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JG-PP Lead-Free Solder Project Teleconference Meeting Minutes January 23, 2003

Govt. Project Manager: Warren Assink, WPAFB

Comments:

Attached please find the minutes from the January 23, 2003, Lead-Free Solder teleconference. If you have questions about the minutes, please contact Warren Assink or Brian Greene. Please further distribute as necessary.

MEMORANDUM FOR RECORD

Subject: Teleconference Summary and Minutes – January 23, 2003

Material(s) Identified: Lead

Process Identified: Electronics soldering

Methodology Phase: II - Technical, III - Business

Summary:

On January 23, 2003, technical representatives from the American Competitiveness Institute, Boeing Company, Concurrent Technologies Corporation, Florida Cirtech, Headquarters Air Force Materiel Command, Hill Air Force Base, ITB, Inc., ITT Industries, Inc., NASA Jet Propulsion Lab, NASA Marshall Space Flight Center, Northrop Grumman, Raytheon, Robins Air Force Base, Rockwell Collins, Sandia Labs, Texas Instruments, U.S. Air Force F-15 Engineering, WR-ALC/LFEA, U.S. Army Picatinny Arsenal, U.S. Army Tank-Automotive and Armaments Command, U.S. Navy Headquarters Chief of Naval Operations and Wright Patterson Air Force Base participated in a meeting with representatives from the Joint Group on Pollution Prevention Working Group and their contractors. The objective of the teleconference was to review comments received on the December 18, 2002 Joint Test Protocol and proposed changes. The intent is to close out the JTP discussions and prepare the final version, which will be sent out for signature. Other telecon objectives included reviewing the latest test board design and discussing business issues. All the teleconference's objectives were met, although some changes must be made to the JTP. Action items were taken to revise and rewrite several section of the JTP including but not limited to JTP section 1.1, 2.2.1, 2.2.2, 2.3, 2.5, and 3.1.1. Action items



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were also taken to develop a plan of action for testing capacitors on the test vehicle and to develop text for the Potential Alternatives Report covering the selection of solder alloys for testing the silver immersion board finish that was selected.

Prior Decisions:

- 5/9/01 – Lead as used is tin-lead (Sn/Pb) solder was chosen as the target HazMat.
- 6/20/01 – A Joint Test Protocol (JTP) will be developed for qualifying lead-free solder alloy used in the manufacture of lead-free printed wiring assemblies (PWAs)
- 11/1/01 – A second JTP will be developed for qualifying lead-free solder alloy used in the rework of lead-containing PWAs.
- 3/7/02 – By consensus, the solder alloys currently recommended for testing are:
 - Wave Solder: Sn/0.7Cu
Sn/3.9Ag/0.6Cu
Sn/3.4Ag/1.0Cu/3.3Bi
 - Reflow/Manual Solder: Sn/3.9Ag/0.6Cu
Sn/3.4Ag/1.0Cu/3.3Bi
 - Baseline: Sn/37Pb
- 10/1/02 – Because of numerous similarities in the testing procedures, all the PWA manufacturing and rework requirements will be folded into just one JTP.

Next Teleconference: TBD

Next Meeting: TBD



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Minutes

Mr. Brian Greene (ITB, Inc.) opened the teleconference by explaining the objective of the teleconference is to review the proposed major and minor changes with the intent to close out the JTP and prepare the finalized version, which will be sent out for signature.

1. *JTP Section 1.1 Lead-Free Solder Overview*

Recommendation (Gordon Davy, Northrop Grumman): A suggestion was made to rewrite most of this section to discuss more of the scientific and engineering arguments against lead-free solder, and in particular to state that the current science does not necessarily lead to the conclusion that Pb in electronics poses a significant environmental or health & safety problem. Another technical representative noted that, while the above argument could be valid, the emphasis should be that the electronics sector and international/national legislation are going to proceed, regardless of the science.

Proposed Change: In an attempt to incorporate both of these viewpoints, a rewrite of Section 1.1 of the JTP is being proposed (see attachment: JTP Section 1.1 Led-Free Overview1_20_03.doc).

Rationale: This write-up hopefully clarifies that, while many in the engineering community have concluded that the use of electrical or electronic products containing lead does not result in any human or environmental lead exposure risk under normal and reasonable patterns of product use, we still believe in the validity, usefulness, and timeliness of the JG-PP Lead-Free Solder project.

Teleconference Discussion:

- a. Mr. Brian Greene (NASA AP2 Office/ITB) started by reviewing the above comments received concerning JTP section 1.1 and asking for comments on the revised paragraph which was distributed to the JG-PP lead-free solder consortium.
- b. Mr. Tom Woodrow (Boeing, Seattle) stated that the paragraph should be edited and possibly rewritten. Mr. Woodrow stated that he preferred the original version of the paragraph that appeared in the December 18, 2002 JTP.
- c. Mr. Greene took an action item (**AI, LFS.03.01.01**) to rewrite the paragraph and edit, as he feels appropriate. Once the paragraph is completed Mr. Greene will redistribute the revised paragraph to the group for approval.

2. *JTP Section 1.2 Project Approach; Table 1*

Recommendation (Jeff Bradford, Raytheon): Change IPC-610 to IPC-A-610.

Teleconference Discussion:

- a. Mr. Greene reviewed the above recommendation, from Mr. Jeff Bradford (Raytheon) to change IPC-610 to IPC-A-610 in Table 1 of the December 18, 2002 JTP. No comments were received from the JG-PP lead-free consortium. Since no comments were received the above recommendation will be incorporated into the finalized JTP.

3. *JTP Section 2.1.1.1 Lead-Free Assembly*



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Recommendation (Dave Hillman, Rockwell Collins): Wherever you call out the Tg of 170C - the laminate we will be using will be per IPC-4101/26 - we could add this info in the paragraphs.

Teleconference Discussion:

- a. Mr. Greene reviewed the above recommendation from Mr. Dave Hillman (Rockwell Collins) to add the following specification “per IPC-4101/26” wherever the JTP calls out the test vehicle board laminate with a Tg of 170C. An example of the change is as follows “The lead-free printed wiring boards shall have an immersion silver surface finish; be made from high temperature laminate (glass transition temperature of 170 °C per IPC-4101/26); and components will be attached using the alternative lead-free solder alloys.” No comments were received from the JG-PP lead-free consortium. Since no comments were received the above recommendation will be incorporated into the finalized JTP.

4. ***JTP Section 2.1.1.2 Baseline Assembly***

Recommendation (Tom Woodrow, Boeing): In the first sentence suggests changing “a tin/lead hot air solder leveled (HASL)” to “an immersion silver surface finish”.

Teleconference Discussion:

- a. Mr. Greene stated that the above recommendation for Table 2 had been agreed upon during the December 12, 2002 meeting, but did not make it into the December 18, 2002 JTP. Mr. Greene will incorporate the appropriate changes to the text so it will read as follows “The baseline printed wiring board shall have an immersion silver surface finish”. No comments were received from the JG-PP lead-free consortium. Since no comments were received the above recommendation will be incorporated into the finalized JTP.

5. ***JTP Sections 2.1.2.1 Lead-Free Rework of Tin/Lead Assemblies and 2.1.2.2 Tin/Lead Rework of Tin/Lead Assemblies***

Recommendation (Dave Hillman, Rockwell Collins): Where ever you call out the Tg of 140C - the laminate we will be using will be per IPC-4101/21 - we could add this info in the paragraphs too.

Teleconference Discussion:

- a. Mr. Greene reviewed the above recommendation from Mr. Dave Hillman (Rockwell Collins) to add the following specification “per IPC-4101/21” wherever the JTP calls out the test vehicle board laminate with a Tg of 140C. An example of the change is as follows “The reworked boards shall have a hot air solder leveled (HASL) surface finish, be made from low temperature laminate (glass transition temperature of 140°C per IPC-4101/21) and initially soldered using eutectic tin/lead solder.” No comments were received from the JG-PP lead-free consortium. Since no comments were received the above recommendation will be incorporated into the finalized JTP.

Recommendation (Dave Hillman, Rockwell Collins): We need to change the lower Tg temperature to 135C instead of 140C.

Rationale: I had my printed wiring board (pwb) folks conduct a quick survey of "available" Tg laminate choices within the Collins pwb fabricator base and found that the 135C was a more available choice. This is not to say that the 140C Tg laminate is not available but the 135C appeared to be cheaper based on availability.

Teleconference Discussion:



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- a. Next, Mr. Greene reviewed Mr. Hillman's comment that printed wiring boards with laminate Tg temperatures of 135 °C are more readily available and easier to obtain for the lead-free solder testing program.
- b. Mr. Hillman explained that he performed a quick survey of material suppliers that Rockwell Collins uses to see what is the availability of printed wiring boards with laminates having Tg temperatures of 135°C and 140°C. Mr. Hillman explained that he found printed wiring boards with laminates having Tg of 135°C more readily available and more common in legacy systems.
- c. Mr. Reza Ghaffarian (NASA, Jet Propulsion Lab) raised the question as to whether there will be issues with solder joint failures associated with the printed wiring boards directly related to the lower Tg temperatures of the laminate material rather than actual solder alloy failures. Mr. Hillman responded that the slightly lower Tg temperature of the laminate material of 135°C should not affect the failure of the solder joints.
- d. Mr. Woodrow stated that he has no problem with printed wiring boards with laminate Tg temperatures of 135°C but was surprised at the lack of availability of printed wiring boards with laminate Tg temperatures of 140°C and suggested that he could attempt to obtain printed wiring boards with laminate Tg temperatures of 140°C if that is what the group wants.
- e. Mr. Greene asked the JG-PP lead-free consortium if a range could be used for calling out the printed wiring board laminate Tg temperatures. The JTP would state that the printed wiring boards used in the testing program would have laminates with Tg laminates in the range of 135°C to 140°C.
- f. Mr. Hillman stated that the laminate Tg temperature will be specified on the design drawing and that his group would make sure that the boards procured would meet the groups' requirements.

Recommendation (Tom Woodrow, Boeing): Suggests deleting the sentence, "A single soldering iron and tweezers will be used to remove the original solder from the board."

Teleconference Discussion:

- a. Mr. Woodrow stated that in Appendix B of the JTP, the rework and repair procedures are spelled out. Mr. Woodrow suggested the following sentence be added to the JTP in section 2.1.2.1 "Please refer to Appendix B for processing procedures for lead-free rework of tin-lead assemblies." A similar sentence will be added to JTP section 2.1.2.2, which will read "Please refer to Appendix B for processing procedures for tin/lead rework of tin-lead assemblies." Mr. Woodrow also stated that all rework and repair procedures will be documented in detail by the facility performing the work.

6. *JTP Sections 2.1.2.2 Tin/Lead Rework of Tin/Lead Assemblies*

Recommendation (Tom Woodrow, Boeing): Suggests adding the sentence, "The remaining tin/lead solder on the pads shall be solder wicked."

Teleconference Discussion:

- a. Mr. Woodrow stated that the above recommendation needs to be incorporated into the JTP so there is consistency between JTP section 2.1.2.1 and 2.1.2.2. No comments were received from the JG-PP lead-free consortium. Since no comments were received the above recommendation will be incorporated into the finalized JTP.

7. *JTP Section 2.2.1 Pre-Test Inspection*



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Recommendation (Tom Woodrow, Boeing): Suggests adding the sentence, “One assembled test vehicle per solder will be set aside for cross sections (i.e., 3 manufactured test vehicles plus 3 reworked test vehicles).”

Teleconference Discussion:

- a. Mr. Greene stated that the decision to set aside one assembled test vehicle per solder alloy for cross section analysis for manufactured and reworked assemblies was decided at the November 12, 2002 lead-free solder meeting. Mr. Woodrow pointed out that JTP section 2.2.2 also references the need to set aside test vehicle assemblies for cross section analysis and there are a total of six test vehicles.
- b. Mr. Greene stated that he would work out the revised text and send it to Mr. Woodrow for review (**AI, LFS.03.01.02**). Mr. Greene also stated that the cross section analysis text will go into one of the two paragraphs and will not appear in both paragraphs.

8. ***JTP Section 2.2.2 Post-Test Inspection***

Recommendation (Jeff Bradford, Raytheon): The following sentence needs to be relocated from section 2.2.1 to section 2.2.2. Otherwise the statement where it stands now implies we will do destructive testing to the test vehicles prior to testing: “Cross sections should be done to document pre-test metallography and measure solder joint height and ball grid array (BGA) and chip scale package (CSP) solder ball alignment.”

Recommendation (Jeff Bradford, Raytheon): The first sentence of paragraph two in section 2.2.2 should be modified as follows.

- **Original:** One finished vehicle assembly will be set aside for post-test inspection, but will not undergo testing.
- **Proposed Change (Jeff Bradford):** One finished vehicle assembly of each solder alloy will be set aside for post-test inspection, but will not undergo testing.
- **Rationale:** Clarifies consensus reached at the 12 November 2002 meeting.

Teleconference Discussion:

- a. Mr. Bradford stated that this issue is the same as the issue outlined in line item 7, and that there needs to be some clarification and consolidation into a single paragraph
- b. Mr. Greene stated that he will be addressing the issue and rewriting the paragraphs in JTP sections 2.2.1 and 2.2.2 (**AI, LFS.03.01.03**) to address the corrections that are outlined in meeting minute topic issue 7 and 8.

9. ***JTP Section 2.3 Common Engineering, Performance, Testing Requirements and Test Flow***

Figure 1, Common Test Flow Diagram for Manufactured Test Boards & Figure 2, Common Test Flow Diagram for Rework Test Boards



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Recommendation (Jeff Bradford, Raytheon/Tom Woodrow, Boeing): Update Mechanical shock block, change the quantity of test vehicles needed from one to two.

- **Rationale:** Use of 2 test PWAs was agreed upon at the December 12, 2002 meeting.

Teleconference Discussion:

- a. Mr. Greene stated that the changes would be made based on a group decision made at the December 12, 2002 JG-PP lead-free solder meeting.

10. ***JTP Section 2.4 Extended Engineering, Performance, Testing Requirements and Test Flow***

Figure 3, Extended Test Flow Diagram for Manufactured Test Boards

Recommendation (Jeff Bradford, Raytheon/Tom Woodrow, Boeing): Update salt fog and humidity blocks, change the quantity of test vehicles needed from five to three.

- **Rationale:** Use of 3 test PWAs was agreed upon at the December 12, 2002 meeting.

Teleconference Discussion:

- a. Mr. Greene stated that the changes would be made based on a group decision made at the December 12, 2002 JG-PP lead-free solder meeting.

Table 4, Common Performance Requirements

Teleconference Discussion:

- a. Mr. Ghaffarian brought up the following topic for discussion on Table 4, JTP section 3.2.4 Thermal Cycling. The testing procedure references IPC-SM-785 (Guidelines for Accelerated Reliability Testing of Surface Mount Solder Attachments). Mr. Ghaffarian pointed out that IPC-SM-785 is just a recommendation for how you conduct the thermal cycling testing, while IPC-9701 (Performance Test Methods and Qualification Requirements for Surface Mount Solder Attachments) specifically defines the thermal cycling testing procedure including specifications on temperature range, duration, and acceptance criteria.
- b. Mr. Bradford pointed out that this issue was discussed at the December 12, 2002 meeting. The group agreed that since the JG-PP lead-free solder test vehicle does not meet the sample size requirements of IPC-9701 the group decided to reference IPC-SM-785 the guidelines document.
- c. Mr. Ghaffarian then stated that you could still follow IPC-9701 and choose your own sample size as long as you make note of the deviations that you make from the IPC-9701 document. Mr. Ghaffarian stated that IPC-9701 is very specific in spelling out testing conditions and criteria, which must be met in order to qualify your test vehicle to the standard. Mr. Ghaffarian pointed out that if you use IPC-SM-785 people can question what specific parameters were used during testing.
- d. Mr. Greene suggested that we write in the JTP that we are going above IPC-SM-785 and meeting IPC-9701 with main difference being sample size.
- e. Mr. Hillman stated that he would compare IPC-9701 to IPC-SM-785 and write a proper paragraph. Mr. Hillman will find differences and spell out properly in JTP (**AI, LFS.03.01.04**). Mr. Greene stated that once Mr. Hillman completes his review of IPC-9701 and IPC-SM-785. Mr. Greene will send out the revised write up for the group to review.



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Table 5, Extended Performance Requirements

Recommendation (Jeff Bradford, Raytheon): Update Table 5 to update acceptance criteria specifications.

- **Original:** $\geq 10^5$ ohms (Ω)
- **Proposed Change:** $IR_{final} \geq (IR_{initial})/10$
No evidence of electrochemical migration
No corrosion of the conductors
- **Rationale:** Be consistent with text in JTP Section 3.3.4.

Teleconference Discussion:

- a. Mr. Greene stated that the changes would be made in-order to maintain consistency with JTP section 3.3.4.

11. ***JTP Section 2.5 Quality Assurance***

Recommendation (Jeff Bradford, Raytheon): Recommend providing a detailed explanation of why we are not following the sample size requirements of IPC-9701 and not running 32 samples.

- The following comments were received in regards to having a test vehicle sample size of 25 not 32 as stated in IPC-9701
 - a. The consortia members do not have enough event detectors to test 32 components of each type with each solder
 - b. The consortium is not using IPC-9701 as a reliability guideline. We are using IPC-SM-785. IPC-SM-785 allows trade offs between sample size and test duration.
 - c. Most reliability studies reviewed do not use a sample size of 32. For example, the current NEMI study. It appears that they used a sample size of approximately 20 (CSPs) to generate their Weibull plots. They also cycled their test vehicles long enough to get greater than 63.2% failures (in some cases close to 100% failures were reached). I don't believe that a larger sample size would have improved the quality of their data. I believe that since the JG-PP is using a sample size of 25 (25 components of each type per each solder being tested), we will get great Weibull plots if we cycle until we get 70% or greater failures.

Teleconference Discussion:

- a. Mr. Greene stated that the issue of concern that appears in the discussion of Table 4 should be folded into the issue that appears under the topic titled JTP Section 2.5 Quality Assurance. Mr. Greene will make sure that the text in the paragraph will be rewritten to be clear and specific
- b. Mr. Greene then asked the group if the above written sections would be sufficient for the group. Mr. Woodrow stated that we need to clarify the number of samples that our testing program will have and



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the percentage of failures that we need to obtain in-order to have reliable statistical data and proper Weibull plots.

- c. Mr. Woodrow then directed a question to Mr. Ghaffarian as to what percentage of samples we would need to fail with a sample size of 25 in order for the data to be relevant. Mr. Ghaffarian responded that the more samples that are tested the better the confidence level of the data and that at least 50% of the samples should fail in-order to obtain reliable data.

Recommendation (Tom Woodrow, Boeing): Suggests deleting the following sentence “In order to generate useful Weibull plots, at least a minimum of 25% of the components must fail with a 50% component failure rate preferred, which” and replacing it with the following “For this test program, the goal is to fail more than 63% of each component type which should result in enough failures for the generation of valid Weibull plots. This will require many testing cycles (many hundreds to many thousands depending on the type of component).

- The following was noted:
 - a. It is the total number of failures that is important, not the %. This is why I deleted the above statement. For example, if the sample size is 5 and you failure percentage is 25% of the samples, you won't get a good Weibull plot.

Teleconference Discussion:

- a. Mr. Woodrow stated that we currently have 25 samples of each type of component on the JG-PP lead-free solder test vehicle and reiterated that question on what percentage of samples should be failed and would 50 to 75 percent failure rate be sufficient.
- b. Mr. Ghaffarian stated that he would review the sample size being used for the JG-PP lead-free solder testing program and rewrite the paragraph in the JTP 2.5 that addresses sample size and statistical analysis (AI, LFS.03.01.05).

12. *JTP Section 3.1.1 Electrical Continuity Testing*

Currently the JTP reads: The failure criteria measured by the event detector will be 10 events per channel with an interruption of electrical continuity ($\geq 300 \Omega$) for periods greater than 0.2 μ sec per the IPC-SM-785 (*Guidelines for Accelerated Reliability Testing of Surface Mount Solder Attachments*).

Question (Dave Hillman, Rockwell Collins): are we talking about 10 events or 10 consecutive events for the continuity testing?

Answer (Tom Woodrow, Boeing): Just 10 events not necessarily consecutive.

Teleconference Discussion:

- a. Mr. Ghaffarian commented that IPC-9701 spells out how to monitor event detection and that the failure criteria should be 10 consecutive events and not to random events.
- b. Mr. Woodrow stated that the current text in the JTP is not very well defined and needs to be rewritten to better describe how event detection will be monitored.



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- c. Mr. Hillman stated that after he reviews and compares IPC-9701 with IPC-SM-785, he would rewrite the current text of the paragraph to better define event detection and the failure criteria (**AI, LFS.03.01.06**).

13. *JTP Section 3.1.2 Coefficient of Thermal Expansion (CTE) Testing*

Recommendation (Jeff Bradford, Raytheon): Recommend changing the following sentence.

- **Original:** “The CTE of each SMT component type and the test vehicle will be measured per IPC-TM-650, Method 2.4.41 (Coefficient of Linear Thermal Expansion for Electrical Insulating Materials).”
- **Modified:** “Measure CTE of SMT components only per IPC-TM-650, Method 2.4.41 (Coefficient of Linear Thermal Expansion for Electrical Insulating Materials).”
- **Rationale:** The model does not work for PTH parts.

Teleconference Discussion:

- a. No objectives were received from the JG-PP lead-free consortium during the teleconference. Since no comments were received the above recommendation will be incorporated into the finalized JTP.

14. *NEW SECTION: JTP Section 3.1.3 Components Height Testing*

Recommendation (Jeff Bradford, Raytheon): Include a new section titled “3.1.3 Component Height Testing”. The section would read as follows: “The component height off the printed wiring board of each SMT component type will be measured during the microsection examination of the finished vehicle assemblies set aside for post-test inspection (see 2.2.2).”

Teleconference Discussion:

- a. Aside from the proposed text change, Mr. Greene asked the group if there was a standard to reference for JTP section 3.1.3 “Component Height Testing”.
- b. Mr. Woodrow stated that there is not a standard to follow and the general practice is to look through a microscope and take a measurement based using a microscope with a ruler in field of view.

15. *JTP Section 3.2.1 Vibration*

Recommendation (Cameron Conacher, Civ OO-ALC/LCEB): In our case vibration is our primary failure mode. Our A-10 gunfire vibration spec sows typical worst-case conditions.

The duration of testing cycling proposed would be to see if there is any plastic deformity of the solder bonds-precursor to failure. Specifically, two cycle, 10-second "gun fire simulation" duration, with a total of 52 cycles (simulate 2 flights/week for 6 months) should ensure either plastic failures occur or they don't occur during six months of aircraft flight operation.

Recommendation (Tom Woodrow, Boeing): The intent of our test is to fail solder joints (both tin/lead and lead-free) and by doing so we will hopefully demonstrate that the lead-free candidates are equal to or better than the tin/lead control. If the lead-free solder joints can survive more g(rms) than the tin/lead solder joints, we can have some confidence that we can use that lead-free solder for any application where tin/lead is currently being used. Obviously, it is impossible to test to everyone's specific testing document.



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However, I think our test runs the gamut from moderate to very severe vibration and encompasses most real world conditions.

Teleconference Discussion:

- a. Mr. Cameron Conacher (Civ OO-ALC/LCEB) stated that he had reviewed the figure for the vibration testing procedure in the JTP and questioned how the failures were to be detected from level one to level six. Mr. Conacher also stated that the vibration specifications for A-10 would be covered by level 3 of the vibration testing procedure in the JTP.
- b. Mr. Woodrow stated that failures would be documented through out the vibration testing and the group will know when parts fail and at which level. Mr. Woodrow explained that the purpose of the vibration testing is to see component failures, then based on number of failures per solder alloy type a comparison would be made to determine if lead-free solder alloys performed as good as eutectic tin-lead solder.
- c. Mr. Conacher suggested that no changes needed to be made to the vibration test in the JTP in order for it to meet his needs.

Recommendation (Tom Woodrow, Boeing): Recommend changing the following sentence.

- Original: “Test the electrical parameters of five PWAs of each solder alloy prior to exposure and record the results.”
- Modified: “Measure the electrical resistance of each channel prior to test.”
- Rationale: This sentence was too vague. Electrical parameters could be anything.

Teleconference Discussion:

- a. Mr. Greene reviewed the above recommendation, from Tom Woodrow (Boeing) to add the following modified sentence to JTP section 3.2.1 “Measure the electrical resistance of each channel prior to test,” No comments were received from the JG-PP lead-free consortium. Since no comments were received the above recommendation will be incorporated into the finalized JTP.

16. *JTP Section 3.2.2 Mechanical Shock Testing*

Review: Cost estimate for Mechanical Shock Testing prepared by Mr. Tom Woodrow of Boeing Seattle.

- See attachment; titled mechanicalshocktest(draft7)01_09_2003.xls.

Teleconference Discussion:

- a. Time expired before this could be brought up for discussion.

17. *JTP Section 3.3.1 Salt Fog*

Recommendation (Tom Woodrow, Boeing): Recommend changing the following sentence.

- Original: “Measure and record net resistance before salt fog exposure.”
- Modified: “Measure and record the electrical resistance of each channel before salt fog exposure.”

Teleconference Discussion:



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- a. Mr. Greene reviewed the above recommendation, from Tom Woodrow (Boeing) to add the following modified sentence to JTP section 3.3.1 “Measure and record the electrical resistance of each channel before salt fog exposure”. No comments were received from the JG-PP lead-free consortium. Since no objections were received to the above recommendation will be incorporated into the finalized JTP.

Recommendation (Tom Woodrow, Boeing): Recommend changing the following sentence.

- Original: “Record net resistance both pre and post execution of the salt fog test.”
- Modified: “Record the electrical resistance of each channel both pre and post execution of the salt fog test.”

Teleconference Discussion:

- a. Mr. Greene reviewed the above recommendation, from Tom Woodrow (Boeing) to add the following modified sentence to JTP section 3.3.1 “Record the electrical resistance of each channel both pre and post execution of the salt fog test”. The JG-PP lead-free consortium made no objections. Since no objections were received to the above recommendation will be incorporated into the finalized JTP.

18. *JTP Section 3.3.2 Humidity*

Recommendation (Tom Woodrow, Boeing): Recommend changing the following sentence.

- Original: “Measure and record net resistance before humidity exposure.”
- Modified: “Measure and record the electrical resistance of each channel before salt fog exposure.”

Teleconference Discussion:

- a. Mr. Greene reviewed the above recommendation, from Tom Woodrow (Boeing) to add the following modified sentence to JTP section 3.3.2 “Measure and record the electrical resistance of each channel before salt fog exposure”. The JG-PP lead-free consortium made no objections. Since no comments were received the above recommendation will be incorporated into the finalized JTP.

Recommendation (Tom Woodrow, Boeing): Recommend changing the following sentence.

- Original: “Record net resistance both pre and post execution of the humidity test.”
- Modified: “Record the electrical resistance of each channel both pre and post execution of the salt fog test.”

Teleconference Discussion:

- a. Mr. Greene reviewed the above recommendation, from Tom Woodrow (Boeing) to add the following modified sentence to JTP section 3.3.2 “Record the electrical resistance of each channel both pre and



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post execution of the salt fog test". No comments were received from the JG-PP lead-free consortium. Since no comments were received the above recommendation will be incorporated into the finalized JTP.

19. *JTP Sections 3.3.3 Surface Insulation Resistance (SIR) and 3.3.4 Electrochemical Migration Resistance Test*

Recommendation (Barrie Dunn, ESA): In JTP sections 3.3.3 and 3.3.4, concerning SIR and Electromigration tests, the results of these tests are dependant on the actual materials used in the board fabrication (e.g. the laminate material which you have fixed, and the final finish on the copper tracks). The final finish will be immersion silver as a "lead-free finish". I would like to propose the following. The immersion silver finish be compared against:

- 1) Hot air leveled tin-lead, and
- 2) Electroplated, then fused tin-lead.

- **Response (Dave Hillman, Rockwell Collins):** We could add the HASL finish to both tests - it would be a very good comparison point as Dr. Dunn described. Do we need the electroplated/fused test samples? The data would be very useful but it also comes as increased cost in terms of samples, processing and testing. The cost increase I think would be in the 3-6K ballpark. I would vote for adding the HASL finish but not the fused finish. I can get the quotations revised depending on the vote of the group.
- **Response (Gordon Davy, Northrop Grumman):** I agree with Dave Hillman that HASL, but not fused tin-lead, be used for the baseline finish for the SIR and electrochemical migration tests. I just assumed that all tests would include the HASL baseline, but maybe it needed spelling out. Mr. Davy stated that a joint team from IPC and Underwriters Laboratory recently conducted a study of silver electromigration with immersion silver board finish. See for example, <http://www.ul.com/pwb/>. Don Cullen of MacDermid and Thomas Farrell of UL were honored at the IPC meeting last month for their work. I hope that the people in your task force who are conducting their study of silver electromigration are aware of this work. The short version is that immersion silver does not electromigrate the way that electroplated silver does. The UL 796 test, which failed everything (it was designed a long time ago for vacuum-tube technology), was modified based on the results of this study.

A friend raised the question of whether, if the silver were too thick, the solder might not dissolve all the silver, and the connection would end up being to silver rather than to copper. An Enthone web page (<http://www.enthone-omi.com/electronics/pdf/finalfinishestu1.pdf>) says that its AlphaLEVEL immersion silver is 0.07 to 0.15 microns thick, so that doesn't seem likely, but it got me thinking! The same paragraph says that its immersion silver "eliminates issues with electromigration".

Teleconference Discussion:

- a. Mr. Hillman stated that SIR and electromigration measure board processing and flux rather than measuring actual solder joints and that it is hard to get fused tin/lead test articles. Mr. Greene asked whether an additional requirement should be added to the JTP to address Mr. Gordon Davy's (Northrop Grumman) issue. Mr. Hillman stated that an additional requirement would only gather information that is just extra data and would not impact the testing data
- b. Mr. Greene stated that he would inform Mr. Davy that the group is not interested in additional SIR and electromigration testing.

Question (Jeff Bradford, Raytheon): Number of IPC-B-24 and IPC-B-25A test boards needed per test?



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Answer (Dave Hillman, Rockwell Collins): 10 boards for 3 alloys plus 5 boards as controls; 35 test boards for IPC-B24 and IPC-B-25A for a total of 70 IPC-B boards.

Recommendation (Jeff Bradford, Raytheon): A paragraph needs to be developed to specify how the IPC-B-24 and IPC-B-25A boards are to be processed.

Recommendation (Dave Hillman, Rockwell Collins): The IPC-B-24 and IPC-B-25A boards will be processed at the end of the JG-PP test vehicle production run in accordance with the IPC-TM-650 test method.

Teleconference Discussion:

- a. Time had expired before the above issues could be discussed.

20. *Updates made to the Appendices*

Recommendations for JTP Appendix B - Test Vehicle Assembly:

Recommendation (Dave Hillman, Rockwell Collins): Assembly Flow charts in the Appendices are incorrect - we don't have bottom side components.

Recommendation (Dave Hillman, Rockwell Collins): The Assembly flow charts don't indicate the use of nitrogen gas - we'll need to have inert reflow ovens to process the test vehicles.

Appendix A updated to include the C-5 Weapons Platform as requested by the Air Force.

The Objective on page 1 in appendix B changed to:

- ***Original:*** The main objectives to this project is to gain experience manufacturing lead-free solder assemblies by building the Joint Group on Pollution Prevention (JG-PP) test vehicles in a production facility. Many assembly processes that work in a lab environment have problems when they get to production. One way to prevent potential impacts to manufacturing is by manufacturing the test assemblies in factory-by-factory personnel.
- ***Proposed Change :*** The main objectives to this project is to validate manufacturing techniques by measuring the performance of the lead free solder assemblies to the military stakeholder requirements expressed in this JTP by building the Joint Group on Pollution Prevention (JG-PP) test vehicles in a production facility. Many assembly processes that work in a lab environment have problems when they get to production. One way to prevent potential impacts to manufacturing is by manufacturing the test assemblies in factory-by-factory personnel.

Teleconference Discussion:

- a. Time had expired before the above issues could be discussed.

21. *Test Vehicle Design:*

- **Issue:** After the November 12 project meeting, there was some confusion over using plated through holes on the test vehicle.



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- **Recommendation:** All component signal paths will be traced on the surface of the test vehicle.
- **Rationale:** There will be no vias or plated through holes for the signal paths, thus eliminating the concern over via reliability. The test vehicle may need to be increased in the x and y-axis slightly, less than one inch in each axis.

Teleconference Discussion:

- a. Mr. Hillman stated that he would be pulling all lead to the surface of the test vehicle and there would be no vias or plated through holes on the boards that could lead to component failures.
- **Issue:** Currently the 64th channel is unused on the test vehicle.
 - **Recommendation:** It has been recommended that 10 vias be added to the test vehicle and monitored using the 64th channel allowing for the collection of data on vias.
 - **Rationale:** Since all plated through holes and vias associated with components will be eliminated from the test vehicle it has been suggested that we place some stand alone vias on the test vehicle in order to collect data on vias during the lead-free solder testing program.

Teleconference Discussion:

- a. Mr. Hillman purposed that 10 vias/holes/plated through holes be tied together on last channel in order to collect data on the no-lead solder alloys and vias/holes/plated through holes.
- **Issue:** We do not have room to put the resistors on the test vehicle and both resistors/capacitors are a common component used in Class 3 systems.
 - **Recommendation:** Remove all resistors from the test PWA
 - **Rationale:** The capacitor data can also be used to compare to other studies such as the Boeing data, Auburn data, NCMS data, etc. The capacitors are not a cost driver - we can utilize minimal sample schemes.

Teleconference Discussion:

- a. Mr. Woodrow stated that he would like to keep resistors on the test vehicle and the he needs resistor data, and then questioned the need for is chip capacitors on the test vehicle.
- b. Mr. Hillman stated that the capacitors could be cross-sectioned, long-wise catching both solder joints, at some predetermined interval, possibly every 250 cycles, and then continue on with the testing. A sampling plan would be developed in order to minimize the amount of work being done. Mr. Hillman also stated that 10 capacitors could be cross-sectioned at a time, and that the capacitors would only undergo thermal cycling.
- c. Mr. Hillman will be putting together a sample plan for everyone's review on how the capacitors will be tested and sampled (**AI, LFS.03.01.07**).

22. Other Technical Issues

To which document, Potential Alternatives Report (PAR), Joint Test Protocol (JTP) or both, should we include a paragraph explaining the decision to use silver immersion as the test vehicle surface finish?

The following comment was received from a JG-PP Stakeholder:

Per Tom Woodrow, the surface finish should be called out on the drawing. This is normal practice. However, there is no reason not to add details to the JTP regarding the surface finish.



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- a. Per Warren Assink, the surface finish information should appear in the PAR and then covered in the Joint Test Report again at the end of the project.
- Why Silver Immersion was chosen.
The following comments were received from JG-PP Stakeholders:
 - a. Tom Woodrow Boeing: Immersion silver, OSP (organic solderability preservative), immersion tin and electroless nickel/immersion gold (ENIG) have all been shown to be suitable board finishes for use with tin/lead and lead-free solders. Each has its strongpoints and limitations. ENIG is susceptible to "black pad" which can cause premature failure of solder joints. Immersion tin and OSP become nonsolderable after several exposures to reflow conditions and OSP exhibits poor wetting with some solders. Several major electronic manufacturing companies are currently using immersion silver in production and the general consensus is that immersion silver has the best balance of desirable properties (good wetting by solders, good solder joint reliability, good long-term solderability upon storage, and retention of solderability after multiple reflow cycles).
 - Identify the silver immersion provider and coating thickness that should be used for the JG-PP No-Lead Solder Project, specifically MacDermid Sterling™ product or Enthone AlphaLEVEL™ product
The following comments were received from a JG-PP Stakeholder:
 - a. There are only two reliable suppliers of immersion silver: MacDermid and Enthone. Mr. Woodrow's experience has shown that they are equivalent. The board shop that will make our boards will probably have one or the other. As far as the JTP is concerned, we probably need to specify only the vendor and the thickness of the silver (0.07-0.15 microns for AlphaLEVEL™; 0.25 microns for MacDermid Sterling™).

Teleconference Discussion:

- a. Mr. Hillman stated that the specification to use MacDermid Sterling™ silver immersion surface finish on the test vehicle would be spelled out on test board design layout.
- b. Brian Greene stated that test explaining the selection of solder alloys and the immersion silver board finish would appear in potential alternatives report (PAR). Mr. Greene stated that he would work with Mr. Hillman and CTC to develop the proper text for the PAR (**AI, LFS.03.01.08**).
- Solder Supply

Question: Who can supply the Sn/3.4Ag/1.0Cu/3.3Bi alloy in wire form?

The following comments were received from Lee Whiteman:

- a. Alpha can provide it, but if it is a custom production run, it might be expensive.
- b. AIM would like more information.
- c. Kester Solders cannot provide it.

Teleconference Discussion:

- a. Mr. Greene asked Mr. Whiteman how his search for the Sn/3.4Ag/1.0Cu/3.3Bi alloy in wire form was progressing.
- b. Mr. Lee Whiteman (ACI) stated that he has had no success in finding the Sn/3.4Ag/1.0Cu/3.3Bi alloy in wire form from his solder suppliers.
- c. Mr. Woodrow stated that Sinju can supply the Sn/3.9Ag/0.6Cu alloy and they have a Sn/Ag/Cu/Bi alloy but it is not the same alloy that the lead-free consortium had agreed on. Heraeus can supply Sn/3.4Ag/1.0Cu/3.3Bi in paste form but do not currently have the alloy in wire form. Heraeus is checking their suppliers to see if the Sn/3.4Ag/1.0Cu/3.3Bi alloy could be found in wire form as a



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custom build. Mr. Woodrow stated that it is his opinion that the Sn/3.4Ag/1.0Cu/3.3Bi alloy in wire form will have to be purchased as a custom made product which will cost more. Mr. Woodrow commented that he especially likes the Sn/3.4Ag/1.0Cu/3.3Bi alloy because it was used in an early NCMS study so we could compare our testing results to the NCMS study and currently Boeing is testing the same alloy and it is outperforming Sn/Ag/Cu alloy.

Closing of the Teleconference:

- a. Mr. Greene stated that the funding being provided by NASA would be available no later than March 1, 2003. Currently the Air Force is still looking into the best avenue to secure funding.
- b. Mr. Woodrow expressed his concern over the need to start testing this year. Procurement of components and boards needs to begin so that the boards can be built and ready for testing.
- c. Mr. Greene plans to have the current comments incorporated into the JTP by the first week of February and the JTP will be ready to be sent out for endorsement (**AI, LFS.03.01.09**).

SIGNED (Approved by W. Assink 02/06/03)

Warren Assink
Govt. Project Manager, WPAFB

Attachments: Action Items

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Action Items Closed at the 01/23/03 Teleconference

LFS.02.12.01

Date Due: 12/13/02
Responsibility: Mr. Tom Woodrow (Boeing)
Required Action: Develop cost estimates for test vehicle test set one and test set two and the "pathfinder" test vehicle.
Comments: Closed 01/23/03

LFS.02.12.03

Date Due: 12/13/02
Responsibility: Mr. Kurt Kessel (ITB, Inc.)
Required Action: Submit latest version of JTP to the lead-free solder consortium no later than January 18, 2002.
Comments: Closed 01/23/03

LFS.02.12.04

Date Due: 12/13/02
Responsibility: All technical representatives
Required Action: Final technical representative comments are due January 16, 2002
Comments: Closed 01/23/03. The following Lead-Free Solder Project participants provided comments to the December 18, 2002 final draft JTP: Jeff Bradford (Raytheon), Barrie Dunn (ESA), Gordon Davy (Northrop Grumman), Mark Feathers (U.S Army), Joe Felty (Raytheon), Dave Hillman (Rockwell Collins), Dennis Jarvi (ITB, Inc.), Debora Personius (Robins Air Force Base), Lynece Pfladderer (Lockheed Martin MFC-Dallas), Mike Selby (NASA/MSFC), Mark Stibitz (F-15 Engineering, WR-ALC/LFEA), Tom Woodrow (Boeing), Geoffrey Yoder (NASA/JSC)

LFS.02.12.02

Date Due: 12/13/02
Responsibility: Mr. Tom Woodrow (Boeing)
Required Action: Rewrite the mechanical shock testing procedure for the JTP
Comments: Closed 01/23/03. Incorporated into 12/18/02 JTP version

LFS.02.12.05

Date Due: 12/13/02
Responsibility: Mr. Dave Hillman (Rockwell Collins)
Required Action: Calculate the cost of the test vehicle
Comments: Closed 01/23/03. Information provided to Mr. Greene

New Action Items

LFS.03.01.01

Date Due: February 7, 2003
Responsibility: Mr. Brian Greene (NASA AP2/ITB)
Required Action: Rewrite JTP Section 1.1 and edit as appropriate. Once the paragraph is

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completed Mr. Greene will redistribute the revised paragraph to the group for approval.

Comments:

LFS.03.01.02

Date Due: February 7, 2003

Responsibility: Mr. Brian Greene (NASA AP2/ITB)

Required Action: Work out the revised text of JTP Section 2.2.1 “Pre-Test Inspection” and send it to Mr. Woodrow for review. Mr. Greene also stated that the cross section analysis text will go into one of the two paragraphs and will not appear in both paragraphs.

Comments:

LFS.03.01.03

Date Due: February 7, 2003

Responsibility: Mr. Brian Greene (NASA AP2/ITB)

Required Action: Rewrite the paragraphs in JTP sections 2.2.1 and 2.2.2 to address the corrections that are outlined in 01/23/03 meeting minute topic issues 7 and 8 (board inspection).

Comments:

LFS.03.01.04

Date Due: February 7, 2003

Responsibility: Mr. Dave Hillman (Rockwell Collins); Mr. Brian Greene (NASA AP2/ITB)

Required Action: Compare IPC-9701 to IPC-SM-785 and write a proper paragraph for JTP sections 2.3 & 2.5. Mr. Hillman will find differences and spell out properly in JTP. Once Complete Mr. Greene will send out the revised write up for the group to review.

Comments:

LFS.03.01.05

Date Due: February 7, 2003

Responsibility: Mr. Ghaffarian (Jet Propulsion Lab)

Required Action: Review the sample size being used for the JG-PP lead-free solder testing program and rewrite the paragraph in JTP Section 2.5 “Quality Assurance” that addresses sample size and statistical analysis.

Comments:

LFS.03.01.06

Date Due: February 7, 2003

Responsibility: Mr. Dave Hillman (Rockwell Collins)

Required Action: Rewrite the current paragraph in JTP Section 3.1.1 “Electrical Continuity Testing” to better define event detection and the failure criteria.

Comments:

LFS.03.01.07

Date Due: February 7, 2003

Responsibility: Mr. Dave Hillman (Rockwell Collins)

Attachment 1

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Required Action: Put together a sample plan for everyone's review on how the capacitors will be tested and sampled

Comments:

LFS.03.01.08

Date Due: February 7, 2003

Responsibility: Mr. Brian Greene (NASA AP2/ITB)

Required Action: Develop text explaining the selection of solder alloys and the immersion silver board finish that will appear in the potential alternatives report (PAR). Mr. Greene stated that he would work with Mr. Hillman and CTC to develop the proper text for the PAR.

Comments:

LFS.03.01.09

Date Due: February 7, 2003

Responsibility: Mr. Brian Greene (NASA AP2/ITB)

Required Action: Plans to have the current comments incorporated into the JTP by the first week of February and the JTP will be ready to be sent out for endorsement.

Comments:

Open Action Items

LFS.02.12.06

Date Due: 12/13/02

Responsibility: OEM Representatives

Required Action: OEM's are to identify point of contact that will officially sign and accept the JTP

Comments: Rockwell Collins= Dave Hillman

LFS.02.12.07

Date Due: 12/13/02

Responsibility: OEM Representatives

Required Action: OEM's are to identify headquarters and management points of contact for a meeting to held in January.

Comments:

LFS.02.11.04

Date Due: 12/01/02

Responsibility: OEM Business Representatives

Required Action: Report to B. Greene and W. Assink the nature and extent of the intended contributions, either direct cash or in-kind, to the lead-free solder testing effort over 2003-04

Comments:

LFS.02.11.05

Date Due: 12/01/02

Responsibility: All Technical Representatives

Required Action: Review the 'Proposed Testing Facilities' table in B. Greene's 11/12/02

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slide presentation and respond to B. Greene and W. Assink whether you agree or disagree with any of the proposed testing assignments shown in the table, the reasons for disagreement, and whether you would propose another facility for conducting a particular test.

Comments:

LFS.02.10.03

Date Due: 11/01/02

Responsibility: All technical representatives

Required Action: Identify to Brian Greene and Warren Assink their organizational business point of contact, if other than themselves

Comments:

LFS.02.10.04

Date Due: 11/01/02

Responsibility: OEMs

Required Action: Identify the frequency of their use of hybrids

Comments: Raytheon uses 13% hybrids

LFS.02.09.02

Date Due: 08/09/02

Responsibility: Rockwell Collins (Dave Hillman) and Raytheon (Jeff Bradford)

Required Action: Determine what effects reducing part count will have on statistical analysis and failure criteria, provide findings to Brian Greene

Comments: No response as of 10/03/2002

LFS.02.08.09

Date Due: 10/26/02

Responsibility: OEMs

Required Action: OEMs submit concept paper

Comments:

LFS.02.08.10

Date Due: 09/16/02

Responsibility: ITB, Inc. (Brian Greene)

Required Action: Distribute guideline and examples of DCMA concept paper

Comments: In progress by JG-PP

LFS.02.08.12

Date Due: 09/16/02

Responsibility: OEMs

Required Action: OEMs identify their past and forecasted in-kind contributions, including labor and other expenses for meetings, JTP development, etc.

Comments: Past contributions: Tom Woodrow of Boeing has provided information on past in-kind contributions
Future contributions: At least the following OEMs have indicated that they will provide testing as an in-kind contribution, Boeing, Raytheon and Rockwell Collins. As of 10/11/2002 the following has provided past LFS contributions; hours per month, travel costs, and materials cost; LM Aero Fort Worth, Boeing Seattle, Rockwell Collins, Naval Air Warfare Center, Weapons Division, Boeing Texas,

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Raytheon-Dallas, and CTC

LFS.02.08.13

Date Due: 09/30/02
Responsibility: ITB, Inc. (Brian Greene)
Required Action: Distribute expected contributions from stakeholders once cost estimate is better defined
Comments: In progress.
11/12/02 - B. Greene presented a summary of the estimated cost of testing and the current amount that that Government indicated they would fund. The shortfall would need to be made up by the OEMs and/or the scope of the testing reduced. A new action items was taken for OEMs to assess the nature and extent of their contributions.

LFS.02.07.02

Date Due: 08/09/02
Responsibility: Potential testing facilities
Required Action: Complete Lab Survey form
Comments: In progress, as of 11/08/2002 survey forms have been received from; ACI, Raytheon, Sandia, Boeing Rockwell Collins and NAVAIR

Action Items Closed at the last (12/12/02) Teleconference

LFS.02.11.03

Date Due: 12/01/02
Responsibility: Rockwell Collins (Dave Hillman)
Required Action: Modify the test board design to incorporate (a) tracing of certain components in lieu of vias, (b) 10 additional resistors, and (c) the possible need for more clearance between components.
Comments:

LFS.02.11.02

Date Due: 11/13/02
Responsibility: ARDEC (Dave Locker)
Required Action: Will write the testing procedure, JTP Section 3.2.2 Mechanical Shock, for the JTP taking into account all stakeholders concerns.
Comments: Closed 12/12/03. Discussed and agreed upon 12/12/03

LFS.02.11.03

Date Due: 12/01/02
Responsibility: Rockwell Collins (Dave Hillman)
Required Action: Modify the test board design to incorporate (a) tracing of certain components in lieu of vias, (b) 10 additional resistors, and (c) the possible need for more clearance between components.
Comments: Closed 12/12/2003. Discussed and agreed at 12/12/03 telecon