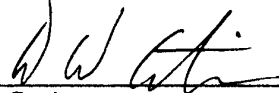
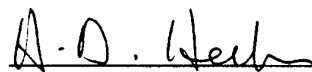


SPACECRAFT HARDWARE AND GROUND SUPPORT EQUIPMENT
ELECTROSTATIC CONTROL PLAN

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1. INTRODUCTION - EXPLANATION OF ESD

1.1. Electrostatic Discharge

ESD is a transfer of electrostatic charge between bodies at different electrostatic potentials caused by direct contact or induced by an electrostatic field.

1.2. Nature of Static Electricity

Static electricity is electrical charge at rest. The electrical charge is due to the transfer of electrons within a body (polarization) or from one body to another (conductive charging). The transfer occurs due to the interaction of charged bodies or charged and uncharged bodies. The magnitude of the charge is primarily dependent on the size, shape, composition and electrical properties of the substances which make up the bodies. Charges on non-conductors tend to remain in the localized area of contact; charges on conductors, however, are rapidly distributed over the entire surface and the surfaces of other contacted conductive objects.

The capacitance of a charged body relative to another body or to ground also has an effect on the electrostatic field. For example, when common polyethylene bags are rubbed, the charge potential may be only a few hundred volts while on a bench. But when the bag is picked up by an operator, the potential may increase to several thousand volts due to the decrease in capacitance and the conservation of charge.

$$Q_1 = Q_2 \text{ (conservation of charge)}$$

$$Q = CV$$

$$C_1 V_1 = C_2 V_2$$

$$V_2 = V_1 (C_1 / C_2)$$

The generation of static electricity caused by rubbing two substances is called the triboelectric effect. The triboelectric series is a list of substances in an order of positive to negative charging as a result of the triboelectric effect, see Table 1-1. Electrostatic charges can also be generated triboelectrically when two pieces of the same material in intimate contact, especially common plastic, are separated: i.e., when the sides of a plastic bag are separated or when tape is removed from a roll.

TABLE 1-1: Sample Triboelectric Series

Positive

+

Air
Human Hands
Asbestos
Rabbit Fur
Glass
Mica
Human Hair
Nylon
Wool
Fur
Lead
Silk
Aluminum
Paper
Cotton
Steel
Wood
Amber
Sealing Wax
Hard Rubber
Nickel, Copper
Brass, Silver
Gold, Platinum
Sulfur
Acetate Rayon
Polyester
Polyethylene
Polypropylene
PVC (Vinyl)
KEE F
Silicon
Teflon

Negative

-

1.3. Prime Sources of Static Electricity

Typical prime sources are listed in Table 1-2. These prime sources are mostly insulators and are typically synthetic materials. Voltage levels generated by these insulators can be extremely high since they are not readily distributed over the surface or conducted to other substances.

1.4. Damage

The passage of a charge through an electronic device can cause localized overheating resulting in catastrophic failure or degraded performance of that device. High voltage can also "puncture" insulating layers in the structure of the device, sometimes depositing a conductive residue of the vaporized metalization on the device thus creating a short circuit.

1.5. Susceptibility

Device susceptibility to ESD damage includes, but is not limited to:

- a. Metal Oxide Semiconductor (MOS) Devices
- b. Junction Field-Effect Devices (JFET)
- c. Bipolar linear and digital integrated circuits
- d. Mixed-process integrated circuits such as
operational amplifiers with MOS capacitors for
compensation and "BIMOS" devices
- e. Hybrid microcircuits
- f. Film Resistors
- g. Capacitors
- h. Assemblies or printed circuit boards containing any of the above

TABLE 1-2: Prime Charge Sources, Typical

Object or Process	Material or Activity
Work Surfaces	Waxed, painted or varnished surfaces Common Vinyl or plastics
Floors	Sealed concrete Waxed, finished wood Common vinyl tile or sheeting
Clothes	Common clean room smocks Common synthetic personnel garments Non-conductive shoes Virgin cotton (at low rh)
Chairs	Finished Wood Vinyl Fiberglass
Packaging and Handling	Common plastic - bags, wraps, envelopes Common bubble pack, foam Common plastic trays, plastic tote boxes, vials, parts bins
Assembly, Cleaning, Test and Repair Areas	Spray cleaners Common plastic solder suckers Solder irons with ungrounded tips Solvent brushes (synthetic bristles) Cleaning or drying by fluid or evaporation Temperature chambers Cryogenic sprays Heat guns and blowers Sand blasting Electrostatic copiers

2. APPLICABLE DOCUMENTS .

The following documents form a part of this specification to the extent specified herein.

MIL-B-81705

ISTP Polar EFI PAIP

ISTP Wind 3-D Plasma PAID

3. GENERAL REQUIREMENTS

3.1. Purpose

This document provides procedural guidelines to assure that adequate Electrostatic Discharge Protection (ESD) measures are applied during the design, assembly, testing and handling of spaceflight hardware developed at the Space Sciences Laboratory.

3.2. Scope

This document establishes ESD measures at facilities where electrostatic susceptible hardware may be handled, assembled, tested or packaged.

These measures must be implemented and adhered to during the design, handling, assembly and testing of spaceflight parts, assemblies, modules or equipment designated as susceptible to electrostatic discharge.

The measures consist of requirements and techniques which will prevent damage, or degradation, to electrostatic susceptible parts and equipment caused by inadvertent application of electrostatic charges.

3.3. Applicability

3.3.1. General

The requirements of this specification apply to all facilities required to produce ISTP and SMEX spacecraft hardware at the SSL, and other projects which choose to use this plan.

3.4. Parts Procurement

When procuring electrostatic sensitive parts or equipment the procurement documents shall be marked STATIC SENSITIVE PARTS, PACKAGE AND IDENTIFY WRAPPER OR CONTAINER ACCORDINGLY.

3.5. Receiving Inspection and Stores Handling

Received parts or equipment marked STATIC SENSITIVE PARTS shall not be removed from their individual package during inspection or while in stores. If inspections or tests are required, handling shall be in accordance with this document at an approved work station (see 4).

Care shall be taken to verify that operating personnel is certified to handle static sensitive parts and utilize the static-mitigating equipment.

3.6. Identification and Marking

3.6.1. Design Documentation

- (1) Design documents (i.e.: assembly drawings, parts list, test procedure, etc.) shall identify parts or assemblies susceptible to electrostatic discharge damage.
- (2) Mark assembly drawing zone, parts list line entry, procedure section or sheet with either an electrostatic symbol or with the caption "STATIC SENSITIVE, HANDLE ACCORDINGLY."
- (3) Design documents cover sheet shall be marked or stamped with the caption "Static Sensitive Parts" use of an electrostatic caution label is also acceptable.

3.6.2. Assembly and Equipment

Electrostatic sensitive assemblies and non-flight equipment shall be tagged with an electrostatic caution label or permanently identified as provided by the design documentation. Manufacturing orders accompanying the assemblies shall be marked or stamped "STATIC SENSITIVE, HANDLE ACCORDINGLY"

4. FACILITY REQUIREMENTS .

4.1. General

All facilities used to handle, assemble or test electrostatic susceptible parts, assemblies or equipment shall be equipped to prevent electrostatic discharges. When an entire facility does not comply with electrostatic discharge prevention measures, a well-defined complying work space shall be created and maintained for not less than two meters around the hardware of concern.

4.2. Static Safe Facilities

The basic concept of providing protection for electronic components is to prevent static buildup and to remove existing charges. A successful ESD program requires that all areas where static-sensitive devices are stored or handled be designed and comply with that concept.

4.2.1. Controlled Area

A controlled area is defined as all parts handling areas which are equipped with static preventative measures and subject to audits.

The following measures apply to a controlled area:

(1) Materials

The use of materials that are prime static generators (Table 1-2) is prohibited.

(2) Flooring

For maximum protection the floor of the work area must be conductive. Conductive footwear offers further protection, its use is recommended.

(3) Access

Access to a work area where static-sensitive devices are stored or handled must be restricted to personnel trained in ESD protective procedures. Visitors should be escorted at all times.

(4) Signs

Warning signs such as "ESD PROTECTED AREA - AUTHORIZED PERSONNEL ONLY" - must be posted.

4.2.2. Environment

(1) Humidity

The relative humidity should be controlled above 40 percent. Where this cannot be achieved, the use of ionized air is required.

(2) Ionized Air

Ionized air dissipates electrostatic charges. There are two types of ionized air generators -nuclear activated and corona discharge. Only nuclear activated generators shall be used. Ionized air is mandatory when relative humidity falls below 40%.

4.3. Grounding

4.3.1. Electrostatic Grounding

Use of the commercial alternating current (ac) power third wire ground for electrostatic grounding is prohibited, except for equipment using ac power for operation.

Electrostatic ground terminals shall be connected to an electrostatic ground bus. This electrostatic ground bus shall be connected to earth ground with a resistance not exceeding 1.0 ohm, a water pipe is generally adequate.

4.3.2. Fixed Structure Grounding

All metallic structures which might contact the parts, assemblies or equipment shall be grounded to the electrostatic ground bus through a resistance of not less than 0.2 megohms, nor greater than 2 megohms. Such structures include, but are not limited to, laminar flow clean benches, assembly benches, inspection stations, test stands, storage shelves and cabinets, equipment used around the work areas.

4.3.3. Static Ground Bars

Static grounding bars shall be installed at work stations in assembly, and inspection areas. These bars shall be individually connected to electrostatic ground bus through a resistance of not less than 0.2 megohm, nor greater than 2 megohms.

All personnel shall be instructed to discharge themselves by touching the static grounding bar before handling any static sensitive parts, assemblies or equipment.

4.3.4. Work Surfaces

Bench tops and other similar places where static sensitive parts, assemblies or equipment are placed shall be conductive and grounded, through a resistance of not less than 0.2 megohms, nor greater than 2 megohms.

4.3.5. Conductive Floors

A conductive floor mat or metallic surface shall be used at each work station used for parts handling, assemblies, or inspection, connected to the electrostatic ground bus through a resistance not less than 0.2 megohms, nor greater than 2 megohms.

Use of a conductive surface in test areas is optional.

Use of natural or synthetic carpets in controlled areas is prohibited.

4.3.6. Stools and Chairs

Stools and chairs used by personnel working on electrostatic sensitive parts, assemblies or equipment shall be completely metallic (seating area included). Caster-equipped stools and chairs are not desirable; if used must be equipped with metallic casters.

Stools and chairs shall rest on a conductive floor surface (see 4.3.5).

4.3.7. Personnel Grounding

Personnel handling electrostatic sensitive parts, assemblies or equipment shall be grounded by an approved method through not less than 0.2 megohm nor greater than 2 megohms. Wrist

straps shall be worn in contact with the bare skin.

4.4. Facility Compliance

4.4.1. Audit

In each facility an individual shall be assigned the duty to assure compliance with the requirements of this document.

The individual assigned the responsibility for control shall survey all applications noted in Table 4-1 and shall maintain a log for items checked, indicating when the survey activities were performed.

Items which fail the acceptance criteria shall be refurbished, or removed from the static controlled areas.

4.4.2. Audit Check List

This checklist should be used as a guideline for ESD audits.

4.4.2.1. Packaging

- (1) An ESD warning label shall be affixed to the outside of the intermediate or final shipping container for flight or critical gse electronics.
- (2) If filler or packing material (the material surrounding the unit containers) is used, it shall be treated for antistatic properties.
- (3) Tubes, boxes, or conductive bags shall be labeled with a static precaution sticker or stamp.
- (4)

Static sensitive devices shall be packaged in conductive material.

TABLE 4-1: Applicability of Requirements to Specific Facilities

Subject	Recv. Insp.	Assembly Area, PCW	Test Area, PCW	Test Area, System
Fixed Structure				
Grounding	1	1	1	1
Grounding Bars	1	1	1	1
Access Doors	2	2	2	2
Personnel				
Grounding	1	1	1	1
Stools/Chairs	2	2	2	2
Soldering Iron Tips	1	1	1	1
Antistatic Covering				
on Furniture	2	2	2	2
Conductive				
Floors/Mats	1	1	1	1
Air Ionizers	2	2	2	2
Humidifiers	2	1	2	2
Clothing	1	1	1	1
Operations	1	1	1	1
1. Mandatory Compliance				
2. Optional Compliance				

4.4.2.2. Work Area

- (1) Is there a static safe work station, where static sensitive devices can be unpacked and handled?
- (2) Is the static safe work station identified by a sign or poster?
- (3) Is there a conductive surface on the work station?
- (4) Is the conductive surface grounded via a one megohm resistor?
- (5) Is the work surface grounded through less than 2 megohms?
- (6) If conductive floor mats are not used, is the floor conductive or treated with a topical antistat?
- (7) If topical antistats are used, are they noncorrosive and bio-degradable?
- (8) Are trays or tote boxes treated with an antistat or made from conductive material?
- (9) Are conductive or antistatic bags checked periodically with a field meter for conformity?
- (10) Is the relative humidity between 40 and 60 percent?
- (11) If the relative humidity is not controlled, are air ionizers in use?
- (12) Are air ionizers cleaned or otherwise certified on a regular basis?
- (13) Are all metal storage rack or shelves grounded?
- (14) Are all metal storage cabinets grounded?
- (15) Are carts (used to transport the devices) conductive, and grounded prior to insertion or extraction of devices?
- (16) Are all ground connections protected by a one megohm resistor?
- (17) Is system or neutral ground (less than one ohm to true earth ground) available in all areas?

4.4.2.3. Personnel

- (1) Are wrist straps utilized at the work station?
- (2) Is wrist strap resistance between 200k ohms and 2 megohms?
- (3) Are the wrist straps checked periodically for resistance and open circuits?
- (4) Are all resistors and ground cords periodically checked?
- (5) Are smocks or other protective clothing periodically cleaned and treated if required?
- (6) Do all personnel ground themselves prior to handling static sensitive devices?
- (7) Is personnel certified in ESD practices?

4.4.2.4. Safety & Caution

Workers should never be connected directly to "hard" ground.

4.4.3. Static Detecting Meter

Audits, surveys and detection of static charges shall be performed without contacting the charged area using the 3M static meter type 703, or equivalent.

4.4.4. Control Methods

In most activities, facility compliance can be determined by a visual inspection or ohmmeter measurement. To verify the adequacy of anti-static treatments, it will be necessary to use a static meter periodically. Each facility covered by this document shall utilize an approved static meter for use as required.

4.4.5. Personnel Training

4.4.5.1. General

All personnel working regularly in the affected areas shall be trained in all necessary procedures. Personnel working only occasionally shall be briefed on procedures and monitored to assure that they comply with the applicable rules.

4.4.6. Facility Maintenance

Facility and work stations recommended maintenance procedures are as noted below.

4.4.6.1. Daily

- (1) Perform a visual inspection of ground wires and terminals integrity at bench top, floor mat, wrist straps and and other items connected to the electrostatic ground bus.
- (2) Verify ambient relative humidity.

4.4.6.2. Weekly

- (1) Clean bench top with a soft, lint free, approved wiper, see 5.2.
- (2) Using an ohmmeter verify grounding of soldering iron tip, and isolation from power circuit.
- (3) Vacuum floor area at and in proximity to the work station.
- (4) Using an ohmmeter verify series resistance to the electrostatic ground bus.
- (5) Damp mop conductive floor area to remove any accumulated dirt or dust which causes high resistivity.

4.4.6.3. Annually

- (1) Replace/service nuclear elements of equipment so equipped.
- (2) Review ESD protection procedures and equipment for updating and adequacy.

- (3) Review type and usage of conductive foams, conductive bags and packaging for adequacy.

5. OPERATIONS .

5.1. Handling

5.1.1. Packing, Unpacking and Carrying Operations

During packing, unpacking and carrying, the attendant operation (such as separation of materials, walking across the floor, etc.) increases the likelihood of static charge generation. Suitable precautions shall be arranged to minimize the likelihood of damage.

5.1.2. Transport Between Facilities

The parts shall be placed in its transport case (made of antistatic materials or antistatic treated) when being transported between facilities. When any ESD vulnerable hardware is boxed for shipment, no charge generating material should be contained anywhere within the confines of the outer container. Otherwise, the shipping procedures should be the same as for any other sensitive electronic devices.

5.1.3. Part Containers

Part containers such as plastic drawers, plastic envelopes, or boxes including shipping containers, shall either be treated to inhibit static charging, or have antistatic properties.

5.1.4. Assembly Sequence

Electronics assembly shall be planned to allow for installation of static sensitive parts, following installation of all other parts. Assembly personnel shall be required to wear an approved smock (see 5.11) and finger cots or gloves when installing static sensitive parts.

5.1.5. In Process Storage or Long Term Storage of Assemblies

- (1) Electrostatic-sensitive parts shall be stored in an enclosure of MIL-B-81705 barrier material or the electrostatic protection equivalent and/or with the leads shunted.
- (2) Assemblies to be stored that have circuitry and parts not isolated from direct contact

shall be enclosed in MIL-B-81705 barrier material, or the equivalent electrostatic protection.

(3) Assemblies which have circuitry, except connectors, and parts which are isolated from direct contact, shall be stored with static discharge connector caps installed on connectors.

5.2. Hardware Peripherals

Miscellaneous hardware peripherals, such as transport cases, dust covers, etc. are considered under the control of this document. When used in support of electrostatic-susceptible hardware, they should be made of antistatic material or be antistatic treated. Static generating material, if used inside packing cases, must be encapsulated with an antistatic material or treatment.

5.3. Hardware Grounding Reference

For operations requiring isolation, the hardware chassis shall be grounded by a wire connection or by conductive contact through a resistance less than 2 megohms, and be handled by properly grounded personnel.

5.4. Operator Grounding Reference

Any one who handles the hardware directly or attaches test equipment to the hardware (breakout boxes, oscilloscope, probes, etc.) shall be connected to ground by a resistance less than 2 megohms, and preferably greater than 200 k ohms, through one of the approved methods of Table 5-1. Conductive shoes to a metal floor may provide as low as 50 k ohms from an operator's hand to the shoe sole; in such a case, the conductive floor should have resistance to provide a minimum of 200 k ohms to ground.

5.5. Personal Clothing

Most clothing contains types of synthetics (nylon, dacron and others) or natural fibers (silk and wool) which can generate static charges. Overcoats with ASQ100 material will be provided by the test facility. These are made by Angelica and are NASA approved. It is recommended that short sleeves be worn so clothing will not hang out under the overcoats.

TABLE 5-1: Approved Methods of Operator Ground Referencing

Method	Verification Frequency	Acceptance Criteria
Wrist strap to ground	daily in use	0.2 to 2 megohms
Conductive shoes to grounded floor	weekly in use	0.2 to 2 megohms

Note:

If a wrist strap has an erratic grounding, it may be due to a broken or loose connection. When detected, all work at that station shall terminate until the problem is corrected.

5.6. Miscellaneous Plastic or Dielectric Items

All plastic bags and folders (envelopes, original parts bags, cable bags, etc.) are prohibited within controlled areas unless they are made of an approved antistatic material.

5.7. Plastics and Tapes

Instrument leads with plastic parts, such as oscilloscope leads, are assumed to be grounded by the operator who is using them and who is grounded. Approved tape is dielectric and can generate static charges when unrolled or when removed. Do not use such tape unless necessary, and if used, care shall be taken to ensure that the pulling off of tapes will not impart an electrostatic discharge to static sensitive components or equipment; for example, unwind the tape slowly in front of an air ionizer. Tools required to accomplish the operation specified shall be metallic or have wood handles; plastic covered tools shall not be used except for insulated tips tweezers.

5.8. Charge Requirements

Plastic materials in which the electrostatic charging properties may be in question shall be checked by a suitable static meter. Materials showing an electrostatic charge shall be treated or rejected.

5.9. Cleaning

5.9.1. Rags & Solvents

Foam "lint free" rags shall be used for cleaning only with an approved solvent.

Approved Cleaning Solvents for Static Sensitive Subsystems are listed in Table 5-2.

TABLE 5-2: Approved Cleaning Solvents for Static Sensitive Subsystems

Cleaning Agent	Purpose
Isopropyl Alcohol (IPA)	For general hardware cleaning, except instruments sensitive to IPA vapors.
Ethyl Alcohol	For electrical connectors. Protect instruments sensitive to ethyl alcohol vapors.
Methyl Alcohol	For certain instruments which are sensitive to IPA and ethyl alcohol vapors.

Use of pressurized air or gases is prohibited on static susceptible subsystems except for established connector cleaning nozzles. Spray cleaning with solvents or dry materials is prohibited. Cleaning by wiping with approved solvents is permitted. Use of aerosol Freon spray solvents or coolants is prohibited.

Vacuum cleaning operations are permitted only with solid nozzles or by 1/4 or 1/2-inch synthetic brushes with stainless steel handles by a properly grounded operator.

It is anticipated that cleaning activities will be at a minimum in those environments covered by this document.

5.9.2. Air or Gas Driven Tools

Air or gas driven tools such as screwdrivers, wrenches, abrasive blasting or cleaning, or any operation which subject static sensitive components of equipment to rapid air flow are prohibited.

5.9.3. Rubbing or Sanding Surfaces

Rubbing or sanding of PC boards, terminal boards, or other surfaces containing static sensitive components is prohibited.

5.10. Electrical Connections to the Hardware

All items being connected to the hardware shall be electrically connected to Earth through, at most, 2 megohms. Prior to mating, connector shells will be touched without connecting any pins. Examples include, but are not limited to the following:

- (1) Oscilloscopes and other instrument chassis shall be grounded.
- (2) Battery powered floating instruments shall first have their ground reference connected to chassis ground to drain off any charge before attaching to subsystem circuitry.

5.11. Facility-Supplied Overclothes

The facility shall provide approved antistatic overclothing or clothing for use in circumstances where static protection is required. Table 5-3 lists such approved clothing or overclothes.

TABLE 5-3: Approved Antistatic Overclothes & Gloves

Material	Verification Frequency	Acceptance Criteria
Angelica ASQ-100 or Vidaro equivalent of	Every 25th laundering	No charge measurable when rubbed with beta cloth when garment is on the body of a wrist strapped person
Treated TYVEC spun bonded polyolefin (new only) [laundering destroys non-charge generating capability]	Spot checks only	Less than 1 kV on static meter 10 sec after rubbing with beta cloth

5.12. Handling Instructions .

The following general guidelines are applicable to the handling of static sensitive devices.

- (1) Operations which require human handling should be minimized.
- (2) Personnel maintaining electrostatic discharge sensitive equipment, where ground straps cannot be used, should ground themselves prior to removing sensitive items from protective packaging.
- (3) Tools and test equipment used in protected areas should be properly grounded if possible. Hand tools should not utilize insulation on the handles. If plastic handled tools must be used, they should be wrapped in metal, foil or tape.
- (4) Assure that all containers, tools, test equipment and fixtures used in protected areas are grounded before and during use either directly or by contact with a grounded surface. Grounding of electrical equipment should be via a grounded plug, not through the conductive surface of the grounded work station.
- (5) Work instructions, test procedures, drawings and similar documents used in a protected area should not be covered in common plastic sheeting or containers.
- (6) Workers clothing should never make contact with the devices, and workers should avoid friction-producing activities in the vicinity of the work station - including putting on and taking off of smocks, wiping feet, rubbing of hands, etc.
- (7) Workers should avoid touching device leads or contacts and should handle parts only by the case.
- (8) When devices are removed from their protection, they should be kept either.
 - a. Pin-down on a conductive surface; or
 - b. In a conductive container with pins in contact with the surface.
- (9) Periodic continuity and resistivity measurements should be performed. The tests should include:
 - a. Worker ground straps
 - b. Work surfaces
 - c. Other ground connections

5.13. Prohibited Materials

Prohibited materials in controlled areas or facilities are as noted below, but not limited to:

- (1) Polystyrene, including styrofoam
- (2) Polyethylene
- (3) Bubblepack and similar plastic packing materials (unless specifically identified as static conductive)
- (4) Freon TF
- (5) Cellophane and masking tapes

5.14. Static Discharge

Any evidence of an electrostatic discharge occurring in controlled areas or facilities, observed by any personnel there, shall be reported immediately to the area responsible individual. All operations in the area or facility shall cease until the cause is determined and corrected.

5.15. Quality Assurance Provisions

Auditing for ESD compliance will be done as a part of the regularly performed review procedures.

5.15.1. Equipment

Equipment used in the inspection, assembly and test of electrostatic-sensitive parts, assemblies and equipment shall be periodically verified for triboelectricity control configuration.

5.15.2. Electrostatic Protection

The electrostatic charge protection packaging and identification shall be verified for flight parts, assemblies and equipment.

5.15.3. Assembly Process

Examination of assembly operations of electrostatic-sensitive items shall be performed to ensure conformance to the requirements of this procedure.