Center-Wide Procedures and Guidelines (PG)

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COMPLIANCE IS MANDATORY

Responsible Office: 300/Safety and Mission Assurance Directorate

Title: GSFC Electrostatic Discharge (ESD) Control Plan

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PREFACE

P.1 PURPOSE

In accordance with GPR 8730.6, this document contains the technical and administrative requirements used to implement Goddard Space Flight Center (GSFC)'s Electrostatic Discharge (ESD) Control Program [1] through:

Roles and responsibilities
Training and personnel certification requirements
Baseline technical performance requirements
Quality control measures which assure performance continuity including:

(1) Standard methods and procedures
(2) Baseline and periodic performance measurements
(3) Visual indicators, standardized record-keeping, and preferred equipment which steer labs and personnel towards compliance

Note: The superscripted bracketed reference numbers used throughout this document (e.g. [1]) show traceability between ANSI/ESD S20.20 and the requirements herein. See section 9 for the document associated with the source requirement.

P.2 APPLICABILITY

P.2.1 Processing Operations within GSFC

The requirements herein are applicable to GSFC operations only. Civil servants, contractors, and visitors working on-site in GSFC facilities shall comply with this control plan no later than six months after its release date. Civil service and contractor personnel whose primary work assignment is on-site are not considered visitors. Visitors, who enter Electrostatic Discharge Protected Areas (EPAs), whether they are handling the electrostatic discharge sensitive (ESDS) hardware or observing the hardware, are subject to the applicable requirements herein. NASA-HDBK-8739.21 may be used as a guide for external National Aeronautics and Space Administration (NASA) suppliers who are preparing their own ESD control program in accordance with contractual or task order requirements. Ensuring that ESD control requirements and methods as defined within this document are implemented is everyone's responsibility, regardless of whether the individual has a formal role as defined in this control plan or not.

P.2.2 Mission Hardware and Critical Ground Support Equipment

The requirements herein are applicable to ESDS items which:

- Will be used during the NASA mission (i.e. "mission hardware")
- Are ESDS critical Ground Support Equipment (GSE) or

- Are engineering model or engineering design unit versions of mission hardware.

ESD control in accordance with the requirements herein is optional for Research and Development (R&D) work with the following exceptions:

a. Signage requirements apply (see paragraph 7.2).
b. When the project exercises the option to forgo any of the ESD control requirements herein, that decision shall be recorded and the record retained with the hardware.

P.2.3 Use of ESD Control for Non-ESD-Sensitive Items

There are costs associated with the deployment of ESD control requirements; therefore these requirements should only be imposed on Mission hardware and critical GSE that is ESD sensitive unless the need to do otherwise is clearly identified.

P.3 AUTHORITY

GPR 8730.6, Electrostatic Discharge (ESD) Control

P.4 REFERENCES

a. NASA-HDBK-8739.21, Workmanship Manual for Electrostatic Discharge Control (Excluding Electrically Initiated Explosive Devices)
b. GPR 1400.1, Waiver Processing
c. GPR 1440.8, Records Management
d. GPR 1700.7, Electrical Safety
e. GPR 3410.2, Employee Task-Specific, Required and Mandatory Training Requirements
f. GPR 8730.1, Calibration and Metrology
g. GPR 8730.7, Laboratory Management
h. ANSI/ESD/JEDEC JS-001, Human Body Model (HBM) – Component Level
i. ANSI/ESD S1.1, Wrist Straps
j. ANSI/ESD S2.1, Garments
k. ANSI/ESD S5.3.1, For Electrostatic Discharge Sensitivity Testing – Charged Device Model (CDM) – Component Level
l. ANSI/ESD S6.1, Grounding
m. ANSI/ESD S7.1, Resistive Characterization of Materials – Floor Materials
n. ANSI/ESD S8.1, Symbols – ESD Awareness
o. ANSI/ESD S20.20, ESD Association Standard for the Development of an Electrostatic Discharge Control Program for – Protection of Electrical and Electronic Parts, Assemblies and Equipment (Excluding Electrically Initiated Explosive Devices)
p. ANSI/ESD SP3.3, Periodic Verification of Air Ionizers
q. ANSI/ESD STM13.1, Electrical Soldering/Desoldering Hand Tools
r. ANSI/ESD STM97.1, Floor Materials and Footwear – Resistance Measurement in Combination with a Person

s. ANSI/ESD TR1.10, Survey of Constant (Continuous) Monitors for Wrist Straps
t. ANSI/ESD TR20.20, Control Program Handbook, Technical Requirements

P.5 CANCELLATION

GSFC-WM-001B, Workmanship Manual for Electrostatic Discharge Control

P.6 SAFETY

The safety of all hardware processed and handled in ESD controlled areas is dependent on the proper grounding of the facility, functioning common ground points, proper maintenance and operation of all safety equipment, such as Ground Fault Circuit Interrupters (GFCI's), and compliance with the resistance requirements herein for all dissipative surfaces. ESD wrist straps are not personal safety devices. The methods prescribed herein are designed for the protection of hardware from damaging electrostatic discharges and are not intended to guarantee the safety of the operators from all possible electrical hazards. This is particularly true when employing conductive work surfaces or floors when operating at 250V and above. Additional human safety precautions may be required and shall be in accordance with GPR 1700.7, Electrical Safety.

P.7 TRAINING

See Section 3.

P.8 RECORDS

Records required by the processes described herein shall be retained in accordance with GPR 1440.8. Records shall be as shown in Table P.8-1.

Table P.8-1: Program Record Management

Record Title	Record Custodian	Retention
Training records	Civil Servants: Office of Human Resources and/or Supervisor, as described in GPR 3410.2 On-site Contractors: Company retains records. Instructors: Training Center or contractor retains training history for certification and retraining credential traceability	NRRS 3/33G1* -- Destroy 5 years after employee discontinues or completes training.
Trainer certification records	ESD Control Program Manager	NRRS 8/107* -Temporary- Destroy/delete when between 2 & 15 years old. Do not retain longer than life of program/project plus 5 years.
ESD Protected Area (EPA) verification records	Laboratory Owner. For EPAs in Integration and Test (I&T) environment: Project Manager	NRRS 8/107*
Equipment verification records	Laboratory Owner. For EPAs in I&T environment: Project Manager	NRRS 8/107*
EPA Procedures and Training Materials	Laboratory Owner. For EPAs in I&T environment or Project-specific records: Project Manager For ESD Control Program training: ESD Control Program Manager	NRRS 8/107*
ESD workstation certification records	ESD Control Program Manager	NRRS 8/107*

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

PROCEDURES

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

1 OVERVIEW

1.1 Document Organization

This ESD Control Plan defines a Center-wide program that uses specific roles and responsibilities for personnel who implement the program, personnel training and certification requirements, standard methods and tools, technical performance limits, baseline and recurring performance verifications, and record-keeping to prevent damaging electrostatic discharges from damaging mission critical hardware.

a. Personnel roles and responsibilities. (sections 2 and 7) A wide variety of personnel roles exist in this ESD control program and are described in section 2. A significant subset of the requirements applies to users of EPAs who are called Operators. A smaller portion of the requirements apply for other roles such as EPA Certifiers, Lab Owners, Managers and Visitors. The majority of the work done to comply with the requirements herein is performed by the role called Program Monitor (section 7) whose duties are much more extensive and distinct from those of the other roles.

b. Personnel training and certification. (section 3) Personnel who perform duties in accordance to the requirements herein are trained and certified based on their assigned role. Training and certification is required for some roles and is optional for other roles.

c. ESD sensitivity level. (section 4) The methods and requirements employed herein for achieving ESD control are relative to the ESD sensitivity of the item being processed (i.e built, tested, transported, etc). The requirements herein are arranged by ESD sensitivity level to allow less complex and less costly methods to be used when sufficient, and more complex and more costly methods only when necessary.

d. Performance criteria and practices for establishing and using ESD Protected Areas (EPAs). (section 5) ESD control is largely achieved through use of grounding approaches and control of materials within the work area for a given level of ESD sensitivity. Requirements which ensure the correct and sufficient use of these methods within EPAs, are found in Table 5-2. Variations to these for either more sensitive or less sensitive items are included in Tables 5-4 and 5-5. Section 5.3.3 provides requirements which are part of the Human Body Model (HBM) Class 1A/Class 0 EPA baseline but do not readily fit into Table 5-2.

e. Operator procedures. (section 5.3.2, 5.4 and 5.5) The majority of the rules Operators must follow when working with Electrostatic Discharge Sensitive (ESDS) items in EPAs are found in Table 5-3. Variations to these for either more sensitive or less sensitive items are included in Tables 5-4 and 5-5.

f. Additional requirements based on work environment. (sections 5.2.a, 5.6 and 5.7) The methods and requirements employed herein for achieving ESD control are relative to the type of work environment (e.g. lab bench, I&T, flatsats). The requirements are baselined to the lab bench

environment and then modified for application to other types of work environments. These requirement modifications are found in Sections 5.6 and 5.7. See Appendix J for general information on the following work environment types and names used herein: lab bench, Integration and Test (I&T), Flatsats, Commercial Off The Shelf (COTS), GSE and Research and Development (R&D).

g. EPA quality assurance. (section 6) EPA performance is assurance using verification measurements which are baselined prior to the EPA's first use and then repeated on a schedule which is determined to be commensurate with acceptable levels of risk. The requirements related to these verifications, which are performed by Program Monitors and EPA Certifiers, are described in section 6.

h. ESD control beyond the EPA. Section 8 includes requirements related to ESD control that are either not related to the EPA or are related to general infrastructure such as facility grounding and floor installations.

i. Requirements traceability to Agency baseline. (section 9) Traceability is provided between the requirements herein and the minimum Agency baseline by using a superscripted reference designator in brackets (e.g. [1]) and the reference list in section 9.

1.2 Interpretation of Requirements and Technical Authority

a. Per GPR 8730.6, Code 300 is responsible for establishing and maintaining this plan and for reporting Program quality metrics. The Code 300 ESD Control Program Manager is the authority on correct and effective interpretation and implementation of the provisions herein.

b. Alternate approaches for satisfying the requirements herein are allowed when reviewed and approved by the Code 300 ESD Control Program Manager or their delegate (e.g. an EPA Certifier) and are not considered cause for establishing waiver.

c. This ESD control plan is considered an institutional quality process. Waivers for requirements herein shall be processed in accordance with GPR 1400.1. Consult with the flight project Chief Safety and Mission Assurance Officer (CSO) regarding waiver requirements and processes for recording and accepting requirements relief on a project-by-project basis.

2 PERSONNEL ROLES AND RESPONSIBILITIES

a. Duties assigned to the Lab Owner may be delegated (e.g. to a Lab Manager or a Program Monitor) at the Lab Owner's discretion however the accountability for compliance with the requirements associated with those duties remains with the Lab Owner. Duties assigned to the ESD Control Program Manager may be delegated (e.g. to EPA Certifiers) at the ESD Control Program Manager's discretion however the accountability for compliance with the requirements associated with those duties remains with the ESD Control Program Manager.

b. Table 2-1 lists the specific duties and responsibilities assigned to all of the participants in the GSFC ESD Control Program. Accountability for the success of this program flows in the following order: the Code 300 ESD Control Program Manager; the Lab Owners (or I&T Managers in some cases); the Program Monitor; the Operator.

c. Lab Managers do not have a formal role in the ESD Control Program and are not assigned duties and requirements above and beyond the awareness training which is part of the Lab Management Program (See GPR 8730.7).

d. Where resources are required to comply with the requirements or to perform the duties assigned to a role herein, the Lab Owner (or I&T Manager as applicable) is expected to provide or arrange for those institutional or project-sponsored resources.

e. Program Monitors may share duties associated with any one or more EPAs.

Table 2-1: Personnel Roles and Responsibilities in the GSFC ESD Control Program

	Role Name {Responsible Organization}	**Duties**
a.	ESD Control Program Manager[1] {Code 300}	• Manages ESD Control Program • Maintains this document and GPR 8730.6 • Maintains the training program for all student levels • Manages EPA certification process • Interprets the requirements herein • Approves institutional level waivers to the requirements herein and approves alternate approaches to requirements compliance • Certifies Level A and Level B instructors and EPA Certifiers • Coordinates transfer of training records to Code 114 as needed • Identifies ESD subject matter experts • Ensures data related to the ESD Control Program is entered and maintained in the https://lqms.gsfc.nasa.gov database. • Performs records management in accordance with Table P.8-1 for: - EPA certification records - Trainer certification records - Student records for personnel taught by Level A and Level B instructors. - Training materials
b.	Personnel Line Supervisor {All organizations}	• Point operators and program monitors to the right training • Certify operators and program monitors after they successfully complete training (certify biennially, see Table 3-2) • Revoke certification from personnel who cease to meet certification requirements (see Table 3-2) • Implement a plan with personnel to reinstate certification • Records management in accordance with Table P.8-1 for: - Personnel certification records.

Table 2-1: Personnel Roles and Responsibilities in the GSFC ESD Control Program

	Role Name {Responsible Organization}	**Duties**
c.	Lab Owner {Branches or Divisions who are responsible for labs which contain EPAs}	• Holds the primary responsibility for compliance of EPAs with the requirements of this Control Program except for in I&T labs • Obtains required training (See Table 3-1). • Procures ESD flooring, arranges for incoming inspection of newly installed floors, and sends incoming inspection data to the ESD Control Program Manager in accordance with paragraph 8.2. • Assigns program monitors to EPAs • Ensures data related to the ESD Control Program is entered and maintained as applicable for their labs in the https://lqms.gsfc.nasa.gov database. • Provides appropriate resources to their lab's ESD Control program monitors including access to EPA facilities and equipment, personal grounding devices (e.g. garments and wrist straps), consumable supplies (e.g. report covers), verification measurement equipment, and equipment calibration • Ensures that assigned Program Monitors obtain the correct training. • Records management is accomplished in accordance with Table P.8-1 for: - EPA verification records - Applicable lab-specific procedures
d.	Integration and Test (I&T) Manager {Code 568, 600 and others as applicable}	• Is responsible for compliance with the ESD Control Program by all members of their I&T team during I&T operations. • Obtains required training (See Table 3-1). • Appoints a member of the I&T team to be the cognizant ESD program monitor • Ensures data related to the ESD Control Program is entered and maintained as applicable for the I&T EPA(s) in the https://lqms.gsfc.nasa.gov database. • Ensures that the ESD Control Plan created by the Project Design Lead (PDL) or Design Engineer is implemented by the cognizant ESD program monitor • Records management is accomplished in accordance with Table P.8-1 for: - EPA verification records - Applicable project-specific procedures

Table 2-1: Personnel Roles and Responsibilities in the GSFC ESD Control Program

	Role Name {Responsible Organization}	**Duties**
e.	PDL or Design Engineer {Code 500, 600}	• Obtains required training (See Table 3-1). • Identify the ESD sensitivity of the hardware at various stages in its development (See paragraph 4.1) • Identify special considerations and procedures that are needed to avoid damaging ESD events throughout the lifecycle of the ESDS item. • Ensure that item marking, if used, includes ESDS indicator as applicable • Ensure that all enclosures used to store and transfer the ESDS item are marked with the appropriate ESDS level throughout the lifecycle of the item. • Provide for a program monitor to set up and verify the EPA during work in an I&T environment if working outside the context of an I&T team. • Create an ESD Control Plan or equivalent instructions for ESD control for operations performed within the context of an I&T team (also see Appendix J)
f.	Program Monitor {All organizations}	• Program Monitor duties and responsibilities are significantly more extensive than those of the other roles in this table and so are fully contained in section 7 which applies solely to Program Monitors.
g.	EPA Certifying Authority {Code 300}	• Obtains required training (See Table 3-1) and certification (See Table 3-2) • Confirms EPA certification prerequisites are met • Reviews technical content of local ESD procedures. • Certifies and recertifies EPAs • Documents and distributes EPA certification activity results
h.	Operator {All organizations}	• Obtains required training (See Table 3-1) and certification (See Table 3-2) • Follows behavior, Quality Assurance (QA), and equipment-use protocols defined herein when working inside an EPA and removing or replacing an ESDS item from or into protective packaging. • Ensures that EPA ratings match the ESDS item's rating before removing it from its packaging and processing it at an EPA • Learns and follows EPA-specific procedures provided by the program monitor • Escorts visitors
i.	CSO or Hardware Quality Engineer {Code 300}	• Obtains required training (See Table 3-1) and certification (See Table 3-2) • Verifies that EPAs used for processing applicable hardware are certified and maintained in accordance with the requirements herein. • Verifies that operators processing ESDS mission hardware in EPAs are certified and comply with the requirements herein.

Table 2-1: Personnel Roles and Responsibilities in the GSFC ESD Control Program

	Role Name {Responsible Organization}	**Duties**
j.	Visiting Operator {GSFC or non-GSFC}	• Obtains required training (See Table 3-1) • Processes ESDS hardware in a certified EPA only, on a temporary basis • Follows behavior, QA, and equipment-use protocols described in the training • Seeks help and guidance from the program monitor as indicated in the training
k.	Visitor	• Observes ESDS hardware in a certified EPA
l.	Level A Instructor {Code 300}	• Trains all student levels and provides evidence of successful completion of training to student (card). Provides replacement cards as needed. • Ensures that training records are provided to the Code 114 training office for all civil service students they train and to the ESD Control Program Manager for all contractor Level B instructors they train within 35 days of completion of training. • Provides training materials to Level B instructors whom they train. • May also perform the duties of a program monitor or operator
m.	Level B Instructor {All organizations}	• Train ESD program monitors and operators and provides evidence of successful completion of training (card). Provides replacement cards as needed. • Ensures that the names of all personnel who they have successfully trained are provided to the ESD Control Program Manager within thirty-five days of the completion of training. • May also perform the duties of an ESD program monitor or operator. • Records management in accordance with Table P.8-1 for "Student records"

3 PERSONNEL TRAINING AND CERTIFICATION

The training classes provided for this Control Plan are shown in Table 3-1 along with the roles from Table 2-1 for which they are required or recommended. GSFC ESD training is not portable outside of GSFC and external ESD training is not a substitute for GSFC ESD training (i.e. not portable into GSFC).

3.1 Training Policies

3.1.1 Hierarchy of Instructors

Operators, Program Monitors, and EPA Certifiers shall take ESD training from a Level A or Level B instructor who is certified in accordance with this document. Level B instructors shall take ESD training from a certified Level A instructor.

3.1.2 Hierarchy of ESD Control Program Training

Level B Instructor training is more advanced than Program Monitor training, which is more advanced than Operator training. Personnel who take the higher level training meet the certification requirement for training for the lower level role(s).

3.1.3 Initial Training

For the first occurrence of training under this document all personnel shall take the full length training for their respective role, regardless of prior training credentials under the GSFC-WM-001 system.

3.1.4 Retraining

Retraining courses may be offered that are shorter and focus on new requirements and lessons learned. Operators, Program Monitors, EPA Certifiers or Level B Instructors whose ESD training has not been repeated successfully in more than two years and six months must retake the full-length initial course as retraining unless approved by the ESD Control Program Manager to take the shortened retraining course. Personnel who are taking training for the first time at a more advanced level shall take the initial course regardless of prior training at the less advanced level. Delay of retraining beyond twenty-four months is cause for revoking personnel certification until appropriate training has been completed (see paragraph 3.2).

3.1.5 Acceptability of Training to GSFC-WM-001

Individuals who are currently trained to GSFC-WM-001 meet the training requirement herein until retraining is required at which time they shall take initial training to this document per 3.1.3 above.

3.1.6 Courses Taught by Level B Instructors

Level B Instructors teach operators or Program Monitors from their own company or organization whose primary work assignment is the GSFC Greenbelt or Wallops Flight Facility Campuses. The Level B Instructor's primary work assignment does not have to be within these locations. Course slides and the training card template shall be provided to Level B Instructors by the Level A Instructor. Level B Instructors are responsible for obtaining and using their own ESD measuring equipment as needed to provide adequate instruction. ESD Operator courses taught by Level B Instructors are subject to audit by the ESD Control Program Manager or their delegate.

3.1.7 Training Records

Training records for all courses identified in Table 3-1 shall be retained in accordance with Table P.8-1. These records shall include the information in a. through g. below as a minimum.

a. Revision of this document used for training

b. Name of the trainee
c. Name of the organization which employs the trainee (organization code for civil service and company name for contractor).
d. Level of training completed
e. Date of completion of training
f. Name of the instructor and organization providing the training
g. Test Score(s) if applicable

All Level A instructors shall ensure that the training records for students are provided to the GSFC training office, Code 114, within 35 days of completion of training. All Level B instructors shall ensure that the training records for students are provided to the ESD Control Program Manager within 35 days of completion of training. For visiting operators, records of completion of training shall be created and stored with the associated project or lab records.

3.1.8 Training/Certification Card

A double-sided training completion card, or equivalent, shall be issued by the instructor upon successful completion of Operator, Program Monitor, or Level B Instructor training. One side shall indicate the date of successful completion of training, level of training, and the instructor's name, and the reverse side shall provide a signature line for the supervisor to use when certifying the individual. A Certificate of Completion of Training may be issued but is not required.

3.2 Personnel Certification

3.2.1 Baseline Requirement

Personnel certification is used to indicate individuals who are suitable for performing the roles and duties described herein. Within the GSFC ESD Control Program, the personnel who must be certified prior to performing work related to the Program are Operators, Program Monitors, Instructors, and EPA Certifiers. Recertification is required every two years. The minimum prerequisites for certification are listed in Table 3-2.

3.2.2 Revocation of Certification

Certification shall be revoked by the applicable certification authority when the conditions for certification are not met. The certifying authority shall determine the method for reinstating certification after it has been revoked for lack of competency or absence from work in an EPA. The certification record shall indicate this has taken place. Certifying authorities do not have the authority to waive retraining. The certification authorities are defined according to the role for which the individual is being certified and are shown in Table 3-2.

3.2.3 Portability of Certification

Training is portable within GSFC regardless of a change of employer. Certification is not portable from supervisor to supervisor and shall be reestablished by the current supervisor (i.e. the party responsible for the individual's work assignments). This requirement applies to both contractors and civil servants.

3.2.4 Certification Card Replacement

A new training/certification card may be obtained from the individual's instructor (Level A or Level B) for the purpose of reestablishing or reinstating certification. The training signature line on certification cards may be completed by the ESD Program Manager based on existing training records when the Level A or Level B instructor is unavailable.

3.2.5 Availability of Evidence of Certification at the Worksite

Evidence of personnel certification status shall be available in the work area. A database record which can be accessed near the EPA or near the lab meets this requirement. An online resource, https://lqms.gsfc.nasa.gov, is available for this purpose.

3.2.6 Situational Certification Maintenance for Level B Instructors.

The ESD Control Program Manager may require Level B Instructors to repeat all or portions of the existing training material or take new training in order to ensure that all of the Operators and Program Monitors that they teach are receiving the most recent information that the Program is distributing through training. Level B Instructor certification will be revoked for those individuals who do not successfully complete this additional training in a timely manner.

Table 3-1: GSFC ESD Training Courses

	Course Name	Course Description	Intended Audience	Instructors	Personnel Required to Take Course
a.	Overview for Facilities Support Personnel	General overview of ESD. Awareness of reasons and ways for avoiding entry into certified EPAs. Preferred materials and methods for cleaning ESD flooring. Slide presentation. 1 hr	• Facilities maintenance personnel. • Janitorial staff. • Administrative staff who work near labs with EPAs.	• ESD Program Manager • Level A Instructor • ESD Program Manager delegate at Wallops Flight Facility (WFF)	None (optional) Taken: Once
b.	Overview for Project Managers	General overview of ESD. Awareness of purpose and methods of GSFC's ESD Control Program. Cost, schedule, and reliability risks associated with an ESD event. Slide presentation. 0.5 hr	• Project personnel who do not work in EPAs such as project managers, systems engineers, and Center senior leadership.	• ESD Program Manager • Level A Instructor • ESD Program Manager delegate at WFF	None (optional) Taken: Once
c.	Overview for Lab Owners, PDLs, Lab Managers, and Supervisors	Overview of the purpose and methods of GSFC's ESD Control Program. Requirements flow-down. Emphasis on roles and responsibilities. Slide presentation. 1 hr	• Personnel who have responsibility for EPAs or ESDS Mission hardware but are not Program Monitors. • Personnel who are responsible for certifying their employees.	• ESD Program Manager • Level A Instructor • ESD Program Manager delegate at WFF	Lab Owners whose labs contain EPAs, PDLs, Supervisors who certify Program Monitors or Operators. Taken: Once

Table 3-1: GSFC ESD Training Courses

	Course Name	Course Description	Intended Audience	Instructors	Personnel Required to Take Course
d.	Visiting Operator	Overview of required behaviors in GSFC EPAs. Explanation of conditions which require action by the Program Monitor or which require the visitor to stop work. This course may be tailored to satisfy project needs. The content consists of a slide presentation. Course duration: 1 hr.	• Visitors who will process ESDS Mission hardware in GSFC EPAs	• ESD Program Manager • Level A or B Instructor • EPA Certifier • Certified Program Monitor or Operator	All visitors who will process ESDS Mission hardware in GSFC EPAs. Taken: Once per project.
e.	Operator (Initial and Retraining)	In-depth training to learn all requirements, responsibilities and procedures defined herein and in GPR 8730.6 which are assigned to operators who will process ESDS Mission hardware in certified EPAs. This course is repeated biennially. This course is a prerequisite for ESD operator certification. The content consists of a slide presentation, demonstrations, and a final exam. Course duration: 5.5 hrs for initial course, 2 hrs for retraining.	• Resident contractors and civil servants who process Mission hardware in GSFC EPAs or otherwise work in GSFC EPAs such as quality engineers.	• Level A Instructor • Level B Instructor who works for the same company as the student.	Operators Taken: Biennially
f.	ESD Program Monitor (Initial and Retraining)	In-depth training to learn all requirements, responsibilities and procedures defined herein and in GPR 8730.6 which are assigned to program monitors who will set up and maintain EPAs (See Table 7-1). This course is repeated biennially. This course is a prerequisite for program monitor certification and also satisfies the training prerequisite for ESD operator certification. The content consists of a slide presentation, hand-on exercises, and a final exam. Course duration: 12 hrs for initial course, 4 hrs for retraining.	• ESD Program Monitors • EPA Certifiers • Quality Engineers	• Level A Instructor, for all students • Level B Instructor who works for the same company as the student.	ESD Program Monitors, EPA Certifiers Taken: Biennially
g.	EPA Certifier	Takes Program Monitor Course above and performs 8 hours of on-the-job training under the mentorship of a certified EPA Certifier.	• Individuals who certify EPAs on behalf of the ESD Control Program	• Level A Instructor • On-the-Job-Training (OJT) from a certified EPA Certifier	EPA Certifier OJT is one-time and Program Monitor training is taken biennially

Table 3-1: GSFC ESD Training Courses

	Course Name	Course Description	Intended Audience	Instructors	Personnel Required to Take Course
h.	Level B Instructor (Initial and Retraining)	In-depth training to learn all requirements and procedures defined herein and in GPR 8730.6 in order to be able to perform the duties of an ESD operator, a Program Monitor, and to teach the Operator or Program Monitor training class. This course is repeated biennially. This course is a prerequisite for Level B instructor certification and also satisfies the training prerequisite for Program Monitor certification as well as for Operator certification. The content consists of a slide presentation, hand-on exercises, instruction practicum, and final exam. Course duration: 16 hrs for initial course, 6 hrs for retraining.	• Level B Instructor	• Level A Instructor	Level B Instructor Taken: Biennially

Table 3-2: Personnel Certification Requirements

	Personnel	Conditions for Certification	Certifying Authority
a.	Operator	• Training per Table 3-1 biennially • Continuous competency • No absence from work in an EPA for greater than one year	Supervisor
b.	Program Monitor	• Training per Table 3-1 biennially • Continuous competency • No absence from work in an EPA for greater than one year	Supervisor
c.	Level B Instructor	• Training per Table 3-1 biennially • Continuous competency • No absence from teaching for greater than one year	ESD Control Program Manager
d.	EPA Certifier	• Training per Table 3-1 biennially • Continuous competency • No absence from certification work for 6 months	ESD Control Program Manager
e.	Level A Instructor	• Prior instructor experience • Prior hands-on experience working in an ESD Controlled work area • Participation in review and coordination of all updates of this document and GPR 8730.6 • Continuous competency • No absence from teaching for greater than one year	ESD Control Program Manager

4 ESD SENSITIVITY LEVELS

This ESD control plan primarily addresses hardware that is sensitive to Human Body Model (HBM) type events of voltage level Class 1A and Class 0 (See Table 4-1). Requirements are also included for hardware which is either less sensitive (e.g. HBM Class 1B) or more sensitive (e.g. Charge Device Model (CDM) Class C1). The sensitivity levels and models (of voltage/current/time events that damage) are defined by ESDA test methods ESD/JEDEC JS-001, for the HBM event and ESD S5.3.1, for the CDM event. Control of ESD for items of sensitivity level HBM 1C or less sensitive is not covered by this control plan. HBM and CDM are not directly comparable due to the differences in their event characteristics (voltage, current, time, and energy). CDM Class C1 and C2 are both considered Ultra-Sensitive within the context of this PG.

4.1 Identification of ESD Sensitivity Level

An ESD sensitivity level shall be identified for all ESD sensitive (ESDS) applicable hardware by model and level (e.g. “HBM Class 1A”; “C1”). Inspection reports, travelers, and other paperwork accompanying the hardware shall contain ESDS labels which identify the sensitivity level as a minimum, as well as applicable cautionary notes.

Table 4-1: ESDS Item Sensitivity Classifications[1/]

GSFC EPA Nomenclature	ESD Class[3][4]	Voltage Range
Ultra-Sensitive	CDM C1	<125 V
	CDM C2	125 to <250 V
	HBM w/ Breakdown Energy ≤ 0.3 μJ	
HBM Class 0	HBM 0	<250 V
HBM Class 1A	HBM 1A	250 to <500 V
HBM Class 1B	HBM 1B	500 to <1000 V

Notes:
1. HBM and CDM sensitivity levels are not proportional or similar by voltage range. The two models differ by duration and shape of the associated pulse when plotted by Current vs. Time.

5 PERFORMANCE CRITERIA AND PRACTICES FOR ESTABLISHING AND USING ESD PROTECTED AREAS (EPAs)

The tables in this section detail minimum requirements as they pertain to set-up and use of the various classifications of EPAs as well as to Operator practices.

5.1 General

a. Handling of ESDS hardware that will be used in a NASA mission shall be done by certified operators in an EPA that has been established and is maintained by a certified Program Monitor, and has been certified by an EPA Certifier who represents the ESD Control Program.

b. EPA certification establishes that the EPA meets the performance requirements herein (See section 6 for EPA certification requirements).

c. When custom procedures apply beyond those required herein, they shall be established and documented and operators using the affected EPAs shall be trained to follow those additional procedures correctly. Routine quality verifications may apply for assuring that performance criteria are being met for custom configurations or practices. Unless otherwise delegated by the Lab Owner or I&T Manager, the Program Monitor is responsible for implementing this requirement.

d. Alternate approaches to achieving the requirements herein shall be reviewed and approved during EPA certification.

e. The procedures for the measurements specified herein for demonstrating that the performance requirements are met shall be provided during Operator, Program Monitor and Level B Instructor training.

f. Figures 5-1 and 5-2 show generic setup and electrical connections associated with EPAs.

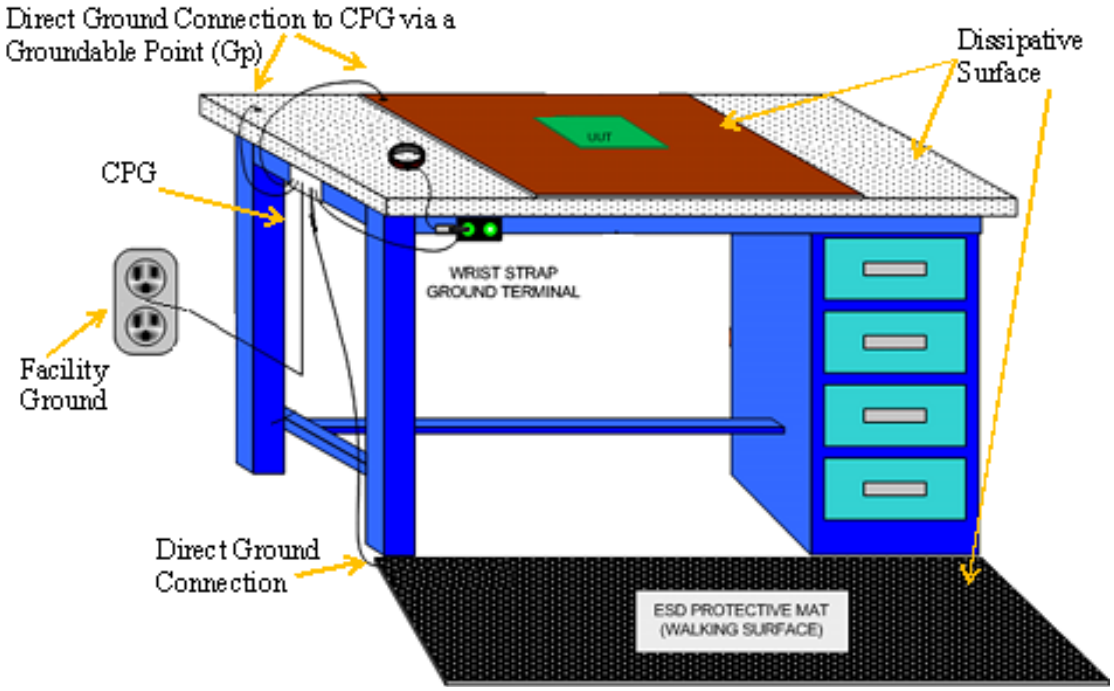

Figure 5-1: Typical ESD Grounded Workstations
(See Table 5-2 for Applicable Requirements and Definitions)

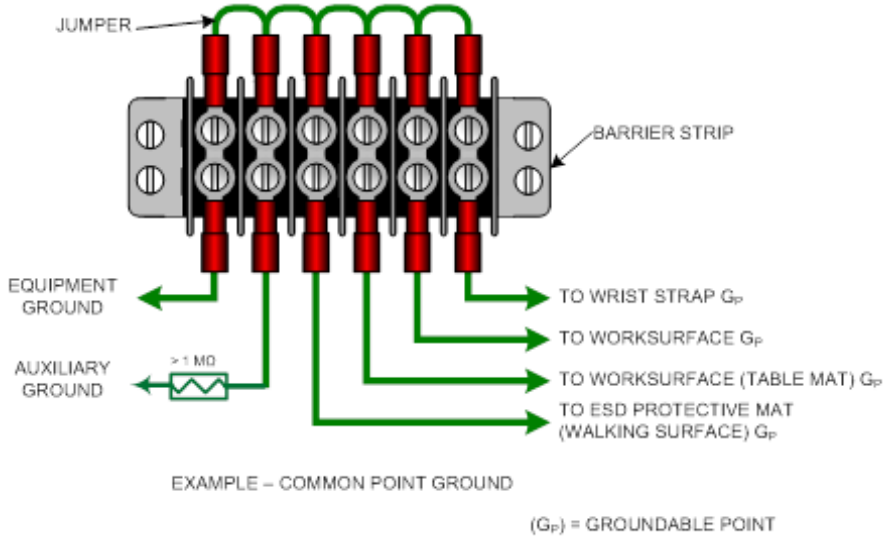

Figure 5-2: Workstation Common Point Ground

5.2 Navigation of Requirements in Section 5

Table 5-1 can be used to quickly locate both EPA performance requirements and Operator practices requirements for the ESD sensitivity levels covered by this ESD Control Plan.

a. The requirements which apply for establishing an EPA (Program Monitor duties) and for handling items (Operator duties) of HBM Class 1A sensitivity at a lab bench are considered the baseline (Table 5-2 and 5-3, respectively).

b. Requirements are added to the baseline for items of HBM Class 0 sensitivity (embedded in Table 5-2 and 5-3).

c. Approaches that may be used in a customized EPA for ultrasensitive items are shown in Table 5-4. Customized EPAs are required for ultrasensitive items per 5.4.

d. Requirements are reduced from the baseline for items of HBM Class 1B sensitivity (and less sensitive, Table 5-5).

Table 5-1: Index of Requirements for EPA Performance and Operator Practices

Requirement	Baseline for Certified EPAs: HBM Class 1A	Additional Require-ments for HBM Class 0	Additional Approaches for Ultra-Sensitive[1/]	Requirements from Tables 5-2 and 5-3 Modified for COTS GSE, HBM Class 1B
EPA Performance Requirement and Practices Used to Achieve and Sustain Required Performance	**Table Number and Row Letter**			
EPA Layout	Table 5-2 a			N/A [2/]
Established Perimeter	Table 5-2 b	Table 5-2 b		
Signage	Table 5-2 c			Table 5-5c
Calibrated and Verified Equipment	Table 5-2 d, Paragraph 5.3.3.1			
EPA Grounding through Direct Connections	Table 5-2 e		Table 5-4 h	
Dissipative Surfaces	Table 5-2 f	Table 5-2 f		N/A
Wrist Strap Design and Grounding	Table 5-2 g			
Wrist Strap Functional Check System	Table 5-2 h		Table 5-4 g	
Grounding Through Dissipative Surfaces	Table 5-2 i			N/A
Grounding of Conductive Work Surface	Table 5-2 j			
Air flow and Pressurized Gas	Table 5-2 k			N/A
ESD Garments	Table 5-2 l, Paragraph 5.3.3.2			N/A
Ionizers	Table 5-2 m	Table 5-2 m		N/A
Tools, Supplies, and Essential Insulators	Table 5-2 n			Table 5-5n
Soldering Irons	Table 5-2 o			N/A
Electrical tools and Test Equipment Grounding	Table 5-2 p			
Relative humidity (RH)	Table 5-2 q	Table 5-2 q		Table 5-5 q
Custom Procedures	Table 5-2 r		Table 5-4 a	

Table 5-1: Index of Requirements for EPA Performance and Operator Practices

Requirement	Baseline for Certified EPAs: HBM Class 1A	Additional Require-ments for HBM Class 0	Additional Approaches for Ultra-Sensitive[1/]	Requirements from Tables 5-2 and 5-3 Modified for COTS GSE, HBM Class 1B
Monthly/Routine Verification Checks	Table 5-2 s			Table 5-5 s
Operator Practices When Using EPAs	**Table Number and Row Letter**			
Use of EPAs for Processing ESDS Items	Table 5-3 a			Table 5-5a
RH Check	Table 5-3 b	Table 5-3 b		Table 5-5 b
ESD Garment Usage	Table 5-3 c			N/A
Wrist Strap System	Table 5-3 d			
Ionizer usage	Table 5-3 e	Table 5-3 e		N/A
Soldering Irons	Table 5-3 f			N/A
Use of Equipment, Tools and Supplies Allowed in EPA	Table 5-3 g			
ESDS Item Protection, Storage, and Transport	Table 5-3 h		Table 5-4 j	
Cell Phone Usage	Table 5-3 i			
Connector Ports			Table 5-4 b	
Finger Cots Instead of Gloves			Table 5-4 c	
Secondary Conductive Surface			Table 5-4 d	
Operator Attire Under ESD Garment			Table 5-4 e	
EMI Signals From Cathode Ray Tubes (CRTs)			Table 5-4 f	
Operator Practices When Using EPAs *continued*	**Table Number and Row Letter**			
Cleaning Methods			Table 5-4 i	
Connecting and Disconnecting Test Cables			Table 5-4 k	

Notes:
1. See paragraph 5.4. "Ultrasensitive" is used to describe items with sensitivity to ESD events with energy of 0.3 µJ or less.
2. N/A = not applicable

5.3 Minimum ESD Control Requirements for HBM Class 1A and Class 0 EPAs

5.3.1 Performance Requirements for HBM Class 1A and Class 0 EPAs

Table 5-2 below contains the minimum performance, design and routine verifications requirements for HBM Class 1A or Class 0 EPAs. The intent of each requirement is included in the table to provide insight to the goal of the requirement. Requirements which state a verification schedule are shown in bold (Section 6 contains detailed instructions related to implementing the required verifications). The applicable test methods are those shown in section 9.

Table 5-2: Minimum Performance Requirements for Certified HBM Class 1A or Class 0 EPAs

Performance Parameter		Purpose	Requirements and Recommended Practices
a.	**EPA Layout**	• Use available space and physical layout to ensure continuous EPA functionality and correct implementation of procedures by operators	• EPAs **shall** not be used regularly for other types of work • Humidity meters **shall** be located near the EPA or in the worst case location if being used for multiple EPAs • Operators **shall** have ready access to any log sheets used. • Readily accessible electrical outlets **shall** be compliant with the grounding requirements herein (see rows e. and p. of this table)
b.	**Established Perimeter**	• Obvious visual indicator to operators of the boundaries of the EPA • Indicates where ESD requirements and procedures must be applied • Keeps charge sources such as insulators, foot traffic, and ungrounded furniture away from ESDS items.	• Perimeter **shall** be ≥1 meter in all directions from the work area or ESDS item whichever is greater (e.g. bench, test chamber or spacecraft) • If the 1-meter perimeter cannot be achieved, only EPA Certifier-approved risk mitigation **shall** be used. • A visual indicator of the perimeter **shall** be used (e.g. floor tape, chain barrier). ***Lesson Learned:*** *Do not delineate entire rooms as EPAs unless those working inside the room will use personal grounding equipment (e.g. wrist straps, ESD smocks) at all times within those rooms. See requirements for covering ESDS items before disconnecting grounded wrist strap (See Table 5-3, row h)*
c.	**Signage**	• Indicates to the operators whether hardware may or may not be processed in that location • Indicates what level of ESD control is provided by that work area • Indicates the area in which ESD operator protocols apply • Indicates clearly if the area is not to be used to process mission hardware.	• EPAs **shall** be clearly identified with appropriate signs. • Signs **shall** be changed when the status of the EPA is temporarily changed from active to inactive. • The EPA certification sticker **shall** be visible. • The sticker **shall** carry the ESD sensitivity level or be included in project records that are accessible by the Operators when in an I&T environment.
d.	**Certified, Calibrated or Verified Equipment**	• Ensures critical equipment is performing as needed • Ensures compliance with the GSFC equipment calibration program in EPAs • Ensures chairs in the EPA are certified	• **Chairs used in the EPA shall be certified prior to use and verified monthly or per 6.3.e.** • **Hygrometers shall be calibrated yearly** • **Equipment used for EPA monthly/routine verification measurements shall be calibrated yearly.** • Wrist strap checkers and CMSs **shall** be verified with calibrated equipment in accordance with paragraph 5.3.3.1 • Ionizers and soldering irons **shall** be verified in accordance with paragraph 5.3.3.1 • **GFCI's, if used, shall be verified once per month using the self-test feature.**

Table 5-2: Minimum Performance Requirements for Certified HBM Class 1A or Class 0 EPAs

Performance Parameter		Purpose	Requirements and Recommended Practices
e.	**EPA Grounding – Direct Connections [6]** **(see below for wrist strap grounding, chair grounding, and grounding through dissipative surfaces)**	• Provides a stable and repeatable reference for multiple ground connections in the EPA. • Ensures effective and low-resistance connection between grounded items and the common point ground (CPG). • Protects against ground loops in EPA ground circuit. • Ensures high quality contact between connection points of items grounded directly to the CPG	• A CPG **shall** be defined for every EPA, the physical connection of which is designed to sustain the performance required within the work environment. • If the CPG is a not a facility ground connection (e.g. the conduit ground screw on the alternating current (AC) outlet or the I&T ground plate), but instead is a contact point elsewhere in the EPA (e.g. on the bench top) the resistance between the CPG and the facility ground connection **shall** be ≤ 5Ω. When using the ground shield cable as facility ground in I&T, the value can be ≤ 25 Ω. • Only one facility ground circuit, or branch, **shall** be used in a completed EPA set-up. • Use of available power/ground connections **shall** not allow ground loops. • The ground port on test equipment **shall** not be used for EPA grounding. • For all items grounded via direct connection to the CPG the resistance between that item's ground contact and CPG **shall** be ≤ 5Ω. • The resistance between the CPG and the third prong of any power strip outlet, or other AC outlet third prong, used for grounding an item in the EPA, **shall** be ≤ 25Ω. • If an auxiliary ground is used for direct grounding of a UUT in the EPA, the resistance between that item's ground contact and CPG **shall** be ≥1MΩ. • The Groundable point (Gp) on the grounded item **shall** be connected directly to the CPG and not daisy chained through Gp's on test equipment, conductive items, or grounded dissipative surfaces (exceptions apply to wrist straps). • Structures and furniture in the EPA **shall** be either direct grounded to the CPG or be grounded through continuous contact with a grounded dissipative floor. • The resistance between the Gp on grounded structures and furniture and CPG for a direct grounded connection **shall** be ≥ 5Ω. • Test chamber walls and shelves **shall** be grounded. • The resistance between grounded test chamber walls and shelves and CPG **shall** be ≤ 25Ω. • **Ground connections shall be verified monthly by the program monitor or per 6.3.e.**

Table 5-2: Minimum Performance Requirements for Certified HBM Class 1A or Class 0 EPAs

Performance Parameter		Purpose	Requirements and Recommended Practices
f.	**Dissipative Surfaces** Work surface (e.g. work bench top), Flooring (e.g. floor, floor mat), Chair surfaces	• Prevents charge accumulation • Provides low-current drain of charge	• All EPAs **shall** have dissipative work surfaces. • When conductive work surfaces are used in the EPA they **shall** be used in conjunction with a dissipative surface. See Row J of this table for additional requirements for conductive surfaces. • Dissipative work surfaces **shall** be large enough for placing ungrounded items located in the EPA (e.g. dry box, microscope) on them, for resting hand tools on the surface, for resting the ESDS item on the surface, as well as for performing work. • Dissipative work surfaces **shall** have a direct connection to ground. • Point-to-point resistance for dissipative surfaces **shall** be between $\geq 10^6\Omega$ to $\leq 10^9\Omega$. • The resistance **shall** be $\geq 10^6\Omega$ to $\leq 10^9\Omega$ from the CPG[7] to the center of the dissipative work surface or the dissipative floor. • Where operating voltages are ≤200V, mats and floors may be accepted using the range $\geq 10^5\ \Omega$ to $\leq 10^9\ \Omega$. • For HBM Class 0 the EPAs flooring **shall** be dissipative and grounded. • The resistance between the Gp on grounded structures and furniture and CPG for grounding through contact with a dissipative surface **shall** be $\leq 10^9\Omega$. • **Dissipative surfaces shall be verified monthly by the program monitor or per 6.3.e.**
g.	**Wrist Strap Design and Grounding**	• Ensures that the wrist strap system is compliant to ANSI/ESD S1.1-2006 • Ensures that low-resistance ground connections which are degrading can be detected. • Ensures sufficient electrical connectivity for draining charge with a current limit. • Allows quick disconnect for wearer's protection	• A grounded connection point **shall** be provided for operators to use to ground their wrist straps. • Operators **shall** be provided wrist strap cuffs and ground cords which are designed for each other; as-received from the supplier. • Wrist strap procurements **shall** require that wrist straps are qualified to ANSI/ESD S1.1 for breakaway force (1 to 5 lbs.). • Wrist straps **shall** be compatible with the CMS system if used in the EPA. • Wrist straps used without a CMS **shall** contain a $10^6\ \Omega \pm$ 20% resistor either in the cord or the cuff. • Wrist strap types listed as not recommended in the preferred equipment list **shall** not be used (see paragraph 7.3). • For systems which include a CMS the resistance between the wrist strap input and the CPG **shall** be $\leq 2\text{x}10^6\Omega$. • For systems without a CMS the resistance between the wrist strap input and the CPG **shall** be ≤5Ω. • **Wrist strap ground points on the EPA shall be verified monthly by the program monitor or per 6.3.e.**

Table 5-2: Minimum Performance Requirements for Certified HBM Class 1A or Class 0 EPAs

Performance Parameter		Purpose	Requirements and Recommended Practices
h.	**Wrist strap Functional Check System [with or without a CMS]**	• Ensures that operators are provided a means for checking that their wrist strap is functional prior to working in the EPA. • Monitors wrist strap and cord integrity • Ensures that operators do not use wrist strap connection points that prevent the CMS from functioning properly.	A wrist strap checking system **shall** be provided, for use by operators, that meets the following conditions: When Not Using a CMS: • A calibrated checker **shall** be provided for verifying wrist strap functionality as it will be worn. • The connection point on the checker **shall** be compatible with the wrist strap lead connector (i.e. banana plug or alligator clip). • Wrist strap checking procedures **shall** be in accordance with the manufacturer's instructions • Wrist strap checking procedures **shall** include a method for recording the results by the operator at least daily (see Appendix G). • Procedures for checking wrist straps **shall** be accessible to the Operators. OR • When Using a CMS: • The CMS **shall** provide visual and audio indication if the wrist strap is not functioning properly • The CMS set up **shall** only allow individually alarmed wrist strap grounding points. • **Wrist strap checking systems shall be verified yearly by the program monitor.** • See paragraph 5.3.3.1 for additional information related to verifying CMS and checker systems.
i.	**Grounding Through a Dissipative Surface** Work surface (e.g. work bench top), Flooring (e.g. floor, floor mat), Chair surfaces	• Ensures that furniture and workbench items are achieving sufficient contact with a grounded surface. • Drains charge from items in the EPA which are not connected directly to CPG through a wire (direct connect).	• Items in the EPA which cannot contain a direct connection to ground **shall** be positioned in contact with a grounded dissipative surface (e.g. bench top or floor). • For HBM Class 0 EPAs chairs **shall** be grounded via the flooring (e.g. with a conductive chain). • The resistance between the CPG and the item in contact with the dissipative surface **shall** be $\geq 10^6 \Omega$ to $\leq 10^9 \Omega$. Essential insulators will not meet this requirement. See row n of this table for control of essential insulators. • Equipment introduced into the EPA after it has been certified **shall** be immediately verified by the program monitor and added to the yearly verification schedule. • **Grounding of furniture and workbench items grounded through a dissipative surface in the EPA shall be verified yearly by the program monitor.**

Table 5-2: Minimum Performance Requirements for Certified HBM Class 1A or Class 0 EPAs

Performance Parameter		Purpose	Requirements and Recommended Practices
j.	**Grounding of a Conductive Work Surface or Floor[6]**	• Provides safe working conditions for the operator	• When using a conductive work surface and providing test voltages or operating the ESDS item at above 30V_{AC}, one of the following **shall** be applied: – The voltage is supplied through a GFCI device; type "A" GFCI's are preferred (Also see P.6 regarding personal safety). – The surface is grounded through a 10^6 Ω resistor [8]. • Alternative methods for ensuring operator safety **shall** be applied for work conditions such as in I&T where the use of a GFCI is not possible. • Protections for conductive work surfaces or floors **shall** be verified during EPA certification. • Where an EPA is using a conductive work surface, EPA certification **shall** require concurrence by a Project Safety Engineer • **GFCI functionality, conductive surface grounding, or approved alternative method shall be verified monthly by the program monitor or per 6.3.e.**
k.	**Air Flow and Pressurized Gas**	• Reduces triboelectric charging of airstream	• The nozzle material **shall** be either dissipative or conductive. • The resistance between the nozzle and CPG **shall** be ≤ 10^9 Ω. • Gas nozzles used in the EPA **shall** be verified and baselined during EPA certification. • **Grounding of pressurized gas nozzles shall be verified monthly by the program monitor or per 6.3.e.**

Table 5-2: Minimum Performance Requirements for Certified HBM Class 1A or Class 0 EPAs

Performance Parameter		Purpose	Requirements and Recommended Practices
I.	**ESD Garments**	• Ensures reduction in charge generation and sufficient charge drain to wrist strap system • Garment performance assurance • Minimize cost of ownership	• Program Monitors preparing EPAs that are not in cleanrooms within the Greenbelt Campus **shall** obtain ESD garments from Code 300 or otherwise seek direction from code 300 for alternative solutions. • Program Monitors preparing EPAs that are in cleanrooms within the Greenbelt Campus **shall** obtain cleanroom ESD garments from Code 549. • Program Monitors preparing EPAs within WFF **shall** have garments designed, procured and verified in accordance with Appendix I. • Contamination requirements **shall** be applied in accordance with project requirements for EPAs in cleanrooms. • See paragraph 5.3.3.2 for special cases pertaining to garment grounding. • ESD Garments **shall** either be: – Stored near the EPA for access by the operators. – Provided instructions for keeping ESD garments in controlled storage areas and for limiting their use outside of EPAs. • **Program Monitors who supply ESD garments which have not been obtained from Code 300 or Code 549 shall verify garment performance in accordance with Appendix I paragraph 3 yearly.** • **The ESD Program Manager shall ensure screening per Appendix I paragraph 3 is accomplished for garments being used that are obtained through rental/laundry services.**

Table 5-2: Minimum Performance Requirements for Certified HBM Class 1A or Class 0 EPAs

Performance Parameter		Purpose	Requirements and Recommended Practices
m.	**Ionizers**	• Ensures that ionizers are functioning properly and are not depositing a net charge on the ESDS items. • Ensures that items or equipment moved into or near the charge stream do not create unbalanced areas in the ionizer's balanced charged ion volume.	• For HBM Class 0 and when using essential insulators with Class 1A, an ionizer **shall** be available to the operators as part of the EPA. • **Shall** be selected and procured to meet the following requirements: – Decay time: ±1000V to ±100V in ≤20 seconds when measured between 1 and 2 feet away. – Charge balance: ≤±50V after 30 +/- 5 seconds – The ionizer peak balance potential **shall** be capable of being less than one half the susceptibility of the most sensitive part in the ESDS item for which it will be used. • Ionizers **shall** not be used when sensitive RF devices (as determined by the PDL) are being processed, regardless of the EPA sensitivity rating. • Decay measurements **shall** not be performed where an ESDS item is exposed within the ionizer's active volume. • The program monitor **shall** establish a reliable ionizer setup based on the EPA environment and determine the appropriate schedule for **charge balance and decay measurements with a minimum limit of once per month.** • See paragraph 5.3.3.1 for additional information on calibration/verification.
n.	**Tools, Supplies, and Essential Insulators**	• Reduce sources of static charge in the EPA	• All tools and other items such as paperwork covers, finger cots and gloves, pliers, tweezers, solder extractors, cleaning brushes, tool boxes, etc. should be dissipative or conductive and **shall** minimize accumulated static charge. • Use of items which are essential to an operation but are insulative ("essential insulators") requires: – That charge **shall** be measured on each item with an electrostatic charge meter prior to its use. – Measured charge on each item **shall** be less than the lowest voltage rating associated with the EPAs sensitivity rating (See Table 4-1). – Essential insulators which do not meet measured charge criterion **shall** either be fully enclosed in an ESD dissipative container or neutralized by an ionizer airstream to reduce accumulated charge to below the minimum voltage rating level. • Insulators which cannot be treated as an essential insulator **shall** not be present in a certified EPA.

Table 5-2: Minimum Performance Requirements for Certified HBM Class 1A or Class 0 EPAs

Performance Parameter		Purpose	Requirements and Recommended Practices
o.	**Soldering Irons**	• Ensure that voltage differentials which can cause a discharge event do not exist between the contact point of the soldering iron and the ESDS item Note: The fixture to perform this test (or instructions to build the fixture) can be obtained from Code 300 along with the manual for use.	• The voltage difference between the soldering iron tip and the CPG, or a point directly connected to the CPG, **shall** be ≤ 2 mVrms (millivolts root mean square)[1]. • When soldering devices which are electrically sensitive to less than 200 mVrms at frequencies above 60Hz, the voltage difference measurement **shall** be performed using equipment with a bandwidth up to 10MHz using an accept/reject limit for voltage which provides a 2X safety margin (e.g. for 100mV sensitivity, the maximum allowable voltage is be 50 mV). • The resistance between the soldering iron contact tip and the CPG or a point directly connected to the CPG **shall** be ≤20 Ω. • A fixture **shall** be used for performing tip voltage-resistance tests which meets the requirements of ANSI/ESD STM 13.1. • The voltage-resistance test fixture **shall** be provided to operators. • **Each soldering iron that is used in an EPA shall be verified at first use and monthly for the period in which it will be used and the data recorded.** • **Soldering iron tip grounding and voltage differential shall be verified after each tip replacement for a Class 0 EPA.** • The program monitor **shall** determine who will perform these measurements in local procedures. • See paragraph 5.3.3.1 for additional information on calibration/verification.
p.	**Electrical Tools and Test Equipment Grounding[5]**	• Ensure that voltage differentials which can cause a discharge event do not exist between the contact point of the equipment and the ESDS item • Prevent current-carrying ground connection on test equipment from interacting with the EPA grounding circuit	• Electrical equipment used in the EPA **shall** either have a three wire grounded power cord or be approved during EPA certification. • The voltage difference between the equipment's ground contact point (e.g. oscilloscope ground lug) and CPG **shall** be ≤ 10 mVrms. • The resistance between the equipment's ground contact point and the CPG **shall** be ≤20 Ω • Ground ports on equipment such as power supplies **shall** not be used for EPA grounding.

Table 5-2: Minimum Performance Requirements for Certified HBM Class 1A or Class 0 EPAs

Performance Parameter		Purpose	Requirements and Recommended Practices
q.	**Relative Humidity (RH)**	• Minimize charge generation • Ensure dissipative surfaces will continue to perform	• For Class 1A the EPAs RH **shall** be between: 30% and 70% RH • For Class 0 the EPAs RH **shall** be between: 40% and 70% RH • A calibrated humidity monitor **shall** be used continuously in or near active EPAs. • RH data **shall** be recorded a minimum of every 15 minutes with no audible alarm or daily with an audible alarm. • All occurrence of non-compliant RH **shall** be recorded. • Humidifiers and dehumidifiers used for bringing an EPA into compliance with RH requirements **shall** be placed outside of the EPA or treated as an essential insulator.
r.	**Custom Procedures**	• Operators are aware of situational considerations and requirements • Operators are informed if they must record RH before start of work. • Operators are aware if conductive work surfaces are used • Operators do not use paralleled CMS connections simultaneously • Operators do not misuse ionizers • Operators correctly discharge measuring equipment and break-out boxes prior to connection to ESDS hardware • Cables and harnesses are discharged to ground prior to mating and de-mating correctly • Inform operators about how soldering iron testing is handled for the EPA or the lab.	• Custom **procedures shall** be documented • Training **shall** be provided. • Custom ESD control procedures **shall** either be reviewed and approved during EPA certification or the Program Monitor may approve additional procedures written by a third party within the context of a project's ESD plan. • EPA Program Monitors and certified operators **shall** follow laboratory-level, branch-level, or project-level ESD control procedures which meet or exceed the requirements herein.

Table 5-2: Minimum Performance Requirements for Certified HBM Class 1A or Class 0 EPAs

	Performance Parameter	Purpose	Requirements and Recommended Practices
s.	**Monthly/ Routine Verification Checks**	• Ensures EPA continues to function in accordance with the above performance requirements	• The verification sheet in Appendix D or equivalent **shall** be used to record monthly/routine verification measurements defined above. • Corrections as needed **shall** be made to the EPA to achieve compliance with the performance limits • Work is stopped and the Project CSO **shall** be notified if non-compliances are found which may have affected mission hardware. **Note: If hardware is on the work surface, bypass the resistance check of work surfaces and perform ionizer balance test only.**

5.3.2 Operator Requirements for HBM Class 1A and Class 0 EPAs

Table 5-3 below contains the minimum operator requirements for HBM Class 1A or Class 0 EPAs. The intent of each requirement is included in the table to provide insight to the goal of the requirement.

Table 5-3: Minimum Operator Requirements for HBM Class 1A or 0 EPAs

	Performance Parameter	Purpose	Requirements and Recommended Practices
a.	**Process ESDS Items in EPAs only**	• Ensures that correct ESD control mechanisms are used when processing ESDS items	• The EPA used **shall** be certified and rated to the same sensitivity level as the item to be processed or a higher control level (i.e. Class 0 is a higher control level than Class 1A). • The operator **shall** comply with the requirements defined for the EPAs sensitivity level regardless of the sensitivity of the item being processed. • Unnecessary operations which generate charge such as wiping of feet and adding or removing layers of clothing **shall** not be performed inside the EPA • The operator shall coordinate operations with the appropriate Program Monitor which includes seeking consultation, concurrence, or complying with the instructions and operating practices of the EPA
b.	**Relative Humidity (RH)**	• Enhances conductivity of atmosphere and surfaces. • Monitor humidity level through long work periods to be aware of a rapid downward trend.	• RH shall be recorded in accordance with EPA procedures. • Work shall be stopped if the humidity is outside of the following range: – Class 1A: 30% to 70% RH – Class 0 and Ultra-Sensitive: 40% to 70% RH **Contact the CSO (for mission hardware) and the Program Monitor to obtain instructions for continuing work.**

Table 5-3: Minimum Operator Requirements for HBM Class 1A or 0 EPAs

	Performance Parameter	Purpose	Requirements and Recommended Practices
c.	**ESD Garments**	• Reduce accumulation of charge • Provide a path to ground that drains accumulated charge • Garment performance assurance • Minimize cost of ownership	• ESD garments **shall** be reviewed and concurred by the Program Monitor • ESD garments **shall** be worn only for working in EPAs, worn at all times in the EPA fully closed (e.g. snapped). • Wearing of ESD Garments outside of their assigned area **shall** be in accordance with the Program Monitor's documented or verbal instructions. • ESD garments **shall** be grounded through continuous contact with the wearer's skin and use of a wrist strap. See paragraph 5.3.3.2 for special cases pertaining to garment grounding. • ESD garments **shall** not be put on, adjusted or taken off while in the EPA. • Non-cleanroom ESD garments **shall** not be worn in cleanrooms or comingled with cleanroom garments including in laundry bins or bags.
d.	**Wrist Strap**	• Provide a path to ground that drains accumulated charge built up on body or clothes.	• Wrist straps and grounding cords **shall** be reviewed and concurred by the Program Monitor • Wrist straps **shall** be verified to be functioning every time they are put on and before interacting with exposed or stored ESDS items. • Where CMS systems are used, visual and audio indication of wrist strap functionality **shall** be witnessed before proceeding. • When a CMS system is not used, a separate wrist strap checker system outside of the EPA **shall** be used. • **When a CMS system is not used, record results of the one-per-shift wrist strap check in accordance with local procedures and Operator training. Recording wrist strap check results where a CMS system is used is not required. (See Appendix G).** • **Shall** be worn at all times in the EPA in contact with the wearer's skin.

Table 5-3: Minimum Operator Requirements for HBM Class 1A or 0 EPAs

	Performance Parameter	Purpose	Requirements and Recommended Practices
e.	**Ionizers**	• Neutralizes charge on ESDS items. • Neutralizes charge accumulation on essential insulators.	• Ionizers **shall** be used when working in EPAs rated to HBM Class 0 and when essential insulators are present in Class 1A EPAs. • Ionizers **shall** be reviewed and concurred by the Program Monitor and used per the methods learned in Operator training and the directions and procedures provided by the program monitor. • Ionizers **shall** be used to minimize charge accumulation on essential insulators, per Program Monitor directions and procedures. • Ionizers **shall** only be used while processing ESDS items. • Ionizers **shall** be verified in accordance with the directions and procedures provided by the program monitor. • Ionizers **shall** not be used when sensitive RF devices (as determined by the PDL) are being processed, regardless of the EPA sensitivity rating.
f.	**Soldering Iron Tip-to-Ground Voltage and Resistance**	• Ensure that the soldering iron is not operating at a net charge difference with the item to be soldered.	• For soldering iron verification measurements, the fixture and procedure provided by the Program Monitor **shall** be used.
g.	**Use of equipment, tools, and supplies allowed in the EPA**	• Ensures that unnecessary insulators are not present in the EPA. • Ensures that static charge on essential insulators is controlled. • Ensures that equipment is correctly grounded • Ensures that tools and supplies are dissipative	• Use only tools, equipment, and supplies reviewed and concurred by the EPA program monitor • All containers, tools, and test equipment in the EPA **shall** be grounded prior to and during use. Note: Dissipative containers placed on a dissipative surface will provide a level of grounding depending on the resistances associated with each material, however direct grounding ensures quicker charge neutralization for the container and its contents. • Every tool **shall** be discharged by placing it in contact with the EPAs dissipative surface for at least 1 second before applying that tool or tip to the ESDS item. • Hand tools **shall** be kept on the grounded work surface when not being used. • Non-essential insulators **shall** not be brought into the EPA. • Process-essential insulators **shall** be neutralized with an ionizer before they can be moved within 12 inches of ESDS items. Note: For Class 0 EPAs, an additional ionizer may be needed to avoid exposing the ESDS item to a charged insulator. • Do not remove paperwork from ESD covers when in the EPA.

Table 5-3: Minimum Operator Requirements for HBM Class 1A or 0 EPAs

	Performance Parameter	Purpose	Requirements and Recommended Practices
h.	**ESDS Item Protection, Storage, and Transport**	• Ensure ESDS items are protected when not being processed at an EPA	• ESDS items **shall** be stored and transported in packaging compliant with Table 8-1 when not being processed in an EPA. • If the ESDS item will be left on the EPA surface between processing sessions, it **shall** be covered with grounded static shielding material prior to the operator disconnecting their wrist strap. • ESDS items **shall** be covered with grounded static shielding material prior to additional operators entering the EPA and establishing their wrist strap ground connection. • Conductive coverings or shunts **shall** be grounded to the EPA surface prior to attachment to the ESDS item. • ESDS parts not received in compliant packaging **shall** not be handled and **shall** be rejected as non-compliant.
i.	**Cell Phone Usage**	• Ensure operators do not engage in charge-producing behaviors when working in an EPA	• Cell phone calls **shall** not be conducted inside an EPA. • Cell phones are considered unnecessary insulators in EPAs and **shall** be kept in the operator's pocket or other non-magnetic carrying holster if necessary in the EPA.

5.3.3 Additional Criteria for the Class 1A and Class 0 EPA Baseline

5.3.3.1 *ESD Control Equipment Calibration or Verification*

a. Equipment used to establish an EPA or to perform monthly/routine performance verifications shall be calibrated in accordance with GPR 8730.1. Typical equipment for HBM Class 1A EPA:

- CMS calibration unit
- Body voltage sensing CMS
- Wrist Strap Checker
- Digital Multimeter
- Low Resistance Meter (Fluke)
- Ionizer Performance Analyzer
- Static Sensor
- Megohmmeter Test Kit

b. Soldering Irons: Soldering irons are not calibrated for grounding (voltage-resistance). All soldering irons shall be tagged with a sticker indicating "verify voltage and resistance monthly". See Table 5-2, row o. for required measurements, performance limits, verification frequency, and required data records. This requirement does not relieve labs of soldering requirements related to temperature calibration.

c. The following equipment does not require yearly calibration and shall be identified as Category 3 items to the GSFC Calibration Program per GPR 8730.1. For this equipment the calibration sticker

applied by the manufacturer or external test organization shall be removed and replaced with a sticker as indicated below.

(1) Ionizer: Ionizers shall be tagged with a sticker indicating "calibration not required". See Table 5-2, row m for required measurements, performance limits, and verification frequency. The following scenarios may indicate the need to re-verify that the ESDS item is located within the ionizer's balanced volume:
- ESDS item moved into or out of the active volume.
- Test equipment moved into or out of the active volume.
- CRT monitor screens or other charge sources are used near the active volume
- Laminar air flow has changed.

(2) CMSs (excluding body voltage sensing types which must be calibrated annually): CMSs shall be tagged with a sticker indicating "calibration not required" .

5.3.3.2 Special Cases for Garments

Personal Grounding through the ESD garment instead of through the Wrist Strap: Personal grounding can be achieved through the garment directly, as an alternative to using the wrist-strap. This approach is permitted only when the cuff-to-cuff resistance of the garment is $<3.5 \times 10^7\ \Omega$. If using a CMS grounding method, the garment and CMS shall be compatible (e.g. single wire CMS with single wire garment snap).[13] Use of this approach to personal grounding shall be approved during EPA certification. A verification schedule shall be identified by the Program Monitor and approved by the EPA certifier for the garment cuff-to-cuff measurement and for grounding checks.

5.4 Minimum EPA Requirements and Operator Practices for Ultra-sensitive Items: CDM Class C2, C1, or Breakdown Energy ≤ 0.3 μJ

Custom approaches are required for set up of EPAs which control CDM Class C2 or C1 events or events which can damage an item which is sensitive to energies at or below 0.3 μJ. This custom approach will be reviewed and approved by the ESD Control Program Manager. As a minimum the requirements identified in Table 5-2 and 5-3 including those for HBM Class 0 shall be applied as shall the requirements in Table 5-4 below unless they are determined by the ESD Control Program Manager to be counterproductive.

Examples of ultrasensitive items are detectors, some high frequency low voltage differential signal (LVDS) transceivers, low noise amplifiers (LNAs), low noise diodes, Schottky diodes and monolithic RF switches.

Table 5-4: Additional Requirements for EPAs and Operators for Ultra-sensitive Items

	Performance Parameter	Purpose	Requirements and Recommended Practices
a.	**Custom Procedures and Checklists**	• Documents and employs control methods which are apt for the ESDS items and the work area	• Procedures **shall** be created • Operators **shall** be trained. • Operators **shall** use custom procedures and techniques. • Checklists **shall** be used to verify required EPA performance has been achieved, working conditions meet requirements, and operators are adequately prepared and provided resources
b.	**Connector Ports**	• Prevents inadvertent exposure of ESDS parts through subassembly connector pins	• Utilize shorting plugs or dissipative caps when the item is not in an ESD container when appropriate for the application. • RF ports may use a metal dust cap to form a faraday cage
c.	**Finger Cots Instead of Gloves**	• Reduces charging energy	• ESD finger cots **shall** be made available to operators for use • Operators **shall** use finger cots reviewed and concurred by the EPA Program Monitor instead of gloves
d.	**Secondary Conductive Surface**	• Reduces or eliminates RF interference during test when applicable	• The ESDS item may be located on a metal plate which in turn is located on a certified EPA's dissipative work surface. • Note: Conductive work surfaces may generate a CDM hazard for sensitive devices. Adding a GFCI or current limiting resistor will not protect parts sensitive to CDM pulses.
e.	**Operator Attire Under ESD Garment**	• Reduces triboelectric charging on ESD garment	• Do not wear silk or wool under the ESD garment. Cotton is preferred.
f.	**EMI Signals from CRTs**	• Reduces the sources of EMI interference to a minimum	• Test equipment with CRTs **shall** be turned ON BEFORE the ESDS item is taken out of the ESD bag • CRTs **shall** be as far as practical from the ESDS item at all times.
g.	**CMS Sense Voltage**	• Avoid voltage difference between ESDS item and CMS system	• The sensing voltage of the CMS system **shall** be lower than voltage sensitivity of the most sensitive ESDS items to be handled.
h.	**Equipotential Test Equipment Grounding**	• To assure that voltage differentials are not present at equipment tips that will touch the ESDS item.	• The resistance between any battery powered equipment grounds (e.g. digital multi-meters) and CPG **shall** be $\leq 10^9$ Ω. • Equipotential grounding of test equipment shall be verified before the shorting plugs are removed.
i.	**Cleaning Methods**	• Prevent triboelectric charging during cleaning procedures	• Cotton swabs **shall** not be used. • Hot air guns **shall** not be used.

Table 5-4: Additional Requirements for EPAs and Operators for Ultra-sensitive Items

	Performance Parameter	Purpose	Requirements and Recommended Practices
j.	**Use of Packaging for Storage and Transport**	• Prevent creating an ESD event during handling into or out of the protective package • To provide electric field reduction to levels well below ESD bag ratings.	• A custom procedure **shall** be created to determine how conductive layers, ESD bags, and ESD containers may be used together to achieve very low levels of electrostatic charge-generated electrical fields inside of ESD bags. • Custom procedures **shall** be reviewed and approved during EPA certification or the Program Monitor may approve additional procedures written by a third party within the context of a project's ESD plan after EPA certification. • When dissipative surfaces are used, the ESDS item may be placed on the surface upon removal from protective packaging. • When secondary conductive surfaces are used, additional procedures are needed to protect the ESDS item. Upon removing the ESDS item from protective packaging, the operator **shall** equalize the grounds between the ESDS item and the EPA work surface (for example, touch, with dissipative finger cots, both the ESDS item and the secondary conductive surface and then place the item on the secondary conductive surface).
k.	**Connecting and Disconnecting Test Cables**	• Prevents CDM type discharges	• A dissipative ground **shall** be provided between an ESDS item and any test equipment before connecting or disconnecting test cables

5.5 Minimum ESD Control Requirements and Operator Practices for Sensitivity Level HBM Class 1B when Processing COTS GSE Only

a. When processing critical ground system hardware, ESD Control is provided through grounding and operator practices requirements. These requirements are tailored to processes that briefly increase the item's sensitivity from HBM Class 1B to a higher sensitivity level (e.g. Class 1A). An example of this case is when an electronic board is in contact with its grounded chassis (Class 1B) and then removed for replacement (Class 1A) and then immediately stored in dissipative bags or boxes.

b. The requirements are those in Tables 5-2 and 5-3 with the exceptions shown in Table 5-5 (Note: the row letters in Table 5-5 correspond with the row letters of Tables 5-2 and 5-3).

c. When these boards are processed such as for repair or troubleshooting, operators shall perform these board-level processes (e.g. soldering, electrical probing) in an appropriately rated, certified EPA for the sensitivity of the board and shall comply with all requirements associated with work in that EPA.

d. A Program Monitor is required for set-up and verification of the necessary ground connections, for providing wrist straps, monitoring systems and procedures to Operators, and for record keeping. For an HBM Class 1B EPA, Program Monitor verification without benefit of third-party certification is sufficient performance quality assurance for the associated level of risk.

Table 5-5: Minimum ESD Control Requirements and Operator Practices in HBM Class 1B EPAs Used to Process COTS GSE Only

Row letter	Performance Parameter or Practice	Requirement Addition or Exception
from Table 5-2, Performance Requirements		
c.	**Signage**	Not required but recommended. See Section 7.2
f.	**Dissipative Surfaces**	Not applicable to this type of work environment when not using a lab bench
i.	**Grounding through Dissipative Surfaces**	Not applicable to this type of work environment when not using a lab bench
k.	**Air flow and pressurized gas**	Not applicable to this type of work environment
m.	**Ionizers**	Not applicable to this ESD sensitivity level
n.	**Tools, Supplies, and Essential Insulators**	Boards **shall** be inserted into protective packaging as soon as possible following their removal from a grounded chassis to avoid exposure to charged items.
o.	**Soldering irons**	Not applicable to this type of work environment
q.	**Relative Humidity**	Do not proceed with operations if the humidity is below 20% RH
s.	**Monthly/Routine Verification**	Verification measurements that assure the grounding performance requirements are met prior to start of work for each new or reconfigured grounding set up.
From Table 5-3, Operator Practices		
a.	**Process ESDS items in EPAs only**	An EPA is not required. Remove boards from grounded chassis only when using grounding systems and procedures provided by the accountable Program Monitor
b.	**Relative Humidity (RH)**	Use 20% RH for the minimum humidity level allowable for continued work.
e.	**Ionizers**	Not required for this ESD sensitivity level
f.	**Soldering Iron Tip-to-Ground Voltage and Resistance**	Not required for this ESD sensitivity level

5.6 Additional Requirements Applicable to the I&T Work Environment

5.6.1 General

a. Lab bench EPAs which are installed in I&T areas shall comply with the requirements applicable to the Lab Bench work environment however the I&T manager or the PDL assumes the responsibilities of the lab owner.

b. Branches providing testing capabilities in I&T facilities, including labs such as cryogenics or electromagnetic interference labs, are not responsible for EPA set-up or for obtaining EPA certification in their facilities. It is the responsibility of the hardware owners for providing personnel, resources, and procedures for compliance with the ESD control requirements herein. Personnel assigned to these test labs who will work within the EPA are required to receive the appropriate training.

c. When ESDS subassemblies are attached to subassemblies or structures which are not ESD sensitive, the owner of the ESDS item is responsible for providing personnel, resources, and procedures for compliance with the ESD control requirements herein.

5.6.2 In the Absence of an Assigned I&T Manager

Product Design Leads (PDLs) using I&T facilities for processing ESDS items, in the absence of an assigned I&T manager, shall ensure that a Program Monitor sets-up and maintains the EPA that will be used.

5.6.3 ESD Control Plan for Operations in I&T After Hand-off to I&T Manager

The PDL or lead design engineer shall provide an ESD control plan, equivalent instructions for ESD control, or additional control methods above those outlined in this PG for operations which will take place while the hardware is under the custodianship of the I&T Manager. This plan must include the following as a minimum:

a. Special methods, conditions, or procedures that are needed to comply with all other applicable requirements of this document.
b. Exceptions taken to the requirements herein and the applicable approved waiver identification number (ref. GPR 1400.1).
c. The ESD sensitivity classification for all assemblies from the PWA level up through the payload level where the sensitivity level is HBM Class 1A, CDM Class C2 or more sensitive. Explanation shall be included for levels of integration which decrease the hardware's ESD sensitivity.

Note: Uses of personal grounding devices such as wrist straps in the I&T environment, for purposes other than ESD control, are outside of the scope of this document.

5.6.4 EPA Certification After Hand-off to I&T Manager

The I&T Manager is responsible for assigning a Program Monitor for implementing all appropriate EPA performance requirements in Table 5-2 (or Table 5-4 or Table 5-5 as applicable). Some work area configurations in the I&T environment, such as testing inside of chambers and at the spacecraft integration level, reduce the applicable requirements from the standard baseline in Table 5-2. The minimum requirements for these types of EPAs will be approved and documented during EPA certification. Included in the baseline will be a definition of configuration changes that do and do not require EPA re-certification and the applicable monthly/routine verification measurements. This baseline will be recorded in the certification report.

5.6.5 Best Practices for Work in I&T Environments

The following requirements are recommended for use in applicable Work Order Authorizations (WOAs) and procedures. The Program Monitor determines when and how they are included.

a. ESD-protective covering or protective caps on external terminals, interconnecting cables, and connector assemblies shall not be removed until necessary to permit the installation.
b. Before opening any protective packaging of an ESDS item, the packaging shall either be grounded through a dissipative surface or any charges neutralized in an ionizer's airstream.
c. As an ESDS item is installed, contact with parts, electrical terminals, and circuitry shall be minimized.
d. The cable connector pins and cable shield (connector outer shell) shall be grounded prior to engaging it with a mating receptacle connected to an ESDS item.

e. Failed ESDS items shall be placed in protective packaging after removal from the equipment. Probing ESDS items with test leads shall be conducted only within a certified EPA.

Lesson Learned: *During the testing of a satellite several J-FETs were damaged due to a discharge event between the digital multimeter leads and a charged breakout box.*

5.7 Additional Requirements Applicable to the Flatsat Work Environment

The rules applicable to EPAs in labs, including the requirements in Tables 5-2 and 5-3 apply to the Flatsat work environment with the modifications specified in the paragraphs below.

5.7.1 Work with Hardware Remotely

Personnel who work with the ESDS hardware remotely (from outside of the EPA) such as via software, are not considered ESD operators and are not required to use personal grounding devices, including ESD garments.

Note: Wearing ESD garments when not using a grounded wrist strap adds cost with no associated ESD control benefit.

5.7.2 Maintaining EPAs within the Flatsat Environment

The EPA verification checks performed by the ESD Program Monitor shall be performed prior to working directly with the hardware inside the EPA.

Verification measurements do not need to be repeated within the same month. A copy of the prior verification data, taken in the same month as the initiation date of a new work order or trouble ticket, may be used to satisfy this requirement. See Section 6 below for more on Certification and Verification of EPAs.

6 EPA QUALITY ASSURANCE

6.1 EPA Certification Requirement

a. EPA certification is a third-party confirmation using inspection and measurements that a newly established or reconfigured EPA meets the technical and housekeeping requirements defined herein; is safe to use with ESDS items of a certain sensitivity level; and can be adequately maintained by the Program Monitor.
b. Certification is required prior to EPA use. The certifying authority for GSFC EPAs is Code 300. Certification is a one-time event. The requirements for EPA certification are met when all the criteria in section 5 are met (as applicable for the sensitivity rating). EPA certifications to GSFC-WM-001 award prior to publication of this document shall be considered valid however these EPAs are not exempted from meeting the performance requirements herein.
c. Allowed risk mitigations (e.g. for perimeters <1 meter), special equipment, custom procedures, and non-applicable requirements shall be reviewed and approved during EPA certification or the

Program Monitor may approve additional procedures written by a third party within the context of a project's ESD plan after EPA certification.

d. The EPA Certifier may choose to require the Program Monitor to perform the measurements that are common to the monthly/routine verification schedule to ensure Program Monitor competency.

e. The minimum steps for completing EPA certification are shown in Table 6-1 in sequential order. Appendices C, D, and E are used to document the data associated with an EPA certification assessment.

Table 6-1: Steps for Completing the EPA Certification Process

Step	Completed By	Estimated Time per EPA
1. Set up EPA, obtain compliant garments, assign each bench a unique identifier (ID), use correct signage, and generate custom procedures as applicable. Enter the EPA into https://lqms.gsfc.nasa.gov	Program Monitor	(varies based on type and equipment availability)
2. Fill out verification log and checklist (Appendix D and E) and send them and applicable custom procedures to the EPA Control Program (Code 300)	Program Monitor	1 hr
3. EPA Certifier reviews custom procedures to verify minimum requirements are addressed.	EPA Certifier	2 – 3 hrs
4. Arrange a date for EPA certification	Program Monitor and EPA Certifier	0.25 hrs
5. EPA certifier checks all items in the certification datasheet (Appendix C or equivalent) with the Program Monitor present. Compliant chairs are marked with a sticker. Program Monitor can be required to perform measurements for the EPA Certifier. 6. Special conditions, procedures, equipment, and tools are assessed for compliance with the requirements of Section 5 herein. 7. The certifier baselines the maximum resistance between the wrist strap input and CPG for the applicable set-up (per Table 5-2, row g.) 8. EPAs which meet all requirements are certified. Both the certifier and the Program Monitor sign the completed datasheet regardless of the result of the assessment.[1/] 9. Variations applicable to monthly/routine verification measurements are identified by the EPA Certifier and communicated to the Program Monitor 10. Evidence of certification is a sticker affixed to the EPA and initialed, and dated by the certifier with the corresponding bench ID noted (See Appendix H).	Program Monitor and EPA Certifier	1 hr
11. Write certification report and enter certification data into database. Send copy of the report to the ESD Control Program Manager and the EPA Program Monitor. 12. Enter certification date and status into https://lqms.gsfc.nasa.gov	EPA Certifier	0.5 hr

Notes:
1. Observations may be remedied during the certification audit. Non-conformances are cause for failure of the certification audit and require a repeat of the audit process.

6.2 Certification Records

The records of EPA certification shall be generated by the EPA certifier and include as a minimum:

a. Certification Stickers located on the workstation and associated chairs with workstation ID

b. Certification Report to include:

(1) Date, building number, room number, bench identification, ESDS rating
(2) Flight project name if applicable
(3) Program Monitor and EPA Certifier names
(4) Result: pass or fail
(5) Data recorded during the on-site assessment
(6) Allowed risk mitigations employed
(7) Special procedures reviewed and approved
(8) Observations and non-compliances if applicable
(9) Minimum monthly/routine verification measurements required.

c. The EPA certification date shall be entered into https://lqms.gsfc.nasa.gov

6.3 Certification Maintenance

a. EPA Certification is maintained when the Program Monitor performs the monthly/routine verification measurements as defined in Table 5-2 and as tailored and documented in the EPA certification report. Variations in the types of tests and checks to be performed monthly (or per 6.3.e) will be identified and approved during certification.

b. If a routine verification is not completed, the EPA shall be temporarily put out of service and marked as such. Use of an EPA that has been taken out of service may be reinstated after the verification is performed as long as it has not been more than six months since the last verification.

c. EPAs shall be recertified prior to use after more than six months has passed since the last verification was performed.

d. Recertification of reconfigured or moved EPAs (i.e. the CPG has been disconnected) is required. This requirement does not apply for labs and work conditions where the risks of non-compliance with the performance requirements herein are low as determined by the ESD Control Program Manager

e. Routine verifications are to be performed on a monthly basis as long as the EPA is in use. However, with the approval of the ESD Program Manager, the routine EPA verification may be performed on a quarterly basis if an EPA consistently passes three consecutive verifications then the verifications may be performed on a quarterly basis, with the fourth verification in the series being completed three months after the third verification. The pre-certification check, as well as the bench certification, may each count as one of the three verifications. If for any regular verification measurement a performance requirement is not satisfied or if an audit results in a valid non-conformance finding, the verification schedule shall return to a monthly schedule. The Program Monitor may return to a quarterly verification schedule when they are able to achieve three consecutive months of measurements with no performance failures or audit findings and have been approved by ESD Program Manager. Chairs are included in this allowance with the exception that approval from Code 300 is not required.

f. Verifications may be recorded on custom forms when the form is approved in advance by an EPA Certifier. The approval will be recorded in the certification report or in an addendum to the certification report, a copy of which will be provided to the Program Monitor for local reference.

6.4 Conditions which Void EPA Certification

Certification is voided if:

a. The EPA has been moved or undergone a major reconfiguration (e.g. rewiring of the area; new floor surface; change of CMS) without approval from the ESD Control Program Manager or their delegate.
b. The control level is increased (e.g. changed from Class 1A to Class 0)
c. An EPA has not been verified for more than six months.
d. An ESD failure has occurred at an EPA.

See paragraph 6.1.c for exceptions to any or all of the above.

6.5 Requirements for Resolving Non-Compliances Prior to Start or Continuing of Work in EPAs

Project CSO approval of the documented risk mitigation methods is required prior to work on mission hardware when any requirement herein cannot be met after the EPA has been certified. The following considerations apply for particular non-compliances:

a. Air ionizers shall be part of risk mitigation when work is done when the humidity falls below 30% in a HBM Class 1A EPA.
b. Grounded Nickel-coated Polyethylene Terephthalate (PET polyester) (“Llumalloy”) sheeting or dissipative curtains are examples of methods that may be employed for reducing risk when the 1 meter EPA perimeter requirement cannot be met.

7 PROGRAM MONITOR ROLES AND RESPONSIBILITIES

7.1 Roles and Responsibilities

The success of the GSFC ESD Control Program largely depends on successful completion of the tasks assigned to the ESD Program Monitor many of which are described in Table 5-2. The role and responsibilities of the Program Monitor are summarized in Table 7-1.

Table 7-1: Roles and Responsibilities of the Program Monitor

	Responsibility	Intent
a.	• Provide custom ESD control methods and procedures as needed such as for ultrasensitive ESDS items, EPA-specific operator practices, battery powered tools, use of ionizers, verification of soldering irons, etc. • Coordinates in advance of the EPA certification assessment with the ESD Control Program Manager or their delegate to obtain guidance for custom EPA set-ups features or risk mitigations. • Documents how EPA verifications will be accomplished in the I&T environment.	• Ensures that ESD control methods are appropriate for the sensitivity level of the hardware. • Ensures specialty or custom approaches are identified during certification and are used as intended and consistently by operators • Ensures operators know how the program monitor wants to manage routine duties and practices. • Ensures operators know how to perform wrist strap system checks and use grounded wrist straps • Ensures configuration changes during I&T do not disturb the certified ESD ground circuits. • Ensures that ESD considerations and instructions defined by the PDL or Design Engineer are integrated into applicable procedures
b.	• Set up the EPA to conform with the requirements of Section 5 for the applicable sensitivity level	• Technical expertise applied to ensuring dissipative surfaces, grounding, and personal grounding devices will function together to mitigate ESD risks when the EPA is used by the operator. • Layout, boundaries and signs ensure non-ESD work is not occurring inside of the EPA and that general traffic does not enter the EPA. • Provides a single point of contact for Operators working in the EPA
c.	• Arranges for and participates in EPA certification or recertification	• Provides a single point of contact for the EPA Certifying Authority.
d.	• Ensures equipment used for ESD control is calibrated and that Category 3 equipment is verified on schedule as applicable. Trains operators as needed to perform verifications that they will be responsible such as for soldering irons.	• Ensures continued functionality of measurement equipment and tools. • Ensures verifications are performed on the required schedule and that data is captured as required.
e.	• Provides humidifiers or dehumidifiers to comply with humidity requirements	• Enables operators to work at EPAs when seasonal ambient conditions do not meet minimum or maximum humidity requirements
f.	• Keeps the EPA free of non-essential items and disallowed items. Prevents use of EPA as a general workbench unless the signage is changed appropriately (See Section 7).	• Prevents creep of non-allowed items into the work area which can be charge sources. • Provides safe use of EPAs whose status toggles between in-service and out-of-service.
g.	• Controls the use by operators of dissipative tools and supplies and correctly grounded equipment in EPAs. Replaces items which are damaged, broken, or near their end-of-performance lifetime.	• Ensures continued functionality of the EPA • Ensures operators do not negate the effectiveness of the EPA design and procedures
h.	• Performs or delegates performance of monthly/routine EPA verifications defined in Table 5-2 and/or custom limits and procedures as applicable.	• Ensures continued functionality of the EPA • Enables real-time grounding verification for configuration changes during I&T operations.
j.	• Provides verification data for EPA performance to records custodian in accordance with Table P.8-1.	• Ensures that lab owners have access to data records in order to fulfill records management requirements.

Table 7-1: Roles and Responsibilities of the Program Monitor

	Responsibility	Intent
k.	• Sets up and maintains EPA and associated procedures, training, and records when ESDS mission hardware is integrated with non-ESDS mission hardware or I&T test systems (See paragraph 6 or Appendix for I&T)	• Ensures that the necessary practices and understanding of the requirements herein are brought to bear in lab operations and facilities which do not routinely manage ESDS items (e.g. cryogenics lab).
l.	• Manages signage and temporary perimeters	• Ensures operators know when an EPA can be used and if the EPA carries the right sensitivity rating for the ESDS item to be processed. • Ensures signs are changed during times when areas are used for non-ESD operation (Class 1A only) or when EPA is decommissioned. (ESDS items are not present). • Differentiates between uncontrolled areas with some ESD controls used for R&D operations and certified EPAs used for processing mission hardware.
m.	• Escort Visiting Operators and Visitors	• Ensures that the ESD Control Program requirements are followed when escorting visiting operators and visitors are in the EPA.
n.	• Notifies the ESD Control Program Manager when an EPA is permanently retired or its certification is voided. Changes EPA status in https://lqms.gsfc.nasa.gov	• Contributes to the Center's tracking of EPA volume and location.
o.	• Disassembles EPAs that will no longer be used and maintained (abandoned) and as a minimum removes: – all signage and stickers relating to its prior certification. – all equipment that requires calibration or monthly/routine/yearly verifications.	• Ensures that operators do not inadvertently use uncertified EPAs to perform work on ESDS mission hardware. • Facilitates compliance with the GSFC Calibration Program requirements.
p	• Provides operators/visitors with all ESD tools to perform the necessary work or approves items operators bring into the EPA. • Ensures ESD garments are not used when not required and when unnecessary.	• Ensures tools and other items entering the EPA are not sources of a damaging ESD event. • Reduces costs associated with unnecessary use of ESD garments.
q	• Provides training to operators in local procedures	• Ensures special conditions and methods are known to operators and followed correctly. • Ensures correct use of ionizers, wrist strap checking systems, and soldering iron testers as applicable in the EPA.

7.2 Use of Signage

Signage shall be used to indicate the operational status of areas prepared and/or certified for processing ESDS hardware. All signs shall as a minimum carry the words described in 7.2.1 through 7.2.3, or equivalent. The sensitivity rating of all EPAs or other areas prepared for processing ESDS items is

assumed to be HBM Class 1A. For all other rating levels, the level shall be noted in the sign. All signs shall carry the official ESD symbol found in ANSI/ESD S8.1, listed as Figure 7-1 below, except signs used to indicate an EPA is out of service per 7.2.3. Program Monitors may generate their own signage or may obtain signs from the ESD Control Program Manager. Signs are not required for areas or benches unrelated to ESD control.

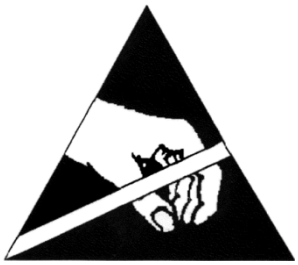

Figure 7-1: Sensitive Electronic Device Caution Symbols

Note: If the event model and sensitivity level is not specified within the symbol, or otherwise named, then the rating level defaults to HBM Class 1A.

7.2.1 "ESD Work Bench, Not Certified"

The language "ESD Bench, Not Certified" shall be used when ESD control systems are in place yet the area is not yet certified or will not be certified (e.g. R&D operations).

7.2.2 "Certified ESD Protected Area"

The language "Certified ESD Protected Area" shall be used to identify EPAs which comply with the requirements herein and may be used for processing mission hardware.

7.2.3 "ESD Protected Area Not In Service"

The language "ESD Protected Area Not In Service" shall be used to identify certified EPAs which are temporarily or permanently out of service. The certification sticker shall be removed from EPAs which are taken out of service permanently.

Caution: Do not use generic ESD signs which demand particular procedures or actions that are not used in the EPA. This conflict in instructions to operators is a quality assurance non-compliance.

7.3 Equipment Selection

A list of preferred equipment and items for use in EPAs is available for download on http://sma.gsfc.nasa.gov/workmanship. Items identified as not-preferred shall not be used. The measuring equipment used for EPA verification tests shall be compatible with the hardware being measured in terms of measurement resolution, bandwidth, and protection from overstress. It shall be used in a manner that protects the EPA and related hardware from damage and avoids false positive results. Data logging is a valid method for capturing and storing relative humidity data.

Caution: Digital multimeters may introduce voltage spikes when changing scales and/or have high voltages when measuring resistance. Use only in manual mode around ESDS items and disconnect when changing scales.

8 ESD CONTROL BEYOND THE EPA

8.1 Handling of ESDS Items Outside of the EPA

Table 8-1 contains the requirements for transporting and storing ESDS items from the time of their shipment from the manufacturer or supplier to their destination point in a GSFC EPA or integration into higher levels of assembly where their sensitivity to an ESD event is highly reduced.

Table 8-1: Protection of ESDS Items During Storage and In-Plant Transport

	Performance Parameter	Purpose	Performance Limit
a.	Container performance	• Communicate to operators the sensitivity level of the ESDS item inside • Provide a Faraday cage around ESDS item • Minimize charge accumulation on container • Reduce triboelectric charging during item movement inside of the container or insertion into or removal from the container	• Carries markings on the outside, which indicate the items inside are ESDS. The container marking shall include the ESD sensitivity level.(See Figure 8-1) • Containers such as bags, tubes, magazine containers, and tape and reels used for ESDS EEE parts shall be made of dissipative material with surface resistance of $\geq 10^4$ Ω and $\leq 10^{11}$ Ω [10]. • Bags shall be made of a single folded piece of material. Two-piece construction is not allowed. • Double bagging is allowable for additional assurance, and is recommended for Class 0 protection. • Static dissipative impregnated containers and topically treated containers are not considered suitable as primary container material. • Items sensitive to inductive charging from electric fields require a container with a multilayered material which has outer layers with surface resistance of $\geq 10^4$ and $\leq 10^{11}$ Ω [10] and an inner conductive layer $\leq 10^2$ Ω that is not in direct contact with the ESDS item. • Tote box lids shall have the same conductivity as the bottom section. The fit of the lid shall be tight enough to ensure conductivity across the lid-bottom interface. • "Anti-static" polyethylene with organic acid additives (i.e. "pink poly") shall not be used 1/ • Accompanying documents shall carry ESD sensitivity level
b.	Transport between EPAs	• Indicates to personnel that the item cannot be removed from the container outside of an EPA • Indicates the sensitivity level rating the EPA to be used to process the item • Protects the ESDS item from ESD damage when it is not in an EPA.	• ESDS items shall be fully contained inside closed containers which comply with the performance requirements above, at all times during transport between EPAs. • The container shall not be opened except in an EPA that has the same sensitivity rating.

Table 8-1: Protection of ESDS Items During Storage and In-Plant Transport

	Performance Parameter	Purpose	Performance Limit
c.	Removal from packaging in an EPA	• Prevent discharges when part is being removed from protective container	• ESDS items should be removed slowly from ESD-safe packaging or containers in a manner that allows slow dissipation of charge that accumulated due to triboelectric effects. • Transfer of an unpackaged ESDS item from an EPA work surface to a storage rack or cart without use of protective packaging requires that the rack or cart are grounded before the transfer is performed. • When an ESDS item in a storage container has been stored in a dry-box, once at the EPA, the ESDS item should be removed slowly and with the use of an ionizer from the container.
d.	Safe-ing ESDS Items in EPAs prior to wrist strap ground connection disconnect	• Ensure ESDS items are protected when operators are leaving and entering the EPA and are not grounded	• Prior to disconnecting the operator's wrist strap, the ESDS item shall be returned to ESD packaging that provides a Faraday cage around the item (e.g. sealed bags or tote boxes) OR • The ESDS item shall be completely covered with a grounded dissipative material such as Llumalloy sheeting.2/

Notes:
1/ This material has been found to compromise the quality of metal surfaces exposed to it [15].
2/ Llumalloy is a trade name for nickel-coated Polyethylene Terephthalate (PET polyester) sheeting (owned by DuPont). This material does not provide EMI shielding. Also, this material may have variable resistivity.

8.2 Floor Procurement and Installation Requirements

a. Use of carpeting in an EPA shall be prohibited. This includes carpeting advertised as "conductive" or "static-eliminating."

b. Conductive wax used on non-conductive floors is not an acceptable substitute for a grounded dissipative floor.

c. Procurements of permanent dissipative flooring, as opposed to ESD mats, shall use the following language to assure that the procured product will be capable of performing to a minimum and maximum resistance value when installed:

(1) The flooring product shall be qualified in accordance with ESD S7.1-2005, paragraph 6.1 to the following limits: $> 2 \times 10^4\ \Omega$ and $< 3.5 \times 10^7\ \Omega$." A Certificate of Conformance (C of C), or a copy of the qualification test results, is required as evidence of compliance with this requirement.

(2) Following installation acceptance testing per ANSI/ESD S7.1 paragraph 6.2 is required using an accept value of $> 10^4\ \Omega$ and $< 3.5 \times 10^7\ \Omega$ for both point-to-point resistance and point-to-ground resistance. A copy of the acceptance test data shall be provided to the ESD Control Program Manager.

d. The lab owner shall perform or arrange for acceptance testing of permanent grounded dissipative floors which have been augmented with a conductive wax treatment using the test method in c.(2) above.

8.3 Facilities Grounding

The resistance from the area CPG to the neutral bond at the main service box should be ≤25 Ω. When there is concern about the quality of the building grounds, seek assistance from the local facilities manager to verifying the available ground circuits meet this limit. This requirements document does not have authority for certification of building-level electrical grounds.

9 REQUIREMENTS TRACEABILITY TO AGENCY BASELINE

The following references are used to form several of the requirements herein and are traceable to the Agency requirement that all Programs and Projects shall invoke ANSI/ESD S20.20 for ESD control.

1. ANSI/ESD S20.20-2007 Paragraph 7.1	ESD Control Program Plan
2. ANSI/ESD S20.20-2007 Paragraph 6.2	ESD Control Program Management
3. ANSI/ESD/JEDEC JS-001-2012	HBM Standard Test Method
4. ANSI/ESD S5.3.1-1999	CDM Standard Test Method
5. ANSI/ESD TR20.20-2008 Paragraph 5.5.2, Page 130	Electrical Hand Tools
6. ANSI/ESD S6.1-2009 Paragraphs 5.1.2 & 5.2.1	Common Point Ground
7. ANSI/ESD S6.1-2009 Foreword	ESD vs. EMI Grounding
8. ANSI/ESD S20.20-2007, Tables 2 & 3	Required Limits
9. ANSI/ESD TR20.20–2008 Handbook, Page 47, Note 3	Recommendations for GFCI
10. ANSI/ESD S4.1-2006 Paragraph 6.4.3	Work Surface Resistance
11. ANSI/ESD S541-2008 Paragraphs 7 & 8	Packaging
12. ANSI/ESD TR20.20-2008 Page 74	Floor Properties
13. ANSI/ESD S20.20-2007 Paragraph 8.2	Garments
14. ANSI/ESD TR20.20-2008 Page 116	Garments Evaluation tests
15. White Paper 2: A Case for Lowering Component Level Industry Council on ESD Target Levels, March 2009	CDM ESD Specifications and Requirements,
16. GIDEP Alert KE-A-89-02	Materials, Pink Plastic, Antistatic
17. ANSI/ESD S1.1-2006	Wrist Straps
18. [1/] ANSI/ESD STM 13.1 2000 Paragraph 5.2.3.9	Soldering Irons

Appendix A: Definitions

The following definitions apply to terms used in this PG:

A.1 Calibration Unit: A piece of test equipment used to verify the accuracy of the wrist strap checkers and continuous monitoring systems.

A.2 Certification: Third party confirmation or guarantee that personnel or electrostatic discharge (ESD) protected areas (EPAs) meets the applicable requirements herein.

A.3 Charged Device Model (CDM): A type of ESD event that is defined in ESD S5.3.1.

A.4 Critical Ground Support Equipment: Equipment that directly interfaces with mission hardware that has the capacity for damaging mission hardware or is critical for operations of the spacecraft or instrument during the mission.

A.5 Direct Connection: An electrical connection made with only wires and no discrete impedances.

A.6 Dissipative: The resistive range between conductive and insulative; $5x10^5$ to 10^9 ohms. The low end of this resistance range is derived from the assumption that 110V discharged through a $5x10^5$ resistor is not life-threatening.

A.7 Dissipative Ground: A connection to ground through an impedance that is sufficiently high to limit current flow to safe levels for personnel.

NOTE: *The maximum allowed current for operator safety is normally <5 milliamperes. The impedance needed for a dissipative ground depends on the voltage levels which could be contacted by personnel near the ground. By this definition a hard ground protected by a functional GFCI is considered a dissipative ground. This is sometimes referred to as a soft ground*

A.8 Equipotential: A connection between two points in an EPA with a maximum resistance between them of $< 10^9$ ohms [1].

A.9 Electrostatic Discharge (ESD): A transfer of electrostatic charge between bodies at different electrostatic potentials caused by direct contact.

A.10 EPA Certifier: The individual approved by the ESD Program Manager to certify EPAs.

A.11 ESD Program Manager: The individual in charge of the GSFC ESD Control Program.

A.12 ESD Program Monitor: An individual who is trained and certified to be in charge of an EPA.

A.13 ESD Protected Area (EPA): An area that is certified to be established and maintained in compliance with the requirements of this document such that mission hardware is protected from damaging ESD events.

A.14 ESD-Protective Packaging: ESD-protective materials used to prevent damage to ESD sensitive (ESDS) items during storage or transport.

A.15 ESD Sensitive (ESDS) Items: Electrical and electronic parts, assemblies and equipment which are sensitive to electrostatic discharges of specific energy levels.

A.16 Essential Insulator: An insulative material required in an EPA due to the work being performed.

A.17 Electrostatic Field: A voltage gradient between an electrostatically charged surface and another surface of a different electrostatic potential.

A.18 Flatsat: An integrated model of mission electronics which is used to support software development and test.

A.19 Ground: A mass such as earth, a ship, or a vehicle hull, capable of supplying or accepting a large electrical charge without a net change in potential.

A.20 Groundable Point (Gp): Any point with a low impedance connection to ground where grounding connections may be attached. Usually it is the common point ground.

A.21 **Hard Ground:** A connection to earth ground either directly or through a low impedance connection.

A.22 **Human Body Model (HBM):** The electrical pulse (current over time) that results from a voltage discharged through a specific electrical circuit which simulates the fingertip of a typical human being coming in contact with a conductive item. The HBM is defined in ESD ANSI/ESD/JEDEC JS-001.

A.23 **Insulative Material:** A material having a surface resistivity $\geq 10^{12}$ ohms/square or a volume resistivity $\geq 10^{11}$ ohms-cm.

A.24 **Laboratory Owner:** The branch head to which the room is assigned per GPR 8730.7.

A.25 **Latent Defect:** Defect that cannot be discovered using screening tests and causes premature failure during the mission.

A.26 **Level A Instructor:** An individual who is certified to train all levels of personnel in the GSFC ESD Control Program.

A.27 **Level B Instructor:** An individual who is certified to train operators and ESD Program Monitors. They may perform the duties of these roles as well.

A.28 **Mission Hardware:** Hardware used during execution of the mission as either the launch vehicle, the payload (spacecraft or observatory), or the subsystem (instrument, or other).

A.29 **Nonconformance**: A nonconformance is a finding during EPA certification or a quality audit that reflects a significant failure to implement a documented requirement.

A.30 **Observation**: Observations are findings during EPA certification or a quality audit that reflects a minor failure to implement a documented requirement and can be corrected on the spot with relative ease.

A.31 **Operator:** An individual who is trained and certified to process ESDS mission hardware in the EPA.

A.32 **Project Manager:** Code 400 flight project manager.

A.33 **Static Dissipative:** A property of a material having surface resistivity $\geq 10^{5}$ but $<10^{12}$ ohms per square or a volume resistivity $\geq 10^{4}$ but $<10^{11}$ ohms-cm.

A.34 **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.

A.35 **Verification:** The act of performing the tests and/or inspections to periodically confirm performance.

A.36 **Visiting Operator:** A person who handles ESDS items in a certified EPA but who is not a member of the GSFC civil service or contractor workforce.

A.37 **Volume Resistivity**: A physical property of a material represented mathematically by the DC voltage per unit thickness divided by the amount of current per unit area passing through a material; the unit of measurement is ohm-centimeters.

A.38 **Triboelectric Effect:** The mechanism by which certain materials become electrically charged after they come into contact with a different material and are then separated (such as through rubbing, or peeling apart). The polarity and strength of the charges produced differ according to the materials, surface roughness, temperature, humidity, and other properties and conditions.

A.39 **Waiver:** A specific written authorization granting relief from one or more requirements herein.

Appendix B: Acronyms

AC	Alternating Current
CDM	Charged Device Model [for electrostatic discharge].
CMS	Continuous Monitoring System
COTS	Commercial Off The Shelf
CPG	Common Point Ground
CRT	Cathode Ray Tube (Monitor)
CSO	Chief Safety and Mission Assurance Officer
EM	Engineering Modules
EPA	ESD Protected Area
ESD	Electrostatic Discharge
ESDA	Electrostatic Discharge Association
ESDS	Electrostatic Discharge Sensitive
ESD SP	Standard Practices
ESD STM	Standard Test Methods
ESD TR	Technical Report
GFCI	Ground Fault Circuit Interrupter
GPR	Goddard Procedural Requirement
GSE	Ground Support Equipment
GSFC	Goddard Space Flight Center
HBM	Human Body Model [for electrostatic discharge]
I&T	Integration and Test
NASA	National Aeronautics and Space Administration
NMTTC	NASA Manufacturing Technology Transfer Center
OJT	On-the-Job-Training
PDL	Product Design Lead
PG	Procedures and Guidelines
PWA	Printed Wiring Assembly
QA	Quality Assurance
R&D	Research and Development
RH	Relative Humidity
RMS	Root Mean Square
UUT	Unit Under Test
WFF	Wallops Flight Facility
WOA	Work Order Authorization
WM	Workmanship Manual

Appendix C: ESD Control Program Certification Test Log

ESD Class Level:		**Lab Code:**	**Project:**
Lab Manager:			**Assessment Date:**
Bldg. #	**Room #**	**Workstation ID #**	**Program Monitor:**

Test Item	Test Parameters	Pass	Fail	Measurement Data	Notes
1. EPA Grounding – Direct Connections	CPG to facility ground ≤5 Ω ≤5 Ω for direct connections ≤25 Ω for power strips in EPA			Ω	
2. Work Surface Resistance	$<10^9$ Ω			Ω	
3.Work Surface Grounding	$\geq 10^6$ to $\leq 10^9$ Ω from the center of the work surface to CPG or <1 ohm w/ GFCI (conductive plate use).			Ω	
4. Floor (or mat) Resistance*	$<10^9$ Ω				
5. Floor (or mat) Grounding*	$\geq 10^6$ to $\leq 10^9$Ω from the center of the high traffic zone to CPG or <1 ohm w/GFCI. (Conductive plate)			Ω	
6. Wrist Strap Check	Check Wrist Straps for signs of damage and function check CMS if in use.				
7. Wrist Strap System Grounding	≤2 x 10^6 Ω with CMS and ≤5 Ω with no CMS				
8. Chair Grounding*	$\leq 10^9$ Ω from the center of the seat to CPG.			See Separate Log Ω	
9. Grounding Through a Dissipative Surface	$\geq 10^6$ to $\leq 10^9$ Ω from the grounded item to CPG.				
10. Grounding of pressurized gas nozzles & test chamber surfaces	≤1.0 x 10^9 Ω between the grounded item and CPG			Ω	
11. Ionizer Average Decay Rate*	Decay +1000V to +100V; -1000V to -100V in 20 sec.			(+) to (-) sec.	
12. Ionizer Balance*	≤±50V after 30 sec ±5 sec.			± V_{peak}	
13. Electrical Test Equipment Contact Point (including soldering irons)	V≤ 10 mVrms R ≤ 20 Ω				
14. Work Area & Bench top Relative Humidity (%RH)	30% to 70% RH for HBM Class 1A 40% to 70% RH for HBM Class 0 20% to 70% for HBM Class 1B			% RH	
15. Essential Insulators	Voltage according to classification HBM 0: V<250V HBM 1A: V <500V				

*Required for Class 0 Work				
	Hygrometer (located in area)	ID	Cal Due	
	Megohmmeter	ID	Cal Due	
Program Monitor Credentials	CMS Checker	ID	Cal Due	Verify RH value @ benchtop:
Checked ☐ Cert ID#_____	Ionizer P.A.	ID	Cal Due	
Exp. Date_____	Psycrometer	ID	Cal Due	
EPA Certification Result **Pass☐Fail☐**	*Comments:*			

Certifier's Signature	ESD Program Monitor's Signature

Appendix D: Recommended ESD Protected Area Verification Test Log

Building #	**Room #**	**EPA ID #**	**ESD Class Level:**	**ESD Program Mon.**	**Lab Owning Code**
		Include notations in the appropriate columns where the routine measurements were not possible because ESDS items were exposed. Use "N/A" where measurement is not applicable. ** indicates measurements required for HBM Class 0 EPAs or where present in Class 1A EPAs			

Verification	**Date:**			**Date:**			**Date:**		
	Pass	Fail	Data	Pass	Fail	Data	Pass	Fail	Data
Monthly/Routine Checks									
1. EPA Grounding									
2. Work Surface Resistance									
3. Floor (or mat) Resistance **									
4. Wrist Strap System Grounding									
5. Wrist Strap Check System(s) functional									
6. Work Area Relative Humidity (%RH) and data capture									
7. Ionizer Decay**									
8. Ionizer Balance**									
9. GFCI functioning									
10. Nozzle Resistance									
11. Chair: dissipative surface									
12. Chair Grounding**									
Yearly Checks									
12. CMS/Wrist Strap Checker resistance sensor									
13. Grounding of mobile items through dissipative surface									

Equipment ID and Cal. Due Date				*Notes:*
	Hygrometer	ID	Cal Due	
	Megohmeter	ID	Cal Due	
	CMS Checker	ID	Cal Due	
	Ionizer P.A.	ID	Cal Due	
	Multimeter	ID	Cal Due	

Use form in Appendix G for chair verification data.	Verifier's Signature	Verifier's Signature	Verifier's Signature

Appendix E: EPA Certification Checklist

Building No		***Instructions:*** *The assigned ESD Program Monitor shall validate all items and complete one form per Bench/Station to be certified. Send the modified file back to the ESD Certifier to schedule the certification survey.*							
Room No.		Program Monitor							
Bench/Station ID		Laboratory Owner Code							
ESD Class Level		EPA Certifier							
			Program Monitor Use			Code 300 Certifier Use			
			Yes	No	N/A	Yes	No	N/A	
1.	**Training**								
	a. Does the area ESD Program Monitor (PM) hold an ESD Program Monitor certification? Enter the certification date or expiration date as it appears on the Certification Card Certification or Certification expiration date:		☐	☐		☐	☐		
	b. Is the ESD PM aware that visitors must be escorted?		☐	☐		☐	☐		
	c. Will special ESD procedures be used which exceed the requirements of 300-PG-8730.6.1?		☐	☐	☐	☐	☐	☐	
	d. If the answer to c. above is Yes, is a training procedure prepared that will be used to inform the operators?		☐	☐	☐	☐	☐	☐	
2.	**Area Controls**								
	a. Is the EPA properly identified as an ESD area with pre-defined boundaries? (e.g. ESD signs, rope guard and/or tape on floor)		☐	☐		☐	☐		
	b. If No to a. above, are risk mitigation methods used?		☐	☐		☐	☐	☐	
	c. Is a NASA-calibrated hygrometer being used?		☐	☐		☐	☐		
	d. Is the relative humidity being logged? (e.g. manual readings entered into a log, real-time charts being archived, digital readings saved in a hard drive)		☐	☐		☐	☐		
	e. Is the EPA free of triboelectric (static generator) materials? (e.g. notebooks, manuals, non-ESD binders, non-ESD-safe paper, cardboard, regular plastic, tape dispensers)		☐	☐		☐	☐		
	f. Have necessary insulators been verified to charge to sufficiently low voltage levels for the applicable EPA sensitivity rating when used as intended?		☐	☐	☐	☐	☐	☐	
3.	**Workstation Controls**								
	a. Are previous Certification stickers removed?		☐	☐	☐	☐	☐	☐	
	b. Is a Common Point Ground (CPG) identified in the EPA?		☐	☐		☐	☐		
	c. Is the workstation properly grounded to the CPG as per 300-PG-8730.6.1?		☐	☐		☐	☐		
	d. Are the work surfaces either conductive or dissipative and connected to the CPG as per 300-PG-8730.6.1?		☐	☐		☐	☐		
	e. Do chairs/stools meet resistance specifications as per 300-PG-8730.6.1?		☐	☐		☐	☐		
4.	Personnel Controls								
	a. Are there only Wrist Strap Continuous Monitoring Systems (CMS) in place?		☐	☐		☐	☐		
	b. If the answer to a. is No, is there a calibrated Wrist Strap Checker in place?		☐	☐	☐	☐	☐	☐	
	c. Are ESD Foot Grounding devices being used in the EPA? (e.g. Heel Straps, ESD Shoes)		☐	☐		☐	☐		

Building No		***Instructions:*** *The assigned ESD Program Monitor shall validate all items and complete one form per Bench/Station to be certified. Send the modified file back to the ESD Certifier to schedule the certification survey.*	
Room No.		Program Monitor	
Bench/Station ID		Laboratory Owner Code	
ESD Class Level		EPA Certifier	

		Program Monitor Use			Code 300 Certifier Use		
		Yes	No	N/A	Yes	No	N/A
	d. If the answer to a. is No, is there a log sheet in place, outside of the EPA, for daily wrist or heel strap checks by the operator?	☐	☐	☐	☐	☐	
	e. Are wrist straps available for visitors?	☐	☐		☐	☐	
	f. Are ESD garments used by all personnel that go into the EPA (residents and visitors)?	☐	☐		☐	☐	
	g. Were the ESD garments procured from Code 300 for non-cleanroom type and from Code 549 for cleanroom type (at Greenbelt)?	☐	☐		☐	☐	
	h. Are the ESD garments kept in a controlled storage area so that they are not used in areas other than the EPA?	☐	☐		☐	☐	
5.	Equipment Controls						
	a. Is any equipment which can generate a static charge (fans, CRT displays, printers, etc.) located outside the EPA?	☐	☐	☐	☐	☐	☐
	b. Are the soldering stations in the EPA ESD compliant as per 300-PG-8730.6.1?	☐	☐	☐	☐	☐	☐
6.	Storage / Packaging						
	a. Are ESD compliant storage bins available for use in the EPA?	☐	☐	☐	☐	☐	☐
	b. Are protective bags and pouches available for use in the EPA?	☐	☐	☐	☐	☐	☐
	c. Are enclosures to be used to store parts in the EPA grounded?	☐	☐	☐	☐	☐	☐
	d. Is there a procedure used to reject incoming ESDS items in unmarked containers/bags or non-ESD-compliant containers or bags?	☐	☐	☐	☐	☐	☐
7.	Class 0 requirements (Not Applicable for Class 1A Benches/Stations)						
	a. Is the ESD Class Level identified in the EPA signs?	☐	☐		☐	☐	
	b. Is an Ionizer being used?	☐	☐		☐	☐	
	c. If a hygrometer alarm is used, are the limits set to 40% and 70% RH?	☐	☐	☐	☐	☐	☐
	d. Is the resistance of the floor/floor mats within specification as per 300-PG-8730.6.1?	☐	☐		☐	☐	
	f. For HBM Class 0 EPAs, are the chairs/stools grounded through the dissipative floor?	☐	☐	☐	☐	☐	☐

Appendix F: Example of ESD Control Program Chair Verification Log

Bldg. #________ Room #________ ESD Mon.________________ Lab Mgr.____________________

Test Parameters R< $10^9\Omega$ **RH** >30%		**Date**			**Date**			**Date**			
Chair ID	**Test Item**	**Pass**	**Fail**	**Data**	**Pass**	**Fail**	**Data**	**Pass**	**Fail**	**Data**	**Comments**
	1. Seat Surface Resistance										
	2. Seat to back Resistance										
	3. Seat to Floor (or mat)										
	4. Left arm rest to Seat										
	5. Right arm rest to Seat										
	1. Seat Surface Resistance										
	2. Seat to back Resistance										
	3. Seat to Floor (or mat)										
	4. Left arm rest to Seat										
	5. Right arm rest to Seat										
	1. Seat Surface Resistance										
	2. Seat to back Resistance										
	3. Seat to Floor (or mat)										
	4. Left arm rest to Seat										
	5. Right arm rest to Seat										
	1. Seat Surface Resistance										
	2. Seat to back Resistance										
	3. Seat to Floor (or mat)										
	4. Left arm rest to Seat										
	5. Right arm rest to Seat										
Hygrometer (located in area)		ID		Cal Due	ID		Cal Due	ID		Cal Due	
Megohmmeter		ID		Cal Due	ID		Cal Due	ID		Cal Due	
		Certifier's Signature			Certifier's Signature			Certifier's Signature			

Appendix G: Example of Wrist Strap or Soldering Iron Log

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

Circle the title that applies. If the check is successful mark the slot with a check (✓), use an "X" to indicate a failed check. Failed checks must be corrected before work can resume at the ESD protected area.

Appendix H: Example of ESD Control Program Stickers

Verify Voltage-Resistance Monthly	Calibration Not Required

This ESD protective workstation is certified
compliant to 300-PG-8730.6.1
HBM Class X
EPA ID: _____
Certified by: _____
Certification date: _____

Appendix I: Specification for ESD Garments

1. ESD garments shall be qualified by the manufacturer using as a minimum the testing procedures specified in ANSI/ESD STM 2.1 and the acceptance criteria given in ANSI/ESD S20.20, Table 3 for Groundable Static Control Garments ($<10^9\Omega$). A lower limit shall also be imposed of $10^5\Omega$. The qualification status of the garment shall be documented either on the manufacturer's product datasheet or on a manufacturer's certificate of compliance.

2. Style:

   a. Conductive elastic cuffs: to ensure grounding through the skin
   b. Raglan sleeves preferred: provides larger number of washings (fewer individual pieces sewn together) and fits more body sizes
   c. Front snap closure: to reduce source of silicones (on zipper) in GSFC production environment
   d. Side snap for ground wire connection: for special (non-standard) cases where a wrist strap cannot be used.
   e. No physical damage.

3. Screening: Nondestructive sample testing shall be used to monitor compliance of purchased and laundered lots as well as for yearly compliance verifications. Incoming inspection tests shall consist of visual inspection and electrical measurement.

   a. Sampling Plan: The number of pieces tested per incoming lot shall be five pieces for lots of 50 pieces or less. A "lot" has an identical design and a similar wash history (i.e. number of washings). Contact the ESD Control Program for sampling requirements for lots larger than 50 pieces.
   b. Visual Inspection. Garments shall be visually inspected to confirm that they are designed with each of the features in paragraph 2 of this appendix.
   c. Electrical Measurement. The samples tested shall meet the resistance limit of 10^5 to $<10^9$when tested in accordance with ANSI/ESD STM 2.1, paragraph 5.3 (sleeve-to-sleeve method), except attachment point shall be cuff-to-cuff. The humidity shall be ambient (30% to 70% RH). Other humidity test conditions are not required. Recorded results shall be the humidity and the measured resistance.
   d. If any garment in the lot fails the sample test the ESD Control Program Manager or delegate shall be notified and shall provide directions for dispositioning the lot.
   e. Failed garments shall be removed from the work area.

4. Washing ESD garments for hygienic reasons is permitted as long as it is accomplished with mild soap that does not contain bleach. Spin drying is not recommended because it increases the aging process due to fiber damage. Following washing, the lot shall be sample inspected per paragraph 3 of this appendix. Washing rented garments is prohibited.

5. Washing is not required to maintain ESD resistance properties however it may degrade those properties. Garment lots which are submitted for washing must be tracked for number of washings experienced and subsequent resistance value. Use resistance test result trends to increase sample size as needed to better monitor lots near their end-of-life.

6. Silicone testing is not required for non-cleanroom ESD Garments. When ESD Control is required within cleanrooms, the ESD performance requirements above apply along with contamination requirements defined by the Project contamination engineer.

Appendix J: Work Environment

Several types of work environments are typical within the GSFC manufacturing and test environment, each requiring unique consideration within this ESD control plan. Paragraphs 1 through 5 of this appendix explain applicable assumptions for these various work environments.

1. Laboratory (Lab) Bench

The lab bench work environment consists of a work bench that can be grounded and for which an EPA perimeter can be identified. Typically, printed wiring assemblies (PWA) and subassemblies are processed at lab benches. Lab benches are most often used in labs but may also be used in integration and test (I&T) areas.

2. Integration and Test (I&T) Facilities.

Unique requirements apply for the I&T work environment. This work environment is characterized by the inability to work at a grounded lab bench due to the type of test being performed or the level of hardware integration (e.g. spacecraft vs printed wiring assembly). For cases where the PDL or electrical designer has not transferred custody of hardware to an I&T manager, the PDL or electrical designer has particular responsibilities for ESD control (See paragraph 5.6.2). For cases where the hardware is in the custody of an I&T manager, the PDL (or the electrical design lead) and the I&T manager have particular responsibilities for ESD control (See paragraph 5.6.3 and 5.6.4).

3. Flatsat

The Flatsat work environment is defined for critical ground support equipment (GSE) and Engineering Modules (EM) used for software development and test that are considered ESD sensitive but are processed intermittently over long periods of time. This work environment is similar to the Lab Bench environment described in paragraph 1 of this appendix however monthly/routine verification requirements are modified (See paragraph 5.7).

4. Commercial Off-The-Shelf (COTS) GSE

The COTS GSE environment is defined for working with COTS electronic hardware that is normally used in a non-ESD sensitive configuration but may become sensitive during board replacements. This hardware is generally less sensitive than HBM Class 1A (e.g. HBM Class 1B). The baseline requirements are modified for this type of work environment in paragraph 5.5.

5. R&D

For R&D activities, the project may choose not to fully implement this ESD Control Program however this decision must be recorded and proper signage is required (See paragraph P.2.2). Failure to use the ESD controls herein when processing ESDS items, risks installing latent defects into the hardware.

CHANGE HISTORY LOG

Revision	Effective Date	Description of Changes
Baseline	09/09/2013	Initial Release