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iNEMI Statement of Work (SOW)
Name of TIG: Board Assembly
iNEMI Pb-Free Alloy Alternatives Project

Instructions for use:

1. Save this file as "Project Name Statement of Work Draft 1"
2. All bold headings should be left as they are. These will form the structure of the document.
3. The Basic Project Information section should cover all the bulleted items, but only *briefly*. The first draft will consist of only this basic information. Later drafts will include detailed information in the Project Plan section.
4. The bullets beneath each heading are suggestions of what should be included in that section. All bullets may not apply to all projects. If none of the bullets apply, then substitute what you think is necessary or simply state "not applicable". Do not delete the heading even if it is not used.
5. For the first draft, the Project Plan section will usually not be filled in. Just state "Project Plan is being developed". Leave all the headings in place so that it will be easy to fill in the Project Plan in subsequent drafts. When you are ready to include the Project Plan, provide *all* available details for each topic.
6. In the Project Plan section, if there are more than two phases, add additional section via cut and paste. If the project consists of just one phase, delete the entire phase 2 section.
7. When you are finished, delete these instructions.

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Project Leader: Greg Henshall (HP)
Co-Project Leader: Steve Tisdale (Intel)
iNEMI Coach: Jim McElroy (iNEMI)

Basic Project Information

Scope of Work

- The major goals of the project are:
  - Provide guidance to the industry that will help make Pb-free proliferation easier to manage.
  - Determine existing knowledge and critical gaps related to new Pb-free alloys, including data requirements and a table of issues to track. Raise awareness through publication and presentation of findings. Use findings to drive follow-on work (if any) in Phase 2.
  - Provide technical information to the industry that will make selection and management of alloys easier.
  - Work with industry standards bodies to establish standard methods for part number changes when BGA/CSP solder ball alloy changes are made, clarify categories of alloys, and update solder material standards to address microalloy additions.
  - The intent is to provide some initial guidance to industry within three months of the start of the project.

Purpose of Project

- This project addresses the recent proliferation of Pb-free solders. It will help to manage the supply chain complexity

and to address reliability concerns and opportunities created by the increasing number of Pb-free alloy alternatives. Issues to be addressed include:

- General lack of knowledge throughout the supply chain regarding new Pb-free alloys, their properties, advantages and risks.
- BGA suppliers are changing Pf-free solder ball alloys, but this information is not always provided to EMS providers in a form that they can use to adjust their reflow process accordingly.
- Standards related to solder alloys require updating to account for new alloys, particularly those with microalloy additions.
- New wave solder alloys are being promoted but impacts to overall PCA reliability, mixing of various alloys, and potential pot composition changes over time are not completely understood.
- Alloy proliferation is creating a "moving target" for OEMs in industry segments not yet converted to Pb-free solder processes. Data are lacking or existing information is not visible.

- The work done on this project will be part of the solution to the problem of complexity resulting from the presence of many new Pb-free solder alloy alternatives available within the industry.
- Phase 1 of this project will focus on the analysis of existing knowledge and assessment of critical gaps, and on driving standards to help manage supply chain complexity and risk. Based on the findings of Phase 1, experimental investigations may follow in Phase 2.
- Anticipated benefits to the industry include better definition of important parameters in determining which Pb-free solders to use for what purposes. The increased awareness of risks and opportunities provided by new alloys and improvements in key standards, will help industry to manage alloy proliferation. A formal, technical white paper will be generated with the intent of publishing this information in a peer reviewed journal.

In summary, the proliferation of new Pb-free alloys is both an opportunity and a risk for the electronics industry. In order to take advantage of the former while minimizing the impact of the latter, much still needs to be learned and the visibility to existing knowledge needs to be improved. In addition, an assessment of critical knowledge gaps needs to be performed so that industry efforts can be focused on them and not on repeating investigations into issues already resolved. Further, standards need to be updated and improved to account for the new alloys and to better manage the risks they present. Addressing these concerns is the goal of this project.

Previous Related Work

- Within the past 1-2 years, the industry has seen a proliferation in the number of Pb-free solder alloy choices beyond the near-eutectic Sn-Ag-Cu (SAC) alloys most companies chose in order to meet the EU RoHS deadline of 1 July 2006. New wave solder alloys were developed with the intent of addressing concerns with copper dissolution, barrel fill, wave solder defects, and the high cost of alloys containing significant amounts of silver. Soon thereafter, the handheld product segment, especially mobile phone producers, became aware of the poor drop/shock performance of near-eutectic SAC alloys. This motivated the development of low Ag and low Cu alloys to improve the mechanical strength of BGA and CSP solder joints, especially under dynamic loading conditions. A significant body of data is now available in the public domain suggesting that these new alloys provide one solution to this problem, though a coherent summary of these data is not yet available. Most recently, investigations into new solder paste alloys for mass reflow have begun. The full impact of these materials on PCA reliability has yet to be determined.

- The increasing number of Pb-free alloys available provides opportunities to address the important issues described above. At the same time, the proliferation of alloys presents challenges in managing the supply chain and introduces a variety of risks. As summarized by Henshall et al. [ref. slide set on iNEMI web site], and recognized by the EMS Forum and a number of iNEMI member companies in a 2007 press release [ref. statement on iNEMI web site], the reliability of printed circuit assemblies (PCAs) is at risk if these challenges are not addressed. High melting point, low Ag alloys represent a risk in the reflow process if not managed properly. They may also present risks for thermal fatigue failure of solder joints in some circumstances, though much appears to be unknown about the impacts of Ag, Cu, and dopant concentration on thermal fatigue resistance of these alloys.

Prospective Participants

Mike Davisson	Agilent	Ailan Zhu	Huawei Technologies
Paul Petri	Agilent	Zhang Yuan	Huawei Technologies
Mike Cox	Agilent	Jim McElroy	iNEMI
Alex Chan	Alcatel-Lucent	R. Bernston	Indium
Richard J Coyle	Alcatel-Lucent	Eric Bastow	Indium
Marc Benowitz	Alcatel-Lucent	Tom Pearson	Indium
Joe Smetana	Alcatel-Lucent	Weiping Liu	Indium
Chen Xu	Alcatel-Lucent	Fay Hua	Intel
Sherwin Kahn	Alcatel-Lucent	Stephen Tisdale	Intel
Mike Magnifico	Analogic	Vasu S. Vasudevan	Intel
Sorin Marcovici	Analogic	Girish Wable	Jabil
Chris Tibbetts	Analogic	Quyen Chu	Jabil
Tony Primavera	Boston Scientific	Marty Rodriguez	Jabil
Enrico Westenberg	Boston Scientific	Peter Biocca	Kester
Scott Dyball	Boston Scientific	Paul Wang	Microsoft
Polina Snugovsky	Celestica	Michael Yuen	Microsoft
Thilo Sack	Celestica	Edwin Bradley	Motorola
Linda Scala	Celestica	Dennis Derfiny	Motorola
Donghyun Kim	Cisco	Masato Nakamura	Nihon Superior
Ashok Domadia	Cisco	Keith Sweatman	Nihon Superior
Tae-Kyu Lee	Cisco	Bill Barthel	Plexus
Robert Healey	Cookson	Robert Kinyanjui	Sanmina-SCI
Ranjit S Pandher	Cookson	Derek Daily	Senju-Comtek
Chrys Shea	Cookson	Jasbir Bath	Solectron
Mike Varnau	Delphi	Diane Sahakian	STATS/ChipPAC
Richard Parker	Delphi	Heidi Reynolds	Sun
Michael Roesch	HP	Karl Sauter	Sun
Greg Henshall	HP	Edgar Zuniga	TI
Cao Xi	Huawei Technologies	Tushar A. Shete	Tyco Electronics
Dr. Sunny Liu	Huawei Technologies		

- Project team members are expected to review and assess some portion of the existing knowledge base on new Pb-free alloys. They are expected to summarize their findings and to identify any gaps in knowledge in a manner consistent with the project schedule. Members will work with the team to put together and communicate an overall picture of what is known and not known about the new alloys, and to publish this information. Alternatively or in addition, members are expected to participate in updating relevant standards. Finally, project team members will work together to develop plans to address some or all of the critical gaps in Phase 2 of this project.
- List any known background IP for each participant

Project Plan

Schedule with Milestones

	Nov-07	Dec-07	Jan-08	Feb-08	Mar-08	Apr-08	May-08	Jun-08	Jul-08
Phase 1									
Determine Knowledge Gaps and Drive Standard on Part Number Change									
Task 1 – Determine what data and information exists and what the critical gaps are	Workshop planned for 01 February 2008 to begin identification of existing information and critical gaps. Additional meetings will follow.								
Task 2 – Drive industry standard specifying when part number changes are needed for specific BGA ball alloys									
Update Standards and Develop Reflow Process Guidelines									
Task 3 – Push to update IPC/JEDEC J-STD-006 on requirements for solder alloys	Open lines of communication with J-STD-006 Committee								
Create Alloy Categories and Define Information Requirements									
Task 4 – Define basic information requirements deeded for users to make decisions on acceptability	Possible to put together initial set of requirements. Strawman proposal? Pull together a table of requirements.								
Determine Knowledge Gaps and Drive Part Number Changes									
Task 5 – Provide guidance on component and PCA alloy labeling per J-STD-609	Pull into Phase 1 Quick strawman where the alloys fit. Forward information to J-STD-609 Committee								
Task 6 – Publish guidelines on the alloying elements that may be undesirable or unacceptable	Keep track of issues that are of concern for technical and non-technical reasons. Team to decide on what would be kept within the team and what would be published to larger audiences.								
Project Reports and Publications									
Task 7 – Provide summary of work for iNEMI members (the team to decide on level of detail to be provided)									
Task 8 - Pull together material collected and analyzed for publication and presentation external to the project team									
Task 9 - Develop a project plan based on information gathered to develop a Phase 2 plan including any test and evaluation vehicle(s)									
Phase 2 Project Plan Development									
Task 10 – Develop reflow process guidelines for alternative alloys with the compatibility with low Ag alloys	Hold until after Phase 1								
Task 11 – Create and/or develop a set of categories for placing similar alloys to be managed as a group	Hold until after Phase 1								
Phase 2									
...						Tentative (18 months max)			
...						Tentative (18 months max)			
						Tentative (18 months max)			

Key Milestones

- Task 1
  - 1 Feb 08: Project team workshop (telecom + web sharing)
  - 3 Apr 08: Final project team meeting at APEX
  - 10 Jun 08: Report on knowledge assessment & gaps to project team
  - 10 Aug 08: Paper submitted to peer reviewed journal
  - TBD: Present findings at industry conference(s)
- Task 2
  - 21 Jan 08: Proposal for P/N guidance provided to JEDEC JC14 Committee
  - Ongoing: Work with JEDEC to updated relevant standard
- Task 3
  - 15 Jan 08: Summarize issues of concern.
  - 15 Mar 08: Propose J-STD-006 updates to committee
- Task 4
  - 3 Apr 08: HP provides strawman requirements
  - 30 Jun 08: Establish table of data requirements for new alloys
- Task 5
  - 15 Jan 08: Strawman established for which alloys belong in which "e" category
  - 15 Feb 08: Proposed update to J-STD-609 provided to the committee
- Task 6 (dates tied to those of Task 1)
  - 1 Feb 08: First draft list of technical and non-technical issues to track
  - 3 Apr 08: Improved draft
  - 10 Jun 08: Final list of technical and non-technical issues to track

Phase 1 – Knowledge Discovery and Gap Analysis

Determine Knowledge Gaps and Drive Standard on Part Number Change

- **Task 1 – Determine what data and knowledge exist and what the critical gaps are**
  - Publish a white paper to raise awareness regarding any concerns identified and any issues to be resolved and managed
  - Leverage data from participants (e.g., HP slide set to be posted on iNEMI web site)
  - Resources
    - Expected to be high effort
    - Only human resources required. No test materials or equipment required. Estimate 1-4 weeks of effort per participant over the course of the task.
    - List of committed resources from participating companies. TBD
    - No additional funding expected for Phase 1 tasks
  - Materials and Processes
    - Not Applicable
  - Testing Procedures
    - Not Applicable
- **Task 2 – Drive industry standard specifying when part number changes are needed for specific BGA ball alloys**
  - Leverage existing iNEMI & EMS forum position papers
  - Mostly an exercise in engaging the proper standards body (most likely JEDEC)
  - Develop criteria for when a part number (P/N) change is needed (e.g., melting temperature, Ag content, …)
  - Resources

        - Expected to be low effort
        - Only human resources required. No test materials or equipment required. Estimate 0.5-1.5 weeks of effort per participant over the course of the task.
        - List of committed resources from participating companies. TBD.
        - No additional funding expected for Phase 1 tasks
    - Materials and Processes
        - Not Applicable
    - Testing Procedures
        - Not Applicable

Update Standards and Develop Reflow Process Guidelines

- **Task 3 – Push to update IPC/JEDEC J-STD-006 on requirements for solder alloys**
    - iNEMI support could be very helpful in pushing the IPC/JEDEC committee to make progress in updating this document
    - Main issues include alloy tolerances and definition of "impurities" for micro-alloyed materials.
    - Goal is to open lines of communication between the project team and the J-STD-006 committee to our concerns and the need for an update of the standard.
    - Resources
        - Expected to be low effort
        - HP may be in a position to lead this (TBD)
        - Only human resources required. No test materials or equipment required. Estimate 0.5-1.0 weeks of effort per participant over the course of the task.
        - List of committed resources from participating companies
        - No additional funding expected for Phase 1 tasks
    - Materials and Processes
        - Not Applicable
    - Testing Procedures
        - Not Applicable

Create Alloy Categories and Define Information Requirements

- **Task 4 – Define basic information requirements needed for users to make decisions on acceptability**
    - Goal is to develop a draft or "strawman" table of data requirements for assessment of new Pb-free solder alloys.
    - Logically ties in with efforts to evaluate existing knowledge and gaps
    - Possibly leverage HP internal efforts (TBD)
    - Concern that this may be very difficult given wide range of companies & sectors represented – look for areas consensus.
    - Possibly limit to subset of requirements all can agree upon
    - Resources
        - Only human resources required. No test materials or equipment required. Estimate 1-2 weeks of effort per participant over the course of the task.
        - List of committed resources from participating companies

        - No additional funding expected for Phase 1 tasks
    - Materials and Processes
        - Not Applicable
    - Testing Procedures
        - Not Applicable

Determine Knowledge Gaps and Drive Part Number Changes

- **Task 5 – Provide guidance on component and PCA alloy labeling per J-STD-609**
    - Some new alloys could be placed in multiple "e" categories
    - Need to clarify in the standard how to deal with these alloys.
    - Develop and provide for the J-STD-609 committee a proposal for handling of new alloys.
    - Resources
        - Possible leadership by Flextronics (TBD)
        - Expected to be low effort
        - Only human resources required. No test materials or equipment required. Estimate 0.5-1 week of effort per participant over the course of the task.
        - List of committed resources from participating companies
        - No additional funding expected for Phase 1 tasks
    - Materials and Processes
        - Not Applicable
    - Testing Procedures
        - Not Applicable
- **Task 6 – Publish guidelines on the alloying elements that may be undesirable or unacceptable**
    - Begin to prepare a list of elements that are unsuitable for reasons of toxicity, environmental or social concerns (not technical)
    - Goal is to keep track of issues that are of concern for technical and non-technical reasons. The team will decide later what information to keep within the project team and what information to publish to wider audiences.
    - Resources
        - HP could possibly lead this effort
        - Only human resources required. No test materials or equipment required. Estimate 0.5-1 week of effort per participant over the course of the task.
        - List of committed resources from participating companies
        - No additional funding expected for Phase 1 tasks
    - Materials and Processes
        - Not Applicable
    - Testing Procedures
        - Not Applicable

Project Reports and Publications

- **Task 7 – Provide summary of work for iNEMI members (the team to decide on level of detail to be provided)**
    - Resources

        - iNEMI members will be provided with the Knowledge Summary and Gaps report submitted for publication, and thus will receive this information well before the general public.
        - No additional funding is expected for providing iNEMI members with a summary of the work performed in Phase 1. No equipment will be required. Project participants are expected to help in the writing and review of the summary. No additional effort beyond that described above is anticipated.
        - List of committed resources from participating companies

- **Task 8 - Pull together material collected and analyzed for publication and presentation external to the project team.**
    - Resources
        - No additional funding is expected for publication and presentation of the Knowledge Assessment findings. No equipment will be required. Project participants are expected to help in the writing and review of the summary. No additional effort beyond that described above is anticipated.
        - List of committed resources from participating companies
- **Task 9 - Develop a project plan for Phase 2 based on information gathered including any test and evaluation vehicle(s)**
    - Resources
        - No additional funding is expected for development of a follow-on plan for Phase 2. No equipment will be required. Project participants are expected to help in the writing and review of the summary. No additional effort beyond that described above is anticipated.
        - List of committed resources from participating companies

Phase – 2 Validation and verification using targeted experiments to address identified gaps

- **Task 10 – Develop reflow process guidelines for alternative alloys with the compatibility with low Ag alloys**
    - NO ACTIVITY PLANNED FOR PHASE 1. HOLD FOR CONSIDERTAION IN PHASE 2.
    - Notes for consideration in potential planning for Phase 2:
        - Leverage data and information gathered from project participants (e.g., HP study, any available studies available from EMS suppliers, and …)
        - Resources
            - Best if led by EMS community.
            - Unclear how much experimental work would be needed.
            - Effort level uncertain
            - A detailed list the resources needed and expenditures expected for the project, including human resources, money, and equipment
            - List of committed resources from participating companies
            - Additional funding TBD.
        - Materials and Processes
            - TBD
        - Testing Procedures
            - TBD
- **Task 11 – Create and/or develop a set of categories for placing similar alloys to be managed as a group**
    - NO ACTIVITY PLANNED FOR PHASE 1. HOLD FOR CONSIDERTAION IN PHASE 2.
    - Notes for consideration in potential planning for Phase 2:

- May fall out of efforts to evaluate existing knowledge & gaps
- Only execute if clear opportunity and need exist based on the information gathered in Phase 1 and 2
- Resources
  - Effort level expected to be small
  - A detailed list the resources needed and expenditures expected for the project, including human resources, money, and equipment
  - List of committed resources from participating companies
  - No additional funding expected for Phase 1 tasks
- Materials and Processes
  - Not Applicable
- Testing Procedures
  - Not Applicable

- **Other tasks to be identified as part of Phase 1 output**

Project monitoring plans

- How will you ensure open lines of communication among participants?
  - Bi-weekly conference calls
  - Meeting minutes provided through e-mail
  - Follow-up with individuals on an as needed basis
  - Workshops and face-to-face meetings as appropriate
- Planned teleconference schedule
  - Bi-weekly conference calls
- Request progress reports as tasks are completed
- Dates of technical reviews (2 per year) and progress reports and what they will contain
- Practice risk analysis by anticipating problems and having alternate solutions ready
  - What happens if??
- Use opportunity analysis to identify new areas or topics that might be addressed in additional projects. This will prevent the scope of the current project from expanding and keep the project focused on original goals
- Review project requirements with suppliers before the project begins

Outcome of the project

- Successful completion of this project will manifest as publication and presentation of the knowledge gap analysis in the public domain. It will also manifest as an update to the standard(s) addressing part numbers for BGA/CSP packages when solder ball alloy is changed. *** Add success metrics for any of Tasks 3-8 that the team commits to perform.
- Deliverables of this project include the following.
  - Workshop & associated slides for project members summarizing preliminary assessment of the state of knowledge on alternative alloys
  - Final slides and publication of our knowledge assessment for alternative alloys

- Updated standard to address concerns with changing BGA/CSP part number when change to ball alloy is made, as appropriate.
- Concerns related to J-STD-006 and alternate alloys communicated to the J-STD-006 committee.
- Develop a “strawman” table of data requirements for assessment of Pb-free solder alloys. Communicate this draft as appropriate.
- Develop a draft method to establish “e” categories for alternative alloys. Communicate this to the J-STD-609 committee for consideration.
- Develop a list of technical and non-technical issues with the use of various chemical elements in Pb-free solder alloys. Communicate as appropriate.

- Project results will be shared with the industry in order to drive alignment throughout the supply chain.
  - Knowledge assessment results will be shared through presentations and industry meetings and publication in an archival journal
  - Updated BGA/CSP standards will be shared through publication of the new standards

NOTE: All changes to SOW must be approved by the TC (version control)