

Raytheon's Pro-Active Approach in Addressing the Challenges Associated with Lead-Free Technologies in COTS Equipment

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Customer Success Is Our Mission

Abstract

Commercial-off-the-shelf (COTS) items continue to play a significant role in the development and production of defense systems under acquisition reform initiatives. With concerns focusing mainly on top-level performance specifications, end-users do not have the luxury of governing processes used in the manufacture of such items. Accordingly, as the electronics industry proceeds with ever-increasing initiatives in “green” technologies, end-users can expect to find new materials and processes present in COTS products. With respect to electronic interconnection, a specific case is the trend to use lead-free solder as a substitute for traditional tin-lead solders. Within commercial applications, these alternate materials have performed sufficiently in relatively benign environments. Since these materials are used as the sole electronic interconnection medium, aerospace and defense original equipment manufacturers (OEMs) need to concern themselves with overall performance characteristics of these materials in harsher service environments.

Major concerns with these materials include reliability of the interconnection and risks associated with the tin whisker phenomenon (an artifact of using pure tin plating for solder preparation). Raytheon, through its company-wide Commercialization Team, is actively engaged in addressing these concerns in several ways.

The Situation as it Stands Today

- Interest in alternatives to lead solders continues to increase [1,2,3,4]
 - The international community is implementing measures to reduce amount of lead usage and exposure to the environment.

In May, a series of FAQ's and answers, from the RoHS committee clarified that defense/aero-space OEMs are exempt

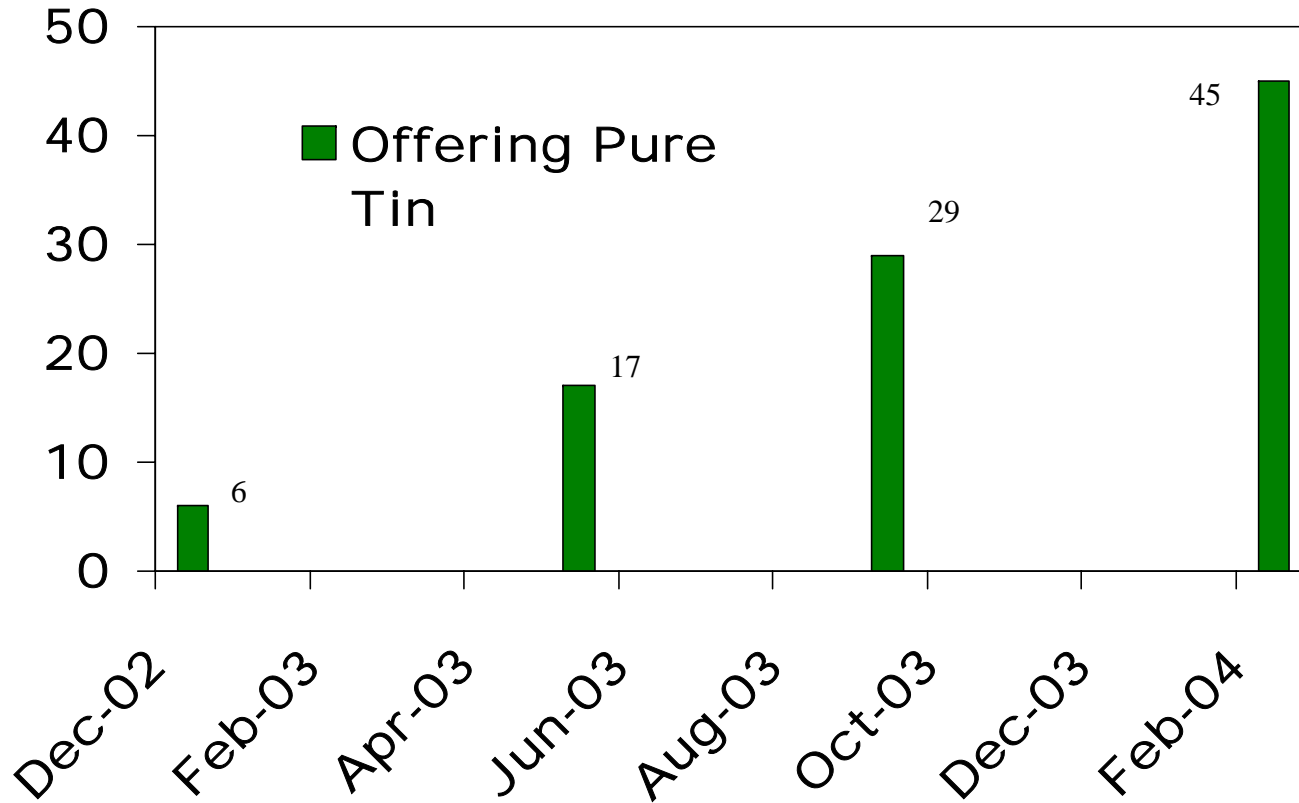


- **Europe: Waste from Electrical and Electronic Equipment (WEEE) calling for drastic reductions (if not elimination) of lead use by 2006 (WEEE became law on January 27, 2003. Implementation is July 1, 2006.) [5, 6]**
- **Japan: Restrictions are now underway**
- **China: In 2003, Chinese Ministry of Information Industry (MII) prepared a regulation, "Management Methods for Pollution Prevention and Control in the Production of Electronic Information Products," which includes restriction of Pb usage.**
- **USA: Legislative Activity is not restrictive although DoE Executive Order 13148 is now being referenced as "boilerplate" in some defense contracts [7]**

Starting to affect US defense/aero space OEMs



The Situation as it Stands Today



Thirteen of these suppliers plan to drop their tin-lead product lines

See Reference 8.

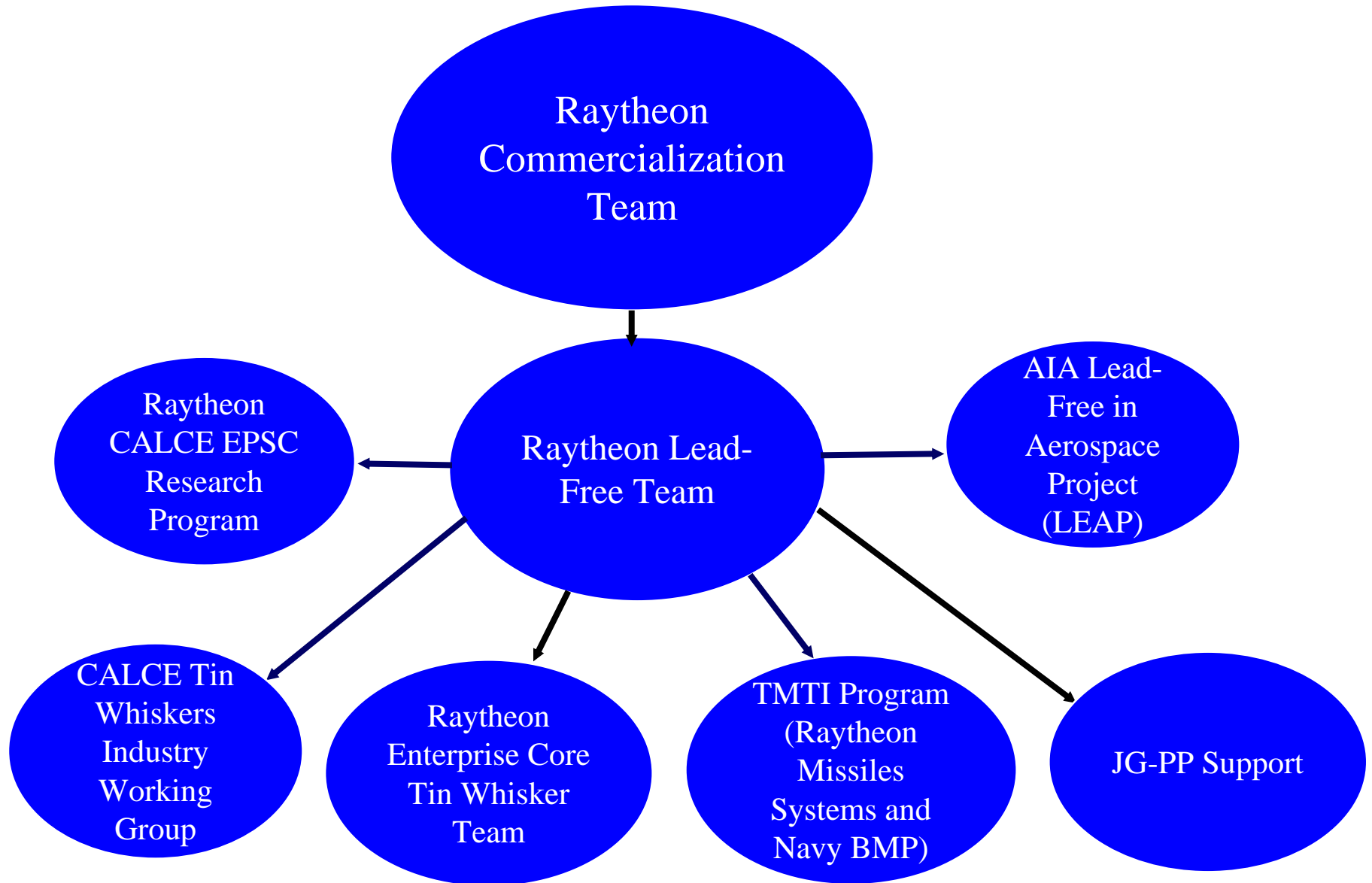
Issues

- Concerns with lead-free solder*
 - Interconnection performance characteristics
 - Fatigue life
 - Mechanical strength
 - Effects of lead-free/mixed finishes (e.g. tin whiskers phenomenon)
 - This is a rapidly approaching threat to the long-term reliability of many military, avionics, and space programs.
 - Conversion of In-house lines to lead-free
 - Not a near-term issue (thanks to legislative exemptions)
 - Long term effects
 - May become an issue: not known how long exemptions will continue to be granted.
 - Perception can influence marketplace standing
 - » OEMs might lose favor with international customers who place a high sense of priority in green technologies
 - Configuration Control
 - Aerospace only major industry that repairs at assembly level

With suppliers focusing on green requirements, as well as top level performance specifications, defense OEMs do not have the market share influence to influence processes used in manufacture of these items.

* This talk is limited to solder alloys. Electrically conductive adhesives are another option and have their own benefits and challenges.







Raytheon
Commercialization
Team

- Raytheon Commercialization Team
 - Original team was comprised of working groups when legacy companies RES, HAC, TI Defense Systems, and E-Systems completed their merger in January of 1998
 - Team has transformed into one working group addressing key industry-level component issues regarding lead-free
 - Activities, across the company, are coordinated by the team.
 - Team membership spans many businesses and geographical locations.
 - » Missile Systems Tucson AZ, Space and Airborne Systems El Segundo CA, Integrated Defense Systems Sudbury, MA, Andover, MA, Tewksbury, MA and Portsmouth RI, Intelligence & Information Systems, Garland, TX and Network Centric Systems, McKinney TX and St. Petersburg, FL



- The Lead-Free Team is essentially the original Commercialization Team whose charter is to oversee all company activities in lead-free technology risk identification and mitigation
 - Oversees the activities of Raytheon's involvement in the University of Maryland Consortium
 - » Influencing/Directing the CALCE lead-free research agenda
 - » Participant in the consortium-separate Long Term Lead-Free Reliability program
 - Initiated the CALCE Tin Whisker Industry working group
 - » Chaired by Raytheon
 - Provides support to the Enterprise Tin Whisker group (Raytheon internal)
 - Participant in Transformational Manufacturing Transformation Initiative (TMTI)
 - Participant in Joint Group on Pollution Prevention (JG-PP)
 - Participant in AIA Lead-Free Electronics in Aerospace Project (LEAP)



- **Significant accomplishments thus far**
 - Plan a series of integrated research projects focusing on generation of required material properties to improve the CALCE PWA reliability tool to account for lead-free interconnection materials
 - Agendas for 2002 through present have been successfully executed
 - Key data now being acquired to characterize lead-free behavior
 - Constitutive relationships
 - Parameter effects during environmental test
 - Understanding intermetallic conditions
 - Also a part of separate (non-consortia) Long Term Lead-Free Reliability Program

Leveraging university research



CALCE Tin Whiskers
Industry Working
Group

Ad hoc industry team, spun off from the Commercialization Team, to address concerns of pure tin as an alternative finish to accommodate lead-free solders. Presently, eighty-five (85) sites are participating.

- Significant accomplishments thus far [9-10]
 - Generation of tin whiskers experiences and case studies paper
 - Generation of a mitigation guide
 - Compilation of supplier data, based on supplier surveys, on actions being taken by suppliers on lead-free compatible finishes
 - Tin Whisker Application Specific Risk Assessment Algorithm (Dave Pinsky of Andover)
 - Program to commercialize whisker mitigation processes
 - Draft report on tin whisker testing



Leveraging industry-wide synergy



Raytheon
Enterprise Core Tin
Whisker Teams

Chartered with task to develop company standards and procedures to mitigate the risks of metal whiskers

- **Significant accomplishments thus far**

- Tin Whisker Mitigation Policy
- Integrated Defense Systems (IDS) Design Guidelines for Metal Whisker Risk Mitigation
- Material Quality Directive for supplier management
- Tin control Engineering Directives

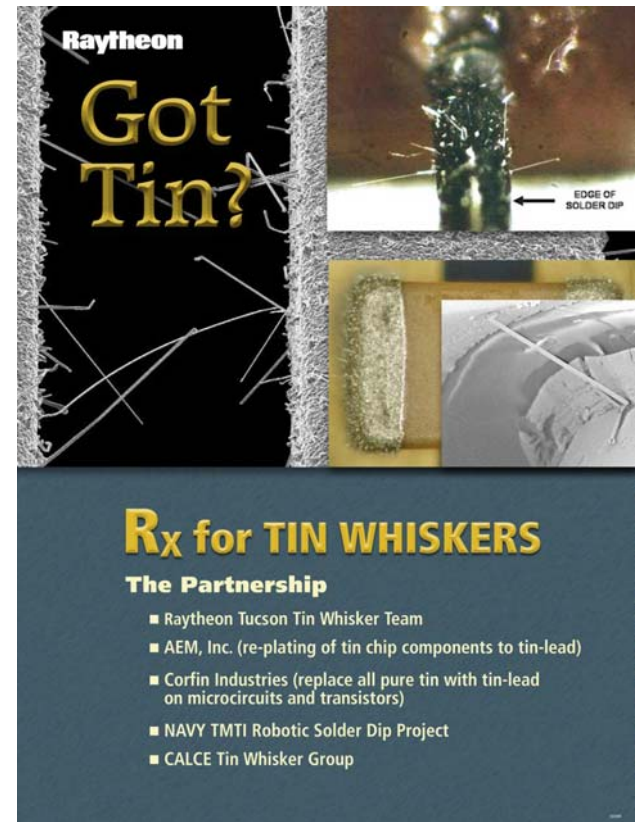


Utilizing results of cross-company efforts

TMTI Program
(Raytheon Missiles
Systems and Navy
BMP)

- **Methodological approach for re-tinning lead-free components**
 - A model for supply chain management

Partnering with our customers and suppliers



Raytheon
Got Tin?

EDGE OF SOLDER DIP

R_x for TIN WHISKERS
The Partnership

- Raytheon Tucson Tin Whisker Team
- AEM, Inc. (re-plating of tin chip components to tin-lead)
- Corfin Industries (replace all pure tin with tin-lead on microcircuits and transistors)
- NAVY TMTI Robotic Solder Dip Project
- CALCE Tin Whisker Group



JG-PP Support

- **Supporting combined environments testing**
 - Thermal cycling and vibration
- **Performing post-combined environments testing failure analysis**



Customer, OEM, and Supplier partnering

AIA Lead-Free in
Aerospace Project
(LEAP)

- ***Direct support in generation of guideline documents**
 - **GEIA-HB-0005-1_-Draft 1.0-, Program Management/Systems Engineering Management Guidelines for Managing The Transition To Lead-Free Electronics**
 - **GEIA-STD-0005-2, Draft 1.0 Standard for Mitigating the Deleterious Effects of Tin in High-Reliability Electronic Systems**

Industry pro-actively guiding itself

*The LEAP effort includes three other documents on performance and technical behavior which Raytheon supports as a reviewer.

Additional activities

- **Presence at all major conferences**
 - SMTA, ASME, IEEE, NDIA, Military/Aerospace COTS Conference
- **Publications in major journals (SMTA, IEEE, ASME, etc.)**
- **Sponsors of workshops/symposia**
 - CALCE Lead(Pb)-Free Forum Meeting **CONCERNS OF OEMs ON THE EFFECTS OF LEAD-FREE TECHNOLOGY ON HIGH-REL PRODUCTS AND SYSTEMS**
October 10, 2002
 - Raytheon Mechanical and Materials Technology Network
- **Activity in public forums**
 - Massachusetts TURI (toxics use reduction initiative)

Concluding Remarks

- Within the realm of performance characteristics, concern, with lead-free materials, is focused in two areas; reliability of the interconnection (joint) itself and performance effects from tin whisker formation
 - Key to these efforts are leveraging involvement from our customers, suppliers and other OEMs
- **By executing a proactive approach, we are giving customers confidence in our products and demonstrating our ability to address critical technology issues**

References

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References

1. University of Maryland CALCE EPSC Report on *Project No.: C03-01 Report Title: Risks to Equipment Manufacturers from the Incremental Transition to Lead-free Electronics in the Supply Chain* , *Principal Investigator: Prof. Michael Pecht*
2. Schneiderman, Ron, "Electronic Waste: Be Part Of The Solution", ED Online ID #7820, URL: <http://www.elecdesign.com/Articles/Index.cfm?ArticleID=7820&pg=1>
3. Pellerin, Bernard, "Transition to lead free soldering, Point of view of AIRBUS Avionics and Simulation products", date/location of presentation unknown, URL: http://www.arinc.com/amc/reports/2004/presentations/03_bernard_pellerin_present.pdf
4. Osterman, Michael, "Tin Whiskering", CALCE Monthly Distance Seminars, June 8th 2004, URL: http://www.calce.umd.edu/seminar/whisker_presentation.pdf
5. Directive 2002/95/EC of the European Parliament and of the Council of 27 January 2003, on the restriction of the use of certain hazardous substances in electrical and electronic equipment (WEEE)
6. DIRECTIVE 2002/95/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 27 January 2003 on the restriction of the use of certain hazardous substances in electrical and electronic equipment (RoHS)
7. Executive Order 13148--Greening the Government Through Leadership in Environmental Management, 21 April 2000
8. Rollins, William, "Tin Whisker Mitigation Roadmap.....", Raytheon Company Private, 22 September 2004
9. Pinsky, David, "Tin Whisker Application Specific Risk Assessment Algorithm", 2003 MILITARY & AEROSPACE / AVIONICS COTS CONFERENCE
10. Pinsky, D. and Lambert, E., "Tin Whisker Risk Mitigation for High-Reliability Systems Integrators and Designers", Proceedings of the 5th International Conference on Lead Free Electronic Components and Assemblies, March 2004

Author Biography

Tony Rafanelli has 27 years of service with the Raytheon Company. In his present assignment, he is a corporate Technology Area Director for Materials and Structures. His last assignment was Manager of the Architecture and Analysis Section in the Sensor and Control Systems Engineering Department. Current experience also includes work on CMMI training resources and development/execution of training programs and systems engineering process. Prior to joining the systems engineering department, he spent over twenty years working in quality assurance, failure analysis, materials/process engineering, and reliability.

He has earned the B.S. (1978), M.S.(1985) and Ph.D. (1995) degrees in Mechanical Engineering and Applied Mechanics from the University of Rhode Island. He is a licensed professional engineer in the states of Rhode Island and Massachusetts. He is a member of ASME International, ASM International, SMTA, and the Navy League of the United States.