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PUBLICLY AVAILABLE SPECIFICATION

PRE-STANDARD

**Process management for avionics – Aerospace and defence electronic systems containing lead-free solder –
Part 22: Technical guidelines**

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PROCESS MANAGEMENT FOR AVIONICS – AEROSPACE AND DEFENCE ELECTRONIC SYSTEMS CONTAINING LEAD-FREE SOLDER –

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The text of this PAS is based on the following document:	This PAS was approved for publication by the P-members of the committee concerned as indicated in the following document
Draft PAS	**Report on voting**
107/131/PAS	107/139A/RVD

Following publication of this PAS, which is a pre-standard publication, the technical committee or subcommittee concerned may transform it into an International Standard.

This PAS shall remain valid for an initial maximum period of 3 years starting from the publication date. The validity may be extended for a single 3-year period, following which it shall be revised to become another type of normative document, or shall be withdrawn.

This PAS is based on GEIA-HB-0005-2 and is published as a double logo PAS. GEIA, Government Electronics and Information Technology Association, has been transformed into TechAmerica Association.

INTRODUCTION

0.1 General

This PAS is intended for use by Aerospace and High Performance (AHP) electronics system Customer, i.e., aerospace and defence vehicle integrators, operators, and regulatory organizations, and their Suppliers, i.e., system Original Equipment Manufacturers (OEMs) and system maintenance facilities as they incorporate Lead-free (Pb-free) solder or Pb-free piece-parts and board finishes.

This PAS is intended to work in concert with IEC/PAS 62647-1 (GEIA-STD-0005-1), IEC/PAS 62647-21 (GEIA-HB-0005-1), and IEC/PAS 62647-2 (GEIA-STD-0005-2). Part way through this documents creation, it was evident that three additional documents were needed. As a result, IEC/PAS 62647-3 (GEIA-STD-0005-3), IEC/PAS 62647-23 (GEIA-HB-0005-3) and the reliability assessment document GEIA-HB-0005-4 have been added to address testing, rework, and reliability prediction respectively.

This PAS may be referenced in proposals, requests for proposals, work statements, contracts, and other aerospace and high performance industry documents.

0.2 Transition to Pb-free

The global transition to Pb-Free electronics impacts the aerospace and other industries having high reliability applications in various ways. In addition to the perceived need to replace the Tin-Lead solders used as an interconnect medium in electronic and electrical systems, the following variations to established practice will need to be considered:

- components and printed circuit boards will need to be able to withstand higher manufacturing process temperatures;
- printed circuit boards will need to have robust solderable Pb-Free surface finishes;
- manufacturing and inspection techniques are needed that yield repeatable reliability characteristics;
- at least initially, Pb-free alloys used within the equipment should be restricted to those that are compatible with Tin-Lead soldering systems;
- a maintenance strategy should be developed that will facilitate the support repair of new and existing equipment throughout a 20+ year life.

This PAS will establish guidelines for the use of Pb-Free solder and mixed Tin-Lead/Lead-free alloy systems while maintaining the high reliability standards required for aerospace electronic and electrical systems. Currently the largest volume of Lead (Pb) in many of these electronic systems is in the Tin-Lead eutectic (Sn-37Pb) and near eutectic alloys (Sn-36Pb-2Ag, Sn-40Pb) used in printed circuit board assemblies, wiring harnesses and electrical systems. High-Lead solder alloys are not specifically addressed in this PAS; however, many of the methodologies outlined herein are applicable for their evaluation.

A good deal of the information desired for inclusion in this technical guidelines document does not exist. A large number of Pb-Free investigative studies for aerospace and high reliability electronic and electrical systems are either in progress or in the initiation stage. The long durations associated with reliability testing necessitates a phased release of information. The information contained herein reflects the best information available at the time of document issuance. It is not the goal of this PAS to provide technical guidance without an understanding of why that guidance has technical validity or without concurrence of the technical community in cases where sufficient data is lacking or conflicting. The PAS will be updated as new data becomes available.

Further complicating matters is the fact that no single alloy across the supply base will be replacing the heritage Tin-Lead eutectic alloy and that it is not likely that qualification of one alloy covers qualification for all other alloys. Given the usual requirement for long, high performance electronic service lives, any Pb-Free alloy must have predictable performance when mixed with heritage Tin-Lead alloys. Pb-Free alloys containing elements such as Bismuth (Bi) or Indium (In) that can form alloys having melting points within the equipments operating temperature range must be considered very carefully before use. Although Pb-Free solder alloys are still undergoing some adjustments, it appears that the Sn-Ag-Cu family of alloys will be used for surface mount assembly and either Sn-Ag-Cu, Sn-Cu or Sn-Cu-Ni (Sn-Cu stabilized with Nickel) alloys will be dominant in wave solder applications. In addition, some applications are using the Sn-Ag alloy family [1] [2] [3].

The majority of the Pb-Free solder alloys being considered have higher melting temperatures than Tin-Lead eutectic solder. In order to make use of the Pb-Free solders, changes to the molding compound, die attach and printed circuit board insulation systems are being introduced to accommodate the 30 °C to 40 °C higher (54 °F to 72 °F higher) processing temperature. Thus, not only is the Pb-Free transition changing the solder alloy, but a significant portion of the electronic packaging materials are changing as well. The higher melting point, greater creep resistance and higher strength of the Pb-Free alloys have driven a significant amount of study into the thermal cycling and mechanical vibration/shock assessments of these new alloys.

The consumer electronics industry has invested considerable resources to ensure that Pb-Free solder will perform adequately for their products. Creep resistance of Pb-free alloys can vary considerably from heritage Tin-Lead solders. The creep/stress relaxation performance of the solder depends on the stress level, temperature and time for a specific solder material and joint composition. Therefore, one needs to establish what the acceleration factor is between a particular test condition and application. The interpretation of the results of a head-to-head testing needs to be assessed in terms of the anticipated service conditions with respect to these acceleration factors. Thermal preconditioning prior to thermal cycling should be considered in the Pb-free solder assessment plan particularly as it relates to changes in solder microstructure. Modeling/Analysis is needed to properly compare the Tin-Lead and Pb-Free alloy performance and correct for the stress relaxation differences obtained for the various piece-parts and thermal cycling conditions.

While there is much data on near eutectic SAC (e.g., 305 and 405) Pb-Free thermal cycling, there is less information regarding Pb-Free vibration and shock performance. Fortunately, the vibration and shock performance data can be obtained relatively quickly. During vibration/shock testing, the near eutectic SAC Pb-Free solder behaves more rigidly than the Sn-Pb solder transferring greater loads to the interfaces between the solder alloy and the substrate interfaces. The increased amount of Tin in Pb-Free alloys increases the intermetallic thickness when Copper substrates are used. In addition, when Nickel or electroless Nickel (Nickel – Phosphorous) substrates are used, the increased Copper in the SAC alloy can result in the formation of intermetallics on the nickel interface, which are less robust than Sn-Cu or Sn-Ni intermetallics that are typical of Tin-Lead solder joints. Mechanical test results to-date suggest that a robust assessment of Pb-Free alloy assembly in vibration and shock environments will need to include thermal aging for interface and microstructural stabilization prior to any dynamic mechanical testing. Alloys other than SAC should be assessed to determine their vibration and shock performance characteristics.

PROCESS MANAGEMENT FOR AVIONICS – AEROSPACE AND DEFENCE ELECTRONIC SYSTEMS CONTAINING LEAD-FREE SOLDER –

Part 22: Technical guidelines

1 Scope

This PAS is intended for use as technical guidance by Aerospace system Suppliers, e.g., Aerospace system Original Equipment Manufacturers (OEMs) and Aerospace system maintenance facilities, in developing and implementing designs and processes to ensure the continued performance, quality, reliability, safety, airworthiness, configuration control, affordability, maintainability, and supportability of high performance aerospace systems (subsequently referred to as AHP) both during and after the transition to Pb-Free electronics.

This PAS is intended for application to aerospace products; however, it may also be applied, at the discretion of the user, to other products with similar characteristics, e.g., low-volume, rugged use environments, high reliability, long lifetime, and reparability. If other industries wish to use this PAS, they may substitute the name of their industry for the word “Aerospace” in this PAS.

The guidelines may be used by the OEMs and maintenance facilities to implement the methodologies they use to ensure the performance, reliability, airworthiness, safety, and certifiability of their products, in accordance with IEC/PAS 62646-1 (GEIA-STD-0005-1), “Performance Standard for High Performance Electronic Systems Containing Pb-Free Solder.”

This PAS also contains lessons learned from previous experience with Pb-Free aerospace electronic systems. The lessons learned give specific references to solder alloys and other materials, and their expected applicability to various operating environmental conditions. The lessons learned are intended for guidance only; they are not guarantees of success in any given application.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC/PAS 62647-1, *Aerospace and defence electronics systems containing lead free solder – Part 1: Lead free management*

IEC/PAS 62647-2, *Aerospace and defence electronics systems containing lead free solder – Part 2: Mitigation of the deleterious effects of tin*

IEC/PAS 62647-3, *Aerospace and defence electronics systems containing lead free solder – Part 3: Performance testing for systems containing lead-free solder*

IEC/PAS 62647-21, *Aerospace and defence electronic systems containing lead free-solder – Part 21: Program management – Systems engineering guidelines for managing the transition to lead-free electronics*

IEC/PAS 62647-23, *Aerospace and defence electronic systems containing lead free solder – Part 23: Rework and repair guidance to address the implications of lead-free electronics and mixed assemblies*

GEIA-STD-0005-1, Performance standard for aerospace and high performance electronic systems containing lead-free solder

GEIA-STD-0005-2, Standard for mitigating the effects of tin in aerospace and high performance electronic systems

GEIA-HB-0005-1, Program management / Systems engineering guidelines for managing the transition to lead-free electronics

GEIA-HB-0005-3, Rework and repair handbook to address the implications of lead-free electronics and mixed assemblies in aerospace and high performance electronic systems

GEIA-HB-0005-3, "Aerospace and defence electronics systems containing lead free solder – Part 23: Rework and repair handbook to address the implications of lead-free electronics and mixed assemblies

GEIA-HB-0005-4, Guidelines for Performing Reliability Assessment for Lead Free Assemblies used in Aerospace and High-Performance Electronic Applications

GEIA-STD-0006, Requirements for Using Solder Dip to Replace the Finish on Electronic Components

ARINC Project Paper 671: Guidelines for Lead-free Soldering, Repair, and Rework, March 16, 2006.

ASTM B117-3 Standard Practice for Operating Salt Spray (Fog) Apparatus, October 2003

ASTM G85 Standard Practice for Modified Salt Spray (Fog) Testing, Annex A4 Salt/SO2 Spray (Fog) Testing 2002.

MIL-I-46058C Insulating Compound, Electrical (for coating printed circuit assemblies), Inactive for new design, July (1982)

IPC/JEDEC JP002, Current Tin Whiskers Theory and Mitigation Practices Guideline, March 2006.

IPC/JEDEC J-STD-001D, Requirements for Soldered Electrical and Electronic Assemblies, Feb. 2005.

IPC/JEDEC J-STD-002B, Solderability Tests for Component Leads, Terminations, Lugs, Terminals and Wires, February 2003

IPC/JEDEC J-STD-006B, Requirements for Electronic Grade Solder Alloys and Fluxed and Not Fluxed Solders for Electronic Soldering Applications, January 2006.

IPC/JEDEC J-STD-020C, Moisture/Reflow Sensitivity Classification for Non-hermetic Solid State Surface Mount Devices, July 2004.

IPC/JEDEC J-STD-033B, Handling, Packing, Shipping and Use of Moisture/Reflow Sensitive Surface Mount Devices, October 2005

IPC/JEDEC J-STD-609, Marking of Symbols and Labels of PCB Assemblies and Piece Parts to Identify Lead (Pb) and other Materials

IPC-A-610, Acceptability of Electronic Assemblies, Revision D, February (2005)

IPC-CC-830, Qualification and Performance of Electrical Insulating Compound for Printed Wiring Assemblies, Revision B, August (2002)

IPC-TM-650, Test Methods Manual Method 2.6.25 Conductive Anodic Filament (CAF) Resistance Test: X-Y Axis November 2003

IPC-1066 Marking, Symbols and Labels for Identification of Lead-Free and Other Reportable Materials in Lead-Free Assemblies, Components and Devices, January 2005

IPC-1752 Materials Declaration Management, February 2006

IPC-2221A, Generic Standard on Printed Board Design, May 2003.

IPC-4552, Specification for Electroless Nickel/Immersion Gold (ENIG) Plating for Printed Circuit Boards, October 2002.

IPC-4553, Specification for Immersion Silver Plating for Printed Circuit Boards, June 2005.

IPC-4554, Specification for Immersion Tin Plating for Printed Circuit Boards

IPC-7095A, Design and Assembly Process Implementation for BGAs, October, 2004.

IPC-9701 Performance Test Methods and Qualification Requirements for Surface Mount Solder Attachments, January 2002, and Lead-Free Appendix B

JESD97 Marking, Symbols, and Labels for Identification of Lead (Pb) Free Assemblies, Components, and Devices, May 2004

3 Terms and definitions

For purposes of this document, the following terms and definitions apply:

3.1
alloy composition
all alloy compositions are stated as weight percent. For instance 63Sn-37Pb corresponds to a mixture of 63 % by weight of Tin(Sn) and 37 % by weight of Lead(Pb)

3.2
alloy 42
refers to a nickel-iron controlled-expansion alloy containing 42 % nickel that is often used as a lead-frame material in electronic packages

3.3
Ag, Au, Bi, Cu, Ge, In, Ni, Pb, Sb, and Sn
refer to the elements Silver, Gold, Bismuth, Copper, Germanium, Indium, Nickel, Lead, Antimony, and Tin, respectively

3.4
AHP
Aerospace, High Performance Systems

3.5
assemblies
are electronic items that require electrical attachments, including soldering of wires or component terminations; examples include circuit cards and wire harnesses

3.6
AR
acrylic resin conformal coating

3.7
CAF
refers to Conductive Anodic Filaments that form in printed wiring boards. See IPC-TM-650 Method 2.6.25

3.8
CALCE
the University of Maryland Center for Advanced Life Cycle Engineering (CALCE) consortium

3.9
CLCC
refers to a Ceramic Leadless Chip Carrier electronic package

3.10
critical
item or function, if defective, will result in the system's inability to retain operational capability, meet primary objective, or affect safety

3.11
creep
refers to time dependent strain occurring under stress

3.12
CSAM
refers to C-Mode scanning acoustic microscopy, which is a method for evaluating electronic packages for internal delamination using high frequency sound waves

3.13
CTE
refers to the coefficient of thermal expansion of a material. PCB CTE (x-y) is measured in the direction in the plane of the piece-part mounting surface and is used to quantify the stresses in the solder joint arising from the differences in CTE between the piece-parts and the PCB during thermal cycling. CTE(z) is measured in the "thickness" direction and is typically used to quantify plated through hole stress

3.14
customer
refers to an entity or organization that (a) integrates a piece part, soldered assembly, unit, or system into a higher level system, (b) operates the higher level system, or (c) certifies the system for use. For example, this may include end item users, integrators, regulatory agencies, operators, original equipment manufacturers (OEMs), and Subcontractors

3.15
dicy cure
refers to the use of dicyandiamide (dicy), as a curing agent for epoxy resins

3.16
EM
refers to electromigration of the PCB metallization. Resistance to electromigration testing is typically performed between electrically biased conductors at elevated humidity and temperature

3.17
ENIG
refers to Electroless Nickel Immersion Gold Printed Wiring Board Finish

3.18
ER
epoxy resin conformal coating

3.19
eutectic
a eutectic or eutectic mixture is a mixture of two or more metals at a composition that has the lowest melting point, and where the phases simultaneously crystallize from molten solution at this temperature. A non-eutectic mixture will exhibit a pasty range during cooling where both liquid and solid phases are present prior to reaching the mixture's solidus temperature

3.20
FR4
refers to Flame Retardant laminate made from woven glass fiber material impregnated with epoxy resin

3.21
Fick's law
refers to the classic diffusive mass transport model where the mass diffusion is proportional to the concentration gradient in the material

3.22
fillet lifting
refers to a separation that occurs between a solder fillet and a PCB pad where the solder fillet has the appearance that it has lifted off the PCB pad. The fillet lifting is caused by the formation of a low melting point phase (often a ternary alloy) or liquid phase in an alloy having a large pasty range. The thin layer of liquid present adjacent to the PCB pad results in a layer that allows the solidified solder above it to pull off the PCB pad [38] [73]

3.23
high performance system or product
requires continued performance or performance on demand, or equipment down time cannot be tolerated, or end-use environment may be uncommonly harsh, and the equipment must function when required, such as life support or other critical systems

3.24
HALT and HAST
refers to highly accelerated life test and highly accelerated stress test, respectively

3.25
HASL
refers to the Hot Air Solder Level PCB surface finish

3.26
incubation period
in the context of Tin Pest formation refers to the time required at cold temperature to initially form the brittle gray (α) Tin phase from the ductile white (β) Tin phase