# NSC Quality Engineering Seminar

# Workmanship Standards


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**NASA Workmanship Program Manager**


**February 14, 2011**

# Welcome

**The purpose of this seminar is to familiarize you with the Workmanship Standards so that you can:**

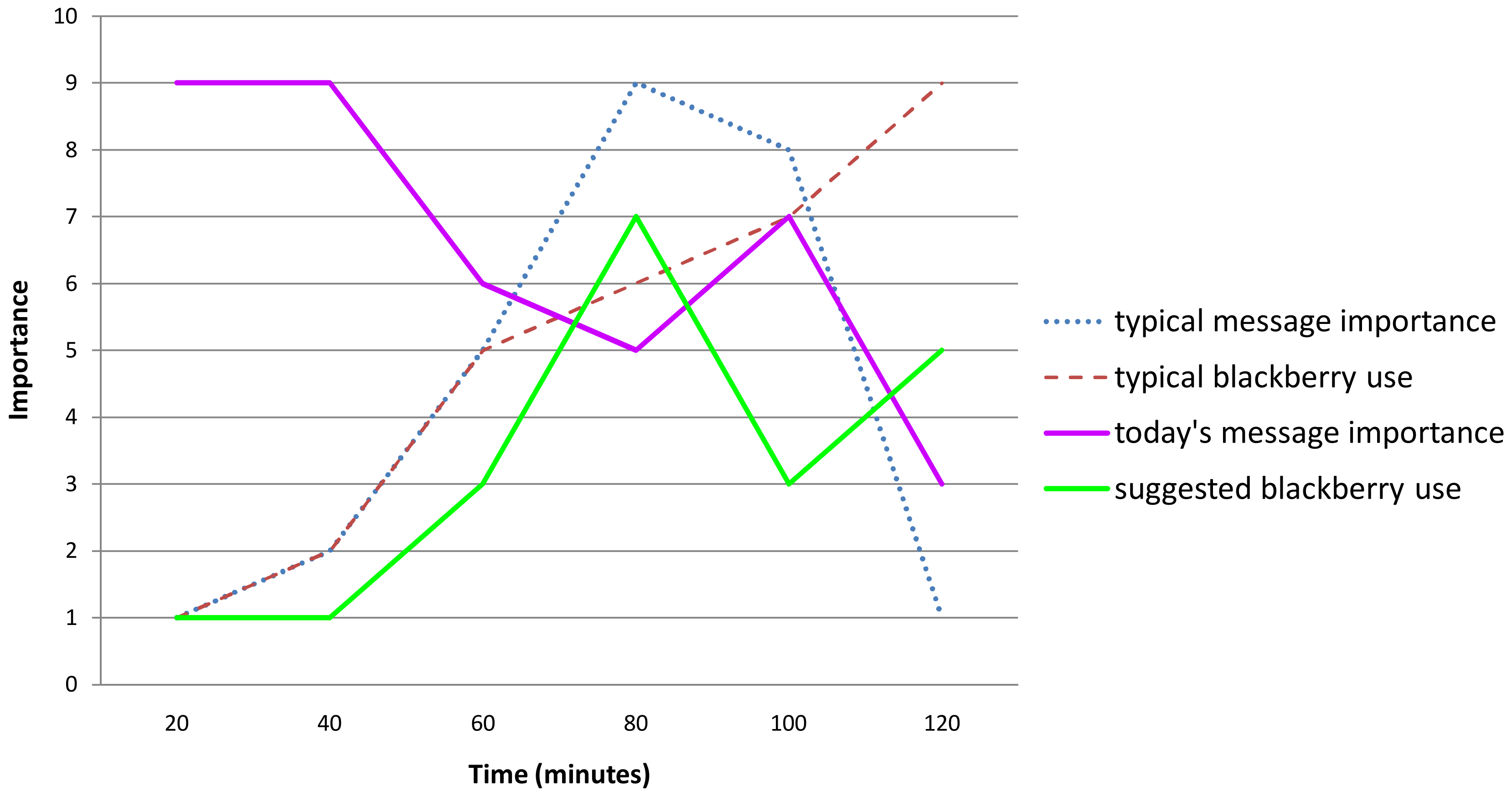
- Be an advocate for their use in the manufacture of NASA mission hardware
- Have insight about how they are intended to be used

**Seminar Organization**

In this seminar, we'll cover the basics of Workmanship Standards, including:

- Terms and Definitions
- Fundamental intent and value added
- Policy authority
- Common requirements
- Examples of technical requirements
- Electrostatic Discharge Control requirements

# Suggested Periods for Clandestine Blackberry Usage



# Intended Audience for this Seminar

**Who Should Take This Seminar?**

- Program managers, systems engineers, product lead engineers, design engineers, process engineers, reliability engineers, quality engineers, chief safety mission assurance officer (CSO), COTR

**Who Should Not Take This Seminar?**

- Assembly/manufacturing technicians or inspectors seeking workmanship training as a prerequisite to workmanship certification
- Reliability Engineers seeking to understand life expectancy of solder joints and cabling interconnects.

# Basic Assumptions of the Workmanship Standards Program

Materials and configurations named in the Workmanship Standards are considered technologically standard and have demonstrated high reliability for a broad range of NASA missions and thus are mature.

The Workmanship Standards specify design, processing, and inspection requirements, which are relevant to the materials and configurations named, which ensure high quality hardware is supplied.

Suppliers are expected to perform manufacturing using controlled processes, which operators implement using established procedures, and which results in a product that is compliant with the Workmanship requirements.

Suppliers who use configurations and materials not named in the Workmanship Standards must establish that the resulting hardware will be reliable for the applicable mission and must establish, declare, and use relevant design, processing, and inspection requirements to assure that the final items have high quality.

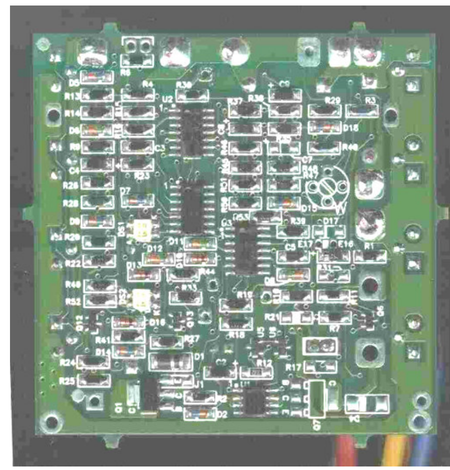
# Terms and Definitions

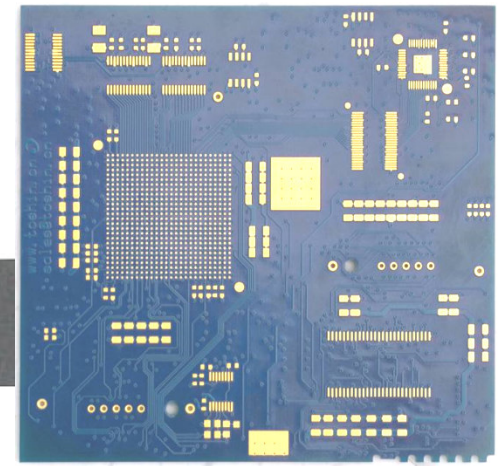
**Workmanship:** Shorthand term for quality rules applied to the assembly of electronic boards and electrical cable harnesses.

NASA groups Fiber optic cable assembly quality and ESD Control with Workmanship

**PCB:** Printed Circuit Board. The bare board, with integrated electrical connections but no electrical parts installed. Treated like a EEE part; it is an integrated unit. Flex cables are a type of PCB.

**PWA:** Printed Wiring Assembly. A populated PCB. An electronic board with all parts installed. Sometimes called a CCA; circuit card assembly.



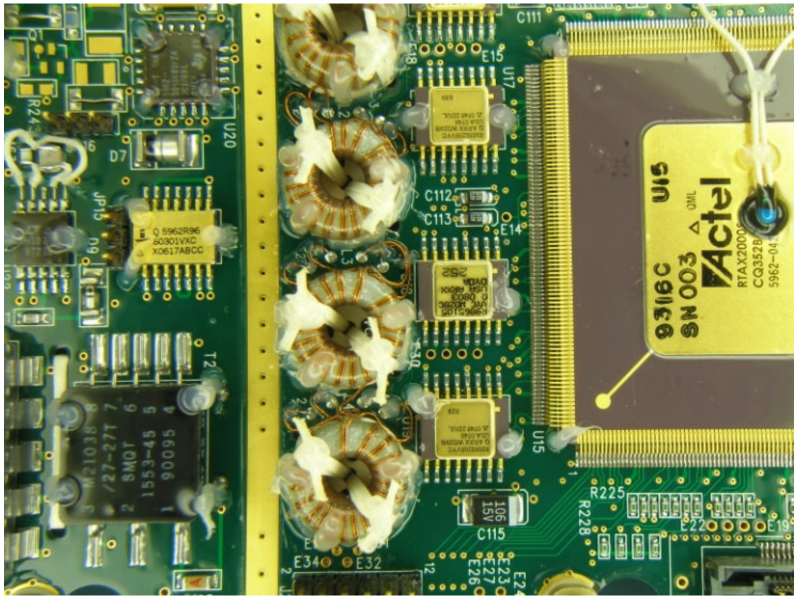


**ESD:** Electrostatic Discharge. Sudden discharge of electrical potential through readily available ground path. The affect on electronic assemblies can be catastrophic or crippling but visually hard to detect. Crippled parts may pass now and fail later.

# Terms and Definitions

**Solder:** Low melt-temperature metal alloy used to provide a conductive, long lasting connection between an electrical part lead and the pad of the printed circuit board or between a wire and a connector contact. 63% Tin (Sn) + 37% Lead (Pb) is standard for electronics.

**Flux:** Acid-containing material (organic or inorganic acid) used to remove oxide and residues from soldered surfaces thereby allowing the solder joint to readily form.




**Staking:** Polymeric material used to mechanically tack-bond part bodies to the PCB surface.

**Conformal Coating**: Polymeric material used to thinly coat a PWA to protect it from "bumps and bruises" and conductive debris. Will also retard surface corrosion of PWA exposed metal surfaces.

# Terms and Definitions

**Wire**:  Single or stranded insulated conductor used alone or in a cable to support a single electrical connection.

**Cable**:  Multiple wires bundled together inside an insulated layer used to support multiple electrical connections.  Cables are terminated with connectors.

**Harness**:  Multiple connectorized cables gathered together for interconnection of subsystems.

**Jumper wire**:  (aka "white wire") Wire used to provide a single electrical connection within a PWA.  The termination method is a solder joint.

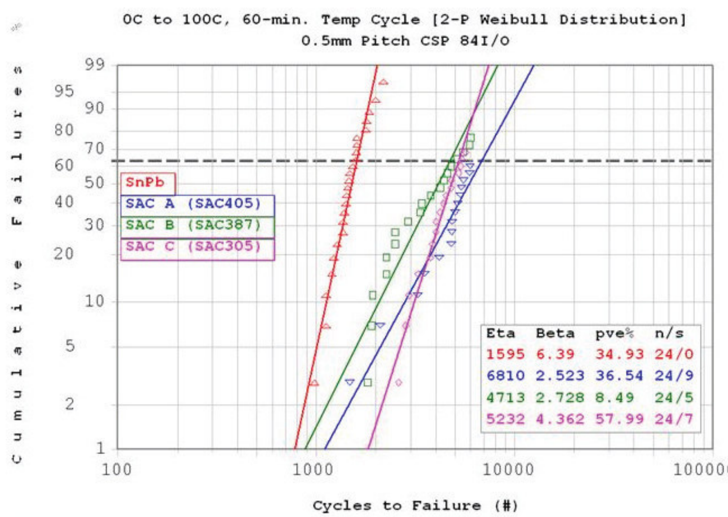
**ESD Event Model**:  Industry standard description of an electrical discharge event using voltage, current, and time or an equivalent RLC circuit.

# Terms and Definitions

**Quality:** measure of an item's compliance with published performance parameters (form/fit/function). Quality is relative to what the item is intended to do and can be measured. ***Production lots with high quality are highly uniform.***

**Reliability (1):** Probability of failure of an item used in its intended operating environment before its intended operating life has been completed. Reliability is relative to the environment stress and minimum required life span. Sample size is important.

**Reliability (2):** Is capable of working in the mission environment for the duration of the mission.




**Other uses of these terms:**
**Quality:** item is good or really good
**Reliable:** item will not fail

Can something that is unreliable have high quality?
Are commercial products generally low quality?

# Terms and Definitions

## Qualified or Qualification

**Process Qualification:** Quality parameters have been identified, are controlled, and are monitored to ensure that (a) un-screenable defects are not produced in the final item, (b) every item produced has identical quality, (c) scrap is minimized.

Prototype runs and destructive tests are used to achieve (a) above. Non-destructive in-line and end-of-line tests and inspections are used to achieve (b) above. **Process Qualification ensures that the manufacturing recipe "works".**

**Product Qualification:** Destructive testing used to (a) identify relevant screening tests to achieve high and uniform quality and to (b) demonstrate the capability of the finished item to perform as intended in the application environment for the duration intended. "Generic" qualification test flows may use very wide temperature ranges (e.g. mil-spec) and durations that test to failure. Mission-specific qualification test conditions may not be applicable to other missions (Qualification by Heritage). **Product Qualification ensures that the design+manufacturing+screening = a part that is not likely to fail in the mission.**

***There is no NASA standard definition for Space Qualified. This is a marketing term.***

# NASA Workmanship Requirements Categories

**Design Requirements:** Controls materials and configurations (e.g. dimensions, placement, interface materials) selected to provide operational performance.

*Workmanship Examples:* Solder material, flux material, staking of wire runs to enable performance in shock/vibration environment.

**Processing Requirements:** Controls the manufacturing methods or techniques.

*Workmanship Examples:* Use of certain type of container to mix polymers to avoid contaminating the polymer, periodic alloy check of solder pot to ensure material purity, control of environmental conditions such as humidity

**Defect Criteria (aka accept/reject criteria, quality criteria):** Physical attributes that are evidence of a defect or known to be indicative of the presence of a defect that will result in premature failure.

*Workmanship Examples:* solder joint appearance, presence of extraneous material, nicks and scrapes in conductors, missing material, delaminated material.

**Training and Certification of Operators, Inspectors, and Instructors**

# Terms and Definitions

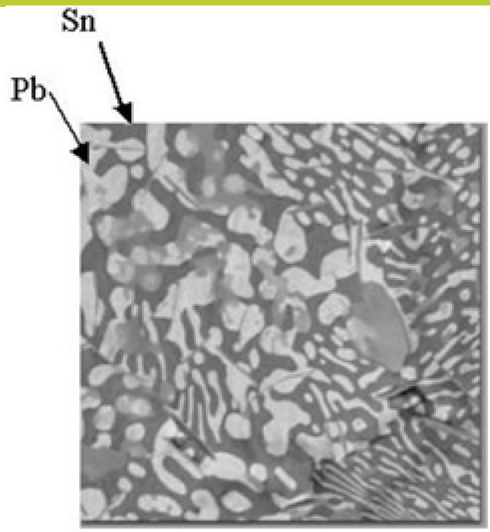
## Procedure or Requirements Document

**Procedure:** Step-by-step instructions for implementing a manufacturing process. Procedures will include steps that ensure that quality requirements are met. These steps may include use of special fixtures, checking temperature, ESD wrist strap check, in-process measurements, and end-point tests and inspections.

**Requirement Document:** Collection of requirement with applicable scope and intended requirements owners. May include accept/reject/defect criteria.

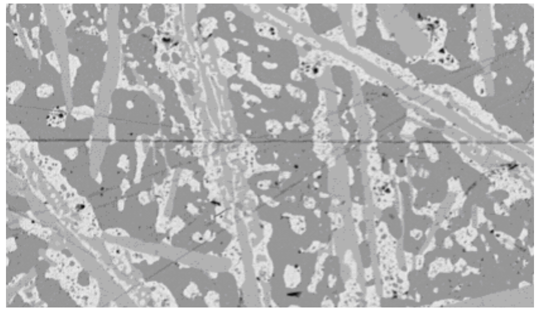
***Workmanship Standards are Requirements Documents***

# Terms and Definitions

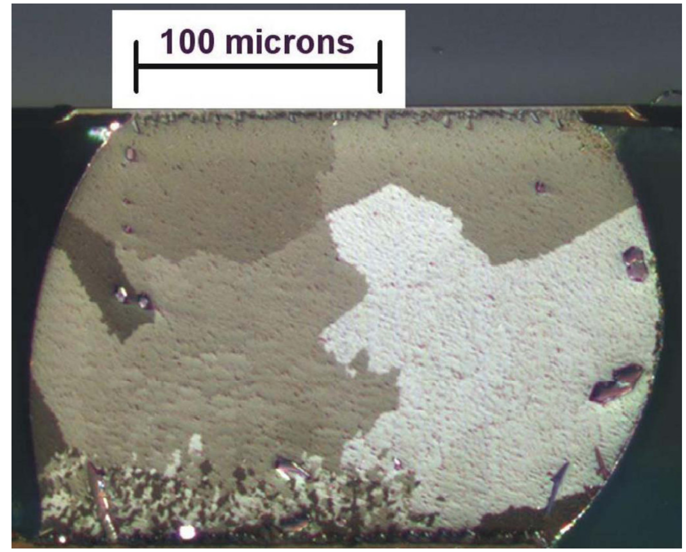



Canonical PbSn eutectic

## Grain structure

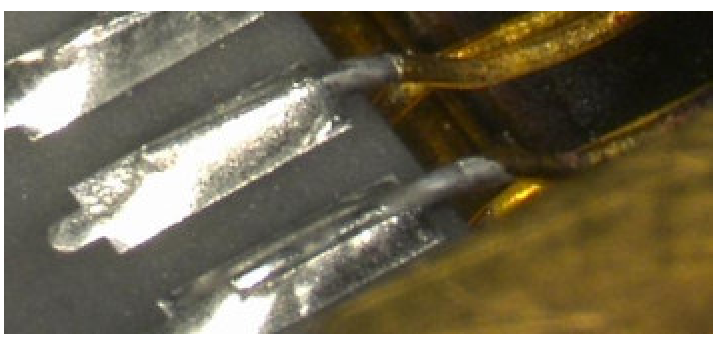


**Eutectic with $AuSn_4$ intermetallic precipitate**

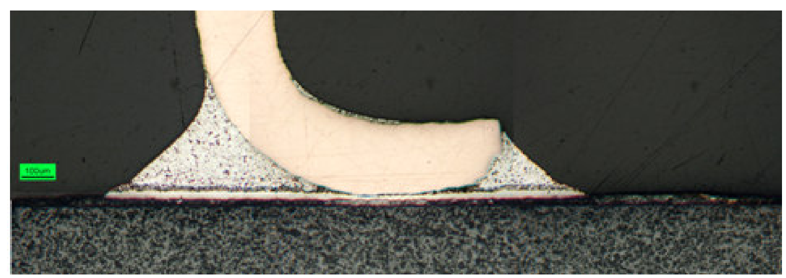



**Pb-free solder with intermetallic growth at solder pad**

## Solder Wetting



## Cross-section of solder joint fillet



# How do PWAs and Cable Harnesses Fail?

## Soldering

**Solder joint forms and hardens incorrectly:**

- Part lead wiggled during hardening
- Not enough solder present
- Not enough heat present
- Soldered surfaces have excessive oxidation
- Joint is reheated repeatedly (reworked, touched-up)
- Gold plating on solder pad is too thick
- Solder dip pot becomes “contaminated” with trace metals

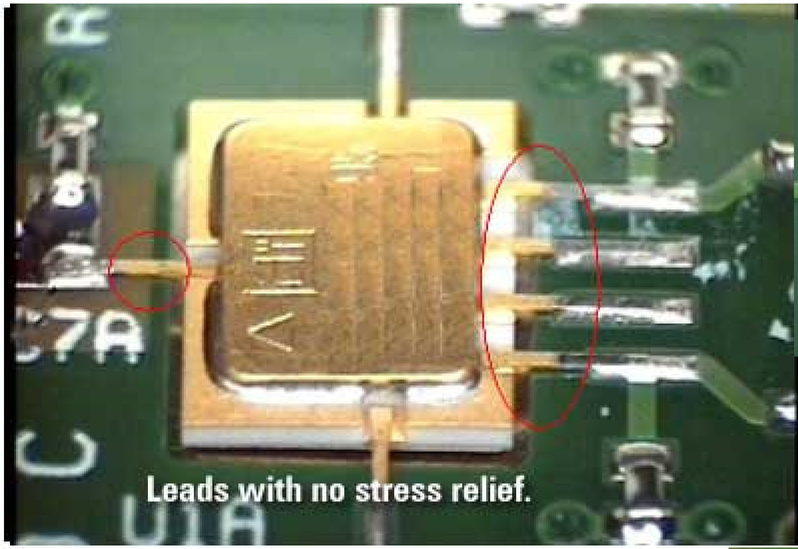
**Internal structure of solder joint is affected:**

- Solder grain coarsening increases rate of crack growth
- Interdiffusion between surfaces does not occur, interconnected zone is smaller
- Intermetallics at interdiffusion layer are too brittle.

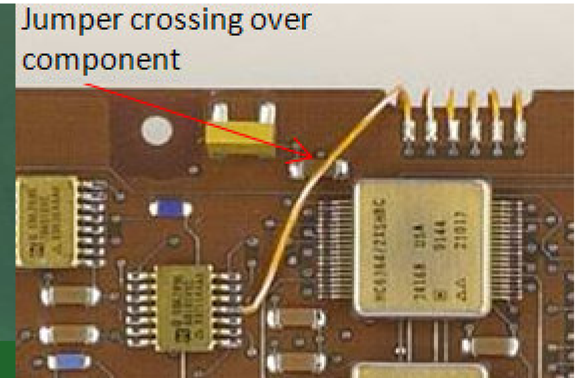
**Related Workmanship requirements:**

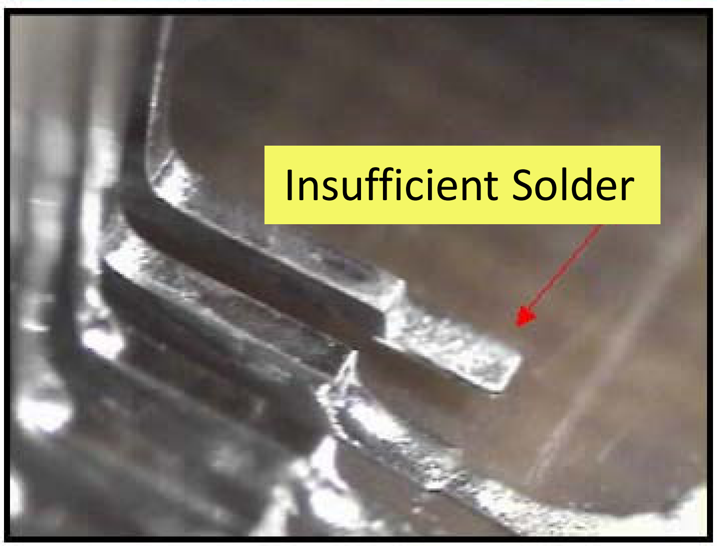
- Spring-back of lead not allowed after soldering
- Dull, grainy appearance is a defect
- De-wetting is a defect
- A negative wetting angle is required
- A crack is a defect
- Stress lines are a defect

# Example of Defects - Soldering



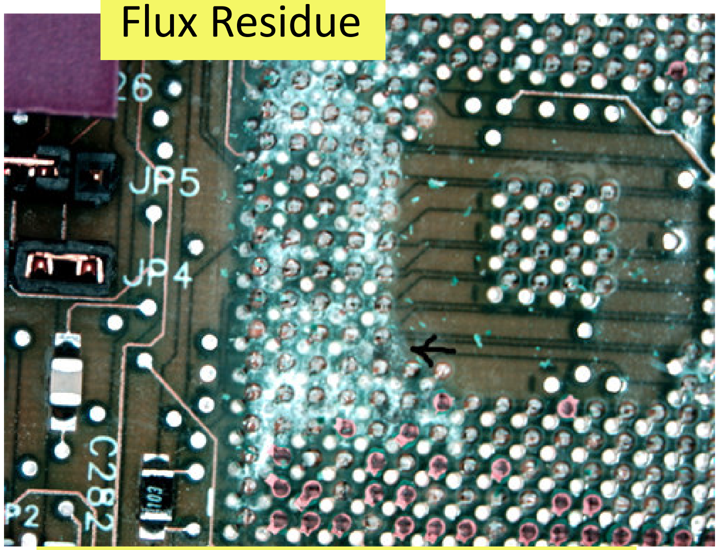




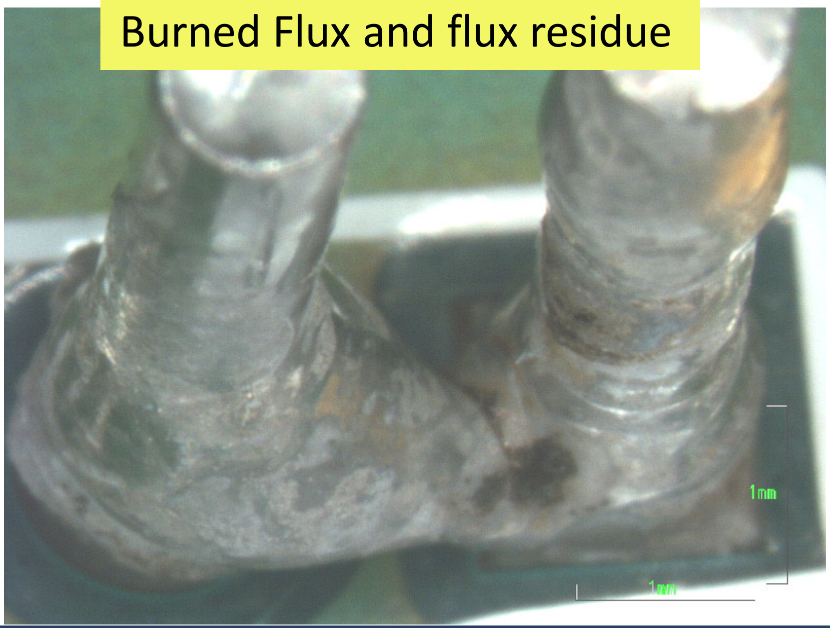




# Example of Defects - Soldering

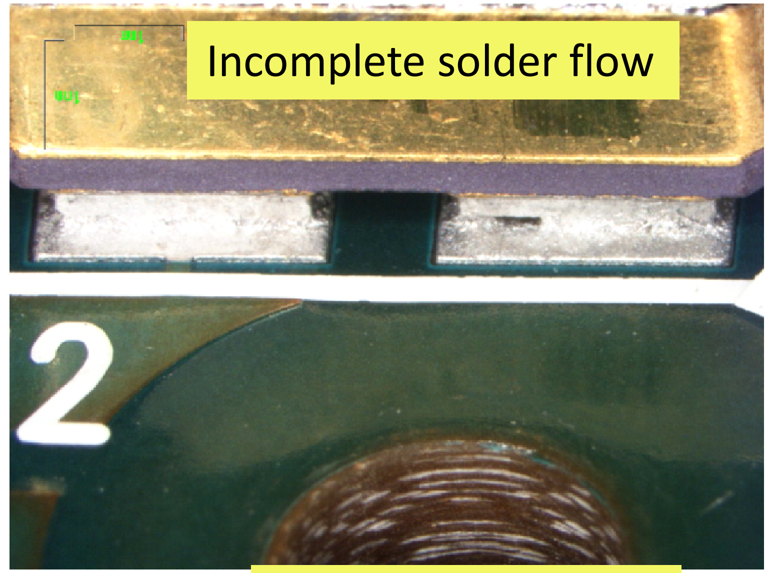
Flux Residue



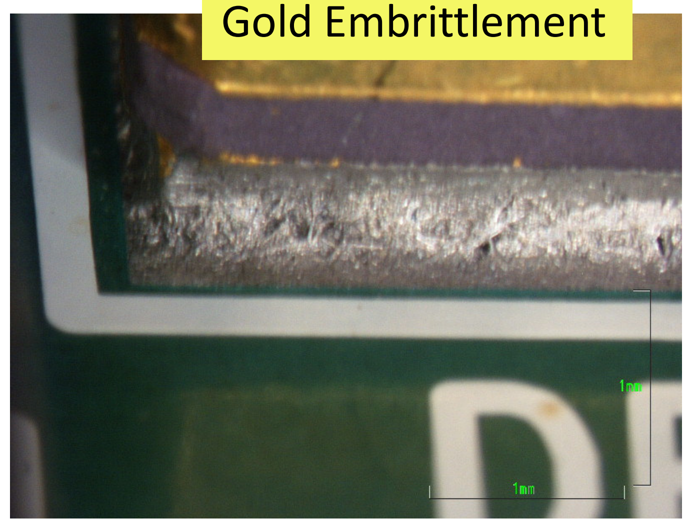
Burned Flux and flux residue



Incomplete solder flow



Gold Embrittlement

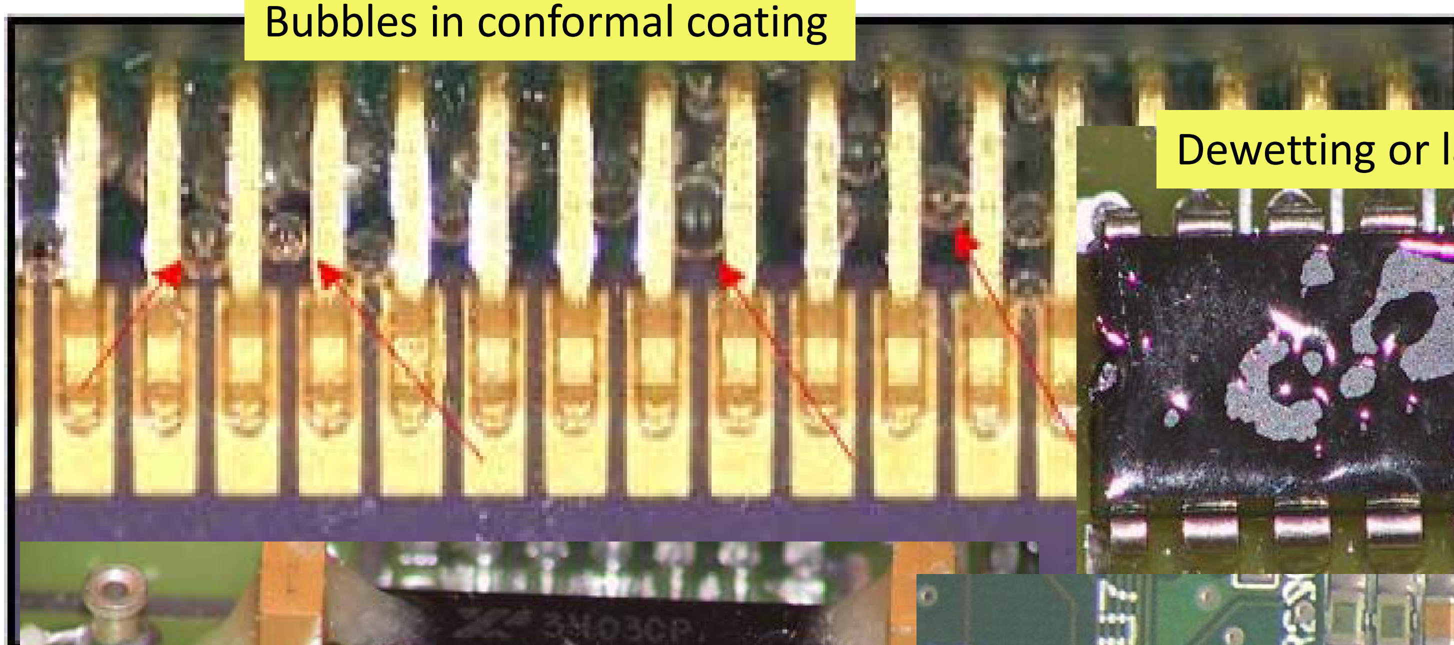


# How do PWAs and Cable Harnesses Fail?

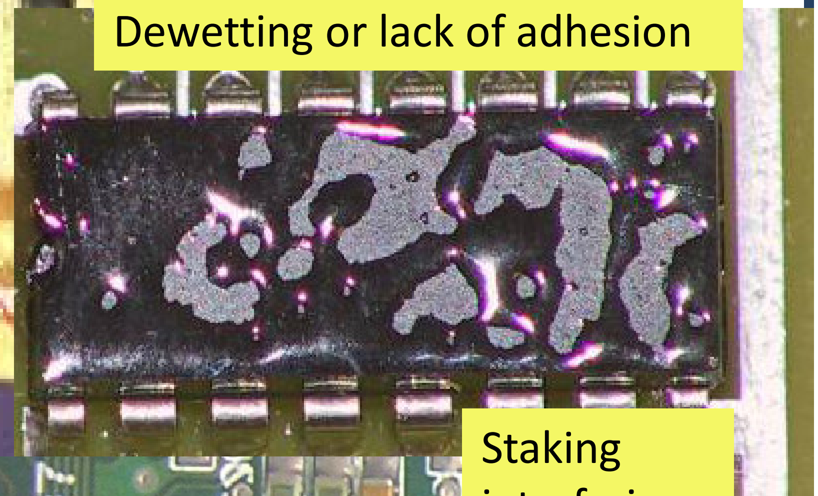
## Conformal Coating

| Physical Feature: | Performance Impact: | Related Workmanship requirements: |
|---|---|---|
| Thickness build up under part packages | Polymer expands and overstresses solder joints | Thickness requirements are defined |
| Thinning at sharp edges | Part lead is exposed to shorting hazard | |
| Lack of adhesion to surfaces | Moisture sink is created at delamination driving up risk of corrosion. | Full and adhered coverage is required |
| Bubbles formed throughout cured material | Material may contain trapped ionics which cause low resistance shorts across surface | The amount of voiding allowed (bubbles) is limited and defined |

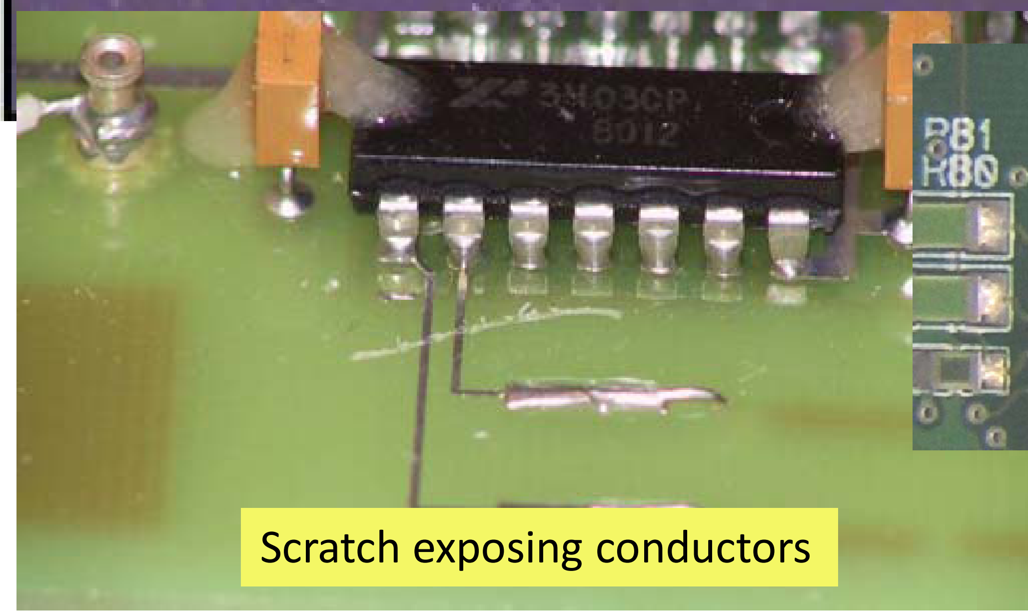
# Example of Defects – Polymeric Applications



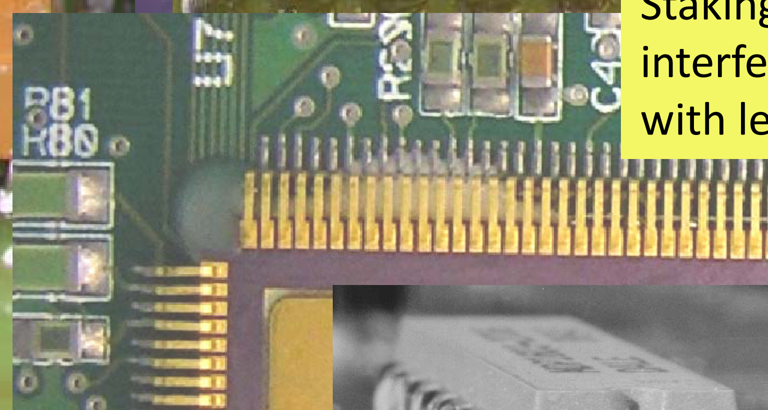
Bubbles in conformal coating



Dewetting or lack of adhesion



Scratch exposing conductors



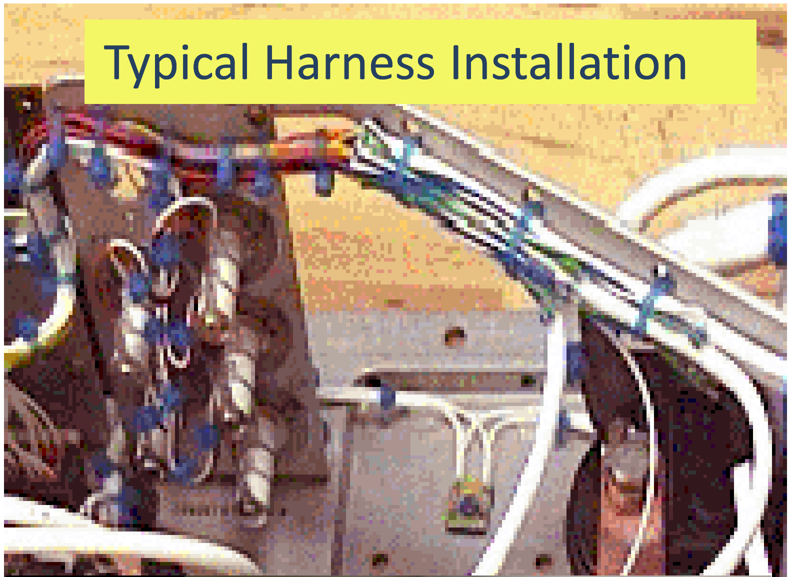
Staking interfering with leads

# How do PWAs and Cable Harnesses Fail?

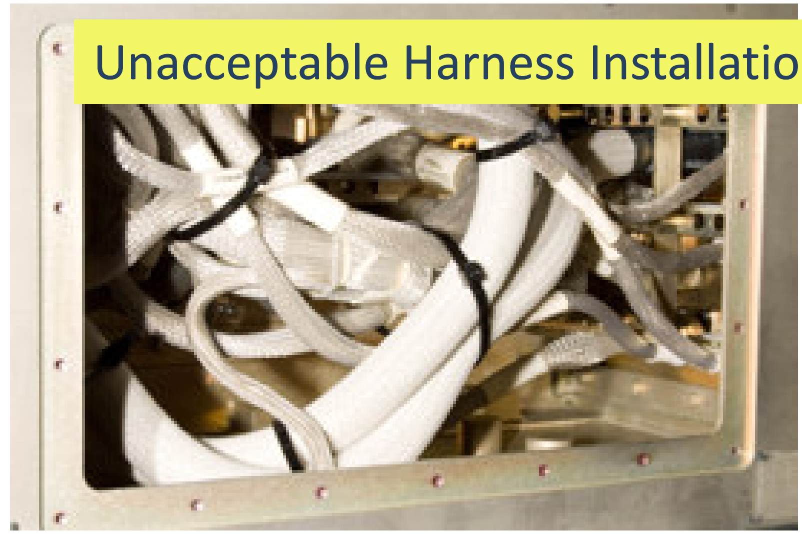
## Harnesses

| Physical Feature: | Performance Impact: | Related Workmanship requirements: |
|---|---|---|
| Bare conductor wire is nicked exposing bare copper | Wire conductor can corrode and fail electrically and/or mechanically | Exposed copper not allowed on wire |
| Too many wire strands are broken | | Limits set on number of broken strands |
| Crack in contact crimp barrel | Crimp connection weakens and fails | Crimping calibration and in-process quality metric required prior to production |
| Splicing behind connector not staggered | Backshell doesn't fit, rework forces increased stress on harness | Staggering of splices required |
| Connector pin not fully seated | Contact backs out of place and connection fails | Pin seating testing required |

# Example of Defects – Cables and Harnesses

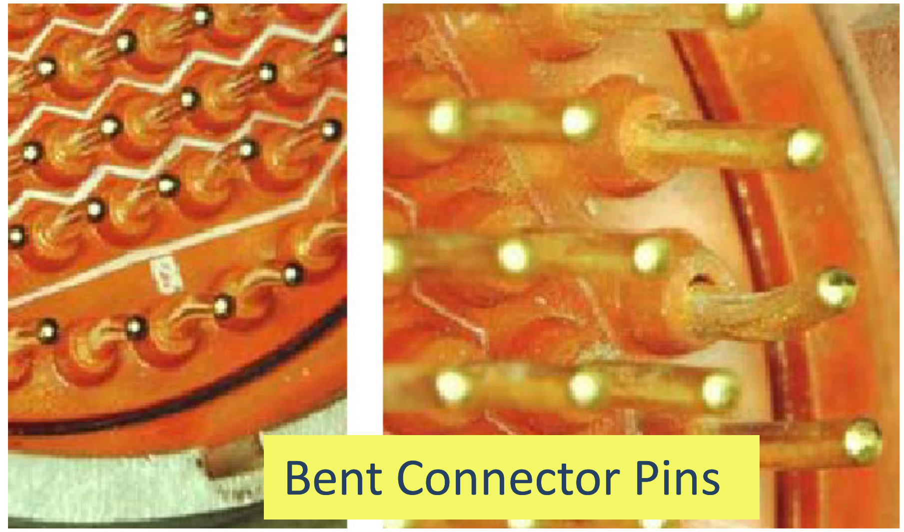


Typical Harness Installation



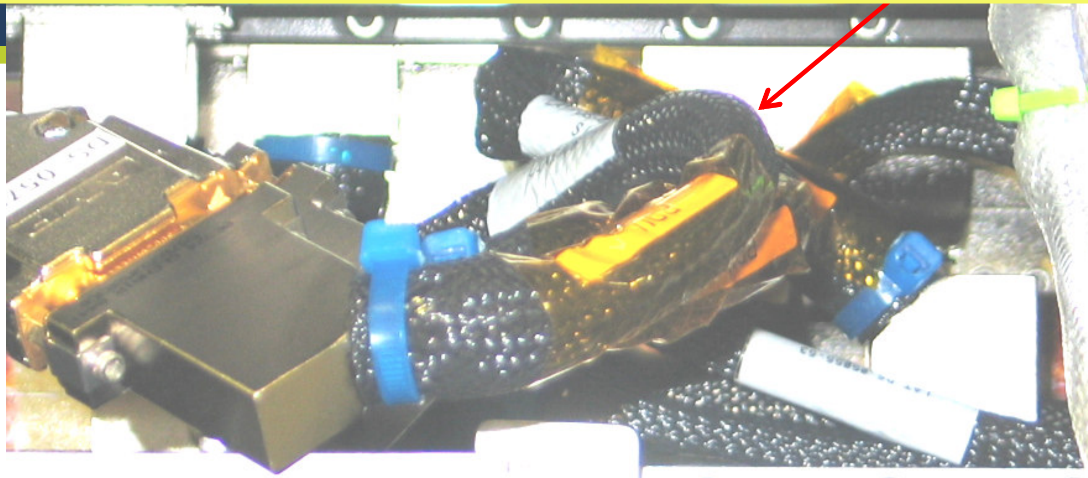
Unacceptable Harness Installation

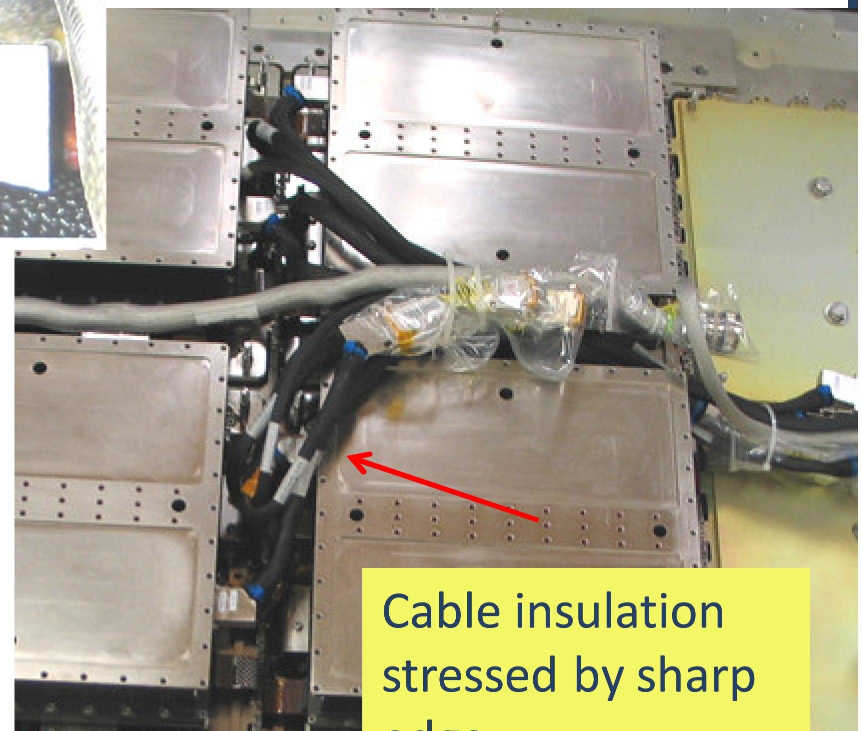
Flux residue/corrosion byproduct

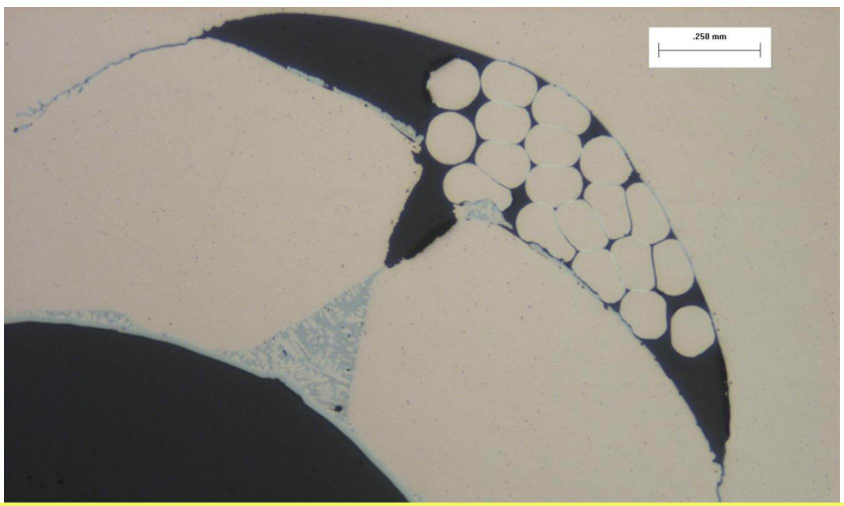


Bent Connector Pins

Cab le insulation stressed by compression of less than minimum bend radius








Cable insulation stressed by sharp edge

Single indenter crimp does not provide gas-tight crimp and leads to cracks in contact crimp barrel.

# Workmanship: Quality vs Reliability

## Will assemblies with Workmanship defects necessarily fail?

- Use of the materials and configurations in the Workmanship Standards and compliance to the Workmanship requirements provides excellent assurance that the hardware remain functional in missions which operate in mil-spec type environments (temperature, shock/vibe, humidity) for 15 years. *This may not be the case for environment extremes (cryogenic) and very long durations (>20 years).*
- Some Workmanship defects have been demonstrated to be associated with shorter service life through use and test. Some are from lessons learned feedback. Some are based on "best NASA practice".
- Use of Workmanship requirements criteria for non-standard, new technology <u>may not</u> be technically value-added or improve assembly reliability.

## Workmanship requirements are better at:

- Pointing out production lines which have not "mastered" the use of a mature interconnect technology.
- Reducing quality problems at a low level of assembly where it is less expensive to rework/repair.

# Rework vs. Repair

**Rework: process hardware to be in accordance with the drawing to correct a quality defect.**

- Existing wording in NASA standards is awkward, mentions process allowed. Improved wording in J-STD-001ES
- Too much rework can reduce reliability. Care must be used to avoid unnecessary soldering touch-ups and part removals.
- Rework processes must be pre-defined to ensure too much is not normally allowed
- Must be recorded for process engineering feedback. Rework history may be reviewed if repair is needed.

**Repair: resolve a quality defect by using a configuration that is not on the original drawing.**

- May introduce non-standard configurations and materials
- May introduce collateral effects such as stress on nearby interconnects or parts
- Must be reviewed and approved prior to use

# Standard vs. Non-Standard Technologies

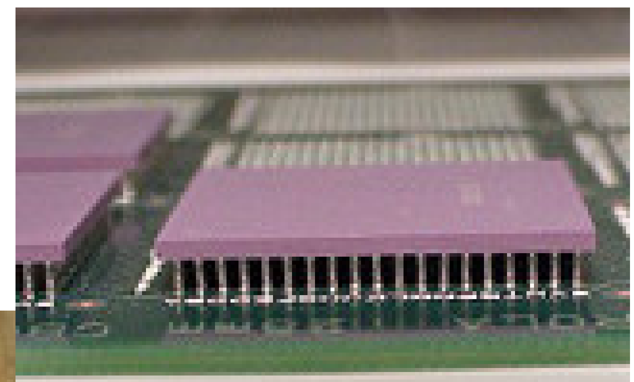
## Standard Technologies:

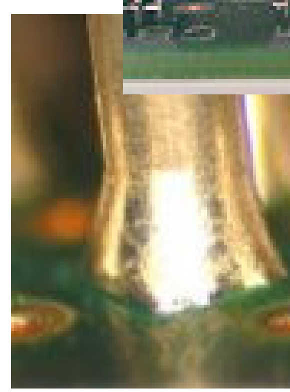
- Do not require special approval prior to use
- Standard Workmanship rules apply
- Examples:
  - Wire terminals (soldered to boards, wires soldered to them)
  - Surface mount solder joints: chips (0603 size and larger), gull wing
  - Through hole joints for DIP packages, and radial leaded and axial leaded two-connection packages
  - Conformal coating with uralane or parylene
  - Staking of tantalum capacitors and wire runs
  - Using cable ties
  - Electrical check-out of harness assembly
  - Rosin flux and 63/39 Sn-Pb solder
  - Mil-spec connectors: 38999 (circular), 39012 (RF), 24308 (mini-D), 83513 (micro-D)
  - Mil-spec wire and cable
  - Wire-to-wire splicing

# Standard vs. Non-Standard Technologies

**Non-Standard Technologies:**

- **Require special approval PRIOR to use**
- **Standard Workmanship rules MAY NOT apply**
- **Examples:**
  - Column Grid Array and Ball Grid Array Attachments (soon to become standard)
  - Modified commercial assemblies (COTS)
  - Pb-free solder
  - cPCI (solder tails) through-hole solder joints
  - Flex cable
  - >5 conductors in a crimp barrel
  - Cryogenic applications
  - Water soluble flux





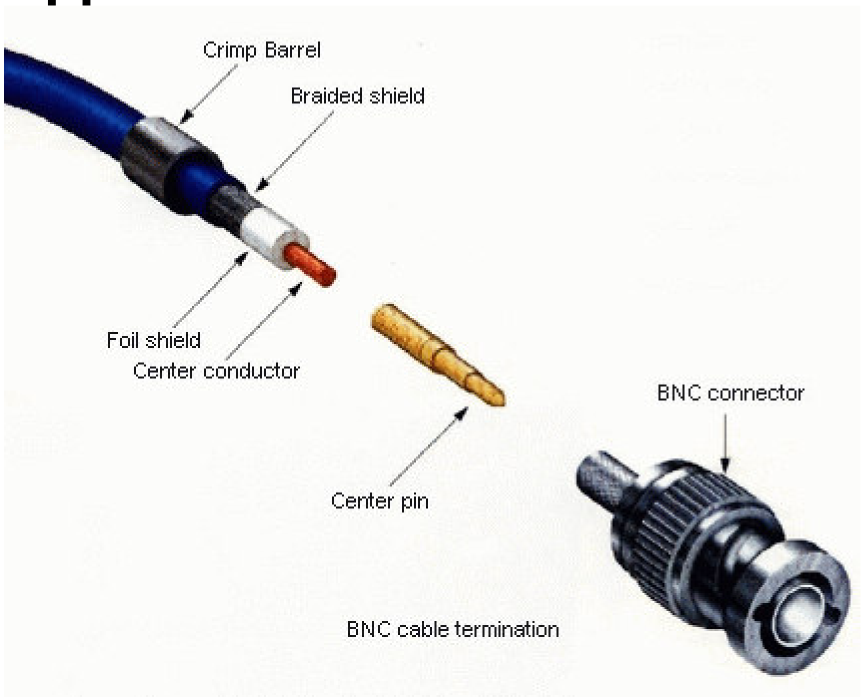
# Design and Processing Requirements

The NASA Workmanship Standards have always been intended to be implemented by the operator and the inspector.

Historically design and processing decisions were made by technicians using experience and corporate knowledge. Miniaturization challenges this approach.

NASA Workmanship Standards capture some well known and accepted design and processing practices

- Some point out that a designer needs to provide the information
- Some state the design rule



# Design and Processing Requirements

**Trend in the Workmanship Standards is to eliminate design requirements and avoid dictating process development**

**Workmanship Standards trending toward operator and inspector requirements only**

**Examples of design requirements being eliminated:**

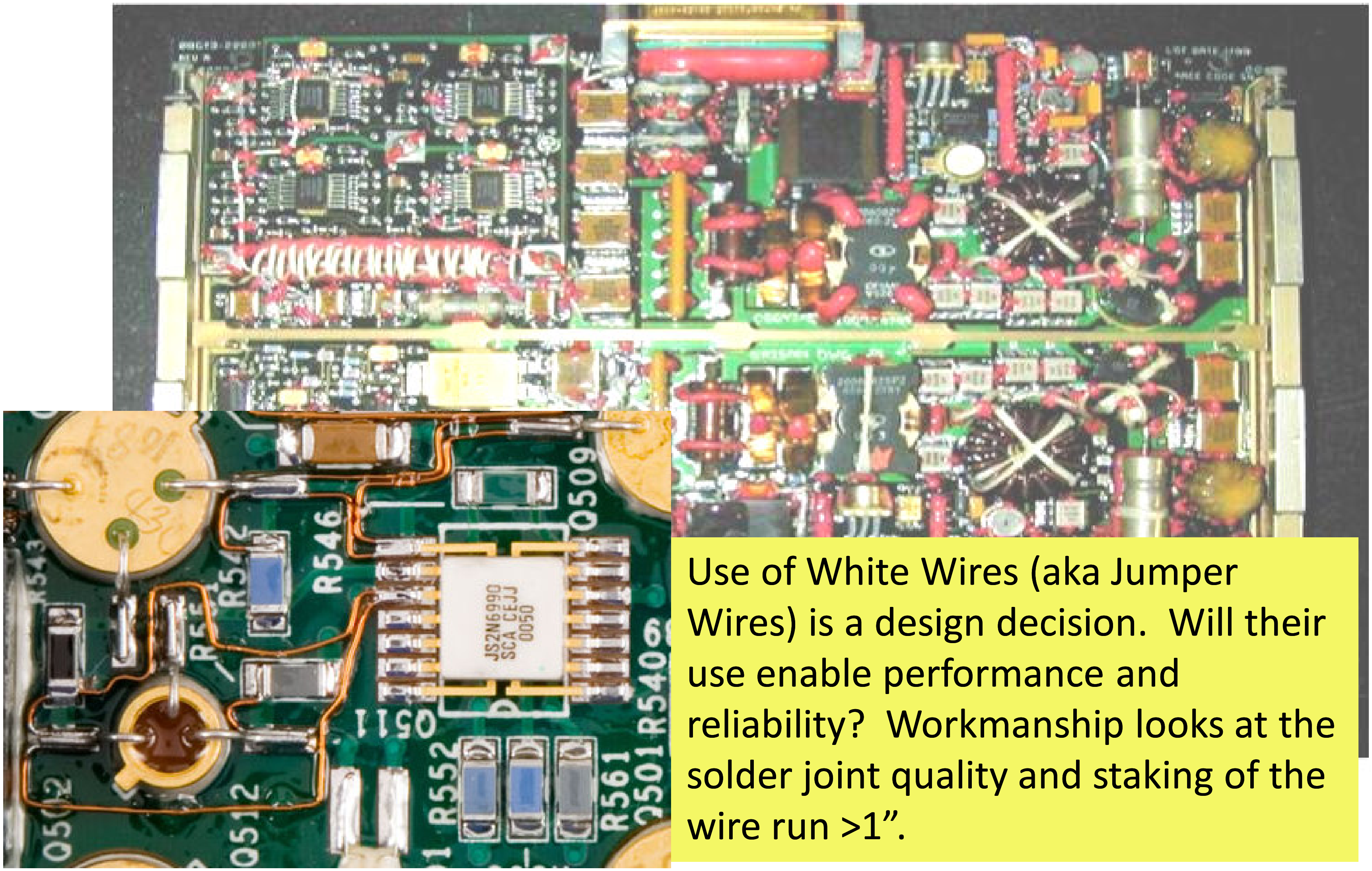
- High strength copper alloy is required for wires gauge 24 and smaller.
- Line voltages shall be limited to socket contacts (for safety).
- Materials to meet NASA-Std-6001, flammability, odor, offgassing
- Design of harnesses shall minimize RFI/EMI.

# Design and Processing Requirements

**Examples of "reminders" to designers and process engineers that will be removed:**

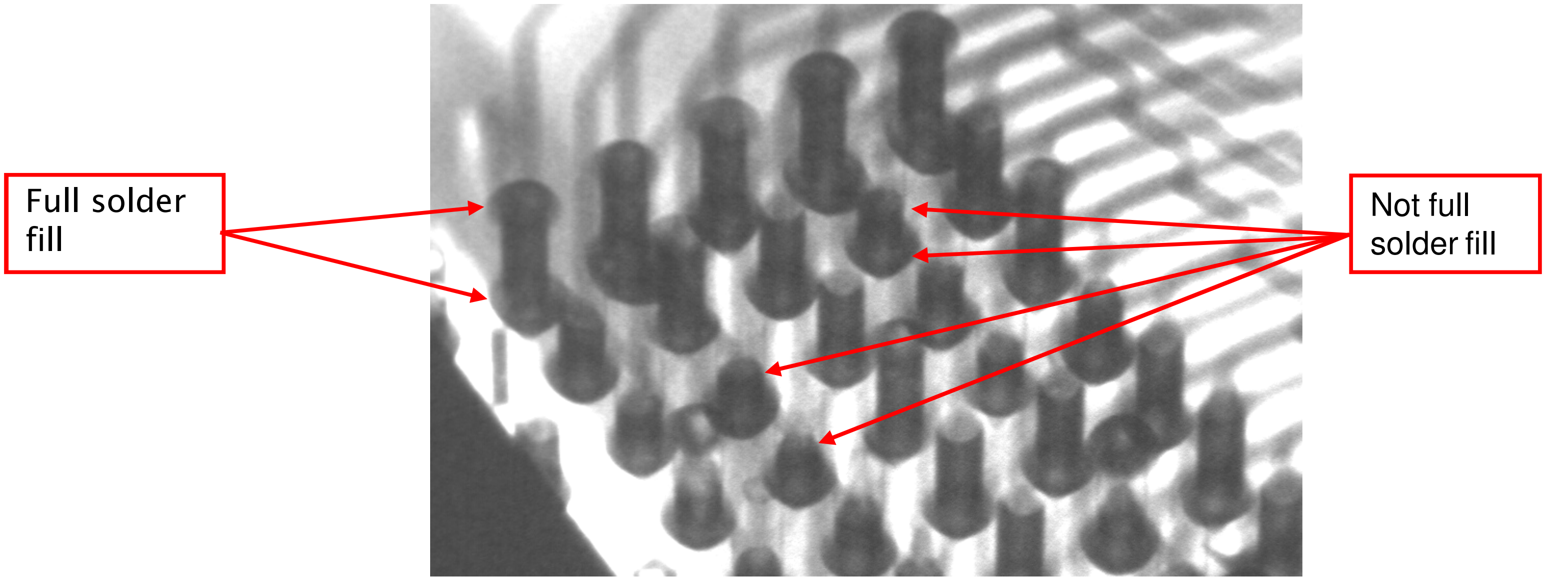
- Staking materials and locations must be defined on the engineering documentation
- Conformal coating material must be defined. Conformal coating materials with a fluorescent indicator are preferred
- Bond line requirements must be defined.
- Conformal coating maskant material and areas to be masked on PCBs must be defined
- Demoisturizing conditions for PWAs prior to polymeric applications (time, temperature, ramp rates) must be defined
- Harness design must plan use of heat-shrinkable sleeving, stress relief, methods for cable identification, preventing mis-mating of connectors

# Design and Processing Requirements




Use of White Wires (aka Jumper Wires) is a design decision. Will their use enable performance and reliability? Workmanship looks at the solder joint quality and staking of the wire run >1".

# New Technologies Need Refined Quality Criteria




When fully filled through-hole solder joints can be readily achieved then underfilled joints mark an un-optimized process and reduced performance margin

But how much reduction in design margin?  10x to 9x?  3x to 1.2x?
*If fully filled joints are readily achievable, quantifying margin is less interesting.*
*If fully filled joints are not readily achievable, quantifying margin is quite interesting.*

# Topics NOT COVERED by Workmanship Standards

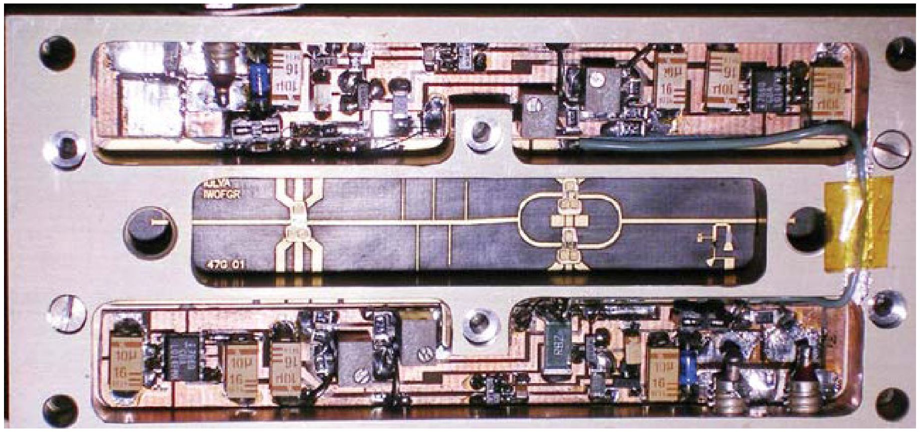
Reliability prediction for standard or non-standard technologies, configurations, and materials

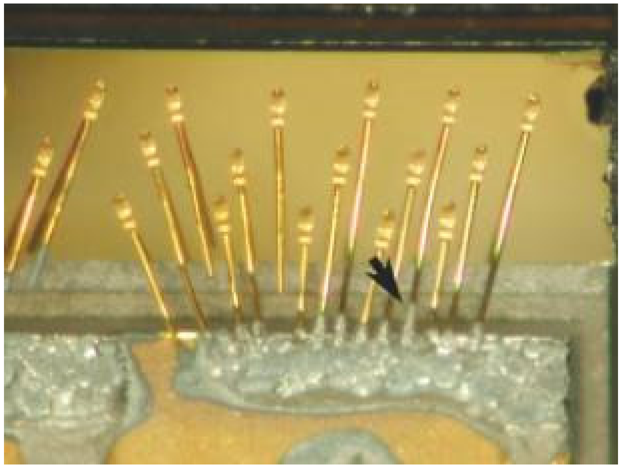
Operating procedures

Printed Circuit Board quality criteria and design rules

Electronic packaging and electrical harness design rules (*except some which are going away*)

Hybrid Microcircuit quality rules (e.g. wire bonding, die attach, hermetic seals, thick-film substrates)





# Part I Summary

**The Workmanship Standards:**

*are* **Directed at operators and inspectors**

**Provide processing instructions (and some design rules)**

**Provide screening criteria for known defects for standard technologies, configurations, and materials**

**Remove units with defects from mission subsystems at a low level of assembly when it is less expensive to repair.**

**Require suppliers to seek prior approval for the use of non-standard technologies, configurations, and materials**

**Require suppliers to justify use of non-standard technologies, configurations, and materials with qualification data**

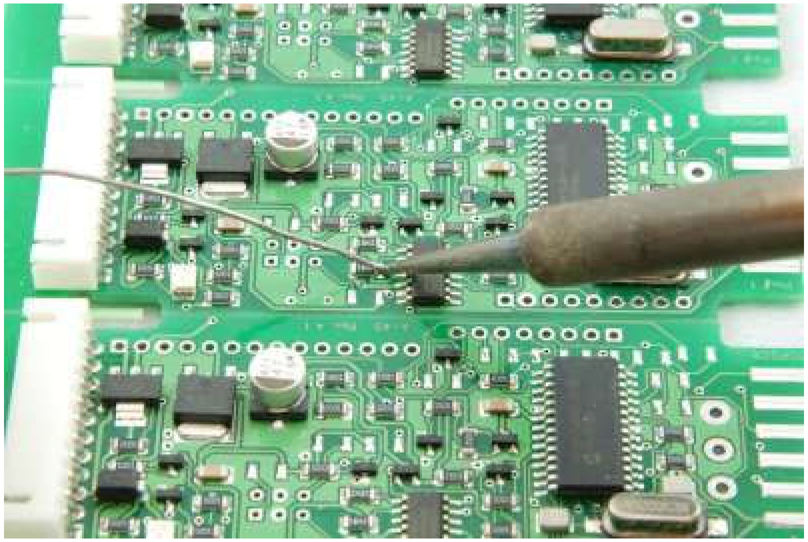
**Require suppliers to define relevant inspection criteria for non-standard technologies, configurations, and materials.**

# Part II: Workmanship Program Authority

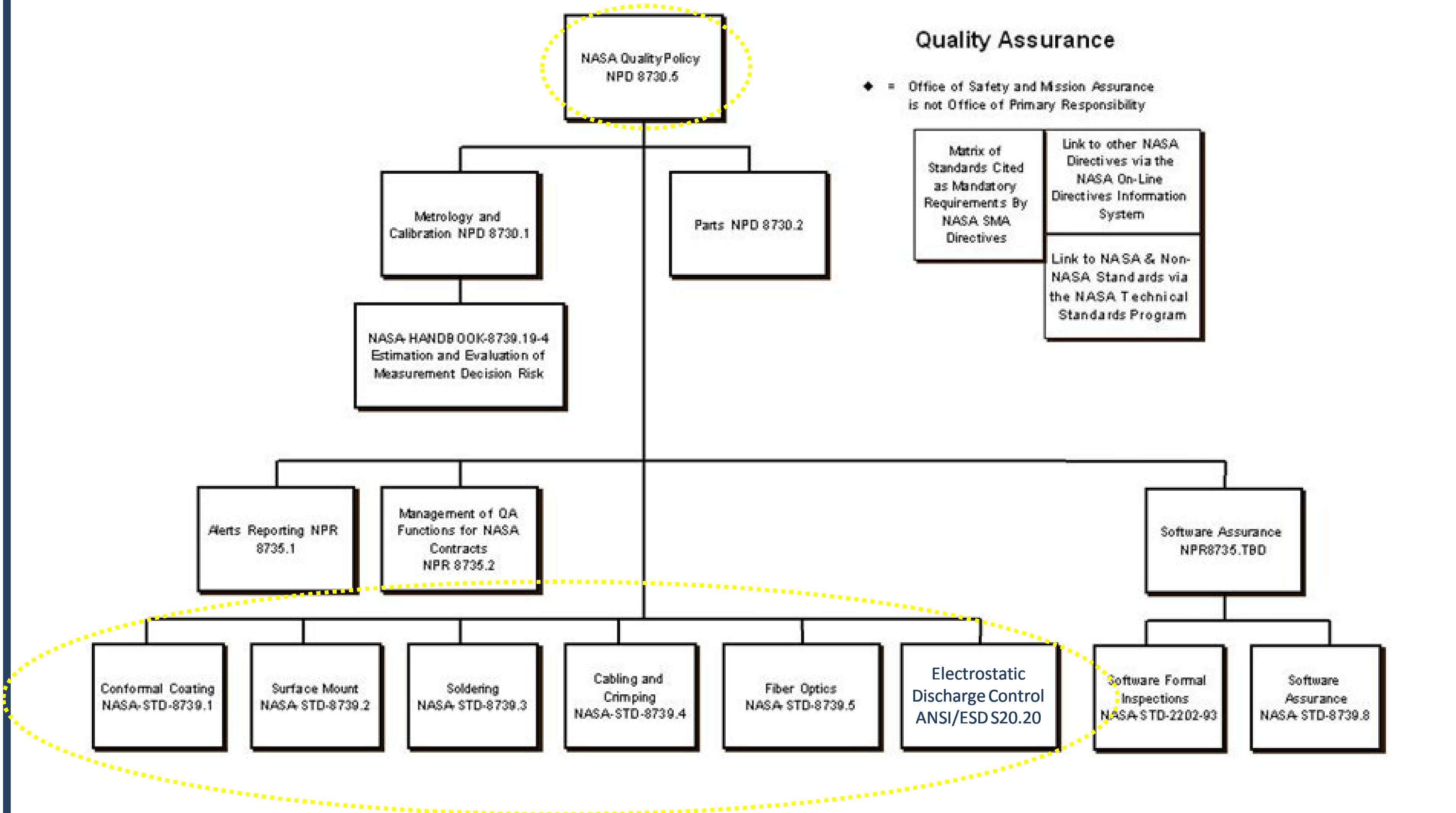
How does NASA Headquarters provide for a common Workmanship quality baseline across the Agency?

How does that system maintain the baseline requirements and promote and explain the information?

Why do we use some NASA Standards and some Industry Standards?



# NASA Workmanship Standards Program Authority



# NASA Workmanship Standards Program Authority

»NASA-STD-8739.1  Polymeric Applications

»NASA-STD-8739.2  Surface Mount Technology

»NASA-STD-8739.3  Soldered Electrical Connections

»NASA-STD-8739.4  Crimp, Cable and Harnesses

»NASA-STD-8739.5  Fiber Optic Terminations

»NASA-STD-8739.X  Workmanship  Implementation Requirements

»ANSI/ESD S20.20   Electrostatic Discharge Control

»IPC J-STD-001ES  Space Applications Electronic Hardware Addendum to J-STD-001D Requirements for Soldered Electrical and Electronic Assemblies

*All Programs and Projects must baseline these requirements and must flow them to all prime contractors and subcontractors. NPD  8709.20 describes the process for seeking relief. Authority for granting relief is NASA HQ OSMA.*

# NASA Workmanship Standards Program Authority

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## Program CoP Site
https://secureworkgroups.grc.nasa.gov/workmanship

Monthly telecoms

Shared documents for coordination

Shared lessons learned

Notices of ballot actions

## Program Public Site
http://nepp.nasa.gov/workmanship

Links to Standards

Application Notes

Links to Training Centers

Lists of Industry Standards

Shared lessons learned

POCs for WSTC

# NASA Workmanship Standards Program Authority

## OMB Circular A-119

*1995, 1998*

MEMORANDUM FOR HEADS OF EXECUTIVE DEPARTMENTS AND AGENCIES

SUBJECT: Federal Participation in the Development and Use of Voluntary Consensus Standards and in Conformity Assessment Activities

Revised OMB CircularA-119 establishes policies on Federal use and development of voluntary consensus standards and on conformity assessment activities. Pub. L. 104-113, the "National Technology Transfer and Advancement Act of 1995," codified existing policies in A-119, established reporting requirements, and authorized the National Institute of Standards and Technology to coordinate conformity assessment activities of the agencies…

- ….Your agency must use **voluntary consensus standards**, both domestic and international, in its regulatory and procurement activities in lieu of government-unique standards, unless use of such standards would be inconsistent with applicable law or otherwise impractical. In all cases, your agency has the discretion to decline to use existing voluntary consensus standards if your agency determines that such standards are inconsistent with applicable law or otherwise impractical.

- (1) "Use" means incorporation of a standard in whole, in part, or by reference for procurement purposes, and the inclusion of a standard in whole, in part, or by reference in regulation(s).

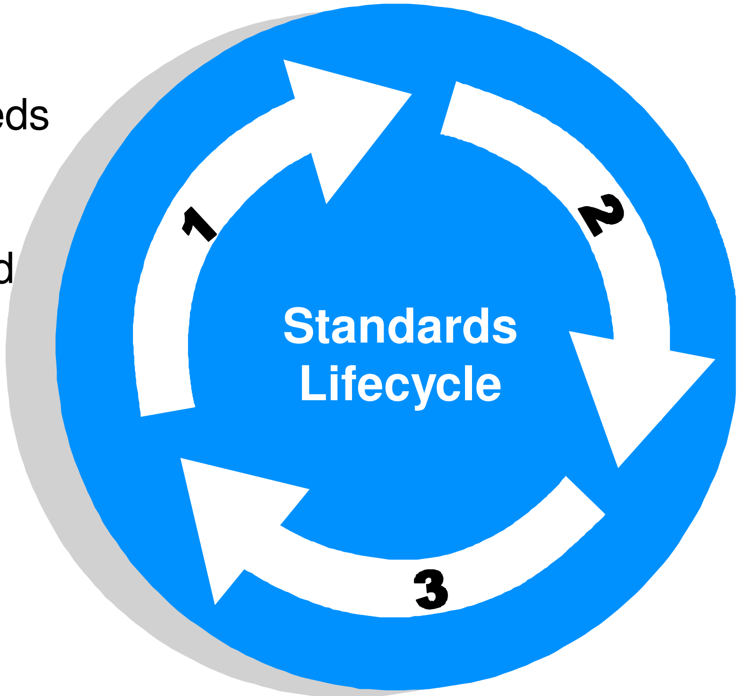
  (2) "Impractical" includes circumstances in which such use would fail to serve the agency's program needs; would be infeasible; would be inadequate, ineffectual, inefficient, or inconsistent with agency mission; or would impose more burdens, or would be less useful, than the use of another standard.

# Process for Adopting and Maintaining Industry Standards for Workmanship

✓Achieve Meets-or-Exceeds

✓Training Programs, Supporting Standards, and Supporting Requirements

✓Impact to Contracts and Quality Processes




✓Document Adoption

✓Facilitate Use of New Document System

✓React to Cross-Industry Change Proposals

✓Coordinate NASA-driven Changes

# Status of Industry Standards for Workmanship as of January 2011

IPC-A-620xS Space Addendum (Cable/Harness):

Requirements gap analysis complete

NASA Centers rated gaps for risk

Preparing inputs to document coordination to close high risk gaps.

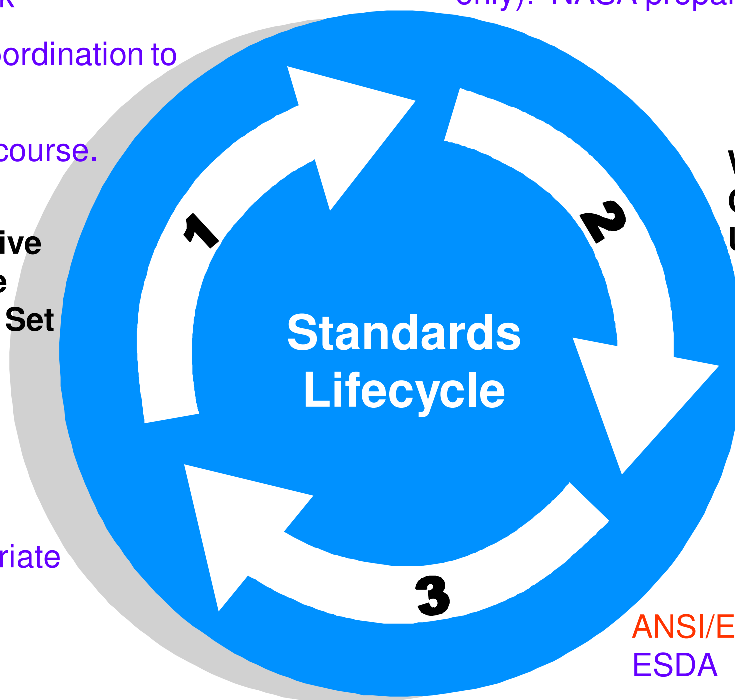
Developing Space-only training course.

J-STD-001xS Space Addendum (Soldering):
NASA coordinating adopting policy (NPD 8730.5)

NASA coordinating implementation standard (gap filler, NASA-STD-8739.X)

IPC to offer two training courses (all quality levels, Space-only). NASA preparing Space-only course for IPC.

**Ensure Cohesive Implementable Requirements Set**




**Widespread & Consistent Usage**

ANSI/ESD S20.20 (ESD):

QAAR Audits

NASA-HDBK-8739.21

NASA-STD-8739.1 (Polymeric Applications):

Gap analysis in process

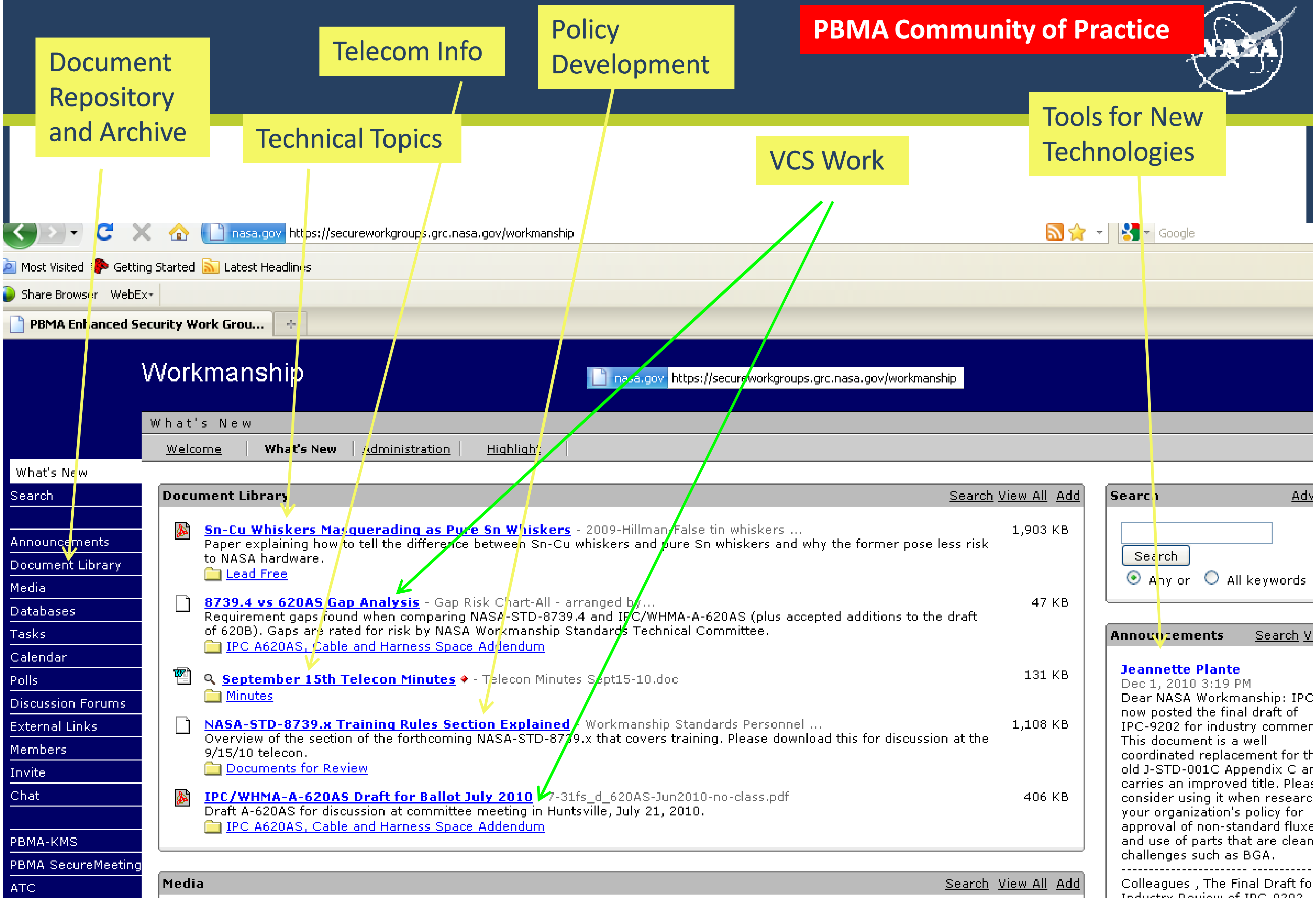
Polling stakeholders on appropriate VCS for content (if any).

**Document Stewardship**

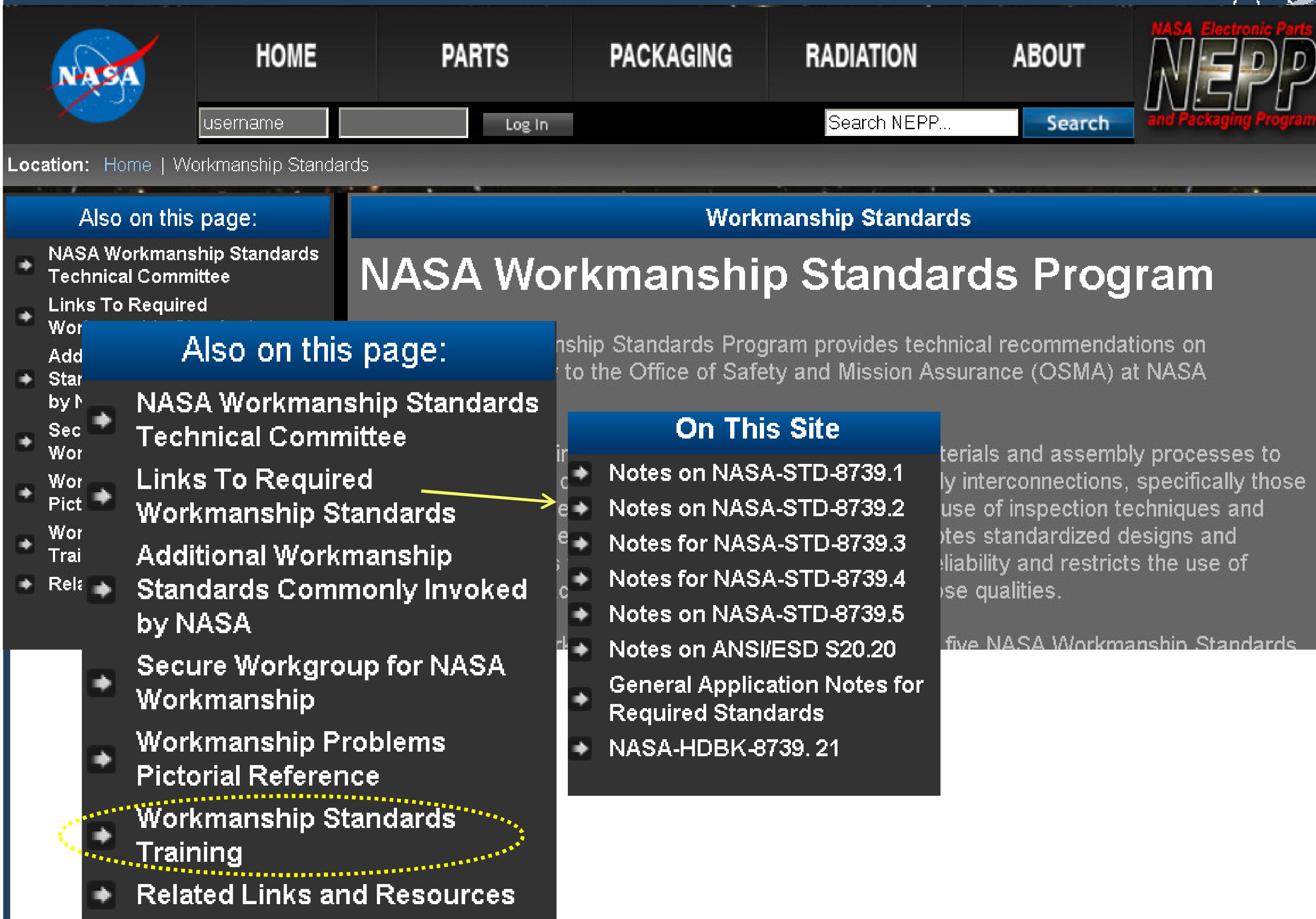
ANSI/ESD S20.20:
ESDA Standards activities

IPC J-STD-001xS:
IPC committee meeting coverage

# PBMA Community of Practice



http://nepp.nasa.gov/workmanship



# NASA Workmanship Standards Program Authority

## There is no third party certification for compliance to NASA or VCS Workmanship Standards.

- NASA uses Program, Project, and contract requirements to **impose the Workmanship requirements**
- NASA uses NSC audits, Project quality engineering oversight, and DCMA to **verify supplier capability and ongoing compliance**

- COTS suppliers may offer compliance with VCS (e.g. IPC Standards) however the supplier's interpretation of the requirements may not be NASA's (e.g. use of IPC-STD-001 Class 3, or IPC-A-610, instead of J-STD-001ES or NASA-STD-8739.2)
- DoD contracts are not required to specify Workmanship requirements. DoD do not use supplier assessments or quality oversight that include Workmanship (except Army AMCOM). Suppliers offer what they use to military customers using their own interpretation of and adherence to the requirements.

**Use of military subsystems or COTS subsystems may not meet NASA Workmanship requirements.**

# Summary of Workmanship Standards Program Authority

## The Workmanship Standards Program:

Is delegated to the Program Manager from HQ OSMA (Technical Authority)

The Program Manager advises HQ OSMA on policy and technical issues relative to Workmanship

The Program Manager seeks inputs for establishing and maintaining Agency Workmanship Standards from the NASA Workmanship Standards Technical Committee

The Workmanship Program is mandated to adopt VCS's where practicable

Two websites are used to disseminate and collect information on NASA Workmanship for the Program; one is secure and one is public.

# Part III: Example of Workmanship Requirements

- General
- Polymeric Applications
- Surface Mount and Hand Soldering
- Cables and Harnesses
- Fiber Optic Harnesses

# Facilities, Tools, and Equipment

**Temperature:** 24±3$^{o}$C (75±5$^{o}$F), 30% to 70% Relative Humidity (RH)

**Safety:** chemical handling and storage, ESD wrist-straps are not human protection devices

**Cleanliness:** use and maintenance of production area for intended use, no food, control of foreign object debris (FOD), proper storage of hardware in-process and after processing.

<u>For polymeric operations silicone operations must be segregated</u>

**Tool Calibration:** per ANSI/NCSL Z540.1

# Facilities, Tools, and Equipment

**Light Intensity:** a minimum of 1077 Lumens per square meter (Lm/m$^2$) (100 foot - candles)

**Magnification:** simultaneous viewing in both eyes, accurate color rendering, shadowless, 1x to 10x magnification

**ESD Control:** language being changed to point to ANSI/ESD S20.20.

# Personnel Training and Certification

**Personnel:** Operators, Inspectors, Level B Instructors

**Certification:** Guarantee employer makes that operator, inspector, instructor meets four minimum criteria:

Training biennially, Vision biennially , Competency, Continuous activity <6 months inactivity

**Local Trainer = Level B Instructor:** Local trainers may be used but must be trained by NASA master trainer (at JPL or GSFC school). Course materials will be provided.

**Courses:** Students may take classes at NASA training centers or from a locally employed Level B instructor. Level B courses shall be made available for review and approval on a project-by-project basis.

# Personnel Training and Certification

## Training for adopted VCS's

**IPC J-STD-001xS:** Must use IPC-certified trainer. May use one of the two IPC courses available (modular version, or non-modular version). May use "home grown" course. Course material shall be made available for review and approval on a project-by-project basis.

**ANSI/ESD S20.20:** Must develop a local implementation plan (local = plant). Must train to local plan. ESDA generic courses, SATURN generic course not sufficient for operators, program monitors, instructors.

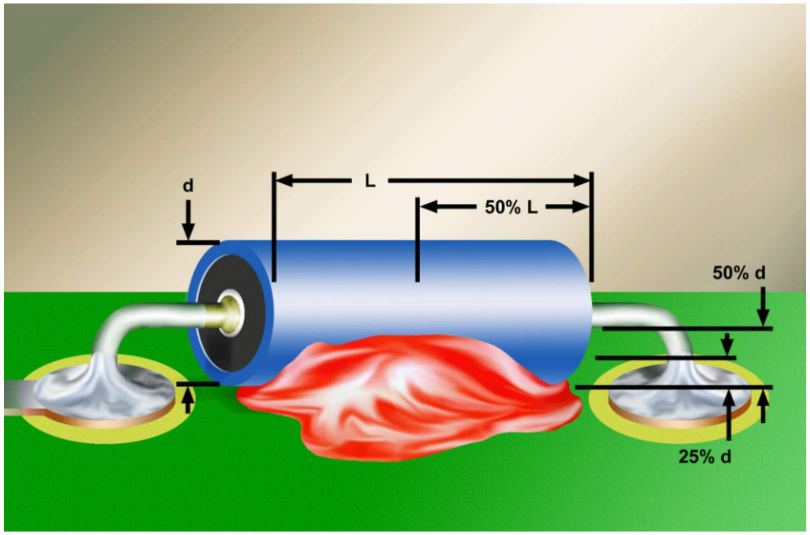
**NASA-STD-8739.X to contain 16-page appendix to explain certification and training requirements.**

# Polymeric Applications

**Polymer Material Processing:** material storage, traceability records, batch mixing, witness sample (test specimen), hardness test

**PWA preparation:** cleaning, solvents, cleanliness test, demoisturizing, priming, masking

**Staking:** Tantalum capacitors, wire runs >1". For all others <u>if part is marked for staking on the drawing</u>, must use 8739.1 requirements.

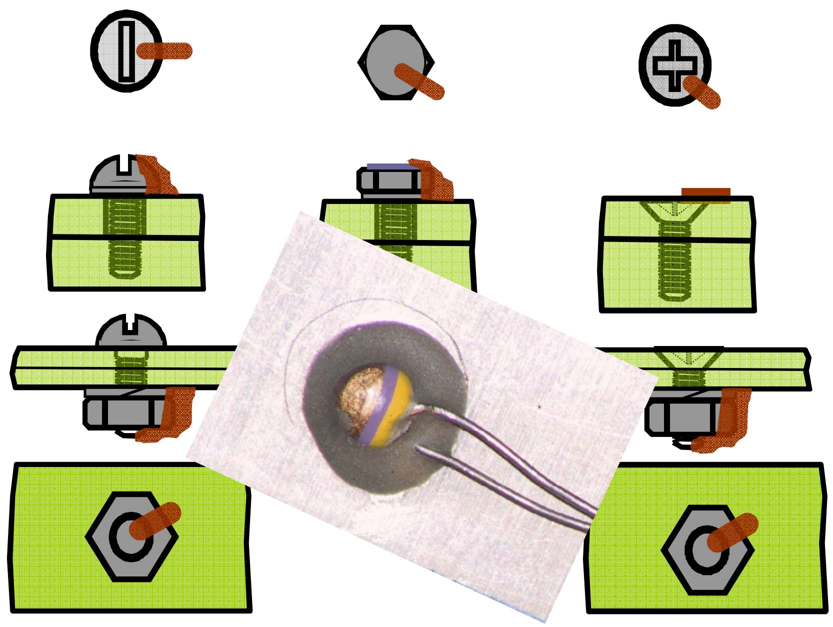


# Polymeric Applications

**Fastener Staking:** applied to fastener, amount defined, thread locking, torque striping

**Conformal Coating:** brushing, spraying, vacuum deposit, dipping, pre-cure thickness measurement, bubbles, bridging, lead interference, UV inspection, FOD

**Bonding:** Bondline thickness must be defined by engineering, squeezout control, voiding must be defined by engineering, one lead free for thermistors

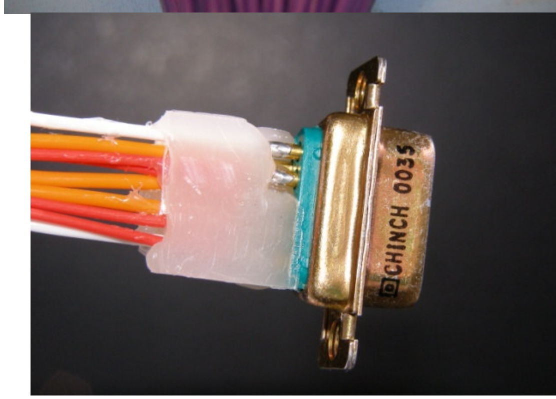


# Polymeric Applications

**Encapsulation:** (Potting) vacuum degass material, pre-cure inspection of coverage and bubbles, post-cure inspection for large voids, cracks, excess material

**Quality Requirements Chapter:**

Every NASA Workmanship Standard contains a requirements summary section for ease of use by inspectors. All “shall’s” are repeated from earlier sections.



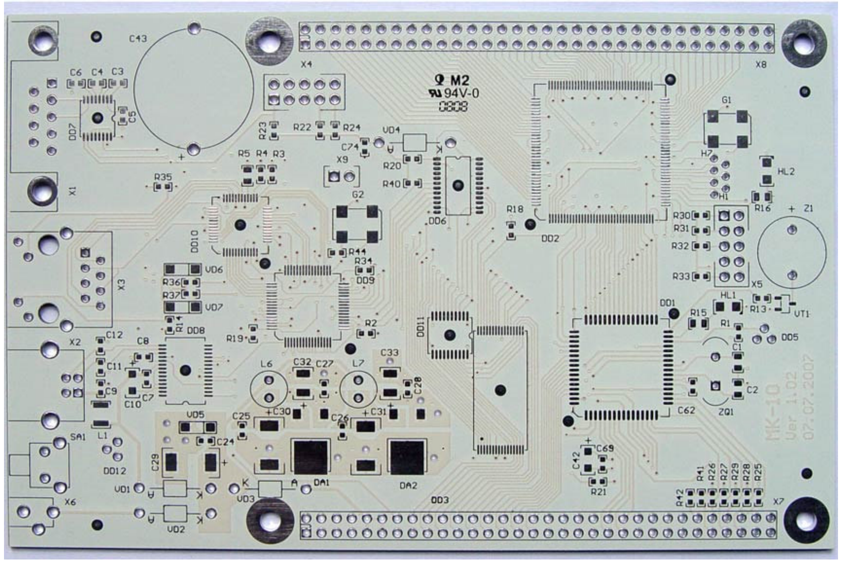
# Machine and Hand Soldering

**Tools:** Heat source selection and control (soldering iron, hot gas, radiant)

**Materials:** Eutectic solder, rosin flux, control of solder pot alloy quality

**Cleaning:** Clean bare boards, solvents, cleanliness test, demoisturizing

**Soldering Prep:** Solder paste slump and oxidation test, deposition methods (screen, stencil, syringe)



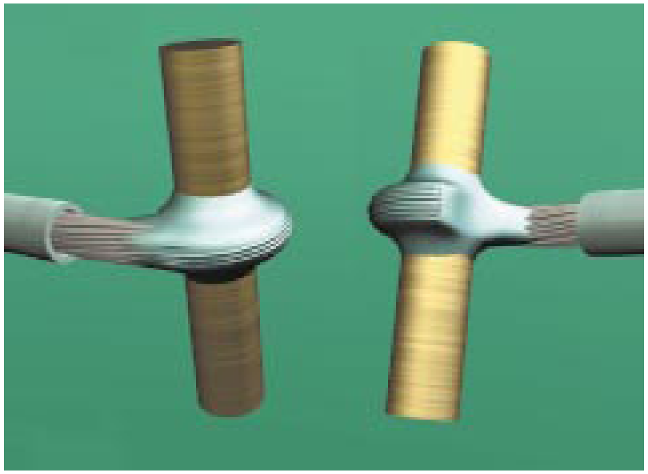
# Machine and Hand Soldering

**Soldering Prep:** lead coplanarity, bending tools, thermal shunts, lead tinning, removal of thick gold, lead and PCB defects, shrink sleeve glass-bodied parts, pre-reflow lead position on solder pad, clearance of wire insulation

## Part Solderability is required

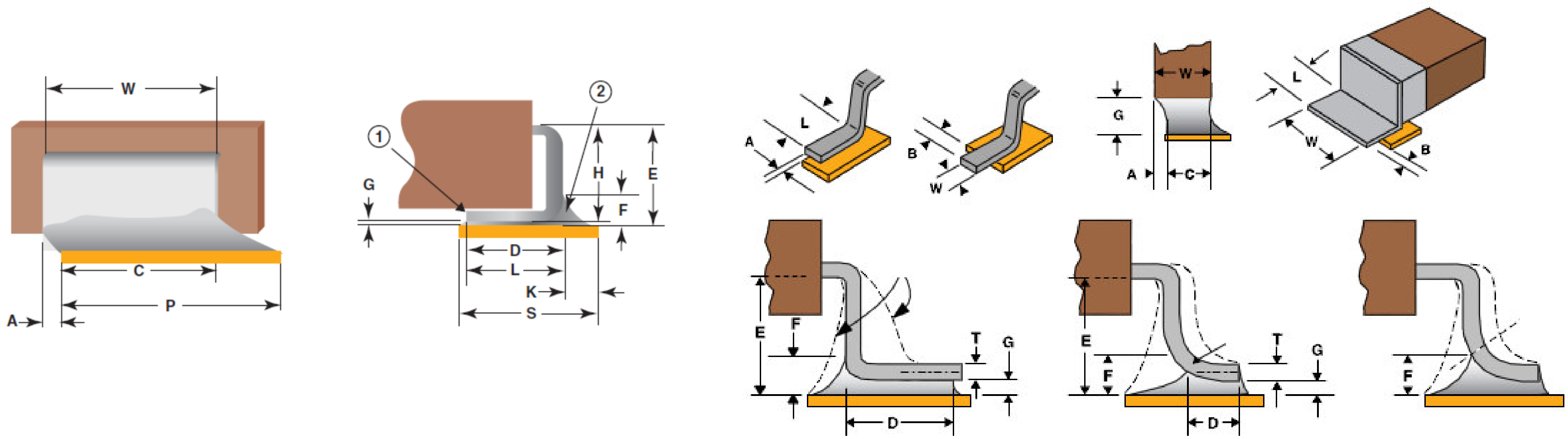
**Hand-soldered part installation:** terminals, wrapped wires, connector contacts, termination on alternate side of part or both sides.

**Reflow:** Process run records, parameter control, post process cleaning



# Machine and Hand Soldering

**Solder Joint Geometry & Surface Appearance:** Cracks, overhang/offset, blow holes, flux residue, stress lines, fillet height, coverage/wetting, excess material

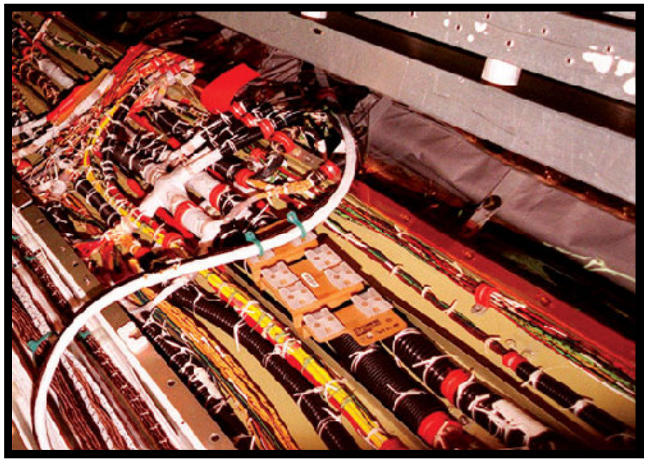


# Cable and Harness

**Design Considerations:** wire gauge selection, redundancy, contact assignments, routing, bend radius, use of splices, use of sealing plugs, potting connectors, signal isolation and use of EMI shielding, use of identifier marking and tags

**Processing prep:** use of full-sized mock-ups and wiring boards, protection of harness in-process and in storage.

**Harness Assembly:** Lacing cord stitches, tie wraps, dress of fabric braid layer, spiral wrap sleeving, heat shrinkable sleeving.



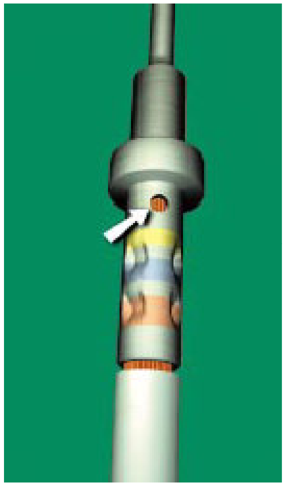
# Cable and Harness

**Cable and Wire prep:** wire strip, damaged conductors and insulation, wire lay, insulation clearance, pre-tin for solder cups, cable jacket removal

**Shield prep:** ground connections, dress, and crimp rings

**Crimp contacts:** contact quality, crimp tool type and calibration, contact/conductor combinations, crimp quality check using pull test

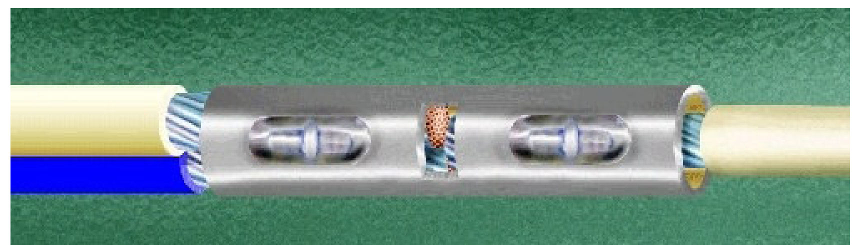
**Connector assembly:** contact installation, sealing plugs, cable clamps, contact seating tests,



# Cable and Harness

**Splices:** several types defined; solder and non-solder

**Electrical acceptance testing:** continuity, insulation resistance, dielectric withstanding voltage, for coax Voltage Standing Wave Ratio (VSWR), and time domain reflectometry (TDR), before and after installation

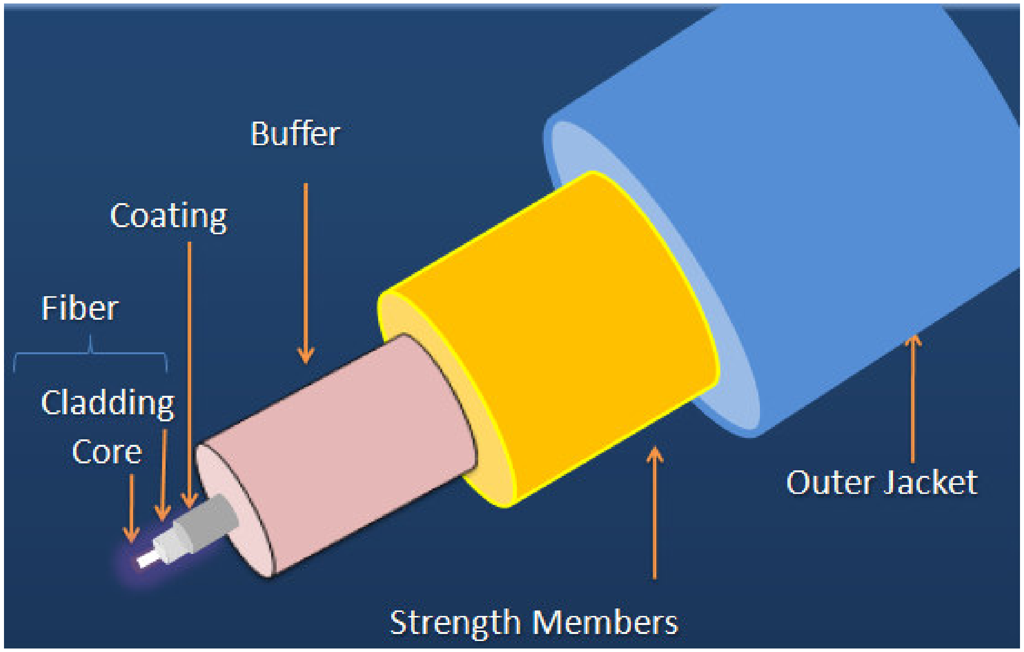


# Fiber Optic Cables

**Materials:** solvents, selection and use of adhesives, traceability of materials, adhesive storage conditions, shelf life and pot life , chemical strippers

**Personal protection:** from glass slivers, eye protection, waste disposal

**Cable prep:** removal of moisture, cable jack and buffer preconditioning, cable layer removal processes

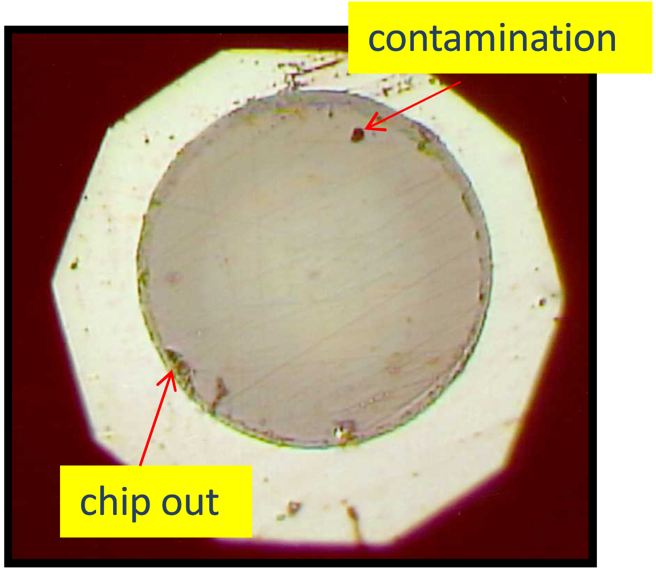


# Fiber Optic Cables

**Fiber end face prep:** ferrule quality check, cleave fiber, polish, inspect, cleaning, protection with dust caps

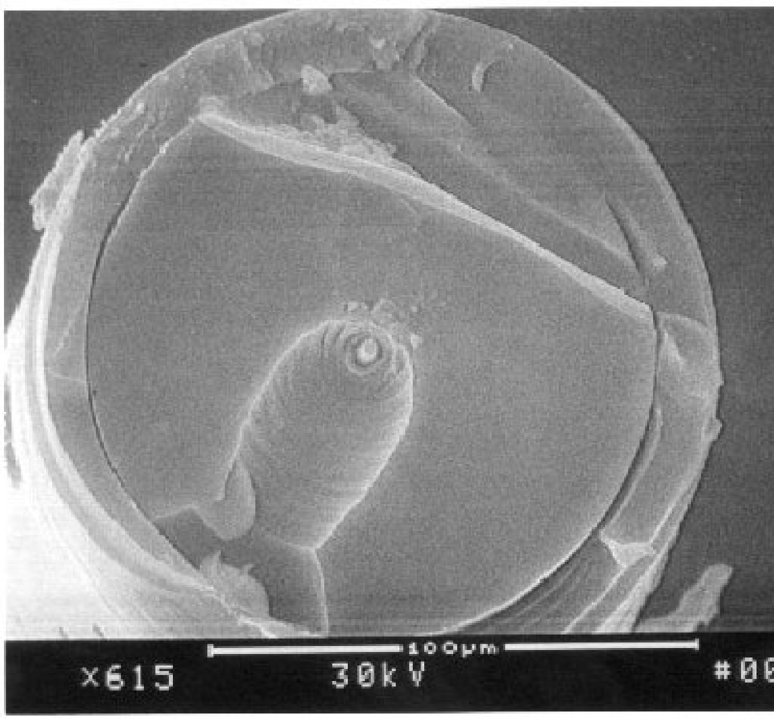
**Splices:** only fusion type allowed for mission hardware, use strength members for stress relief, no loss of tensile strength in cable, optical time domain reflectometry (OTDR) and attenuation testing

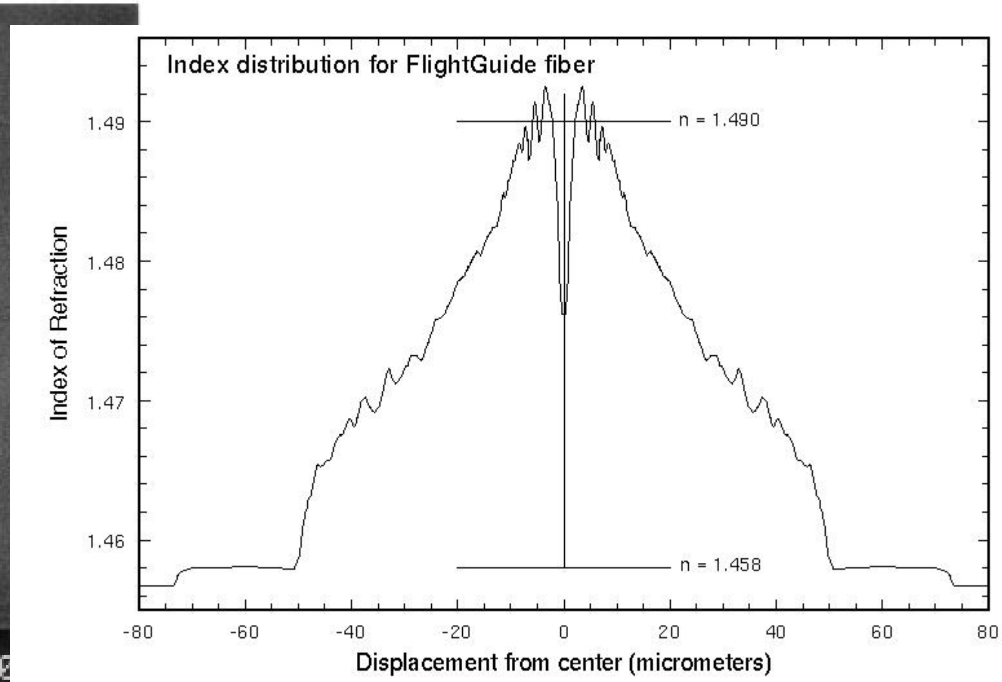
**Design considerations:** cable bend radius, use of splice trays, microbending from cable ties, distinguish from RF cables with marking, cable exits coaxially behind connector for at least 2”.



# Fiber Optic Cables

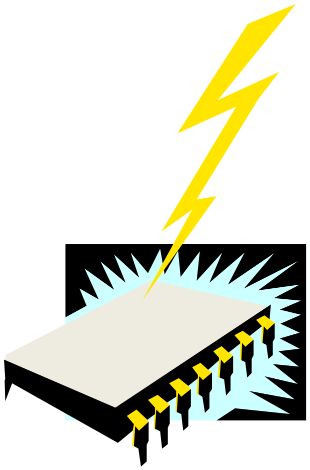
**Quality inspection:** magnification of 50X – 200X, 100X - 200X for end faces, cracks in end face, cracks in epoxy line, fiber pistoning, buffer or jacket shrink, ferrule quality check, cleave fiber, polish, inspect, cleaning,



# Part IV:  Electrostatic Discharge


- What is ESD?
- NASA technical standard (VCS)
- Local program responsibilities
- Resources



# Electrostatic Discharge

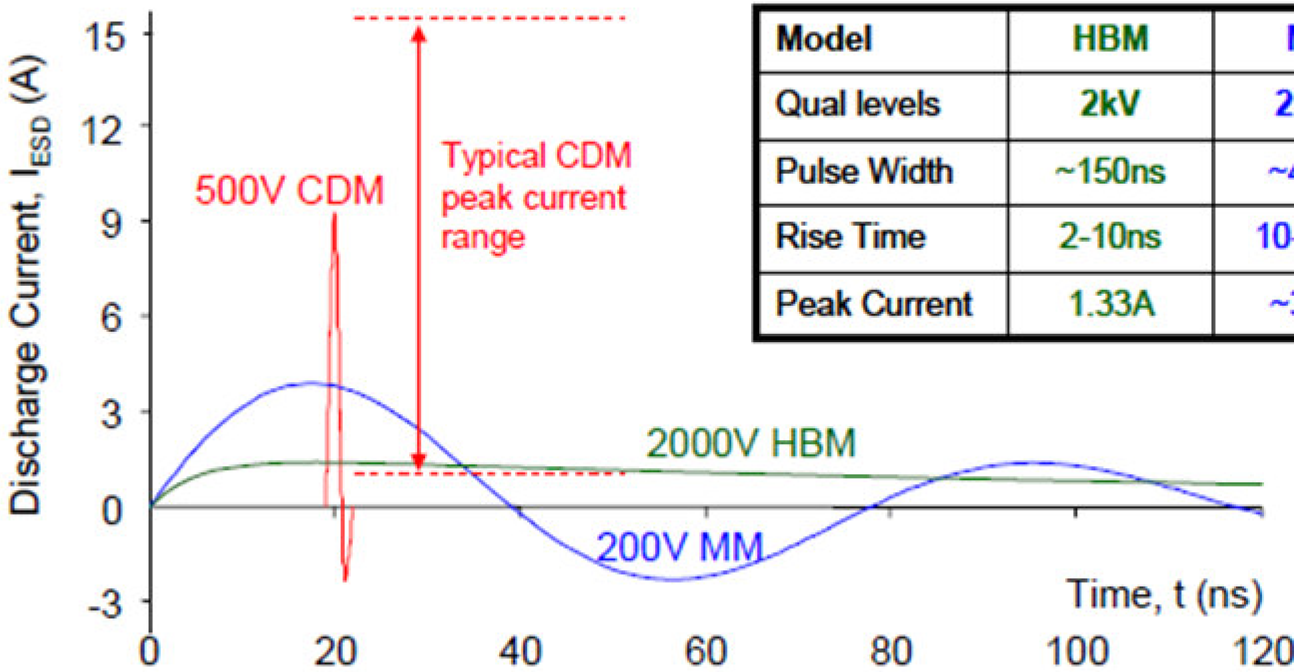
ESD Events are a sudden release of charge through the most readily available low-resistance path to ground. When this circuit runs through mission hardware, the resulting current can be damaging to electronics.

ESD control methods reduce charge build up and provide low-resistance circuit paths to ground that divert discharge currents away from mission hardware.

# Electrostatic Discharge

Different discharge paths lead to different current/time/energy results.

ESD control methods must be tailored to the event type.




| Model | HBM | MM | CDM |
|---|---|---|---|
| Qual levels | 2kV | 200V | 500V |
| Pulse Width | ~150ns | ~40ns | ~1ns |
| Rise Time | 2-10ns | 10-15ns | 100-500ps |
| Peak Current | 1.33A | ~3.6A | 1-16A |

[Gieser] (modified)

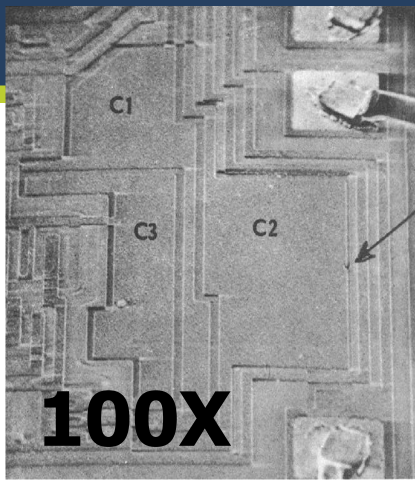
# Electrostatic Discharge

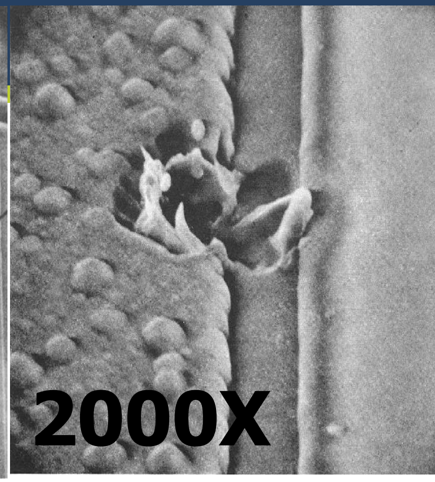
•**Human Body (HBM):** discharging event through the body and the part to ground.

• **Machine (MM)**: discharge voltage through automated handling equipment or hand-tools and the part to ground.

• **Charged Device (CDM)**: discharge into or out of a part due to charge accumulation within the part itself.

| Examples of Sources of Threats (charge or discharge path) | HBM | MM | CDM |
|---|---|---|---|
| Operator | √ | | |
| Work bench | √ | | |
| Pick and Place Machine | | √ | |
| Automatic Test Equipment | | √ | √ |
| Device package charging/discharging | | | √ |
| Mate/De-mate of harnesses | | | √ |
| RF Signals (including cell phone signals) | | | √ |


C1
C3
C2
100X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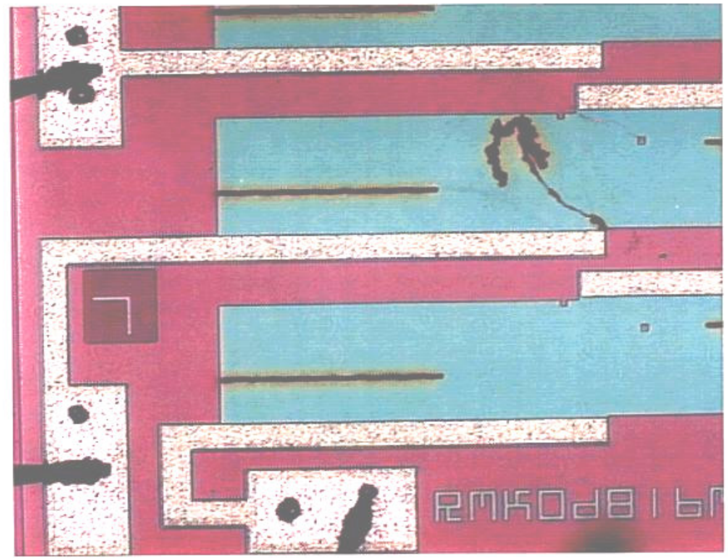

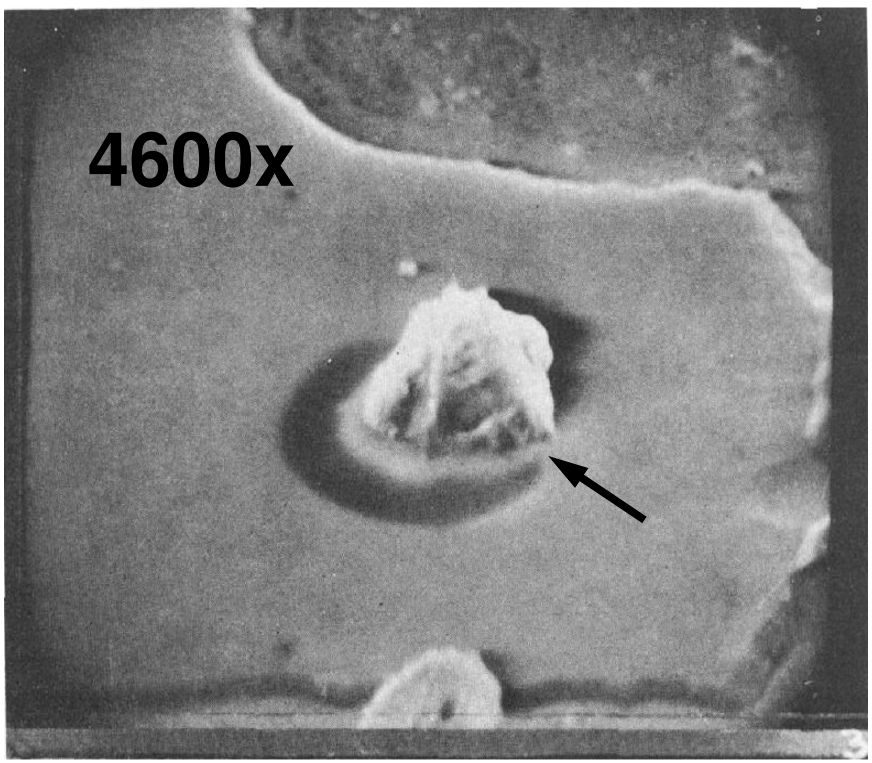
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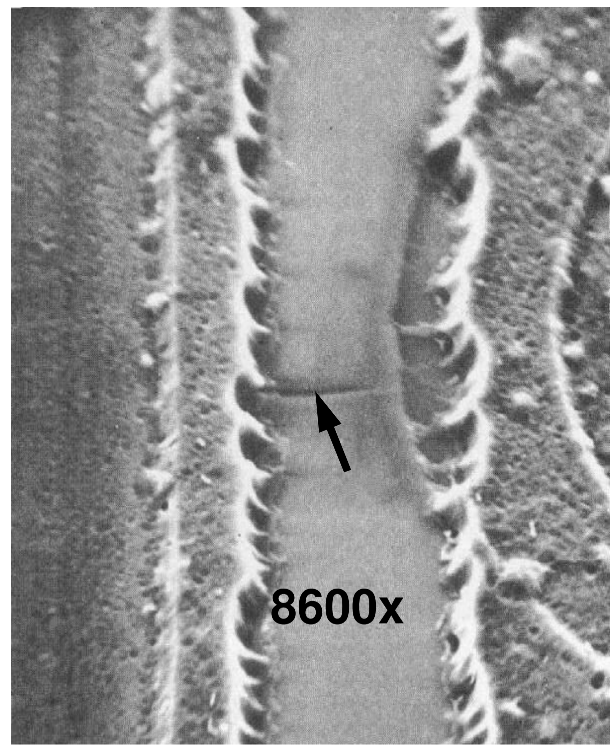

8600x

# Refers to 38 standard procedures and test methods

ANSI/ESD SP3.3 Verification of Air Ionizers.

ANSI/ESD S4.1 Work Surfaces Resistance

ANSI/ESD STM4.2 Work Surfaces Charge Dissipation

ANSI/ESD S6.1 Grounding

ANSI/ESD STM97.1 Floor Materials Resistance

ANSI/ESD S8.1 ESD Awareness Symbols

ANSI/ESD STM9.1 Footwear Resistance

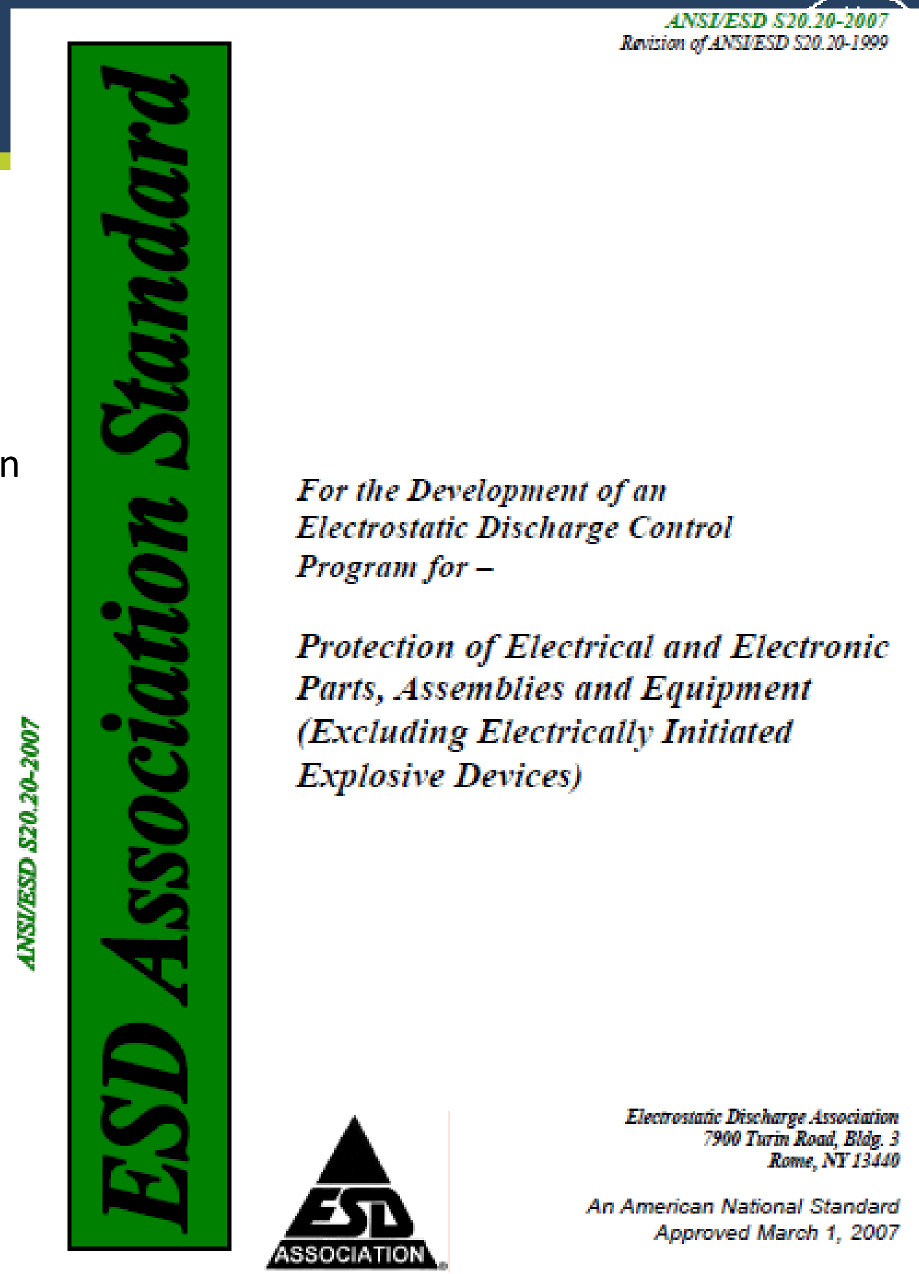
ESD SP9.2 Foot Grounders Resistance

ANSI/ESD STM11.31 Evaluating Shielding Bags

ESD STM13.1 Soldering/Desoldering Hand Tools

ANSI/ESD SP15.1 Gloves and Finger Cots

ANSI/ESD S541 Packaging Materials



ANSI/ESD S20.20-2007
Revision of ANSI/ESD S20.20-1999

ANSI/ESD S20.20-2007

ESD Association Standard

*For the Development of an Electrostatic Discharge Control Program for –*

*Protection of Electrical and Electronic Parts, Assemblies and Equipment (Excluding Electrically Initiated Explosive Devices)*

ESD ASSOCIATION

Electrostatic Discharge Association
7900 Turin Road, Bldg. 3
Rome, NY 13440

An American National Standard
Approved March 1, 2007

## 7.1 ESD Control Program Plan

The Organization **shall** prepare an ESD Control Program Plan that addresses each of the requirements of the Program. Those requirements include:

- Training
- Compliance Verification
- Grounding / Equipotential Bonding Systems
- Personnel Grounding
- ESD Protected Areas Requirements
- Packaging Systems
- Marking

Table 3. EPA ESD Control Items

| ESD Control Item | Product Qualification[1] | | Compliance Verification | |
|---|---|---|---|---|
| | Test Method | Required Limit(s)[2] | Test Method | Required Limit(s) |
| Worksurface | ANSI/ESD S 4.1 and/or ANSI/ESD STM 4.2 | $< 1 \times 10^9$ ohms and/or < 200 volts | ESD TR53 Worksurface Section | $< 1 \times 10^9$ ohms |
| Wrist Strap Cord | ANSI/ESD S1.1 | $0.8 \times 10^6$ to $1.2 \times 10^6$ ohms | For compliance strap system | |
| Wrist Strap Cuff | ANSI/ESD S1.1 | Interior $< 1 \times 10^5$ ohms<br>Exterior $> 1 \times 10^7$ ohms | | |
| Wrist Strap Cord Bending Life | ANSI/ESD S1.1 | > 16,000 cycles | | |
| Footwear | ANSI/ESD STM9.1 | $< 1 \times 10^9$ ohms | See Table 2 | |
| Foot Grounders | ESD SP9.2 | $< 1 \times 10^9$ ohms | See Table 2 | |
| Flooring | ANSI/ESD S7.1 | $< 1 \times 10^9$ ohms | See Table 2 | |
| Seating | ANSI/ESD STM 12.1 | $< 1 \times 10^9$ ohms | ESD TR53 Seating Section | |
| Ionization other than Room Systems | ANSI/ESD STM 3.1<br>- Discharge time<br>- Offset voltage | User defined<br>$< \pm 50$ volts | ESD TR53[3]<br>- Discharge time<br>- Offset voltage | |
| Ionization (Room Systems) | ANSI/ESD STM3.1<br>- Discharge time<br>- Offset voltage | User defined<br>$< \pm 150$ volts | ESD TR53[3]<br>- Discharge time<br>- Offset voltage | |
| Shelving | ANSI/ESD S4.1 | $< 1 \times 10^9$ ohms | ESD TR53 Worksurface Section | $< 1 \times 10^9$ ohms resistance to ground |
| Mobile Equipment (Working Surfaces) | ANSI/ESD S4.1 | $< 1 \times 10^9$ ohms | ESD TR53 Mobile Equipment Section | $< 1 \times 10^9$ ohms resistance to ground |
| Continuous Monitors | User defined | User defined | ESD TR53 Continuous Monitors Section | Manufacturer defined |
| Garments | Static Control Garment (ANSI/ESD STM2.1) | $< 1 \times 10^{11}$ ohms | ESD TR53 Garments Section | $< 1 \times 10^{11}$ ohms |
| | Groundable Static Control Garment (ANSI/ESD STM2.1) | $< 1 \times 10^9$ ohms | ESD TR53 Garments Section | $< 1 \times 10^9$ ohms |
| | Groundable Static Control Garment System (ANSI/ESD STM2.1) | $< 3.5 \times 10^7$ ohms | ESD TR53 Garments Section | $< 3.5 \times 10^7$ ohms |

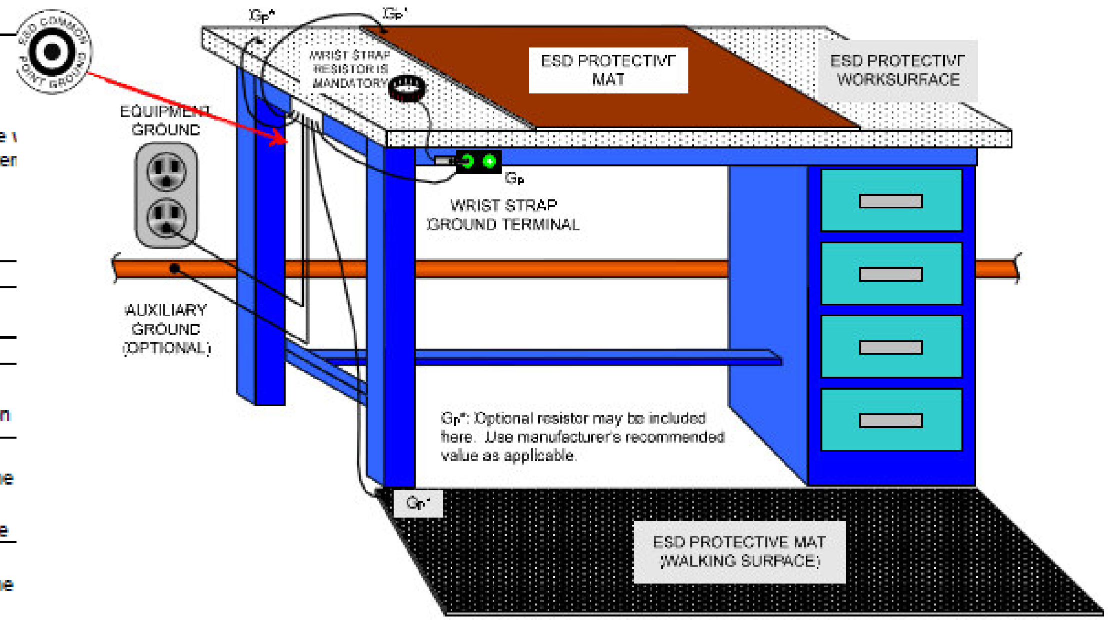



Figure 7-1: Typical ESD Grounded Workstations

*Note: These control methods are for HBM and MM events*

| NASA HANDBOOK | NASA-HANDBOOK 8739.21 |
| --- | --- |
| National Aeronautics and Space Administration<br>Washington, DC 20546 | Approved: 2010-06-18 |

# WORKMANSHIP MANUAL FOR ELECTROSTATIC DISCHARGE CONTROL

**(EXCLUDING ELECTRICALLY INITIATED EXPLOSIVE DEVICES)**

**Measurement System Identification:**
**Metric**

**APPROVED FOR PUBLIC RELEASE – DISTRIBUTION IS UNLIMITED**

*Provides a template for creating an S20.20-compliant ESD control program.*

*Training also needs to be developed that traces to the requirements in the control program.*

*Contact the Workmanship Program for slides which work with a 8739.21 program.*

# Deep Breath

*in summary.....*

# Seminar Summary

Materials and configurations named in the Workmanship Standards are considered technologically standard and have demonstrated high reliability for a broad range of NASA missions and thus are mature.

The Workmanship Standards specify design, processing, and inspection requirements, which are relevant to the materials and configurations named, which ensure high quality hardware is supplied.

Suppliers are expected to perform manufacturing using controlled processes, which operators implement using established procedures, and which results in a product that is compliant with the Workmanship requirements.

Suppliers who use configurations and materials not named in the Workmanship Standards must establish that the resulting hardware will be reliable for the applicable mission and must establish, declare, and use relevant design, processing, and inspection requirements to assure that the final items have high quality.

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## The NASA Workmanship Standards Program:

Has as its Technical Authority, NASA HQ Office of Safety and Mission Assurance

Establishes Workmanship requirements which are applicable Agency-wide

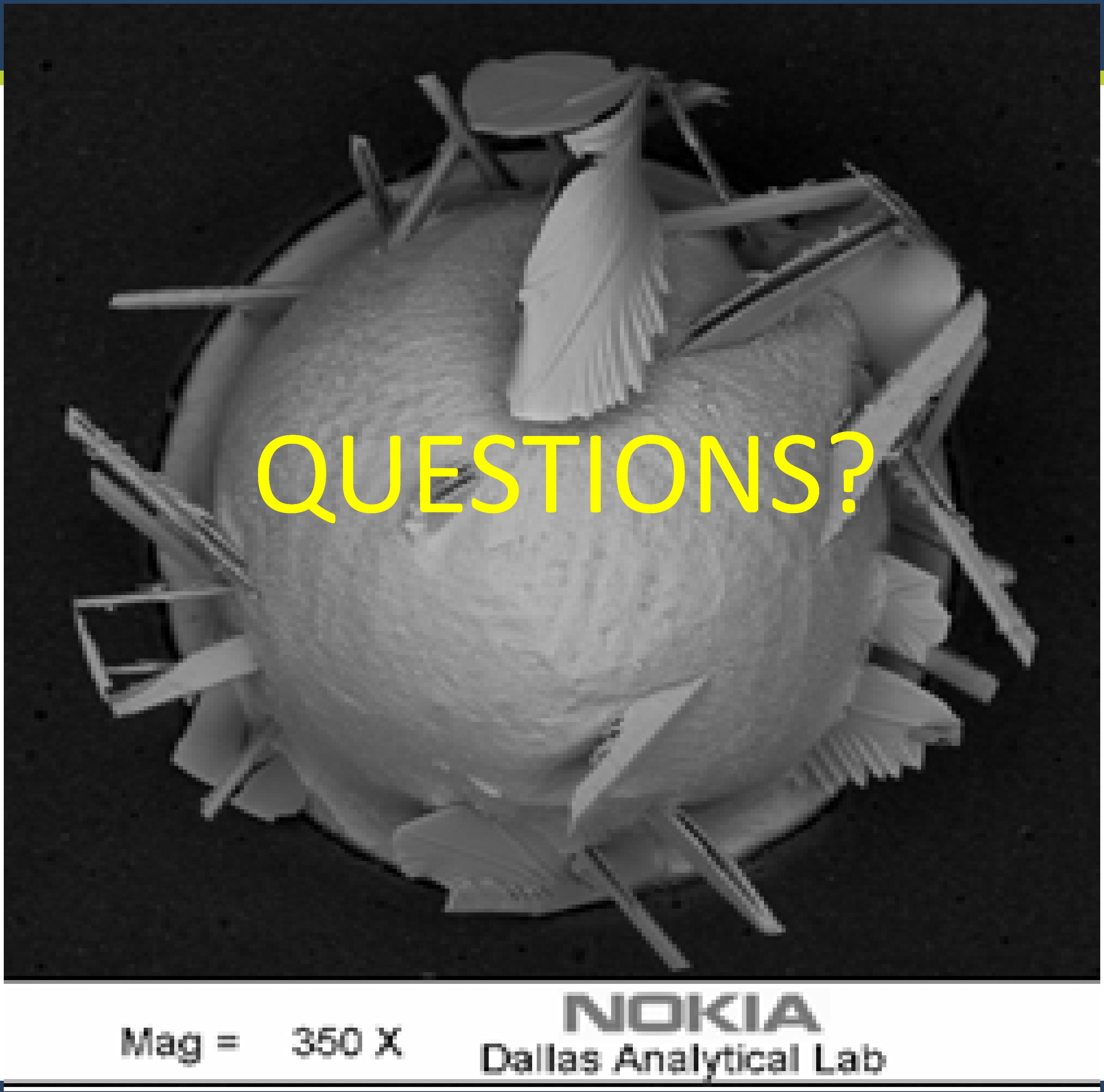
Has a closed loop system via oversight and auditing by Project quality assurance personnel, DCMA, and the NASA Safety Center

## The NASA Workmanship Standards:

Contain requirements that enable removal and repair of defects at a relatively low level of hardware integration when it is most affordable.

Work best as tools for Quality Assurance (rather than for reliability assessment) and for inspecting mature technologies.

Have a technology-limited scope. Quality rules for technologies outside of that scope must be developed, defined, and approved prior to use.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Dallas Analytical Lab