ManTech Lead-Free Electronics White Paper
Project –F/A-18, AEGIS, SM-2, LRLAP, Joint DoD Lead-free (Pb-free) Electronics Demonstration FY'07& FY'08

Problem Statement

The European Union has mandated that by July 1, 2006, virtually all electronic equipment placed for sale on the European market not contain six substances, one of which is lead (Pb). The worldwide electronics industry has used tin-lead (SnPb) solders and surface finishes for the past 60+ years. Most US suppliers of electronics will convert their products over to lead-free to enable sale in Europe. The DoD, although technically exempt from the European legislation (COTS components are specifically not exempt) must procure components and assemblies from these same suppliers. Therefore, the DoD must use lead-free electronics simply because that is all that will be available from their suppliers.

The reliability of electronics made using lead is well known, but not well understood for electronics built using the lead-free mandate. Three issues are of major concern:

- Do the physical properties of lead-free solders result in solder joints of equivalent strength and reliability to the predictable legacy tin-lead joints?

- Do the higher assembly temperatures that must be used to assemble electronics with the high melting point lead-free solders damage electronic functionality of the components of the assembly, causing premature failure?

- If lead-free components are surface finished with pure electroplated tin, which is the preferred surface finish to replace tin-lead, will the resulting electronics fail because of short circuits caused by tin whisker growth?

These reliability issues are not severe for the shorter service lives and less harsh environments of commercial electronics. DoD applications are much more stringent.

Relevance to ManTech Strategic Plan

The proposed program will provide the DoD and its supporting industrial base with manufacturing guidelines, processes, and risk mitigation techniques when lead-free (Pb-free) solder alloys are employed in the build up of electronic platforms. The project is part of a planned phased approach to address the risk associated with Pb Free transition. This task is a **follow-on to the current 2005-2006 Navy ManTech effort. The expanded scope is** based upon additional government and industrial partner participation on other DoD platforms in order to cover a joint spectrum of platform applications. This project is unique among the myriad of Pb-free projects being conducted throughout the US by companies and academic consortia because it uses **actual fielded hardware designs** and conducts demonstration tests using the same approach that OEMs use to built and test their fielded hardware

Several DoD platforms have currently and will be selected to be the platforms of relevance for conducting this series of demonstration testing. The F/A-18 family of aircraft used by both Air Force and Navy an integral part of the DoD joint war fighting capability. The SM-2 missile and LRLAP are integral to the Navy DDG 1000 platform. The AEGIS system is critical to the existing fleet. These combined applications address the transition of electronics manufacturing technology for the U.S. Navy aircraft, missile, and ship platforms which are vital to continued Navy interests and future capability. In addition, assessment of Pb-Free electronics reliability may be applicable to other essential DoD platforms, such as J-UCAS and MMA in the Navy, T/R Module assembly within MDA phased array radars, Air Force space based electronics, Army avionics and guided munitions, and multiple other DLA acquisitions.

In the current 2005-2006 Navy ManTech project, actual Shop Replaceable Assemblies (SRAs) for the F/A-18 and AEGIS systems are being built using a selected Pb Free alloy and are used to conduct functional Pb-Free demonstration testing. These assemblies are being fabricated and tested with tin-lead controls. In the follow –on project, the SRAs, including those representing the other DoD stakeholders, will be tested in a higher level of assembly called Weapons Replaceable Assembly (WRA), and exposed to suitable conditions of shock and vibration and other recommended test environments.

The SRAs currently used in the 2005/2006 work are as follows:

- ITT – IDECM Electronic Counter Measure System for the F/A-18
- Rockwell Collins F/A-18 Head-Up Display (HUD) – I/O processor P/N 131220-19A
- Boeing generic F/A-18 HDI (High Density Interconnect) technology test vehicle.

The proposed Honeywell 5x5 Advanced Multipurpose Display (AMPDL) ITB Card (A3) 8525358-90 was also of specific interest to the F/A-18 program but was not used because Honeywell could not be brought on contract within the time contsraints of the initial project. The addition of this project item to proposed 2006-2007 work is now integrated into this plan.

The broadened DoD-wide scope will include representative electronic hardware from the Air Force, Army, MDA, and DLA.

The 2007/2008 work would include the Honeywell AMPDL ITB Card (A3) 8525358-90 , and, in addition, will add two boards from Lockheed Martin (AEGIS Digitizer Assembly and LMMFC LRLAP Long Range Land Attack Projectile) assembly, a Raytheon SM-2 representative assembly, and representative Army, Air Force, MDA and DLA hardware each of which are anticipated by the OEMs to require a Lead-free Manufacturing accommodation within the next two years to mitigate the risk of using lead-free commercial components and sub-assemblies in these critical DoD systems. Work on these F-18, AEGIS, and other critical DoD applications of lead-free electronics will continue into the next stage of WRA (Weapons Replaceable Assembly) reliability testing.

A Matrix which summarizes the proposed Lead-Free Vehicles is shown in the following table:

Company	Test Vehicle	Weapons System	Program Office	Letter of Support
Boeing	Generic Advanced HDI	F/A-18	PMA-290	YES
ITT Avionics	IDECM Electronic Counter Measure System	F/A-18	PMA-290	YES
Rockwell Collins	I/O processor P/N 131220-19A	F/A-18	PMA-290	YES
Lockheed Martin	AEGIS Phase Shifter Driver	AEGIS IWS (Deployed)	PMS-400	No
Honeywell	AMPDL ITB Card (A3) 8525358-90	F/A-18	PMA-290	YES
Lockheed Martin	LRLAP SRA	LRLAP (DDG 1000)	PMS-400	No
Raytheon	SM-2 SRA	SM-2 (DDG 1000)	PMS-400	No
TBD	Critical DoD electronic hardware for functional reliability assessment	Radars, Munitions, Procured Commercial Sub-Assemblies	TBD	No
ITT, ACI	Critical Legacy DoD electronic hardware (5-20 years old) for tin whisker risk assessment	Radars, Munitions, Procured Commercial Sub-Assemblies	TBD	No

The last five entries, as shown in blue font are an augmentation to the 2005/2006 existing Navy ManTech program.

In addition to the industrial partners participating in the hardware builds, BAE Systems , as an member of the IAB, will be added to the project to integrate and facilitate the technology transfer among the industrial participants. The role of BAE Systems is will be to:

- Provide recommendations on project approach to enhance commonality, maximize efficacy of project results, and enable leveraging of work already being performed as part of other initiatives
- Provide independent technical review and evaluation of the team project report at appropriate stages during development and finalization.

- Generate report on transferability of technologies developed under the individual project elements for the final project report.
- Facilitate technology transfer within the IAB community

Finally, ACI will provide the coordination and project management role for the effort, as a continuation of that role from the 2005/2006 program.

The program is estimated at 26 month duration, to begin in fiscal 2007, and expected to require $7.5 M to accomplish.

ManTech Priorities

The continued and expanded lead-free project will:

1. Enable the adoption of Pb-Free materials and processes needed to meet performance or affordability requirement for electronics systems that will be fielded within 5 years. The instance of Pb-Free materials within platform inventories is increasing, and the need for risk-mitigation data is paralleling this increase

2. Provide decision data to existing as well as planned systems that may face obsolescence as the commercial electronics industry transitions to lead-free and will improve manufacturing processes across many, if not all, DoD systems.

Acceptance by the Electronics Industry

The electronics industry is heavily dominated by the commercial industry marketplace; consequently, defense applications of electronics technologies are dependent upon the acceptance of lead-free technologies and their use, once developed. This commercial dependence has led to a need to transition to lead-free materials and processes. The commercial electronics industry typically requires only relatively short lifetimes for their products, with less severe environmental operating conditions, leading to a mismatch of requirements when the technology is used in a DoD/Navy platform. Since the entire military industry represents less than 2 percent of the total electronics market, lead-free adoption within commercial industry has been continuing with little regard to military applications. Specific considerations or concerns are:

1. Lead-free technology is being universally accepted and implemented by the worldwide electronics industry.

2. Lead-free technology has viability within the commercial electronics industry but has no demonstrated reliability maturity as required by DoD/Navy systems, the environmental conditions in which they must operate.

3. Lead-free technology may benefit the commercial electronics industry but hasn’t been adopted nor embraced by the DoD community.

4. Military hardware will be forced, due to availability of electronic components, to include lead-free components and sub-assemblies that have no proven military solder joint or functional reliability history. These assemblies may also be susceptible to tin whisker failures.

Level of Program Office Commitment

The F/A-18 program has committed to having the lead-free test demonstration project be accomplished. The project involves a partnership with The Boeing Company as the prime and several of the major suppliers including ITT, Rockwell Collins and potentially Honeywell and Raytheon, as participants who provide flight hardware.

The AEGIS program has shown commitment to the evaluation of lead-free in the AEGIS weapons system as evidenced by the inclusion of Lockheed Martin, at the AEGIS PM Office expense, maintaining involvement in the present 2005/2006 project and Lockheed Martin's desire to add the Lockheed Martin LRLAP (Long Range Land Attack Projectile) slated for DD(X) deployment, in addition to continuing work with the present AEGIS hardware, into the proposed 07 project. The commitment is within the industry partners, the DoD/Navy, and the F/A-18 program.

Raytheon proposes SM-2 as a lead-free test vehicle

While there is commitment to develop plans to look at insertion in the outlying years, and there is no definitive insertion point, Lead-free Electronics is recognized as having to be accommodated in military systems, and funding has been committed by each industrial partner, as well as the AEGIS program office, in the 05/06 program, and is expected to continue in 2007. This is in addition to any ManTech funding that may be realized. .

Technology Readiness Level (TRL)

The maturity of the proposed manufacturing technology has a direct impact on the risk of insertion and the potential planned benefit to the DoD platforms. The initial TRL level for this project is TRL 4. It is the expectation that this project will progress the technology and processes to a TRL 5 or 6. The current lead-free funded project is part of a phased approach to improving the TRL level to point of maturity for insertion. The initial phase, currently funded under ManTech and AEGIS Program Offices, dealt with building hardware to a defined process based upon industry partner acceptance of a lead-free alloy. These boards, or SRAs, were then tested using a proven acceptance test protocol. The project outlined here would advance this acceptance to the WRA level for the same systems and five additional deliverable DoD hardware systems which appear at risk from the Lead-free electronics mandate, including tin whisker occurrence on existing electronic hardware.

This proposed phase would build the SRAs using the same hardware configuration and demonstrated lead-free processes. The SRAs would be placed into the corresponding F/A-18, AEGIS, LRLAP, SM-2 and one other representative DoD WRA for test under defined, acceptance operational environments. Tin whisker failure risk would be Upon success, the test articles would go through delta-qual testing and move into eventual flight-and/or sea-worthiness testing to demonstrate their behavior in a fielded DoD

platform under actual operational conditions. The demonstrated data and processes would be collected and used to establish risk-mitigation decisions concerning lead-free technology insertion into DoD platforms.

Proposed 2007-2008 Approach

The 2007 -2008 approach will be, in general, an extension of the 2005/2006 project. Additional tasks that are proposed in 2007 -2008 project are to demonstrate board level application (SRA) (Shop-Replaceable Assembly) in the WRA "delta" acceptance test.

The selection of printed-wiring assemblies will include the SRAs of the 05/06 project from Boeing, ITT, Rockwell Collins, and Lockheed Martin as stated above. In addition, the Honeywell AMPDL board that was not evaluated in the current project will be used This is of great interest to Boeing and other high reliability/harsh environment OEM applications, since it is mounted behind the gun and experiences extreme vibration environments. The additional assemblies, the Raytheon SM-2, Lockheed Martin LRLAP SRAs, and the other SRAs chosen, will give insight into the durability of Pb-Free solder joints in high-vibration missile and high-g munitions applications.

A high-level statement of work proposed would be:

1. Assemble SRAs using the IDECM, F/A-18 Heads-Up Display, AEGIS, assemblies from the 05/06 program, and the AMPDL ITB card, SM-2, LRLAP and any additional chosen SRAs. For the lead-free boards, SAC 305 (tin-siver-copper) soldering alloy would be used to reflect the current work and conventional tin-lead solder will be used in the controls. Solder Hybrid assemblies will be included as a result of the 2005-2006 work, to confirm hypotheses developed in the earlier work.

2. WRAs will be exposed to the established acceptance tests for and will be functionally tested and individual sub-assemblies reworked (as required).

3. A limited environmental test series will be performed to assess performance of the candidate materials and processes in relevant aircraft, shipboard, missile and munitions operational conditions.

4. A survey of legacy (5 to 20 years old) mixed tin-lead and lead-free assemblies (termed "solder hybrid" in the 2005-2006 ManTech project, will be microscopically examined to reveal the presence or absence of tin whiskers on lead-free components and sub-assemblies and assess the actual risk such tin whiskers represent on functional hardware.

Industry Benefit

The benefit to the industry is a lead-free process that has been evaluated in suitable relevant shipboard, aircraft, missile, and high-g munitions environmental conditions. This project will assess the potential suitability of Pb-Free manufacturing processes and

materials (alloys) using representative current hardware in realistic environmental conditions.