Fax/Email

Joint Council on Aging Aircraft
Joint Group on Pollution Prevention

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Lead-Free Solder Project Meeting Minutes
18 March 2004
Irving, TX

Comments:

Attached please find the minutes for the March 18, 2004 Lead-Free Solder face-to-face meeting at the Boeing Commercial Electronics facility, Irving, TX. Please further distribute as necessary.

MEMORANDUM FOR RECORD

Subject: – Meeting, Summary and Minutes – March 18, 2004

Next Teleconference: TBD

Next Meeting: September 2004, Florida (tentative: exact date and location to be determined)

Minutes:

1. **Opening:** Mr. Brian Greene, ITB/ NASA Acquisition Pollution Prevention (AP2) Program Office, opened the meeting by welcoming everyone and thanking them for their attendance at the meeting and their participation in the project.

   Mr. Greene stated that the objective of the meeting was to formally kick-off the testing phase of the LFS project. The meeting would consist of briefings discussing the details of the assembly process, the testing, and the data analysis and reporting. Then a tour of Boeing's electronics assembly line being used to assemble to project's test vehicles would be offered.

2. **Assembly and Rework Procedures:** Before the tour, Ms. Lety Campuzano-Contreras, Boeing Commercial Electronics facility-Irving, TX, presented to the group the details and specifics of the test vehicle assembly and rework procedures and provided a status of the test vehicle assembly process.

   Mr. Dave Hillman, Rockwell Collins, has been receiving parts and solder alloys for testing since January and sending them to Ms. Campuzano-Contreras at Boeing, where they are being stored in preparation for assembly. The Boeing facility has taken special care to ensure that the PWB and SnPb containing and lead-free parts and solders are not intermingled.

   Ms. Lety Campuzano-Contreras noted that Boeing planned to adhere to the following assembly schedule:
   - 18 Mar 04 - Begin assembly of SnPb/SnPb test vehicles
   - 20 Mar 04 - Begin assembly of SnAgCu test vehicles, and begin assembly of SnAgCuBi test vehicles
   - 9 Apr 04 - Begin rework on rework test vehicles

   Discussion: Ms. Campuzano-Contreras noted that the suggested reflow profile for the Sn/3.9Ag/0.6Cu solder alloy, provided by Senju, should have a duration time above 220 degrees C for 30-60 seconds and could possibly have a duration time above 220 degrees C for 30-90 seconds. Dr. Reza Ghaffarian, NASA JPL, suggested that the peak reflow temperature should be at least 240 degrees C, and preferably 243 degrees C in accordance with recent IPC recommendations. Concern was then raised that at the high (>240 deg. C) temperatures, the board layers could delaminate and separate destroying the test vehicle. To accommodate this, Boeing-Irving process engineers agreed to perform a test run of a Sn/Pb soldered board at 245 deg. C (the same peak reflow temperature that the

Sn/3.4Ag/1.0Cu/3.3Bi solder alloy manufacturer Heraeus suggests) and observe any board delaminating.

Another concern raised was the option of baking the components prior to assembly to eliminate moisture. Mr. Dave Hillman stated that Rockwell Collins does not bake components, and felt that baking was not necessary for this project's components because all guidelines of J-STD-033A "*Handling, Packing, Shipping and Use of Moisture/Reflow Sensitive Surface Mount Devices"* have been adhered to. Boeing process engineers added that baking of Level-3 electronic components was not their normal operating procedure, either. For these reasons, the group agreed that no baking of components was necessary.

Conclusion: Later in the morning on March 18, Boeing process engineers reported that everything went well with the assembly practice run. The board did not delaminate and all components were intact following the reflow procedure. The Boeing process engineers recorded the following peak reflow temperatures and duration times during the reflow process:

- Duration of time above 244 degrees C was 54 seconds
- Duration of time above 247 degrees C was 74 seconds

Subsequent Group Decision:

- Boards will not be baked prior to assembly
- Components will not be baked prior to assembly
- High temperature reflow profile prepared by Boeing for lead-free solders are acceptable

3. **Project Overview:** Mr. Greene and Mr. Kurt Kessel, ITB, provided an overview of the JCAA/JG-PP Lead-Free Solder project, highlighting activities over the past several months.

   Mr. Greene emphasized that while considerable attention has been paid to Class 2 lead-free solder issues, little work has been accomplished on Class 3 (aerospace) parts. This project is aimed at solder joint reliability through side-by-side comparison tests to failure.

4. **Mechanical Shock Test Procedure:** Dr. Ghaffarian presented to the group a modified Mechanical Shock Test procedure that would meet the specifications of all consortium members.

   Discussion: Dr. Ghaffarian presented a mechanical shock test conducted in an increasing, stepwise fashion, similar to the vibration test. This test is a modification based upon Mil-Standard 810F, Method 516.5, Shock, Figure 516.5-8. All shocks run in the Z-axis. The first run would be 100 shocks peaking out at 20g (to coincide with Air Force requirements). If the 20g level were not attainable, then the first run would be 100 shocks peaking out at 45g. If more component failures are required, then run another 100 shocks peaking out at 75g. If still more component failures are required, run 50-75 shocks at 150g. If still not enough failures, run another 50-75 shocks at 300g. The test will continue, doubling the shocks (600g, 1200g…) until the appropriate number of component failures.

   A consortium member questioned the use of a strain gage on the bottom of the boards during testing to measure board deflection, stating that board deflection measurements are critical for understanding board dynamics and for modeling procedures.

Dr. Ghaffarian will contact ACI to discuss equipment capabilities and work out the fine details of the procedure.

Group Decision:

- The group agreed to the concept of the Mechanical Shock Test Procedure that Dr. Ghaffarian presented. Consortium review is required before finalizing the Mechanical Shock Test Procedure.
- Strain gage measurements of board deflection, during testing, are required for at least one board

5. **Component Review:** Mr. Hillman presented to the group the latest status on component procurement.

Discussion:

Hybrid Components: Due to improper packaging by the component supplier, the initial shipment of 291 hybrid components arrived at Rockwell Collins with damaged leads, thus rendering the components useless in their current condition. Mr. Hillman returned the hybrid components to Solitron in the hopes that the leads are repairable by straightening. This will delay the installation of the hybrid components to the month of April. The late delivery of the hybrid components will force hand placement on the boards.

TSOP-50 Components: This particular component needs to have wire bonds repaired on each side of the part located directly in the center of the part. The group thought this would not present a problem since the gap was in the center of the component and should perform adequately when soldered.

PLCC Components: Due to an error by the component supplier, the PLCC components arrived with no daisy chains. Mr. Hillman proposed that assembly initially begin without the PLCC components; new, daisy-chained PLCC components will be ordered and placed on the test vehicles at a later time (April 2004) by hand soldering.

CSP Components: Due to a likely engineering drafting error, the received CSP-100 components do not match the pattern on the board. The component measures .8mm from the center of each ball to the center of the next ball while the board placement measures .7mm. Because the board dimensions are already fixed, there is no easy solution. Mr. Hillman proposed, and the group agreed, that the CSP components be left off entirely from the test board.

Subsequent Group Decision:

- Hybrid components will be placed on the board, by hand soldering, after board assembly
- TSOP-50 components will have wire bond repairs made on each side, near the center.
- PLCC components will be placed on the board, by hand soldering, after board assembly
- CSP components will be left off the assembled test vehicle

6. **Vibration/ Thermal Cycle Review -20oC/ +80oC:** Dr. Tom Woodrow, Boeing Phantom Works, briefed the tests his group proposes to accomplish. The thermal cycle test range, as

stated in the statement-of-work is -20°C to 80°C. He plans to use Anatech Event detectors and can have four test vehicles on one computer for 1024 channels of data.

The vibration tests may be accomplished using a Laser Vibrometer, although this has not been requested in the statement of work he received. He plans to employ strain gauges providing he has sufficient funds to accomplish that work. Mr. Woodrow told the group that comparisons on failures of a specific device in a specific location of one board could be compared to that same devise in exactly the same location on another board. Mr. Dave Hillman stated information can be gained by other relationships has well with other devices in different locations on the boards.

7. **Thermal Cycle Review, -55/ +125°C:** Mr. Hillman reviewed the thermal cycle test procedure that he hopes to conduct at Rockwell Collins (pending subcontract award).

   Discussion: Mr. Hillman asked for group consensus on the frequency by which the capacitors should be removed from the break-off coupon and monitored for failures.

   Group Decision:
   - The group agreed to the following method for measuring capacitor failure: Cut initial row of capacitors from the test vehicle following the completion of the first 1000 thermal cycles. Continue to remove rows of capacitors at 500 cycle intervals thereafter. At the 3000 cycle decision point, if the appropriate failure level has not been met for capacitors, place good ones back into test chamber.

8. **Thermal Cycle Dwell Times:** Dr. Reza Ghaffarian presented to the group data showing that longer dwell times are needed for thermal cycle testing.

   Discussion: Dr. Ghaffarian conducted a very large paper search and test data review pertaining to solder alloy performance based upon component type for thermal cycle testing. His analysis of CBGA 625 I/O devices at -40°C/60°C and the -40°C/125°C test regimes shows the dwell time must be long enough to measure the creep effects. He provided a graph of his research that has been independently corroborated that shows a cross-over of SnPb and Sn3.9Ag0.6Cu solders comparing the characteristics of crack growth compared to time of failure. The dwell time for eutectic solders should be at least 10 minutes, but this does not apply to lead-free solders.

   Dr. Ghaffarian concluded that maximum temperature dwell time, at the hot temperature limit, of 10 minutes is not sufficient. Solder alloy creep at maximum temperature dwell, at the hot temperature limit, greatly alters a solders performance over time. It was proposed that the dwell time for the hot temperature limit be increased from 10 minutes to 30 minutes. The dwell time for the cold temperature limit will remain at 10 minutes. Increasing the dwell time for the hot temperature limit could increase the time needed to complete thermal cycle testing and create increased testing costs. Rockwell Collins and Boeing Seattle plan to conduct the thermal cycle test, and both agreed that, pending company approval, they might be able to absorb the additional testing costs from increasing the hot temperature dwell time, so as not to impact the funds the Aging Aircraft program office are providing to the project.. There is the possibility that increasing the hot temperature dwell time could possibly reduce the number of thermal cycles required to reach the acceptable component failure rates.

Group Decision:

- The group agreed that the hot temperature dwell time for thermal cycle testing should be increased from 10 minutes to 30 minutes. The cold temperature dwell time for thermal cycle testing will remain at 10 minutes. This will be applied to the -55/ +125 degrees C and -20/ +80 degrees C thermal cycles.

9. **Combined Environments Test:** Mr. Jeff Bradford, Raytheon, TX, presented on the Combined Environments Test Procedure that Raytheon is planning to perform if funding is made available. The CET is based upon the HALT (highly accelerated life test) tests. The test includes a temperature range from -55^{o}C to 125^{o}C with a 20^{o}/min slope and a 15-minute dwell. The aim of the test was to accomplish the entire test in two months. Anatech detectors would be used to capture the data. Micro-sections would be employed in failure analyses. If funded, the tests will be conducted at the Raytheon McKinney, TX facility that has a -100 ^{o}C to 200 ^{o}C, up to a 60 ^{o}/min ramp and up to 60 g_{rms} capability.

   Discussion: Following Mr. Bradford's presentation, there was much discussion on the purpose of the Combined Environments Test. Many agreed that the test would be valuable, although some indicated that could not use the results of the test to determine long-term reliability. A question was raised: Should the test conditions of the Combined Environments Test mirror those used in the Thermal Cycling tests? Some in the group thought matching the ramp rates between the two tests would allow for the added effects of vibration to be determined. Others in the group felt that nothing new would be learned; other factors, such as humidity and barometric pressure, are not being controlled and could affect the outcome.

   Mr. Denny Jarvi, ITB, reminded the group this is an unfunded test and the test that would be accomplished was the one funds were available to do. Jeff Bradford took an action item to provide a cost estimate with a second and third option, one with matching the ramp rate and the other with increasing the dwell time. If funds are available to conduct these tests, the group, together with Raytheon can select which of the proposed tests to accomplish based upon the funds available, including any contributed funds by Raytheon.

   Conclusion: The group concluded that since funding has not yet been secured for this test that Mr. Bradford should work up cost estimates, including schedules for alternative Combined Environments Test procedures.

   Group Decision:
   The group agreed that cost estimates including schedules should be generated for the following:

   - Combined Environments Test conducted using a thermal cycle temperature range of -55/ +125 degrees C with a 20 degree C ramp rate with 30 minute dwell time at the hot temperature limit and a 10 minute dwell at the cold temperature limit, vibration in conjunction with thermal cycle as spelled out in JTP
   - Combined Environments Test conducted using a thermal cycle temperature range of -55/ +125 degrees C with a 20 degree C ramp rate with 30 minute dwell time at the hot temperature limit and a 10 minute dwell at the cold temperature limit, vibration in conjunction with thermal cycle as spelled out in JTP at the hot temperature dwell only

10. **Surface Insulation Resistance (SIR) and Electrochemical Migration Resistance (EMR) Test:** Mr. John Kerr from Boeing Anaheim will be performing the SIR and EMR test. Mr. Kerr provided an overview of the testing for the group.

    Discussion: Ms. Lety Campuzano-Contreras asked which solders will be applied to how many of each test coupon. A short discussion ensued, in which the group agreed to the following: 10–SnAgCu wave solder, 10–SnAgCuBi wave solder, 10–SnPb, 10–SnCu wave solder, and 5–bare copper, no paste processed through reflow, wave and cleaning procedures, 10–back-up.

    Group Decision:
    The group agreed to the solder paste distribution by the number of IPC coupons, as outlined in the previous paragraph, would be acceptable.

11. **Data Modeling:** Mr. Dave Locker, U.S. Army Aviation and Missile Command (AMCOM), spoke about the modeling work AMCOM is pursuing. AMCOM is asking the SBIR candidates to use the JG-PP developed test vehicle to collect data where information gaps exist. They intend to use test data to build the model algorithms and Weibull plots on levels of confidence of 5% and 95% for each test run.

Attachment 1: Action Item Status

New Action Items (from 03/18/2004 meeting)

LFS.04.03.17
Date Due: **04/01/04**
Responsibility: Kurt Kessel, ITB, Inc
Required Action: Make PowerPoint Presentations from March 18 meeting available to the consortium
Comments: Assigned at 03/18/04 meeting.

LFS.04.03.18
Date Due: **04/01/04**
Responsibility: Kurt Kessel, ITB, Inc
Required Action: Distribute the revised Mechanical Shock Testing Procedure once completed by NASA-JPL
Comments: Assigned at 03/18/04 meeting.

LFS.04.03.19
Date Due: **04/01/04**
Responsibility: Dave Hillman
Required Action: Obtain specifics on the board laminate, send to ITB who will distribute to group and place in the appropriate documents
Comments: Assigned at 03/18/04 meeting.

LFS.04.03.20
Date Due: **04/01/04**
Responsibility: Lety Campuzano-Contreras
Required Action: Determine the wave solder flux for the SnAgCu solder alloy
Comments: Assigned at 03/18/04 meeting.

LFS.04.03.21
Date Due: **04/01/04**
Responsibility: Kurt Kessel, ITB, Inc
Required Action: Check the thermal cycle reference in the JTP to determine if the reference is to IPC-785 or IPC-9701
Comments: Assigned at 03/18/04 meeting.

LFS.04.03.22
Date Due: **04/01/04**
Responsibility: Jeff Bradford
Required Action: Prepare cost estimates for alternative Combined Environments Test procedures
Comments: Assigned at 03/18/04 meeting.

LFS.04.03.23

Date Due:	**04/01/04**
Responsibility:	Brian Greene and Denny Jarvi, ITB, Inc
Required Action:	Send letter to Mr. Dick Pinckert, Boeing to sure-up project testing funds
Comments:	Assigned at 03/18/04 meeting.

LFS.04.03.24

Date Due:	**04/01/04**
Responsibility:	Kurt Kessel, ITB, Inc
Required Action:	Notify project stakeholders of all JTP changes initiated at the March 18 meeting
Comments:	Assigned at 03/18/04 meeting.

LFS.04.03.25

Date Due:	**04/01/04**
Responsibility:	Dave Hillman
Required Action:	Create a standard data-reporting sheet, build upon previous submittals
Comments:	Assigned at 03/18/04 meeting.

LFS.04.03.26

Date Due:	**04/08/04**
Responsibility:	Kurt Kessel, ITB, Inc
Required Action:	Distribute Dave Hillman's standardized data collection sheet to the group for review
Comments:	Assigned at 03/18/04 meeting.

LFS.04.03.27

Date Due:	**04/01/04**
Responsibility:	Dave Hillman
Required Action:	Send out board schematics to potential testing sites
Comments:	Assigned at 03/18/04 meeting.

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LFS.04.03.28

Date Due:	**04/01/04**
Responsibility:	Lety Campuzano-Contreras
Required Action:	Send to Dave Hillman one board each (5 total) for High Tg PWB, low Tg PWB, (as delivered Tg & thicknesses) SAC/SAC PWA, SACB/SnCu PWA, SnPb/SnPb PWA for characterization (for Tg [changes] and cutting up)
Comments:	Assigned at 03/18/04 meeting.

Open Action Items

LFS.04.03.16

Date Due:	**3/26/04**
Responsibility:	Dave Hillman
Required Action:	Check into the possibility of getting different CSPs that will match the boards.
Comments:	Assigned at 03/15/04 telecon.

LFS.04.03.15

Date Due:	**3/26/04**
Responsibility:	Kurt Kessel, Brian Greene
Required Action:	Follow-up with Lee Whiteman to determine if the boards are instrumented to measure strain and the costs associated with strain measurement.
Comments:	Assigned at 03/15/04 telecon.

LFS.04.03.14

Date Due:	**3/18/04**
Responsibility:	Brian Greene
Required Action:	Contact Lee Whiteman to discuss the group's interaction with ACI and BAE Systems during testing to ensure proper data is obtained.
Comments:	Assigned at 03/15/04 telecon.

LFS.04.03.12

Date Due:	**3/26/04**
Responsibility:	Brian Greene
Required Action:	Contact Paul Vianco to discuss SMTAI and the details of presenting the LFS Project
Comments:	Assigned at 03/15/04 telecon.

LFS.04.03.04

Date Due:	**3/16/04**
Responsibility:	Reza Ghaffarian, Lee Whiteman
Required Action:	Revise Mechanical Shock Test procedure
Comments:	Update 3/15/2004: Mr Ghaffarian will work to have a draft prepared by March 18, 2004 for discussion

LFS.04.03.02

Date Due:	**3/16/04**
Responsibility:	Lee Whiteman
Required Action:	Confirm BAE's ability to measure board deflection and possibility of obtaining strain gage measurements. Pass information directly to Brian Greene.
Comments:	ITB, Inc. will follow with Mr. Whiteman in order to confirm BAE's capabilities

LFS.04.02.08

Date Due:	**2/24/04**
Responsibility:	Dave Hillman
Required Action:	Make sure the appropriate Gerber files were provided to Lety for the IPC Electrochemical migration test coupons
Comments:	

LFS.04.02.01

Date Due:	***Date Changed from* 2/20/04 to 03/10/2004**
Responsibility:	Brian Greene
Required Action:	Distribute article on lead contamination written by John Paul Clech
Comments:	*Open:* Distributed to Tom Woodrow and Reza Ghaffarian for comment. This paper was presented at the Feb. 2004 APEX conference. This paper will be distributed following the March 18 meeting in order to avoid confusion.

Action Items Recommended for Closure

LFS.04.03.13

Date Due:	**3/18/04**
Responsibility:	All
Required Action:	Prepare ideas for discussion for hybrid placement on the manufactured boards following the assembly process, include thoughts on solder alloys
Comments:	Closed: Hybrids will be hand soldered to the PWAs following final assembly. The appropriate solder wire will be used. Hybrids will be staked to the board with adhesive in all four corners.

Action Items Closed on March 18, 2004

None.

Agenda

Lead-Free Solder Project Meeting
Thursday, 18 March 2004
Boeing Commercial Electronics facility, Irving, Texas

Time	Event	Presenter
8:00 – 8:15	Welcome and Introductions	Brian Greene/ Lety Campuzano-Contreras
8:15 – 8:50	Assembly and Rework Procedures	Lety Campuzano-Contreras
8:50 – 9:00	**BREAK**	
9:00 – 10:00	**TOUR**	
10:00 – 10:45	Project Overview Presentation	Brian Greene
10:45 – 11:30	New Mechanical Shock Procedure	Reza Ghaffarian
11:30 – 12:00	Component Issues	Dave Hillman
12:00 – 12:30	**LUNCH**	
12:30 – 12:45	Pre-Assembly Characterization	Dave Hillman
12:45 – 1:15	Thermal Cycle Test	Dave Hillman/ Tom Woodrow
1:15 – 1:30	Thermal Cycle Dwell Times	Reza Ghaffarian
1:30 – 1:45	Vibration Test	Tom Woodrow
1:45 – 2:00	Thermal Shock Test	Tom Woodrow
2:00 – 2:15	Combined Environments Test	Joe Felty
2:15 – 2:30	Salt Fog/ Humidity Tests	Dave Hillman
2:30 – 2:45	EMR/ SIR Test	
2:45 – 3:30	Open Discussion for Testing	All
3:30 – 3:50	Data Modeling	Dave Locker
3:50 – 4:00	Action Item Review	Kurt Kessel