NASA Workmanship Standards Overview for Managers and Engineers

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Office of Safety and Mission Assurance

Agenda:

- Scope of workmanship standards requirements in context of mission assurance
- Awareness of design and process engineering requirements
- Approach to assurance and approvals for non-standard materials, processes, and configurations
- Policy developments for ESD Control
- Policy developments for NASA use of VCSs for workmanship
- Implementing the J-STD-001ES for soldering
- Policy developments for cable and wire harness standard

NASA Workmanship Scope

Criteria which enhance **printed wiring assembly and cable harness assembly** quality and which protect mission hardware from damaging **electrostatic discharges**.

Design Considerations

1. Design for functionality (including qualification)
2. Design for reliability
3. Design for manufacturability (including qualification)

Process Engineering Considerations

4. Manufacturing quality control parameters
5. Specified requirements for integral parts and materials (*+ capable suppliers*)
6. Trained and certified personnel
7. Controlled Processes and Quality Metrics
8. Defect Screening
9. System feedback

Implementation and Other Considerations

10. Capable suppliers

12. Failure Analysis

11. Risk-based decision-making for defects and repairs

Quality Processes

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Widely recognized Workmanship requirements

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Also important Workmanship requirements

Why don't we widely recognize these?

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Operators
Inspectors
Instructors

Designers
Process Engineers

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Operators
Inspectors
Instructors

NASA Workmanship training and certification requirements

Designers
Process Engineers

No *NASA training*

- *Workmanship training tends to focus on educational needs of operators/inspectors*
- *NASA quality oversight often performed by individuals who take inspector training*

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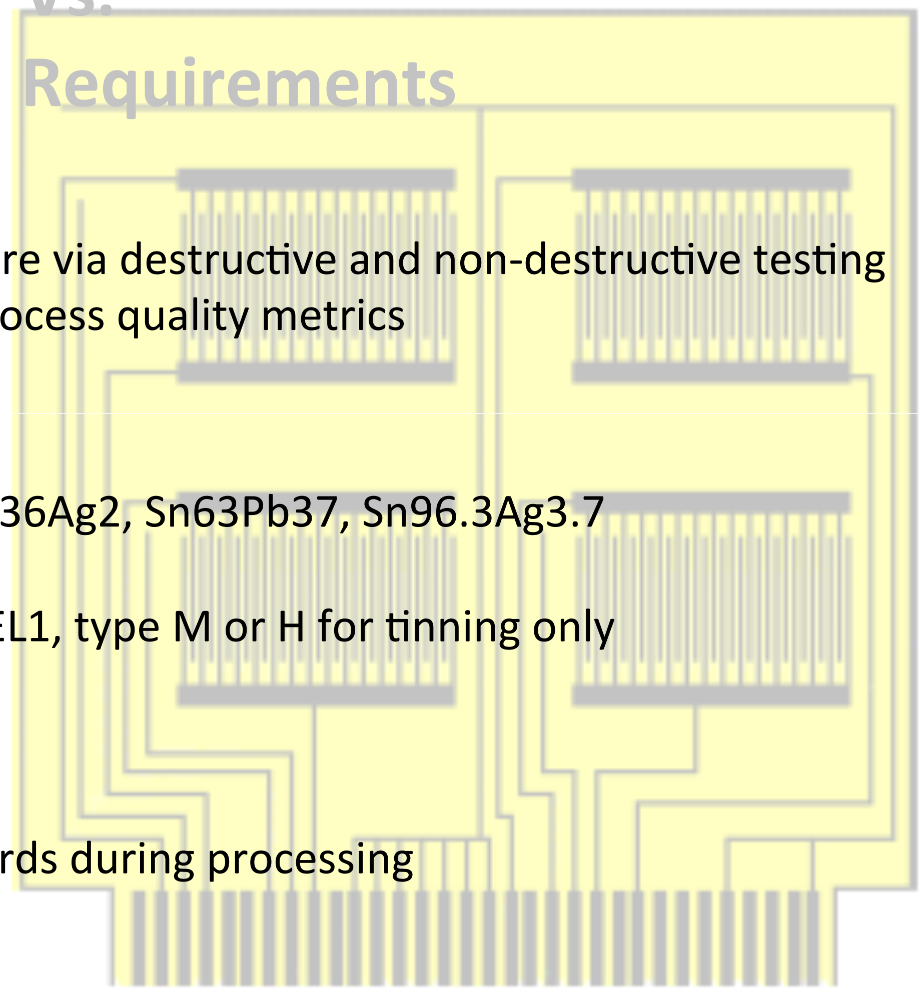
Design and Process Control Requirements Vs. Inspection Requirements

Process Control is:

Implemented by process engineer
Drives raw material specifications
Drives process parameters and settings
Qualified prior to use on mission hardware via destructive and non-destructive testing
Monitored during production using in-process quality metrics



Examples

Solder per J-STD-006, Sn60Pb40, Sn62Pb36Ag2, Sn63Pb37, Sn96.3Ag3.7
Solder purity
Flux per J-STD-004, ROL0, ROL1, REL0, REL1, type M or H for tinning only
Equipment control and calibration
Lead forming and cutting
Lighting
Thermal protection to EEE parts and boards during processing
Cleanliness process

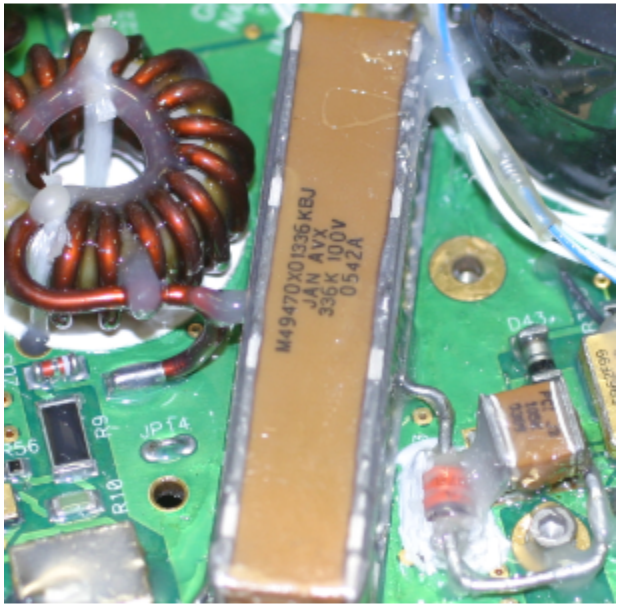
There are approximately 510 requirements in NASA-STD-8739.4. How many are design and processes requirements vs. operator practice and inspection requirements?

Many Requests for Requirements Relief are Related to Design, Processes and Repairs

Highly active flux
Water soluble flux
LCCs retrofitted with leads
Different types of wire splices

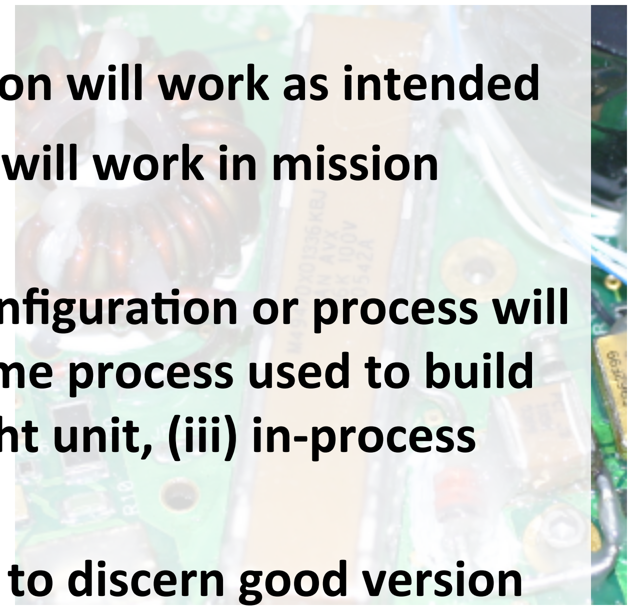
Piggy-backed and dead-bugged parts
Part used that is different than one planned; solder pads no longer match
Jumper wires

Shortened bake-outs
Staking encapsulating lead bend
Damaged boards: exposed fibers and lifted pads/traces



Many Requests for Requirements Relief are Related to Design, Processes and Repairs

What criteria do we use to "Approve"?



- **<u>Performance</u>: Evidence that configuration will work as intended**
- **<u>Reliability</u>: Evidence that configuration will work in mission environment for duration of mission**
- **<u>Controlled Process</u>: (i) Evidence that configuration or process will not damage flight hardware, (ii) that same process used to build qualification sample is used to build flight unit, (iii) in-process quality metrics used if applicable.**
- **<u>Defect screening</u>: Quality criteria exists to discern good version from defective version**

Highly active flux
Water soluble flux
LCCs retrofitted with leads
Piggy-backed and dead-bugged parts
Part used that is different than one planned; solder pads no longer match
Jumper wires
Damaged boards: exposed fibers and lifted pads/ traces

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Example: Solvents

Supplier wants to use a non-standard solvent. Justification for approval needs to address:

A. <u>Performance</u>: Evidence that configuration will work as intended

B. <u>Reliability</u>: Evidence that configuration will work in mission environment for duration of mission

C. <u>Controlled Process</u>: (i) Evidence that configuration or process will not damage flight hardware, (ii) that same process used to build qualification sample is used to build flight unit, (iii) in-process quality metrics used if applicable.

D. <u>Defect screening</u>: Quality criteria defined and used to remove defective units from batch (lot).

What is the goal?	What evidence demonstrates goal is achieved?
Does not expose humans or hardware to extreme chemical risk (A)	Manufacturer's datasheet Chemical analysis
Solvent supplier's cautions and recommendations are followed when used. (A, B)	Manufacturer's datasheet Procedures which conform to manufacturer's recommendations
Removes ionic and non-ionic residue (A, B, C, D)	On a process qualification test article produced on the production line being assessed using same processes, flux, solder, solvents as will be used to build flight hardware ("equivalent"): • Ionic conductivity testing • Surface insulation resistance testing • Visual inspection
Does not damage hardware (A, B, C)	Materials compatibility testing (mass +/-, hardness -/+, corrosion)
Process used to build "passing" test articles will be same as those used to build NASA hardware (C, D)	Procedures which: • Ensure process stays same regardless of day or operator • Ensures critical parameters are monitored and maintained. • Ensures batch-level screening tests are performed.

Case Study: Staking in the Lead Bend

Over thermal cycles the printed circuit board and the electronic parts soldered to its surface will expand and contract. This change in geometry of the board is not the same as it is for the part. Electronic packaging design decisions will drive this delta to a minimum. Using leads with a bend in them is one way to do this.

The bend allows the package to move without stressing the solder joint. Without a compliant lead, the stress due to the delta will be fully absorbed by the solder joint, driving crack growth and reducing solder joint life.

Staking material may be applied to the part package to prevent solder joint rupture during vibration. Staking material which "clamps" the leads prevents the bent lead from isolating the solder joint from stress during thermal cycling.

The workmanship standard for polymeric applications, NASA-STD-8739.1, says for several part package styles:

" iii. Slight flow under the part is allowed however staking shall not contact lead, enclose the lead, or negate stress relief (*Requirement)*."

Case Study: Staking in the Lead Bend

The supplier has a process that always puts staking material in contact with the lead bend of a particular type of surface mount part and would like relief from the applicable Workmanship requirement.

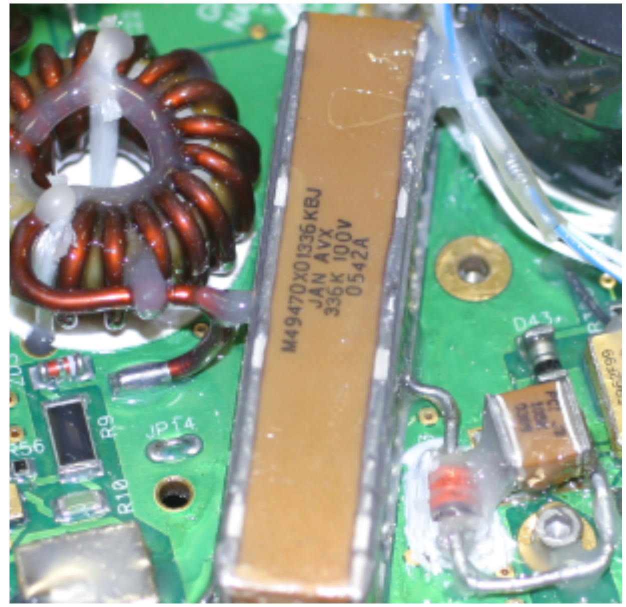
What does the supplier need to do to ensure that this configuration will be reliable for the mission?

What evidence is needed to justify allowing this configuration?

Consider:

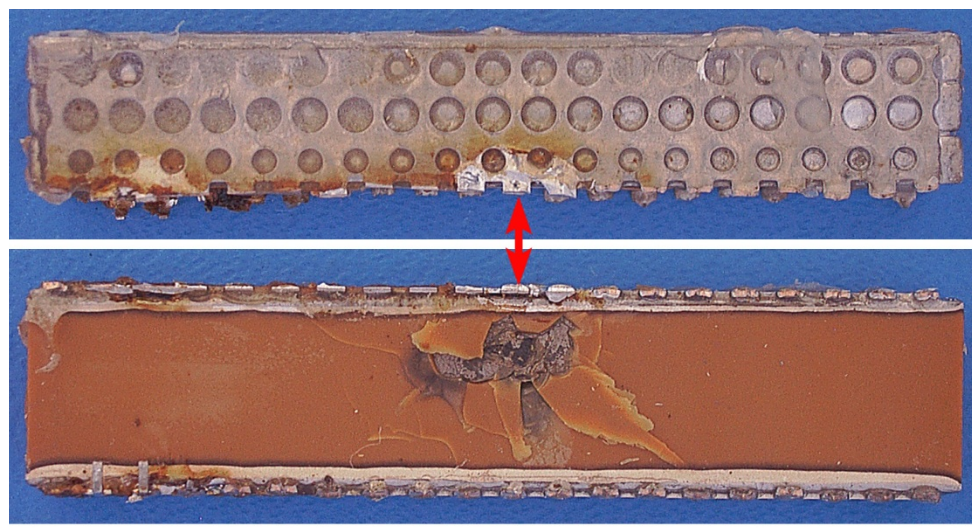
Design for reliability
Design for manufacturability
Process as designed and documented controls critical quality parameters
Personnel who will build item understand how to run the process
In-line and end-of-line inspections performed for quality control
Defect screening used to remove defective items from batch (lot)

This non-standard configuration turned out to be unreliable due to a design flaw that exposed the capacitor to electrical overstress.

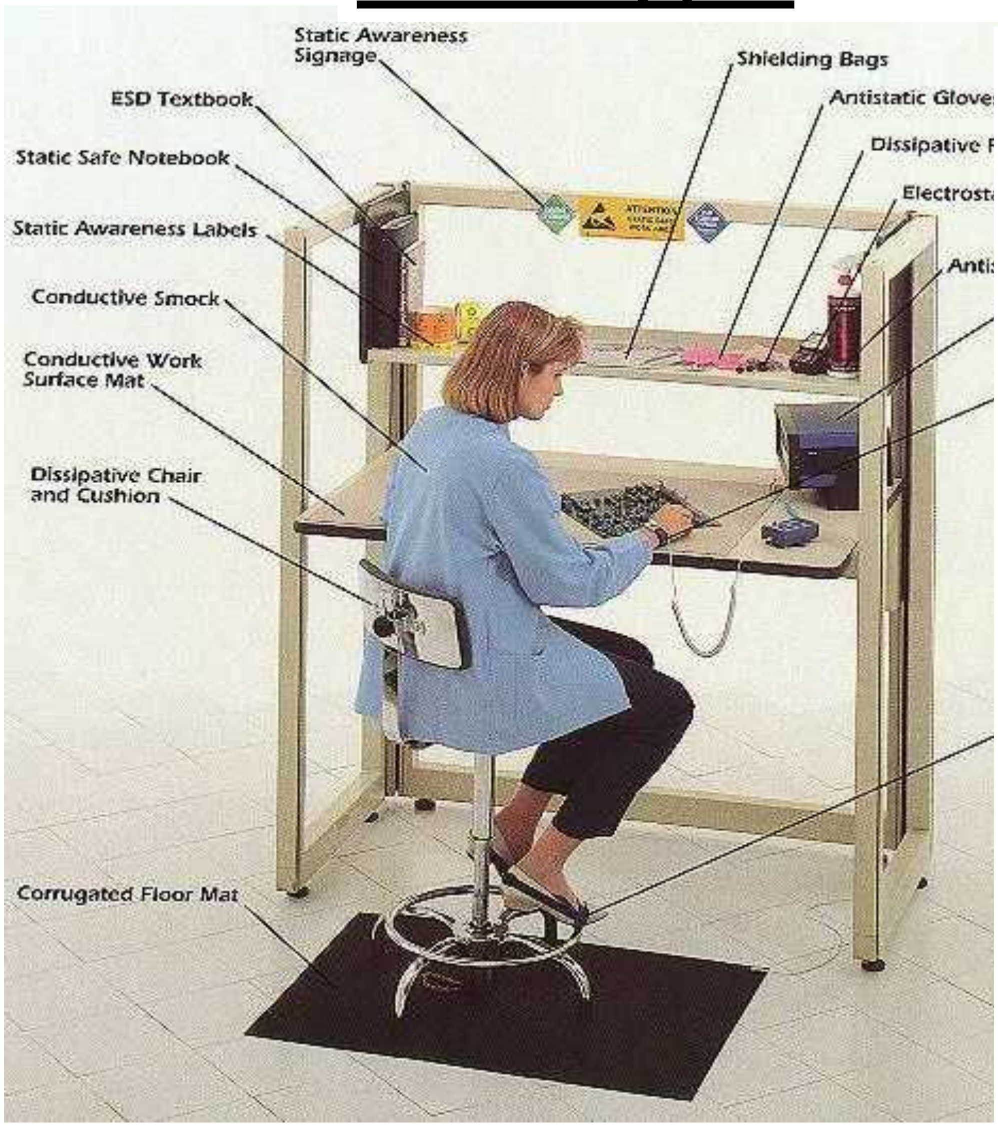


Consider how the reliability of a “Class B” or “Class S” capacitor is affected by this packaging design.

Do we adjust our reliability estimates when this sort of unqualified modification or a repair is implemented?



<u>One type</u> of EPA: ESD Bench



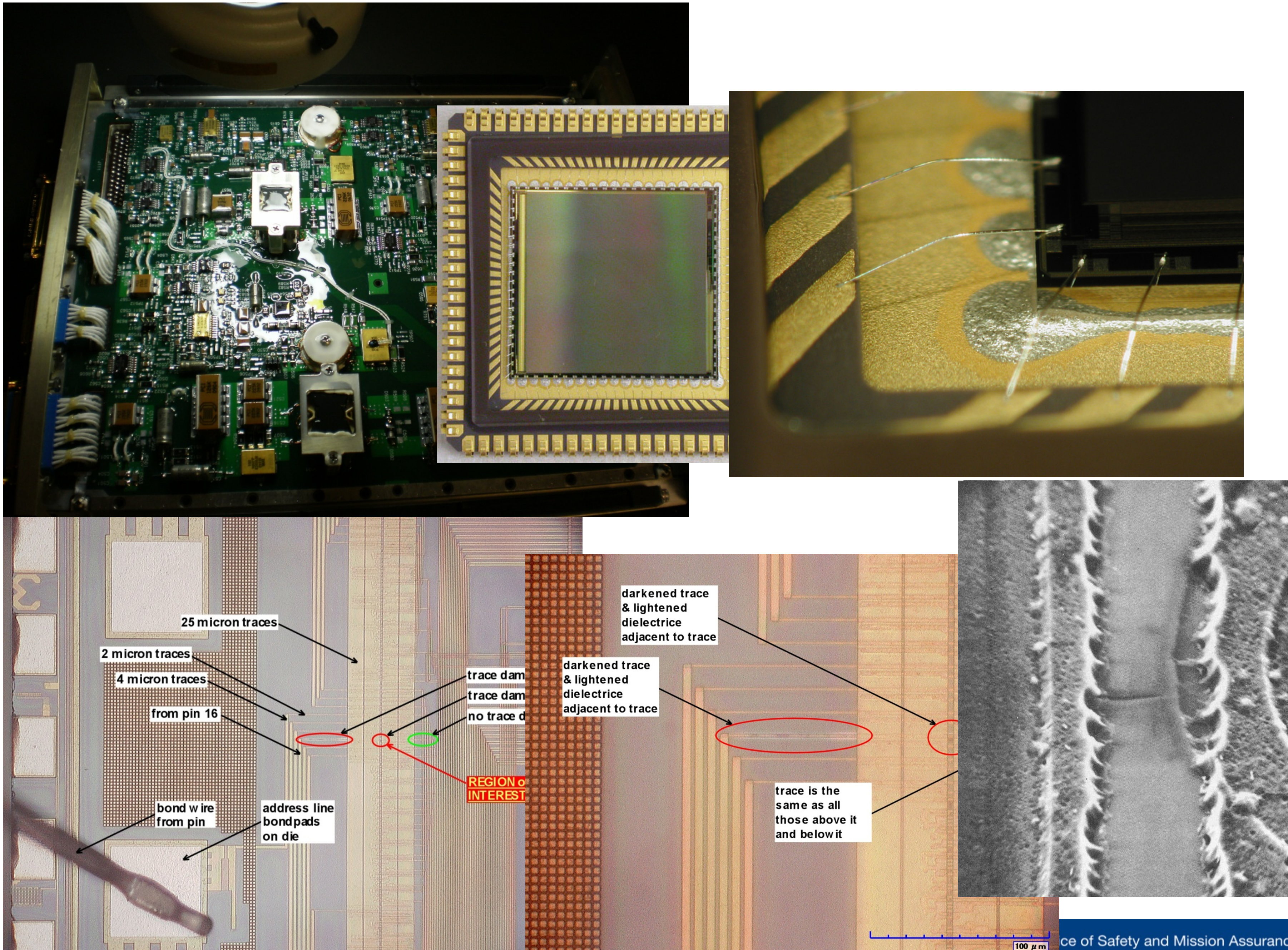
The goal is to:

- Prevent charge accumulation

Triboelectric charging is avoided, electric fields are monitored and controlled.

- Enable accumulated charge to discharge with a <u>controlled</u>, <u>low</u> current.

Dissipative materials are used to enable accumulated charges to readily find a “gentle” discharge path that keeps current low and charge transfer slow.



25 micron traces
2 micron traces
4 micron traces
from pin 16
trace dam
trace dam
no trace d
REGION o
INTEREST
bond w ire
from pin
address line
bondpads
on die
darkened trace
& lightened
dielectrice
adjacent to trace
darkened trace
& lightened
dielectrice
adjacent to trace
trace is the
same as all
those above it
and below it
100 μm

ESD S20.20, *For the Development of an Electrostatic Discharge Control Program for – Protection of Electrical and Electronic Parts, Assemblies and Equipment (Excluding Electrically Initiated Explosive Devices)*

- Adopted by NASA February 2002, cancelled NASA-STD8739.7
- For protecting items sensitive to ≥ 100V HBM discharges
- ESD control program requirements: program manager, tailoring and documented rationale, training, compliance verifications, grounding systems, personnel grounding, practices within EPAs, packaging, marking
- Required test methods and acceptance limits: grounding/bonding, personnel grounding system, wrist strap pieces, surfaces, seating, ionizers, shelving, mobile equipment, continuous grounding monitors, garments

ANSI/ESD S1.1, Wrist Straps
ANSI/ESD STM2.1, Garments
ANSI/ESD STM3.1, Ionization
ANSI/ESD SP3.3, Periodic Verification of Air Ionizers
ANSI/ESD S4.1, Worksurfaces – Resistance Measurements
ANSI/ESD STM4.2, ESD Protective Worksurfaces – Charge Dissipation Characteristics
ANSI/ESD S6.1, Grounding
ANSI/ESD S7.1, Floor Materials – Characterization of Materials
ANSI/ESD STM9.1, Footwear – Resistive Characterization
ESD SP9.2, Footwear – Foot Grounders Resistive Characterization
ANSI/ESD STM97.1, Floor Materials and Footwear – Resistance Measurement in Combination with a Person
ANSI/ESD STM97.2, Floor Materials and Footwear – Voltage Measurement in Combination with a Person
ESD TR53, Compliance Verification of ESD Protective Equipment and Materials
ANSI/ESD STM12.1, Seating – Resistive Measurement
ANSI/ESD S541, Packaging Materials for ESD Sensitive Items

Assurance Standard for ESD Control for Aerospace

- Fills in assurance language lost when NASA-STD-8739.7 was cancelled in favor of ANSI/ESD S0.20. Example:

  ESD wrist straps and heel strap systems shall be verified to be functional each time they are put on prior to entry into an Electrostatic Protected Area (EPA) or prior to coming within one meter of an ESD sensitive item (Requirement).

- Early 2012: ESDA informally agrees to allow NASA to pursue writing this standard
- September 2012: "Form 3" submitted, ESD Association Standards Work Statement Form:

"The intention of the Aerospace Addendum is for the sole purpose of adding Quality Assurance requirements standards that government and industry may use to ensure mission critical safety, on projects where loss of life may be at risk, and/or loss of expensive equipment."

"…area of concern is also related to the need by buyers ("users") of high reliability systems to impose assurance requirements that are unique to ESD control on producers of those systems, to ensure an absence of latent defects in the delivered items and to minimize cost and schedule risk related to damaging ESD events occurring during production…"

Gene Monroe, NASA LaRC is leading effort on behalf of the NASA Workmanship Standards Program. He is assembling the working group at this time.

NASA-STD-8739.6, Implementation Standard for NASA Workmanship Standards

- Published September 5, 2012
- Provides unified requirements for facilities
- Codifies historical and previously undocumented training policies
- Establishes acceptability for Level B training centers at JSC and MSFC
- Closes gaps between NASA's needs and adopted VCSs.

  - ESD wrist straps and heel strap systems shall be verified to be functional each time they are put on prior to entry into an Electrostatic Protected Area (EPA) or prior to coming within one meter of an ESD sensitive item (Requirement).

  - Maximum relative humidity: 70 percent RH
  - For ESD-sensitive hardware, minimum humidity: 30 percent RH.
  - For ESD-sensitive hardware, HBM Class 0, minimum humidity: 40 percent RH.

  - Chapter 10 of IPC J-STD-001ES shall not be used without waiver approval (Requirement).

  - Where NASA-STD-8739.4 invokes NASA-STD-8739.3 for soldering processes and inspections, IPC J-STD-001ES may be used without waiver approval.

  - J-STD-001ES integration into heritage processes, J-STD-001ES training

  - General training and certification, training center policies

Roll Out of J-STD-001ES for Soldering

- **Adopted by NASA on October 17, 2011. Cancelled NASA-STD-8739. and NASA-STD-8739.3 for new Project starts.**
- **All new Projects must baseline J-STD-001ES**
- **Projects with NASA-STD-8739.2/.3 baseline may use J-STD-001ES without waiver. Project decision, <u>not a supplier decision</u>.**
  - Includes building hardware with 8739 on drawings
  - Includes inspecting hardware built to 8739
  - Includes repairing or reworking hardware built to 8739
  - Includes replacing or duplicating hardware built to 8739
- **Three training options**
  - IPC CIS Modular: must take Module 1 + Module (2, 3, 4, 5) + Module 6; Class 1, 2, 3, Space
  - IPC CIS Non-Modular: Four days, all content included; Space Class only
  - Homegrown: taught by IPC CIT, available for Project review
- **IPC CIT takes IPC Modular training only.**

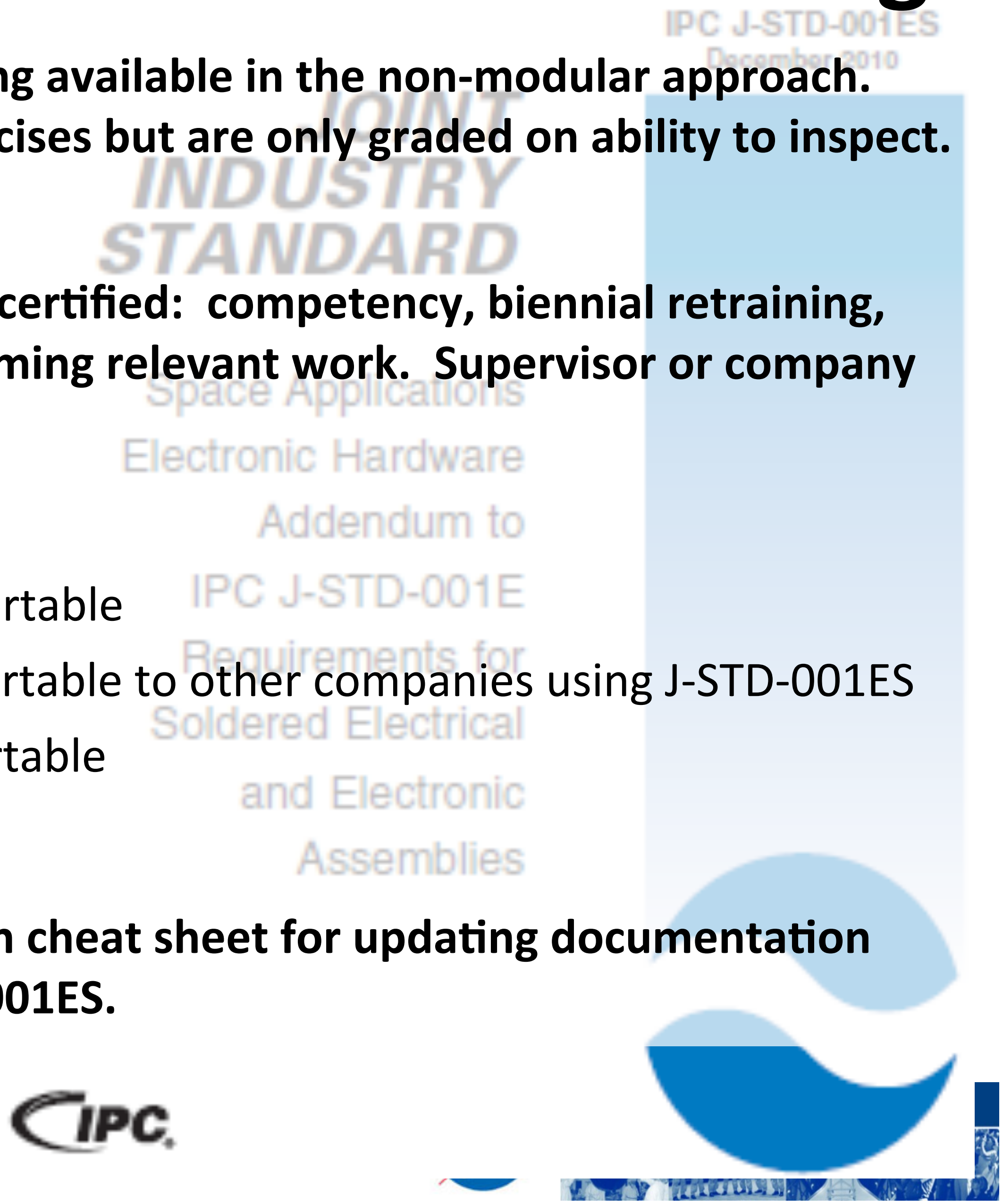
Roll Out of J-STD-001ES for Soldering

- **"Operator" and "Inspector" training available in the non-modular approach. Inspectors perform hands-on exercises but are only graded on ability to inspect. CIT, Inspector Only-CIT**

- **Operators and Inspectors shall be certified: competency, biennial retraining, vision, no lapse of 6 month performing relevant work. Supervisor or company certifies.**

- **Portability:**
  - IPC Modular training is fully portable
  - IPC Non-modular training is portable to other companies using J-STD-001ES
  - Homegrown training is not portable
  - Certification is not portable

- **Workmanship program working on cheat sheet for updating documentation from 8739.2/.3 baseline to J-STD-001ES.**



From J-STD-001E:

1.13.2 Procedures for Specialized Technologies As an industry consensus standard, this document cannot address all of the possible components and product design combinations, e.g., magnetic windings, high frequency, high voltage, etc. Where uncommon or specialized technologies are used, it may be necessary to develop unique process and/or acceptance criteria. Often, unique definition is necessary to consider the specialized characteristics while considering product performance criteria. The development should include user involvement. The acceptance criteria **shall [N1N2D3]** have user agreement. Mounting and soldering requirements for specialized processes and/or technologies not specified herein **shall [N1D2D3]** be performed in accordance with documented procedures which are available for review. Whenever possible these criteria should be submitted to the IPC Technical Committee to be considered for inclusion in upcoming revisions of this standard.

Requirements Flow-down: Who is the User?

From J-STD-001ES:
Solder alloys **shall** be Sn60Pb40, Sn62Pb36Ag2, Sn63Pb37, or Sn96.3Ag3.7 in accordance with J-STD-006 or an equivalent controlled specification. Other solder alloys that provide the service life, performance, and reliability required of the product may be used if all other conditions of this standard are met and objective evidence of such is reviewed and approved by the User prior to use. High temperature solder alloys, e.g., Sn96.3Ag3.7, **shall** only be used where specifically indicated by approved drawings.

NASA is the User.

- NASA performs the approvals assigned to the User.
- The Prime contractor flows down the requirement so that NASA is able to act as the User for all hardware.
- If NASA is not afforded approval rights, then the requirement is not flown down adequately.
- The first "approved" above is directed at supplier program managers. The second "approved" is directed at operators.

NASA-STD-8739.4
Change-over to IPC/WHMA-A-620AS.1

In 2012 this IPC document achieved a "meets or exceeds" condition with NASA-STD-8739.4 for requirements.

NASA Workmanship Standards Program reviewing and making inputs to a hands-on training program. Features of the current IPC approach are:

3-Day slide-based training for all requirements all Class levels (1, 2, 3)

5-Day hands-on training for space grade level, based on NASA-STD-8739.4 training:

- **fabrication chassis**
- **tools and equipment**
- **student workbook**
- **grading scheme**

Includes soldering but does not teach soldering (assumes competency)

Questions?

Example Electrostatic Charge Field Effect

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