JET PROPULSION LABORATORY
CALIFORNIA INSTITUTE OF TECHNOLOGY

A TRAINING AND CERTIFICATION COURSE IN

Electrostatic Discharge (ESD) Control

PRESENTED BY THE

NASA/JPL WESTERN REGION
TRAINING CENTER

January, 2006

JPL Quality Assurance Training Program

Student Guide
for
Certification in
Electrostatic Discharge (ESD) Control

January, 2006

in accordance with
JPL D - 1348 Rev. F

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Theory

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INTRODUCTION

- This class presents:
  - a tutorial on how electrostatic charge is generated and how electrostatic discharge is controlled.
  - specific requirements used at JPL to control ESD. The course is designed to do more than inform: it is designed to create a specific behavior.
- This class is intended for anyone who enters an ESD protected work area, including:
  - assemblers
  - technicians
  - inspectors
  - engineers
  - scientists
  - managers

INTRODUCTION

- This course is based on the requirements of JPL standards D -1348 Rev. F, the JPL Standard for Electrostatic Discharge (ESD) Control.
- Suggestions, comments or questions pertaining to the material presented should be directed to:

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m/s 83-204

INTRODUCTION

- An open notes, 50 question test is given at the end of this presentation.
  - A minimum score of 90% (45 of 50 correct) is needed to receive ESD Control Certification.
- ESD Control Certification is valid for one year. Recertification is available by attending the JCI class.

INTRODUCTION

- Lack of ESD control can result in electronic parts being “zapped” leading to:
  - failed parts.
  - intermittent failures, reduced performance.
  - increased costs to locate and replace the failed parts.
  - decreased reliability.
  - missed schedules.
  - unhappy customers (public, NASA HQ, Congress).
- Repair of a failed electronic part on a spacecraft launched into deep space is IMPOSSIBLE

INTRODUCTION

If not controlled, ESD can ruin electronic devices.

Before ESD

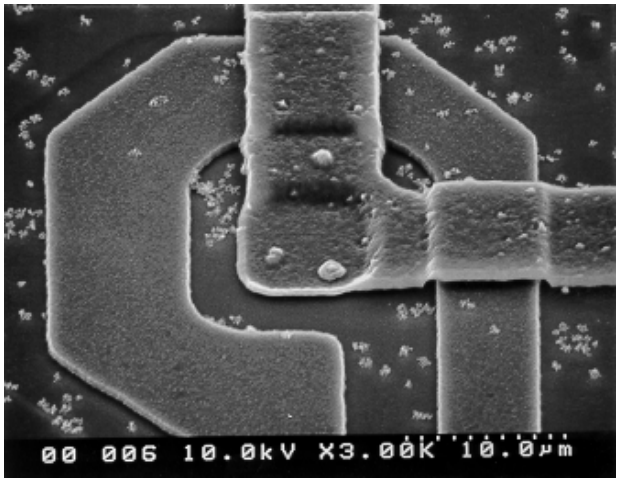


Figure 1: Scanning Electron Microscope (SEM) micrograph showing magnified (3000X) metal traces within a TCC-244 1K SRAM made by Sandia used in the Galileo AACS. (Source: Office 514 Failure Analysis Group)

After ESD

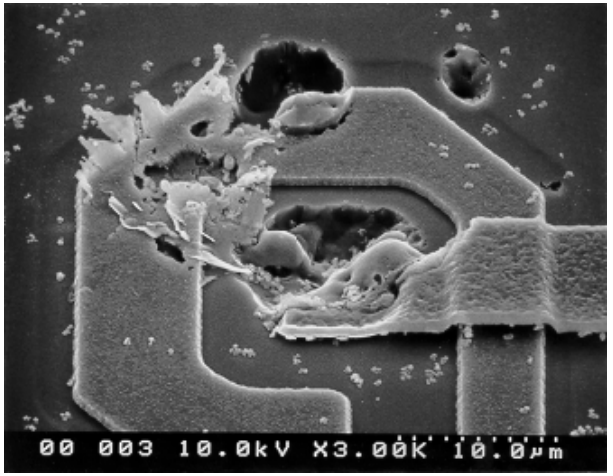


Figure 2: SEM micrograph showing damaged metal traces after the chip was purposely "zapped" from a human body model ESD simulator 3 times at 8000Volts. (Source: Office 514 Failure Analysis Group)

INTRODUCTION

- $40 billion (Est.) per year losses. (Halpern Associates, 1998).
- Approximately 30% of the failed electronic parts at JPL (91-92) were attributed to ESD (source: Section 514 Failure Analysis Reports).
- Due to semiconductor advances, electronic parts are becoming:
  - smaller,
  - operate faster,
  - perform more functions,
  - and use less power,
  - as a result, are becoming more sensitive to ESD.

THE ESD PROBLEM WILL NEVER GO AWAY !!

CLASS OUTLINE

Introduction

Theory

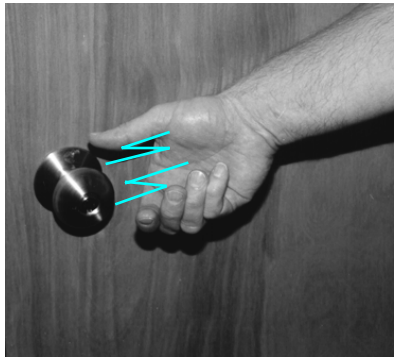
JPL ESD Control Program

THEORY

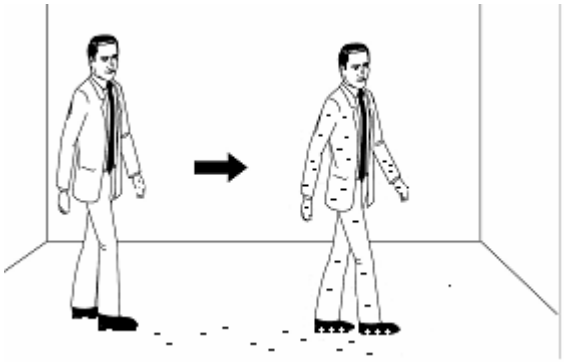
- What is ESD ?

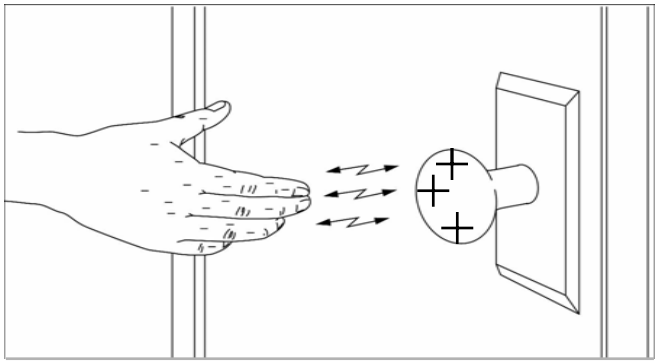
  An electrostatic discharge (ESD) is the sudden transfer of static charge between bodies at different charge potentials caused by near contact or induced by an electric field.

- *People* are the most common source of ESD.
- Human bodies will charge. On a dry day, the “zap” we sometimes feel is ESD. A one centimeter spark is produced by a 25,000 volts difference in potential!



THEORY



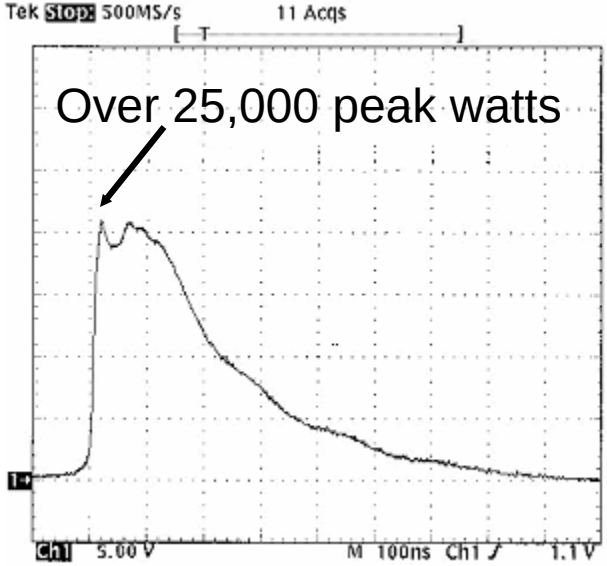


The human body and ESD:

- As a person walks, the repeated contact and separation between the bottom of their shoes and the floor generates charged surfaces.
- The charge on the bottom of the shoe induces the opposite charge on the person's body.
- As the hand approaches the doorknob, it induces the opposite charge on the doorknob.
- An ESD event or "zap" occurs when the person gets near the door knob, which is at a different potential.

THEORY

Human-generated ESD can be powerful!



Actual ESD measured from a person initially charged to about +6000 volts. The discharge was measured when the charged person touched the tip of a grounded wire. A current probe attached to an oscilloscope was placed around the wire and was used to make the measurement. The peak current is approximately 4.2 amps, resulting in a peak power of over 25,000 Watts. The Y-axis scale is 1 amp per division, the X-axis scale is 100 nsec per division.

THEORY

Other static electricity-related phenomena include:

- clothes that have “static-cling”.
- the “zap” you feel after sliding across your car seat.
- static in your hair after brushing with a plastic comb.
- plastic Saran© wrap that “sticks” together.
- ignition of anesthetic gases in hospital operating rooms.
- dust particles that “stick” to TVs, computer monitors and oscilloscopes.
- applying toner to paper in laser printers and copy machines.
- air filtration systems
- natures version - lightning.

THEORY

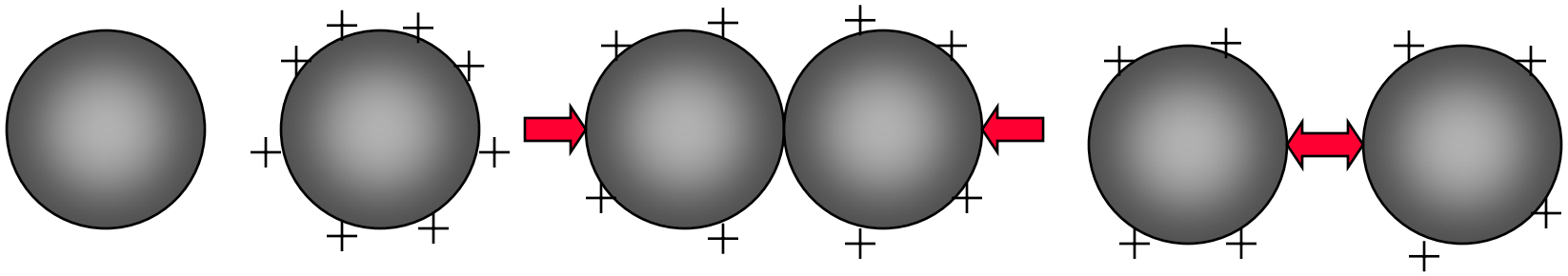
- People start to feel ESD from their finger tips starting at about 3000 Volts:
  - Some electronic parts can be damaged by 300V or lower, meaning that a person could “zap” a part without knowing.
- This is one reason why people sometimes think that ESD is NOT a threat to electronic parts
  - “If I can’t see or feel ESD, then it can’t be there”. **Not true !**
  - ESD events don’t always produce noticeable “sparks”.

THEORY

Objects become charged by three mechanisms:

1) Contact with another charged object
2) Triboelectric charging
3) Induction charging

1) Contact with another charged object:



a. b. c.

THEORY

2) Triboelectric Charging:

- "Tribo" is derived from Greek tribein meaning "to rub".
- Charge is generated after contact between dissimilar materials. Rubbing increases area that is contacted, therefore more charge is developed.
- During separation, some materials allow removal of surface electrons easier than others.
  - a material that has lost some electrons will be positively charged.
  - a material that has gained some electrons will be negatively charged

THEORY

Electronegativities of some elements

H 2.1																	He
Li 1.0	Be 1.5											B 2.0	C 2.5	N 3.0	O 3.5	F 4.0	Ne
Na 0.9	Mg 1.2											Al 1.5	Si 1.8	P 2.1	S 2.5	Cl 3.0	Ar
K 0.8	Ca 1.0	Sc 1.3	Ti 1.5	V 1.6						Cu 1.9	Zn 1.6	Ga 1.6	Ge 1.8	As 2.0	Se 2.4	Br 2.8	Kr

Increasing

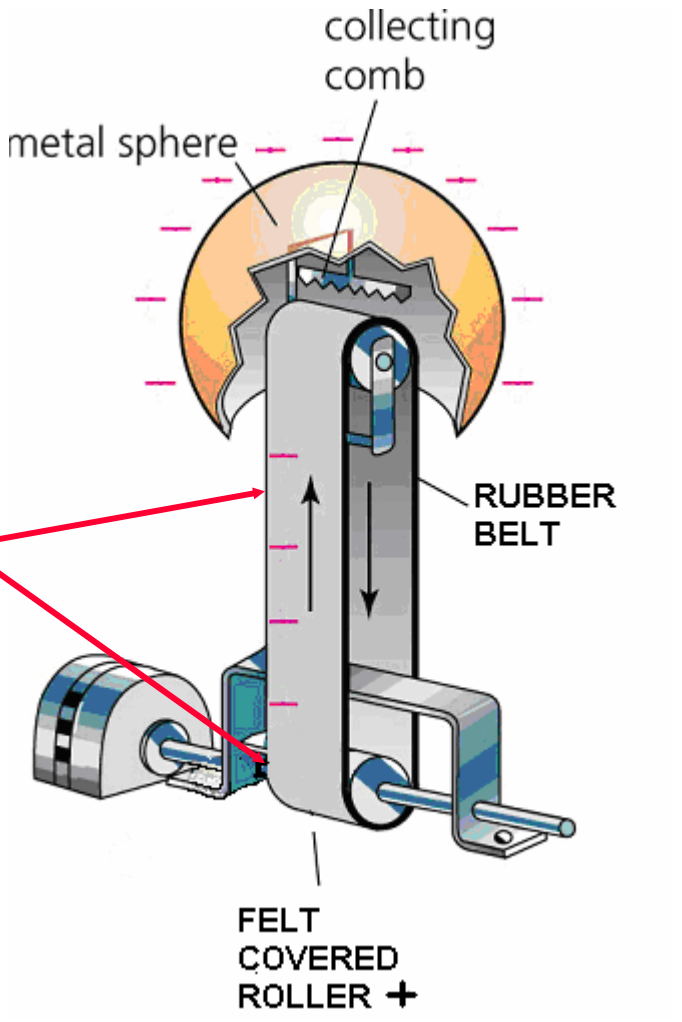
THEORY

Sample Triboelectric Series

Positive Charge

Human Hands
Plexiglas
Human Hair
Nylon
Wool(felt)
Lead
Silk
Aluminum
Paper
Cotton
Steel
Wood
Hard Rubber
Nickel, Copper
Brass, Silver
Gold, Platinum
Rayon
Polyester
Celluloid
Polyurethane
PVC (vinyl)
Silicon
Teflon

Negative Charge



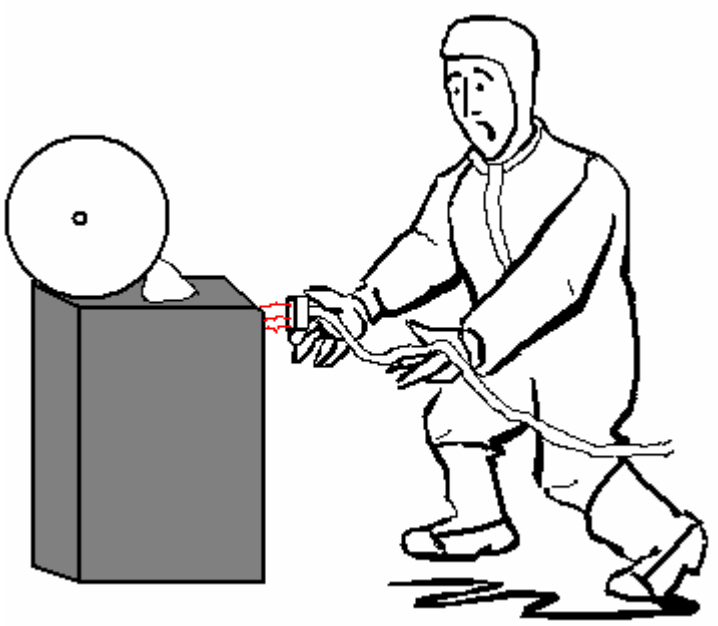
THEORY

Sample Triboelectric Series – CABLE HANDLING

Positive Charge

Human Hands
Plexiglas
Human Hair
Nylon
Wool(felt)
Lead
Silk
Aluminum
Paper
Cotton
Steel
Wood
Hard Rubber
Nickel, Copper
Brass, Silver
Gold, Platinum
Rayon
Polyester
Celluloid
Polyurethane
PVC (vinyl)
Silicon
Teflon

Negative Charge



THEORY

- The *amount of charge* created during triboelectric charging depends upon:
  - contact pressure
  - speed of separation
  - surface contaminants
  - humidity levels
  - relative position in triboelectric series

THEORY

Typical Electrostatic Voltages in Unsuppressed Environments

	Relative Humidity Level	
Means of Static Generation	10%	55%
Person walking across carpet	35,000	7,500
Person walking across vinyl floor	12,000	3,000
Worker movement at bench	6,000	400
Chips sliding in plastic tube	2,000	400

THEORY

3) Induction Charging:

- Charged objects can charge other conductors that are nearby within the same voltage field.
- No physical contact with the charged object is necessary.
- Four possibilities exist for current flow:
  - Current flows in the conductor when it is moved into the field.
  - Current flows in the conductor when it is moved out of the field.
  - Current flows in a conductor if it is connected to a sink for or a source of electrons while within the field.
  - Current will flow if a conductor has stored charge while in the field and is subsequently grounded.
- This gives 4 chances to cause a potentially damaging ESD.

THEORY

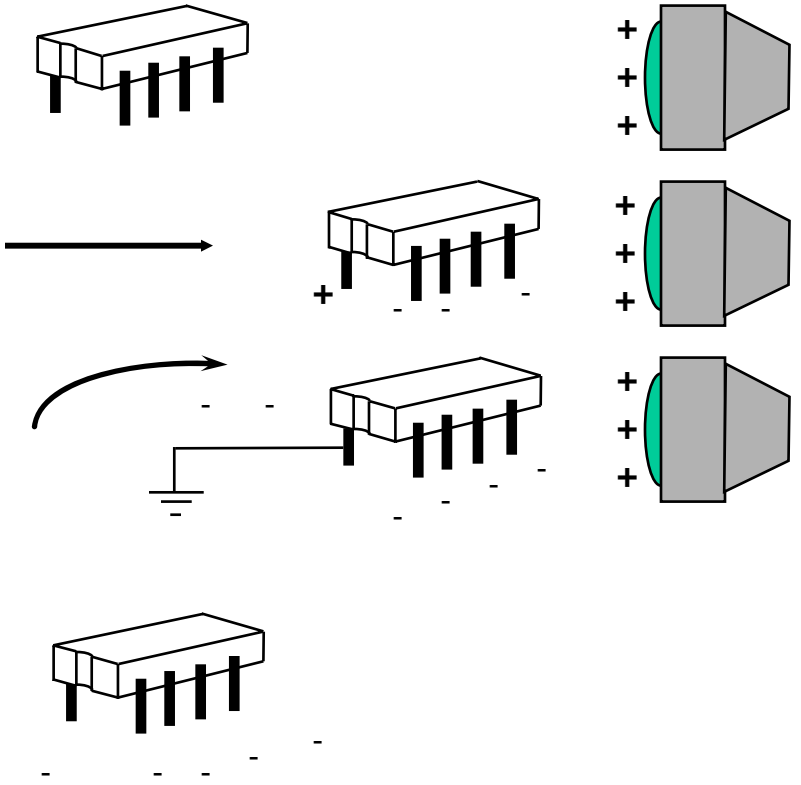
Example of Inductive Charging

1. Neutral Chip

2. Polarized Chip

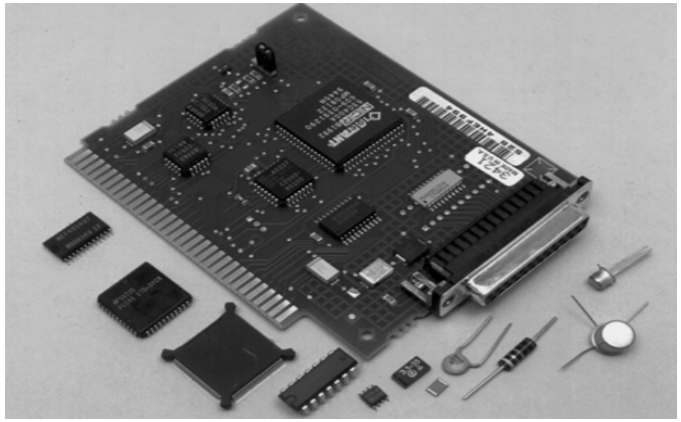
3. Add ground or a person - charges neutralize

4. Field removed, negatively charged chip could now suffer ESD damage.

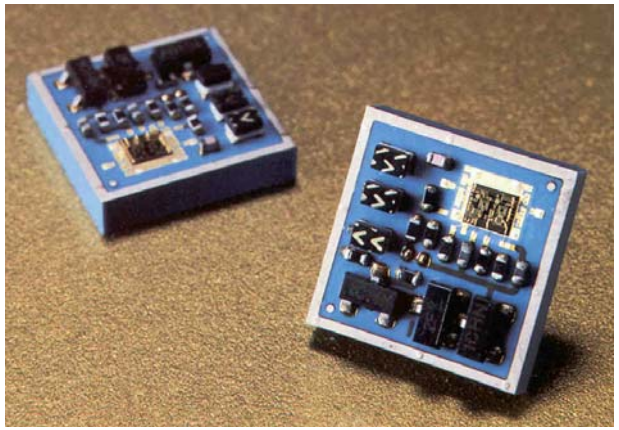


THEORY

Examples of electronic devices that are ESD-sensitive:

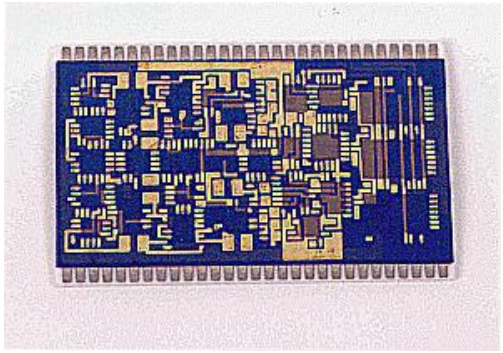


Circuit card and chips



Embedded passives

Multi-chip modules



Multi-layer substrate

THEORY

ESD sensitivity thresholds of various electronic components, V.

Device Type	ESD Sensitivity Range
V-MOS	30 - 1200
MOSFET, EPROM, GaAsFET	10 - 300
JFET	150 - 7000
OP Amp	190 - 2500
Schottky Diodes	30 - 2500
Thin Film Resistors	300 - 3000
SAW Devices	150 - 5000
Schottky TTL	1000 - 2500
CMOS	150 - 3000
256K DRAM	200 - 3000
Bipolar Transistors	300 - 7000

(Source: Venkatraraman Lakshminarayanan, ISD Magazine, 4/3/2000)

THEORY

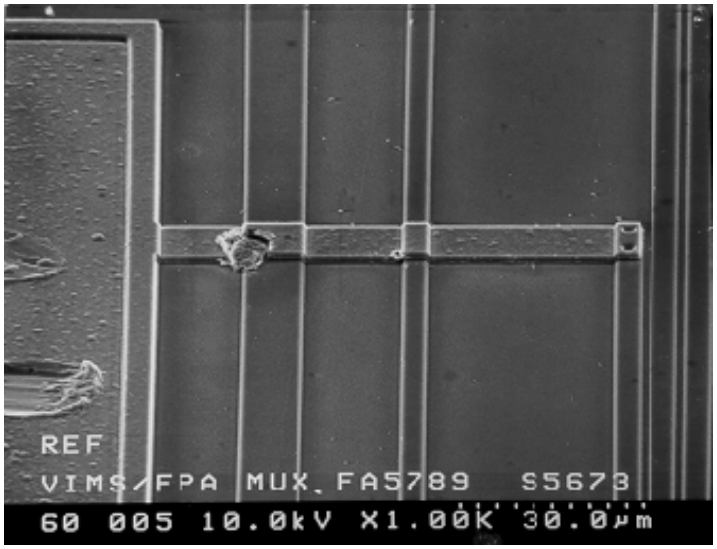
ESD Effects on Electronic Parts - *Types of failures:*

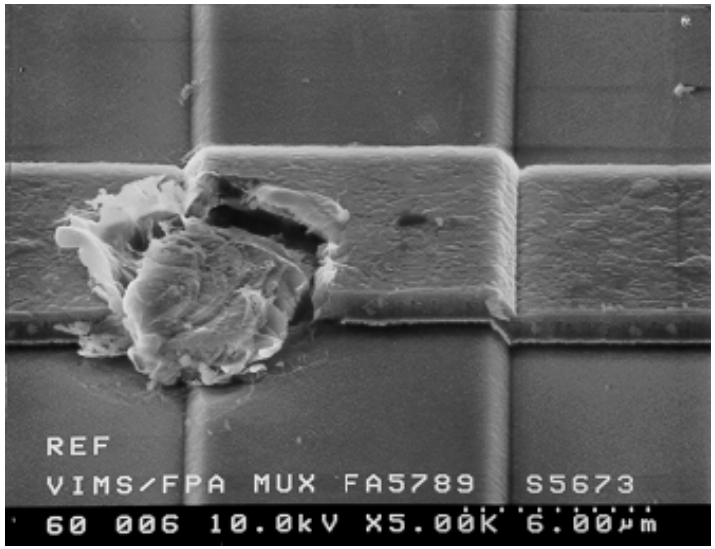
- Catastrophic Failure:
  - A part has been “zapped” to the point where it no longer works.
- Parametric Failure:
  - A part has been “zapped” causing damage. The part works, but not perfectly. Example: A flip-flop that operates correctly at low speeds, but fails at higher speeds.
- Latent failure:
  - A part has been “zapped” causing damage, but it still continues to work correctly. However, over time and use, the part eventually fails.
- Microprocessor lock-up.

THEORY

ESD Effects on Electronic Parts

Examples showing catastrophic failure

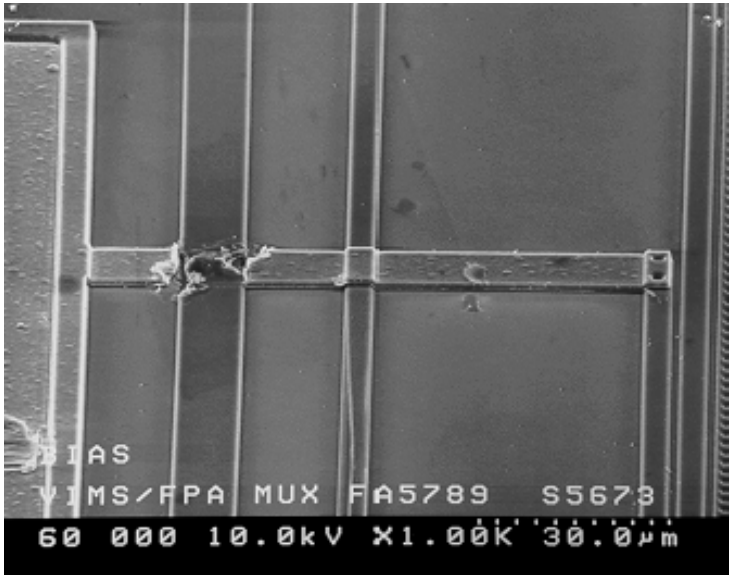


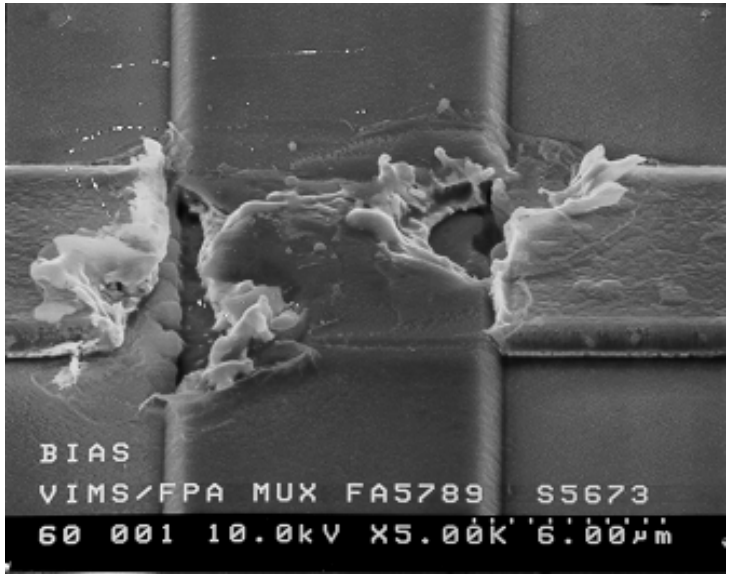


THEORY

ESD Effects on Electronic Parts

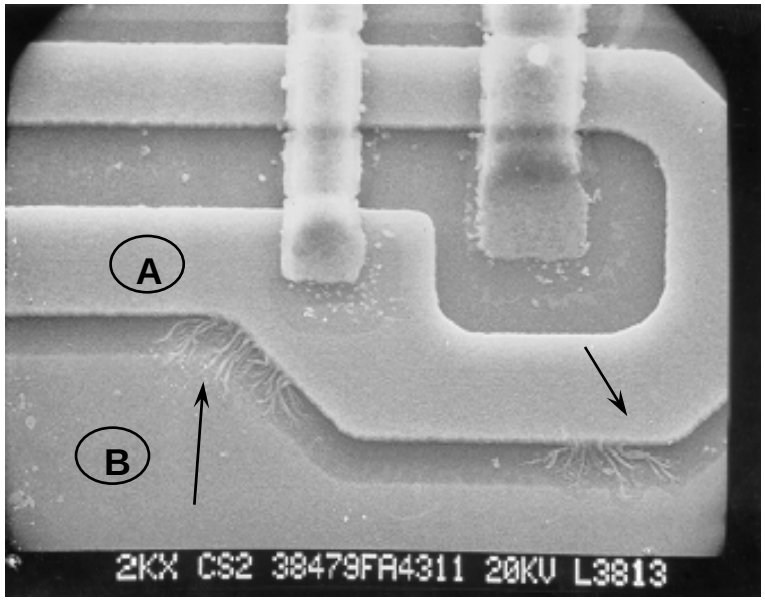
Examples showing catastrophic failure





THEORY

ESD Effects on Electronic Parts - Catastrophic failure



Sometimes ESD damage is not obvious. These small hair-like dendrites (arrows) were sufficient to short trace A to trace B, making the chip useless. The damage was caused somewhere at JPL but the exact location and source is unknown.
(Source: Office 514 Failure Analysis Group)

THEORY

ESD Protective Materials: Surface Resistivity

- Important characteristic of ESD control materials.
- Used to characterize a materials' charge dissipation capabilities.
- For ESD protection, the value shall be within a specified range:
  - if too low, current may surge through an inadvertently charged ESDS part when contacting the protection material.
  - if too high, charge may stay on the surface of the material, making it an electrostatic field generator which persists, increasing the probability of a ESD event.

THEORY

ESD Protective Materials: Surface Resistivity

Surface Resistivity (ohm/square) ranges

> 0 10^6 10^{12}

Conductive	Static-Dissipative	Insulative

- Surface resistivity is
  - the ratio of voltage to current across an infinitesimally thin surface of a material.
  - measured using special instruments and probes (not point probes used with hand-held volt-ohm or multimeters).
  - nondimensional, the size or shape of the electrodes doesn't matter.

THEORY

ESD Protective Materials: Surface resistivity measurement

Large probes
on the back.

Don't use multimeters to measure surface resistivity,...

use a surface resistivity meter.
(Quality Assurance Representatives have access to these meters)

THEORY

Conductive Materials: (> 0 (nil) - <10^6 ohms/square)

- Have large numbers of mobile electrons, charges are distributed evenly around the surface
  - metals such as nickel, aluminum, gold, silver, etc.
  - human skin
- Can shield/block voltage fields (Faraday shield)
  - gray static-shielding bag has buried metal layer.
  - black conductive tote boxes have impregnated conductive carbon particles
  - black carbon coated corrugated cardboard boxes

THEORY

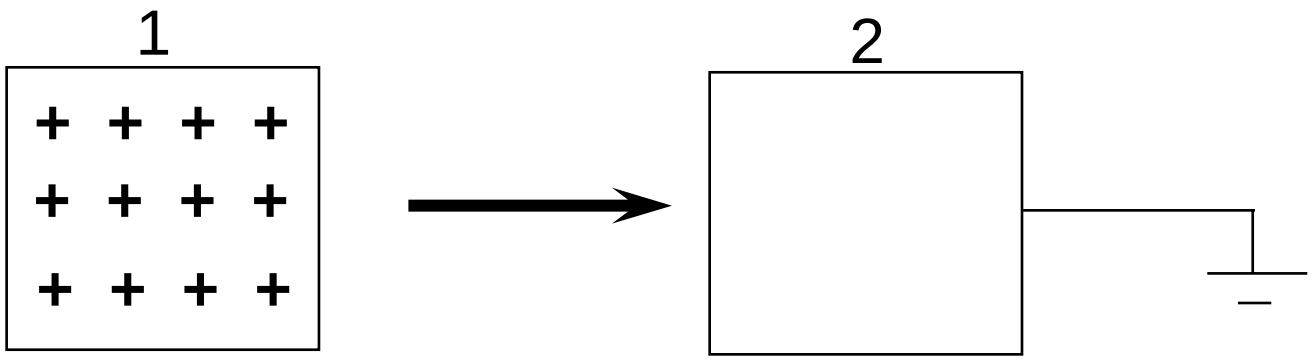
Conductive Materials: (continued)

- Will spark (remember the metal doorknob)
- Will NOT provide a safe current discharge rate after contact with an inadvertently charged electronic part.
  - This is why conductive materials shall never be allowed to directly contact ESDS parts.
- Can generate a voltage field when charged *and* isolated from ground.
- Charges on surface can be neutralized when the conductor is isolated from ground and placed within the output stream of an air ionizer.

THEORY

Conductive Materials: (continued)

- Can be grounded to neutralize charges



Charged Conductor, charge is evenly distributed.

After contact with ground, charge is neutralized.

THEORY

Static-Dissipative Materials: ($\geq 10^6$ to $\leq 10^{12}$ ohms/square)

- Safest material for direct contact with ESDS items
- Provides a safe and controlled rate of current discharge when near or in direct contact with a charged electronic part.
- Charges on surface can be drained (neutralized) with connection to ground
- Available in many forms:
  - hard laminate bench tops
  - soft table mats
  - static-shielding bags

THEORY

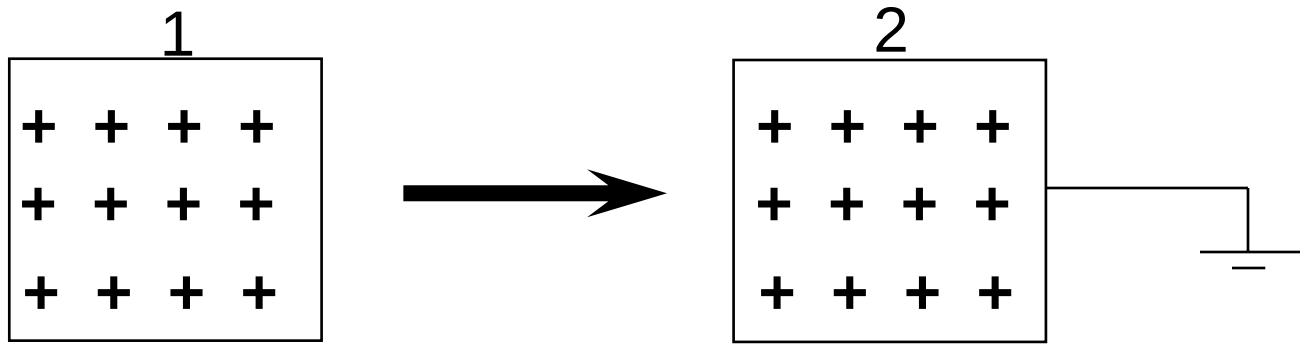
Insulative Materials: **(> 10^{12} ohms/square)**

- Insulative materials
  - don't allow current flow.
  - have relatively few mobile electrons.
  - hold charges.
  - develop hot spots.
- Insulators are generally the type of material that should be kept out of ESD protected areas.
  - ex: plastic bags, Plexiglas, Styrofoam cups, etc.

THEORY

Insulative Materials: (continued)

- When charged, generate an electrostatic voltage field.
- Cannot be neutralized by grounding.
- Can be neutralized with ionized air.



Charged Insulator, charge is unevenly distributed.

After contact with ground, charge still remains.

CLASS OUTLINE

Introduction

Theory

JPL ESD Control Program

JPL ESD CONTROL PROGRAM

Development of JPL's ESD Control Program:

- The Hierarchy of Control Documents:
  - NASA Standards – 8739.7 (abandoned)
  - ESD Association Standard S20.20 adopted in place of 8739.7
  - JPL D – 1348, "JPL Standard for ESD Control"
  - Project ESD Control Plans
  - Process Instructions

- ESD control program is the responsibility of Section 512 ESD Control Engineer.
- ESD control plans are the responsibility of each project.

JPL ESD CONTROL PROGRAM

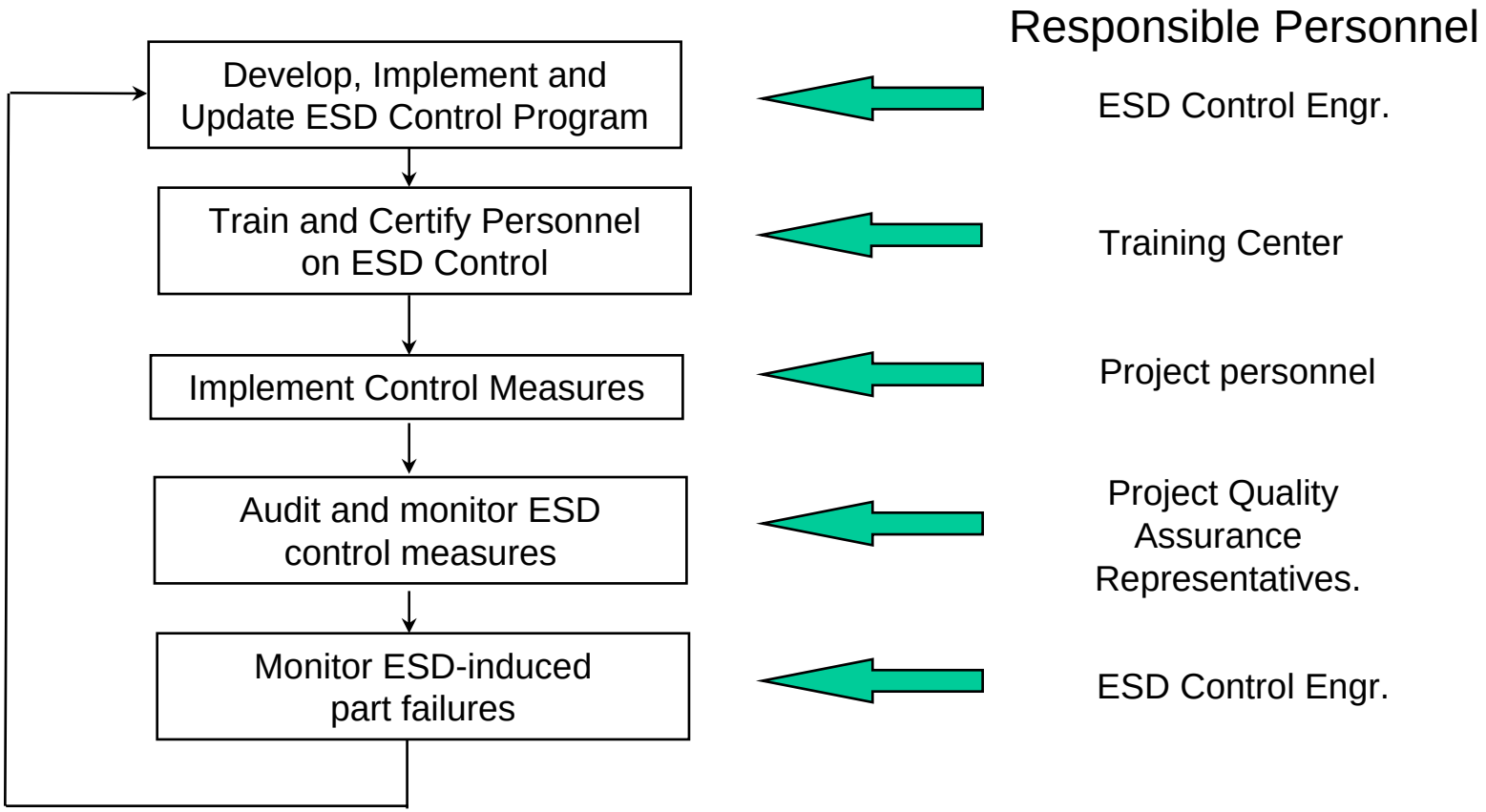
Basic components of the JPL ESD control program:

1. Plans: each project has an ESD Control plan.
2. Training: obtain ESD Control training and use it “on the job”.
3. Facilities: ESD protected areas, work stations and tools that control charge on objects and provide a way to safely discharge devices that have become inadvertently charged.
4. Personnel: provide protective garments, footwear, wrist straps, etc.
5. Packaging: Provide protection for ESD sensitive devices when outside of ESD protected work areas.
6. Materials: ESD and Contamination Control approved materials
7. Procedures: the correct way to do things.

All need ***YOU*** for success !!

JPL ESD CONTROL PROGRAM

ESD Control Program Flow Diagram



We *all* are part of the JPL ESD Control Program

JPL ESD CONTROL - TRAINING

- This training and certification is required for all personnel working around JPL Critical Items (JCIs). These are items critical to the success of a mission. ESD sensitive parts, assemblies and equipment that are JCIs include:
  - Flight Hardware
  - Ground Support Equipment (GSE)
  - Deep Space Network (DSN) equipment
  - Engineering Models
- Why do you need this training?
  - Regulations
    - JPL and NASA standards.
    - ISO 9000 Certification.
  - Quality:
    - It will help you on the job to better protect our hardware.

JPL ESD CONTROL - TRAINING

Personnel requirements:

- Facility supervisor is responsible for:
  - providing the materials, furnishings and equipment necessary for compliance with JPL D - 1348.
  - maintaining ESD controls during ESD operations.
- Cognizant engineer is responsible for ensuring that the ESD controls are appropriate for the ESDS items under their control.
- Personnel working with ESDS items are responsible for implementation of the ESD controls.

JPL ESD CONTROL - TRAINING

Personnel requirements: (continued)

- Quality Assurance Representatives are responsible for ESD Control Surveys.
- Personnel occasionally entering ESD protected areas must:
  - be authorized by the facility supervisor or cognizant engineer.
  - be briefed on ESD control procedures.
  - be monitored for ESD control compliance while within ESD protected area.

JPL ESD CONTROL – PROJECT PLANS

- Determine ESD sensitivity:
  - Test the hardware using ESD simulation models.

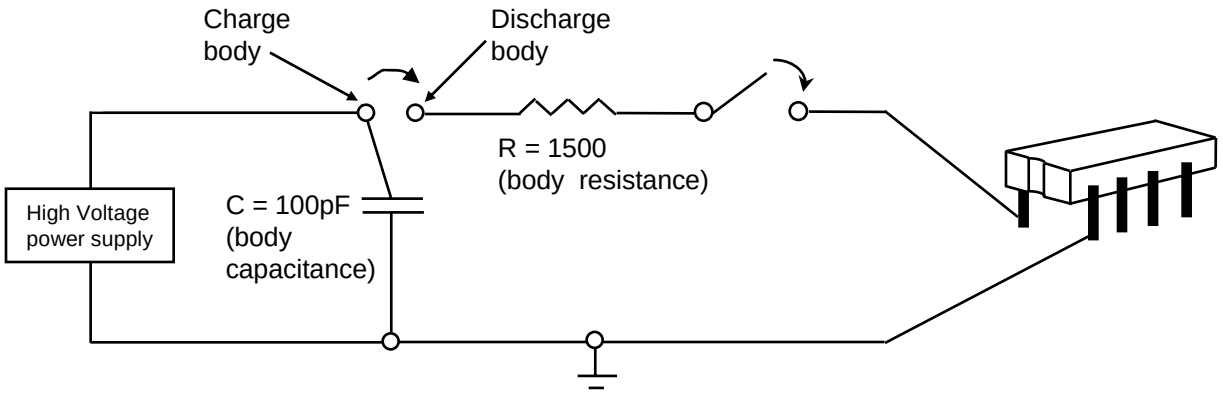
    or
  - Ask the hardware manufacturer what the ESD sensitivity is.

    or
  - By analogy with devices of similar materials and dimensions.

- Devise ESD control plan to protect the most sensitive items.
  - Select protection materials and equipment.
  - Establish procedures.
  - Audit criteria for the ESD protected work area.

JPL ESD CONTROL – PROJECT PLANS

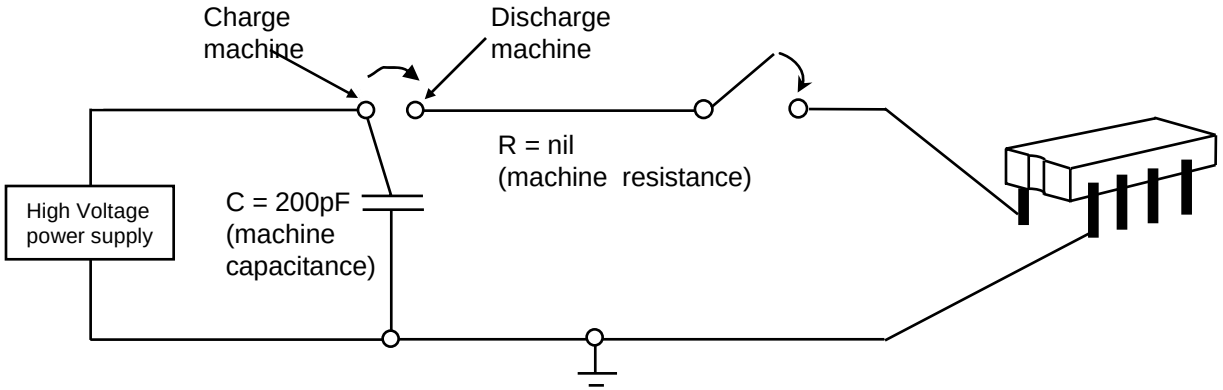
- ESD Simulation Models: all three failure models are important.
- Human Body Model (HBM)
  - oldest model, most widely used for classifying device sensitivity.
  - simulates the ESD from a person's body through their finger tip.



Human Body Model Circuit Schematic

JPL ESD CONTROL – PROJECT PLANS

- Charged Device Model (CDM)
  - simulates the effect of discharging a charged electronic device by connecting a lead to ground
- Machine Model (MM)
  - simulates the charge transferred to an electronic part by a charged conductor including automated handlers, carts, pick and place equipment, etc.



Machine Model Circuit Schematic

JPL ESD CONTROL - FACILITIES

ESD Protected Area:

- An area that incorporates techniques to reduce or eliminate ESD events and electrostatic fields
  - Physical barriers or defined one meter perimeter in all directions.
- Area designated as “ESD Protected” by wall signs or floor tape.
- Entries to ESD protected areas must be lockable.

Wall Sign

11”

8.5”

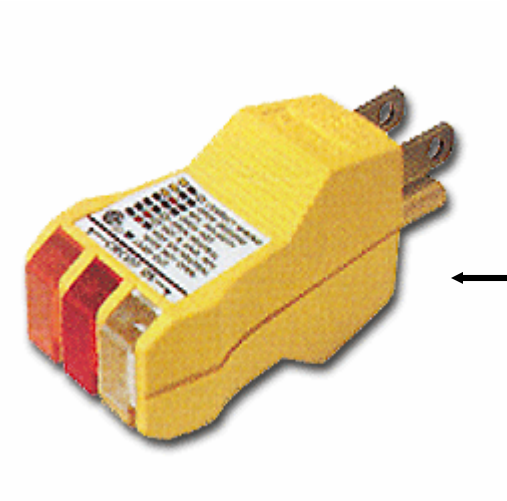
Floor-mounted tape

JPL Forms 11009

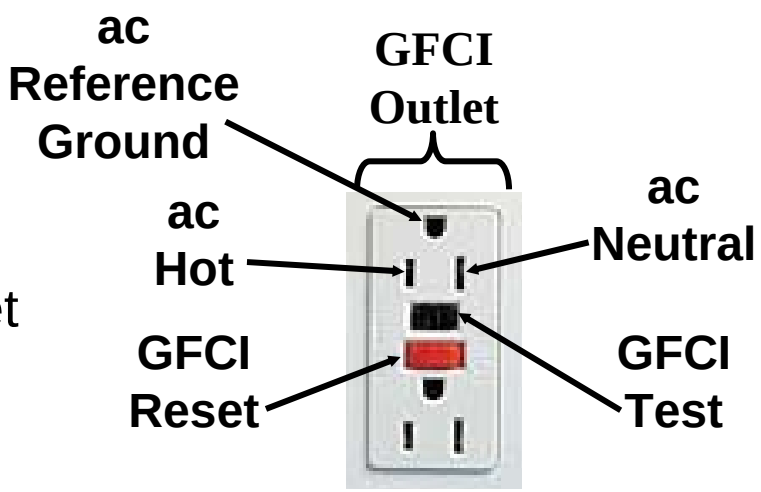
JPL ESD CONTROL - FACILITIES

Grounding:

- Physical connection of conductive and static-dissipative objects to ground to eliminate charges.
- ac reference ground is the preferred ground.
- Where safety is a concern, ground through a ground fault circuit interrupter (GFCI).



ac outlet tester



JPL ESD CONTROL - FACILITIES

Grounded Floors:

- Mandatory when the floor is needed to ground personnel.
- Available in floor mats or tile forms.
- ESD safe double-face tape available for temporary floor use.
- Must be kept reasonably clean to ensure proper grounding.
- Shall not be waxed.

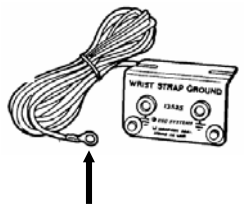
Floors are tested with a surface resistivity meter →

JPL ESD CONTROL - FACILITIES

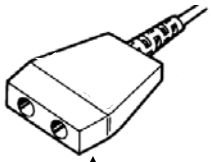
Work Station Grounding:

- The grounding system shall provide:
  - a secured wire connection from the ESD Ground at the work station to the facility ground.
  - an input socket for connection of wrist straps.

Under bench mount

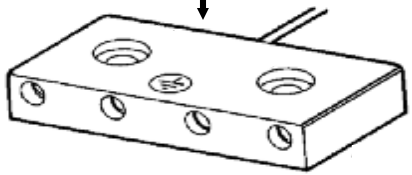


Eye lug



Snap to mat type

Multipoint ground bus



- A metal bench with a resistor to ground is **not** an acceptable ESD-safe work surface.

JPL ESD CONTROL - FACILITIES

Work Station Grounding: The resistance between the ESD ground and the facility ground shall be less than one ohm.

- Using the third wire ground at a power receptacle is preferred.
- An Earth grounding electrode may be used in place of the facility ground. When used, the resistance between the facility ground and Earth ground must be less than one ohm.
- Each workstation ESD ground must be identified using a sticker.

JPL Forms 11006-1

JPL ESD CONTROL - FACILITIES

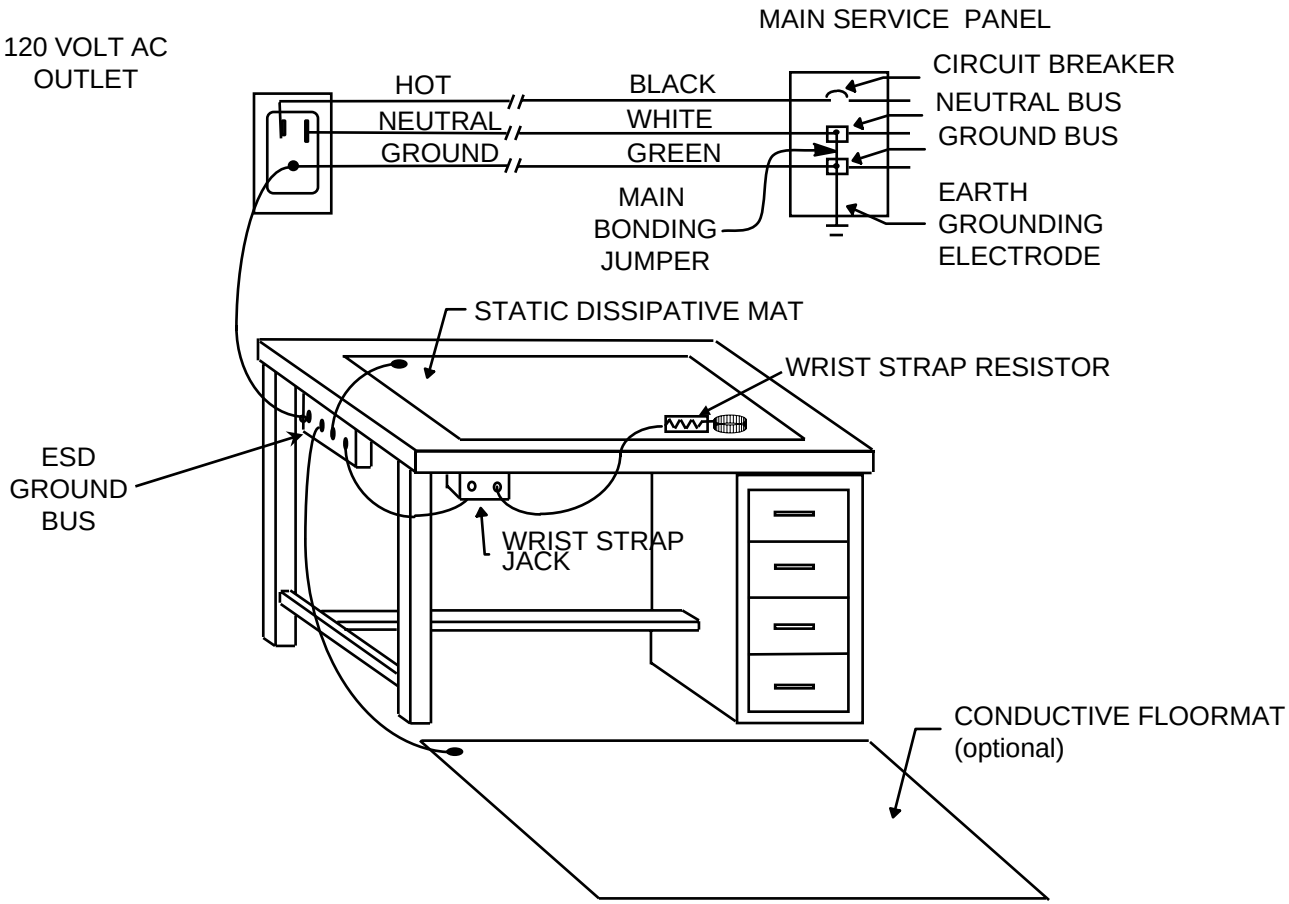


Figure 2 -1 from JPL D –1348 rev. F

JPL ESD CONTROL - FACILITIES

Work Surfaces, Tables and Benches:

- Type of work surface that contacts ESDS items is important.
- Only grounded static-dissipative surfaces shall be used:
  - ex: static-dissipative table mats.
  - ex: static-dissipative hard-laminate table tops.

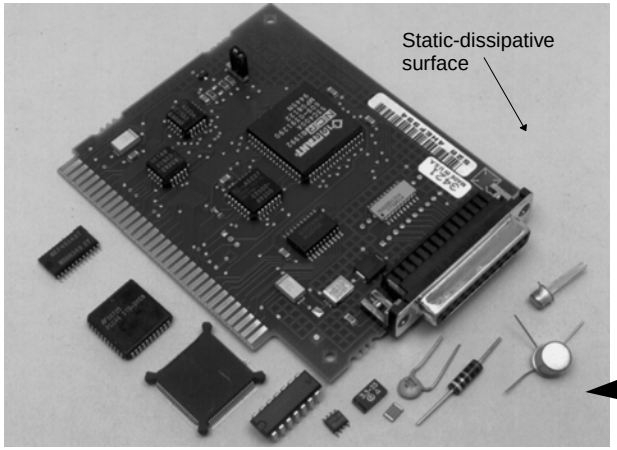


Figure 2-2 from D -1348 showing the proper surface to support unprotected ESDS items.

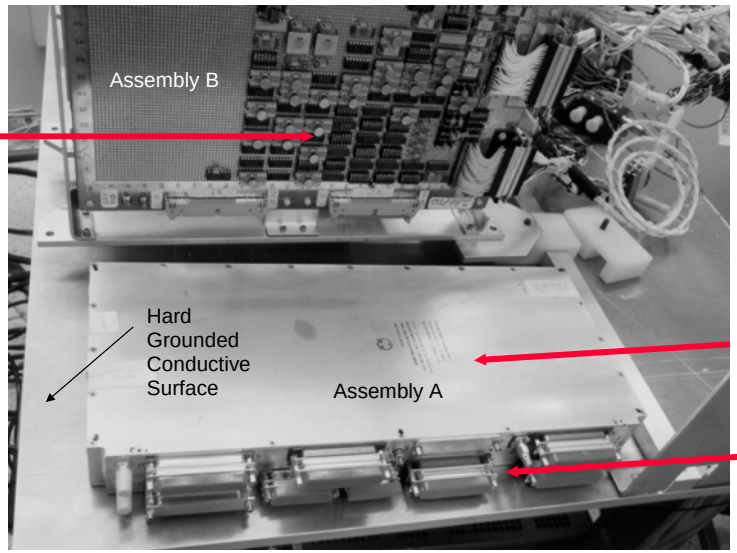
JPL ESD CONTROL - FACILITIES

<u>Work Surfaces, Tables and Benches</u>: Bare conductive bench tops shall not be allowed to contact <u>unprotected</u> ESDS items (too rapid discharge).

- Bare conductive bench tops may be used where there are <u>no unprotected ESD sensitive items</u>.

Assembly B -

Exposed ESD Sensitive parts



Assembly A - No ESD sensitive parts are exposed.

Fully closed metal box

Connectors covered

Figure 2-3 from D -1348 showing when it is acceptable to use metal work surfaces.

JPL ESD CONTROL - FACILITIES

Relative Humidity:

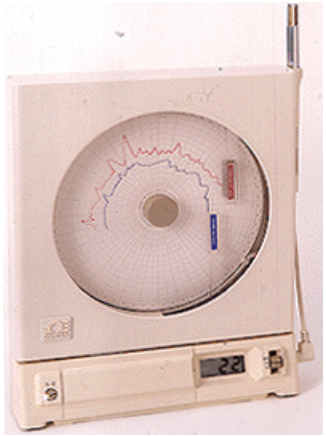
- Increased humidity makes surfaces of objects “wet”.
- Charges on wet surfaces move easier, making local charge build-up less and reducing ‘hot spots’.
- Objects tend to charge less at higher relative humidity.
- Effect on charging is obvious in Southern California during dry Santa Ana conditions.
- Excessive humidity levels can lead to moisture contamination and possible high voltage arcing within hardware or to corrosion.

JPL ESD CONTROL - FACILITIES

Relative Humidity (rh) Limits:

- Relative humidity shall be maintained above 30%.
- If relative humidity falls below 30%, work must stop.
- If work must continue below 30% rh, the use of air ionization is mandatory.
- The upper humidity limit shall be established by the project personnel.
- The humidity level shall be monitored using calibrated chart hygrometers.

"Chart" type satisfies ISO 'proof' requirement.



Item available from JPL Loan Pool

JPL ESD CONTROL - FACILITIES

Stools, Chairs and Other Furniture:

- shall not charge to more than ± 200V during normal/intended use.

Support and Test Equipment:

- shall be hard grounded using the third wire ground.

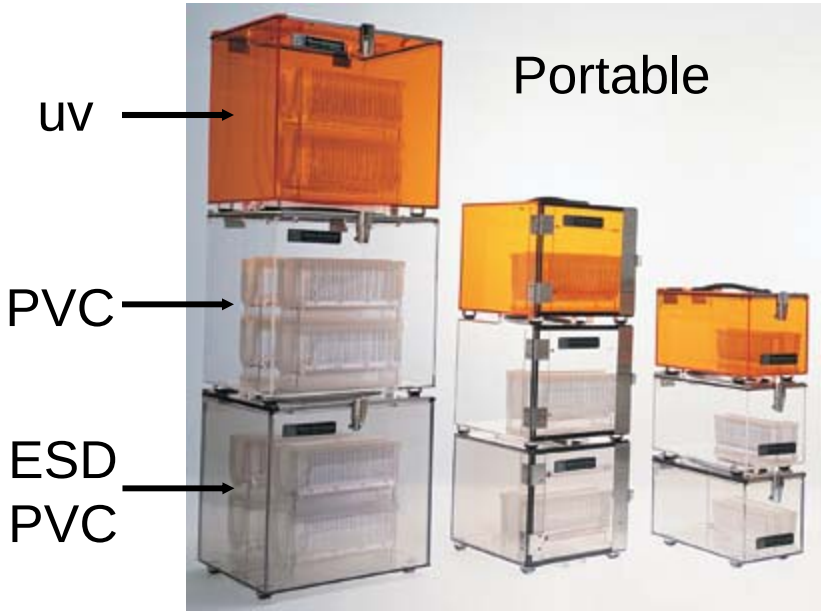
Tooling and Fixtures:

- shall be constructed of grounded conductive or static-dissipative materials.
  - Conductive tooling shall not directly contact ESDS items.
    - Exceptions: tweezers, soldering irons, wire strippers, etc.

JPL ESD CONTROL - FACILITIES

Environmental Test Chambers (cryo, cryovac, ovens, etc):

- Must be constructed of metal and be grounded. Conductive surfaces shall not contact ESDS items.
- Desiccators and dry boxes:



JPL ESD CONTROL - FACILITIES

ac Powered Tools:

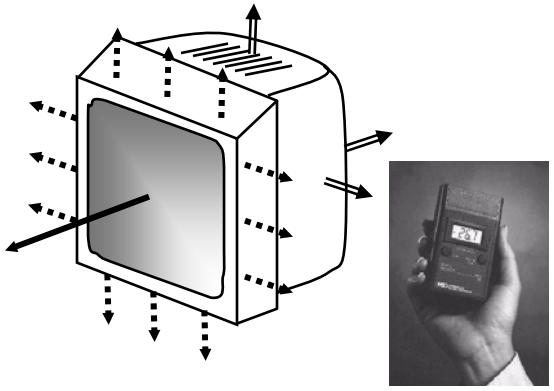
- All ac powered tools such as soldering irons, wire strippers, powered drivers, wire bonders, etc., shall be grounded.
- ac powered tools must be checked every day they are used.
- The portion of the tool that contacts any ESDS item shall:
  - have a resistance to ground of less than 20 ohms,
  - have a voltage to ground of less than 0.020 Volts ac (20 mV_{ac})
  - shall be tested under operating conditions (a hot and clean tip)
- You need proof in the form of a test log that each ac powered tool was checked each day it is used (an ISO 9000 traceable record).

JPL ESD CONTROL - FACILITIES

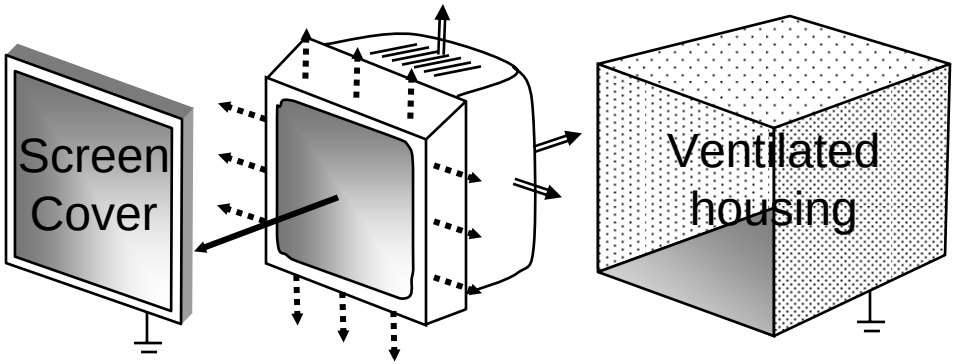
Computer Monitors, Video Displays and Oscilloscopes:

- Monitors, displays and scopes that emit more than ± 200V within one meter of unprotected ESDS items shall be neutralized. Neutralizing options include:
  - relocate the monitor to > than 1 meter from ESDS items.
  - use grounded screen covers to suppress screen field. ⟶
  - use perforated housing for target ⇢ and gun fields. ⟹

Check all areas for fields.



Provide Protection as Needed



JPL ESD CONTROL - FACILITIES

Air Ionization Systems:

- Two basic types in use: radioactive and corona discharge.
- Radioactive Ionizers:
  - The most common radioactive ionizers use the isotope polonium 210 (Po^{210}).
  - Generally found on air guns.
  - Inherently self balancing.
  - Short half-life (134 days, replace annually).
  - A generally licensed nuclear device, but don't throw them in the trash.

JPL ESD CONTROL - FACILITIES

Radioactive Air Ionization Systems:

Fan powered blowers:

Blow-off gun:

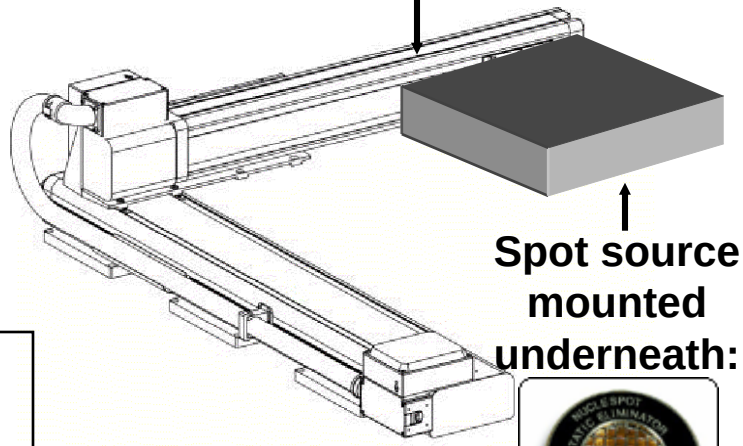
Trigger

Replaceable cartridge

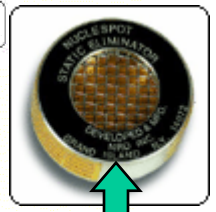
Filter

Nozzle

Restricted airflow applications



Spot source mounted underneath:



1.25 “ diameter
by 0.38 “ thick

JPL ESD CONTROL - FACILITIES

Corona Discharge Air Ionization Systems:

- Positive and negative air ions are produced when a high voltage is applied to an electrode containing a sharp point.
- Available in different sizes and shapes.

Overhead (room)

In-line

Blow-off guns

- Used in cleanrooms to reduce surface contamination rates.

JPL ESD CONTROL - FACILITIES

Corona Discharge Air Ionization Systems:

Bench top (Come in a variety of sizes)

Horizontal flow clean bench with ionizer grid

JPL ESD CONTROL - FACILITIES

Air Ionization Systems:

- Corona discharge air ionizers can sometimes cause more harm than good by charging rather than neutralizing
- This is why corona discharge ionizers must have a current calibration sticker. Minimum 6 months calibration interval.
- Electrodes may become dirty or worn over time and use
  - reduces charge efficiency causing unbalanced outputs.
- Output stream should be directed onto ESDS devices

JPL ESD CONTROL - FACILITIES

Calibrating Air Ionization Systems:

Charged Plate Monitor for Calibration

Ionizer Verifier for Surveys

JPL ESD CONTROL - FACILITIES

Waste Receptacles:

- Plastic waste containers and liners can be a source of static charge.
- Plastic waste containers and liners shall not be allowed within one meter of unprotected ESDS items.

JPL ESD CONTROL - FACILITIES

ESD Control Surveys:

- Performed by the project QA rep. using JPL Form # 2731 before ESDS items are unpacked.
- QA Rep. shall be trained and certified as an “ESD Control Auditor” (a separate class from this).
- Facility supervisor or the Cog E shall correct survey problems.

JPL ESD CONTROL - FACILITIES

ESD surveys shall be performed using an “ESD Survey Kit”

Wrist strap
footwear
tester

Surface resistivity
meter

Multimeter

Field Meter

T/r.h. meter

JPL ESD CONTROL - FACILITIES

ESD Control Certification:

- Upon successful completion of the ESD control survey process, an "*ESD Control Certification*" sticker will be issued.
- Sticker must be posted at the outermost lockable entrance lab.
- Flagrant violations or repeated failures to observe ESD control disciplines shall be considered grounds for decertification.

Each project within a common facility must have its own ESD survey

JPL Forms 11005

JPL ESD CONTROL - FACILITIES

ESD Warning Stickers:

- The following warning stickers are available for use:

JPL Forms 11010

JPL Forms 11010-1

JPL ESD CONTROL - FACILITIES

JPL Facilities Re-Survey Requirements:

- Shall be repeated when one of the following conditions occurs:
  - one year has elapsed since the last ESD survey
  - a facility has been non-operable for three months or more
  - major reconstruction has occurred in the area
  - the ESD certification for the subject area has been cancelled

Contractor Facilities:

- When required by contract, contractors are subject to the same requirements as JPL facilities.
- Section III of D-1348 defines ESD surveys for contractors.

JPL ESD CONTROL - FACILITIES

Static-generating sources:

- Nonessential and personal items are not allowed in ESD protected areas.
- All essential items and materials used during normal/intended conditions shall not generate static voltages greater than ± 200V within one meter of unprotected ESDS items.
- Work shall be stopped if items are found to be charged greater than ± 200V.

JPL ESD CONTROL - FACILITIES

Corrective Actions

- What to do if something charges more than ± 200V:
  - Move the item outside of the one meter boundary and keep it there. Label the item:

JPL Forms 11010

  - Replace the item with static-dissipative materials and retest.
  - Use air ionization to neutralize the item.
  - the use of anti-static sprays is not acceptable.

JPL ESD CONTROL - PERSONNEL

Personnel Grounding:

- Your body is a capacitor, able to store charge. Personnel tribocharging can charge your body.
- Connecting your body to ground removes the charge.
- Any person within one meter of unprotected ESDS items must be grounded.
- The limits on the electrical resistance from a person's body to ground are important:
  - if the resistance is too low, a person could be electrically shocked.
  - if the resistance is too high, it may take too long to discharge the person's body

JPL ESD CONTROL - PERSONNEL

Personnel Grounding:

- Personnel grounding techniques exist that protect ESDS items and contain the required resistance to protect personnel:
  - wrist straps
  - groundable footwear

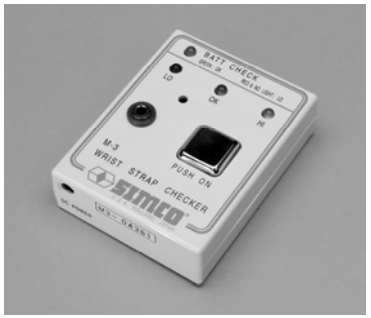
Wrist Straps:

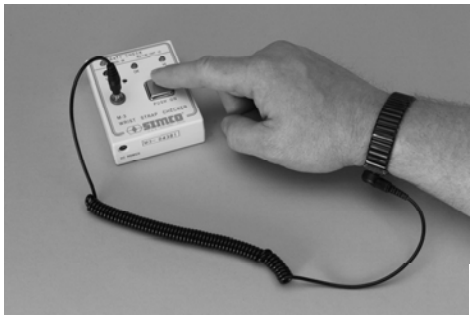
- Primary method to ground personnel.
- Must be worn in direct contact with the user's skin.
- Wearing a wrist strap over clothing or gloves is prohibited.
- Must have an internal resistance of 1 megohm ± 20% for personnel safety.

JPL ESD CONTROL - PERSONNEL

Wrist Straps:

- Must be tested every day they are to be used before handling ESDS hardware.
- Test must be performed while the user is wearing the wrist strap in direct contact with the skin.
- Shall be tested using JPL-calibrated testers that includes the wearer's body in the test.
- The use of cloth-type wrist straps is prohibited due to possible shedding of metal fibers from within the cuff.





JPL ESD CONTROL - PERSONNEL

Wrist Straps (approved versions):

Speidel Twist-O-Flex

3-M 4600

JPL ESD CONTROL - PERSONNEL

Groundable Footwear:

- Is *not* a mandatory requirement.
  - sometimes worn as an additional safeguard.
- Is only effective when used in conjunction with a grounded conductive or static dissipative floor or floor mat.
- Is **mandatory** when the use of wrist straps is inappropriate or unsafe for use.
- Must be tested every day they are to be used before handling ESDS hardware.
- Record on the test log.

JPL ESD CONTROL - PERSONNEL

Groundable Footwear:

- Includes heel straps, toe straps, booties, disposable shoe covers and shoes.

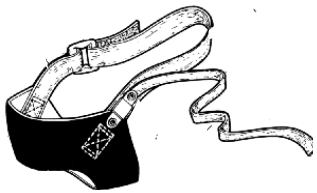
Don't wear conductive ribbon against bare skin

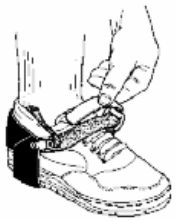
Can have a steel toe.

JPL ESD CONTROL - PERSONNEL

Goundable Footwear:

- Shall be worn on both feet and be tested before use, every day they are used.
- If groundable footwear is used, the use of a footwear tester is **mandatory**.
- Shall be tested using JPL calibrated testers.
- Test one foot at a time.





JPL ESD CONTROL - PERSONNEL

ESD Protective Garments:

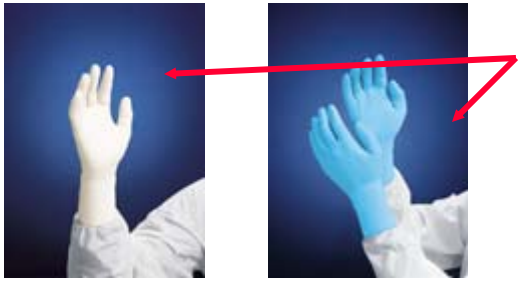
- Ordinary clothing charges.
- ESD-protective garments (smocks, bunny suits) contain a grid of conductive fibers that block fields from your charged clothes (similar to a metallized bag).
- ESD protective garments must be worn by all personnel within one meter of unprotected ESDS items.
- Must be laundered by a qualified laundry service. Home laundering is prohibited.
- Garments that exhibit static voltages greater than ± 200 volts shall be removed from service.

JPL ESD CONTROL - PERSONNEL

ESD Protective Garments:

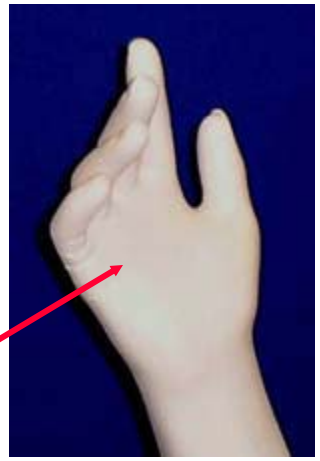
Gloves and Finger Cots: Not a requirement, but when needed shall be constructed of static-dissipative materials

- Natural Rubber Latex – Not Approved (Contamination Issues, Allergic Reactions, ESD Problems)
- PVC – Not Approved (Contamination Issues, Durability)
- Nitrile – Ansell Edmont Nitrilite ™, Safeskin Critical ™
- Urethane – Wilshire DuraCLEAN



Safeskin Critical ™

Wilshire DuraCLEAN ™



JPL ESD CONTROL - PACKAGING

ESD Protective Packaging

- All ESDS items shall be packaged in static-shielding containers when outside of ESD protected areas.
  - static-shielding bags.
  - carbon coated cardboard boxes.
  - carbon filled molded plastic boxes
- Packages shall be identified with ESD-warning stickers.

JPL D-1348, Rev. B

MIL-STD 129J

JEDEC-14

ESD ASSOCIATION

CAUTION

ESD SENSITIVE HARDWARE

USE JPL D1348 PRECAUTIONS

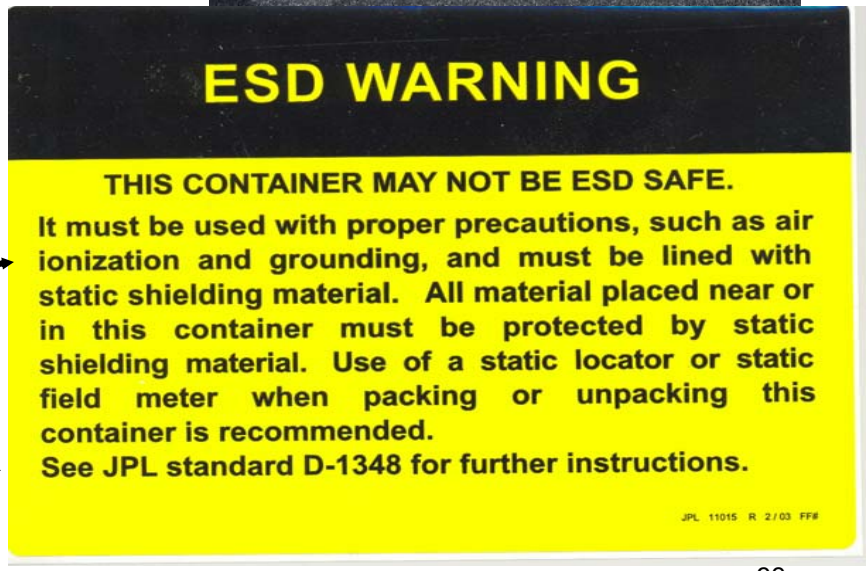
D-1

JPL ESD CONTROL - PACKAGING

ESD Protective Packaging

- Shipping containers has:
  - an outer shell to provides adequate mechanical support
  - static dissipative foam or other cushioning (if needed)
  - static shielding around the ESDS item.
  - use shipping container label.
  - Follow QAP 61.12

JPL Forms 11015 R 2/03



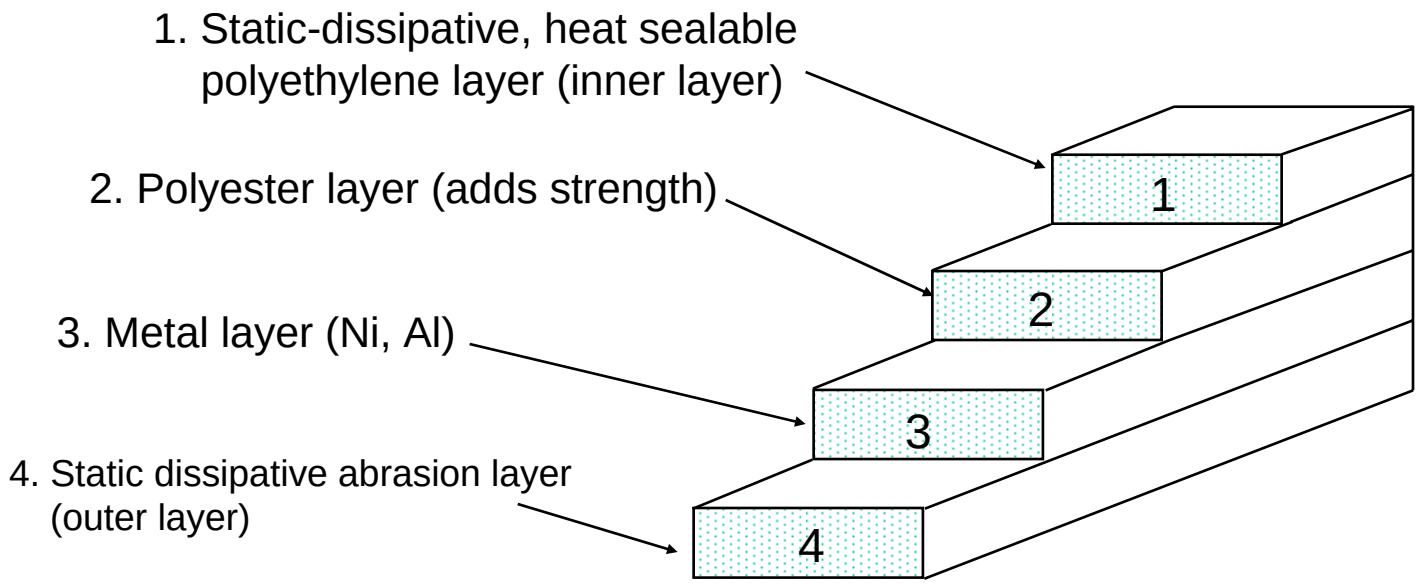
JPL ESD CONTROL - PACKAGING

Packaging Materials: Static shielding bags and Sheet stock

- Grayish in appearance, somewhat transparent
- Available in bags and rolled stock forms. Bags can be sealed using different techniques - never staple!
- Buried, conductive metal layer shields contents from direct ESD and electrostatic voltage fields
- Static-dissipative inner and outer layers provide safe current discharge.
- Reusable, but excessively crumpled bags may be ineffective.

JPL ESD CONTROL - PACKAGING

- All static shielding bags are not the same – only use JPL approved bags.



Typical Construction of Metallized Film

JPL ESD CONTROL - PACKAGING

Types of Packaging:

Metal – in Static Shielding Bags

Shielding (gray)

Shielding and Moisture Barrier (silver)

Foam

Totes (not to scale)

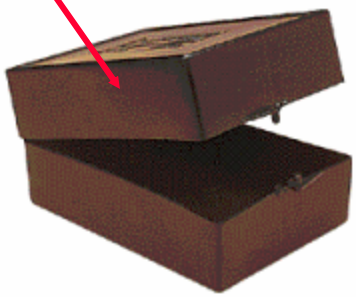
Carbon Filled Polystyrene

Carbon Coated Corrugated Cardboard Boxes

Storage

Shippers

Hinged Boxes



JPL ESD CONTROL - PACKAGING

Pink-polyethylene (pink-poly):

- Using pink-poly bags, film, bubble wrap or foam near any ESDS item is prohibited.
- Surfactants within pink-poly leach and outgas, making it a contaminant.
- Does not provide proper shielding.
- An acceptable alternative is the static shielding bag which is grayish in appearance.

Packing and Filler Materials

- Materials, such as shipping popcorn, foam liners and Styrofoam shall not be used near ESDS items unless they charge to less than ± 200V during normal/intended use.

JPL ESD CONTROL - MATERIALS

Adhesive Tape:

- Ordinary tapes can generate static-charge.
- Use only approved adhesive tapes.
- Remove tape slowly from the roll and any ESDS assembly to which it may have been applied.
- The use of any aluminized duct tape is prohibited (conductive particles that shed from the tape have led to contamination problems).

Approved tape dispenser

Don't put post-it notes on ESDS items.

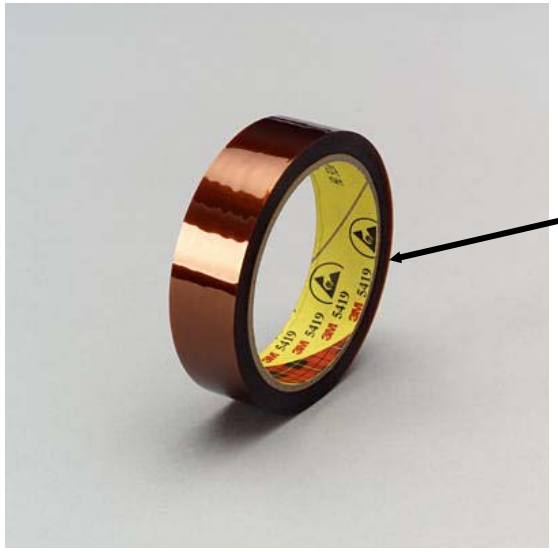
JPL ESD CONTROL - MATERIALS

Aluminum Foil Tape

Smooth Copper Tape

Embossed Copper Tape

3M Clear Utility Tape



Kapton ™ (polyimide), Use with Caution

Wescorp Static Shielding Tape

JPL ESD CONTROL - MATERIALS

Plastic Handled Hand Tools:

- Plastic handled hand tools (screwdrivers, pliers, wire strippers, etc.) are acceptable for use near ESDS items.
- The handles shall not be wrapped or treated.

JPL ESD CONTROL - MATERIALS

Plastic Fluid Bottles:

- Hand-held plastic bottles commonly used to hold DI water, flux and solvents shall be checked for the ± 200V limits.
  - check bottles after using in normal/intended manner.
  - special static-dissipative bottles are available.
  - all plastic bottles must be left untreated.

ESD Safe Versions:
but – no spray

No sleeves

JPL ESD CONTROL - MATERIALS

ESD Control Material Requirements:

- All ESD control equipment and materials used at JPL must be listed on the approved materials list:
  - items have been tested and meet both JPL ESD and contamination control requirements.

- Materials and/or equipment deemed necessary for use that are not on the approved materials list must be approved by the JPL ESD and contamination control before the material or equipment is used.

JPL ESD CONTROL - MATERIALS

3-Ring Binders:

- Binders that generate greater than ± 200V under normal/intended use shall be neutralized.
- Neutralization techniques include:
  - relocate binders to > than one meter from ESDS items.
  - use static dissipative binders and sheet protectors.
  - cover binders with static-shielding film.

Static dissipative 3-ring binders, 0.5, 1, 1.5, 2 & 3 inch wide →

← Static dissipative sheet protectors, 8.5 x 11” and B size drawing

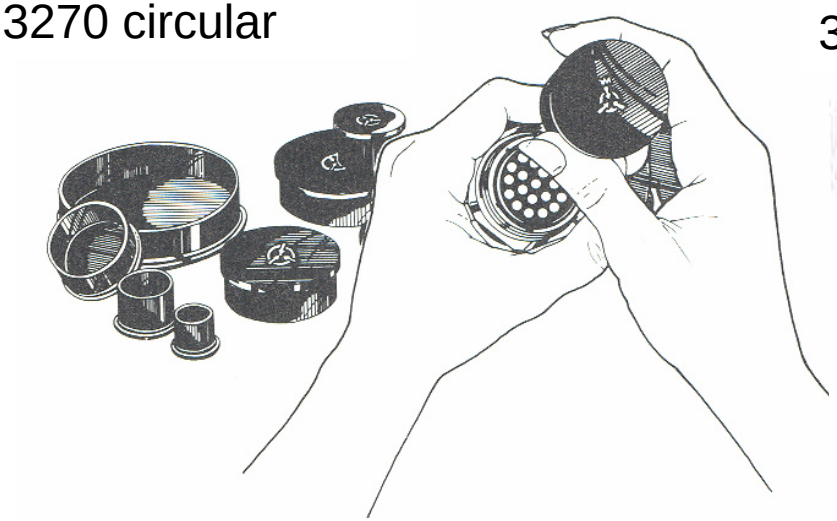
JPL ESD CONTROL - MATERIALS

Plastic Connector Dust Caps:

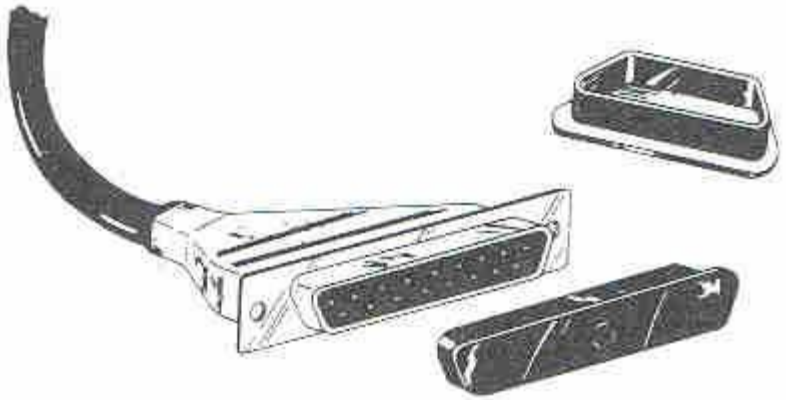
- Plastic connector dust caps are acceptable for use.

Preferred connector covers are ESD safe 3M 3270 and 3272

3270 circular



3272 d-type



JPL ESD CONTROL - MATERIALS

Conductive Hand Lotion:

- Only approved hand lotions may be used within ESD-protected work areas. Non-approved lotions contain chemicals that may be contaminants.

R&R Lotions IC Hand Lotion

JPL ESD CONTROL - PROCEDURES

ESDS Items Exposure:

- Unprotected ESDS items shall not be left openly exposed.
- Equipment which must be left unattended for short periods of time (i.e. lunch break) must be protected:
  - Return to original package
  - Put in a static shielding bag, box, dry box.
  - Cover with static shielding bag or film

JPL ESD CONTROL - PROCEDURES

Receiving:

- All items received displaying ESD warning symbols shall be opened only by personnel trained in ESD control at ESD-protected work stations.
- Packages received that do not contain warning symbols, but obviously contain electronic devices, shall only be opened in ESD-protected areas.
- ESDS items received that are not packaged in static-shielding containers or marked with warning labels shall be identified on an Inspection Report for disposition by the cognizant engineer. It may be non-conforming material.

JPL ESD CONTROL - PROCEDURES

Packaging and Unpackaging:

- Follow QAP 61.12
- Neutralize packaging material by grounding or exposing to ionized air.
- Use electrostatic field meter to verify packaging material neutrality </= 200 V.

JPL ESD CONTROL - PROCEDURES

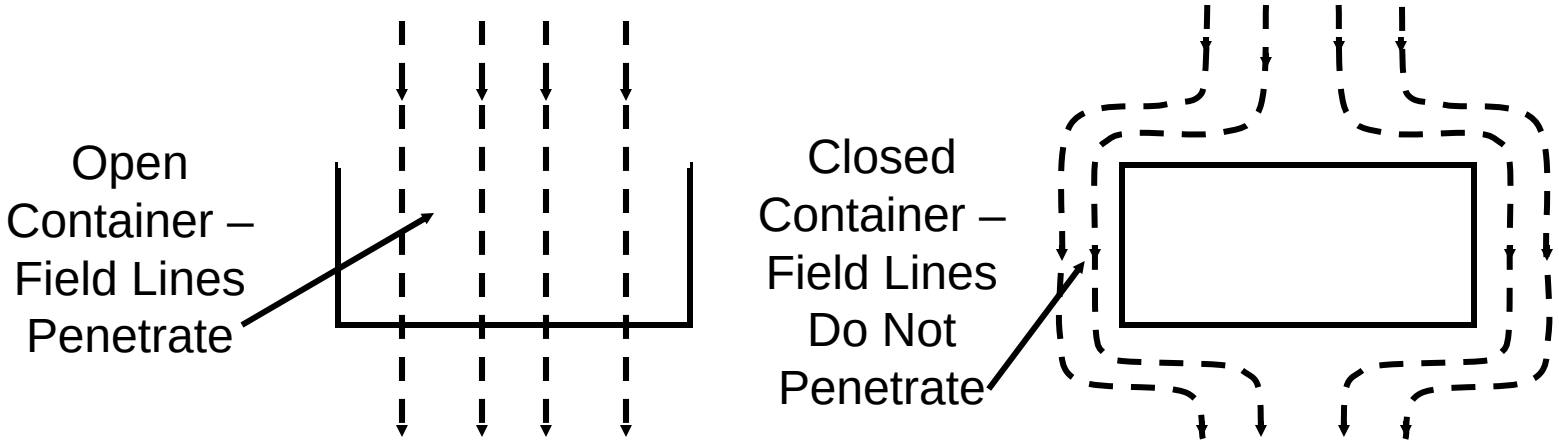
Movement and Handling of ESDS items:

- Unprotected ESDS items shall not be passed from one person to another unless both people are safely grounded.
- ESDS items shall not be moved from within ESD protected rooms or work areas without ESD protection.
- If conditions arise (e.g., field testing) where wrist straps or groundable footwear are not available, always touch a grounded surface before and during the handling of ESDS items.

JPL ESD CONTROL - PROCEDURES

Storage of ESDS Items:

- When stored, ESDS items shall be enclosed within static-shielding packaging.
- Static shielding must be fully closed to be effective.



JPL ESD CONTROL - PROCEDURES

Cleaning and Coating Operations: (continued)

- It is acceptable to use pressurized “air cans” on ESDS items.
  - however, don’t shake the can before or during use since particles can charge.
- Rubbing or sanding of ESDS devices and traces on boards is prohibited.
- Tacky floor mats shall not be used or stripped within three meters of unprotected ESDS items.
- The use of anti-static spray cleaners is prohibited.

JPL ESD CONTROL - PROCEDURES

Interconnect Cables:

- Charge can accumulate on cable insulation and conductors within the cable itself.
- Unconnected cables about to be connected or mated to ESDS items or assemblies shall have their metallic backshell momentarily grounded, either by contact to the hand of a grounded person or to a ground wire.

JPL ESD CONTROL - PROCEDURES (continued)

Procurement:

- When procuring ESDS items, both the requester and purchasing agent shall state that the item is ESD-sensitive.
- Designation that the item is ESD-sensitive shall be made on the purchase requisition.
- When procuring equipment and materials, only purchase items on the approved materials list.

JPL ESD CONTROL – PROCEDURES

Test Logs (wrist straps, footwear, ac powered hand tools):

- You need proof in the form of a checklist that each person checked their ESD equipment each day it is used.
- Checklist shall contain as a minimum:
  - operator's name
  - building/room
  - date
  - a check mark indicates that the test was performed and that the results satisfy the requirements.
- Records of inspections must be retained using the JPL records retention policy: until six months after the project is finished.

Summary

ESD Control web page:

http://eis.jpl.nasa.gov/qa/esd

- ESD Approved Materials List
- Frequently Asked Questions
- List of Certified Auditors
- List of Certified Rooms

Contains links to:

- D-1348.
- ESD Control Survey Report (JPL Form #2731)

SUMMARY

- Provide an ESD-safe environment for all applications involving ESDS items.
- Reduce or eliminate sources of ESD and electrostatic fields.
- Obtain JPL ESD control training and certification and implement it “on the job”.
- Keep all plastics and clutter out of ESD protected areas.
- Safely ground your body before and during handling of ESDS items.
- Handle ESDS items only at ESD protected work stations.
- Keep the humidity above 30%RH.

SUMMARY (continued)

- Use approved ESD control equipment and materials.
- Make sure your lab has a current ESD Control certification.
- Use only static-dissipative surfaces to support ESDS items.
- ESD control items prohibited for use at JPL:
  - pink poly bags, bubble wrap and foam.
  - non-approved conductive hand lotion.
  - wrapped hand tools and plastic bottles.
  - anti-static sprays and cleaners.
  - aluminized duct tape.
  - cloth-type wrist straps.

SUMMARY (continued)

ESD-related questions on the job ?

Call your assigned QA Rep

or

Roger Welker (4 - 9415)