

June 30, 2025

LPR 8739.21C-1



LPR 8739.21C-1

Effective Date: June 29, 2020

Expiration Date: June 30, 2025

Langley Research Center

Langley Research Center (LaRC) Procedures and Guidelines for Electrostatic Discharge (ESD) Control of ESD Sensitive (ESDS) Devices Program

National Aeronautics and Space Administration

Responsible Office: Safety and Mission Assurance Office (SMAO)

TABLE OF CONTENTS

PREFACE	6
P.1 Purpose	6
P.2 Applicability	6
P.3 Authority	7
P.4 Applicable Documents and Forms	7
P.5 Measurement/Verification	8
CHAPTER 1. GENERAL	9
1.1 Configuration Control	9
1.2 Implementation	9
1.3 Records	10
CHAPTER 2. ESD CONTROL PROGRAM	11
2.1 General	11
2.2 ESD ADMINISTRATIVE OVERVIEW	11
2.3 ESD Technical Overview	11
2.4 ESD Sensitivity Levels	13
2.5 Declaring the Model and Class Required	14
2.6 Personnel Safety	15
2.7 ESD Control Program POC	15
2.8 ESD Program Monitor AND LAB MANAGER	16
2.9 ECA	17
2.10 EPA	17
2.11 Temporary, provisional, and intermittent-use epas	18
2.12 ESD Control Program	19
2.13 Audits and Inspections	19
CHAPTER 3. TRAINING AND CERTIFICATION PROGRAM	21
3.1 PURPOSE	21
3.2 SCOPE	21
3.3 REQUIREMENTS	21
3.4 Training Program	22
3.5 TRAINING Record Maintenance	23
3.6 Maintenance of Training and Certification	24
CHAPTER 4. ESD CONTROL REQUIREMENTS FOR FACILITIES	25
4.1 General	25
4.2 Compliance	25
4.3 Traceability	25
4.4 Identification and Access – ESD Areas	26
4.5 Temporary Use of ESD benches for Non-ESDS Work	27
4.6 Prohibited Materials and Activities	28

4.7 ESD-Protective Work Surfaces	30
4.8 Mobile epas	31
4.9 ESD-Protective Floor Surfaces.....	31
4.10 Personal Grounding Devices.....	32
4.11 Integrity Testing of Personal Grounding Devices	33
4.12 Equipment and Facilities GROUND	34
4.13 Hand Tools, Equipment, and Fixtures	39
4.14 Protective Packaging.....	40
4.15 Temperature Chambers and Cooling Agents	41
4.16 Cleaning and Cleaning Agents	41
4.17 Electrostatic Survey Meters, Voltmeters, and Monitors	41
4.18 Clothing Requirements	42
4.19 Orbit Replaceable Units (ORU) Requirements	43
CHAPTER 5. ESDS ITEM HANDLING	46
5.1 General	46
5.2 Special Requirements for Highly Sensitive Items	46
5.3 Receiving, Internal Handling, and Shipping.....	49
5.4 Equipment Level Test, Maintenance, AND INSTALLATION	49
5.5 Identification and Marking.....	49
CHAPTER 6. ASSURANCE PROVISIONS	51
6.1 Surveillance.....	51
6.2 EPA “PASS” Certification Requirements	51
6.3 EPA Area “FAIL” Requirements	51
APPENDIX A. Definitions	53
APPENDIX B. Acronyms	56
APPENDIX C. EPA Verification Test Procedure.....	57
APPENDIX D. Lab Tailoring Interoffice Format.....	63
APPENDIX E. Procedure for Verifying Manual Wrist Strap Checkers.....	64
APPENDIX F. Resistive Ranges	65
APPENDIX G. Non-Conformance Procedure	66

LIST OF FIGURES

Figure 4-1: Typical ESD Grounded Workstations	29
Figure 4-2: Workstation Common Point Ground	29
Figure 4-3: Main Service Box	35
Figure 5-1: Sensitive Electronic Device Caution Symbol.....	50
(with & without sensitivity class level).....	50
Figure 5-2: ESD Protective Item Symbol.....	50
Figure 5-3: ESD Common Point Ground Symbol.....	50

LIST OF TABLES

Table 1-1: Record Retention (NPR 1441.1)	10
Table 2-1: ESDS Component Sensitivity Classifications – HBM	13
Table 2-2: ESDS Component Sensitivity Classifications – MM	14
Table 2-3: ESDS Component Sensitivity Classifications – CDM.....	14
Table 4-1: ESD Control Program Verification Schedule and Measurements	26
Table 4-3: ESD Sensitivity for Selection and Performance of Air Ionizers.....	39
Table 5-1: Summary of Requirements Applicable to HBM Class 0 (see §2.4.2.1).....	47

CHANGE HISTORY LOG

Status	Document Revision	Approval Date	Description
Baseline	A	4/13/2011	Initial Release <i>This document is derived from NASA-HANDBOOK 8739.21</i>
First Mod	B	3/5/2015	First revision includes modified control parameters, ESD Control specifications regarding metrology, inclusion of Mission Assurance standards for practice
Second Mod	C		Five-year review of document including updating citations and changes to procedures, as well as clarifying requirements.
Third Mod	C-1	9/29/22	Removed reference to canceled Agency directive NPD 8730.5

PREFACE

P.1 Purpose

- a. The National Aeronautics and Space Administration (NASA) quality requirements for Electrostatic Discharge (ESD) safety and control, which are defined herein, are specified in addition to the administrative and technical requirement guidelines listed in the American National Standards Institute (ANSI)/ESD S20.20 requirements document. The ANSI/ESD S20.20 is the ESD Association's 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).
- b. This NASA Langley Research Center (LaRC) Procedural Requirement (LPR) sets the standard for the development of an ESD Control Program Plan (CPP) for all projects, or any portion of any external project, where NASA LaRC has the responsibility to build and handle ESD Sensitive (ESDS) hardware.
- c. This LPR describes the responsibilities and requirements for establishing and maintaining an ESD CPP that meets or exceeds the ESD Association (ESDA) ANSI/ESD S20.20 requirements, and provides specific instructions pertaining to ESD standards related to personnel, laboratories, tools, equipment, training, and safety.

P.2 Applicability

- a. This LPR is applicable to all NASA LaRC personnel, civil servants and contractors (to the extent provided by their contracts), and to all NASA LaRC support organizations performing work on all aeronautical flight, space flight, Ground Support Equipment (GSE), or any mission-critical work related to electrical and electronic parts, assemblies, and equipment, excluding electrically initiated explosive devices.
- b. This LPR is provided as the NASA LaRC ESD CPP resource for all organizations that handle ESDS items for NASA projects and are subject to the requirements of ANSI/ESD S20.20.
- c. This document applies to all facilities where NASA aeronautical flight, space flight, or GSE hardware will be processed, including electrical and mechanical (as well as lifting fixtures), and hardware production where the end item may not be mission-critical yet is expensive to replace or is a long-lead acquisition item.
- d. The practices described herein are generally suitable for the ESD sensitivity levels of the Human Body Model (HBM) Classes 0 and 1A and Machine Model (MM) Class M1.
- e. For special instances where the Charge Device Model (CDM) applies, additional precautions and practices beyond those described herein may be necessary. See section 5.2.
- f. In this directive, all mandatory actions (i.e., requirements) are denoted by statements containing the term "shall." The terms "may" denotes a discretionary privilege or permission, "can" denotes statements of possibility or capability, "should" denotes a good practice and is recommended, but not required, "will" denotes expected outcome, and "are/is" denotes descriptive material.

- g. In this directive, all document citations are assumed to be the latest version unless otherwise noted.

P.3 Authority

- a. NASA Policy Directive (NPD) 1400.1, Documentation and Promulgation of Internal NASA Requirements and Charters.
- b. NASA Notice of Cancellation of NASA-STD-8739.7, w sites ANSI/ESD S20.20 for future acquisitions, which defines the requirements necessary to design, establish, implement and maintain an Electrostatic Discharge (ESD) Control Program for activities that manufacture, process, assemble, install, package, label, service, test, inspect or otherwise handle electrical or electronic parts, assemblies and equipment susceptible to damage by electrostatic discharges greater than or equal to 100 volts Human Body Model (HBM) and 200 volts Charged Device Model (CDM).

P.4 Applicable Documents and Forms

- a. NASA Procedural Requirements (NPR) 1441.1, NASA Records Management Program Requirements.
- b. LF 21, ESD Control Program Certification Log.
- c. LF 22, Check Log (ESD).
- d. LF 23, ESD Protected Area Test Log.
- e. LF 126, Laboratory Daily Humidity Log.
- f. LF 191, Bonded Stores Audit Checklist.
- g. LF 442, ESD Non-Conformance Corrective Action.
- h. LF 359, Workmanship Standards Certification Record.
- i. LF 382, Certification/Verification Sticker.
- j. ANSI/ESD S6.1, For the Protection of Electrostatic Discharge Susceptible Items – Grounding.
- k. ANSI/ESD S8.1, For the Protection of Electrostatic Discharge Susceptible Items – Symbols – ESD Awareness.
- l. ANSI/ESD S20.20, Protection of Electrical and Electronic Parts, Assemblies and Equipment (Excluding Electrically Initiated Explosive Devices).
- m. ANSI/ESD SP3.3, Periodic Verification of Air Ionizers.
- n. ANSI/ESD STM2.1, Garments – Resistive Characterization.
- o. ESD JS-001, Electrostatic Discharge Sensitivity Testing – Human Body Model (HBM) – Component Level.
- p. ESD STM5.2, Electrostatic Discharge Sensitivity Testing – Machine Model (MM) – Component Level.
- q. ANSI/ESD STM12.1, Seating – Resistive Measurement.

- r. ESD STM7.1, Resistive Characterization of Materials – Floor Materials.
- s. ESD TR20.20, Handbook for the Development of an Electrostatic Discharge Control Program for the Protection of Electronic Parts, Assemblies and Equipment.
- t. ESD TR53-01, Protection of Electrostatic Discharge Susceptible Items Compliance Verification of ESD Protective Equipment and Materials.

P.5 Measurement/Verification

Methods for personnel verification are listed in Section 3. Methods for equipment verifications are listed in Appendix C, Section 5.

P.6 Cancellation

LPR 8739.21B, dated March 5, 2015

David F. Young June 29, 2020

Title

Date

Distribution:

Approved for public release via the Langley Management System; distribution is unlimited

CHAPTER 1. GENERAL

1.1 CONFIGURATION CONTROL

1.1.1 This Langley Procedural Requirement (LPR) is controlled and enforced by the NASA LaRC Safety and Mission Assurance Office (SMAO).

1.1.2 Requests for technical or content changes shall be processed in accordance with NASA LaRC Langley Management System (LMS) document control change procedures.

1.2 IMPLEMENTATION

1.2.1 This LPR includes requirements for facility preparations and certifications, records management, minimum qualifications and training of responsible personnel, guidance for assessing the sensitivity of the hardware to be handled, and the declaration and execution of special processes/criteria as applicable.

1.2.2 The Electrostatic Discharge (ESD) Point of Contact (POC) is the ESD Control Program Manager and shall be a civil servant from SMAO.

1.2.2.1 The ESD POC shall advise and assist inspectors, operators, program monitors, lab managers, contractors, and other authorized personnel in the proper and effective implementation of the provisions of this LPR.

1.2.2.2 The ESD POC and the Program Manager are the same person, whose title shall be used interchangeably.

1.2.2.3 The ESD POC shall verify the compliance of the NASA LaRC ESD Control Program Plan (CPP), as required by the ESD Association (ESDA) that it meets or exceeds the industry standard ANSI/ESD S20.20.

1.2.3 The requirements contained herein shall be implemented by all personnel, including but not limited to, the NASA LaRC ESD POC, inspectors, operators, program monitors, lab managers, contractors (to the extent provided by their contracts), all Audit Team members, and Audit Coordinators.

1.2.4 The hardware designer, based on the most sensitive/vulnerable component to be protected, in coordination with the SMAO POC, shall determine the adequate ESD Protected Area (EPA) certification level and associated ESD event model to be used.

1.2.4.1 The typical default EPA certification level is Human Body Model (HBM) Class 1A (See Table 2-1).

1.2.4.2 Where the HBM does not provide sufficient protection for the hardware, the Machine Model (MM) or the Charge Device Model (CDM) should be considered when designing the EPA. See Section 2.3 for a technical overview of the models and see section 2.4 for the model classification limits.

1.2.4.3 For areas required to protect extremely sensitive devices, see Section 5.2.

1.2.5 The requirements herein facilitate compliance to NASA LaRC ESD requirements; however, these requirements shall not supersede or preclude project review and approval of external suppliers' ESD CPP for compliance with ANSI/ESD S20.20.

1.2.5.1 The Project's Contracting Officer shall ensure that Project Suppliers' ESD CPPs meet the requirements of ANSI/ESD S20.20, as well as any Project-specific ESD requirements. Projects shall use this LPR as a benchmark against which external suppliers'

plans are evaluated.

1.2.5.2 When the supplier proposes to use ESD control techniques not specified in this LPR, the supplier shall document the details of the proposed techniques and provide appropriate test data.

1.3 RECORDS

1.3.1 Records required by the processes described herein shall be retained per Table 1-1 below.

Table 1-1: Record Retention (NPR 1441.1)

Record Title	Record Custodian	Retention
Training records	Langley Human Resources Office and/or Supervisor	NPR 1441.1; 1/22B – Temporary – Destroy 2 years after employee discontinues or completes training.
ESD Workstation Records: ESD Control Program – Certification Log: LF 21 Check Log when no CMS is used: LF 22 EPA Test Log: LF 23	Laboratory Manager or owning project manager when there is no Program Manager	NPR 1441.1; 8/103 & 8/107 – Temporary – Destroy/delete when between 5 & 30 years after program/project termination. Do not retain longer than life of program/project plus 5 years.
Temporary/Intermittent Workstation records: ESD Control Program – Certification Log: LF 21 Check Log when no CMS is used: LF 22 EPA Test Log: LF 23	Project Manager	NPR 1441.1; 8/109 – Temporary – Destroy/delete when between 2 & 15 years old. Do not retain longer than life of program/project plus 5 years.

CHAPTER 2. ESD CONTROL PROGRAM

2.1 GENERAL

2.1.1 The requirements contained within this LPR meet or exceed the requirements of ANSI/ESD S20.20, to include the NASA ESD Workmanship requirements for processing ESD-sensitive equipment.

2.1.2 Proper control of ESD is critical at every process step, from electronic part manufacturing through testing and shipment; to incorporation on printed wiring boards, electronic modules, and directly into boxes; to final installation or integration.

2.2 ESD ADMINISTRATIVE OVERVIEW

2.2.1 All paperwork or copies thereof associated with maintaining any given EPA shall be kept at or near the EPA. Paperwork includes, but is not limited to:

- a. Tailor document that describes any deviation from the requirements listed herein. See Appendix D for the recommended format.
- b. LF 382, "Certification/Verification Sticker."
- c. LF 21, "ESD Control Program Certification Log."
- d. LF 23, "ESD Protected Area Test Log," filled in with inspection data.
- e. LF 22, "Check Log (ESD)." Used when Continuous Monitoring Systems (CMS) are not in use for wrist strap and/or foot wear, and to record hand tools
- f. LF 126, "Laboratory Daily Humidity Log," unless a continuous automated recording system is in use.

2.2.2 When the humidity recording process is automated, periodic data dumps shall be forwarded to the NASA ESD Program Manager in electronic form.

2.3 ESD TECHNICAL OVERVIEW

2.3.1 If not properly addressed, ESD could be a formidable threat to active components.

2.3.2 Proper preparations and handling are necessary to prevent damage during different phases of development, fabrication, installations, packaging and transportation, and assembly.

2.3.3 ESD Sensitive (ESDS) components shall be clearly marked ESDS.

2.3.4 All personnel and facilities shall be prepared to take precautions and follow best practice procedures to avoid an ESD event.

Note: A good example of an ESD event is the discharge experienced when touching the metal doorknob on the way out of a carpeted room. Charge accumulates by friction. Temperature, dryness, and other conditions contribute to the level of charge accumulated on the body. The "zap" experienced and heard is a form of ESD discharge. ESD is the transfer of electrostatic charge between bodies with an electrical potential difference.

2.3.5 In general, there are three methods of charge generation when considering the basics of static electricity:

- a. **Triboelectrification:** The phenomena that produces electrostatic charges by friction. Although the name comes from the Greek word "tribos," for "rubbing" of materials, the

two materials need only to come into contact for electrons to be exchanged; a charge is generated when the two materials separate. For example, two atoms of different materials may each have a neutral charge until contact-separation occurs, by which one atom may lose one electron from its outermost shell to the outermost shell of the other, leaving one atom positively charged and the other negatively charged.

- b. **Induction** alone merely polarizes one object by a charged object; an example would be a positively charged rod polarizing a gold-leaf electroscope. The electroscope remains neutral unless the top plate becomes momentarily grounded, i.e., by touching it with a finger. The electrons from ground will flow into the polarized electroscope, leaving the electroscope negatively charged when the ground connection is removed.
- c. **Conduction** charging occurs when a charged object makes contact with a neutral object, and therefore transfers its \pm charge. A negative object will transfer electrons to the neutral object; a positive object will pull electrons from the neutral object. One example is a person with a built-up static charge on his body discharging that energy into a printed circuit board (PCB) through his finger by pointing too closely to the board.

2.3.6 Conductive objects can become electrostatically charged if not properly grounded. If an ESD event occurs in the proximity of an ESDS device, damage can occur. Charge is not localized on the surface of a conductor but is spread uniformly over the conductor's surface. Thus, very low voltages are capable of damaging ESDS devices.

2.3.7 Flat panel monitors, and other high-voltage electric devices can create high electrical field potentials. Exposing ESDS components through such a field can induce internal currents causing damage even if the device does not come in direct contact with the charged surface.

2.3.8 Precautions shall be taken (for a slow controlled discharge) when grounding a device that is suspected of becoming charged by an external electrostatic field.

2.3.9 Packaging of Integrated Circuits (ICs) and modern sophisticated avionics and sensing components are extremely small and continue to shrink as technology advances. This trend increases the ESD vulnerability of these devices because slight charges accumulate on these conductive elements that can easily exceed the breakdown potential of the insulating layers or the air gaps between them, causing irreparable damage. The presence of physical damage, such as fine scratches or contaminants within and on the surface of the device, tends to increase ESD sensitivity.

2.3.10 Inside a clean room, requirements of contamination control may place restrictions on the approaches that ordinarily are available for controlling ESD.

2.3.10.1 A field meter shall be used to measure the static voltage on a clean tent's wall panels; the voltage measurement on those panels shall be $< \pm 200V$.

2.3.10.2 All tools, equipment, and gear shall be wiped clean using Isopropyl alcohol prior to entering into a clean room.

2.3.10.3 A clean room is a critical application area and shall be free of clutter.

2.3.11 The smallest ESD event most people can detect is about 2,000 volts. A similar voltage level, when applied to an ESDS device, can result in catastrophic failure. Some parts

are severely damaged by ESD events in the orders of tens of volts. Therefore, many ESD destructive events are not noticeable by human detection alone.

2.3.12 Three general ESD damage failure modes can be defined:

- a. Catastrophic failure – when a catastrophic failure occurs, the device does not function at all.
- b. Parametric failure – when a parametric failure occurs, the device has been slightly damaged so that it still performs, but not to specification.
- c. Latent failure – when a latent failure occurs, the device has been stressed, but it does not fail immediately upon exposure. The device continues to perform within acceptable tolerance limits, but is likely to fail later.

2.3.13 Both catastrophic and parametric failures are usually found during product testing, where isolation and replacement are possible.

2.3.14 Latent failures remain undetected during routine system testing and product development.

2.4 ESD SENSITIVITY LEVELS

2.4.1 The ESD sensitivity of devices shall be determined using three electrical models: the HBM, the MM, and the CDM.

2.4.2 Device classification using any of the electrical model classes in Tables 2-1, 2-2, or 2-3 indicates that the device will not be damaged by that type of discharge, with an energy level that relates to the voltage level shown for that class level.

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

Table 2-1: 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

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

Table 2-2: ESDS Component Sensitivity Classifications – MM

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

2.4.2.3 CDM: This model considers the situation where a device is charged and then discharged to ground through one pin or connector. The CDM sensitivity of a given device may be package-dependent.

Table 2-3: ESDS Component Sensitivity Classifications – CDM

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

2.5 DECLARING THE MODEL AND CLASS REQUIRED

2.5.1 The EPA shall be designed and verified to an ESD Sensitivity level by the ESD Program Monitor; see section 2.8 below for a full description of this person's duties.

2.5.2 This rating shall be specified in the EPA's engineering documentation and will be determined by one of the following methods:

- Assuming that all ESD products have an HBM sensitivity of 100 volts.
- Actual testing of products using accepted test methods.
- Referencing ESD part test data in published documents.
- Or use an alternate option listed in ANSI/ESD S20.20 Table 4, "ESD Susceptibility Test References for Devices," when the previous three options are considered neither cost effective nor technically viable.

2.5.3 The Research Model (RM) is yet another category specific only to NASA LaRC, and generally based on the HBM 1A classification. The RM is an ESD Controlled Area (ECA), and within it is at least one EPA. The category of EPA is established solely for the research community who routinely works with exposed ESDS components or exposed ESDS assemblies, in any such area where research and non-mission critical hardware or software is being used. The minimal set of requirements shall include:

- All persons must have a current ESD certification.

- b. A Relative Humidity (RH) monitor exists in the room.
- c. Work surfaces where these parts and assemblies are located are dissipative.
- d. Grounding through ESD wrist strap is provided for all ESDS hardware interfaces.
- e. All deviations shall be justified in the tailored document.

2.5.4 The ESD POC shall certify the EPA based on the ESD model and Class level reported by the ESD Program Monitor.

2.5.5 The most sensitive device to be handled during processing shall dictate the minimum protection afforded by the EPA.

Note: Parts mounted in high-level assemblies are usually less sensitive. The recommended default EPA certification level is HBM Class 1A (see Table 2-1).

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

2.5.7 Any requirement specified for HBM Class 0 shall also apply to MM Classes M1 and M2 and CDM Classes C1 and C2.

2.6 PERSONNEL SAFETY

2.6.1 The procedures and equipment described in this document may expose personnel to hazardous electrical conditions.

2.6.1.1 Users of this LPR shall comply with all applicable laws, regulatory codes, and both external and NASA LaRC internal applicable safety procedures.

2.6.1.2 Users are cautioned that this document alone shall neither replace nor supersede requirements for personnel safety found in other guidance.

2.6.2 Ground fault circuit interrupters (GFCI) and other electrical safety procedures shall be used whenever personnel might come into contact with electrical sources.

2.6.3 Users shall exercise electrical hazard reduction practices.

2.6.4 Users shall follow proper grounding.

2.7 ESD CONTROL PROGRAM POC

2.7.1 The ESD POC shall be the primary point of contact and responsible party for the ESD plan implementation.

2.7.2 The ESD POC shall carry out the following responsibilities:

- a. Produce, submit, and execute the ESD CPP traceable to the applicable requirements of ANSI/ESD S20.20.
- b. Verify LaRC's compliance with this ESD CPP.
- c. Certify new EPAs.
- d. Recertify expired or failed EPAs.
- e. Maintain records of EPA certification.
- f. Periodically audit certified EPAs. The ESD POC may provide advance notice of a randomly scheduled audit inspection but is not required to do so.

- g. Maintain a record of audits performed.
- h. Report results of certifications and audits to the proper ESD Program Monitors.
- i. Report results of certifications and audits to upper management.

2.7.3 The POC shall follow the Non-Conformance procedure defined in appendix G if any one of the test parameters listed on LF-21 fail.

2.8 ESD PROGRAM MONITOR AND LAB MANAGER

2.8.1 Program Monitor: The organization responsible for an EPA shall designate an ESD Program Monitor for that area.

2.8.1.1 ESD Program Monitors may be responsible for more than one EPA.

2.8.1.2 The ESD Program Monitor is responsible for:

- a. EPA maintenance.
- b. ESD signage in the area.
- c. Scheduled EPA verifications.
- d. Random inspections and audits of EPAs.
- e. Up-to-date verification records (logs) and maintenance records.
- f. Reactivation of EPAs with less than 6 months of inactivity.
- g. Transfer of records during project transitions.
- h. Monitoring and maintenance of additional protective measures when needed to meet specialty certification requirements for handling highly sensitive devices.
- i. Authorization to use EPAs (except Class 0 rated EPAs) for non-ESDS work.
- j. Notifying ESD POC of any deviations sought against this LPR, and providing that person with a copy of the tailored document.
- k. May assign one Lab Manager per EPA. The Lab Manager shall have been trained by the POC or by the Program Monitor.

2.8.1.3 The ESD Program Monitor shall follow the Non-Conformance procedure defined in appendix G if any one of the test parameters listed on LF-23 fail.

2.8.2 Lab Manager: The Program Monitor may delegate their authority to a Lab Manager.

2.8.2.1 The Lab Manager shall be responsible for no more than one EPA.

2.8.2.2 The Lab Manager shall be certified to the current version of the LPR 8739.21 for Awareness training, and to LaRC Program Monitor training.

2.8.2.3 The Lab Manager is responsible for:

- a. Scheduled EPA Verifications
- b. Up-to-date verification records (logs) and maintenance records.
- c. Notifying ESD Program Monitor of any deviations sought against this LPR.

2.9 ECA

2.9.1 An ESD Controlled Area (ECA) shall have at least one EPA within it.

2.9.2 An ECA could be an entire room or a segment of a room. There is no requirement to have an ECA, but in cases where it is desired to have a large area set aside for ESD sensitivity and certifying that whole area is too costly and technically not necessary, then that area may be defined as an ECA.

2.9.3 An ECA is an area where ESD caution shall be observed, but adherence to EPA protocol is not necessary throughout the area other than where the EPA is properly marked.

2.10 EPA

2.10.1 An EPA may be a single workstation, laboratory, room, or building, or any area with pre-defined boundaries, designed to limit damage to electrical hardware by ESD events.

2.10.2 EPAs may be permanent or temporary.

2.10.3 During the certification process or a subsequent verification test, if a test item from Table 4-1 causes the EPA to fail, the non-conformance shall be identified and recorded in the applicable Certification/Verification Langley Form.

2.10.4 All non-compliances that cause an EPA to fail will be dispositioned as either repair, replace, or use-as-is, and the corrective action shall be documented through completion.

2.10.5 When an EPA is not maintained, the ESD Program Monitor shall decommission it by marking the area as not approved for use with signage provided by the POC.

2.10.6 If the area to be used has not been maintained for a period not to exceed six months, the ESD Program Monitor shall reactivate the area by verifying that the area passes the tests in Table 4-1, by affixing an LF 382 sticker, and by initiating an LF 23, "ESD Protected Area Test Log" (ATL).

2.10.7 When an EPA has been decommissioned and marked as not approved for use for a period exceeding six months, it shall be considered "abandoned."

2.10.7.1 Activation of an abandoned area shall be accomplished via certification by the ESD POC.

2.10.7.2 The ESD Program Monitor shall properly mark the status of abandoned workstations if they may be mistaken for active EPAs.

2.10.8 Certified EPAs can protect ESD-sensitive parts, assemblies, and equipment that are without ESD-protective covering or packaging; however, ESDS devices shall not be transported away from the EPA, or between EPAs, without using ESD-safe packaging or carriers due to the risks of ESD damage.

2.10.9 The ESD POC shall initially certify all EPAs and recertify them as needed (see section 2.7 and APPENDIX C). The following are prerequisites for EPA certification:

- a. Personnel entering the EPA shall have current ESD awareness certification.
- b. A control program for verification records is instituted.
- c. EPA environment measurements are up-to-date and meet Class-level requirements.
- d. ESD workstation measurements are up-to-date and meet Class-level requirements (see Table 4-1).

2.10.10 The ESD POC shall recertify EPAs when:

- a. Rewiring of the area has occurred.
- b. New work areas are added or moved.
- c. New features are added, such as a new conductive floor or an upgrade to a Continuous Monitoring System (CMS).
- d. An abandoned EPA is reactivated.
- e. An ESD failure is traced to the particular ESD-protected workstation.

2.10.11 The ESD Program Monitor shall use LF 21, "ESD Control Program Certification Log," to record the certification data.

2.10.9.1 The ESD Program Monitor shall use proper identification stickers to indicate the compliance of all benches, chairs, stools, shelving, microscopes, wrist straps, foot straps, and other grounding devices.

2.10.12 Once certified by the ESD POC, certification of an EPA shall be maintained via scheduled inspections, which will be performed by the assigned ESD Program Monitor.

2.10.10.1 EPA certification shall be voided if the scheduled verification is not performed for more than 6 consecutive months, or if any of the conditions in 2.10.8 above have been encountered (see also paragraph 6.2.2).

2.10.13 The ESD Program Monitor shall ensure that all verification equipment is calibrated to the manufacturer's specifications and kept up-to-date to properly execute an EPA certification/recertification.

2.11 **TEMPORARY, PROVISIONAL, AND INTERMITTENT-USE EPAS**

2.11.1 Temporary EPAs are areas created for use while working on a specific project for a continuous period of less than 3 months (1 month for Class 0).

2.11.1.1 These areas shall be certified by the ESD POC for a specific period of time.

2.11.1.2 The ESD POC shall store all verification records with the Project's Integration and Test (I&T) records.

2.11.1.3 A long-term verification schedule requirement is not applicable to these types of EPAs; however, all other requirements shall apply if the temporary EPA is converted to a permanent EPA.

2.11.2 Provisional EPAs are areas created for a one-time use only and where it is not practical to set up a temporary EPA.

2.11.2.1 Provisional EPAs shall be the responsibility of the ESD POC.

2.11.3 The lack of certification and oversight associated with provisional EPAs makes them incompatible with applications that require handling items that require tighter controls and lower ESD voltage levels than the default HBM 1A (see Table 2-1).

2.11.4 Intermittent use of EPAs is defined as the use of a permanent EPA for periods lasting less than one month at a time, with longer periods of idle time.

2.11.4.1 When not in use, the ESD Program Monitor shall mark intermittent-use EPAs as temporarily Out-of-Service.

2.11.4.2 Following the idle period and prior to use, the ESD Program Monitor shall re-commission the EPA using standard verification methods (see Appendix C).

2.11.4.3 These EPAs are not required to be recertified by the ESD POC as long as the idle period does not exceed 6 months.

2.11.4.4 During idle periods, the ESD Program Monitor shall ensure that intermittent-use HBM Class 0 EPAs are not used for any other purpose and they are kept clean.

2.12 ESD CONTROL PROGRAM

2.12.1 The NASA LaRC ESD POC shall use the following criteria when conducting internal audits:

- a. Verification that EPAs conform to the limits described in Table 4-1 prior to use.
- b. Use of protective personnel clothing and proper personnel grounding at all necessary points where ESDS items will be handled.
- c. All personnel handling ESDS items, or the inspection thereof, have received the necessary training to the appropriate working level (e.g., Operator, Inspector, or ESD Program Monitor) and have current certification.
- d. Performance of audits and inspections to ensure the integrity of the EPAs and equipment in accordance with the requirements listed in Table 4-1.
- e. Inspection of documentation for ESD markings, precautions, and handling procedures, as applicable.
- f. Proper identification of ESDS items.
- g. Handling of ESDS items only at approved EPAs.
- h. Description of field operations and precautionary procedures, when applicable, to prevent ESD damage.
- i. Maintenance of auditable records and documentation for all measurements required in Table 4-1.
- j. When several projects share an EPA, the original records are kept at the EPA and copies are distributed to each project as needed.
- k. Use within EPAs only of materials recognized by the ESD Association as ESD-protective materials (i.e., the material complies with ESD Association-recommended practices).

2.13 AUDITS AND INSPECTIONS

2.13.1 General: The ESD Program Monitor shall be responsible for the following activities related to records:

- a. Maintain records regarding the EPA at the site.
- b. Use LF 23 for creating the area test log and recording data related to deficiencies, corrective actions, and related verification and validation.

2.13.2 Audits: EPA certifications are achieved through audits performed by the ESD POC or on their behalf by an Audit Team or Audit Coordinator.

2.13.2.1 Certification is based on yearly audits of randomly selected EPAs.

2.13.2.2 The ESD Program Monitor shall perform internal audits on an annual basis of all EPAs under the program's jurisdiction, using LF 21, "ESD Control Program Certification Log," and providing that data to the ESD POC to meet this requirement for each year subsequent to the initial certification, which was done by the POC or designated technical expert.

2.13.3 Inspections/Verifications: Program Monitors shall perform inspections of their EPA.

2.13.3.1 The inspections consist of a general review of the area and records, as well as the verification described in Appendix C.

2.13.3.2 These inspections may be carried out any time the ESD Program Monitor deems them necessary to ensure continuous compliance of the EPA to the ESD-assigned safety level.

2.13.3.3 As a minimum, inspections shall be done concurrently with the verification tests (see Table 4-1).

2.13.4 New Projects: If a new Project takes over the EPA and the old records are not available, the ESD Program Monitor shall perform a re-verification of the EPA in accordance with Appendix C and for attaching new dated stickers to the applicable workstations.

CHAPTER 3. TRAINING AND CERTIFICATION PROGRAM

3.1 PURPOSE

3.1.1 The purpose of the ESD Training and Certification Program is to teach and make personnel familiar with the NASA LaRC ESD CPP and to minimize both catastrophic and latent failures associated with an ESD event.

3.1.2 Successful completion of this NASA LaRC training program shall be achieved by those persons listed in section 3.2.1 who are involved in any of the functions listed in section 3.3.2 prior to any flight, space flight, or mission-critical work being performed.

3.2 SCOPE

3.2.1 Training and certification to this program shall apply to all NASA LaRC personnel, civil servants and contractors (to the extent provided by their contracts), and to all support organizations on or off the Center who are performing inspections and/or operations on any flight, space flight, or mission-critical work related to electrical and electronic parts, assemblies, and equipment, excluding electrically initiated explosive devices.

3.3 REQUIREMENTS

3.3.1 The NASA LaRC ESD POC shall be responsible for the development of an online training module for ESD Awareness.

Note 1: To access the online ESD training in SATERN you must (a) Log into SATERN, (b) Search for: "ESD CONTROL TRAINING PREREQUISITE," (c) Complete the course requirements, (d) Print your certificate and your LF 359 and have your LF 359 signed by your supervisor, and (e) send a copy of your signed LF 359 to the Safety and Facility Assurance Branch (SFAB) Safety Specialist; you will be notified when your certification card is ready for pickup.

Note 2: If you are not part of NASA LaRC nor working on a NASA LaRC project, you may use this training as part of your training program; however, you are responsible for your own certification process.

3.3.2 ESD awareness training and certification shall be applicable to all personnel who perform or supervise any of the following ESD-related functions:

- a. Instruction
- b. Design
- c. Operator (i.e., handling, installation, maintenance, and repair)
- d. Inspection and testing
- e. Procurement (only if handling or specifying ESDS materials), storage, shipping, and receiving
- f. Janitorial (only if responsible for cleaning in EPAs)

3.3.3 The NASA LaRC SMAO shall implement an ESD training program and will provide a Level B instructor for classroom instruction for those not able to take the online SATERN training and test.

3.3.4 ESD training instructors shall be certified based on their competency as instructors and their knowledge of the NASA LaRC ESD CPP.

3.3.4.1 A “Train the trainer” system can be used by the NASA LaRC ESD POC to train larger numbers of “Level B” trainers, who in turn may train Operators and Program Monitors.

3.3.4.2 The ESD POC is a “Master” and “Level A” instructor.

3.3.5 Operators that handle ESDS devices shall pass the basic training module before being certified to work on flight hardware.

3.3.6 Personnel performing inspections and/or conducting tests shall be certified through the NASA LaRC online awareness training.

3.3.7 The ESD Program Monitor shall ensure that EPAs provide protection to sensitive items not only with approved and verified equipment, furniture, fixtures, tools and materials, but also by limiting access only to trained and certified personnel.

3.3.7.1 Certification audits of EPAs shall include confirmation of the certification status of the personnel operating therein.

3.3.7.2 Training shall be performed on a biennial basis.

3.3.7.3 The certifying authority shall ensure that certified individuals will correctly implement this NASA LaRC ESD CPP.

3.3.8 The training organization shall provide evidence of completion of training to the trained individual (and may call this evidence “certification of training”); however, a completion of training card or a completion of training certificate is not a substitute for certification.

3.4 **TRAINING PROGRAM**

3.4.1 The online SATERN instruction consists of a video from the IPC, followed by a NASA LaRC specific slide presentation, and a test.

- a. A passing score of at least 90 is required.
- b. This LPR may be kept open for reference during the test.
- c. Certification is required for Operators, Inspectors, Procurement officials who handle ESDS items, the Janitorial staff responsible for cleaning an EPA, and personnel involved with testing Mission Critical Hardware.

3.4.2 Classroom instruction may be offered for those in Procurement and Janitorial, and will be 2 hours in duration.

3.4.3 The NASA LaRC ESD POC shall have and maintain a database of trained individuals who work at or on NASA projects where ESD is a concern. This includes all NASA LaRC personnel, civil servants and contractors alike.

3.4.4 The training shall include the following, at a minimum:

- a. ESD Control Program policies, procedures, and practices.
- b. Principles of static electricity and methods of ESD control.
- 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 audits.
- i. Administration and recordkeeping.
- j. Class preparation, presentation, and test administration.
- k. Demonstration of ability to teach a class.

3.4.5 The NASA LaRC training program shall instruct Program Monitors in how to fully implement the NASA LaRC ESD CPP in their respective EPAs.

3.4.5.1 NASA-approved ESD certification may be used in lieu of NASA LaRC ESD certification, but a record and photocopy of that certification shall be forwarded to the NASA LaRC ESD POC.

3.4.5.2 Non-NASA ESD training shall not replace formal NASA training, and such training is not recognized under this LPR.

3.4.6 Civil servant personnel or personnel performing work in a NASA LaRC facility shall contact the NASA LaRC ESD POC for information regarding the ESD CPP Control implementation plan and availability of required training.

3.5 **TRAINING RECORD MAINTENANCE**

3.5.1 NPR 1441.1 records retention requirements apply to training records.

3.5.2 Training records shall be retained for at least two years.

3.5.3 Federal Acquisition Regulations and/or other Project-level requirements may specify longer retention periods.

3.5.4 Training records shall include the following information:

- a. The applicable standard: NASA LaRC ESD CPP LPR 8739.21, “Langley Research Center (LaRC) Procedures and Guidelines for Electrostatic Discharge (ESD) Control of ESD-Sensitive (ESDS) Devices Program” (i.e., the NASA LaRC ESD CPP)
- b. Name of the trainee.
- c. Name of the organization that employs the trainee.
- d. Date of completion of training.
- e. Name of the instructor and organization providing the training.
- f. Traceability number of the completion record or training certificate.
- g. Successful completion of training shall be provided to students for submission to the personnel certifying authority.

3.6 MAINTENANCE OF TRAINING AND CERTIFICATION

3.6.1 Level B instructors, ESD Program Monitors, Designers, Operators, Inspectors, Testers, Procurement/Storage/Shipping/Receiving, and Janitorial personnel shall undergo periodic retraining and recertification under the following conditions:

- a. New ESD control techniques have been approved that require different skills.
- b. Two years have elapsed since last certification.
- c. Job performance indicates inadequate understanding of ESD controls.
- d. Evidence of successful completion of training is not available to the certifying authority.

CHAPTER 4. ESD CONTROL REQUIREMENTS FOR FACILITIES

4.1 GENERAL

4.1.1 This section pertains to EPAs, including facilities, equipment, tools, and materials. The instructions and recommendations in this section include specific facility inspection methods used by ESD Program Monitors and the ESD POC in periodic verifications and certification audits.

4.1.2 The default EPA certification level shall be HBM Class 1A. HBM Class 0 applies when handling parts sensitive to lower than 250 volts.

4.1.3 Personnel shall use additional protective measures when protecting items to which the protection level is HBM Class 0. Where an ESD protection level applies that is more restrictive than HBM Class 1A (i.e., protects more highly sensitive items), signage shall be used to clearly mark and communicate to personnel the boundaries and class level of the EPA.

4.1.4 The measurements of Table 4-1 shall be performed as follows:

- a. Operators at the EPA shall perform all continuous, daily, and weekly verifications as they apply to their areas.
- b. The Operator shall use LF 22, "Check Log" when no CMS is used (ESD)," and LF 126, "Laboratory Daily Humidity Log," to record test results.
- c. The area ESD Program Monitor shall perform all monthly, quarterly, and annual verifications for each EPA under his or her jurisdiction; the ESD Program Monitor is ultimately responsible for all verification tests.
- d. The Program Monitor shall use LF 23, "ESD Protected Area Test Log."
- e. The ESD Program Monitor for the area shall ensure that the logs are up-to-date.

4.2 COMPLIANCE

4.2.1 The ESD Program Monitor shall:

- a. Identify non-conformances.
- b. Implement corrective actions.
- c. Ensure that "unusable" areas and equipment are not used with ESDS items.

4.2.2 A work bench or work area shall not be certified or treated as active until all non-conformances relative to Table 4-1 are corrected.

4.2.2.1 Corrections may involve repair or replacement of equipment and marking the equipment and/or space "unusable" in the interim.

4.2.3 ESD Program Monitors shall use a corrective action system to identify and track all non-conformances to ensure that all findings are addressed before the work area is used again for handling or processing ESDS items.

4.3 TRACEABILITY

4.3.1 ESD Program Monitor verification records, especially those related to Table 4-1, shall be kept in the proximity of the associated EPA.

4.3.2 These records shall be passed between program monitors if benches or spaces

transfer between departments or projects.

4.3.3 The record retention period shall be a five year minimum, as defined in Table 1-1, "Record Retention."

4.4 IDENTIFICATION AND ACCESS – ESD AREAS

4.4.1 The ESD Program Monitor shall use prominently placed signs and a partition, rope guards, or similar barriers for clear demarcation of the presence and boundaries of EPAs where ESDS items are to be processed.

4.4.2 The boundary-defining method is intended to prevent unauthorized and untrained personnel from entering the EPA.

4.4.3 Personnel who are not ESD-certified (e.g., visitors or maintenance personnel) shall be accompanied by an ESD-certified escort when entering the EPA.

Table 4-1: ESD Control Program Verification Schedule and Measurements

Test #	ITEM	Para. Ref.	Test Parameters	Verification Intervals				
				Continuous	Daily	Weekly	Monthly ⁴	Annual
1	² Work Surface Resistance	C.5.2.1	$10^6 \Omega$ to $10^9 \Omega$ between two points 10" apart on the Work Surface and 2" from the edge in the commonly used area.				X	
2	Work Surface Grounding	C.5.2.2	10^6 to $10^9 \Omega$ from the center of the work surface to the equipment ground or <1 ohm if a GFCI is used.				X	
3	^{1,2} Protective Floor Resistance	4.9.2.2	$10^6 \Omega$ to $10^9 \Omega$. After cleaning the floor shall be checked and the data recorded. See restrictions in paragraph 4.9.2 (This is a Class 0 requirement).				X	
4	^{1,2} Protective Floor Grounding	4.9.2.2	10^6 to $10^9 \Omega$ from the floor surface to the equipment ground or <1 ohm if a GFCI is used (This is a Class 0 requirement).				X	
5	³ Wrist Strap Check	4.10.2.1 4.11.5	Use approved Wrist Strap checkers and log daily. The use of CMS is preferred	X				
6	Wrist Strap Resistance range	4.10.2.4	$800k\Omega \leq$ wrist strap $\leq 1.2M\Omega$ as measured between groundable point and skin contact surface.				X	
7	Wrist Strap Checkers	4.11.13	Resister Pods for testing CMS and conventional checker's internal resistance meets manufacturers' parameters Where manual wrist strap checkers are used, follow the procedures listed in Appendix E.					X
8	² ESD CMS	4.11.5	Verify functionality before handling ESDS items. Check alarm limits per Mfr. instructions yearly.	X			X	
9	² Stool / Chair Grounding.	4.12.7	< 10^9 ohms to the chair's groundable point (Required for Class 0 Work, recommended for all other work; verify monthly).				X	X

10	² Carts	4.12.8	<ul style="list-style-type: none"> • < 1 ohm if tied directly to equipment ground, via GFCI receptacle. • $\leq 10^6\Omega$ to $<10^9\Omega$ when grounded thru conductive flooring, referenced to CPG. 					X
11	Relative Humidity (RH)	4.12.9.1	30 to 70% RH at room temperature continuous for work area. For Class 0 Work Area certification RH should be > 40%.	X				
12	² Ionizers	4.12.10.5.a	Dissipation rate shall be ≤ 10 seconds.				X	
13	Ionizers	4.12.10.5	The Offset Voltage on ionizers shall be $\geq -10V$ and $\leq 10V$.					X
14	Ionizers	4.12.10.5	Ionizer tips shall be cleaned.				X	
15	Soldering Iron Tip to Ground Resistance	4.13.3	Soldering Stations with self-contained checkers shall use them per schedule. Otherwise check to $\leq 2\Omega$, or $\leq 1\Omega$ when new.	X				
16	Equipment GND to Auxiliary GND Resistance	C.5.2.11.4. a	Where the Auxiliary ground enters the ECA, the resistance between the Auxiliary ground and the Equipment ground shall be $\leq 1\Omega$				X	
17	Auxiliary GND Buss resistance	C.5.2.11.4. b	The resistance of the Auxiliary ground from end to end shall be $\leq 25\Omega$.				X	
18	⁵ Garments	ANSI/ESD STM2.1	ESD Category 1 < $1.0 \times 10^{11}\Omega$ ESD Category 2 < $1.0 \times 10^9\Omega$ ESD Category 3 < $3.5 \times 10^7\Omega$				X	
19	⁶ GFCI	4.7.2.3.4	Where used, the GFCI's self-check shall be toggled.				X	
20	⁶ Gloves / finger cots (GR)	TBD	$10^6 \leq GR < 10^9 \Omega$					X
<p>¹ Additionally, the Protective Floors resistance are checked and documented at least 2 hours after the floor has been cleaned but before the room is used. The area does not need to be checked after vacuuming.</p> <p>² These items require proof of verification (i.e., sticker or log entry).</p> <p>³ Automatic data loggers may be used for wrist strap and foot grounding daily checks.</p> <p>⁴ For workstations with sensitivities of HBM Class 1A ONLY, this interval may be done semi-annually.</p> <p>⁵ Category 1 ESD garment is a Static Control Garment Category 2 ESD garment is a Groundable Static Control Garment Category 3 ESD garment is a Groundable Static Control Garment System</p> <p>⁶ Gloves and finger cots shall be sample tested from each box they are packed in.</p>								

4.5 TEMPORARY USE OF ESD BENCHES FOR NON-ESDS WORK

4.5.1 The ESD Program Monitor shall ensure that non-ESDS work performed at EPAs does not cause ESD CPP non-conformances or lead to damage to ESDS items.

4.5.1.1 The following requirements shall apply:

- Permission from the responsible ESD Program Monitor is obtained before work is started.
- The ESD Program Monitor will clearly mark the affected area as a "Non-ESD Protected Area" with a LF 385 during the period it is used for non-ESDS work.
- The ESD Program Monitor verifies the EPA before ESDS items are again handled in that area, when reactivation occurs within six months of the previous verification; otherwise, the EPA must be certified as if it were a new EPA.

4.5.2 ESD workstations designated as Class 0 shall not be used for Non-ESDS work.

4.6 PROHIBITED MATERIALS AND ACTIVITIES

4.6.1 The following housekeeping practices are critical for continuous EPA compliance and shall be adhered to:

- a. Smoking, eating, and drinking in EPAs are not allowed.
- b. Non-essential materials are not permitted in the EPA.
- c. Insulative materials that are essential to the work being performed shall be kept no closer than 12 inches to the ESDS work area.
- d. All EPAs rated HBM 1A or lower where non-essential insulative pieces of equipment, such as a monitor or a lamp are required to exist within the EPA, an ionizer shall be used. The ionizer directed to the middle of the work area will prevent static buildup from non-essential insulators that may cause an ESD event.
- e. Other than materials specifically made and verified to be safe in an EPA, including, but not limited to, clipboards, books, notebooks, and loose sheets of paper used to read or record data or follow instructions (this LPR included), are kept at least 1 meter (3.3 ft.) from ESDS items or placed in ESD-safe bags or totes.
- f. Floors or mats are kept free of dust, dirt, and other contaminants.

4.6.2 A 1-meter minimum separation shall be maintained between the location where ESDS items are handled and ESD-protective mats, or “tacky mats,” are used at the entrance to clean rooms, cathode ray tube (CRT) displays, and other equipment, including equipment that generates a static charge.

4.6.3 The risk of damaging an item by an ESD event is heightened when the item is left exposed and/or unattended at a workstation or elsewhere.

4.6.3.1 ESDS items shall be placed on an ESD-protective surface and wrapped or covered with static shielding material when they are left unattended for short periods of time, such as a lunch break.

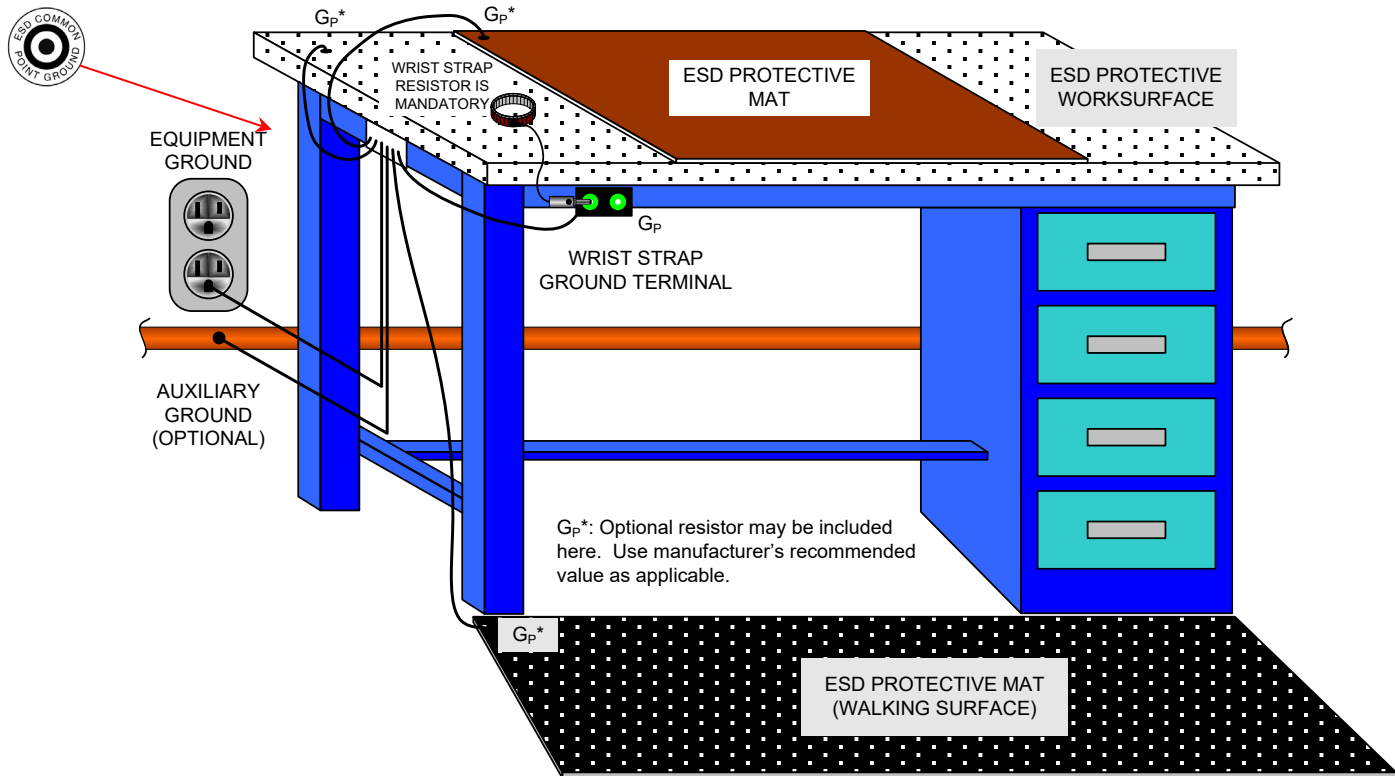
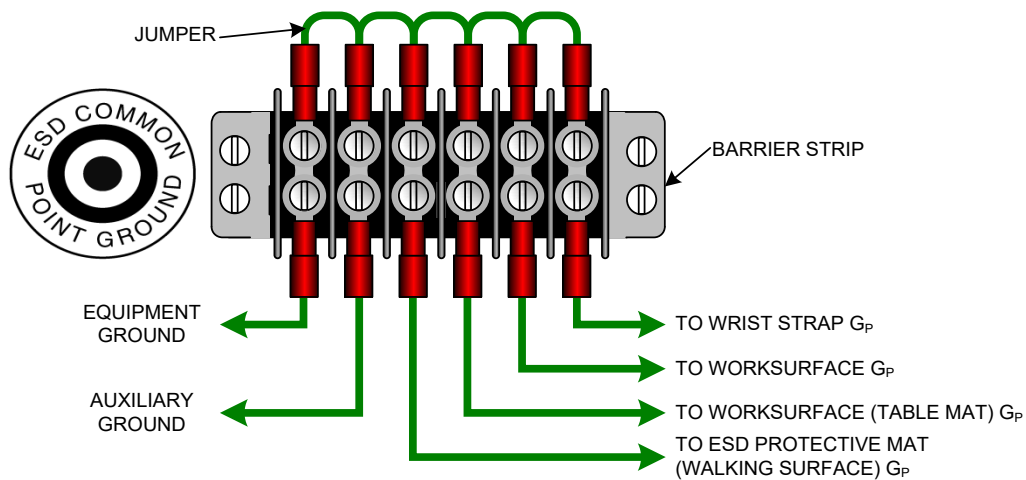


Figure 4-1: Typical ESD Grounded Workstation



EXAMPLE – COMMON POINT GROUND

 (G_p) = GROUNDABLE POINT

Figure 4-2: Workstation Common Point Ground

4.7 ESD-PROTECTIVE WORK SURFACES

4.7.1 The default conductivity level for all work surfaces in an EPA shall be static dissipative. See the following table to identify the resistive limits of all conductive levels.

Table 4-2. Resistive Limits

Resistance (Ohms)	Surface Resistivity (Ohms Per Square)	Material	Description
$\geq 10^{11}$	$\geq 10^{12}$ ohms	Insulative	Insulators and Base Polymers. Not an ESD material.
10^9 ohms to $< 10^{11}$ ohms	10^9 ohms to $< 10^{12}$ ohms	Antistatic	Provides a thin moisture layer to minimize Triboelectrification (charging by friction).
10^6 ohms to $< 10^9$ ohms	10^6 ohms to $< 10^9$ ohms	Dissipative	You can have high charging in the static dissipative range despite favorable resistance. Promotes electrostatic decay or rapid discharge in the 1.0×10^6 ohms to $< 5.0 \times 10^{10}$ range but it DOES NOT SHIELD OR ATTENUATE.
$< 1.0 \times 10^4$ ohms	10^3 ohms to $< 10^6$ ohms	Conductive	No initial charge. Provides path for rapid charge to bleed-off and some shielding.
$< 1.0 \times 10^3$ ohms	1ohm to $< 10^3$ ohms	Shielding	Prevents High Voltage Discharge Penetration.
$< 1.0 \times 10^4$ ohms to $< 1.0 \times 10^2$ ohms	10^{-3} ohms to < 1 ohm	Carbons	Carbon Black powders and fiber Prevents High Voltage Discharge Penetration.
$< 1.0 \times 10^2$ ohms to 1.0×10^{-6} ohms	$< 10^{-3}$ ohms	Metals	Prevents High Voltage Discharge Penetration and provides both RFI/EMI Shielding.

4.7.2 Some work within an EPA may require a conductive work surface

4.7.2.1 ONLY enclosed assemblies may be worked on when the work surface is conductive. There shall be no exposed electronics on a conductive work surface.

4.7.2.2 When a conductive work surface is grounded via an auxiliary buss bar, there shall be a 1MΩ resistor in series between the work surface and the buss bar, but not connected to Common Point Ground (CPG).

4.7.2.2.1 The CPG shall be a direct connection to the buss bar.

Note: When the work surface is connected to the buss bar via a 1MΩ resistor, you cannot connect in series the wrist strap. If you did, that would add in series and thus make the operator part of the circuit, in case of a current flow through the ground. Therefore, the CPG must connect to the buss bar in parallel to the work surface's connection to the buss bar, thus remaining separate and apart from where the operator will connect the wrist strap.

4.7.2.3 When a conductive work surface is grounded directly to the AC equipment ground via the CPG, the AC receptacle shall be a GFCI.

4.7.2.3.1 To eliminate the safety hazard associated with a high current event that results from touching a high voltage circuit with one hand and a hard ground with the other hand, work surfaces shall be protected by a GFCI.

4.7.2.3.2 The GFCI receptacle shall disconnect the circuit when an unsafe current event is detected, usually ≈ 5 ma.

4.7.2.3.3 Type "A" GFCI is preferred.

4.7.2.3.4 GFCIs shall be tested as part of the EPA's verification cycle using their self-test feature. The GFCI manufacturer's website usually has a preferred/recommended method to check their particular model.

4.7.3 Conductive work surfaces generate CDM hazards for very sensitive devices.

4.7.4 The protective work surface shall be selected such that:

- a. It releases no particle contaminants.
- b. It resists attack by common solvents or cleaners (see section 4.16.1).
- c. It is sufficiently large to accommodate the resting of common hand tools on the protective surface rather than on adjacent non-protected surfaces.

4.7.5 ESD work surfaces shall be electrically connected to the CPG.

4.7.5.1 The CPG may be a terminal strip, bus bar, or any other convenient configuration and shall be, within itself, electrically continuous to no greater than 1 ohm measured from point to point with an ohmmeter.

4.8 MOBILE EPAS

4.8.1 A mobile EPA, for example the mobile packaging workbench, "ESD Safety Edge," sold by Global®, may be used as either a stationary EPA or as a mobile cart.

4.8.2 It shall be treated initially as an Intermittent-Use EPA as defined in 2.11.4 of this document.

4.8.3 The ESD POC shall perform the initial certification.

4.8.4 The verification frequency of a mobile EPA shall be done monthly, but additionally each time it is moved to a different location.

4.8.5 When used to transport ESDS items, the mobile EPA shall be treated as a mobile equipment cart, as defined in section 4.12.8 of this document.

4.8.5.1 The mobile EPA shall be grounded prior to placing ESDS items on it.

4.8.5.2 The ESDS item(s) shall be protected with ESD-approved wrap material and totes during the transportation process.

4.8.5.3 Upon arrival at its intended destination, the cart shall be grounded first; thus, becoming once again an Intermittent-Use EPA.

4.8.5.4 The EPA shall be verified-tested before any ESD work takes place, and this should be done before removing the ESD protection material from the ESDS item(s).

4.9 ESD-PROTECTIVE FLOOR SURFACES

4.9.1 Conductive or dissipative floors and/or grounded conductive/dissipative floor mats shall be used in EPAs where personnel are not wearing wrist straps.

4.9.1.1 To provide the intended ESD protection under these conditions, the use of leg straps, heel straps, or conductive shoes shall be used (see 4.10).

4.9.1.2 Conductive/dissipative flooring combined with ESD chairs shall be used in HBM Class 0 EPAs to provide equipotential ground.

4.9.2 ESD protective flooring is not effective if it is not grounded.

4.9.2.1 ESD protective flooring may be connected directly to equipment or an auxiliary ground without the optional resistor (see Figure 4-1).

4.9.2.2 For testing purposes, the dissipative floor-to-system ground resistance target shall be $\geq 10^6$ to $< 10^9$ ohms.

4.9.3 After each cleaning, the ESD Program Monitor shall verify floor resistance per Section 4.9.2 above and the results recorded in LF 23, "ESD Protected Area Test Log." Vacuuming or dry sweeping the floor does not require a subsequent check.

4.9.3.1 Conductive waxes shall be used in compliance with manufacturer recommendations.

4.9.3.2 The ESD Program Monitor shall verify the floor resistance after application and that the results have been recorded in the EPA Test Log (LF 23).

4.9.3.3 The conductive wax used in an EPA shall be approved by the ESD POC.

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

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

4.9.3.5 No carpeting, including products advertised as "conductive" or "static-eliminating," is considered suitable for use in an EPA.

4.10 PERSONAL GROUNDING DEVICES

4.10.1 All personnel working with or handling ESDS items shall be issued and required to use personal grounding devices to prevent the accumulation of dangerous electrostatic charge levels.

4.10.2 All personnel coming within 1 meter (3.3 feet) of any ESDS item shall be issued and required to use a personal grounding device.

4.10.2.1 Wrist Strap: The wrist strap is the preferred means for ESD protection. It is the "first line of defense." The wrist strap system consists of four major components:

- a. Lead: Only the lead supplied with the wrist strap should be used, as it may contain the safety resistor.
- b. Cuff: The design of the wrist strap cuff shall ensure conductive contact with the wearer's skin. Metallic cuffs are preferred over plastic or fabric cuffs. Bead-type chains are not effective and are normally prohibited.
- c. Safety Resistor: All wrist strap systems shall contain an integral current-limiting safety resistor (1 megohm \pm 20%).
- d. Ground Termination: The wrist strap ground termination shall ensure a positive and durable connection between the lead and the CPG.

4.10.2.2 The wrist strap shall have a cuff connector, which breaks away with a force between 1 and 5 pounds, as specified in ESD S1.1, "The Protection of Electrostatic Discharge Susceptible Items Wrist Straps."

4.10.2.3 The resistance between CPG and the equipment ground or the auxiliary ground shall be <1.0 ohm.

4.10.2.4 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 situations where the operator needs to be mobile and the use of a wrist strap is impractical or unsafe.

4.10.2.5 The total resistance to ground, including the person, footwear, and floor shall be $<3.5 \times 10^7$ ohms to keep voltage on the body below the HBM of 100V.

4.10.2.6 When employing foot-grounding devices, the ESD Program Monitor shall set up a footwear checker and an LF 22, "Check Log" when no CMS is used (ESD)," sheet to monitor the continued performance of the personal grounding device system.

Note: Foot-grounding devices that are not kept clean will have reduced effectiveness from contaminants inhibiting their conductive interface with the floor.

4.11 INTEGRITY TESTING OF PERSONAL GROUNDING DEVICES

4.11.1 The integrity of the connection between the operator, the personal grounding device, and the ground connection is critical to proper ESD protection.

4.11.1.1 The ESD Program Monitor shall schedule periodic verification of personal grounding device performance to identify non-compliant units.

4.11.1.2 Typically, damaged or worn units are not repairable and must be replaced.

4.11.2 Wrist straps shall be either continuously monitored or checked each time the wearer enters the EPA using an approved wrist strap tester, as defined in section 4.11.3.

4.11.2.1 Operators shall use an LF 22 Check Log to record the first daily test.

4.11.2.2 Logging wrist strap checks is not required for EPAs that use CMSs.

4.11.2.3 If a CMS is used at a workstation, all wrist strap connection points shall be enabled through the CMS.

4.11.2.4 Exceptions should be made for instances where the voltage-sensing from the CMS may damage very sensitive components.

4.11.3 Approved wrist strap testers are those wrist strap checkers used daily to verify the resistance of the wrist strap and to ensure that the wrist strap's internal resistance measures between 800 kilo ohms and 1.2 Mega ohms.

4.11.3.1 CMS shall be verified initially by the NASA LaRC ESD CPP POC on LF 21 for the EPA's initial certification, and then each time the EPA is recertified by the Program Monitor (or their appointee). The method of verification will follow the manufacturer's written procedure using the manufacturer's measuring resistor pods.

4.11.3.2 The resistor pods' resistive values shall be verified annually using a currently calibrated Volt-Ohm meter.

4.11.3.3 Conventional wrist strap checkers shall be verified annually using either the procedure listed in Appendix E with a calibrated Volt-Ohm meter or the manufacturer's

written procedure using currently calibrated test equipment.

4.11.4 Foot grounding devices shall be checked and logged each time the Operator enters the EPA.

4.11.5 The ESD Program Monitor shall check all Workstation Real Time 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 Table 4-1; yearly verification of the trip limits is required.

4.11.6 If one of the checks in sections 4.10.2.2 - 4.10.2.4 fails, corrective action shall be taken before work is performed and a subsequent re-check shall be conducted before work resumes. Appropriate corrective actions include but are not limited to:

- a. Replacing the cord.
- b. Replacing the complete system.
- c. Using a conductive lotion designed for use with ESD wrist straps (if acceptable in the area of use).
- d. Cleaning the wrist band.

4.11.7 If it is found that an ESDS item was handled in an EPA with faulty ESD protection (e.g., wrist straps, grounding, and/or other ESD controls), that item shall carry a risk lien that must be retired by the affected Project.

4.11.7.1 The failure of the ESD protection shall be recorded by the ESD Program Monitor in the associated project traveler, the non-conformance reporting system, and any other fabrication tracking workmanship system.

4.11.7.2 The ESD Program Monitor shall inform the project's Mission Assurance Engineer (MAE) of the ESD protection failure; however, if there is no MAE, the Program Monitor will notify the project's Chief Safety Officer (CSO).

4.12 EQUIPMENT AND FACILITIES GROUND

4.12.1 Facilities Grounding: The preferred practice is to use the third wire AC line ground (a.k.a., equipment ground conductor) for grounding all items at the EPA.

4.12.2 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 per ANSI/ESD S6.1.

4.12.3 The resistance of the conductor from the Common Point Ground to the equipment ground (AC ground) shall be less than 1 ohm.

4.12.4 The impedance from the area Common Point Ground to the neutral bond at the main service box shall be less than 2 ohms (see Figure 4-3).

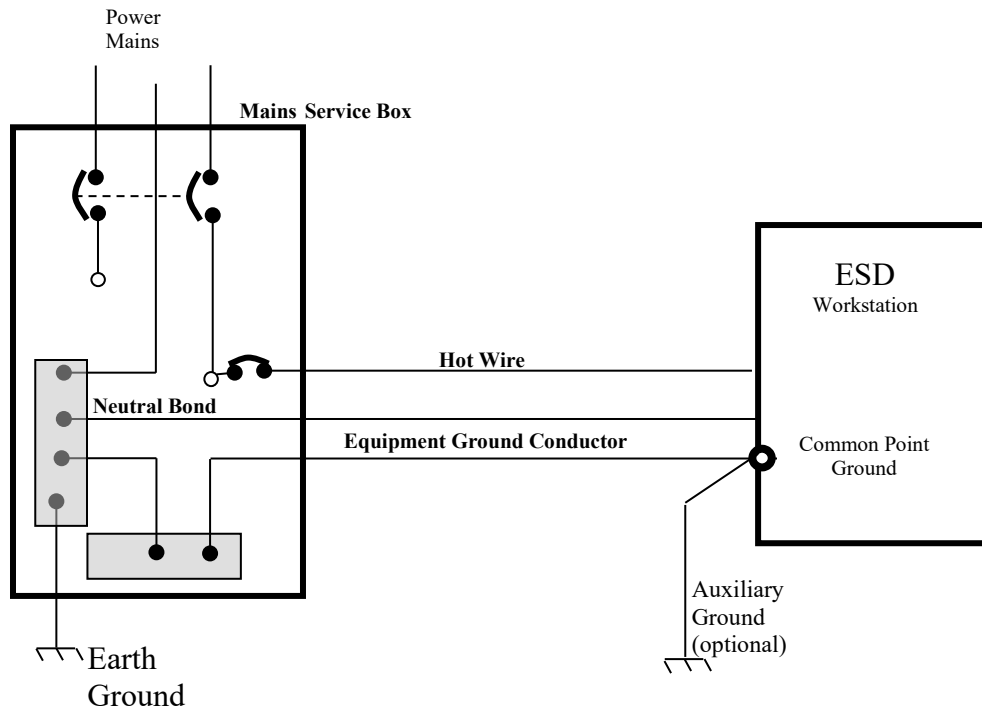


Figure 4-3: Main Service Box

4.12.5 Daisy chaining is not permitted.

4.12.6 Bonded Stores

4.12.6.1 There shall be no carpet on the floor of a bonded store.

4.12.6.2 Bonded stores shall be established as an EPA, and maintained in like manner.

4.12.6.3 In addition to all “normal” administrative paperwork associated with an EPA, an LF 191 shall also be kept and readily accessible.

4.12.6.4 All cabinets used for storage of electrical or electronic components shall be grounded.

4.12.6.5 A detailed database of all components shall be maintained within the bonded store.

4.12.6.6 In the case where not all these controls are reasonable to use, all ESDS items shall be bagged and desiccants placed in the associated area.

4.12.6.7 In cases where the previous statement is in effect, there shall be technical justification, and stated as such in the EPA’s Tailor document.

4.12.7 Stools, Chairs, and Carts

4.12.7.1 The ESD Program Monitor is responsible for the certification and proper use of stools, chairs, and carts in EPAs.

4.12.7.2 Stools and chairs shall be ESD safe in an HBM Class 0 EPA, recommended

for use in an EPA with a safety classification level of HBM 1A or less.

4.12.7.3 Carts should have a dissipative surface when used inside an EPA to hold ESDS items and will be grounded at all times.

4.12.7.4 Carts may be conductive only when used to transport ESDS items outside of the EPA.

4.12.7.5 Local ESD safety procedures shall address EPA-specific uses of chairs, stools, and carts relative to the employed grounding scheme.

4.12.7.6 Certification: The required verification levels and verification intervals for chairs and stools are shown in Table 4-1.

4.12.7.6.1 The resistance shown in Table 4-1 applies to measurements between any part of the chair and a groundable point.

4.12.7.6.2 The resistance for any part of the chair to a groundable point shall be $<10^9 \Omega$.

4.12.7.7 Grounding: For handling Class 0 sensitive items, there shall be a positive electrical contact between the Common Point Ground and the chair or stool.

4.12.7.7.1 This contact may be achieved through an ESD protective floor or ESD protective floor mat.

4.12.8 Mobile Equipment Carts

4.12.8.1 Where carts, wagons, trams, or other mobile equipment are used, they shall be grounded while in use in the EPA.

4.12.8.1.1 When conductive floors are being utilized, there shall be a positive electrical contact between the floor and conductive structure of the mobile equipment.

4.12.8.1.2 The required resistance used for verification from the equipment to the Common Point Ground is shown in Table 4-1.

4.12.8.1.3 If the floor is non-conductive, the vehicle shall be grounded before ESDS items are loaded or removed from the vehicle.

4.12.8.1.4 The use of protective packaging (ESD-approved wrap material and totes) shall be used when moving ESDS items for transport away from the EPA, even if a certified-safe cart is employed.

4.12.8.2 Other Mobile Equipment: When other tabletop equipment, such as microscopes or lead-bending equipment, is used within an EPA, it shall be ESD grounded.

Note: Such equipment may have a large capacitance and present a hazard to components susceptible to CDM-type pulses. To avoid damage, the equipment and the component shall be at the same potential before they contact each other. This can be done by using dissipative materials to make first contact to both the component and the equipment.

4.12.9 Humidity

4.12.9.1 The relative humidity (RH) target range for EPAs at 20°C is 30 percent to 70 percent when monitored near the ESDS item (40 percent to 70 percent for Class 0).

4.12.9.1.1 At levels below 30 percent, ESD risk increases and additional precautions shall be used, such as turning on a humidifier and/or using an air ionizer.

4.12.9.1.2 If additional precautionary methods are unavailable (e.g., the use of an ionizer), work shall be halted, and the RH will be recorded for traceability until the required humidity level is obtained (see section 4.3 on records retention).

4.12.9.1.3 If at any time the RH drops to 20 percent, all work shall come to a stop until the RH is brought back within the limits; all work will stop at 30 percent for Class 0.

4.12.9.2 The ESD Program Monitor shall check the RH level in each EPA at the start of the workday and ensure that the result has been logged in the lab's LF 126, "Laboratory Daily Humidity Log."

4.12.9.2.1 Continuous compliance is verified with periodic observations and recording of the results. If the RH level is close to 30 percent or is seen to be dropping rapidly, increased vigilance is mandatory.

4.12.9.2.2 Data loggers with an integral alarm system are suitable substitutes for the daily check.

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

4.12.9.4 Sealed ESD protective bags that have been stored in "dry boxes" with desiccant gel bags to prevent high humidity problems are easily charged.

4.12.9.4.1 Care shall be taken when removing ESDS items from ESD bags to prevent ESD events from triboelectric charging.

Note: Surface resistivity changes exponentially with humidity changes.

4.12.9.5 In EPAs with limited environmental control capabilities, projects may choose to use a psychrometric chart to monitor the Humidity Ratio (HR) for real-time changes.

4.12.10 Air Ionizers

4.12.10.1 Air ionization is a technique used to neutralize charges on insulators and ungrounded conductors.

4.12.10.1.1 Air ionizers shall be used when handling Class 0 sensitive parts, as well as when the RH falls below 30 percent in a Class 1A work area (see Table 4-3).

4.12.10.1.2 Air ionizers shall be used when essential insulators are within 3 feet (and no closer than 12 inches) to an ESDS item, regardless of the Class certification.

4.12.10.2 Air ionizers are designed to work where unrestricted airflow exists between the ionizer and the ESDS item.

4.12.10.2.1 Air ionizer design also requires sufficient distance between the ionizer and the ESDS items to ensure proper ion balance in that airflow, being careful not to exceed 24 inches.

4.12.10.2.2 Operators shall consult the ionizer manufacturer's documentation for detailed ionizer operating instructions.

4.12.10.3 The ionizer shall be carefully selected in order to realize its benefits in the EPA.

4.12.10.3.1 Ionizers shall undergo routine maintenance and testing in accordance with manufacturer's recommendations to ensure acceptable continued performance.

4.12.10.4 Ionizers shall be cleaned and verified annually.

4.12.10.4.1 The verification process for ionizers may be used in place of annual calibrations.

4.12.10.5 The verification procedure shall test to verify the following parameters:

- a. The dissipation rate shall be less than 10 seconds.
- b. The offset voltage range shall be $\geq -10V$ up to $+10V$.
- c. Tips shall be cleaned using cotton swabs dipped in isopropyl alcohol.

4.12.10.6 The presence of ionized air creates an increased risk for corona discharge in the presence of "powered-up" high-voltage or radio frequency (RF) sensitive equipment; therefore, the use of ionizers is not recommended in those environments.

4.12.10.6.1 To avoid fire hazards from corona discharge, flammable materials shall be kept away from air ionizers.

4.12.10.6.2 Corona discharges have been known to occur in work areas when work surfaces are conductive.

4.12.10.7 Electrostatic field meters in conjunction with a charging plate may be used to verify the effectiveness of ionizers in extremely sensitive work areas (e.g., Class 0, Class M1) before work is started.

4.12.10.7.1 It is important that the meter used has sufficient resolution and time response to detect values beyond the minimum performance limits required.

4.12.10.7.2 To avoid meter saturation or generating false data, the meter should be slowly moved into the area being measured while watching for readings close to the limits of the meter. When essential insulators are required in any certified EPA (e.g., keyboards and monitors), an ionizer shall be used to prevent an ESD event.

4.12.10.8 Though ionizers shall be used for Class 0 EPAs, it is important that the ESD Program Monitor ensures that the ionizer is not the source of unacceptable charge deposition into the ESDS items.

4.12.10.8.1 In these cases, the ESD Program Monitor shall ensure in advance that the ionizer peak balance potential is less than one half the susceptibility of the most sensitive part (≤ 50 percent of item sensitivity level).

CAUTION: An improperly adjusted air ionizer can charge ESDS devices and lead to possible damage to the device.

Table 4-3: ESD Sensitivity for Selection and Performance of Air Ionizers

Class	ESD Sensitivity	Air Ionization	Discharge time	Float Potential
1A +	≥250 V	Optional	± 1000 to < ± 100 V in < 10 sec.	< ± 10 V
0 ¹	>100 V to < 250 V	Required	± 1000 to < ± 50 V in < 10 sec.	< ± 10 V
0 ²	≤100 V	Required	± 1000 to < ± 20 V in < 10 sec.	See below ²
M1 ³	<100 V	Required	± 1000 to < ± 20 V in < 10 sec.	< ± 10 V

¹ Class 0 covers all HBM <250V but 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

4.13 HAND TOOLS, EQUIPMENT, AND FIXTURES

4.13.1 The ESD Program Monitor shall approve all the following tools used in the EPA:

- a. Tools designed for ESD areas, such as static dissipative cushioned tools.
- b. Tools not designed for EPAs, including uninsulated metal hand tools, such as pliers, cutters, tweezers, and wire strippers.

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

4.13.3 Hand tools that require a measurement to ground, such as solder irons, which shall measure the Tip-To-Ground resistance only, at the start of each day and checked off on LF 22. If the solder iron(s) used have built-in self-checks, this requirement is not applicable.

4.13.3.1 This test procedure is defined in ESD TR53-01 section 13.3.2.

4.13.3.2 This test is to prevent Electrical Overstress (EOS) damage to components. See ESD TR20.20-2016, Section 5.4.4.3.4.

4.13.4 Only antistatic solder extractors made of metal, or having a metalized plastic barrel and tip, shall be used in an EPA.

4.13.5 The following applies to electrical tools used in EPAs:

- a. They shall employ a three-wire grounded power cord.
 - b. They shall have static dissipative handle grips.
 - c. The tool's contact point (e.g., soldering iron tip) that touches the work piece shall have a tip to ground resistance of less than or equal to 2 ohms (< 1 Ω when new).
- (1) Note 1: The tip to ground resistance check is the only solder iron test that LaRC will conduct for solder iron compliance. The two additional tests listed in the ANSI/ESD S20.20 document for voltage and leakage current are not technically justifiable, and therefore shall not be required.
 - (2) Note 2: Motor-driven tools are not to be used near ESDS items due to inductive charging in the ESDS devices.

CAUTION: GFCI systems can indicate a faulty soldering station but do not prevent damage to hardware from damaged soldering tips. Soldering stations are easily

moved to the workbench; however, their records are not usually kept by lab monitors and the tips cannot be easily identified as verified ESD-safe.

4.13.6 Digital Multimeters (DMMs) may introduce voltage spikes when changing scales and/or have high voltages when measuring resistance.

4.13.6.1 The ESD Program Monitor shall ensure that the measuring equipment is compatible with the hardware being measured.

4.13.7 Fixtures used while working at an EPA shall be ESD safe and ground-bonded to the Common Ground Point.

4.13.8 Measuring equipment, breakout boxes, harnesses, and similar equipment shall be properly discharged via ground before making connection to flight hardware.

4.13.8.1 Consult with the hardware design engineer to ensure that test procedures clearly document hardware limitations and procedural considerations relative to the equipment normally used in the laboratory.

4.14 **PROTECTIVE PACKAGING**

4.14.1 Electrostatic protective packaging shall prevent charge generation (e.g., triboelectric contact and separation) and protect from external electrostatic fields.

4.14.1.1 Static dissipative materials used in packaging are considered to provide both properties.

4.14.1.2 Static dissipative materials in intimate contact with devices shall have a surface resistance range of $\geq 10^4 \Omega$ to $< 10^{11} \Omega$.

4.14.2 Protective bags and packaging are considered ESD protective based on the following:

- a. Materials used in protective bags and pouches shall possess like characteristics found in the Triboelectric series to satisfy the resistance requirements to avoid triboelectric charge buildup.
 - b. Acceptable bags and pouches used for electrostatic shielding shall be constructed from a single folded piece of material.
 - c. Two-piece construction is not considered ESD-safe.
 - d. If bags or pouches are not transparent, allowing identification of contents without removal, the Operator shall label the bag by listing its contents on the outside of the bag or pouch.
 - e. Materials in contact with the protected hardware shall have a dissipative surface.
 - f. Neither static dissipative impregnated nor topically treated plastics provide electrostatic shielding.
- (1) The Operator shall enclose both types in an outer container which will provide shielding to the contents during shipping.
 - (2) For acceptable electric field shielding, the package shall be electrically conductive with a surface resistance of $< 10^4$ ohms.

4.14.3 Compliant shipping packaging for all integrated circuits used by NASA shall be non-metallic conductive or static dissipative magazines, chutes, and dip tubes.

4.14.3.1 Integrated circuits that are shipped in non-compliant packaging shall not be

used in flight hardware.

4.14.4 ESD-safe tote boxes shall be made of conductive or static dissipative material.

4.14.4.1 Compliant tote boxes shall be fitted with covers of the same conductivity as the bottom sections that fit tightly enough to ensure conductivity across this interface.

4.15 TEMPERATURE CHAMBERS AND COOLING AGENTS

4.15.1 ESD Program Monitors shall take appropriate precautions, such as air ionization, to neutralize the static charge on insulated and isolated objects when gas flow is utilized in the area of ESDS items.

4.15.1.1 Particles in the gas flow can be a significant generator of electrostatic charges.

4.15.2 To ensure the safety of ESDS items in cold chambers, conductive baffles and shelves within the chamber shall be grounded.

4.15.2.1 ESDS items contained within those chambers shall have a path to ground by mounting them or placing them on conductive material (preferably a dissipative surface) that is in contact with the grounded shelves.

4.15.3 ESD Program Monitors shall take appropriate ESD precautions when pressurized cryogenic cooling agents are used for localized cooling, such as in troubleshooting. "Mist Freeze" has proven to be a very good ESD generator.

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

4.15.5 Resistance checks shall be a minimum requirement for normal test chamber environments.

4.15.5.1 For extremely sensitive parts, the use of electrostatic survey meters shall be used.

4.15.5.2 Survey meters can provide information on stray fields harmful to the hardware being tested.

4.15.5.3 The ESD Program Monitor shall consult the meter manufacturer's documentation for additional cautions.

4.16 CLEANING AND CLEANING AGENTS

4.16.1 Cleaning personnel who have been ESD trained shall ensure that the cleaning agents and methods used on ESD-protective items (e.g., work surfaces and floor coverings) have been selected and applied so that they do not reduce the effectiveness of these items, cause leaching, or leave insulating residues.

4.16.2 In addition to other required properties (e.g., solvency), the ESD POC shall approve of cleaning agents used directly on ESDS items that have been selected for low electrostatic charging propensity and approved for use in flight hardware.

4.16.3 Only natural bristle or static dissipative brush materials shall be used on ESDS items.

4.17 ELECTROSTATIC SURVEY METERS, VOLTMETERS, AND MONITORS

4.17.1 Electrostatic survey meters are used to detect the presence of electrostatic charges.

4.17.1.1 Only those types of electrostatic survey meters that read the electrostatic charge on a surface area without requiring contact shall be used in NASA EPAs.

4.17.1.2 These 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).

4.17.1.3 For areas handling highly sensitive parts, other methods may be needed.

4.17.1.4 Always follow the manufacturer's recommendations.

4.17.2 Use of electrostatic monitors designed to actuate an alarm when an electrostatic field reaches a preset level shall be used in an EPA handling ultra-sensitive hardware.

4.17.2.1 It should be noted that these monitors are very sensitive and require a lot of trial and error to properly position them to avoid false alarms.

4.17.3 Wrist strap testers and recording logs shall be made available in all areas where ESDS items are handled, unless the ESD protective area exclusively uses a CMS.

4.18 CLOTHING REQUIREMENTS

4.18.1 A static-dissipative outer garment (smock or "bunny suit") shall be worn at all times when inside an EPA.

4.18.1.1 Garments with snap cuffs shall not be used at NASA LaRC. The reasoning is that when an operator using a wrist strap snaps the grounding plug to the garment's snap poorly, it can become a "short-to-ground" hazard when the operator reaches for something and accidentally drags that (grounded) snap across electrical/electronic hardware.

4.18.1.2 When in non-cleanroom environments:

- a. A smock compliant with the garment requirements listed in Table 4-1 shall cover all personal garments above the wrist, except at the neck area, and make intimate contact with the skin.
- b. Smocks shall be fully zipped/buttoned at all times they are worn.

4.18.1.3 When in cleanroom environments:

- a. A compliant bunny suit, gloves, booties, head cover, and facial cover (when applicable) shall be worn to completely cover the body.
- b. Only non-hair parts of the face shall be exposed.

4.18.2 The ESD Program Monitor shall properly check all garments after laundering. At the very minimum, this will include 10 percent of randomly selected garments.

4.18.2.1 Only ESD garment cleaning facilities that are compliant with ANSI/ESD STM2.1 shall be used.

4.18.3 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.

4.18.3.1 Some garments have the provision for attachment to the wrist strap coil cord snap.

4.18.3.2 Some configurations also allow for continuous monitoring.

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



Figure 4-4. Chest to Chest

Figure 4-5. Cuff to Cuff

4.18.4.1 This setup does not work with the dual wire CMS.

4.18.5 For less sensitive areas (Class 1A and above), smocks may be used over cotton shirts or short-sleeved shirts without the extra ground connection.

4.18.5.1 This configuration permits slow static dissipation of the charge acquired by the garment (wrist straps shall be worn).

4.18.6 Finger cots and gloves, when worn in an EPA, shall be made of static dissipative materials.

4.19 ORBIT REPLACEABLE UNITS (ORU) REQUIREMENTS

4.19.1 An electronic assembly manufactured with a conductive outer enclosure is expected to be ESD sensitive only through exposed connector pins.

4.19.1.1 If conductive or static dissipative caps cover the connectors, the box forms a Faraday cage around the internal ESDS components.

4.19.1.2 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.

4.19.1.3 All ORUs installed in their normal flight configuration, with all connectors mated and/or covered, whether in a launch vehicle or in a test configuration simulating flight conditions, are not considered ESDS unless analysis or testing has shown otherwise.

4.19.2 ESD precautions shall be implemented prior to the connector or connector caps being removed.

4.19.2.1 Exposed connector pins shall be touched or tested only after the Operator and the box are at the same ground potential (equipotential bonded ground).

4.19.3 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.

4.19.3.1 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.

4.19.3.2 Prior to the initial mating of newly installed cables, the connector pins and cable shield shall be grounded to discharge any electrostatic potential.

4.19.3.3 An existing cable that is connected to another ORU does not require shorting prior to mating.

4.19.3.4 When installing test equipment to flight hardware, the cables shall be installed to the non-flight equipment prior to the flight equipment.

4.19.4 Operator grounding during ORU installation: As noted in the previous paragraph, an ORU with protective connector caps is not considered ESDS, but it is highly recommended that personnel be grounded throughout the installation or removal process.

4.19.4.1 The use of a wrist strap in a spacecraft shall be regulated by the need to protect metal surfaces from scratches caused by alligator clips on soft metals and the need to preclude conductive debris generated by the teeth of the clips.

4.19.4.2 In addition, the working space may be too constrained to wear a wrist strap. In these cases, the Operator shall use some other means to equipotential bond themselves with the ORU and connector prior to mating and de-mating.

4.19.5 Procedures for ESD-safe handling of ORUs shall include the following practices:

- a. Upon arrival at the equipment rack with the ORU, the mobile cart shall be tied to ground.

Note: If the ORU cannot be grounded through connection to the grounded cart, it is acceptable to momentarily ground the ORU by touching it with one hand and touching a grounded conductive surface with the other hand.

- b. Conductive or dissipative covers shall be installed securely in place.
- c. Prior to moving the ORU from the cart, all personnel shall momentarily ground themselves by touching a grounded object.
- d. The ORU may be moved to the equipment rack without the use of a grounded wrist strap; however, a wrist strap or other grounding method shall be used by the technician/operator prior to removing any connector covers.
- e. The procedure for removing an ORU from the equipment rack is the reverse of items in section 4.19.5.a-d above. A grounded wrist strap shall be worn prior to removing a connector from the rack and reinstalling the connector cover.
- f. When a patch-panel/breakout box has been installed into the wiring harness of an ESDS ORU, all operations performed using the breakout box require the Operator to be grounded and a sign shall be placed at the worksite warning of the ESD damage concern.

4.19.6 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.

4.19.6.1 The hardware shall be properly marked and documented as to the HBM sensitivity Class (e.g., 0, 1A, and 1B) or non-ESDS and the proper procedures for handling and packing shall be provided.

4.19.6.2 All ORUs with an unknown ESD sensitivity shall be handled as HBM Class 1A.

Note: The requirements above imply ESD susceptibilities of above 1 kV and below (HBM 1C).

4.19.7 Hardware handled by the crew during flight should not be ESDS.

4.19.7.1 It is highly recommended that flight items are transported in ESDS safe packaging even if they are known to be ESD immune.

4.19.8 Static generating materials are a hazard if they come in close proximity to ESDS hardware.

CHAPTER 5. ESDS ITEM HANDLING

5.1 GENERAL

5.1.1 ESDS items shall be handled only in EPAs.

5.1.1.1 When outside of EPAs, ESDS items shall be completely enclosed inside ESD-protective packaging in an ESD protective container (e.g., tote or box).

5.1.1.2 When outside of EPAs and too large to be completely enclosed, ESDS items shall remain covered by ESD-protective material.

5.1.2 Paperwork accompanying an ESDS item (e.g., QA records, routings, and instructions) shall be contained in static dissipative bags or envelopes.

5.1.2.1 This paperwork shall never come in physical contact with an ESDS item.

5.1.2.2 Materials specifically made and verified to be safe in an EPA are exempt from this requirement.

5.1.3 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.

5.1.3.1 An ESD event may occur if extreme care is not exercised to ensure that both items are at the same potential when attaching any conductive material to an ESDS device.

5.1.3.2 Process-essential insulators (e.g., Kapton® tape) and isolated conductors shall be neutralized with an ionizer before they are moved within 12 inches of ESDS items.

5.1.3.3 Non-process-essential insulators (e.g., keyboards, monitors) shall not be any closer to the work in an EPA than 12 inches.

5.1.4 All containers, tools, test equipment, and fixtures used in EPAs shall be grounded before and during use.

5.1.4.1 Before connecting or disconnecting test cables, a common soft ground between an ESDS item and any test equipment shall be established.

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

5.2 SPECIAL REQUIREMENTS FOR HIGHLY SENSITIVE ITEMS

5.2.1 Table 5-1 summarizes the requirements made throughout this document that are particular to HBM Class 0 (as defined in section 2.4.2.1).

5.2.1.1 For higher sensitivity levels, for devices sensitive to CDM events, or for other special cases, the Project engineers shall partner with the ESD POC to determine suitable ESD CPP requirements.

5.2.2 When assembling parts sensitive to low voltage and low energy pulses, the measures prescribed for HBM and MM models do not provide sufficient component protection.

5.2.2.1 This section provides guidance for handling components sensitive to breakdown voltages as low as 2 volts and energies as low as 0.3 μ J.

5.2.2.2 Electromagnetic interference (EMI) signals can inductively charge components with these low-level sensitivities and put them at risk of failure from an ESD event that can be so rapid that it evades HBM and MM safety methods.

5.2.2.3 Parts in this category include detectors, some high-frequency low-voltage differential signal (LVDS) transceivers, low noise amplifiers (LNAs), noise diodes, and integrated circuit (IC) RF switches.

5.2.3 Equipment

5.2.3.1 All ports in the flight hardware shall use shorting plugs/ESD caps when not in use, including when inside their ESD bags.

5.2.3.1.1 RF ports shall use a metal dust cap to form a Faraday cage.

5.2.3.2 Operators should use ESD finger cots instead of ESD gloves.

Table 5-1: Summary of Requirements Applicable to HBM Class 0 (see §2.4.2.1)

Topic	Recommendation
Chairs & stools	Ground and periodically verify as ESD protective. See Table 4-1 for intervals.
Conductive or dissipative floors or floor mats	Use them in the area in front of the protected area or in the designated EPA floor space.
RH	Keep over 40%, monitor and record just before work is started when CMS are not in place. Additional precautions must be used to operate below 40% RH.
Ionizers	Keep them in place and working properly. See Table 4-3. It is recommended that an ESD survey meter be used to check the area before work is begun.
Smocks	Must be grounded to the Common Point Ground or through the wrist strap. However, the CMS, if used, must not interfere with grounding of the smock or vice versa.
Mating and De-mating cables and harnesses	Must be discharged to ground through an approved method prior to mating and de-mating to ESD sensitive assemblies
Survey meters	In resistance mode, the two probes shall be contacted to one another prior to use.
Soldering irons	Check for proper ESD operation before start of operation.
Signage	Display them, describing the Class sensitivity level for the area

5.2.3.3 The DUT shall be placed on a conductive metal plate that in turn is placed on a certified ESD workbench.

5.2.3.4 This plate shall be permanently grounded to the power supply in the test setup using a separate ground braid and connected in the same fashion as the chassis connection called out in the test procedure setup.

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

5.2.3.5 ESD garments shall have conductive elastic cuffs or have means by which they can be grounded.

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

5.2.3.7 Continue to use wrist straps per the current requirements.

5.2.3.8 If a CMS is used, the sensing voltage of the system shall be lower than the most sensitive component to be handled.

5.2.3.8.1 If CMS cannot be used, the Operator/garment combination shall be checked and recorded at least once a day.

5.2.3.8.2 Operators shall check themselves every time they enter the area.

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

5.2.3.10 Cleaning procedures around sensitive parts should be performed using ethyl or isopropyl alcohol and a small horsehair brush (not cotton swabs).

5.2.3.10.1 Hot air guns shall not be used.

5.2.4 Handling and Operational Procedures

5.2.4.1 An ESD checklist shall be created as part of the production traveler, which includes a RH check (40 percent to 60 percent RH), possible EMI sources, static survey, and ionizer balance voltage, as a minimum.

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

5.2.4.2 Pagers, cell phones, or RF transmission devices shall not be powered ON in the room/area.

Note: Setting devices to “vibrate” does not eliminate the inductive charging risk from the EMI source originating from the wireless device.

5.2.4.3 The test setup shall be completed before the flight hardware is taken out of the ESD bag.

5.2.4.4 The ionizer shall be run during the operation.

5.2.4.4.1 Sensitive device(s) shall be within the “sweet spot” of the ionizer. It should be noted that some nearby electrostatic generators may change the “sweet spot” of the ionizer.

5.2.4.5 Test equipment with CRTs shall be turned on and neutralized by an ionizer before the DUT is taken out of the ESD bag and kept as far as practical away from the DUT.

5.2.4.6 Once the setup is completed, the DUT shall be removed from the ESD bag, the grounds shall be equalized by touching with finger cots both the DUT and metal plate, and then the DUT shall be placed on the metal plate.

5.2.4.7 Before power is applied to any RF device in the DUT, the ionizer shall be turned off.

5.2.4.8 Every tool shall be discharged by placing it on the ESD mat (or any dissipative surface).

5.2.4.8.1 Test leads shall be discharged by touching the ESD mat with the lead for at least one second.

5.2.4.8.2 This instruction applies to screwdrivers, tweezers, and special tools.

5.2.4.9 The proper ionizer discharge time and float potential shall be selected per Table 4-3.

5.3 RECEIVING, INTERNAL HANDLING, AND SHIPPING

5.3.1 Incoming inspection shall include examining all ESDS items for proper ESDS precautionary marking and ESD-protective packaging.

5.3.1.1 Inadequate precautionary markings shall be corrected and handling history investigated prior to further processing.

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

- a. Rejected as defective.
- b. Processed as non-conforming material.
- c. Labeled as failed ESDS material and the incident reported.

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

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

5.4 EQUIPMENT LEVEL TEST, MAINTENANCE, AND INSTALLATION

5.4.1 The following practices apply 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 kept to a minimum.
- d. Failed ESDS items shall be placed in protective packaging after removal from the equipment to facilitate root cause analysis.
- e. Probing ESDS items with test leads shall be conducted only within a certified EPA.

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

5.4.3 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 that is connected to an ESDS item.

5.4.3.1 Soft grounding shall be used to avoid rapid discharge.

5.5 IDENTIFICATION AND MARKING

5.5.1 The ESD Program Monitor shall properly identify all ESDS items, equipment, and assemblies in order to warn personnel before any potentially ESD-damaging procedure can be performed.

5.5.1.1 For this purpose, packing lists, inspection reports, travelers, and other paperwork accompanying the hardware shall contain ESDS labels and cautionary notes.

5.5.2 Alternative identification shall be applied when the prescribed marking is not available.

5.5.2.1 Approved identification methods from ANSI/ESD S8.1 shall be used.

5.5.3 The standard ESD Protective Item Symbol, illustrated in Figures 5-1 and 5-2, shall be used to identify items that are specifically designed to provide ESD protection for ESDS assemblies and devices.



Figure 5-1: Sensitive Electronic Device Caution Symbol
(with and 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 1.2.4.1.



Figure 5-2: ESD Protective Item Symbol

5.5.4 The standard ESD common point ground symbol, illustrated in Figure 5.3, shall be used to indicate the location of an acceptable Common Point Ground.



Figure 5-3: ESD Common Point Ground Symbol

CHAPTER 6. ASSURANCE PROVISIONS

6.1 SURVEILLANCE

6.1.1 Project MAEs shall ensure that processes used for their project are properly controlled and meet requirements.

6.1.1.1 MAEs or their designated representatives shall audit ESD controlled areas prior to beginning work on their flight hardware and ensure compliance to this document's requirements.

6.1.2 The area's ESD Program Monitor shall periodically verify EPAs (see Table 4-1).

6.1.3 The ESD POC (see Section 2.7) is responsible for the initial certification of all EPAs.

6.1.3.1 This task may be delegated to an audit team who represents the ESD POC.

6.1.4 The ESD POC shall perform random audits where deemed necessary.

6.1.4.1 This task may also be performed by any assigned auditor.

6.2 EPA "PASS" CERTIFICATION REQUIREMENTS

6.2.1 If the EPA meets the requirements of this NASA LaRC ESD CPP, then the ESD Program Monitor shall certify it as approved for use.

6.2.1.1 The certifier shall initial, date, and record "Approved" on the LF 23, "ESD Protected Area Test Log."

6.2.2 The certifier shall also affix an LF 382, "Certification/Verification Sticker," 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).

6.2.2.1 For ESD workstations inside clean rooms or other restricted areas, sticker placement shall comply with the clean room's management requirements and positioned for clear visual access.

6.2.3 The EPA remains certified for use until a discrepancy is found during its use (e.g., broken ground wire, workstation was moved, or rewired) or the verification has not been performed in over 6 months.

6.2.3.1 See abandoned EPAs in section 2.10.5.

6.3 EPA AREA "FAIL" REQUIREMENTS

6.3.1 If an EPA fails to meet the requirements of this ESD CPP, then the ESD Program Monitor shall mark the area Out of Service in an obvious location.

6.3.1.1 The area shall remain out of service until the discrepant item(s) have been corrected and the ESD Protected Area Test Log (LF 23) has been updated to show the area acceptable for use.

6.3.1.2 When ESDS hardware has been handled in the area since the last passing verification, the hardware shall be handled as non-conforming material.

6.3.2 The NASA LaRC ESD POC 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.

6.3.2.1 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.

APPENDIX A. DEFINITIONS

The following definitions apply to terms used in this manual:

Assembly. A functional subdivision of a system consisting of subassemblies that performs functions necessary for the operation of the system as a whole. Examples: regulator assembly, power amplifier assembly, gyro assembly, and similar assemblies.

CAP Tracs. The Langley Management System Corrective, Preventive, and Improvement Action Tracking System.

Certificate of Completion of Training. The actual certificate issued, or the wallet-sized card given to a trainee after successful completion of training.

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

Certification of Competence. The act of verifying and documenting that personnel are competent to perform work in an EPA as required by this document.

Certification of Training. The act of verifying and documenting that personnel have successfully completed training. The Certification of Completion of Training documents this certification.

Charged Device Model. A specified circuit characterizing an electrostatic discharge, which results when a device isolated from ground is first charged and then subsequently grounded.

Cheater Plug. An AC plug adapter used to connect a three-pronged plug to a two-pronged AC socket. It can be used to separate the ground wire from the socket for testing purposes.

Component. A functional subdivision of a subassembly, generally a self-contained combination of parts performing a function necessary for the subassembly's operation. Examples: power supply, transmitter, gyro package, and similar parts.

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

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

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

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

Equipotential Bonding. A connection between two points with a maximum resistance between them of $<10^9$ ohms (with no current flow).

ESD Controlled Area (ECA). An ESD Controlled Area that has at least one, but could have many, EPAs within it. An entire room may be an area where ESD caution is required, but adherence to the EPA requirements is not necessary throughout the area.

ESD Program Monitor. A trained and certified individual who is responsible for the day-to-day maintenance of the certification status of an EPA.

ESD Protected Area (EPA). An area constructed and equipped with the necessary ESD-protective materials and equipment to limit ESD voltage below the sensitivity level of ESDS items handled therein. This may include benches, rooms, or buildings.

ESD-Protective Material. Material capable of one or more of the following functions: limiting the generation of static electricity, safely dissipating electrostatic charges over its surface or volume, or providing shielding from ESD spark discharge or electrostatic fields.

ESD-Protective Packaging. Packaging with ESD-protective materials to prevent damage to ESDS items during storage or transport.

ESD Protected Workstation. See ESD Protected Area (EPA).

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

ESDA Advisory Document (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.

ESDA Draft Standard (ESD DS). Draft standards, test methods, and standard practices that are subject to revision before being issued as full standards.

ESDA Standard (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.

ESDA Standard Practice (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.

ESDA Standard Test Methods (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.

ESDA Technical Report (ESD TR). A technical report is a collection of technical data or test results published as an informational reference on a specific material, product, system, or process. The opinions expressed in a technical report are the opinions of the author(s) and may or may not be endorsed by the ESD Association.

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

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

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

Human Body Model (HBM). An electrostatic discharge circuit that meets the set model values by conforming to waveform criteria specified in ESD-STM 5.1, characterizing the discharge from the fingertip of a typical human being.

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

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

Level B Instructor. An individual who is certified to train Operators and ESD Program Monitors. Certified Level B Instructors are qualified to perform the duties of an ESD Program Monitor.

Machine Model (MM). 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).

Mission Hardware. Includes aeronautical flight hardware, space flight hardware, critical ground support equipment, and launch vehicles.

Operator. An individual who is trained and certified to perform tasks in an EPA.

Organization. A NASA center, support contractor, supplier, department, group, or team.

Part. An element of a component, assembly, or subassembly that is not normally subject to further subdivision or disassembly without destruction of its designed use, e.g., a module, IC, resistor, and similar elements.

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 that could be contacted by personnel near the ground. By this definition, a hard ground protected by a functional GFCI is considered a soft ground.

Static Dissipative. A property of a material having surface resistivity $\geq 10^6$ but $\leq 10^{12}$ ohms per square or a volume resistivity $\geq 10^4$ but $< 10^{11}$ ohms-cm.

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

Surface Resistivity. The surface resistivity is an inverse measure of the conductivity of a material. Surface resistivity of a material is numerically equal to the surface resistance between two electrodes forming opposite sides of a square. The size of the square is immaterial. Surface resistivity applies to both surfaces and materials with constant volume conductivity and has the value of ohms per square.

System. A system is a functional subdivision of a spacecraft generally composed of two or more components designed to perform an operation. An instrument is considered a system.

Tailored document. A formal Office Memorandum that technically justifies any deviation from the accepted standard.

Triboelectric. Pertaining to electricity generated by friction.

Verification. The act of performing the tests and/or inspections required in Table 4-1 and reviewing EPAs for compliance to the requirements of this LPR.

APPENDIX B. ACRONYMS

AC	Alternating Current
ATL	Area Test Log (synonymous with ESD Protected Area Test Log)
CDM	Charged Device Model [for electrostatic discharge].
CMS	Continuous Monitoring System
CPG	Common Point Ground
CPP	Control Program Plan
DMM	Digital Multimeter
DUT	Device Under Test
ECA	ESD Controlled Area
EMI	Electromagnetic interference
EPA	ESD Protected Area
ESD	Electrostatic Discharge
ESDA	Electrostatic Discharge Association
ESD ADV	Advisory Document
ESDS	Electrostatic Discharge Sensitive
ESD DS	Draft standards
ESD S	Standards
ESD SP	Standard Practices
ESD STM	Standard Test Methods
ESD TR	Technical Report
GFCI	Ground Fault Circuit Interrupter
HBM	Human Body Model [for electrostatic discharge]
HR	Humidity Ratio
I&T	Integration and Test
LPR	Langley Procedural Requirement
MAE	Mission Assurance Engineer
MM	Machine Model [for electrostatic discharge]
NASA	National Aeronautics and Space Administration
NPR	NASA Procedural Requirement
NMTTC	NASA Manufacturing Technology Transfer Center
QA	Quality Assurance
RH	Relative Humidity
RM	Research Model
RMS	Root Mean Square
SAM	Systems Assurance Manager
WM	Workmanship Manual

APPENDIX C. EPA VERIFICATION TEST PROCEDURE

C.1 PURPOSE

This appendix provides an example of a procedure that an ESD Control Program Monitor can use to support verification checks in accordance with the ESD CPP.

C.2 SCOPE

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

C.3 REQUIREMENTS

C.3.1 Personnel Requirements

C.3.1.1 The organization shall ensure that:

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

C.3.2 Equipment Calibration

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

C.3.3 Equipment Verification

C.3.3.1 Equipment maintained in the EPA, such as ionizers and CMSs, that does not require an official and updated calibration sticker. This equipment shall be measured monthly as per manufacturer's procedures.

C.3.3.2 Once a year the equipment used to verify instruments as mentioned in the previous paragraph, shall be calibrated.

C.4 EQUIPMENT LIST

C.4.1 The following equipment, or equivalent, shall be used:

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

C.5 PROCEDURE

C.5.1 Verifications and Results

C.5.1.1 The applicable elements of EPAs shall be verified by personnel currently certified in accordance with paragraph C.3.1 of this appendix.

C.5.1.2 See Chapter 6 of this ESD CPP for personnel responsibilities. The frequency of verifications, conditions of tests, and limits shall be in accordance with Table 4-1 of this ESD CPP.

C.5.1.2.1 Area verifications shall be documented on the EPA ATL (LF 23).

C.5.1.2.1.1 The EPA ATL shall be used for data entry.

C.5.1.2.2 Measurements shall be compared with previous data for the relevant area in order to identify trends toward a noncompliant condition.

C.5.1.2.2.1 If a trend is noted, the organization responsible for the EPA shall be notified so correction can be implemented before failure occurs.

C.5.2 Test Procedures

C.5.2.1 Test 1: Work Surface Resistance

C.5.2.1.1 This test shall be performed by measuring the resistance between two 5-pound, 2.5-inch diameter electrodes.

C.5.2.1.2 The electrodes shall be positioned 10 inches (25 cm) apart and at least 2 inches (5 cm) from the edge of the work surface.

C.5.2.1.3 Set the megohmmeter voltage to 100 V, then measure the resistance after 15 seconds, and record the value in the ATL.

C.5.2.1.4 The area shall be clean and dry prior to performing this test.

C.5.2.1.5 For older surfaces, the measurement shall be made on the most worn area.

C.5.2.2 Test 2: Work Surface Grounding

C.5.2.2.1 Measure the resistance between the equipment ground (the nearest permanent electrical outlet ground) and the center of the work surface.

C.5.2.2.1.1 Use a 5-pound, 2.5-inch diameter electrode at the work surface.

C.5.2.2.1.2 Set the megohmmeter voltage to 100 V, then measure the resistance after 15 seconds, and record the value in the ATL.

C.5.2.2.2 When checking highly conductive surfaces, a GFCI outlet shall be used to protect personnel.

C.5.2.2.2.1 Check the GFCI using the self-test feature in the outlet.

C.5.2.2.2.2 Plug a lamp in the receptacle and press the TEST button in the GFCI.

C.5.2.2.2.3 The light must go out.

C.5.2.2.2.4 Unplug the lamp, press RESET, and record the result in the ATL.

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

C.5.2.3 Test 3: Floor Resistance

C.5.2.3.1 Measure the resistance between two points on the “High Transit” area of the floor at least 12 inches apart.

C.5.2.3.2 Use a 5-pound, 2.5-inch diameter electrode at the work surface.

C.5.2.3.3 Set the megohmmeter voltage to 100 V, then measure the resistance after 15 seconds, and record the value in the ATL.

C.5.2.3.4 This is a minimum test for recertification only and can be used for either floor mats or conductive floors.

C.5.2.3.5 For initial certification of a newly installed conductive floor, follow the test procedure in ESD STM7.1.

C.5.2.4 **Test 4: Floor Grounding**

C.5.2.4.1 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.

C.5.2.4.2 Use a 5-pound, 2.5-inch diameter electrode at the work surface.

C.5.2.4.3 Set the megohmmeter voltage to 100 V, then measure the resistance after 15 seconds, and record the value in the ATL.

C.5.2.4.4 This is a minimum test for verification only and can be used for either floor mats or ESD-protective floors.

C.5.2.4.5 For initial certification of a newly installed ESD-protective floor, follow the test procedure in ESD STM7.1.

C.5.2.5 **Test 5: Wrist Strap Grounding**

C.5.2.5.1 Resistance shall be measured using an ohmmeter.

C.5.2.5.2 The measurement shall be made from the wrist strap groundable point to a facility ground in the nearest permanent electrical outlet.

C.5.2.5.3 Record resistance value in ATL.

C.5.2.6 **Test 6: Continuous Monitoring Systems**

C.5.2.6.1 Check that the CMS alarm activates when the ground is removed by using a "cheater plug," and again by physically removing the cord from the wrist strap while wearing it.

C.5.2.6.2 This test shall be performed when the CMS is being tested for functionality or when there is doubt about the reliability of the CMS.

C.5.2.6.3 For a complete calibration of the CMS, use the manufacturer's recommended fixture and test procedure.

C.5.2.7 **Test 7: Stool and Chair Grounding**

C.5.2.7.1 Qualification tests for any seating used in an EPA shall be in accordance with ESD STM12.1.

C.5.2.7.2 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.

C.5.2.7.2.1 For conductive flooring, use a caster or a grounding chain to make contact between the stool/chair and the floor;

C.5.2.7.2.2 For non-conductive flooring, use of a metal plate may be necessary to measure from the caster to the seat's surface.

C.5.2.7.3 The test shall be repeated for the back and arms of the chair, if present.

C.5.2.7.4 Record the largest resistance measured.

C.5.2.8 Test 8: Humidity

C.5.2.8.1 RH shall be constantly monitored using a calibrated hygrometer.

C.5.2.8.2 The hygrometer shall be in the same room and as close as possible to the work area.

C.5.2.8.3 Continuously recording chart recorders or automatic logging are recommended.

C.5.2.8.4 For places where there is no continuous record, a log shall be maintained by the organization responsible for the EPA.

C.5.2.8.5 The log shall document the humidity levels.

C.5.2.8.5.1 If the humidity levels are not within the acceptable limits, the responsible organization's POC shall halt work and take steps to bring the humidity levels into acceptable limits.

C.5.2.8.6 Daily entries shall be made each time the EPA is in use.

C.5.2.8.7 The verifier shall record the current RH in the ATL and review the humidity charts/log for large variations in humidity, which indicate that more frequent checks may be necessary.

C.5.2.9 Test 9: Ionizers

C.5.2.9.1 For most applications, ionizer performance is considered acceptable as long as the ionizer is in a current status of calibration.

C.5.2.9.1.1 Ionizer average decay rate and ion balance shall be measured in accordance with ESD Association Standard Practice ESD SP3.3.

C.5.2.9.2 The limits for decay and balance measurements are determined by the ESD classification of the EPA being verified (see Table 4-1).

C.5.2.9.3 Because some ionizers tend to collect dust and lose their effectiveness, periodic cleaning and verification of all air ionizers is recommended.

C.5.2.9.4 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.

C.5.2.9.4.1 Follow the instrument manufacturer's operating instructions.

C.5.2.9.4.2 Record decay time and balance on the ATL.

C.5.2.10 Test 10: Soldering Iron Tip to Ground

C.5.2.10.1 Soldering iron tips may be checked using a DMM and a FR-4 copper-clad PC Board of size 2 by 0.5 inches.

C.5.2.10.2 Attach one lead of the DMM to the AC outlet common ground and the other lead to the PC Board.

C.5.2.10.2.1 Set the meter to measure AC voltage.

C.5.2.10.3 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.

C.5.2.10.3.1 It should measure <2.0 mV AC.

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

C.5.2.10.4 Set the DMM to read ohms, then melt the solder pool using the soldering iron and check the resistance value on the DMM.

C.5.2.10.4.1 The resistance should be <1 ohm when certifying a new soldering station and < 2 ohms during periodic verification.

C.5.2.10.5 For soldering irons with integral protection, use the manufacturer's recommended procedures to check proper circuit operation.

C.5.2.11 **Test 11: Equipment and Facility Grounding**

C.5.2.11.1 Measure the resistance between the main service box neutral bond and the EPA CPG.

C.5.2.11.2 This test may require the assistance of the maintenance department to access the neutral bond at the main service box.

C.5.2.11.3 A quick check can be done using a commercial socket tester.

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

C.5.2.11.4 When an auxiliary ground (e.g., quiet ground) is used:

- a. Resistance between the equipment ground and the auxiliary ground shall not exceed 1 ohm when measured at the entrance of the ECA.
- b. Resistance between the equipment ground and the far end of the auxiliary ground shall not exceed 25 ohms.

C.5.3 **Reporting**

C.5.3.1 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.

C.5.3.1.1 These reports shall be retained as described in paragraph 4.3.

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

C.5.4.1 Only test and measuring equipment in a current state of calibration shall be used.

C.5.4.2 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 EPAs were verified using that piece of equipment since its last known "good" status.

C.5.4.2.1 A Nonconformance Report shall be prepared documenting the impact of the out-of-tolerance condition on all products or services processed in the areas in question since the last acceptable assessment of calibration.

C.5.4.2.2 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 analyses (e.g.,

dates of prior verifications, how far out of tolerance the equipment was found to be).

APPENDIX D. LAB TAILORING INTEROFFICE FORMAT

INTEROFFICE MEMORANDUM

TO: PROGRAM MANAGER

<p>From: Lab Manager or Program Monitor Subject: EPA certification Date: Actual date of Program Manager's certification EPA Location: Building # / Room #</p>

Brief entry on what was done, where it was done, and who was present

The modifications to the Langley Form 21 are as follows (list as many items as necessary):

- 1)
- 2)
- 3)
- 4)

Lab Manager Signature _____

Lab Monitor Signature _____

APPENDIX E. PROCEDURE FOR VERIFYING MANUAL WRIST STRAP CHECKERS

E.1 Equipment required as shown in Figure E-1 includes:

- a. One resistance decade box
- b. One manual wrist strap checker or Resister Pods of a CMS system
- c. Two interconnect cables with Banana plugs on either end
- d. One circular Dual Test Bed

E.2 A powered resistance decade box, e.g., like the one shown, shall be calibrated.

E.3 If a non-powered resistance decade box is used, a calibrated multi-meter in Resistance mode shall connect to the decade box in parallel and be used to verify the resistance from the resistance decade box.

E.4 Procedure:

E.4.1 Connect the black interconnect cable to the decade box, and to the wrist strap checker.

E.4.2 Connect one end of the red interconnect cable to the decade box, and use the free end to press onto the metal plate on the face of the wrist strap tester.

E.4.3 Adjust the decade box, making several measurements above and below the required $1\text{M}\Omega \pm 20\%$ ($800\text{k}\Omega$ to $1.2\text{M}\Omega$) wrist strap resister requirement, ensuring that the wrist strap tester fails any measurement $< 800\text{k}\Omega$, and that the wrist strap tester fails any measurement $> 1.2\text{M}\Omega$.



Figure E-1. Setup for Verifying Wrist Strap Checker

E.5 Performing this verification on a quarterly basis shall eliminate the need to calibrate the manual wrist strap tester.

E.5.1 A NASA “Calibration Not Required” sticker shall be placed on the wrist strap checker in clear view.

APPENDIX F. RESISTIVE RANGES

Ohms	Ohms Per Square (Surface Resistivity)	Material	Description
$> 10^{11}\Omega$	$\geq 10^{11}\Omega$	Insulative	Insulators and Base Polymers. Not an ESD material
	$10^9\Omega$ to $< 10^{11}\Omega$	Antistatic	Provides a thin moisture layer to minimize Triboelectrification (charging by friction).
$10^4\Omega$ to $< 10^{11}\Omega$	$10^6\Omega$ to $< 10^9\Omega$	Dissipative	You can have high charging in the static dissipative range despite favorable resistance. Promotes electrostatic decay or rapid discharge in the 1.0×10^6 ohms to $< 5.0 \times 10^{10}$ range but it DOES NOT SHIELD OR ATTENUATE
0Ω to $< 10^4\Omega$	$10^3\Omega$ to $< 10^6\Omega$	Conductive	No initial charge. Provides path for rapid charge to bleed-off and some shielding
0Ω to $< 10^3\Omega$ for Field Strength	0Ω to $< 10^3\Omega$	Shielding	Prevents High Voltage Discharge Penetration
	$10^{-3}\Omega$ to $< 1\Omega$	<u>Carbons</u> ¹	Carbon Black powders and <u>fiber</u> Prevents High Voltage Discharge Penetration
	$< 10^{-3}\Omega$	<u>Metals</u> ¹	Prevents High Voltage Discharge Penetration and provides both RFI/EMI Shielding

NOTE: WHILE THE OMEGA SYMBOL IS USED IN THE OHMS PER SQUARE COLUMN, IT IS A MEASURE OF OHMS PER SQUARE.

¹ https://en.wikipedia.org/wiki/Electrostatic_discharge_materials

APPENDIX G. NON-CONFORMANCE PROCEDURE

G.1 A non-conformance (NC) of one or more ESD control test items listed in Table 4-1 may cause a work-stoppage (WS) if no mitigation procedure(s) are identified, and if a waiver signed by the project Environmental Engineer (or Project Manager) of the project using the EPA has not been submitted to the EPA's Program Monitor.

G.1.1 The previous statement allows use of the EPA if the appropriate mitigation procedure(s) are enacted and the proper signature is in place.

G.1.2 A Corrective Action (CA) shall not be required if no WS is required.

G.2 When a NC is discovered during an ESD control test of an EPA for either certification, or for verification and it causes a WS, then a CA shall be identified and described on LF 442. Below is a description of the parts on that Langley Form, and what information is expected to be defined therein.

G.2.1 A CA will be identified to include:

G.2.1.1 The Immediate Action

G.2.1.1.1 Actions to contain the problem.

G.2.1.1.2 May include notification of the customer affected.

G.2.1.2 The Cause Analysis

G.2.1.2.1 Determine the cause(s) leading to the noncompliant condition.

G.2.1.3 The Scope of Investigation

G.2.1.3.1 Investigate the scope of the noncompliant condition.

G.2.1.3.2 Additional Immediate Actions to correct any associated problems.

G.2.1.4 The Corrective Action Plan

G.2.1.4.1 Address the cause(s).

G.2.1.4.2 Possible solution(s) should be identified and evaluated.

G.2.1.4.3 Define any action plan with owners and due dates.

G.2.1.5 Verification of Effectiveness

G.2.2 The Program Monitor will submit a copy of all paperwork associated with any WS to the LaRC ESD POC.