IPC Midwest 2011

Thermal Cycle Solder Joint Integrity Assessment of SnBi Plated Components

David Hillman

Rockwell Collins

Executive Summary:

The implementation of the European Restriction of Hazardous Substances (RoHS) Directive has initiated an electronics industry materials evolution. Printed wiring board laminate suppliers, component fabricators, and printed wiring assembly operations are engaged in numerous investigations to determine what lead-free (Pbfree) material choices best fit their needs. The complexities of Pbfree soldering process implementation insures a transition period in which Pbfree and tin/lead solder finishes will be present on printed wiring assemblies for many electronic product segments. One of the component surface finishes being offered by electronics industry component fabricators is 98% tin - 2% bismuth (98Sn2Bi) as a Pbfree component finish option. This presentation documents an investigation of a solder joint integrity assessment of tin/bismuth component surface finishes in both tin/lead and Pbfree soldering processes under thermal cycle conditions. The investigation results are also compared/contrasted with other industry published data sets.

98% Tin / 2% Bismuth Component Surface Finish: Solder Joint Integrity and Tin Whiskers Aspects

Dave Hillman
Rockwell Collins
IPC Midwest September 2011

Rockwell Collins

Agenda

- **Background**
- **Objective**
- **Test Vehicle and Assembly**
- **Thermal Cycle Testing**
- **Hot Shear Testing**
- **Results & Failure Analysis**
- **Discussion**
- **The Second Topic – Tin Whiskers**
- **Conclusions**
- **Questions**

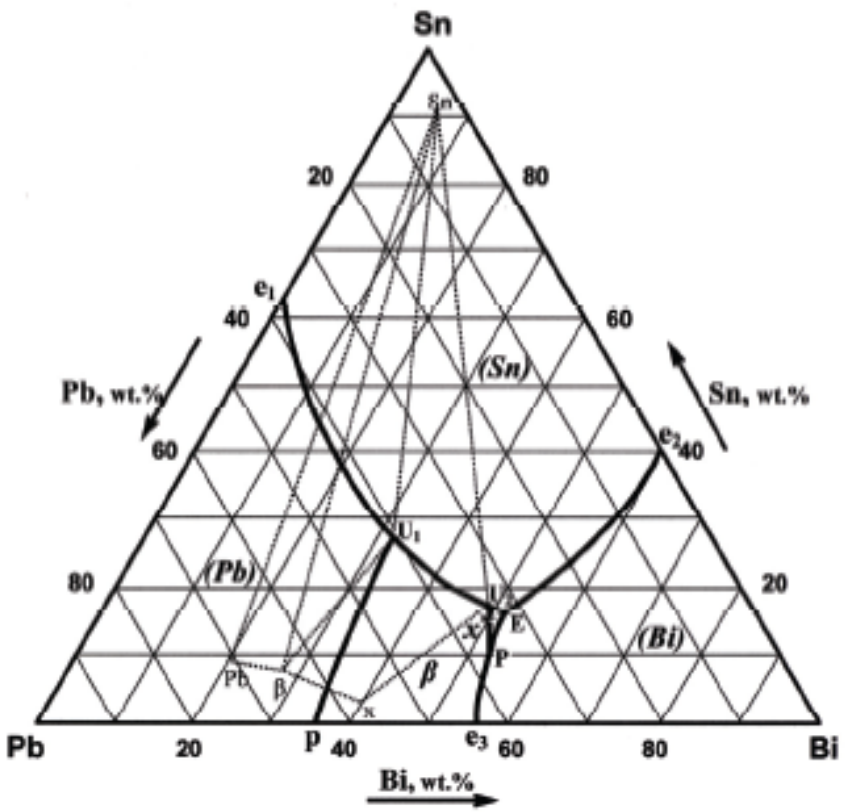
Background

- **One of the component surface finishes being offered by electronics industry component fabricators is 98% tin - 2% bismuth (98Sn2Bi) as an alternative LF component finish (tin whisker mitigation response)**

- **Bismuth is a "Weird" Element!**
  - **Bismuth has the second lowest metallic thermal conductivity (Hg)!**
  - **Bismuth is more electrically conductive in a liquid form than solid!**
  - **Bismuth *expands* 3.3% during solidification!**
  - **Bismuth is historically the dominate low melting point alloy system of choice – 58%Bi/42%Sn Tm = 138°C**

Background

- **Industry Tribal Knowledge:**
  - **Sn/Pb/Bi ternary eutectic phase**
    - ❖ **96°C melting point**



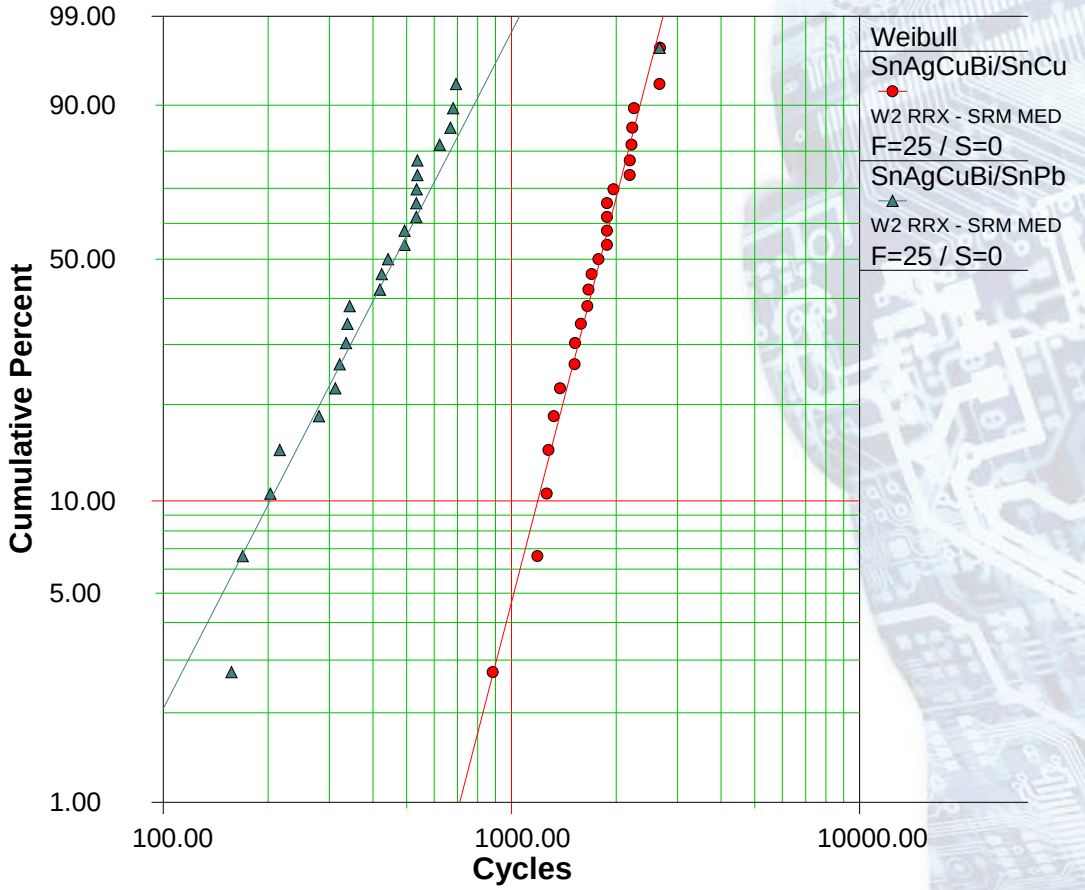
Phase Diagram from ASM International Handbook

Background

- **Interaction of lead and bismuth in a bismuth containing LF solder alloy: Joint Council on Aging Aircraft (JCAA) / Joint Group on Pollution Prevention (JGPP) LF Solder program.**

- **Solder Alloy Included in Test Program:**
  - **Sn3.4Ag1.0Cu3.3Bi With SnCu and SnPb TSOP Component**

  - **Weblink: http://acqp2.nasa.gov/JTR.htm**



β1=4.5553, η1=1950.6106, ρ=0.9890
β2=2.2892, η2=542.1344, ρ=0.9096

Key: Solder Alloy/Component Finish

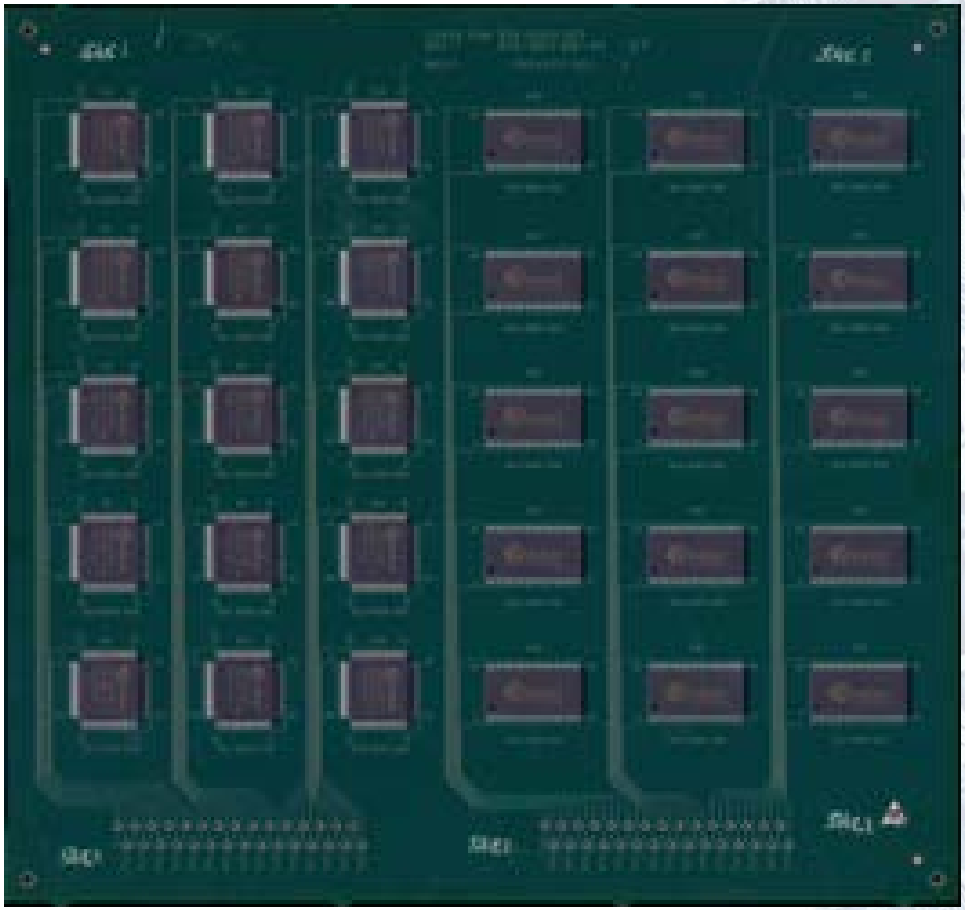
Objectives

- **The primary objective of the investigation was to determine the impact of tin/bismuth component surface finishes used in either a tin/lead or a lead-free soldering process on solder joint integrity for a -55ºC to +125ºC thermal cycle temperature range.**

- **A secondary objective of the presentation is a discussion of tin/bismuth component surface finishes and tin whisker phenomena interaction**

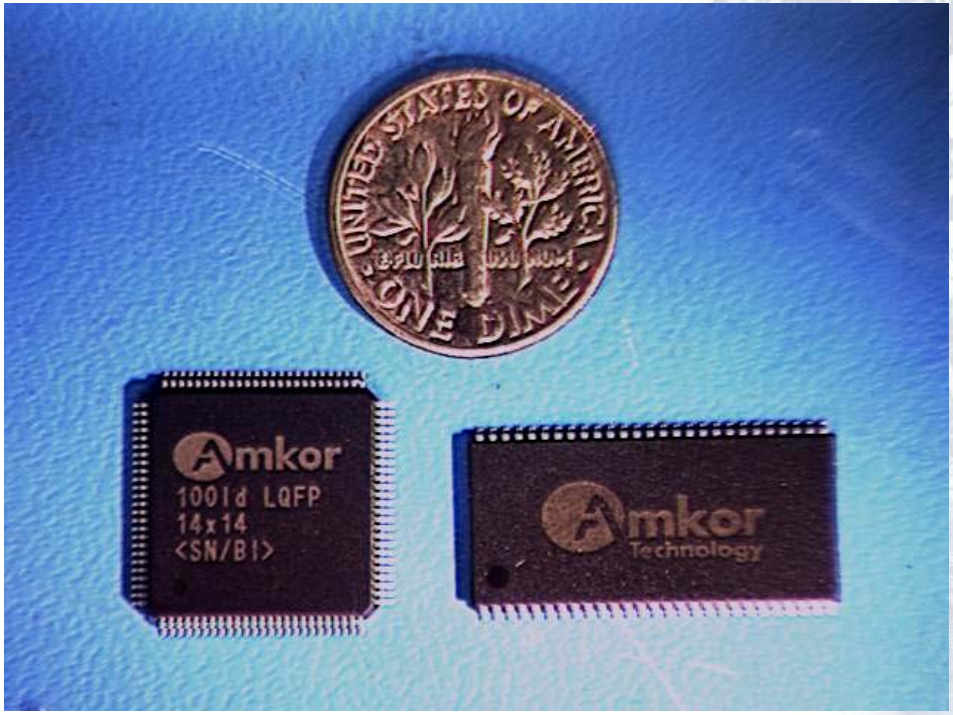
Test Vehicle and Assembly

- **Test Vehicle**
  - **8 inches wide by 8.5 inches high by 0.069 inches thick**
  - **8 layers of 0.5 ounce copper**
  - **Per IPC-6012, Class 3, Type 3 requirements**
  - **FR4 per IPC-4101/26**
  - **Minimum Tg of 170ºC**
  - **Immersion silver finish (MacDermid's Sterling)**



Test Vehicle and Assembly

- **Test Components**
  - **Thin small outline package (TSOP) with an Alloy 42 lead frame**
  - **Quad flatpack (QFP) with a copper lead base metal**
  - **Finish: 98 wt% tin -2 wt% bismuth**
  - **Plating bismuth content tolerance range of 1 wt% - 5 wt%**
  - **Chemical analysis: bismuth content of 3.10 +/- 0.2 wt%**
  - **Solder Alloys Used:**
    - **Sn63Pb37**
    - **SAC305**



Thermal Cycle Testing

- **Thermal Cycle Testing Methodology:**
- **In Accordance with IPC-9701**
- **Temperature Extremes: -55°C and +125°C**
- **Temperature Ramp: 5°C-10°C per minute maximum**
- **Temperature Dwells: 10 minutes at temperature extremes**
- **Total Cycles: 2000**

- **Continuous Monitoring with Event Detector:**
  - **An Event = channel resistance exceeded 300 Ω for longer than 0.2 μsec within a 30-second period**

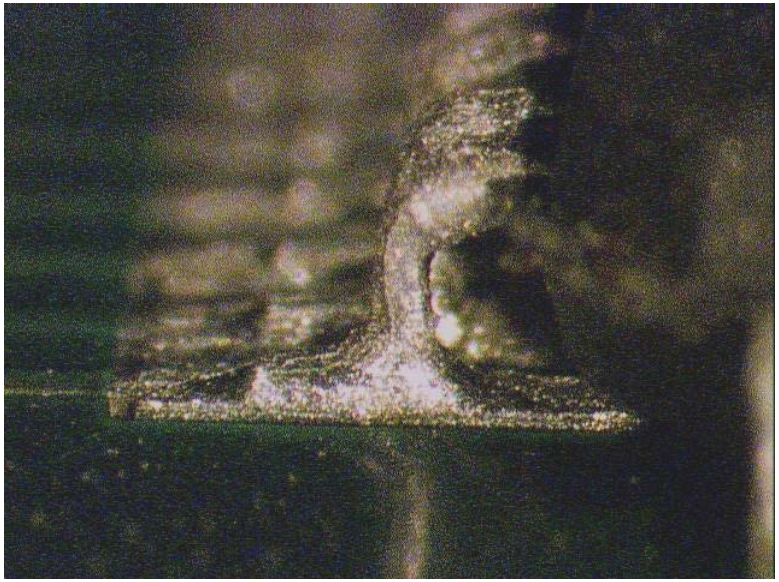
- **A failure was defined when a component either:**
  - **15 consecutive maximum resistance events,**
  - **5 consecutive detection events within 10% of current life, or**
  - **Became electrically open**

Hot Shear Testing

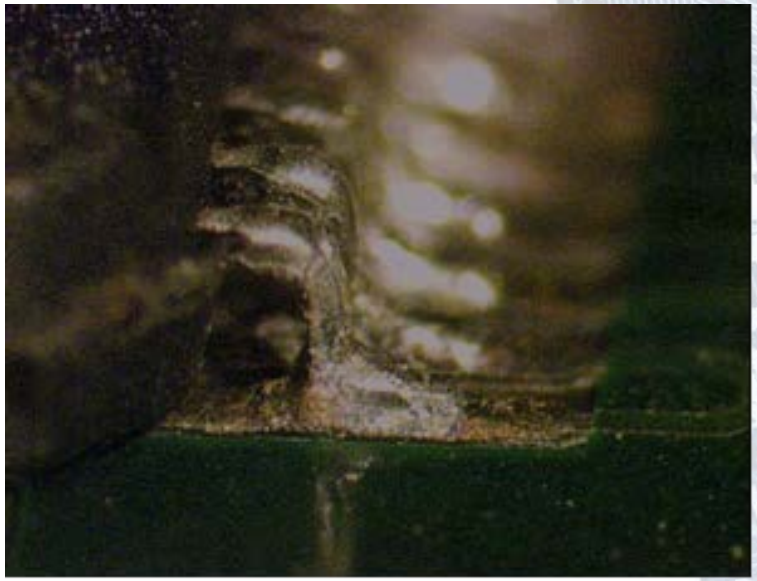
- **Elevated Temperature Shear Parameters**
  - **Only for SnPb Soldered TSOP Components (60 gram load)**
  - **Rising thermal profile with different step increments:**
    - **5°C incremental to 90°C**
    - **2°C incremental for 90°C -100°C**
    - **5°C incremental for 100°C-125°C**
    - **10°C incremental for 125°C to 220°C**

Results & Failure Analysis

- **Results:**
  - **No QFP failures for Sn63Pb37 or SAC305**
  - **Significant TSOP failures Sn63Pb37 or SAC305**



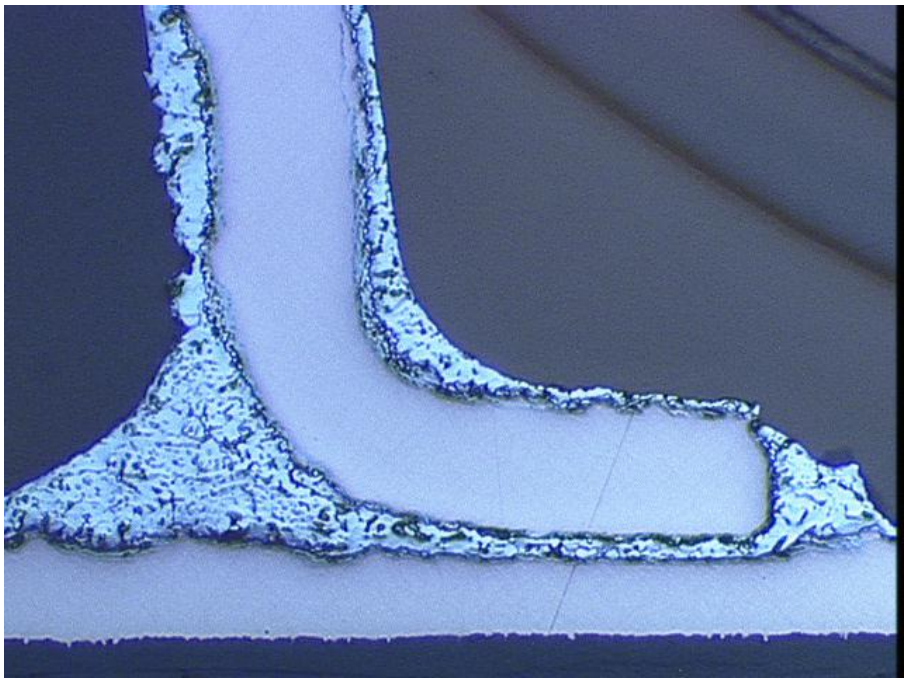
Sn63Pb37 - QFP



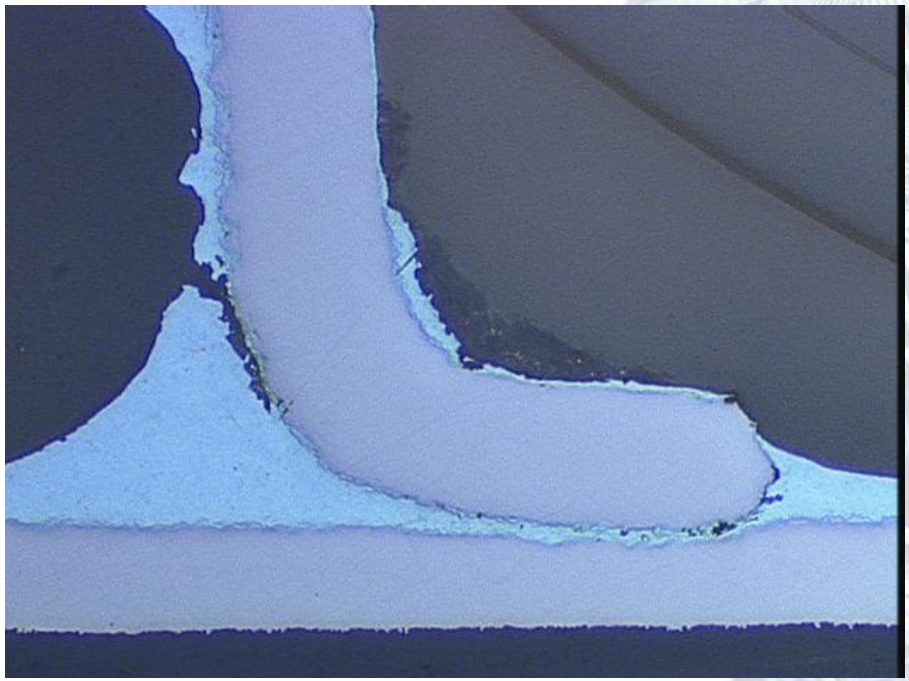
SAC305 - QFP

Results & Failure Analysis

- **QFP Results: Cross section @2000 cycles**



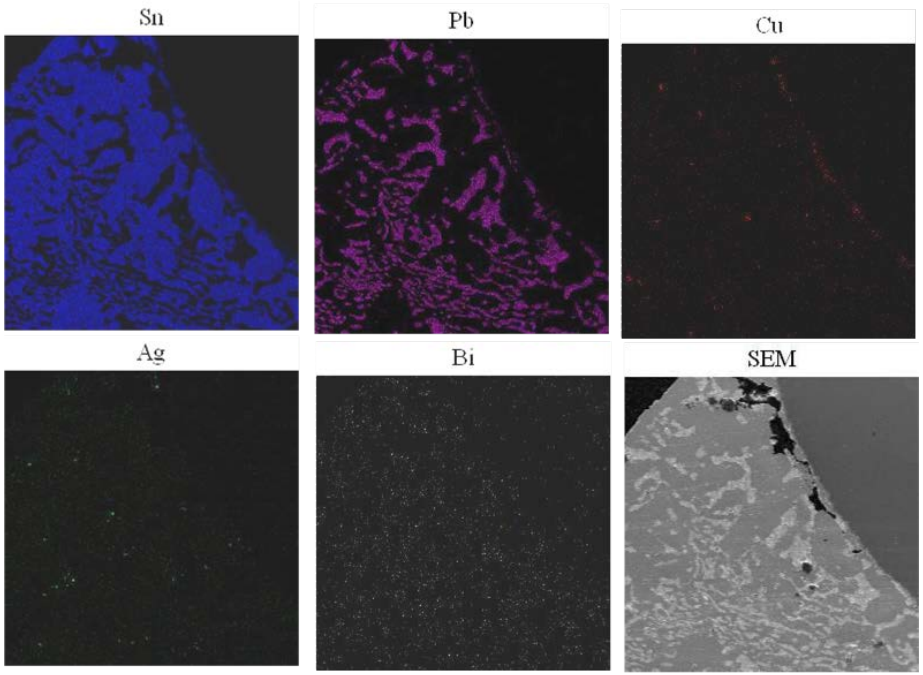
Sn63Pb37



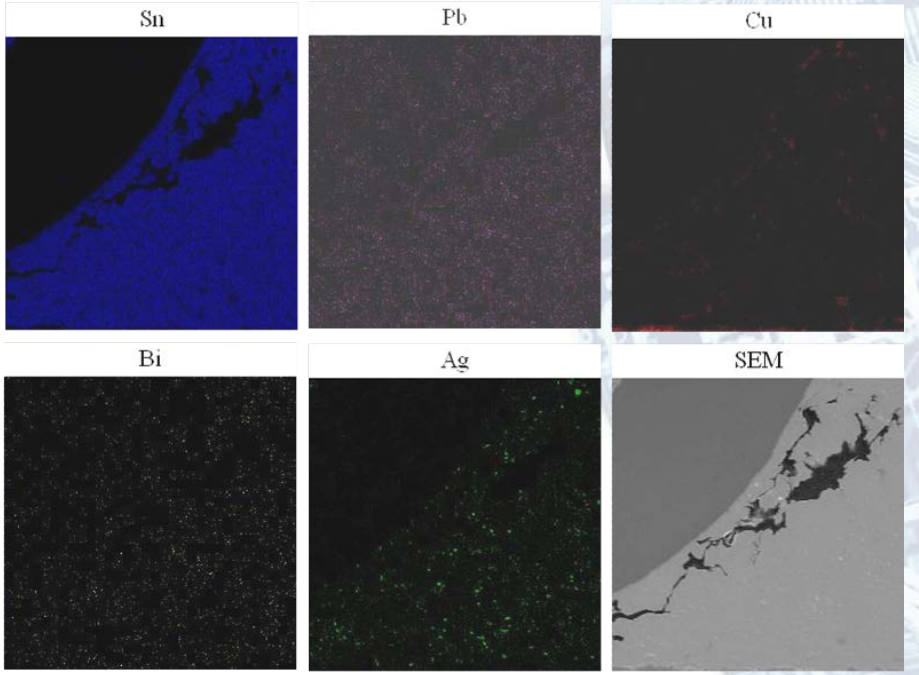
SAC305

Results & Failure Analysis

- **QFP Results: SEM Mapping**



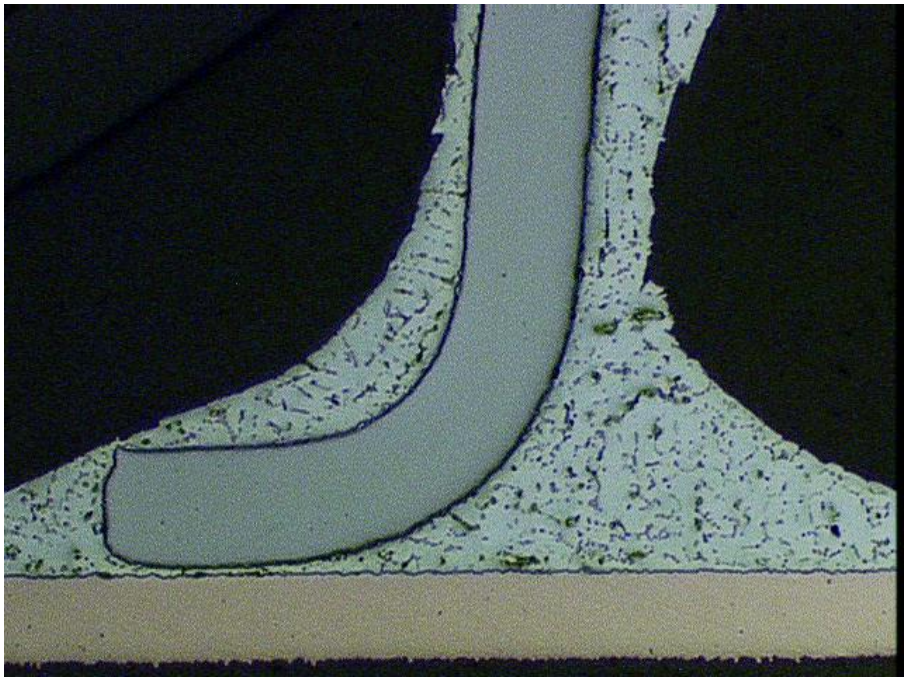
Sn63Pb37



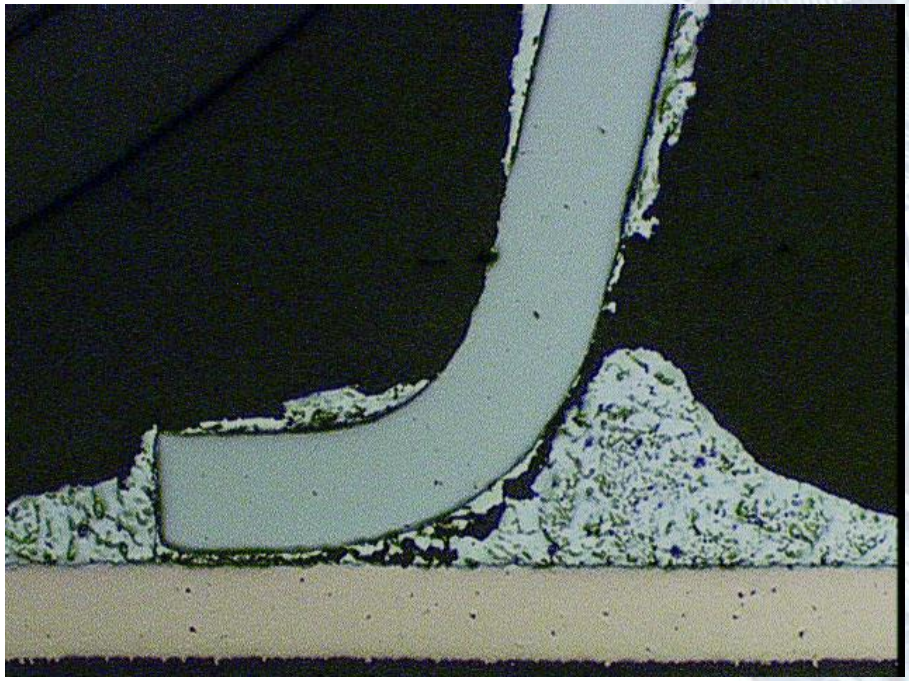
SAC305

Results & Failure Analysis

- **TSOP Results: *SnPb* Cross section: 200/500 cycles**



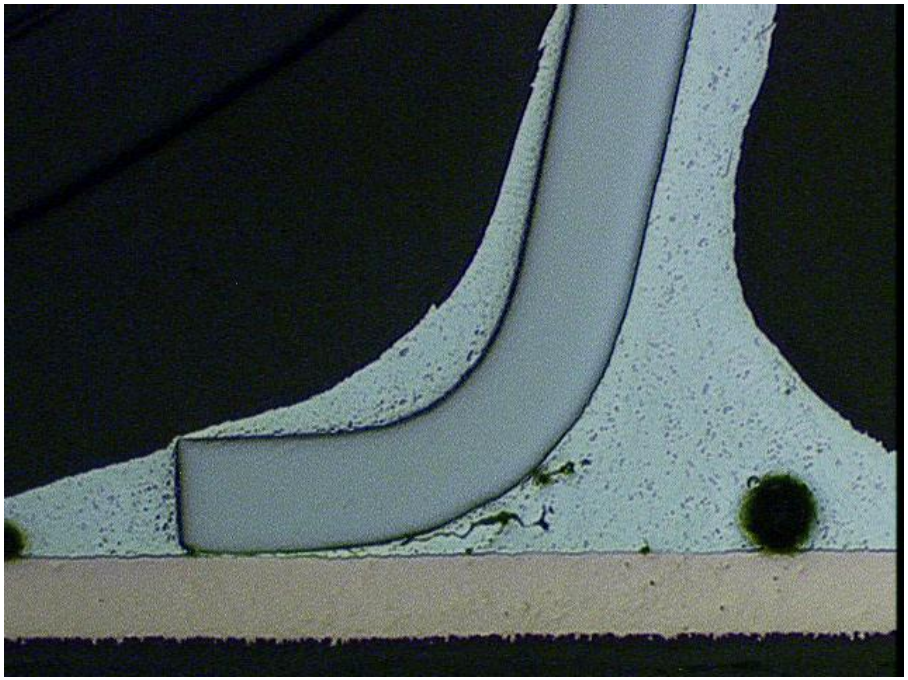
200 Cycles



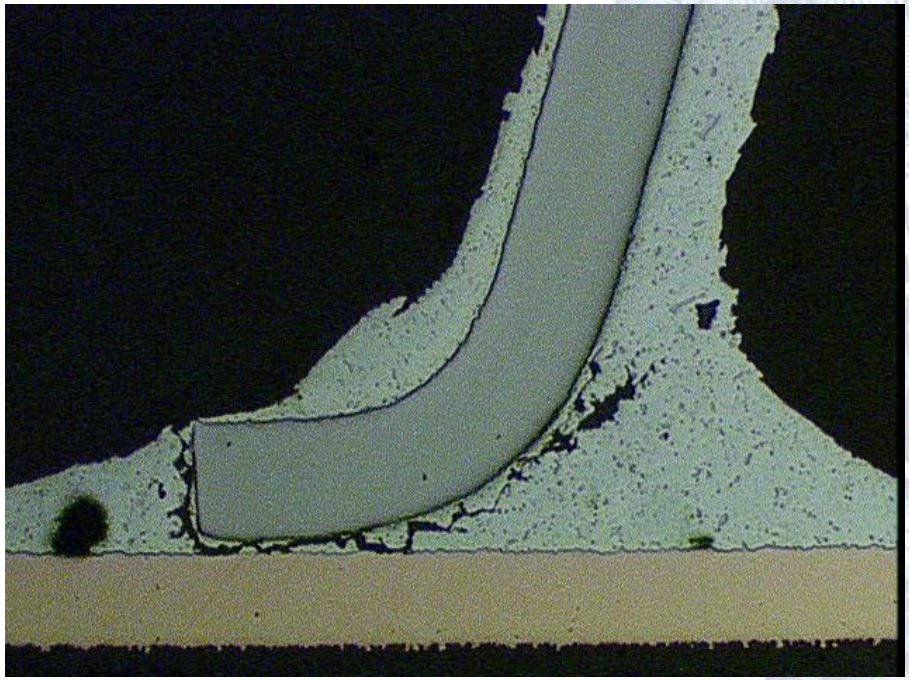
500 Cycles

Results & Failure Analysis

- **TSOP Results: *SAC305* Cross section: 200/500 cycles**



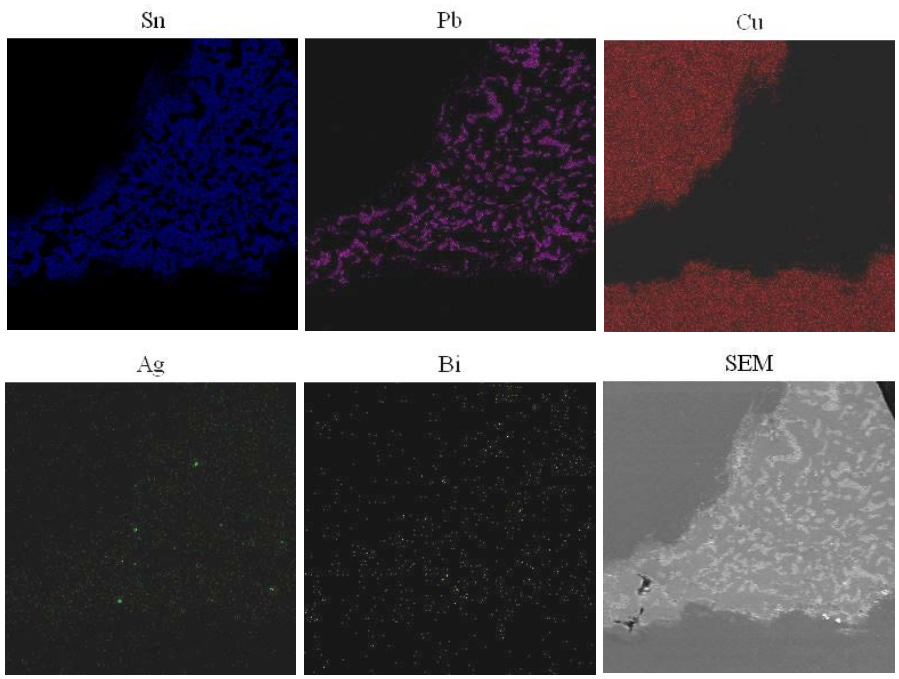
200 Cycles



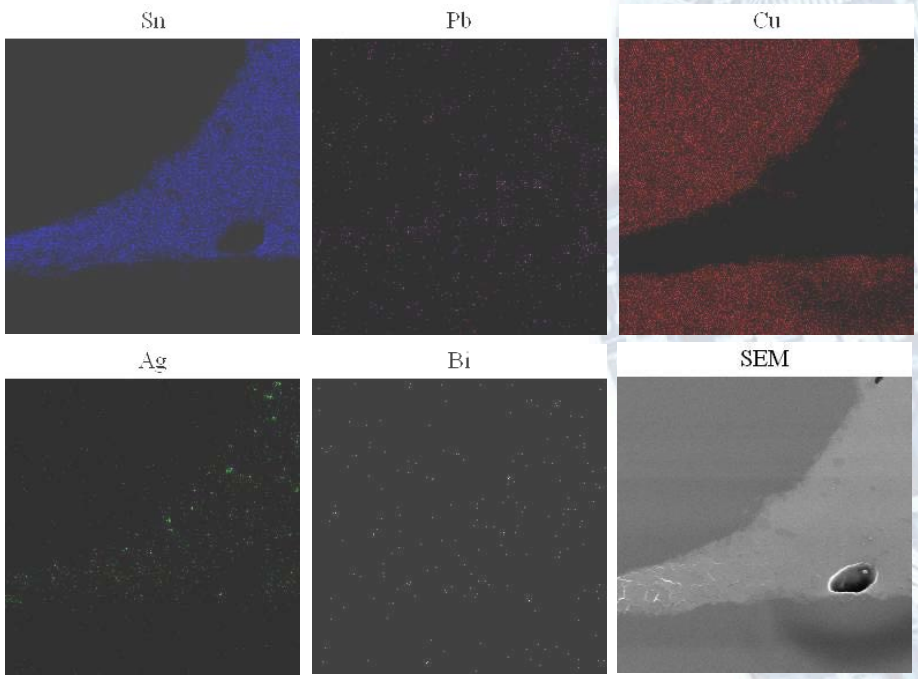
500 Cycles

Results & Failure Analysis

- **TSOP Results: SEM Mapping**



Sn63Pb37



SAC305

Results & Failure Analysis

- **Elevated Shear Testing Data: TSOP**

Sample Number	Shear Failure Temperature (degrees C)
1	Not Tested
2	Not Tested
3	190
4	210
5	190
6	200
7	188
8	196

Discussion

- **Metallurgical Assessment**
  - **Snugovsky reference**
  - **Moon reference**
  - **This investigation**

"SnPb solder alloy can contain up to 6% Bismuth addition without the formation of the SnPbBi low melting phase using typical solder processes"

Discussion

- **Thermal Cycle Reliability Assessment**
- **Meilunas et al: SnBi and SnPb performed equally for elevated temperature pull tests at 100°C for QFPs**
- **Snugovsky et al: 0°C- +100°C TC testing, 60 min cycle, TQFP, no solder joint degradation (2000 cycles)**
- **Hunt et al: -55°C – +125°C TC testing, 50 min cycle, SOIC & DIP, no solder joint degradation (2000 cycles)**
- **Syed et al: -55°C – +125°C TC testing, 120 min cycle, TSOPs, SnBi surface finish results dependent on component base metal alloy (+4000 cycles)**
- **NEC: -40°C – +125°C TC testing, QFP, no solder joint degradation (2000 cycles)**
- **This investigation**

Conclusions

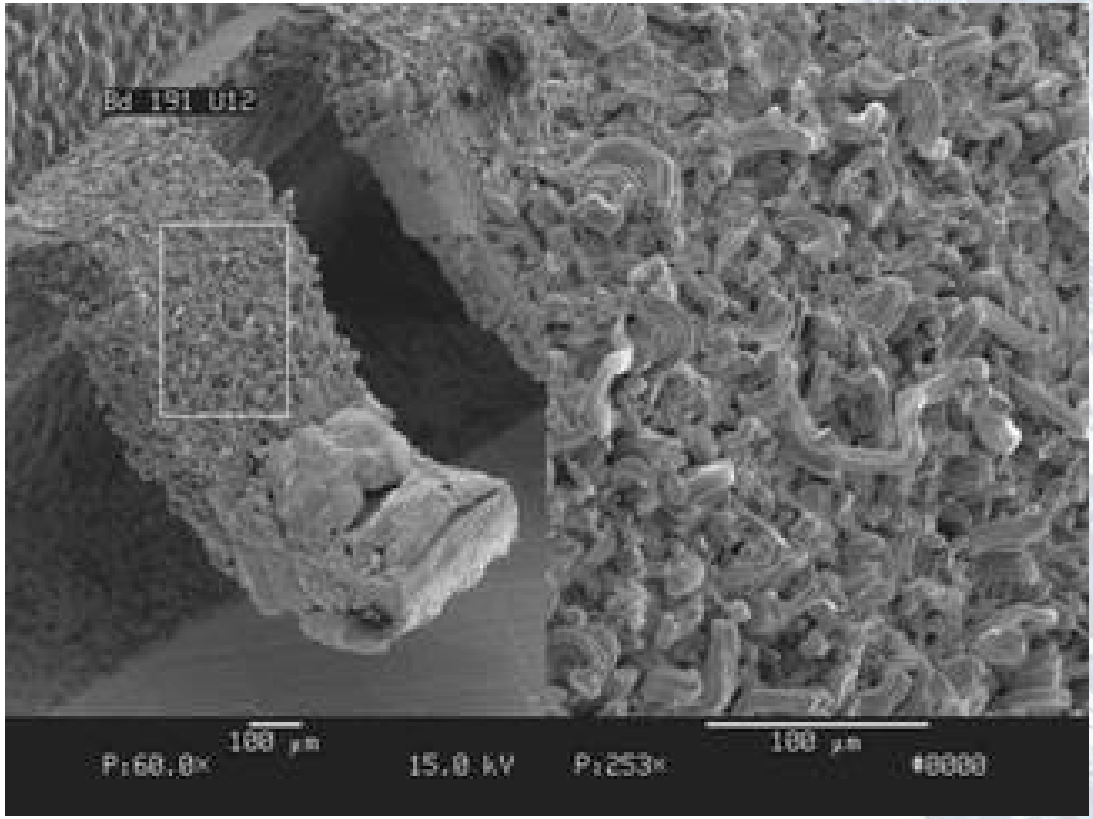
- **The investigation test results and data analysis demonstrate that 98Sn2Bi surface finishes on components will not degrade solder joint integrity of SnPb and SAC305 solder alloys for avionics product use environment.**

For More Details On Results Presented In This PPT, See Published Paper:

D. Hillman et al, "Solder Joint Integrity Impact of 98%Tin/2%Bismuth Component Surface Finishes", 2007 SMTAI Conference Proceedings.

Tin Whisker Phenomena

- **Tin Whisker Risk Mitigation:**
  - **"Poison / Alloy" Pure Tin with Another Element**
  - **Bismuth has industry attention**



SnCu Finish TSOP After 4743 Thermal Cycles

Source: D. Hillman et al, "JCAA/JGPP No Lead Solder Project: -55C to +125C Thermal Cycle Testing Final Report, Contract Number GST 0504BM3419

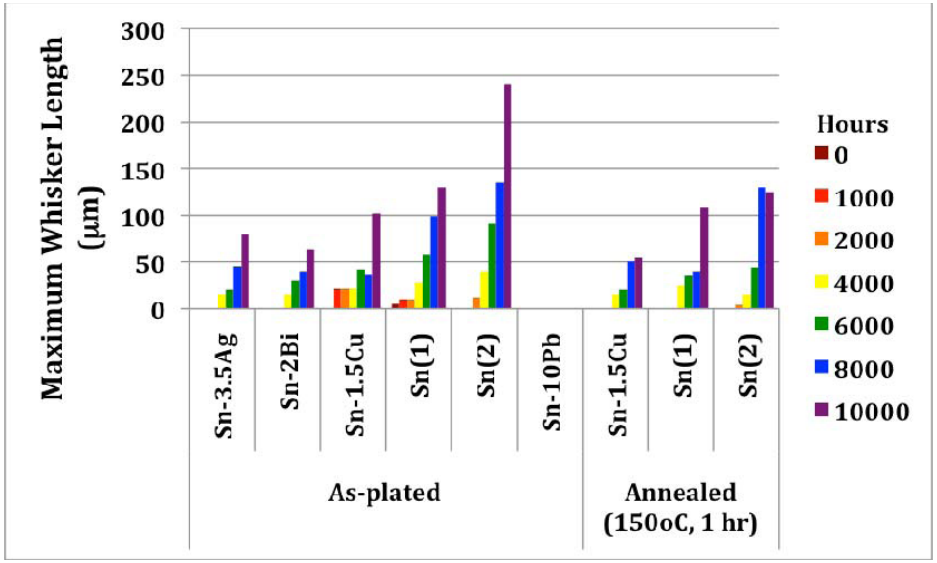
Tin Whisker Phenomena

Table 4.2 Acceleration Whisker Test Result (sample whiskered/total sample)

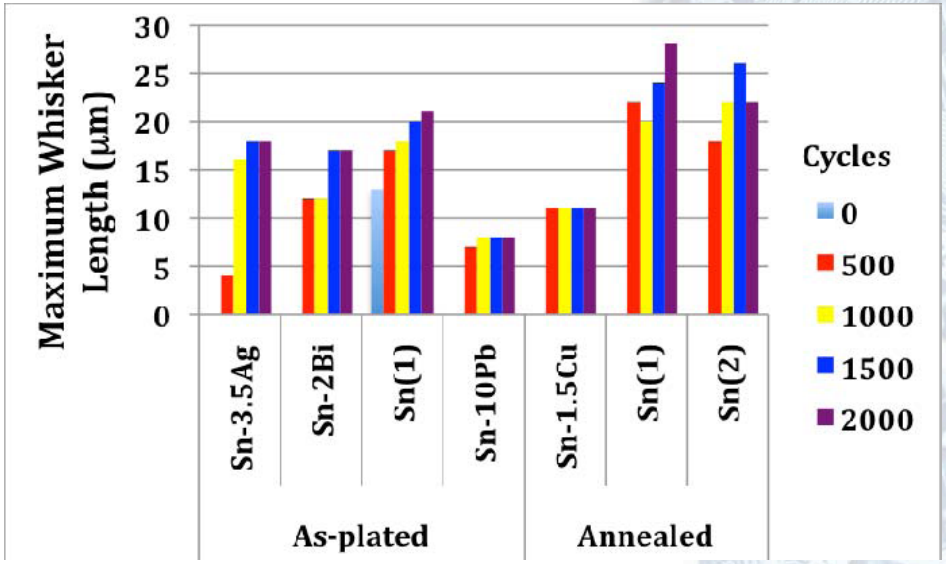
Condition	Sn/2Bi	Sn/10Pb
Storage: 60°C/95%RH/3wks	0/2	2/2
Storage: 85°C/85%RH/500hrs	0/2	0/2
Temp cycle: -35°C/125°C/500cyc	0/2	0/2
Temp cycle: -55°C/85°C/500cyc	2/2	2/2
Autoclave:121°C/100%RH /15PSIG/576hrs	0/2	0/2

Graph Source: N.Vo, Y. Nadaira, T. Matsura, M. Tsuriya, R. Kangas, J. Conrad, B. Sundram, K. Lee, and S. Arunasalam, "Pb-free plating for peripheral/leadframe packages," in *Proc. IEEE Electronic Components and Technology Conf.*, 2001, pp. 213–218.

Tin Whisker Phenomena



55C/85%RH Conditioning



-40C/+80C Cycle Conditioning

Graph Source: R. Zhang et al, "Tin-Bismuth Plating for Component Finishes", 2011 Electronic Components and Technology Conference, pgs 2060-2066.

Tin Whisker Phenomena

iNEMI Information:

“When added to tin in amounts of 2-4% by weight, bismuth may aid in suppressing whisker growth and can be a viable mitigation practice.”

Source: iNEMI Recommendations on Lead-Free Finishes for Components Used in High-Reliability Products, Version 4 (12-1-06)

Tin Whisker Phenomena

So, this indicates…….

Do Your Homework and Establish a Supportable Position For Usage in Your Product

Conclusion

- **The use of 98Sn2Bi as a tin whisker risk mitigation methodology has not reached industry consensus opinion yet.**

For More Details On Results Presented In This PPT, See Published Paper:

D. Hillman et al, "Solder Joint Integrity Impact of 98%Tin/2%Bismuth Component Surface Finishes", 2007 SMTAI Conference Proceedings.

Questions ?