



TECHNICAL REPORT

GEIA-STD-0005™-1

REV. B

Issued 2006-06
Revised 2023-08

Superseding GEIA-STD-0005-1A

(R) Standard for Developing a Lead-Free Control Plan
to Manage the Risks of Lead-Free Solders and Finishes
in Aerospace, Defense, and High-Performance
Soldered Electronic Products

RATIONALE

This technical report was revised to incorporate the knowledge accrued from managing risks of using lead (Pb)-free materials in aerospace, defense, and high-performance (ADHP) soldered electronic products and to comply with the SAE Five-Year Review policy.

INTRODUCTION

In 2002, the European Union enacted two regulations: 2002/95/EC Restriction of Hazardous Substances (RoHS) and 2002/96/EC Waste Electrical and Electronic Equipment (WEEE). These and other government regulations on the use of Pb have resulted in a global transition to Pb-free electronics, particularly in the commercial electronics sector.

The aerospace and defense electronics sectors (and some other high-performance sectors) have been more cautious in the adoption of Pb-free technologies for several reasons: stringent reliability requirements (e.g., safety critical or security critical applications), long service life, complex harsh environments, and sustainment (i.e., existing SnPb products may require repair/rework). Pb-free materials require characterization for use in ADHP operational environments.

Given the commercial electronics transition to Pb-free, there are certain incentives for ADHP products and systems to transition to Pb-free materials. These incentives include the use of commercial off-the-shelf (COTS) assemblies, the need to use new electronic package styles, availability, and affordability.

SAE G-24 and IPC PERM were formed by the aerospace and defense industry to develop standards, handbooks, and guidelines to manage the risks of transitioning to Pb-free technology. The GEIA-STD/HBK-0005 suite of documents, as well as documents released by IPC such as IPC/PERM-2901, are the approaches developed and recommended by these committees. While these documents were primarily developed by the aerospace and defense industry, the techniques are applicable to any ADHP product needing mitigation to Pb-free material risks.

GEIA-STD-0005-1 identifies the requirements for a lead-free control plan (LFCP), a tool to control the inclusion of Pb-free materials and to manage the risks of using Pb-free materials in ADHP products. An LFCP ensures these risks do not compromise the required reliability throughout the specified service life of an ADHP product.

SAE Executive Standards Committee Rules provide that: "This report is published by SAE to advance the state of technical and engineering sciences. The use of this report is entirely voluntary, and its applicability and suitability for any particular use, including any patent infringement arising therefrom, is the sole responsibility of the user."

SAE reviews each technical report at least every five years at which time it may be revised, reaffirmed, stabilized, or cancelled. SAE invites your written comments and suggestions.

Copyright © 2023 SAE International

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording, or otherwise, without the prior written permission of SAE.

TO PLACE A DOCUMENT ORDER: Tel: 877-606-7323 (inside USA and Canada)
Tel: +1 724-776-4970 (outside USA)
Fax: 724-776-0790
Email: CustomerService@sae.org
http://www.sae.org

SAE WEB ADDRESS:

Full document details: SAE GEIASTD0005_1B

For more information on this standard, visit
https://www.sae.org/standards/content/GEIASTD0005_1B/

Documents

Document Sharing Hub

TABLE OF CONTENTS

1.	SCOPE.....	3
2.	APPLICABLE DOCUMENTS.....	3
2.1	SAE Publications.....	3
2.2	IPC - Association Connecting Electronics Industries Publications	3
2.3	Related Publications	4
2.3.1	SAE Publications.....	4
2.3.2	IPC - Association Connecting Electronics Industries Publications	4
2.3.3	IEC Publications.....	5
2.3.4	Other Publications.....	6
3.	DEFINITIONS	6
4.	ACRONYMS	7
5.	GENERAL REQUIREMENTS	8
5.1	Organization.....	8
5.2	Terms and Definitions	8
5.3	Point of Contact.....	8
5.4	References.....	8
5.5	Requirements for Suppliers	8
5.6	Acceptance	8
5.7	Modifications	9
6.	TECHNICAL REQUIREMENTS.....	9
6.1	Pb-Free Components and Mixed Assembly	9
6.1.1	Manufacturing and Reliability.....	9
6.1.2	Configuration Control and Product Identification	12
6.1.3	Rework, Repair, and Maintenance.....	13
6.2	COTS Products	13
6.2.1	Manufacturing and Reliability.....	13
6.2.2	Configuration Control and Product Identification	14
6.2.3	Rework, Repair, and Maintenance.....	15
6.3	Pb-Free Design and Assembly	15
6.3.1	Manufacturing and Reliability.....	15
6.3.2	Configuration Control and Product Identification	17
6.3.3	Rework, Repair, and Maintenance.....	18
7.	NOTES.....	18
7.1	Revision Indicator.....	18
APPENDIX A	REQUIREMENTS VERIFICATION MATRIX FOR GEIA-STD-0005-1B	19
APPENDIX B	SUPPLEMENTAL TECHNICAL INFORMATION	24

1. SCOPE

This technical report identifies the requirements for an LFCP for ADHP soldered electronic products built fully or partially with Pb-free materials and assembly processes. An LFCP documents the specific Pb-free materials and assembly processes used to assure customers their ADHP soldered electronic products will meet the applicable reliability requirements of the customer. This standard specifically addresses LFCPs for:

- a. Pb-free components and mixed assembly: Products originally designed and qualified with SnPb solder and assembly processes that incorporate components with Pb-free termination finishes and/or Pb-free BGAs, i.e., assembling Pb-free parts using eutectic/near-eutectic SnPb processes (also known as mixed metallurgy).
- b. COTS products: COTS products likely built with Pb-free materials and assembly processes.
- c. Pb-free design and assembly: Products designed and qualified with Pb-free solder and assembly processes.

This standard does not include detailed descriptions of the processes to be documented in an LFCP, but lists high-level requirements for ADHP soldered electronic products using Pb-free materials and assembly processes, such as requirements for manufacturing and reliability, configuration control and product identification, and rework, repair, and maintenance.

This standard is structured to enable tailoring, i.e., deleting, adding, or modifying requirements as applicable to the product, system or program under consideration. Tailoring GEIA-STD-0005-1 requires agreement between the LFCP user and customer before implementation.

2. APPLICABLE DOCUMENTS

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

ARP6537	Risk Mitigation for Pb-free Solders Used Internally to Parts
ARP6415	Use of Pb-Free Ball Grid Array Component Soldered Using SnPb Solder
GEIA-STD-0005-2	Standard for Mitigating the Effects of Tin Whiskers in Aerospace and High-Performance Electronic Systems
GEIA-STD-0005-3	Performance Testing for Aerospace and High-Performance Electronic Interconnects Containing Pb-Free Solder and Finishes

2.2 IPC - Association Connecting Electronics Industries Publications

Available from IPC, 3000 Lakeside Drive, 309 S, Bannockburn, IL 60015, Tel: 847-615-7100, www.ipc.org.

IPC-4552	Specification for Electroless Nickel/Immersion Gold (ENIG) Plating for Printed Boards
IPC-4553	Specification for Immersion Silver Plating for Printed Boards
IPC-4554	Specification for Immersion Tin Plating for Printed Circuit Boards
IPC-4556	Specification for Electroless Nickel/Electroless Palladium/Immersion Gold (ENEPIG) Plating for Printed Circuit Boards

IPC-9202	Material and Process Characterization/Qualification Test Protocol for Assessing Electrochemical Performance
IPC-9203	Users Guide to IPC-9202 and the IPC-B-52 Standard Test Vehicle
IPC-CH-65	Guidelines for Cleaning of Printed Boards and Assemblies
IPC/JEDEC J-STD-609	Marking and Labeling of Components, PCBs and PCBAs to Identify Lead (Pb), Pb-Free and other Attributes.
IPC-PERM-2901	Pb-free Design & Assembly Implementation Guide
IPC-T-50	Terms and Definitions for Interconnecting and Packaging Electronic Circuits
IPC-WP-019	An Overview on Global Change in Ionic Cleanliness Requirements
IPC/WHMA-A-620	Requirements and Acceptance of Cable and Wire Harness Assemblies
IPC/WHMA-A-620_S	Space and Military Applications Electronic Hardware Addendum to IPC/WHMA-A-620

2.3 Related Publications

The following publications are provided for information purposes only and are not a required part of this SAE Technical Report.

2.3.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

GEIA-HB-0005-1	Program Management/Systems Engineering Guidelines for Managing the Transition to Lead-Free Electronics
GEIA-HB-0005-2	Technical Guidelines for Aerospace and High-Performance Electronic Systems Containing Lead-Free Solder and Finishes
GEIA-HB-0005-3	Rework/Repair Handbook to Address the Implications of Lead-Free Electronics and Mixed Assemblies in Aerospace and High-Performance Electronic Systems
GEIA-STD-0006	Requirements for Using Robotic Hot Solder Dip to Replace the Finish on Electronic Piece Parts

2.3.2 IPC - Association Connecting Electronics Industries Publications

Available from IPC, 3000 Lakeside Drive, 309 S, Bannockburn, IL 60015, Tel: 847-615-7100, www.ipc.org.

IPC-J-STD-001	Requirements for Soldered Electrical and Electronic Assemblies
IPC-J-STD-001_S	Space Applications Electronic Hardware Addendum to J-STD-001H Requirements for Soldered Electrical and Electronic Assemblies
EIA/IPC/JEDEC J-STD-002	Solderability Tests for Component Leads, Terminations, Lugs, Terminals, and Wires
IPC-J-STD-003	Solderability Tests for Printed Boards
IPC-J-STD-004	Requirements for Soldering Fluxes
IPC-J-STD-005	Requirements for Soldering Pastes

IPC-J-STD-006	Requirements for Electronic Grade Solder Alloys and Fluxed and Non-Fluxed Solid Solders for Electronic Soldering Applications
IPC-7711/7721	Rework, Modification, and Repair of Electronic Assemblies
IPC/JEDEC J-STD-020	Moisture/Reflow Sensitivity Classification for Non-Hermetic Solid State Surface Mount Devices
IPC/EIA J-STD-028	Performance Standard for Flip Chip/Chip Scale Bumps
IPC/JEDEC J-STD-033	Handling, Packing, and Shipping and Use of Moisture/Reflow Sensitive Surface Mount Devices
IPC/PERM-WP-022	Mitigation of Pure Tin Risk by Tin-Lead SMT Reflow - Results of an Industry Round-Robin - Final Report
IPC/PERM-2901	Pb-free Design and Assembly Implementation Guide
IPC-2221	Generic Standard on Printed Board Design
IPC-2222	Sectional Design Standard on Rigid Organic Printed Boards
IPC-2223	Sectional Design Standard for Flexible/Rigid-Flexible Printed Boards
IPC-2225	Sectional Design Standard for Organic Multichip Modules (MCM-L) and MCM-L Assemblies
IPC-6012	Qualification and Performance Specifications for Rigid Printed Boards
IPC-6013	Qualification and Performance Specifications for Flexible/Rigid-Flexible Printed Boards
IPC-6015	Qualification and Performance Specification for Organic Multichip Module Mounting and Interconnecting Structures
IPC-9202	Material and Process Characterization/Qualification Test Protocol for Assessing Electrochemical Performance Using the IPC-B-52 Test Assembly
IPC-9203	Users Guide to IPC-9202 and the IPC-B-52 Standard Test Vehicle
IPC-9701	Thermal Cycling Test Method for Fatigue Life Characterization of Surface Mount Attachments IPC-A-610Acceptability of Electronic Assemblies
IPC-SPVC-WP-006	Round Robin Testing and Analysis - Lead-free Alloys - Tin, Silver and Copper

2.3.3 IEC Publications

Available from IEC Central Office, 3, rue de Varembe, P.O. Box 131, CH-1211 Geneva 20, Switzerland, Tel: +41 22 919 02 11, www.iec.ch.

IEC 60068-2	Environmental Testing
IEC 61188-5	Design Guide for Printed Boards and Board Assemblies
IEC 61190-1	Attachment Materials for Electronic Assemblies
IEC 61191-1	Printed Board Assemblies
IEC 61192	Workmanship requirements for Soldered Electronic Assemblies - Part 1: General

2.3.4 Other Publications

Hillman, D., Wells, M., and Cho, K. (2008). The impact of reflowing a Pb-free solder alloy using a tin/lead solder alloy reflow profile on solder joint integrity. *Rockwell Collins*. Retrieved from https://smtnet.com/library/files/upload/The_impact_of_reflowing_a_pbfree_solder_alloy.pdf.

3. DEFINITIONS

ACCELERATION FACTORS: For a given failure mechanism, the ratio of the time it takes for a certain fraction of the population to fail, following application of one stress or use condition, to the corresponding time at a more severe stress or use condition.¹

COMMERCIAL OFF-THE-SHELF (COTS): Components or products developed for multiple commercial consumers, whose design and configuration is controlled by the supplier's specification or an industry standard.

COMPONENT: An individual part or combination of parts that, when together, perform a design function.²

CONFIGURATION CONTROL: The activity associated with controlling initial releases, changes, cancellations, and other actions associated with hardware and/or software drawings, specifications, and other descriptive documents.

CUSTOMER: An organization that (a) integrates a component, soldered product, 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 suppliers.

HIGH-PERFORMANCE PRODUCT: A product that requires continuous performance or performance on demand, or cannot tolerate equipment downtime, or has an uncommonly harsh end-use environment; the equipment must function when required, such as life support or other critical systems.

LEAD-FREE (Pb-FREE): Less than 0.1% by weight of Pb in accordance with WEEE guidelines and IPC-T-50.

LEAD-FREE CONTROL PLAN (LFCP): A document that defines the materials and assembly processes to assure all stakeholders that ADHP electronic products containing Pb-free solder, Pb-free components, or Pb-free printed board finishes will be reliable.

LEAD-FREE TIN FINISH (Pb-FREE Sn FINISH): Pb-free Sn final finishes or under-plates either external or internal to a device, printed board, or other hardware. This includes all terminations and surfaces, even those coated, encapsulated, or otherwise not exposed. It may include finishes on electrical component terminations, mechanical components, and printed boards. It does not include Pb-free bulk solders, assembly materials, solder balls/columns/etc., or those devices where the Pb-free Sn finish has been completely replaced. Components with Sn termination finishes having less than 3% Pb by weight are considered a Pb-free Sn finish per GEIA-STD-0005-2.

MAINTENANCE: All action, including inspection, testing, servicing, classification as to serviceability, repair, rebuilding, and reclamation, taken to retain materiel in a serviceable condition or to restore it to serviceability.

MODIFIED COMMERCIAL OFF-THE-SHELF (MOTS): COTS products customized or modified to survive harsh environments or uses other than originally intended. COTS modified for ruggedization may also be known as ROTS.

PRINTED BOARD: A composite structure incorporating point-to-point interconnections for electronic circuits. It may include embedded components. (This includes single-sided, double-sided, multilayer, rigid, rigid-flex, and flex constructions.)²

PRINTED BOARD ASSEMBLY: An assembly that uses a printed board for component mounting and interconnecting purposes.²

PRODUCT IDENTIFICATION: The ability to describe a product (hardware, software, or firmware) such that it can be specified for use.

¹ © JEDEC. Reproduced from JEP122H with permission by JEDEC.

² © 2023 IPC International, Inc. Reprinted from IPC-T-50N with permission by IPC.

REPAIR: Action on a non-conforming product to make it conform to form, fit and functional attributes, but will not meet all drawing requirements. It may involve materials and processes that are not specified by the controlling drawing. Unlike rework, repair can affect or change parts of the non-conforming product.²

REWORK: The act of reprocessing non-conforming product in a manner that assures compliance of the product with the applicable drawings or specifications.²

SOLDERED PRODUCT: An electronic product with two or more components interconnected with a solder alloy.

SUPPLIER: An organization that designs, manufactures, repairs, reworks, or maintains a component, unit, or system. For example: OEMs, repair and rework facilities, subcontractors, and component manufacturers.

TECHNICAL DATA PACKAGE (TDP): The authoritative technical description of a product. This technical description supports the acquisition, production, inspection, engineering, and logistics support of the product. The description defines the required design configuration, performance requirements, and procedures required to ensure adequacy of product performance. It consists of applicable technical data such as models, engineering design data, associated lists, specifications, standards, performance requirements, quality assurance provisions, software documentation, and packaging details.

TIN WHISKER: A spontaneous crystal growth that emanates from Sn-rich finishes. They may be cylindrical, kinked, or twisted. Typically, they have an aspect ratio (length/width) greater than two with shorter growths referred to as nodules or odd-shaped eruptions.

4. ACRONYMS

ADHP	Aerospace, defense, and high-performance
ASIC	Application-specific integrated circuit
BGA	Ball grid array
COTS	Commercial off-the-shelf
DoD	Department of Defense
FOD	Foreign object debris
GEIA	Government Electronics and Information Technology Association
JCAA/JG-PP	Joint Council on Aging Aircraft Joint Group on Pollution Prevention
JEITA	Japan Engineering and Information Technology Association
LEAP WG	Pb-Free Electronics in Aerospace Project Working Group
LFCP	Lead-free control plan or Pb-free control plan
MOTS	Modified commercial off-the-shelf
NASA	National Aeronautics and Space Administration
OEM	Original equipment manufacturer
Pb	Lead
PERM	Pb-Free Electronics Risk Management Council
PMP	Parts materials and processes

RoHS	Restriction of hazardous substances
ROSE	Resistivity of solvent extract
SAC	Tin-silver-copper (SnAgCu)
SACx	Tin-silver-copper with additional trace elements
SME	Subject matter expert
Sn	Tin
SnBix	Tin-bismuth with additional trace elements
TAL	Time above liquidus
TDP	Technical data package
WEEE	Waste electrical and electronic equipment

5. GENERAL REQUIREMENTS

5.1 Organization

There is no specific format required for the LFCP. Any format is permissible providing it includes all applicable requirements described in this standard. The LFCP should be organized so all requirements in Sections [5](#) and [6](#) are addressed clearly, concisely, unambiguously and are verifiable by the customer. A requirements verification matrix template is provided in Appendix A to aid in confirming compliance to the requirements herein.

NOTE: As this revision represents a concentrated and dedicated effort to minimize risks, it is strongly recommended that an experienced (components, packaging, printed board assembly, SME, etc.) engineer work with the user to generate a LFCP in accordance with the requirements of this standard.

5.2 Terms and Definitions

The LFCP shall include terms and definitions not included in Section [3](#).

5.3 Point of Contact

The LFCP shall identify a point of contact who acts as the primary interface with outside parties in matters pertaining to the LFCP.

5.4 References

The LFCP shall include applicable assembly processes or reference applicable process documentation. Industry specifications can be leveraged when referenced in the LFCP.

5.5 Requirements for Suppliers

The LFCP shall identify how the requirements in the LFCP are imposed on suppliers, and how such requirements are verified. The LFCP shall identify suppliers' requirements and how the requirements are verified.

5.6 Acceptance

The LFCP user and the customer shall agree the LFCP is acceptable before implementation, when the customer chooses to exercise the right of acceptance.

5.7 Modifications

The LFCP shall identify the process to notify all affected organizations of a change.

6. TECHNICAL REQUIREMENTS

This section defines the technical requirements for an LFCP.

This section addresses three technical risk areas associated with the use of Pb-free materials in ADHP products (see Section 1.) These are:

- a. Pb-free components and mixed assembly (see [6.1](#)).
- b. COTS products (see [6.2](#)).
- c. Pb-free design and assembly (see [6.3](#)).

Within each risk area, three highlevel requirements are incorporated:

- a. Manufacturing and reliability.
- b. Configuration control and product identification.
- c. Rework, repair, and maintenance.

6.1 Pb-Free Components and Mixed Assembly

This risk area applies to various types of soldered electronic products designed and produced for ADHP customers, under formal configuration control, using SnPb solder, parts and assembly processes together with components with Pb-free termination finishes and/or ball grid arrays (BGA) having Pb-free solder balls resulting in a mixed SnPb and Pb-free product.

6.1.1 Manufacturing and Reliability

6.1.1.1 Manufacturing Process Controls

For the manufacture of mixed SnPb and Pb-free products, the LFCP shall:

- a. Include a method to identify the solder alloys, component finishes, and printed board finishes.
- b. Identify any other approved solder alloys, component finishes, or printed board finishes.
- c. Identify the source documents for soldering acceptance requirements, such as IPC-J-STD-001, IPC-A-610, or IPC/WHMA-A-620, as applicable. Include the IPC-J-STD-001-S and IPC/WHMA-A-620-S space and military addendums if contractually invoked.
- d. Identify operator training requirements for SnPb solder processing/inspection including when Pb-free parts are used.
- e. Validate that the SnPb soldering equipment, materials, and process parameters are compatible with Pb-free parts used. See [6.1.1.9](#), Notes 1 and 2.
- f. Require all solder materials and equipment to be labeled to avoid cross-contamination.