SSDS
ESD Control Training

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Overview

1) Introduction
2) Theory
   - Charging Methods
   - Humans and ESD
   - Types of Failure
   - Materials and ESD
3) ESD Control
   - Fundamentals
   - Personnel
   - Workstation

Introduction

- 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.
- Why does ESD matter?
  - A lack of ESD control can lead to electronic parts being “zapped” leading to:
    - Failed parts
    - Increased costs
    - Wasted time and missed deadlines
    - A dead satellite and an unhappy team
  - Repair of a failed electronic part on a launched spacecraft is impossible.

The SSDS and ESD

- The SSDS has lost many parts to ESD damage.
- Significant investments have been made to combat ESD
  - ESD floors in B30A
  - Continuous wrist strap monitors
  - Active humidity control
  - Custom electrical workstations
  - The cleanroom and all tools

All these investments are meaningless if you do not follow all ESD precautions

Introduction

If not controlled, ESD can ruin electronic devices

Before ESD

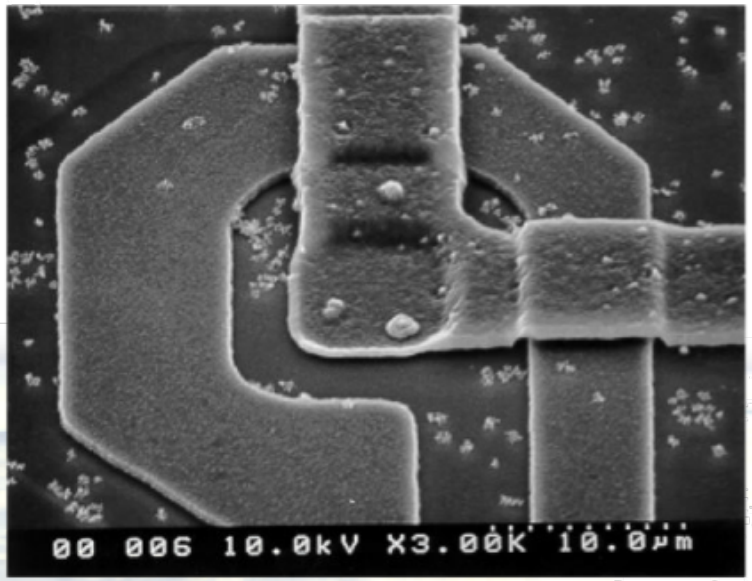


Figure 1: Scanning Electron Microscope (SEM) micrograph showing magnified (3000X) metal traces within a TCC-244 1K SRAM made by Sandia used in the Galileo AACS. (Source: Office 514 Failure Analysis Group)

After ESD

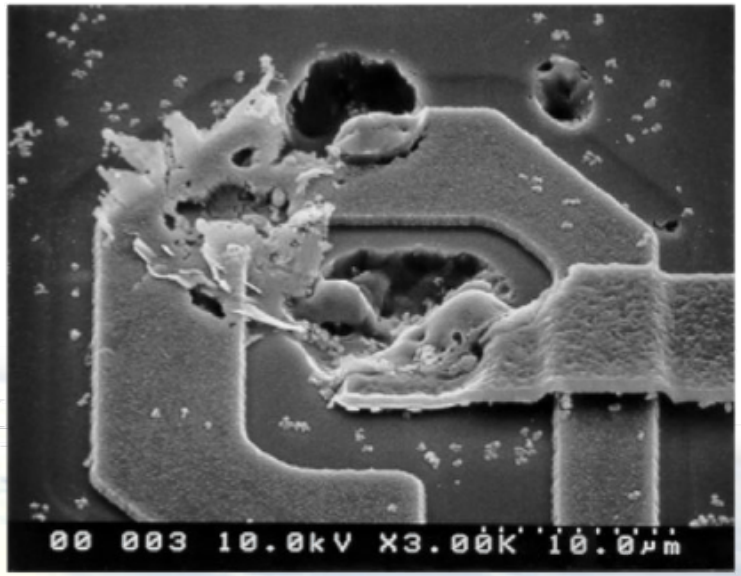


Figure 2: SEM micrograph showing damaged metal traces after the chip was purposely "zapped" from a human body model ESD simulator 3 times at 8000Volts. (Source: Office 514 Failure Analysis Group)

Introduction

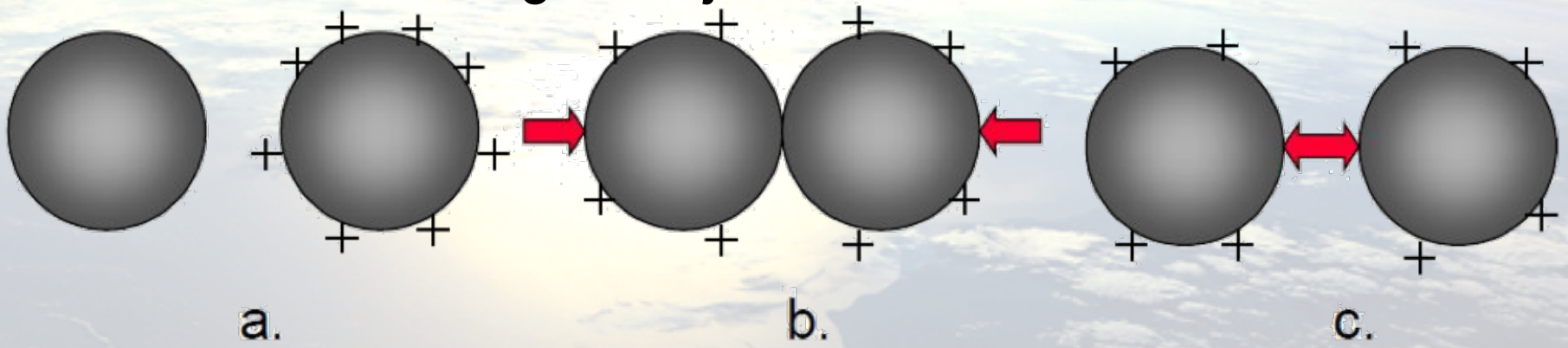
- ESD results in $40 billion (EST.) per year losses. (Halpern Associates, 1998).
- Approximately 30% of the failed electronic parts at JPL (91-92) were attributed to ESD (JPL Section 514 Failure Analysis Reports)
- With advanced in semiconductors, electronic parts are become smaller and faster, while performing more functions.
  - This means they are become **more** sensitive to ESD.

Theory

Objects can become charged by three mechanisms:

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

1) Contact with another charged object.

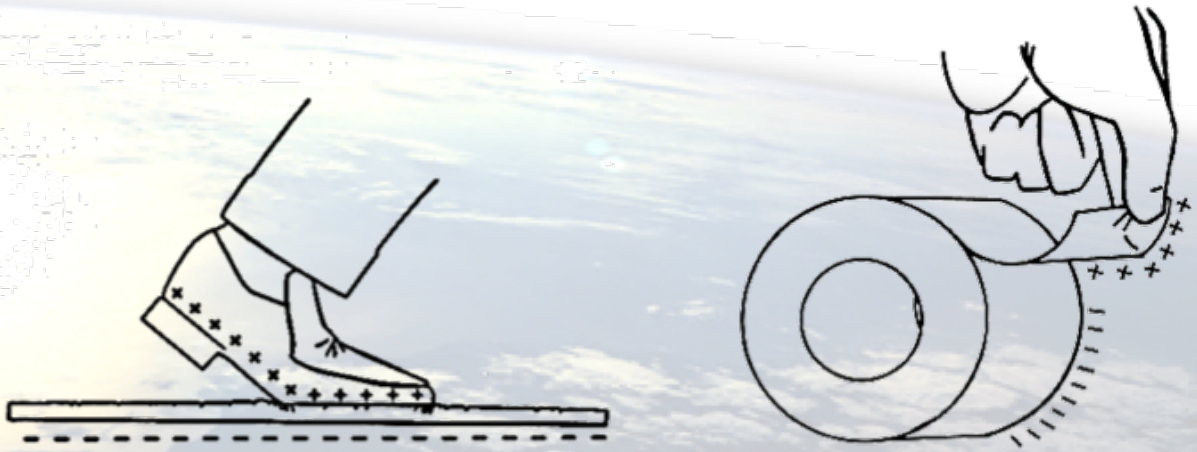


Theory

2) Triboelectric Charging

- When charge is generated after contact between dissimilar materials.
- Rubbing increases area that is contacted, thus more charge is developed.
- During separation, some materials allow removal of surface electrons easier than others, resulting in the two materials becoming oppositely charged.

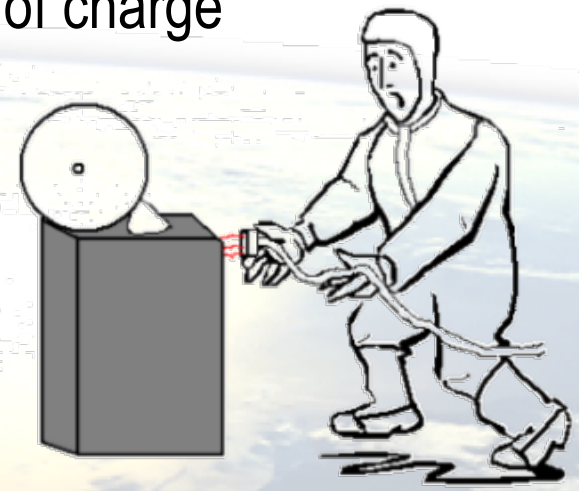
- Everyday examples of this include:
  - Walking across a carpet
  - Peeling tape
  - Taking off a fuzzy sweater

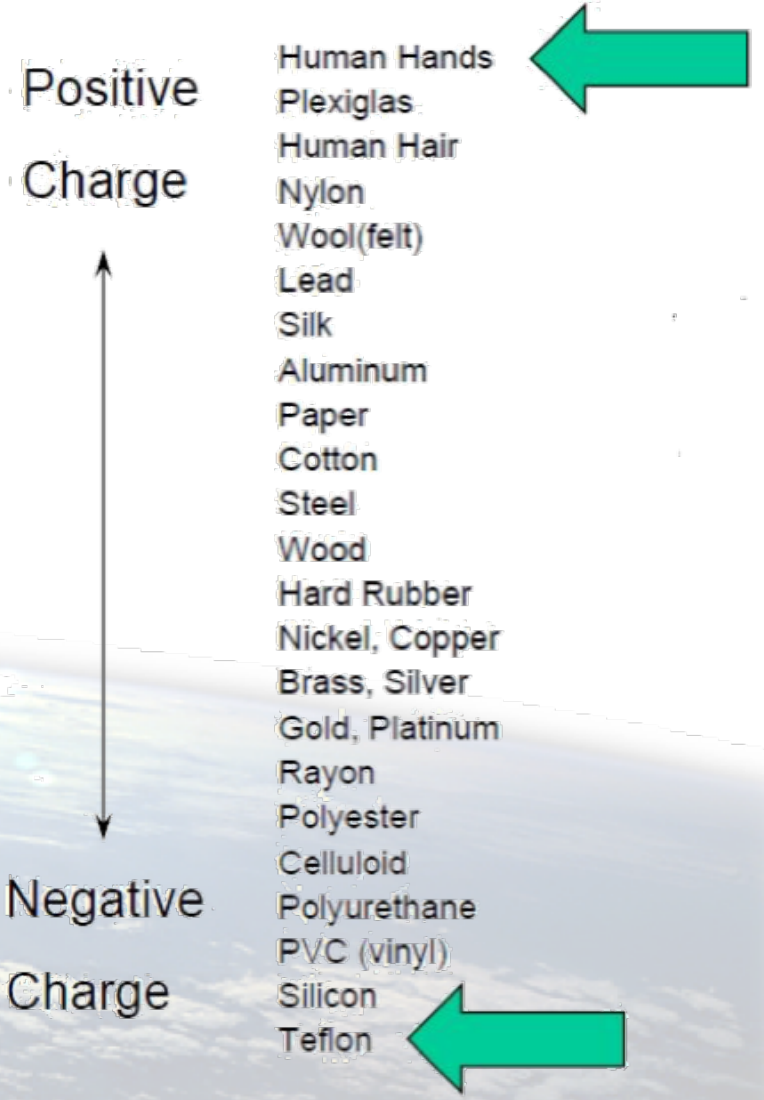


Theory

Triboelectric series

- The further materials are apart in the series, the more charge is generated.
  - Note Human Hands and Teflon for cable handling.
- Contact pressure, speed of separation, and humidity levels also affect the amount of charge created.





Theory

3) Induction Charging

- Charged objects can charge other conductors that are nearby.
- No physical contact necessary.

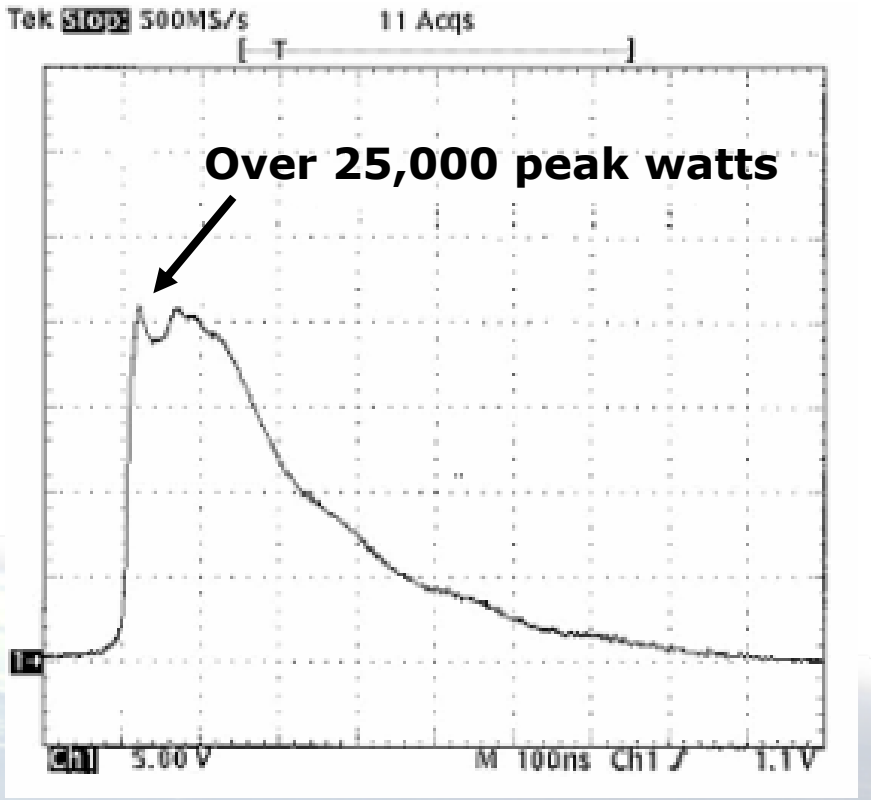
- The most likely situation in which you will experience induction charging is when bringing an object near a screen.

Theory

- **People are the most common source of ESD.**
- Human generated ESD can be powerful

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



Actual ESD measured from a person charged to 6000V touching a grounded wire.

Source: NASA/JPL Western Region Training Center, 2006

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

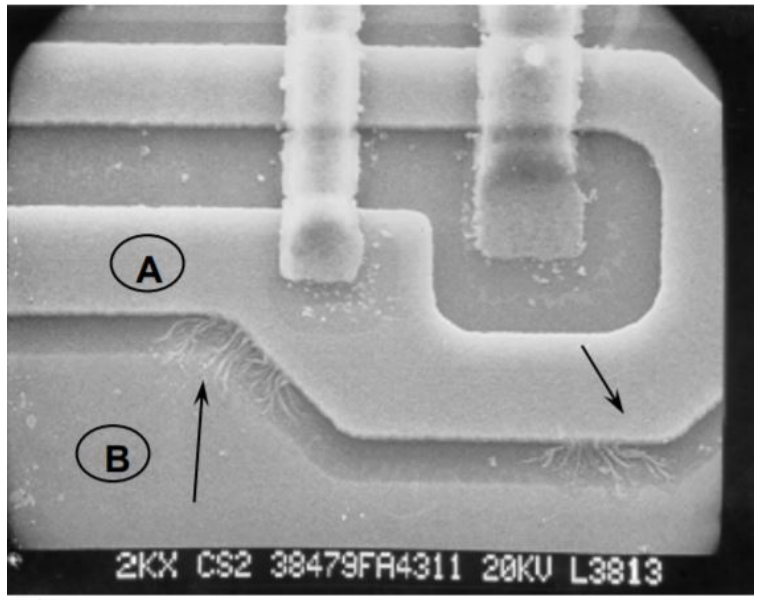
Humans only feel discharges over 2000V!

Source: NASA/JPL Western Region Training Center, 2006

Theory

Types of Failure from ESD

- Catastrophic Failure
  - A “zapped” part no longer works.
- Parametric Failure
  - A “zapped” part is damaged and still works, but not perfectly.
- Latent Failure
  - A “zapped” part is damaged and works correctly. However, over time and use the part eventually fails.
    - Failure after delivery or launch!
  - Most costly type of failure

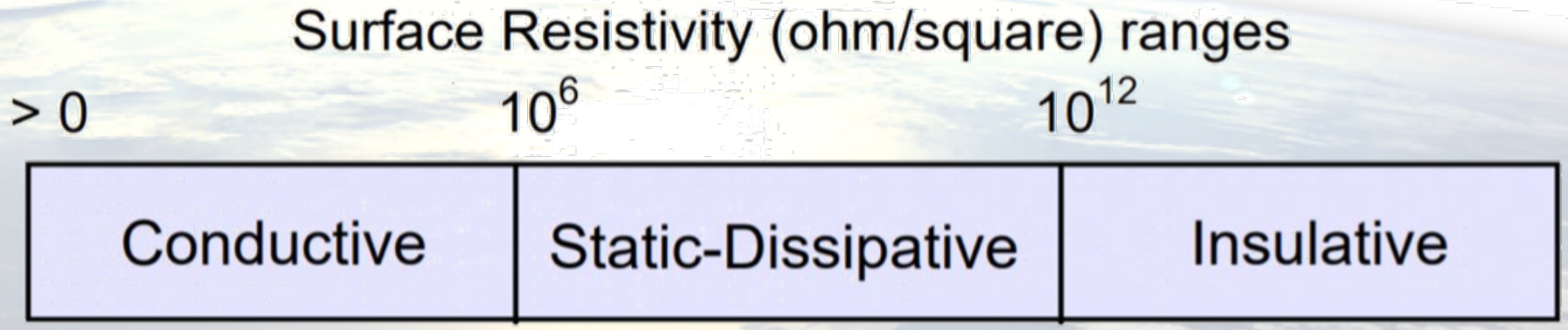


Catastrophic failure. Small hair-like dendrites short traces A and B.

Theory

ESD Protective Materials

- Surface Resistivity
  - The ratio of voltage to current across an infinitesimally thin surface of a material
  - Nondimensional unit
  - Measured by special equipment → Can't use point-probes

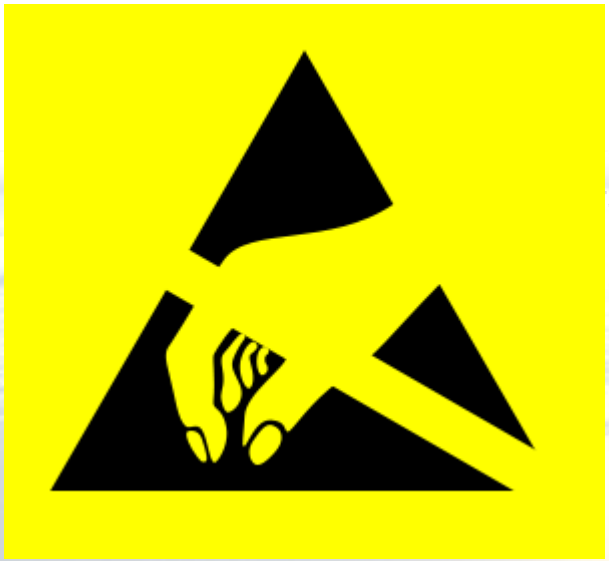


Theory

- Conductors
  - Will spark, think of a metal doorknob
  - Will NOT provide a safe current discharge rate after contact with charged electronics
- Static-Dissipative Materials
  - Safest material for direct contact with electronics
  - Provides a safe current discharge rate
- Insulators
  - Don't allow current flow
  - Cannot be discharged by grounding
  - Keep out of ESD protected areas!!

ESD Control: Fundamentals

- ESD Protected Areas (EPA)
  - Only conduct electrical work in these designated areas
  - All ESD control procedures must be followed in these areas

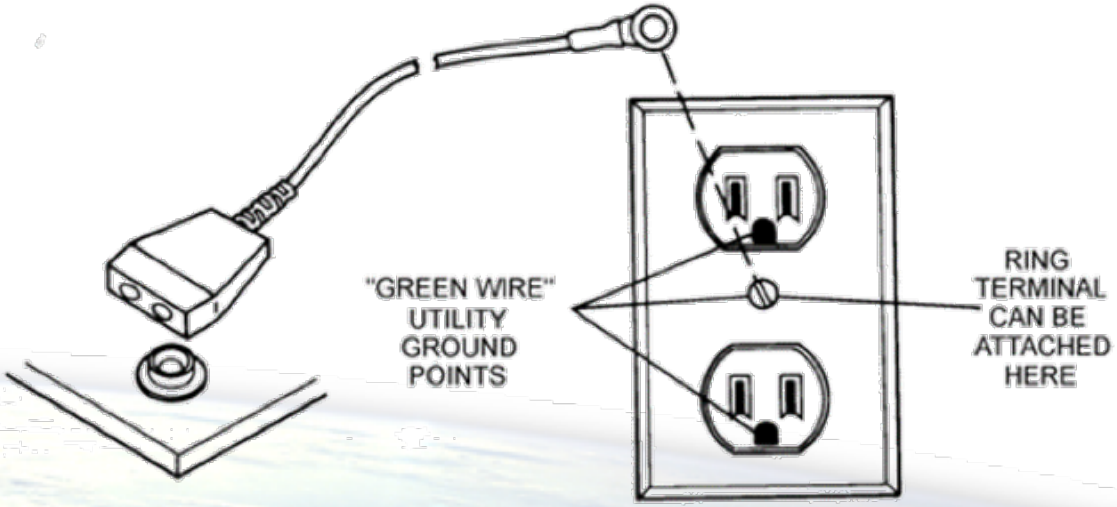


ESD Protective Symbol

EPA Marking Tape

ESD Control: Fundamentals

- Grounding
  - All conductors in the EPA must be grounded
    - You, your partners, benches, test platforms, etc…
  - Third prong on an outlet is ground
  - Hard Grounding
    - Direct to ground
    - Dangerous for personnel and components
    - Tables, shelves, etc...
  - Soft Grounding
    - Through a 1MOhm resistor
    - Safe for personnel
    - Floor mats, work mats, wrist straps



ESD Control: Personnel

- Wrist Straps
  - Operators are required to wear wrist straps when working in a EPA
  - Must be tested for conductivity with skin every time it is put on
- Wrist Strap Test – Standard Straps
  1) Put wrist strap on preferred arm
  2) Plug into the Wrist Strap Tester
  3) Use the opposite hand the strap is on to push the test button
  4) If you pass, you may start working. If you fail, it means there is a poor connection with your skin
     - If you fail, apply ESD Lotion to the area with the wrist strap and test again.
- Wrist Strap Test – Continuous Monitoring Straps
  - The continuous monitoring machine will beep once connection with skin is lost.
  - Must use the Continuous Monitoring Straps, not the Standard Straps

Continuous Monitor

Standard Wrist Strap Tester

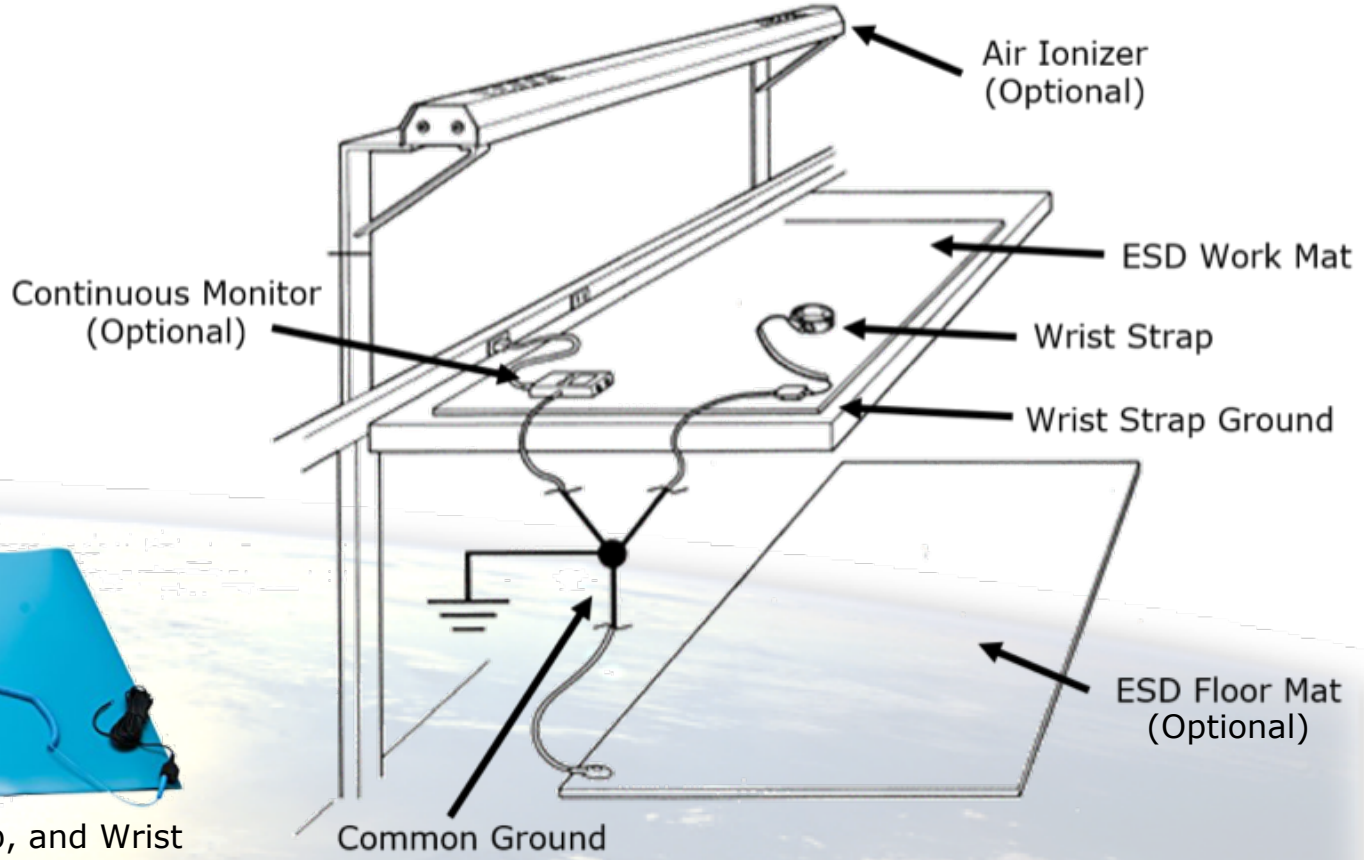

ESD Lotion


Standard Wrist Strap

ESD Control: Workstation

- Two-Fold Purpose
  - Provide a surface with minimal charge on it
  - Provide a surface that will remove charges from conductors placed on the surface (such as sensitive electronics)
- A workstation must include:
  - An ESD Work Mat
  - A Wrist Strap
  - A Wrist Strap Ground
  - A Common Ground
- Optional:
  - An ESD Floor Mat
  - A Continuous Monitor

ESD Mat, Wrist Strap, and Wrist Strap Ground



ESD Control: Workstation Rules

- Don’t take off your wrist strap
  - Unplug the strap to move around, don’t take it off your hand or you’ll need to retest
- Keep out all insulators
  - Watch out for packaging materials like plastic bags and Styrofoam
  - Includes **paper**, tissues, and Kimwipes
- Keep all sensitive hardware directly on the work mats
- No rolling chairs
- No food or drinks
- Move slowly and precisely

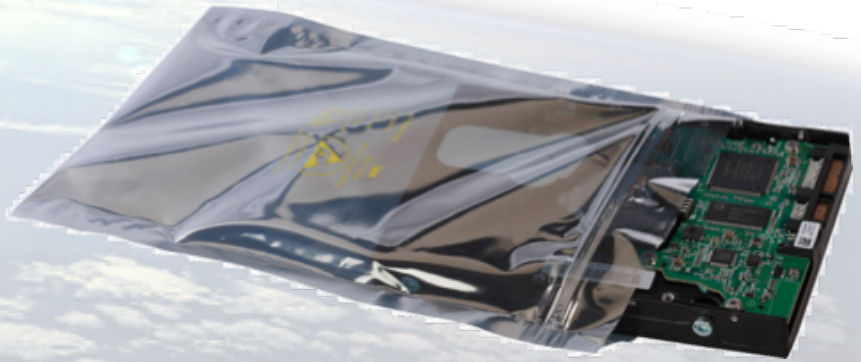
ESD Control: Personnel Rules

- Stay moisturized!
  - Dry skin, especially in the winter, is a leading cause of ESD
- Wear cotton
  - Synthetic fibers and wool pick up a lot of static charge
- Move slowly and precisely
  - Motion and the rubbing of you against your environment or clothing generates charge
  - Also prevents accidentally knocking over sensitive hardware

ESD Control: Workstation Rules

- Tape
  - Tape holds a lot of static charge!
    - Scotch, masking, duct, electrical tape are all ESD hazards
  - **Only use Kapton tape when working with hardware!**
    - It's a gold colored tape that should always be in stock
- ESD Safe Bags
  - Store all sensitive hardware in silver ESD Safe Bags outside the EPA
  - Do not use plastic bags for storing any electronics
    - Pink poly bags

Kapton Tape Roll



ESD Safe Bag

Bad Excuses (Heard in the SSDS)

- "It's just a $15 Arduino"
  - The cost of a piece of hardware is irrelevant when it's on-orbit. When it breaks, it breaks.
  - Just because it's $15 doesn't mean that it won't hold up development due to parametric failure.
  - ESD precautions must be followed for **all** electronic hardware.
- "This is a structural component, I don't need to be plugged in when integrating it."
  - You're certainly going to be connecting that component to an electrical one during I&T. The entire spacecraft is considered sensitive, so while you may not damage that part itself, the charge on it is now a danger to everything else.
- "I've never plugged in while using this part and nothing has ever gone wrong."
  - You rarely know if something is ESD damaged until its too late. Catastrophic failure (the most ideal case) is rare.
- "I'm only touching the part for a second."
  - The majority of ESD will occur immediately upon contacting a part. You don't get zapped on a doorknob halfway through turning it.
- "It's really annoying having to keep my wrist strap on. It gets in the way."
  - Too bad. You'll be more inconvenienced when your part/program fails.


Questions?