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MULTIPROGRAM/PROJECT COMMON-USE DOCUMENT

ELECTROSTATIC DISCHARGE (ESD) CONTROL FOR PROPELLANT AND EXPLOSIVE DEVICES

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DOCUMENT HISTORY LOG

Status (Baseline/ Revision/ Canceled)	Document Revision	Effective Date	Description
Baseline		12/10/1990	Baseline
Revision	A	12/20/2004	General Update. Revised paragraph 5.4.7 to address multi-layer composites. Updated reference and applicable document list.

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1.0 Scope

1.1 Purpose. The purpose of this document is to establish requirements for the development of appropriate control measures to provide protection against personnel injury, property damage, and/or mission degradation due to the discharge of electrostatic energy (ESE) and subsequent initiation of propellant or explosive devices (ordnance).

1.2 App1icability and Exclusions. This document establishes mandatory electrostatic discharge (ESD) control requirements for NASA/MSFC and NASA/MSFC contractor facilities where ordnance and/or propellant may be received, distributed, assembled, disassembled, handled, tested, repaired., or stored. These requirements shall be contractually imposed and implemented during all phases of receiving, inspection, manufacturing, testing, repair, handling, storage, and shipping of all items *of* potential concern. In the case of conflict with documents in Appendix A, this document shall take precedence unless otherwise specified by the contract.

1.3 Tailoring. The acquiring activity may modify the requirements of this document by specifically identifying the functions considered applicable to the acquisition and delete or add an ESD control program element by reference in the contract. Likewise, a contractor or end user of this document may, upon approval by the Director, Safety and Mission Assurance, delete, or reduce the requirements of, certain aspects of this document that are not required for their usage. The request to delete or reduce requirements shall be accompanied by supporting documentation. The requirements of this document may be tailored to meet the specific needs of different projects and programs with only the applicable sections being imposed.

2.0 Applicable Documents

The applicable and. referenced documents are found in Appendix A.

3.0 Definitions

The definition of terms is found in Appendix B.

4.0 General Requirements

4.1 ESD Control Program. An ESD Control Program plan that addresses each of the applicable functions and elements required by the acquiring activity shall be prepared and submitted for approval in accordance with the data requirements

of the contract. This plan shall define the responsibility of each organization *or* function and shall address how each of the organizations and functions will, be affected and how they will interact.

Organizations and Functions:

A. Acquisition
B. Design engineering
C. Reliability engineering
D. Quality assurance
E. Safety
F. Manufacturing
G. Test and field engineering
H. Packaging, marking, and transportation
I. Housekeeping
J. Drafting
K. Inspection
L. Test
M. Manufacturing and processing
N. Assembly
O. Maintenance, repair, and rework
P. Training
Q. Installation
R. Failure analysis

4.2 Test Program. A test program, as detailed in Section 5 of this document and the procurement specification, shall be established for each explosive device (ordnance) except those types of devices specifically exempted from ESD testing in Paragraph 5.5.1.1, solid propellant formulation, solid rocket motor, and liquid rocket propellant storage and supply subsystems, to determine the ESD sensitivity of the item. This test program will include tests conducted on propellants and ordnance for initiation sensitivity due to ESD. Testing shall include characterization *of* articles/items used, in processing and handling which generate ESE as well as determination of those items which readily retain, absorb, and/or store ESE.

Testing and analysis must define the safe distance envelopes and various physical contacts that would pose an unsafe condition. Operations and processes shall be developed based on the results, of the testing program. A test plan shall be submitted to the Government for review and approval. The test plan shall include schematics of the test setup and a list of equipment and instrumentation. All equipment and instrumentation shall be calibrated. Test results shall be furnished during preliminary design review (PDR) or as contractually required.

4.2.1 Test Program Results. The relative ESD sensitivity of the propellant, rocket motor or explosive device shall be determined by this test program, and the results shall be used in the determination of operational ESD mitigation techniques as defined in paragraph 5.2. If the test program reveals that the propellant, rocket motor or device does not detonate, deflagrate, dud, or otherwise react to a discharge of electrostatic energy equivalent to that which would be experienced during worst case processing and handling operations, it is considered insensitive to ESD for purposes of this standard, and operational controls may be tailored accordingly. If, however, the propellant, rocket motor or device detonates, deflagrates, duds, or otherwise reacts to the discharge of electrostatic energy, the item shall be considered ESD sensitive and all applicable mitigation techniques shall *be* implemented. Those types of explosive devices exempted from ESD testing in paragraph 5.5.1.1 are also considered to be insensitive to ESD for purposes of this standard.

4.3 ESD Training Program. An ESD awareness briefing shall be provided to all applicable personnel. ESD training shall be given *to* all personnel that have, or are likely to have, direct relation with ESD sensitive items, operations, or areas. *Visitors to* any ESD sensitive area shall be required to attend an ESD briefing, and must be escorted at all times by a fully ESD trained employee. The personnel training program shall address, as a minimum, the ESD subjects set down in Appendix C. The ESD training shall be oriented to the functional needs of the personnel being trained, and the material involved. A comprehensive ESD training program should include the following:

A. ESD control program
    a. Organization and responsibility
    b. Program requirements
B. Principles of static electricity
    a. Definition of static electricity
    b. Causes
    c. Prime electrostatic generators
    d. Triboelectric generators, electrostatic fields
    e. Control methods
        i. Grounding/bonding
        ii. Protective handling
        iii. Topical antistats
        iv. Ionized air
        v. Relaxation time
        vi. High humidity

C. ESD protective materials and equipment
   a. ESD protective materials
      i. Conductive
      ii. Dissipative
      iii. Antistatic
   b. Applications
   c. Personnel apparel
   d. ESD protective equipment
D. ESD protective areas
   a. Design and construction
   b. Material choice
   c. Movement of people and objects
   d. Cleaning systems and devices
   e. Monitoring
   f. Grounding/Bonding
E. ESD in systems design
   a. Materials
   b. Protection safeguards
   c. Manufacturing techniques
F. Electrostatic energy meters/detectors
G. Failure/hazard analysis techniques
H. Handling precautions and procedures
I. Packaging and shipping

4.3.1 ESD Training Documentation. The training program documentation shall describe the following, as applicable:
A. Qualification of the instructors
B. Lesson Plans
C. Hours of instruction
D. Procedures for certification and recertification
E. Procedures for recording of training, retraining, and methods of identifying trained personnel
F. Certification criteria

4.4 Quality Requirements. Quality requirements shall be established to verify conformance to this standard. These provisions shall include monitoring and auditing of ESD requirements in-house, on site at MSFC, and those invoked on contractors, subcontractors, suppliers, and vendors.

4.4.1 Inspection Responsibility. Unless otherwise specified in the contract or purchase order, the contractor is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified in the

contract or order, the contractor may use his own or any other facilities suitable for the performance of the inspection requirements specified herein, unless disapproved by the Government. The Government reserves the right to perform any inspections deemed necessary to assure supplies and services conform with this document.

4.4.2 Internal Quality Records. The contractor shall prepare and maintain internal records of each audit performed to ensure compliance with the approved ESD control plan. A tracking system shall be established *to* assure all problems or nonconformances are addressed and necessary corrective actions are followed.

4.4.3 Documentation. All test plans, test procedures, and test reports relating to ESD sensitivity characterization and mitigation, and all operating procedures related to ESD sensitive items or operations shall be approved in writing by the cognizant contractor quality assurance personnel.

4.4.4 ESD Testing. ESD characterization testing shall be verified by the cognizant contractor's quality personnel. Government quality assurance personnel shall be notified and given the option to witness the test. All data shall be made available for review by the Government,

4.5 Safety Requirements. Safety requirements shall be established to verify conformance to this standard. These provisions shall include monitoring and auditing of ESD requirements in-house, on site at MSFC, and those invoked, on contractors, subcontractors, suppliers, and vendors.

4.5.1 Training. The ESD training program shall be reviewed by ESD knowledgeable personnel from Safety to ensure an adequate program to accomplish the necessary training level for each personnel group.

4.5.2 Documentation. All test plans, test procedures, and test reports relating to ESD sensitivity characterization and mitigation, and all operating procedures related to ESD sensitive items or operations shall be approved in writing by the cognizant contractor safety personnel.

4.6 Audits and Reviews

4.6.1 Internal Audits. Audits shall be conducted by ESD knowledgeable personnel from Quality, Safety, and Engineering at periodic intervals, but at least annually. Audits shall cover all aspects of this standard, compliance to operational procedures, and training requirements. A formal report shall be prepared and maintained, and shall be made available to the audited group and, upon request, to the procuring NASA installation. This report shall include date of audit, performing personnel, items or activities reviewed, requirements audited, objectives of the audit, all. Detected problems or areas of nonconformance, and any recommendations and corrective actions resulting from the audit. These records shall be made available to contractor management. A training system shall be set up to assure all problems or nonconformances are addressed and necessary corrective actions are followed.

4.6.2 Government Audits. The Government reserves the right to perform audits and to review documentation specified herein as required to determine conformance to the requirements specified in this standard. The results of these audits will be made available to the contractor for corrective action.

4.6.3 Design Review. All hardware designs shall be reviewed by ESD knowledgeable personnel from Quality Assurance, Safety, and Design Engineering to ensure incorporation of all required ESD standards or specifications.

4.6.3.1 Design Review Requirements. Design decisions relating to the ESD control program shall be presented at design reviews and shall include the following, as a minimum:

A. The identification of all ESD sensitive items, areas, and operations on drawings, in procedures, or in other appropriate documentation

B. Identification of all non-conductive materials used on, or within the electrical field of, ESD sensitive items

C. Identification of all triboelectric charge generators and accumulators (such as composite materials, and handling equipment)

D. Identification of all electrostatic field generators (such as computer terminals, and radio transmitters)

E. Identification of all. ESD sensitive operations

F. Identification of all ESD sensitive areas

G. Identification of adjoining hazardous areas

H. Results of analysis and tests

I. Protective measures

J. Handling procedures

K. Storage requirements

L. Marking of hardware as ESD sensitive

M. Problem areas relative to meeting the requirements of this standard and proposed corrective actions

N. Shipping container design

4.6.4 Program Reviews. Progress shall be assessed by the review of the following information, as a minimum:

A. Identification of all ESD sensitive items (such as explosive devices, and propellant)

B. General design, construction, and maintenance requirements for all ESD sensitive items (explosive devices, propellant formulations, case/tank designs, etc.)

C. General design, construction, and maintenance

requirements for all ESD sensitive areas

D. Procedures used to control the handling and storage

of ESD sensitive items.

E. Methods and procedures for assuring adequacy of design for ESD sensitive hardware, associated equipment, and handling areas

F. Quality Assurance and Safety methods and procedures for monitoring *the* continued effectiveness of ESD protection equipment

G. Quality Assurance and Safety methods and procedures for performing audits of the ESD control program

H. ESD training program

I. Packaging and package marking for ESD sensitive items

J. Problem areas in meeting the requirements of this standard and proposed corrective action

K. Storage and shipping containers

4.7 MSFC On-site Operations

4.7.1 MSFC Personnel and On-site Contractors. All MSFC personnel and on-site contractors involved in explosive operations are responsible for the implementation of the requirements contained herein.

4.7.2 Verification. The MSFC Industrial Safety and Quality Assurance personnel shall verify compliance with this standard during all MSFC on-site explosive operations.

4.7.3 Document Approvals. All test plans and test procedures relating to ESD sensitivity characterization and mitigation, and all operating procedures related to ESD sensitive items or operations shall be approved in writing by the cognizant Government Quality Assurance and Safety office personnel.

4.8 Prime Contractor Operations. All contractor personnel involved in explosives operations are responsible for the implementation of the requirements contained herein. Verification of compliance shall be performed by Safety and Quality Assurance personnel.

4.9 Subcontractor Control. The Prime Contractors shall ensure that subcontractors, suppliers, and vendors have established ESD control programs, as required.

5.0 DETAILED REQUIREMENTS

5.1 Handling, Shipping and Storage Requirements. Detailed procedures shall be developed, documented and implemented for handling ESD sensitive items during all phases of manufacturing, test, inspection, handling, shipping and storage. Detailed shipping and storage requirements (temperature, humidity, etc.) will be addressed in specific procedures. Handling, shipping and storage procedures shall be submitted for approval in accordance with the contract.

5.1.1 Shipping Container Design. During storage and shipment, each ESD sensitive item shall be enclosed in a conductive barrier material, which provides protection from triboelectric charging and electrostatic energy (Faraday shielding). Conductive materials shall have a maximum resistivity of $3XI0^{4.}$ ohms per square at all levels of relative humidity. The design of all shipping containers shall be such that triboelectric charging is held to the safe energy threshold for the item.

5.2 Operational controls. All operations on or involving explosive devices, and/or propellants shall be conducted in accordance with approved procedures. These procedures shall include appropriate ESD mitigation techniques, such as grounding/bonding of personnel and equipment, personnel protective equipment and clothing, monitoring for static electricity, humidification, ionization, and temperature constraints. They shall also contain necessary hazard controls and steps to be taken to lessen the build-up of static electricity during operations and storage. Each operation shall be analyzed for applicability of the following mitigation techniques.

A. Material selection and design to reduce ESD concerns.

B. Grounding/bonding of personnel, tools, equipment, solid rocket motors and liquid, propellant systems, storage containers, and transport vehicles. On removable (clip) type ground connectors, the ground shall be verified prior to start of operations. Can permanent connections, the ground shall be verified at the time of installation, and periodically thereafter. All grounds shall be of the same electrical potential in a given work area. All grounding/bonding devices for personnel shall have a 1 megohm resistor.

C. Conductive and/or dissipative shielding of explosives.

D. Wrist or leg straps, cotton clothing, conductive coveralls and hardhat covers, conductive gloves and, where practicable, conductive shoes. All connections shall be through a 1 megohm resistor. Avoid wearing clothing (this includes undergarments, socks, and stockings) made of nylon or other synthetics, silk, or wool. Garments shall not be put on or removed while engaged in explosives operations. This reduces the generation of static charges caused by physical separation of materials. If outer garments (coats, coveralls, etc.) need to be removed, personnel will step cut of the immediate area of operation, remove the garment, ground themselves, then reenter.

E. Monitoring for static with electrostatic meters (“stat guns") and static alarm devices during all operations which have the potential of generating ESE. Operations shall halt when static approaches 1000v or a level determined to be hazardous for the specific item, or the alarm sounds, as required by procedure.

F. Precautions when working around liquid oxygen, since oxygen gas may permeate clothing and a static discharge could result in ignition.

G. The use of conductive coatings and antistatic wax on materials such as glass, acrylic, or polycarbonate materials, used for barricades, windows, etc.

H. Electrical circuits designed to prevent arcing.

I. Temperature, air movement or wind, and humidity (absolute/specific) constraints for internal and external operations.

J. Design of shipping *and* storage containers and facilities to reduce ESD concerns.

K. Use of antistatic spray.

L. Designs to mitigate triboelectric charging (friction, rubbing, etc.).

M. Humidification.

N. Ionization.

O. Design and control of manufacturing operations, such as mixing, pressing, and removing mandrels, to mitigate triboelectrification and static accumulation, and to allow for dissipation of static electricity.

P. Sufficient safety and quality mandatory inspections to ensure compliance with approved procedures and constraints.

Q. Design of ground support equipment, including transportation and handling equipment to reduce ESD concerns.

R. Prohibition of the introduction of static generators (tape, musical and adhesive, foam cups, snack food bags, etc.) into ESD sensitive areas.

S. Prohibition of the unauthorized introduction of electrostatic or electromagnetic field generators (computers, radios, electronic devices, etc.) into ESD sensitive areas.

5.3 Solid Propellant

5.3.l Analysis and Tests. As a minimum, the following analyses and tests shall be performed to characterize the ESD sensitivity of each deliverable specific solid propellant formulation.

A. Resistivity measurements

B. Dielectric constant measurements

C. Dielectric breakdown measurements

D. Resistive capacitive discharge tests

The above tests shall be performed at worst case high and low, and at ambient temperature to initially characterize the propellant

formulation. Test results may be compared to existing data from other formulations with extensive processing histories. This allows a relative ranking of the formulation in regard to ESD sensitivity. For each propellant formulation, a fully defined electrical property characterization program will be established to determine lot to lot differences or variabilities that might result. The contractor shall submit for approval, a test program plan for process verification of propellant batches based on the initial characterizations. Test results which differ from the initial characterization shall be cause for rejection. Any change in the propellant formulation will be cause for reanalysis and retest.

5.3.2 Solid Rocket Motors. The solid rocket motor, shall be designed to mitigate ESD sensitivity. Composite case motors, if made necessary by mission performance requirements, shall either contain graphite, be coated with conductive paint, contain conductive insulation, or other ESD shielding, and have a surface resistivity less than 10^9 ohms per square.

5.3.3 Rocket Motor Assessment. Verification of mitigation techniques will be performed using a pathfinder. This verification program will include all phases of manufacturing, handling, transportation, assembly, disassembly, and test.

5.3.3.1 Modeling. Where the verification assessment program will not or cannot provide direct measurements, a proven modeling technique shall be used to calculate the predicted ESD sensitivity.

5.3.4 Hazard Analysis. A hazard analysis shall be performed during the preliminary design phase of the rocket motor and the test or launch facility, to identify potential ESD hazards, so that they can be eliminated or reduced.

5.3.5 Grounding and Bonding. All items, articles, and operations shall be grounded and bonded in accordance with applicable DOD and NFPA requirements.

5.4 Liquid Propellant. Liquid propellant hazards relative to ESD differ from solid propellant hazards, primarily because prior to combustion the fuel and oxidizer are stored separately. By removing fuel or oxidizer from the triad of combustion (fuel, oxidizer, and heat) an ESD event, representing heat, in principle could not initiate an

explosion. Steps shall be taken to prevent the simultaneous occurrence of a fuel vapor, oxidizer (air), and a spark (static discharge).

5.4.1 Design Requirements. New liquid propellant tanks and engine assemblies, and facilities where engines and components are undergoing testing, along with propellant handling and loading systems, shall be designed with ESD sensitivity in mind. Static is generated when liquids or gases move in contact with other materials. This occurs commonly in operations such as pumping, filtering, flowing through pipes, sloshing, and transferring from one tank to another. Static may accumulate in liquids, and a discharge may occur if the accumulation is sufficient. Existing components, systems, and testing areas will be tested or analyzed for ESD sensitivity, or their tendency to generate ESE, and controls implemented accordingly.

5.4.2 Hazard Analysis. A hazard analysis shall be performed during the preliminary design phase of the rocket, engine, *or* component and the test or launch facility, to identify potential ESD hazards, so that they can be eliminated or reduced. The hazard analysis shall be updated to support succeeding design reviews and utilized in management safety risk assessments.

5.4.3 Grounding and Bonding. All metal components of a fuel system (storage tanks, piping, valves, structure, etc.) shall, be electrically bonded in accordance with KSC-STD-E-0012-A or equivalent.

5.4.3.1. Personnel Grounding. Personnel shall ground themselves before touching, or using a tool on, any surface. (Note:The energy required for ignition of a hydrogen and air atmosphere is so small that even "spark proof" tools can cause ignition. Therefore all tools must be used with caution to prevent slipping, glancing blows, or dropping, all of which cause sparks.)

5.4.4 Loading. When loading or unloading tank trucks, a difference in charge may develop between the vehicle and the grounded piping system. To avoid this possibility, a bond shall be established between the piping and the truck. The

offloading facility shall provide easily accessible common grounding connections. The connection shall be made at the truck first, then to the common grounding point (same as piping). The connection shall be made before commencing operations and shall not be disconnected until after completion. Connections to complete the grounding circuit shall be located outside the immediate transfer area.

5.4.4.1 Sampling Operations. Sampling and other operations shall be avoided for approximately 30 minutes after a tank has been filled to allow for charge dissipation.

5.4.5 Storage Tanks. Storage tanks shall be verified to be free of combustion sustaining air (inert) prior to any filling operation. For the initial filling of tanks, and any filling where combustion sustaining air is present, the ullage space shall be made inert prior to being filled.

5.4.6 U11age Gases. In order to reduce ignition susceptibility in a vapor space, an inert gas (such as nitrogen or helium) shall be used as ullage to displace air, when practical. When inert gas is not practical, the potential for flammable atmospheres shall be prevented by defining the flammable limits for any contained vapor mixture as a function of temperature and pressure. By keeping the vapor mixture either too lean or too rich for the ambient temperature or pressure, potential for ignition by an ESD event can be reduced.

5.4.7 Composites. The surface resistivity of the composite shall be less than 10^9 ohms per square (i.e., dissipative or conductive), for prevention of charge accumulation on the surface, and to enable grounding of the propellant tank, motor case, or other items. If materials with surface resistivity greater than 10^9 ohms per square must be used for storage vessels, the outer surface shall be painted with a conductive coating *to* achieve the value of less than 10^9 ohms per square. Although materials with surface resistivities between 10^9 to 10^{14} ohms per square are antistatic and do not exhibit static charging properties, these materials cannot be grounded. Materials with surface resistivities greater than 10^{14} ohms per square shall not be used. If the propellant tank, motor case, or other item is composed of various layers of different materials, the design shall include a means of ensuring that

static does not build up on the inner layer and that the item can be grounded.

5.5 Explosive Devices

5.5.1 Testing. Devices shall be tested for ESD sensitivity at high, low, and ambient temperature. High and low temperature test values will be determined from a worst case combination of storage, transportation, and operation temperatures. The number of tests required will be specified in the qualification section of the component design specification.

5.5.1.1 Secondary or Tertiary Explosives. Devices which contain only secondary and/or tertiary explosives fully encapsulated in a metal housing, and which do not contain pyrotechnic mixtures, initiators, percussion primers, or solid propellants, do not require ESD testing.

5.5.1.2 Test Method. Explosive devices shall be tested with the faraday cap and/or shorting clip or spring removed. Electroexplosive devices (EEDs) shall be tested using test method 205 of MIL-STD-1512. Non-EEDs not specifically exempted from ESD sensitivity testing in paragraph 5.5.1.1, shall be tested using the discharge test circuit as shown in Figure 205-1 of MIL-STD-1512, test method 205. A minimum of ten devices of each type shall be tested. Each device shall be subjected to a minimum of two discharges, with the test points located at opposite ends of the long and short axis of the device. The test points shall be positioned such that a straight line drawn between them would pass through the center of the explosive charge contained within the device which is determined to be most sensitive to ESD. Test points shall be specified in the test plan and as a minimum will include shipping and functional configurations.

5.5.1.3 Acceptance Criteria. The devices will not fire or dud when subjected to the test method of 5.5.1.2. Any devices that do function pose definite personnel hazards, and design changes shall be considered. If the device fires or duds, the Government shall be notified and an evaluation of the design shall be performed. If no design changes can be made due to performance requirements, the device shall be designated ESD sensitive and all applicable ESD mitigation techniques shall

be implemented. All operational procedures involving storage, transportation and handling, test, inspection, and installation of these ESD sensitive devices shall be approved by cognizant MSFC Safety, Quality, and Design Engineering personnel.

5.5.1.4 Sampling. A sample will be tested to verify the ability of a device to function properly after withstanding an electrostatic discharge per 5.5.1.2. The sample will include devices in shipping and functional configurations. Any degradation in performance will be reported to the Government for evaluation.

5.5.2 Lead Azide and Lead Styphnate. Due to extreme ESD sensitivity, the use of lead azide and lead styphnate shall be carefully evaluated. These explosives shall be used only when dictated by performance requirements.

5.5.3 Grounding and Bonding. Whenever possible, all explosive devices shall be grounded. In addition, all conductive parts of each device must be electrically bonded together, and each device must be electrically bonded to adjacent conductive structure (motor case, vehicle structure, test stand, etc.). Each explosive subassembly of an ordnance assembly consisting of two or more explosive segments (e.g., linear shaped charges) shall either be electrically bonded to the adjacent explosive subassembly or to adjacent conductive structure. All explosive subassemblies of the ordnance assembly must be electrically bonded to adjacent conductive structure, either directly or through another subassembly. Electrical resistance across each bonding interface shall not exceed 2.5 milliohms, in accordance with MIL-B-5087, Class "R" requirements.

5.5.4 Storage and Shipment. Storage and shipment criteria shall conform to Paragraph 5.1.1. A faraday cap, or approved equivalent, shall be affixed to all devices with electrical connector type interfaces in the firing circuit during storage and shipment. The electrical leads on other types of electroexplosive devices (EEDs) must be shorted during storage and shipment.

5.5.5 Operating Precautions.

5.5.5.1 Grounding. Operations such as manufacturing, test, and inspection of ESD sensitive explosive devices shall be performed in areas equipped with effective electrostatic grounding systems. Conductive-soled shoes or leg straps shall be worn when conductive flooring is used as the primary grounding method. For table top assembly, the top shall be static dissipative on a conductive backing. During operations where conductive floors and/or table tops are not available, such as installation of the explosive devices into the next higher assembly, operators shall wear wrist or leg straps attached to a certified ground. All personnel grounding devices shall be checked prior to use far proper functioning. All personnel connections shall be through a 1 megohm resistor. All grounds shall be of the same electrical potential in a given work area.

5.5.5.2 Precautions. All electrical equipment, except that equipment necessary for test, inspection, or rather approved operations (e.g., packing), shall be located out of the reach of an operator working on or with an explosive device. Soldering shall never be performed with a connected soldering iron.

APPENDIX A
APPLICABLE AND REFERENCE DOCUMENTS

A) Applicable Documents Latest revision unless otherwise specified.

1. DA Pamphlet 385-64, *Ammunition and Explosives Safety Manual*

2. DOD 6055.9, *Ammunition and Explosives Safety Standard*

3. KSC-STD-E-0012, *Bonding and Grounding, Standard for*

4. NSTD 08060, *Space Shuttle System Pyrotechnic Specification*

5. MPR 7120.2, *Multiprogram/Project Common-Use Documentation*

6. MWI 7120.4, *Documentation Preparation, Programs/Projects*

7. NSS 1740.12, *NASA Safety Standard for Explosives, Propellant and Pyrotechnics*

8. NPG 8715.3, *NASA Safety Manual*

9. MWI 8715.10, *Explosives, Propellant and Pyrotechnics Program*

B. Reference and Associated Documents. Latest revision unless otherwise specified

1. AFR 127-100, *Explosives Safety Standards*

2. DOD-E-83578, *Explosive Ordnance for Space Vehicles*

3. MIL-HDBK-263, *Electrostatic Discharge Control, Handbook for Protection of Electrical and Electronic Parts, Assemblies and. Equipment (Excluding Electrically Initiated Explosive Devices)*

4. NFPA 77, *Recommended Practice on Static Electricity*

5. NSS 1740.16, *Safety Standard for Hydrogen and Hydrogen Systems*

6. MIL-B-5087, *Bonding, Electrical, and Lightning Protection, for Aerospace Systems*

7. MIL-B-81705, *Barrier Materials, Flexible, Electrostatic-free, Heat Sealable*

8. MIL-I-23659, *Initiators, Electric, General Design Specification for*

9. MIL-HDBK-1512, *Electroexplosive Subsystems, Electrically Initiated, Design Requirements and Test Methods*

10. MIL-STD-1576, *Electro Explosive Subsystem Safety Requirements and Test Methods for Space Systems*

11. MIL-STD-1686, *Electrostatic Discharge Control Program for Protection of Electrical and Electronic Parts, Assemblies and Equipment (Excluding Electrically Initiated Explosive Devices)*

12. Report, CPIA Publication 510, March 1989 *JANNAF Propulsion Systems, Hazards Subcommittee, Electrostatic Discharge Panel Report*

13. Report, CPIA 88-43, JAN 1988, T. Moskios *Electrostatic Discharge Test Methodologies for Solid Rocket Propellants*

14. Report, NWC TP 7071, JULY 1990, J. Covino and F. E. Hudson, Research Department, Naval Weapons Station, China. Lake, CA *Methodology for the Assessment of Electrostatic Discharge (ESD) Hazards of Energetic Materials*

15. SKB 26100866, *Design and Performance Specification for NSI-1*

16. NFFA 70, *National Electrical Code*

17. ASTM Manual 36 *Safe Use of Oxygen and Oxygen Systems*

APPENDIX B

ESD TERMS AND DEFINITIONS

1. Antistatic - This term has a dual connotation:
a) By definition, materials in this category exhibit a surface resistivity greater than 10^9 ohms per square, but less than 10^{14} ohms per square.
b) This implies that the material does not exhibit triboelectric charging propensities, usually due to the topical treatment or volume impregnation of the material with a surfactant.

2. Bonding - The process of electrically connecting two or more conductive items together. This ensures the voltage difference between the "bonded" items is continuously equalized.

3. Brush/Corona Discharge - An arcing of electric charge across a gap between a highly charged insulative surface and a grounded conductor with a small radius of curvature (i.e. human finger, corner on tooling, or needle point). This type of discharge generally is not incendiary since the effective discharge energy is expended into more than one discharge channel.

4. Capacitance - The ability of an object to store electrical energy in the form of charge.

5. Charge - A fundamental property of matter. It can be identified with subatomic particles of matter. Electrons are negatively charged particles and protons are positively charged particles. An object is positively charged if it has a deficiency of electrons, and is negatively charged if it has an excess of electrons.

6. Conduction - The charging of an isolated conducting object by the flow of charge onto or from the object.

7. Conductive - An electrical property denoting a material's tendency to sustain the flow of (conduct) current or electrical charge. By definition, materials in this category exhibit a surface resistivity of less than or equal to 10^5 ohms per square.

8. Corona - Ionization of the air by localized electric fields.

9. Current - The flow of charge from one point to another, caused by a difference in voltage between the points.

10. Deflagration - A rapid chemical reaction in which the output of heat is sufficient to enable the reaction to proceed and be accelerated without input of heat from another source. This is a surface phenomenon with the reaction proceeding towards the unreacted material, along the surface at subsonic velocity. The effect of a true deflagration under confinement is an explosion. Confinement of the reaction increases pressure, rate of reaction and temperature, and may cause transition into a detonation.
11. Detonation - A violent chemical reaction within a chemical compound or mechanical mixture involving heat and pressure. This is a reaction which proceeds through the reacted material toward the unreacted material at a supersonic velocity. The result of the chemical reaction is exertion of extremely high pressure on the surrounding medium forming a propagating shock wave which is originally of supersonic velocity.
12. Dielectric Breakdown - When the dielectric strength of the material has been exceeded and current flows through the material.
13. Dielectric Breakdown Voltage - The voltage required to cause dielectric breakdown.
14. Dielectric Constant - See "Permittivity".
15. Dielectric Strength - The ability of a material to withstand a given voltage across it without conducting electricity.
16. Dissipative - The disappearing, vanishing or diffusing of voltage or energy. By definition, materials in this category exhibit a surface resistivity of greater than 10^5 ohms per square but not greater than 10^9 ohms per square.
17. Electroexplosive Device - Any device which uses a difference in electrical potential to initiate an explosive reaction.
18. Electrostatic Discharge(ESD)- Thus is an arcing of electric charge across a gap between two points not in contact or through a nonconductor when the voltage exceeds the dielectric breakdown voltage of the nonconductor. All static electricity hazards are initiated by this sudden energy release or discharge mechanism.
19. ESD Sensitive Area - Any area in which propellant or explosive devices may be received, distributed, inspected, assembled, disassembled, manufactured, handled, tested, repaired, stored or shipped and the initiation of the

propellant or explosive device would have the possibility of personnel injury, property damage, and/or mission degradation.

20. ESD Sensitive Item - Any item which has the possibility of initiation and/or explosion from ESE/ESD and which would have the possibility of personnel injury, property damage, and/or mission degradation.

21. Electrostatic Energy(ESE) - This is the storage of electric charge. It can accumulate on almost any item regardless of size or properties. Its accumulation can result in an uncontrolled/unplanned discharge. *A* conductor will only store electrostatic energy if it is ungrounded.

22. Explosives - Includes any chemical compound or mechanical mixture which, when subjected to heat, impact, friction, detonation, or other suitable initiation, undergoes a very rapid chemical change with the evolution of large volumes of highly heated gases which exert pressure in the surrounding medium. This term applies to materials that either detonate or deflagrate.

23. FaradayShield - A fully enclosed conductive container or nonconductive container coated with a conductive paintsystem. This system functions such that no electric field flux is experienced inside the Faraday shield.

24. Grounding - The process of electrically connecting one or more conductive items to earth ground. This ensures all energy is continuously dissipated from the item.

25. Induction - The charging of an isolated conducting object by momentarily grounding it while under the influence of an electric field.

26. Insulative - An electrical property denoting a material's tendency to resist the flow of current or electrical charge. Materials in this category generally exhibit a volume resistivity of greater than 10^{13} ohm-cm.

27. Ionizatign - The formation of one or more ions by the addition of electrons to or the removal of electrons from an electrically neutral atomic or molecular configuration by heat, electrical discharge, radiation, or chemical reaction.

28. Lead Azide -($Pb(N_3)_2$) A primary initiating explosive used to initiate less sensitive explosives. It is a crystalline, cream colored compound and is very sensitive to friction, heat, impact, and ESD.

29. Lead Styphnate - ($PbO_2C_6H(NO_2)_3$)A primary initiating

explosive used to initiate less sensitive explosives. It is a yellow-orange to reddish brown colored compound with rhombic needle-like crystals. It is very sensitive to friction, heat, and impact, and is particularly sensitive to ESD. The dry material can be readily ignited by a static discharge from the human body.

30. Ordnance - For this document, any of a number of explosive devices, squibs, and initiators, electrically or otherwise activated.

31. Permittivity - Also known as "Dielectric Constant". The ability of a dielectric to store electrical potential energy under the influence of an electric field measured by the ratio of the capacitance of a condenser with the material as dielectric to its capacitance with vacuum as dielectric.

32. Propellant - Any substance or combination of substances, liquid or solid, that when ignited, propels or provides thrust through a deflagration reaction. A propellant is an explosive that is suitable for effecting the controlled propulsion of a solid body.

33. Pyrotechnic - Any item or device manufactured from explosive or chemical ingredients, including powdered metals, that is capable of deflagration or detonation. Pyrotechnic devices are generally designed to produce large quantities of heat and/or light instead of large volumes of high pressure gases.

34. Relaxation time - A measure of how quickly a solid medium will flow or dissipate the charge through its volume. The rate is calculated by multiplying the volume resistivity by the permittivity of the medium.

35. Spark Discharge - An arcing of electric charge across a gap between two distinct conductors. This type of discharge is the most prevalent electrostatic ignition source since all of the effective discharge energy is expended into one discharge channel.

36. Surface Resistivity - A measure specifying the resistance of a square section along the surface of the material which is usually specified in ohms per square. The ohms per square units denote that the same ohms resistance value will be exhibited independent of the size of the square of surface material being measured.

37. Triboelectrification - The generation of electric charge caused by the contact and separation of two materials.

38. Voltage - A measure of the potential energy of a unit of charge. Voltage and potential are synonymous terms with the exception that the term "voltage" is used with an earth ground reference implied.
39. Volume Resistivity - Often referred to as bulk resistivity, a measure specifying how much uniform electrical current a homogeneous medium will conduct independent of its dimensions. It is a constant and is usually specified in ohm-cm.

APPENDIX C

Personnel	Training course outline
Management	A, B, H
Engineering	A, B, C, D, E, F, G, H,
Procurement	A, B, C, D, H, I
QA	A, B, C, D, E, F, G, H, I
Safety	A, B, C, D, E, F, G, H, I
Field Engineer, Installation and Maintenance	A, B, C, D, E, H, I
Production Operators and Technicians	B, C, D, E, H, I
Material Handlers and Stockroom Personnel	B, C, D, E, H, I
Test Personnel	A, B, C, D, E, F, G, H, I
Janitorial	B, C, D, E, H

ESD Control Plan
Principles of Static Electricity ESD sensitive items
ESD Protective Materials and Equipment Protected
Facilities and Areas
ESD in Design
Failure Analysis Techniques
Handling Precautions and Procedures
Packaging and Shipping of ESD Sensitive Items

PACKAGE NO. 10443R

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C H	DOCUMENT NUMBER	DRL DSH	DRL REV	TITLE	CCBD NO.	PCN	PC	EFFECTIVITY
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			MSFC-HDBK-2221		203	-			
			MSFC-HDBK-505		202	-			
			MSFC-HDBK-670		202	-			
			MSFC-MNL-1951		209	-			
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			MSFC-PROC-547		202	-			
			MSFC-QPL-1918		204	-			
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			MSFC-SPEC-1198		202	-			
			MSFC-SPEC-1238		202	-			
			MSFC-SPEC-1443		202	-			
			MSFC-SPEC-164		202	-			
			MSFC-SPEC-1870		202	-			
			MSFC-SPEC-1918		203	-			
			MSFC-SPEC-1919		206	-			
			MSFC-SPEC-2083		202	-			
			MSFC-SPEC-2223		202	-			
			MSFC-SPEC-2489		206	-			
			MSFC-SPEC-2490		205	-			
			MSFC-SPEC-2491		203	-			
			MSFC-SPEC-2492		203	-			
			MSFC-SPEC-2497		211	-			
			MSFC-SPEC-250		202	-			
			MSFC-SPEC-445		202	-			
			MSFC-SPEC-504		202	-			
			MSFC-SPEC-521		202	-			
			MSFC-SPEC-548		202	-			
			MSFC-SPEC-560		202	-			
			MSFC-SPEC-626		202	-			
			MSFC-SPEC-684		202	-			
			MSFC-SPEC-708		202	-			
			MSFC-SPEC-766		202	-			
			MSFC-STD-1249		202	-			
			MSFC-STD-1800		202	-			
			MSFC-STD-246		202	-			
			MSFC-STD-2594		203	-			

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			MSFC-STD-2904		202	-			
			MSFC-STD-2905		202	-			
			MSFC-STD-2906		202	-			
			MSFC-STD-2907		202	-			
			MSFC-STD-366		202	-			
			MSFC-STD-383		202	-			
			MSFC-STD-486		202	-			
			MSFC-STD-506		203	-			
			MSFC-STD-531		202	-			
			MSFC-STD-557		202	-			
			MSFC-STD-561		203	-			
			MSFC-STD-781		202	-			

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EUGENA GOGGANS
12/19/06

SUBMITTED BY:

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