



U.S. AIR FORCE



Lead-Free (Pb-free) Electronics & Finishes

29 April 2014

AFMC AFSC 448th
415 SCMS/GUMBB
DSN 586-1442



Overview



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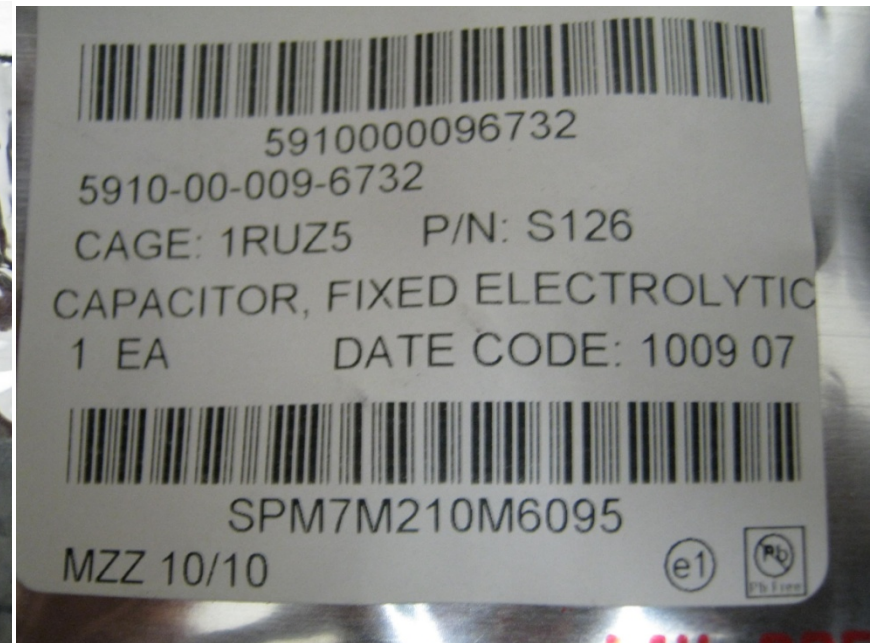
- Introduction
- Lead-free – the issue
- Lead-free Actual Cases
- Way Forward
- Risk Mitigation Improvements
- Summary



Introduction

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What if your repair line discovered Pb-free parts in bins?



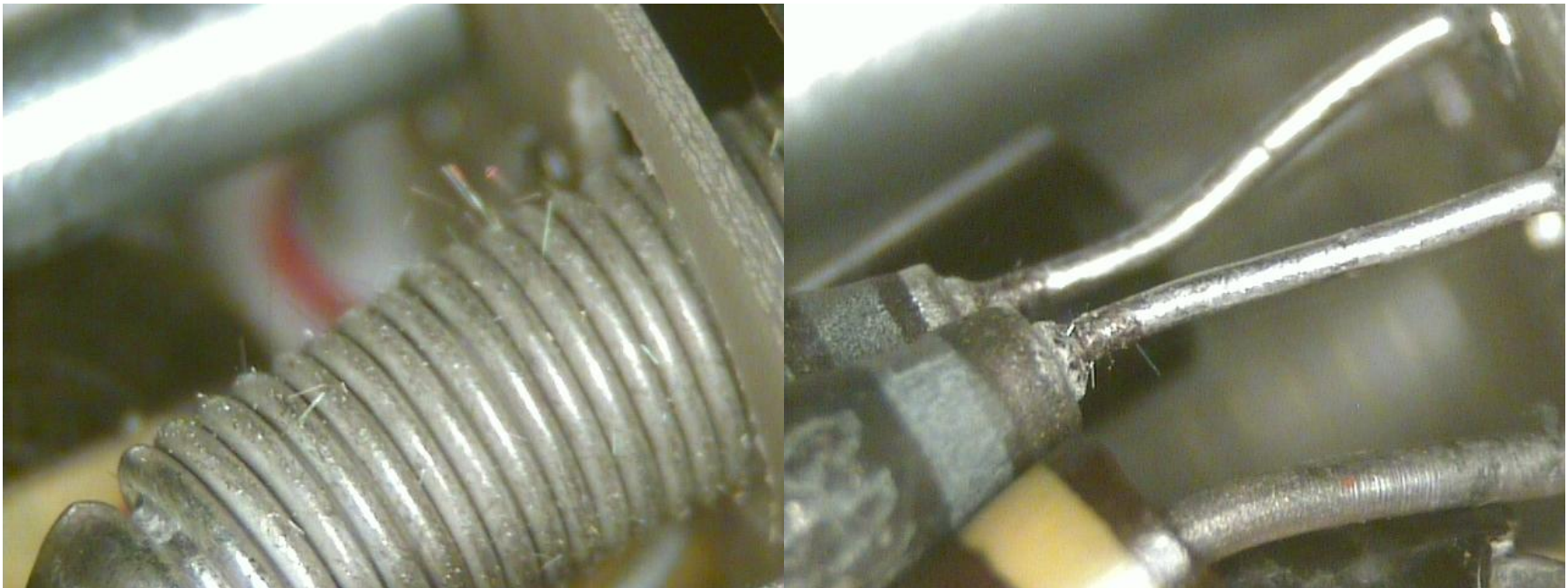
Aircraft Control Amp



Introduction

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What if your repair line discovered whiskers?



Aircraft Fuel Quantity Indicator

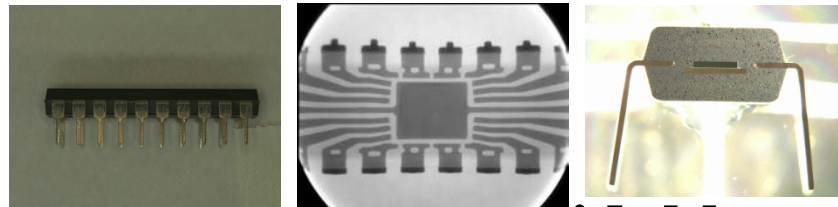


Principle #1 – Not just Solder

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Soldering

- Electronics has established reliability baseline with SnPb solder (63% Tin, 37% Lead)
- There is no direct replacement or substitution that “gets the lead out”



Electronic Components

- Lead-free electronic components are unavoidable

Surface Plating

- Pure tin plating is attractive, low cost, and environment “green”

Not Just Solder



Principle #2 – Not just Whiskers

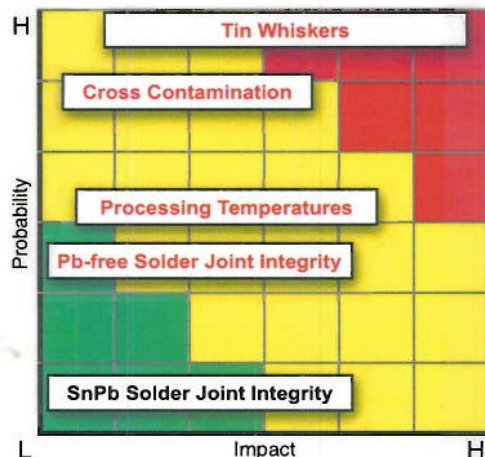
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Tin Whiskers – random in nature

Cross Contamination – material mixing in soldering

Solder Temperatures – collateral heating (over-heating)

Pb-free Solder Joints – “New” compared to Tin-Lead
(SnPb)



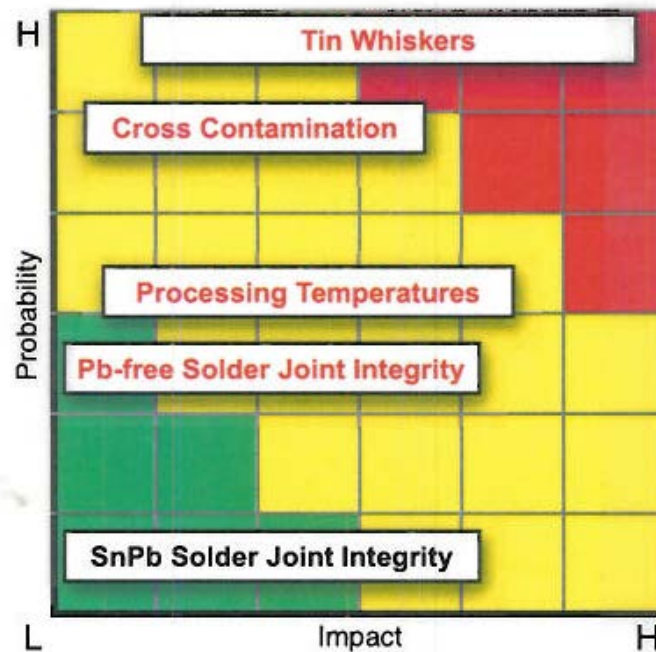
Not Just Whiskers



Not Just Solder or Whiskers

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Risk Assessment for Pb-free Processes per LSA SOLD-08-07



Frequency of Occurrence is X Times the SnPb Baseline

LSA = Lead (not Pb but lead as in leader) Standardization Activity



Solder Temperatures

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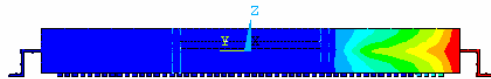
Processing Temperatures Phenomenon

2
NODAL SOLUTION

TIME=9.004
TEMP (AVG)
SMN =29.715
SMX =249.964

ANSYS

JUL 18 2006
23:01:09



29.123 53.665 78.207 102.749 127.291 151.833 176.374 200.916 225.458 250

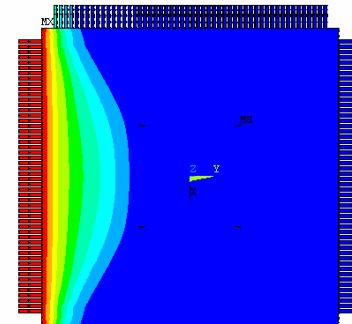
PakSi-TM FE Model

1
NODAL SOLUTION

TIME=9.004
TEMP (AVG)
SMN =29.715
SMX =249.964

ANSYS

JUL 16 2006
08:41:38



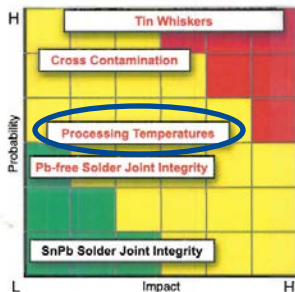
29.123 53.665 78.207 102.749 127.291 151.833 176.374 200.916 225.458 250

PakSi-TM FE Model

Thermal Simulation of 208 PQFP

Blue = 30 - 50 °C

Red = 225 - 250 °C



Soldering Iron set to 315 °C (600 °F)
Solder Pot set to 245 °C (473 °F)



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Lead-free Actual Cases at Hill AFB

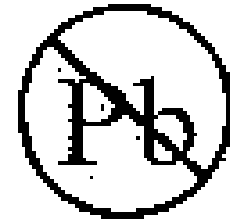


Know What To Look For

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Become familiar with these designations for **ELECTRONIC COMPONENTS** (J-STD-609)

- Traditional Tin-Lead Construction/Component Leg Finish
 - e0 contains lead (> 0.1 wt %), traditional Sn/Pb solder tinning
- These Designations are Lead-free (Pb-free)
 - e1 Sn/Ag/Cu (shall not be included in category e2)
 - e2 Sn alloys with no Bi or Zn, excluding Sn/Ag/Cu
 - e3 Sn
 - e4 Precious metal (Ag, Au, Ni/Pd, Ni/Pd/Au) [no Sn]
 - e5 Sn/Zn, Sn/Zn/X (no Bi)
 - e6 Contains Bi
 - e7 Low temperature solder containing Indium (no Bi)
- e8 and e9 symbols are unassigned



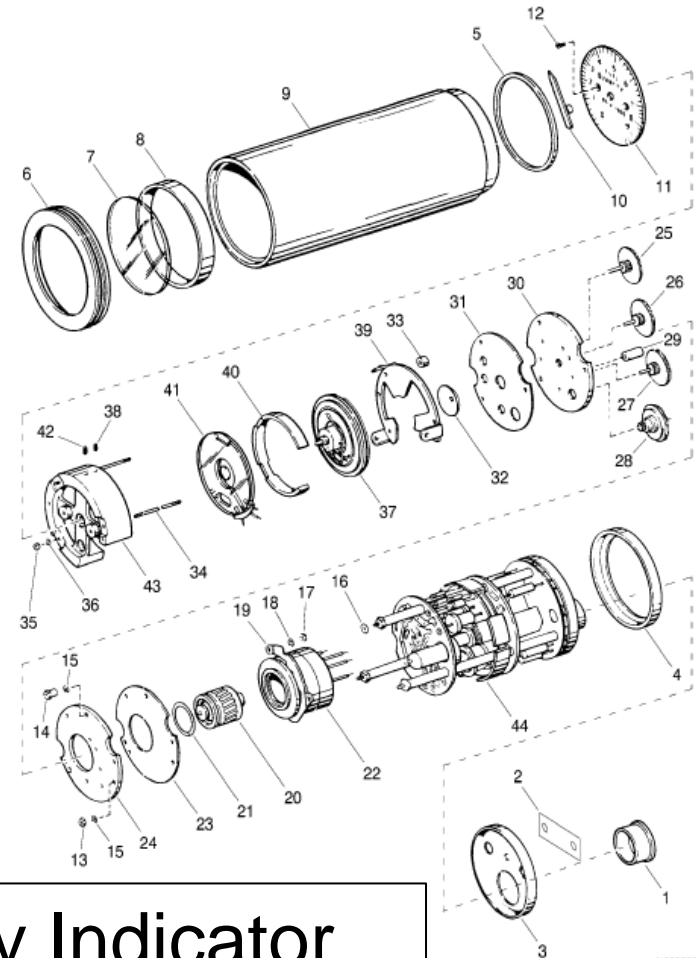
Know Your Repair Process and Component Inventory



Hill AFB Affected Product – Resolved through Risk Analysis



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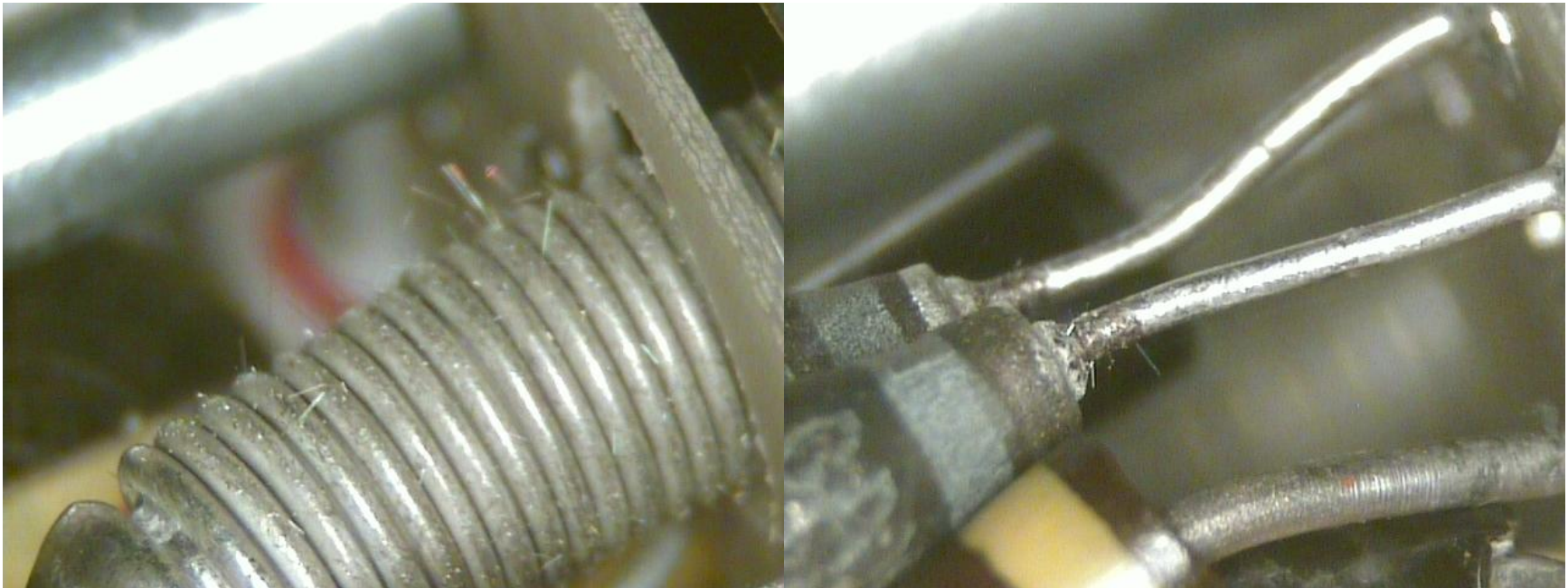
Aircraft Fuel Quantity Indicator



Hill AFB Aircraft Fuel Quantity Indicator - Whiskers



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Aircraft Fuel
Quantity Indicator

Product designed/manufactured prior to 2000

“Spring” part is not an electrical part

Example of whisker mitigation technique effectiveness
– solder dip



Hill AFB Aircraft Alpha Computer – Critical Safety Item Pre-RoHS Parts in Inventory



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225V 400ma Diode
JANTXV1N645-1
NSN 5961-01-071-6704



Potentially Fused
Tin (Sn)

Pb below 2% on
2 samples

Example where legacy construction is lead-free

Lead-free/RoHS transition began ~2003 and these parts are manufactured 1998

Fusing (reflow above 232°C where the tin fully melts) within a short time frame
after plating – mitigates whiskers

Yesterday's traditional construction, Today's lead-free e3, JESD Class 2



Gold Leads

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Digital Microcircuit
Buffer/Driver IC 55462H
55462HMQB
NSN 5962-01-123-3164



71% Gold Legs
0.2% Lead (Pb)

Therefore Pb-free

Example where legacy construction is lead-free

DLA Case # DSCC-FM-09-15764 to add supplier – no issue with 339

Yesterday's traditional construction, Today's lead-free e4, JESD Class 2

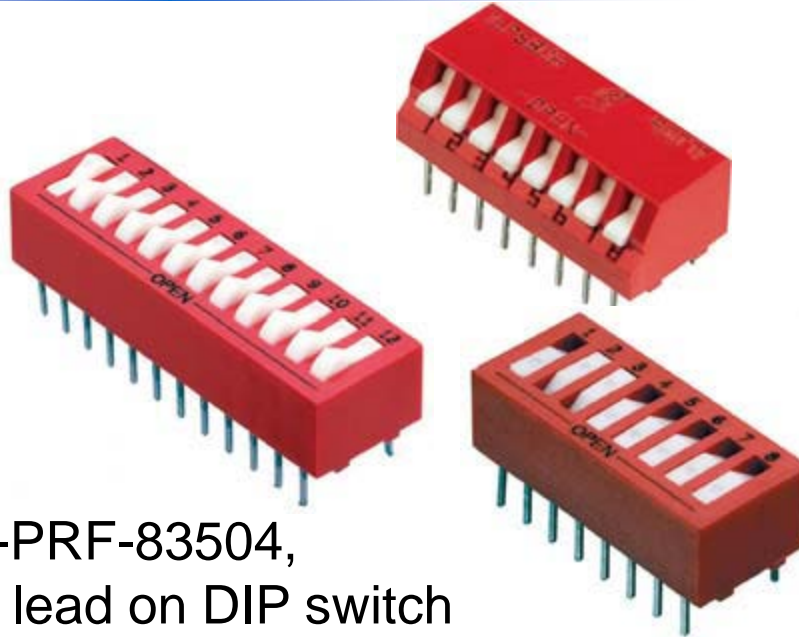


Conscious Lead-free Approval through DLA 339



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500V 3 A Switch
2 through 12 position
0.28" through 1.28"
NSN 5930-01-7015



Cancellation of MIL-PRF-83504,
Which specifies 3% lead on DIP switch
component legs

Terminals: Copper
alloy, matte tin
plated over
nickel barrier (per
JESD 201).

Only available in
lead-free

Supplier Grayhill
(distributor not
manufacturer)

Engineering Authority Approved with full awareness

Satellite Ground Station Application

Case Number: DSCC-FM-11-02139 October 2010



Lead-free Part Meets Spec



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20V 150ma Diode
per drawing 033549
(last dwg Rev 1991)
NSN 5961-01-105-4854



e4 - Ag, Au, or
Ni/Pd instead of tin

Spec does not
prohibit lead-free

Dwg 033549 “3.3.1 Lead Finish: Leads shall be solderable (tinned or gold plated)”

DLA: “No 339s or engineering authority activity that accepted this part”

MXW Technician: “Cannot purge/QDR the Integrated Parts Vendor bins, because we do not have anything in writing that says we can't use lead free”



Supplier Solder Dipped Lead-free to Meet Spec



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150V Tantalum
Electrolytic
Capacitor per
M39006/01
NSN 5910-00-009-6732

DLA Case #
DSCC-FM-10-42179



e1 - Sn/Ag/Cu
96.5 Sn 3.0Ag 0.5Cu

Contractor dipping
In SnPb bath
before delivery -
mismarked

Part approved
through DLA 339
and Pb-free not
part of decision

M39006/01

3.4.3 Pure tin. The use of pure tin, as an underplate or final finish, is prohibited both internally and externally. Tin content of capacitor and solder shall not exceed 97%, by mass. Tin shall be alloyed with a minimum of 3% lead.

6.11 Tin whisker growth. The use of alloys with tin content greater than 97%, by mass, may exhibit tin whisker growth problems after manufacture.



Manufacturer's Data Sheet Does Not Show an e1 Option



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600V 1 A Diode
1N5061
80131-RELEASE5452
0.032 leg diameter
NSN 5961-00-111-4795

Potential replacement
200V 3 A Diode
JANTX1N5417
0.040 leg diameter
NSN 5961-00-403-4545

e1 - Sn/Ag/Cu
96.5 Sn 3.0Ag 0.5Cu

Approved as a
replacement by OC-
ALC (422nd) & WR-
ALC (407th)

Specification may
not prohibit lead-free

DLA Case # DSCC-FM-10-17097

“DLAD Clause 52.211-9063, 'Unit Package Marking Requirement for Component Lead Finish', Applies”

Part is Vishay per DLA but Vishay does not show an e1 version per datasheet, 29 samples measure e0

80131-RELEASE5452 Specification (1967) – “no fragile whiskers”

Latest Vishay datasheet - E3 suffix meets JESD 201 class 1A whisker test, HE3 suffix meets JESD 201 class 2 whisker test

An item authorized for procurement as a result of a formal item reduction study & accepted as a replacement



Air Force Way Forward



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- **Lead-free components are unavoidable – Prohibiting lead-free is unrealistic and not effective**
- **Lead-free is not a brand new threat, increased threat**
 - **“Legacy” Lead-free parts have been in Air Force processes for over 20 years – (e.g., fused tin, gold leads)**
- **Depot Solder is traditional tin-lead (63Sn37Pb)**
- **Discovery relies on the depot technician – all trained but skills/enforcement vary**
- **Estimated Lead-free Inventory at Hill AFB is 5% (not including “legacy” lead-free)**



Follow Navy Lead



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- **Naval Surface Warfare Center Instruction
NSWCCCRANEINST 4855.18C**
 - **Guides to solder components with pure tin finishes with SnPb solder, if ...**
 - **...approval obtained from the engineering authority and program manager**
 - **Engineering authority approval = risk analysis**
- **Air Force Activity**
 - **Adopting Navy soldering TO – TO 00-25-234 (AF)
converted to 00-25-259 (Navy)**
 - **Air Force Lead-free Electronics Team (LFET)**



Navy Instruction NSWCCRANEINST 4855.18C document, table 1



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Risk Management for Pb-free Solder Technology Repair Processes 1 and 3

	SnPb	1	2	3	4	5	5a
<i>Solder</i>	Sn37Pb	Sn37Pb	Sn37Pb	Sn37Pb	Sn37Pb	Pb-free	Pb-free
<i>Component Finish</i>	>3%Pb	Non-Sn	HSD	Sn	Sn	Pb-free	Pb-free
<i>Board Finish</i>	>3%Pb	Non-Sn or >3%Pb	Non-Sn or >3%Pb	Non-Sn or >3%Pb	Sn	Pb-free	Pb-free
<i>Tin Whiskers</i>	Avoids the risk	Avoids the risk	Mitigates the risk	Mitigates the risk	Mitigates the risk	Mitigates the risk	Accepts the risk
<i>Solder Joint Integrity</i>	Avoids the risk	Avoids the risk	Avoids the risk	Avoids the risk	Avoids the risk	Accepts the risk	Accepts the risk
<i>Processing Temperatures</i>	Avoids the risk	Avoids the risk	Avoids the risk	Avoids the risk	Avoids the risk	Accepts the risk	Accepts the risk
<i>Component Reliability</i>	Avoids the risk	Avoids the risk	Accepts the risk	Avoids the risk	Avoids the risk	Avoids the risk	Avoids the risk



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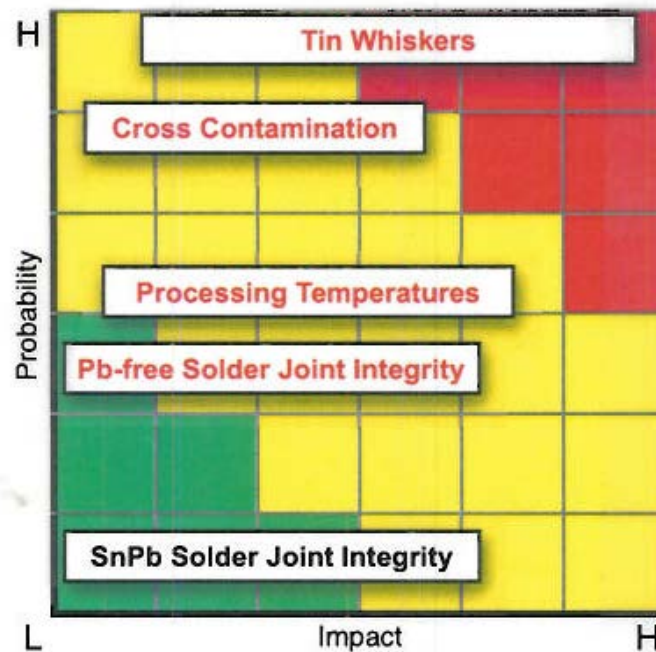
What the Air Force could be doing



Risk Assessment

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Risk Assessment for Pb-free Processes per LSA SOLD-08-07



Frequency of Occurrence is X Times the SnPb Baseline

LSA = Lead (not Pb but lead as in leader) Standardization Activity



Get Control

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- Assign a Control Level per SAE/GEIA-STD-0005-2
 - Different based on criticality (aircraft and ground systems may have different control levels)
 - Control Level 2C for Aircraft avionics is a starting place
- Know your Weapon System Specs that prohibit/limit Pb-free
 - MIL-STD-1276, MIL-PRF-38535, MIL-STD-1796A, Industry standard JESD 201, etc
- Notify suppliers of designated Control Level
 - share responsibility and supplier control to contractors – buys and repairs
- Develop a Pb-free Control Plan (LFCP) – Supplier Management, 339 processes, 202 processes



Get Control



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Example Control Level Assignments

Subsystem Name	Flight/Ground	Critical Safety Items? Yes/No	GEIA-STD-0005-2 Control Levels	Comments
Aircraft Structure	Flight	Yes – 8 items	Level 2C	Associated electronics and surface plating and finishes shall not be pure tin
Aircraft Avionics – Critical Safety Items (CSI)	Flight	Yes – 8 items	Level 2C	CSIs have a higher control level
Aircraft Avionics – non-CSI	Flight	No – 8 items	Level 2B	Non-CSIs control level can be below CSI's control level
Aircraft Support Equipment	Ground	No	Level 2A	Reliability to be monitored
Repair Source automatic test equipment	Ground	No	Level 1	Many components are commercial-off-the-shelf
Commercial off-the-shelf (COTS)	Flight/Ground		Procured Lead-free (Level 1)?	



Depot Repair Risk Mitigation Implementation



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- Mitigation 1 – 202 for Risk assessment from engineering authority
- Mitigation 2 - Do not use lead-free solder, stay with traditional tin-lead (63Sn37Pb) solder
- Mitigation 3 - Solder dip electronic component prior to soldering (coverage of entire lead up to package is difficult)
- Mitigation 4 - Use conformal coat (disadvantage on next repair cycle)



Summary

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- Prohibiting lead-free keeps status quo and saves engineering effort (an objective that is unrealistic)
- Unavoidable lead-free use requires awareness of issues and risk analysis
- Highly likely that your legacy system is being repaired with lead-free components (including fused tin) – go find out
- Commit to an office position on Lead-free - Adopt a method of control and monitoring
- Delegate responsibility and control to suppliers – buy and repair



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Backup Slides



Results of Industry and DoD Working Groups



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Industry Documents - GEIA to TechAmerica to SAE

- ANSI/GEIA-STD-0005-1 – Specifies a Pb-free Control Plan
- ANSI/GEIA-STD-0005-2 – Tin Whisker Mitigation Plans
- ANSI/GEIA-STD-0005-3 – Default reliability testing
- ANSI/GEIA-STD-0006 (draft) – Hot Solder Dip Component Leads
- ANSI/GEIA-HB-0005-1 – Program guidelines to Pb-free transition
- ANSI/GEIA-HB-0005-2 – Tech Guidelines for Pb-free/mixed solder
- ANSI/GEIA-HB-0005-3 (draft) – Repair and maintenance of Pb-free
- ANSI/GEIA-HB-0005-4 (draft) – Quantifying effects of Pb-free
- JEDEC standard JESD 22A121 (iNEMI) - Tin Whisker Test Methods
- JEDEC standard JESD 201 (iNEMI) - Tin Whisker Acceptance Criteria

DoD Documents

- LSA SOLD-08-01 – DoD Soldering Technologies Working Group
- LSA SOLD-08-02 – Manage by avoidance, inspection, and control plans
- LSA SOLD-08-03 – Tech guidance and control plan for rework and repair
- LSA SOLD-08-04 – USDoD Lead-Free Control Plan (templates -05/-06)
- LSA SOLD-08-07 – Risk Management
- Naval Surface Warfare Center Instruction NSWCCRANEINST 4855.18C



Hill X-Ray Fluorescence (XRF) Equipment



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For Material Composition Analysis



Back-Up

Acronyms

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- AIA – Aerospace Industries Association
- AMC – Avionics Maintenance Conference
- CALCE – Center for Advanced Life Cycle Engineering
- GEIA – Government Engineering and Information Technology Association
- IEC – International Electrotechnical Commission (Standards Publisher)
- JSRC – Joint Service Review Committee
- LEAP – Lead-free Electronics in Aerospace Project
- LFCP – Lead Free Control Plan
- LFET – USAF Lead Free Electronics Team
- LFWG – Hill Lead Free Working Group
- LSA – Lead (not Pb but lead as in leader) Standardization Activity
- Pb – Chemical element symbol of lead
- PERM - Pb-free Electronics Risk Management
- STWG - DoD Soldering Technologies Working Group