly discharged (grounded) before making connection to flight hardware. If in doubt, consult with the designer of the hardware if the equipment you are using can cause damage to their hardware.

Lesson Learned: *During the testing of the Astro-E satellite several J-FETs were damaged due to discharging of the DMM leads while in the proximity of a charged breakout box.*

7.14.6 Fixtures used while working at an ESD protected area shall be ESD safe and grounded through the ESD protective work surface.

7.15 Protective Packaging

7.15.1 Electrostatic protective packaging requires both the prevention of charge generation (e.g., triboelectric contact and separation) and protection from external electrostatic fields. The surface resistance of any static dissipative material shall be $\geq 10^4$ & $< 10^{11}$ ohms [^{14}].

7.15.2 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.

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

c. All integrated circuits used by GSFC should be received packaged in non-metallic conductive and static dissipative magazines, chutes and dip tubes. Parts not received in compliant packaging shall not be handled and shall be rejected as non-compliant.

d. Neither static dissipative impregnated nor topically treated plastics provide electrostatic shielding. Both types shall be enclosed in an outer container, which will provide such protection during shipping. For electric field shielding, the package shall be electrically conductive and have a surface resistance of $< 10^4$ ohms.

e. Tote boxes shall be made of conductive or static dissipative material. All tote boxes shall be fitted with covers of the same conductivity as the bottom sections. The fit of this cover shall be such as to ensure the conductivity across this interface.

7.16 Temperature Chambers and Cooling Agents

7.16.1 Gas flow can be a significant generator of electrostatic charges. Precautions shall be taken when gas flow is utilized in the area of ESDS items.

7.16.2 Cold chambers shall have the conductive baffles and shelves within the chamber grounded. The ESDS items shall be contained within or mounted on conductive material.

7.16.3 When pressurized cryogenic cooling agents are used for localized cooling, as in troubleshooting, they shall be electrostatically safe.

7.16.4 The stability of ESD-protective materials which are used in temperature chambers should be suitable for the test temperature and humidity ranges.

7.16.5 Resistance checks shall be sufficient for normal test chamber environments. For extremely sensitive parts the use of electrostatic survey meters may be required (see paragraph 7.18). Survey meters can provide information on stray fields harmful to the hardware being tested. Consult the meter manufacturer's documentation for additional cautions.

7.17 Cleaning and Cleaning Agents

7.17.1 Cleaning agents and methods used on ESD-protective items (e.g., work surfaces and floor coverings) shall not reduce the effectiveness of these items and shall not cause leaching or leave insulating residues.

7.17.2 In addition to other required properties (e.g. solvency), cleaning agents used on ESDS items shall be chosen for low electrostatic charging propensity and shall be approved for use in flight hardware.

7.17.3 Only natural bristle or static dissipative brush materials shall be used for cleaning ESDS items.

7.18 Electrostatic Survey Meters, Voltmeters and Monitors

7.18.1 Electrostatic survey meters shall be used to detect the presence of electrostatic charges, and shall be of the type which read the electrostatic charge on a surface area without requiring contact. Such instruments shall 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.

7.18.2 The use of electrostatic monitors designed to actuate an alarm when an electrostatic field reaches a preset level is recommended in an ESD-protected area.

7.18.3 A wrist strap tester shall be available in all areas where ESDS items are handled, unless the ESD protective area exclusively uses a Continuous Monitoring System.

7.19 Clothing Requirements

7.19.1 Static dissipative outer garments (smocks) shall be worn in ESD protected areas. The smocks shall cover all personal garments above the wrist except at the neck area and make intimate contact with the skin. Smocks shall be fully zipped/buttoned all the time they are worn.

7.19.2 The garments shall be properly checked after laundering [15]. This requirement may be met by using an approved cleaning facility for ESD garments.

7.19.3 When handling ESD Class 0 sensitive parts, the ESD smock shall 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.

7.19.4 When cuff-to-cuff resistance of the garment is $< 3.5 \times 10^7$ Ω, the garment can be grounded using a single wire wrist strap cord [16]. 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.

7.19.5 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)

7.19.6 Finger cots and gloves, when worn in an ESD-protected area, shall be made of static dissipative materials.

7.20 Orbit Replaceable Units (ORU) Requirements *(from JSC JPR 8730.1)*

7.20.1 An electronic assembly manufactured with a conductive outer enclosure should only be ESD sensitive 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 ORU 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.

7.20.2 ESD precautions shall be implemented just prior to the connector or connector caps being removed. Exposed connector pins shall not be touched or any testing or troubleshooting performed unless the operator and the box are at the same ground potential (equipotentially bonded ground)

7.20.3 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 shall be grounded to discharge any electrostatic potential. An existing cable that is connected to another ORU does not require shorting prior to matting

b. When installing test equipment to flight hardware, install the cables to the non-flight equipment prior to the flight equipment.

7.20.4 Mounting and Unmounting Orbital Replaceable Units. 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 an spacecraft shall be regulated by the need to protect metal surfaces from scratches caused by alligator clips on soft metals and the knowledge that conductive debris is generated by the teeth of the clips In addition the working space may be to constrained to wear a wrist strap. In these cases the operator shall use some other means to equipotentially bond (ground) themselves with the ORU and connector prior to mating and de-matting.

7.20.5 The following guidelines should be used in establishing a procedure for handling ORUs that have been determined to be safe from ESD damage when all connectors are protected:

a. Upon arrival at the equipment rack with the ORU, the mobile cart should be tied to ground. If the ORU cannot be grounded through this procedure, momentarily ground the ORU by touching it with one hand and a grounded conductive surface with the other hand.

b. Verify that all connectors have conductive or dissipative covers securely in place.

c. Prior to moving the ORU from the cart, all personnel should momentarily ground themselves by touching a grounded object. (This requirement is a “last resource” requirement since a person could charge back up triboelectrically by merely lifting the soles of their shoes).

d. The ORU may be moved to the equipment rack without the use of a grounded wrist strap.

e. Prior to removing any connector covers, the technician shall be wearing a grounded wrist strap or using another grounding method.

f. The procedure for removing an ORU from the equipment rack is the reverse of items a-e. A grounded wrist strap shall be worn prior to removing a connector from the rack and reinstalling the connector cover.

g. 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 to section 7.20.3 of this manual.

h. 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 be grounded and a sign be placed at the worksite warning of the ESD damage concern.

7.20.6 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).

7.20.7 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, that these items be transported in ESDP packaging. Static generating materials are a hazard if they come in close proximity of ESDS hardware.

8 OPERATING REQUIREMENTS

8.1 Requirements for Handling ESDS Items

8.1.1 ESDS items shall be handled only in an ESD protected area. When outside ESD protected areas, ESDS items shall be completely enclosed inside ESD-protective packaging and in a ESD protective container (Tote or box).

8.1.2 Paperwork accompanying an ESDS item (e.g., QA records, routings, and instructions) shall be contained in static dissipative bags or envelopes. This paperwork shall not come in physical contact with an ESDS item. Materials specifically made and verified to be safe in an ESD area are exempt from this requirement.

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

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

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

8.2 Special Requirements for Highly Sensitive Items

NOTE: These requirements apply to HBM Class 0 and MM Class M1 only. For higher sensitivities e.g.: CDM or newer special cases please refer to the engineering documentation.

8.2.1 The requirements for handling Class 0 or higher sensitive parts are found elsewhere in this document. They are provided here as a guide to the ESD program monitors.

8.2.2 Highly sensitive areas shall implement the following requirements:

a. Chairs & stools shall be grounded and periodically verified as ESD protective. See Table 7-1 for intervals.

b. Conductive or dissipative floors or floor mats shall cover the area in front of the protected area or the designated EPA floor space.

c. Relative Humidity shall be kept over 40%, and it shall be monitored and recorded just before work is started. A waiver is required prior to start operations below 40% RH.

d. Ionizers shall be 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.

> ***CAUTION:*** *An improperly adjusted, functioning air ionizer can actually charge ESDS devices and lead to possible damage to the device.*

e. Smocks shall be grounded to the Common Point Ground or through the wrist strap. This is an exception to the daisy chain rule (See Para. 7.11.1). However, this grounding must not interfere with the operation of the CMS if one is used.

f. Cables and harnesses shall be discharged to ground through an approved method prior to mating and de-mating to ESD sensitive assemblies.

g. Soldering irons, if used, shall have a continuous monitoring circuit to protect the hardware.

h. Signage shall be displayed, describing the Class sensitivity level for the area.

8.3 Receiving, Internal Handling, and Shipping

8.3.1 The following requirements shall apply during receipt, internal handling, and shipping:

a. All ESDS items received shall be examined for proper ESDS precautionary marking and ESD-protective packaging. See paragraph 8.6.

b. Inadequate precautionary markings shall be corrected prior to further processing.

c. When an item is received that has not been protected during shipment or internal transfer, it shall be rejected as defective and processed as non-conforming material. The package shall be labeled as failed ESDS material and reported per GPR 5340.2.

d. When a kit is assembled that includes an ESDS item, the entire kit shall be packaged and marked as ESDS. Accompanying documentation shall identify the kit.

e. ESDS items packaged for shipping shall be packaged and marked as required by the contract in addition to the requirements of this publication.

8.4 Equipment Level Test and Maintenance

8.4.1 The following requirements are applicable, both within a facility and in the field, when the equipment being serviced contains ESDS items:

a. Personnel shall 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 shall 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 shall be minimized.

d. Failed ESDS items shall be placed in protective packaging after removal from the equipment.

e. Probing ESDS items with test leads shall be conducted only within a certified ESD protected area

8.5 Equipment Level Installation

8.5.1 ESD-protective covering or protective caps on external terminals, interconnecting cables, and connector assemblies shall not be removed until necessary to permit the installation.

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

8.6 Identification and Marking

8.6.1 ESDS items, equipment, and assemblies shall be identified so as to warn personnel before any potentially ESD-damaging procedure can be performed. Packing lists, inspection reports, travelers, and other paperwork accompanying the hardware shall contain ESDS labels and cautionary notes.

8.6.2 Alternative identification shall be used as approved by the GSFC procuring activity when the prescribed marking is not present. Approving procuring officials shall be qualified by training as described in paragraph 6.1.1.

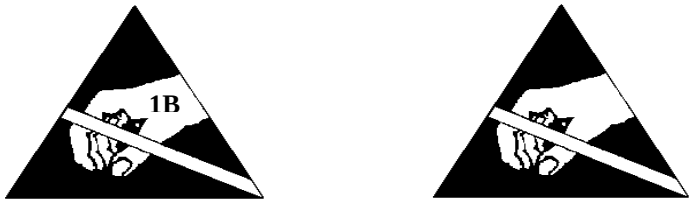


Figure 8-1: Sensitive Electronic Device Caution Symbol (with & without sensitivity class level)

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

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

Figure 8-2: ESD Protective Item Symbol

8.6.4 The ESD common point ground symbol should be used to indicate the location of an acceptable Common Point Ground.

Figure 8-3: ESD Common Point Ground Symbol

9 ASSURANCE PROVISIONS

9.1 Surveillance

9.1.1 Chief Safety and Mission 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 should assess ESD controlled areas prior to beginning work on their flight hardware, and thereafter as necessary to ensure compliance to these requirements.

9.1.2 The area's ESD program monitor shall periodically verify ESD Protected Areas.

9.1.3 The ESD Control Program Manager/Coordinator (see Para. 5.5) is responsible for the initial certification of all ESD Protected Areas.

9.1.4 The ESD Control Program Manager/Coordinator (or their delegate) may perform random assessments.

9.2 ESD Protected Area "PASS" Certification Requirements.

9.2.1 If the ESD protected area meets the requirements of this manual, it shall be certified as approved for use. The certifier shall initial, date, and enter "Approved" on the ESD Protected Area Test Log (see Appendix A). A record shall be maintained by the ESD Control Program Manager of the latest applicable certification date for each location certified.

9.2.2 The certifier shall 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, etc.). For ESD workstations inside clean rooms or other restricted areas, the sticker shall be attached to the ESD Protected Area Test Log and filed with the other records for that area.

9.2.3 The ESD protected area shall remain certified for use unless a discrepancy is found during its use (e.g., broken ground wire, workstation was moved, or rewired, etc.) or has expired "verification" sticker older than 6 months. See abandoned EPAs in Para. 5.6.5

9.3 ESD Protected Area "FAIL" Requirements.

9.3.1 If an ESD protected area fails to meet the requirements of this manual, it shall have a "**Failed ESD Protected Area"** sign placed in an obvious location indicating the station is out of service for handling ESDS items (See appendix C). The person certifying the EPA shall initial, date, and enter "Not Approved for Use" and provide a brief description of the problem in the comments box 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 shall be handled as non conforming material and processed according to GPR5340.2.

9.3.2 The certifying organization and the department responsible for the area shall 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 a required part of the GSFC ESD Program. Standard versions of items a-e below are available through Code 300. However, 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. Failed ESD Protected Area Sign (Appendix C)

e. Wrist Straps/Footwear/Hand Tools Logs (Appendix D)

f. Other area-specific logs as required by each particular ESD protected area (e.g., humidity log).

g. If electronic data logging is used, a soft copy of the data shall be available at the ESD protected area for the certifier to review.

References

1. ANSI/ESD S20.20-2007 Paragraph 6.1
2. ANSI/ESD S20.20-2007 Paragraph 6.2
3. ESD STM5.1-2001
4. ESD STM5.2-1999
5. ESD STM5.3.1-1999
6. ANSI/ESD S20.201999 Paragraph 6.2.6.1
7. ESD TR20.20-2000, Paragraphs 5.3.1.7.1-2 & 5.1.5
8. ESD S4.1-1997
9. ESD TR20.20-2000, Paragraph 5.3.1.7.1
10. ESD TR20.20 – 2000 Handbook, Page 43, Note 1
11. ESD TR20.20-2000 Paragraph 5.3.4.8.1.1
12. ESD TR20.20-2000 paragraph 5.2.3
13. ESD STM12.1-1997
14. ANSI/ESD S541-2003
15. ESD STM2.1
16. ANSI/ESD S20.20-2007 Paragraph 8.2 Note

Appendix A ESD Protected Area Verification Test Procedure

A1. Purpose

This appendix is not part of the ESD Control Plan requirements but defines procedures for performing ESD protected area tests, according to the ESD Control Plan.

A2. Scope

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

A3. Requirements

A3.1 Personnel Requirements

The line manager (branch or office level) shall ensure that:

a. Their ESD program monitor has the appropriate resources and knowledge to implement this procedure (e.g., approved personnel training, current Certificate of Completion of Training, equipment procurement/calibration, etc.).

b. Personnel providing ESD support have the appropriate knowledge and Certificate of Completion of Training to perform the assigned task and that the verifications they perform are within specified time frames, records are current, and reports are issued as specified herein.

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, etc.).

A3.2 Equipment Calibration

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

A4. 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.

A5. Procedure

A5.1 Verifications and Results

A5.1.1 The applicable elements of ESD protected areas shall be verified by personnel currently certified in accordance with paragraph A3.1 of this appendix. See Section 9.1 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.

A5.1.2 Area verifications shall be documented on the ESD Protected Area Test Log (see Appendix B2). The ESD Protected Area Test Log (ATL) shall be used for data entry.

A5.1.3 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.

A5.2 Test Procedures

A5.2.1 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 megohmmeter voltage to 100 V, measure the resistance after 15 seconds, and record 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-out area.

A5.2.2 Test 2: Work Surface Grounding

a. Measure the resistance between 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 megohmmeter voltage to 100 V, measure the resistance after 15 seconds, and record value in the ATL.
b. When checking highly conductive surfaces, a 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 shall go out. Unplug the lamp, press RESET, and record in ATL.

A5.2.3 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 megohmmeter voltage to 100 V, measure the resistance after 15 seconds, and record 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.

A5.2.4 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 megohmmeter voltage to 100 V; measure the resistance after 15 seconds, and record the value in 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).

A5.2.5 Test 6: Wrist Strap Grounding

Resistance shall be measured using an ohmmeter. The measurement shall be made from the wrist strap Groundable Point (Gp) to facility ground in the nearest permanent electrical outlet. Record resistance value in ATL.

A5.2.6 Test 8: Continuous Monitoring Systems

Check for alarm to activate 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.

A5.2.7 Test 9: Stool & Chair Grounding

The qualification tests for any seating used in an ESD protected area shall be in accordance with ESD SMT12.1-1997. 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 megohmmeter voltage to 100 V, measure after 15 seconds. Record the largest resistance measured.

A5.2.8 Test 11: 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 RH, which indicate that more frequent checks may be necessary.

A5.2.9 Test 12: 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 (as determined by the project or organization) of all air ionizers is highly 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.

A5.2.10 Test 13: Soldering Iron Tip to Ground

Soldering iron tips may be checked using a Digital Multimeter and a FR-4 copper-clad PC Board measuring at 2 x 0.5 inches.

a. Attach one lead of the DMM to the AC outlet common ground and the other lead to the PC Board. Set meter to measure AC voltage.
b. 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.

c. 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. See S20.20-1999 Para. 6.2.6.1 (*S20.20-2007 deleted the verification recommendation*).

d. For GFCI-equipped soldering irons, use the manufacturer's recommended procedures to check proper circuit operation.

A5.2.11 Test 14: Equipment & Facility Grounding

a. Measure the resistance between the Main Service Box neutral bond and the ESD protected area 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.

b. When an auxiliary ground (e.g., quiet ground) is used, resistance between the equipment ground and the auxiliary ground shall not exceed 25 ohms.

A5.3 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.

A5.4 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 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 (see GPR 8730.1) 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 (i.e., dates of prior verifications, how far out of tolerance the equipment was found to be, etc.).

Appendix B1 ESD Control Program Certification Log

Measurement Date: _____ HBM Class: _____

Bldg. #	Room #	Workstation ID #	ESD Mon.			Lab 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 Ω from the center work surface to Common Point Ground or <1 ohm w/GFCI. (Conductive plate use)				
3. Floor (or mat) Resistance*		$<10^9$ Ω (*Floor mat required for Class 0)				
4. Floor (or mat) Grounding*		10^6 to 10^9 Ω 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		≤ 1 MΩ				
8. ESD Continuous Monitoring System Alarm		Verify alarm functionality.				
9. Stool/Chair Grounding		10^5 to 10^9 Ω				
10. Mobile equipment resistance to groundable point.		< 1 Ω if tied directly to equipment ground. $<10^9$ Ω 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*		± 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 Ω 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.						
			Certifier's Signature			

*Required for Class 0 work.

Appendix B2 ESD Protected Area Test Log (example)

Building #	**Room #**	**Work Stn ID #**	**HBM Class___**	**ESD Mon.**	**Lab 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 C Examples

Example of Certification/Verification Stickers

This ESD protective workstation is certified compliant to GSFC-WM-001 HBM Class___
Workstation ID: _____
Certified by: _____
Certification date: _____

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

Example of Failed ESD Protected Area Sign

This ESD Protected Area has

FAILED

The requirements of GSFC-WM-001B. It is

NOT APPROVED FOR ESD WORK

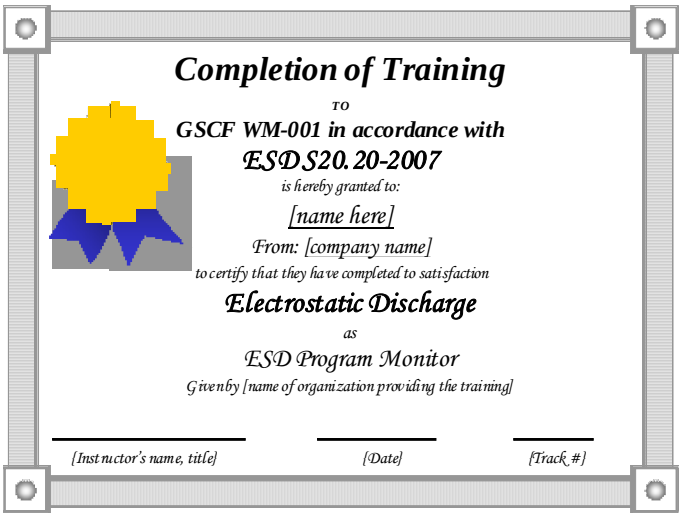
Failed by: _____

On (date): _____

For more information contact the area ESD Monitor

This notice shall not be removed until the Area is re-inspected

Example of Completion of Training Certificate



Appendix D Check Log (example)

Wrist Strap / Footwear / Hand tool

Project(s)_____**Building**_____ **Room**_____

Checker calibration ID_____ **Expiration Date:**_____

Name	**Day of the month**

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31

A different sheet shall be used for wrist strap, footwear or hand tool. ***Circle the title that applies***. If the check is successful mark the slot with a check (✓), use an "X" to indicate a failed check. Failed checks must be corrected before work can resume at the ESD protected area.

The Corrective Action taken shall be recorded on the back of this form.