

Mission Success Starts With Safety

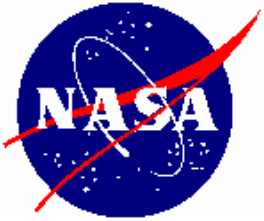
Lead-free from One NASA Perspective

Lead-free Summit

ACI Philadelphia, PA

July 13, 2005

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Lead Free

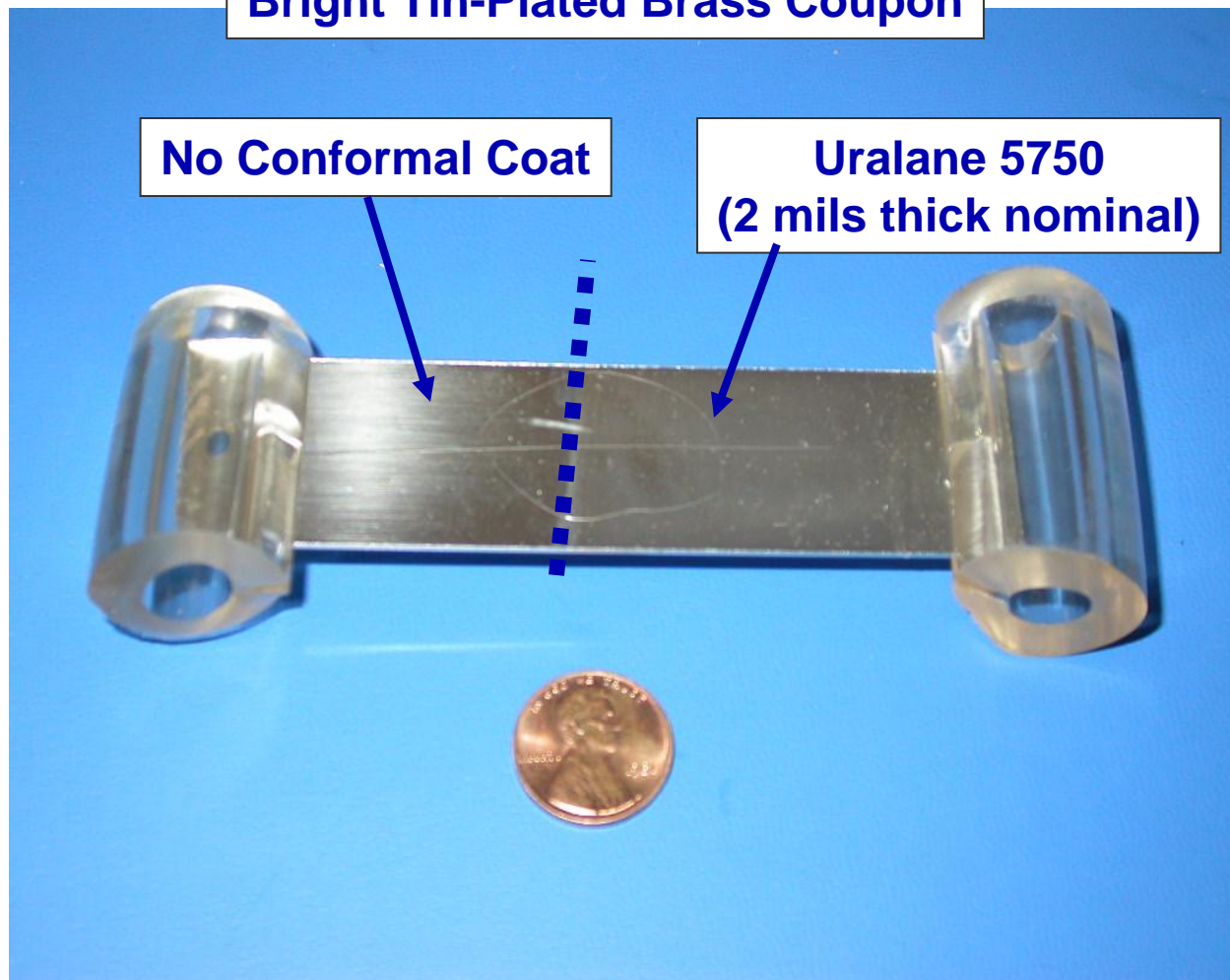
- **Tin Whiskers**

- A “stakeholder consultation” questionnaire for input to RoHS (Restriction of the use of certain Hazardous Substances) has been received from the European Commission on WEEE (Waste Electrical and Electronic Equipment)
 - Results from this action could allow the limited use of lead in surface finishes for EEE parts
 - Sony part of one organization petitioning for an exemption
 - NASA is preparing a response



NEPP Tin Whisker Test Coupon

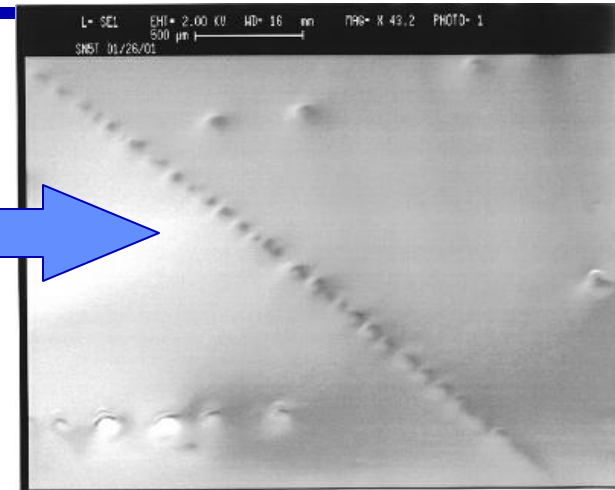
Bright Tin-Plated Brass Coupon



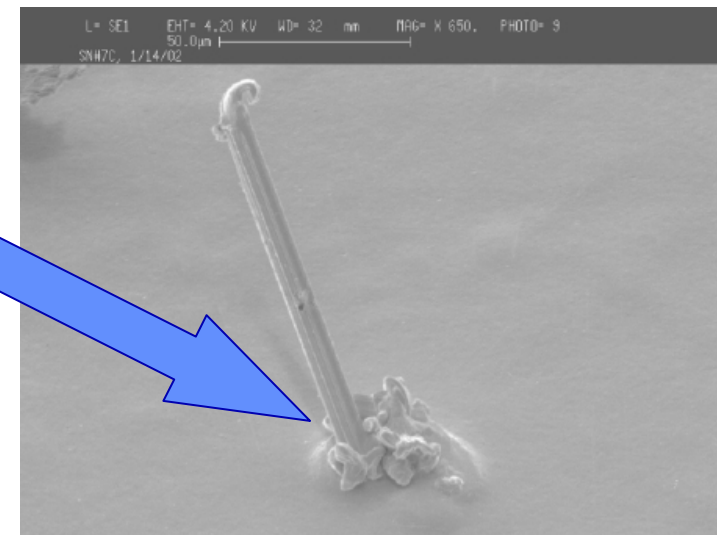
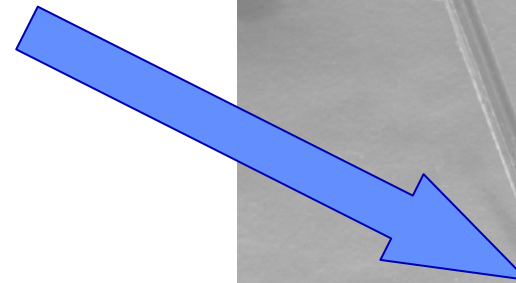


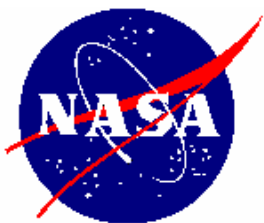
We Knew ...

- **2 Mils of Polyurethane Mostly Effective at Keeping Tin Whiskers at Bay**

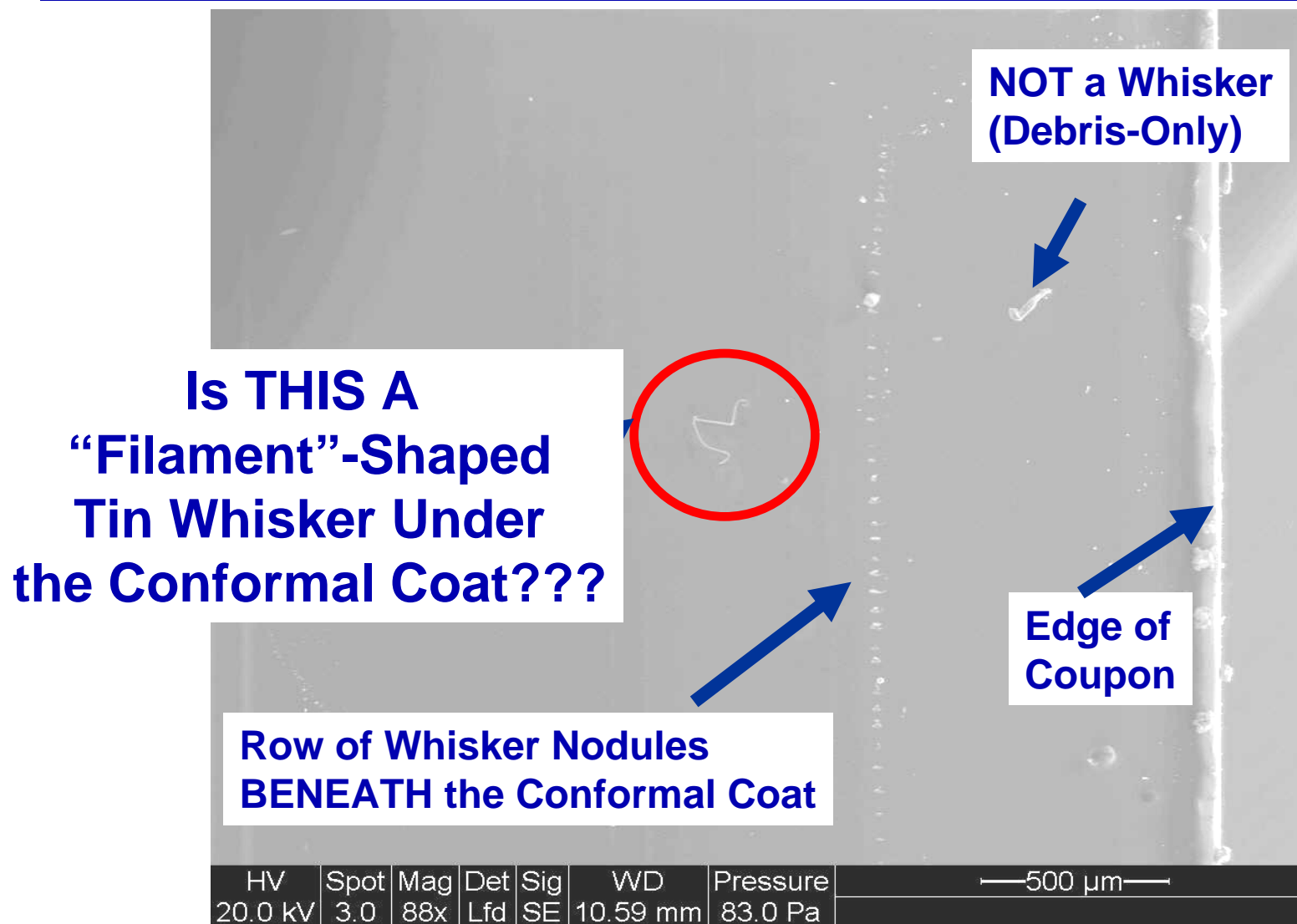


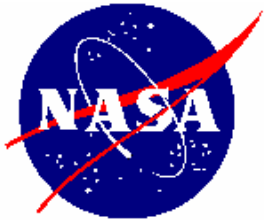
- **However, Whiskers Can Grow Through “Thinner” Coatings (~ 0.1 mils thick)**





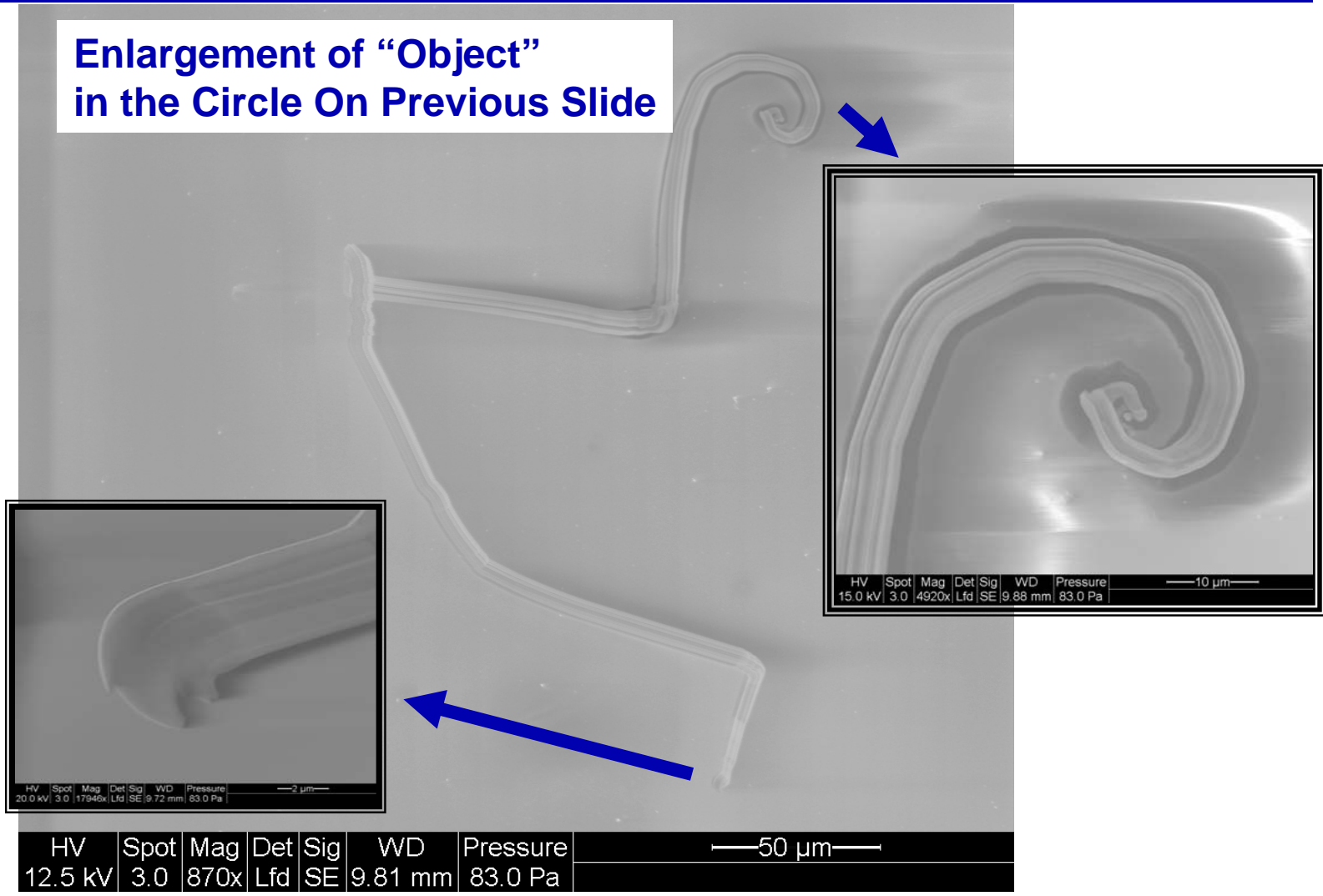
Whiskers Under the Conformal Coat?





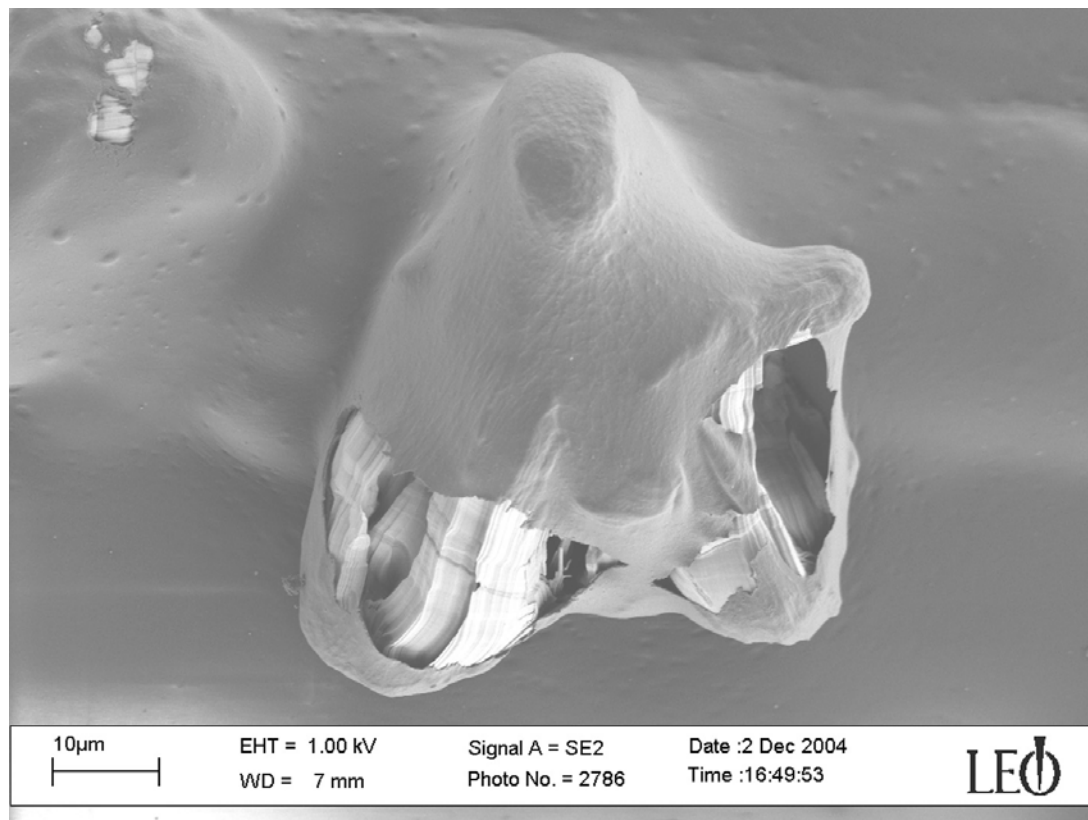
Close-up

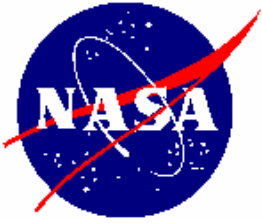
Enlargement of "Object"
in the Circle On Previous Slide





The Conformal Coat is Tearing Too





Tin Whiskers

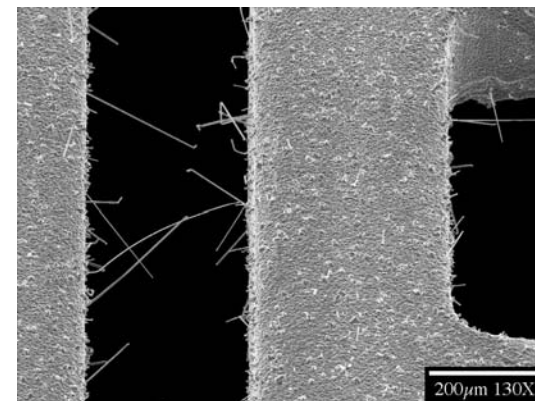
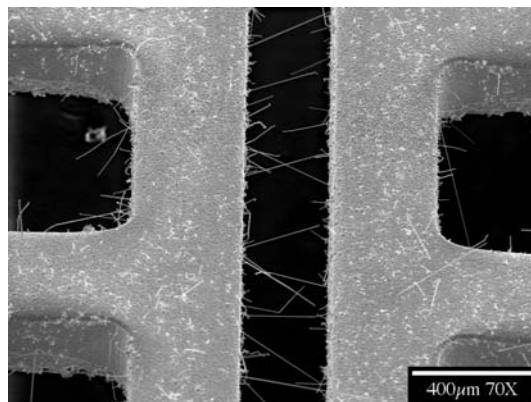
- **Tin Whisker Mitigation Via Conformal Coat Experiment**
 - After 6 years, inspection of tin-plated test coupons suggests whiskers have been able to grow along the surface beneath the Uralane conformal coating (“mole runs”)
 - If confirmed, conformal coating will be shown to have limitations as a whisker mitigation strategy
 - Accurate inspection and imaging of the samples is technically challenging
 - Confirmation examinations using E-SEM have been delayed by SEM availability



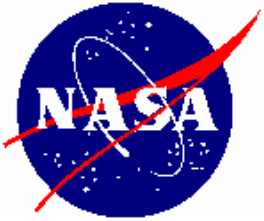
The Trouble with Tin Whiskers

Problem:

- ~~Tin Whiskers Can Grow from Items Having Pure Tin Finishes~~
 - Tin Whiskers Pose Reliability Risk (e.g., Electrical Shorting)
 - This is NOT a New Phenomenon. Known Since 1940s!
- **Confounding: Despite ~60 YEARS of Research!!!**
 - **FUNDAMENTAL MECHANISMS** that Produce Whisker Initiation and Growth are NOT UNDERSTOOD
 - **PROVEN Test Methods** to Predict Whisker Behavior **HAVE NOT** Been Established



***Tin Whiskers on “Matte” Tin-Plated 28-Pin SOIC after 3 Years Ambient Storage
(Courtesy of Peter Bush/SUNY Buffalo- Dec. 2003)***



Tin Whiskers Meet 21st Century Legislation

- European legislative measures (e.g., RoHS and WEEE) have established restrictions on use of Pb in consumer electronics by mid-2006
 - Japan and some US localities have (or are considering) their own restrictions on Pb usage
- One effect of Legislation has been for component suppliers (Domestic AND International) to adopt Electroplated Pure Tin surface finishes as the Prevailing Pb-free Alternative
- BUT the Tin Whisker Riddle Still Has NOT Been Solved.

Should we be Concerned?

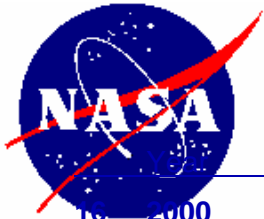


NASA EEE Parts Program

"Reported" Tin Whisker Problems (Only the Last 15-20 Years Considered)

Year	Application	Industry	Whiskers on?
1 1986	Heart Pacemakers		Medical (RECALL) Crystal Can
2 1986	MIL Aircraft Radar		Military Hybrid Package Lid
3 1987	MIL/Aerospace PWB	MIL/Aerospace	PWB traces
4 1988	Missile Program "A"		Military Relays
5 1989	Missile Program "B"		Military Electronics Box
6 1992	Missile Program "C"		Military Xsistor Package
7 1993	Govt. Electronics		Govt. Systems Xsistor, Diode, Lug
8 1996	MIL Aerospace		MIL Aerospace Relays
9 1998	Aerospace Electronics	Space	Hybrid Package Lid
10 1998	Commercial Satellite #1	Space (Total Loss)	Relays
11 1998	Commercial Satellite #2	Space	Relays
12 1998	Commercial Satellite #3	Space	Relays
13 1998	Military Aerospace		Mil/Aerospace Film Capacitor
14 2000	Missile Program "D"		Military Terminals
15 2000	Commercial Satellite #4	Space (Total Loss)	Relays

**Many of these Incidents Involve "Multiple" Failures.
NOT a Unique Concern to Any One Industry, Application or**



MORE "Reported" Tin Whisker Problems
 (Only the Last 15-20 Years Considered)

NASA EEE Parts Program

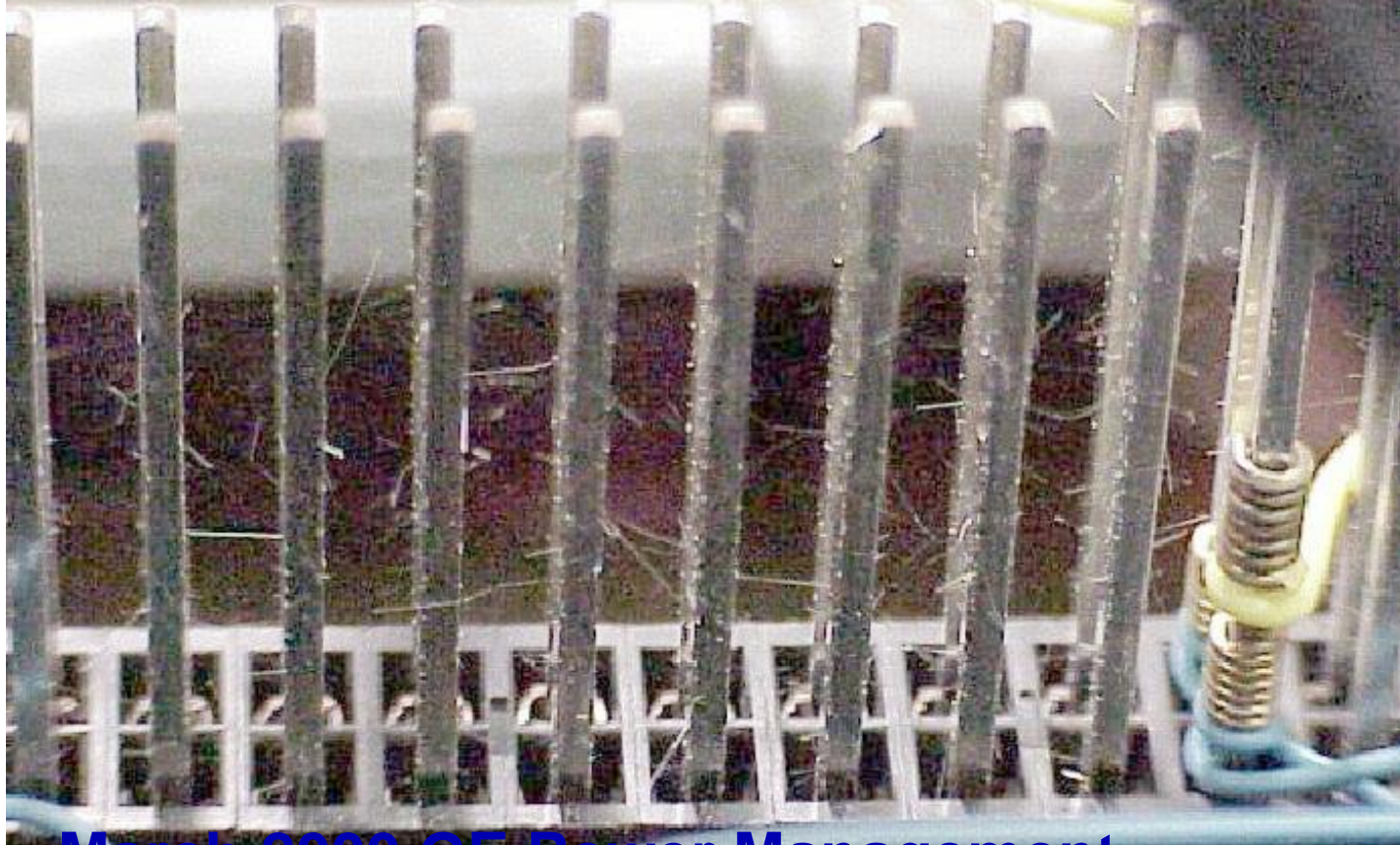
	Application	Industry	Whiskers on?	
16	2000	Commercial Satellite #5	Space (Total Loss)	Relays
17	2000	Power Mgmt Modules	Industrial	Connectors
18	2001	Commercial Satellite #6	Space	Relays
19	2001	Nuclear Power Plant	Power	Relays
20	2001	Hi-Rel	Hi-Rel	Ceramic Chip Caps
21	2002	Commercial Satellite #7	Space	Relays
22	2002	Military Aircraft	Military	Relays
23	2002	Electric Power	Power	Microcircuit Leads
24	2002	GPS Receiver	Aeronautical	RF Enclosure
25	2002	MIL Aerospace	MIL Aerospace	Mounting Hardware
26	2003	Telecom Equipment	Telecom	RF Enclosure
27	2003	Telecom Equipment	Telecom	Ckt Breaker
28	2003	Missile Program "E"	Military	Connectors
29	2003	Missile Program "F"	Military	Relays
30	2004	Radar	International Mil	Wave Guide
31	2004	Test Equipment	International	Test Probes

NOT Just a Problem of "The Past"
This is NOT a Comprehensive List. Only Cases that Have Been



Mission Success Starts With Safety

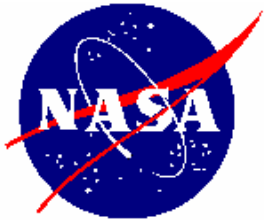
Examples of Tin Whiskers on Components



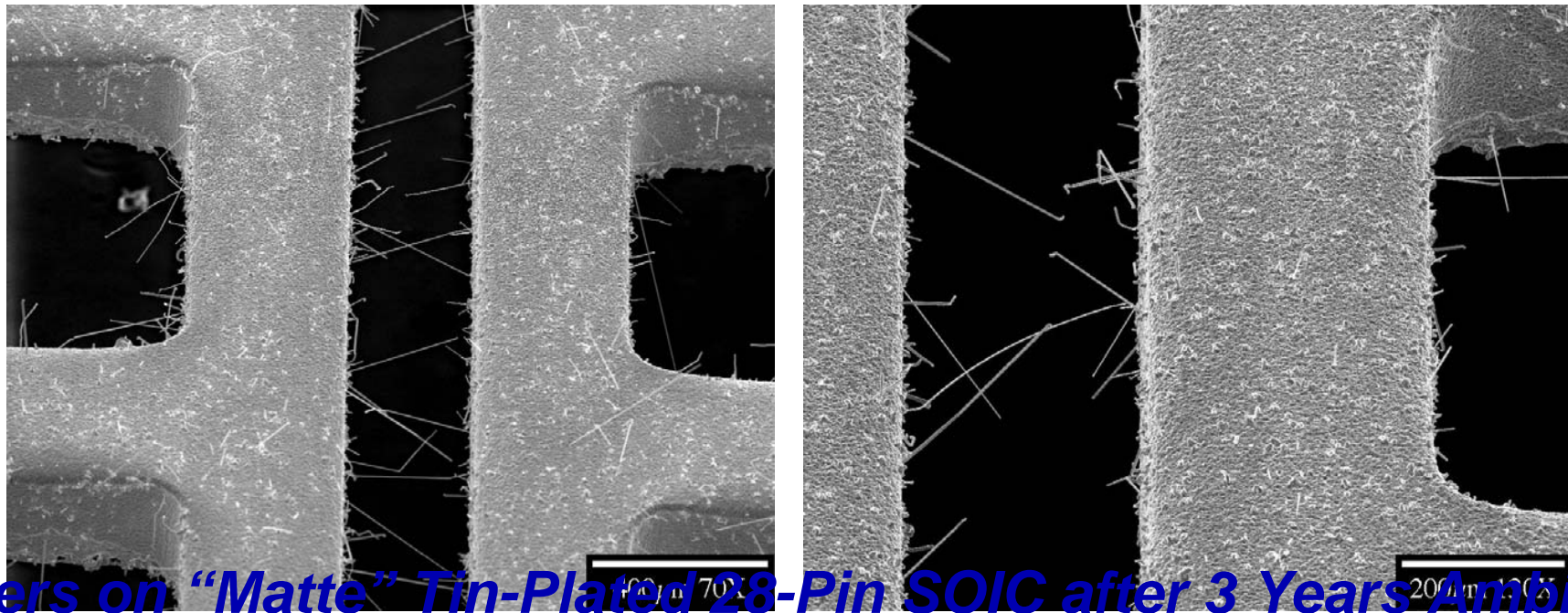
March 2000 GE Power Management,

"Technical Service Bulletin: Tin Whiskers in MOD10 F

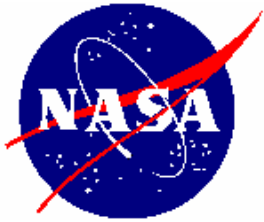
<http://www.geindustrial.com/pm/support/dls/dlssb01.p>



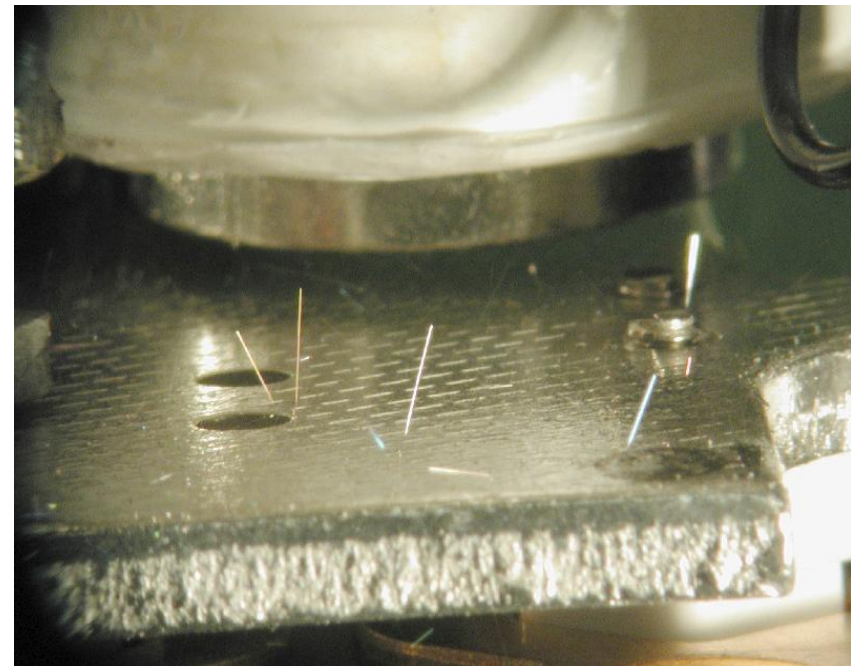
Examples of Tin Whiskers on Components



***Whiskers on "Matte" Tin-Plated 28-Pin SOIC after 3 Years Ambient
(Courtesy of Peter Bush/SUNY Buffalo- Dec. 2003)***



Examples of Tin Whiskers on Components



G. Davy, "[Relay Failure Caused by Tin Whiskers](#)",

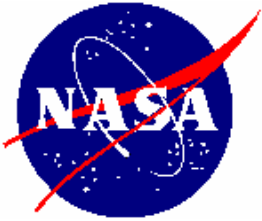
Northrop Grumman Electronic Systems Technical Article, October 2002

[//nepp.nasa.gov/whisker/reference/tech_papers/davy2002-relay-failure-caused-by-tin-whis](http://nepp.nasa.gov/whisker/reference/tech_papers/davy2002-relay-failure-caused-by-tin-whis)



Tin Whiskers Meet 21st Century Test Standardization

- Industry (Suppliers AND Users) Would LIKE TO HAVE (PROVEN) Standard Methods to Judge Whisker Propensity
- But Research To Date CONTINUES to Show Confusing/Conflicting Results from Commonly Suggested Test Techniques (T-Cycle, Humidity, Elevated Temp, etc.).
 - In other words, No One has Shown the Ability to Repeatably Control and/or Predict Whisker Behavior By Controlling Test Environment
- NEVERTHELESS... in Aug. 2004 - JEDEC JC 14.1 Proposed an INDUSTRY STANDARD Tin Whisker Test Method
 - Ballot was Voted Down (>50% Voted “NO”)
 - Currently Meetings are Underway to Reconcile Comments
 - Anticipate Revised Method and Re-ballot in Coming Weeks



Tin Whiskers: More about Standards

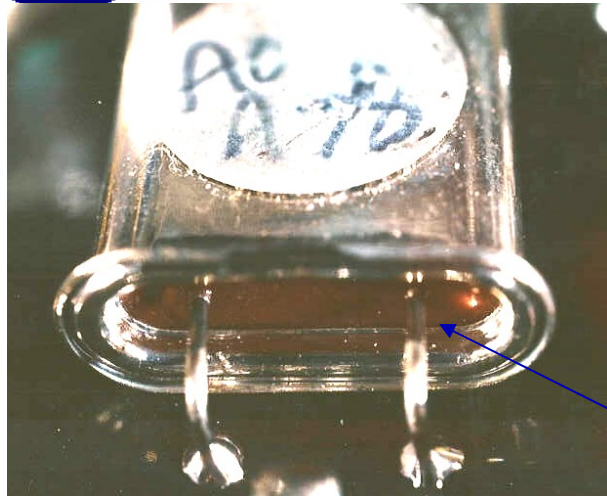
- JEDEC JC 14.3 has a task group developing “QUALIFICATION” Standards for tin whisker susceptibility which Hinge Upon the UNPROVEN Test Environments Being Proposed By JC 14.1
 - One Argument FOR this Approach has been that a Single Common BUT UNPROVEN Method to Test for Whiskers is Better Than No Method at All or Multiple User Specific Methods.

*A DANGEROUS PRECEDENT TO SET
CAVEAT EMPTOR!!!!*

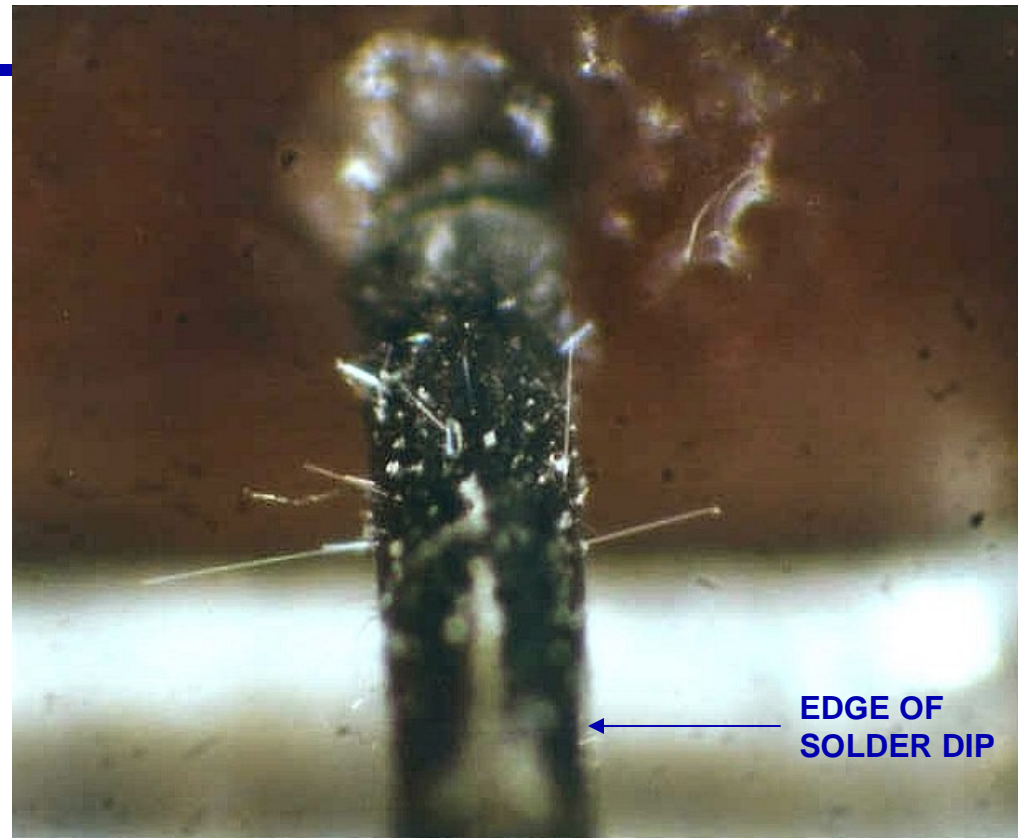


Tin Whisker Failure On Crystal Oscillator

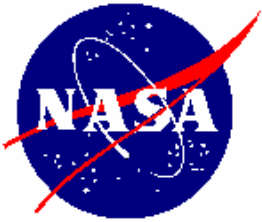
NASA EEE Parts Program



- Thru hole oscillator.
- Lead diameter 18 mils.
- Bright tin finish leads and case.
- Solder dipped within 50 mils of glass seal and hand soldered to PWB.

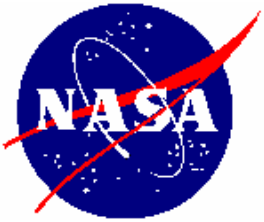


Tin Whisker growth noted from seal to about 20 mils from edge of solder coat. Electrical failure traced to 60 mil whisker that shorted lead to case.



Lead-free

- **Being driven by Europe and Asia**
- **Not supposed to be required for military or space hardware**
- **BUT broad use in commercial sector will impact NASA and military systems**
- **2 principal concerns:**
 - Durability of lead-free solder connections
 - Use of pure tin for termination platings
- **Ironically, this action will have a negligible impact on the environmental risk from lead and may in fact add to other pollution**

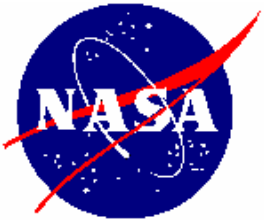


Expected Lead Reduction

- Texas Instruments (TI) is a \$9.83B electronics component manufacturer that sells millions of devices all over the world. They estimate that complete conversion to lead-free products will result in an annual worldwide lead reduction equivalent to only **ten** automobile batteries.



Slide courtesy of Andy Kostic and Charlie Minter of Northrop Grumman from their MAPLD 2004 presentation



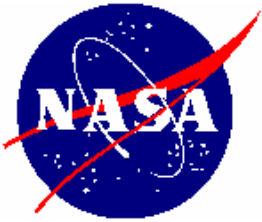
Lead-free Solder

- Information is beginning to surface that suggests the most popular lead-free replacement for 60/40 tin/lead may be susceptible to solder joint embrittlement due to formation of voids (Kirkendall) and “black pad” under some test conditions
- The test conditions may not be representative of the majority of use conditions
- However, this is a concern given the current lack of good long-term reliability data on lead-free solders



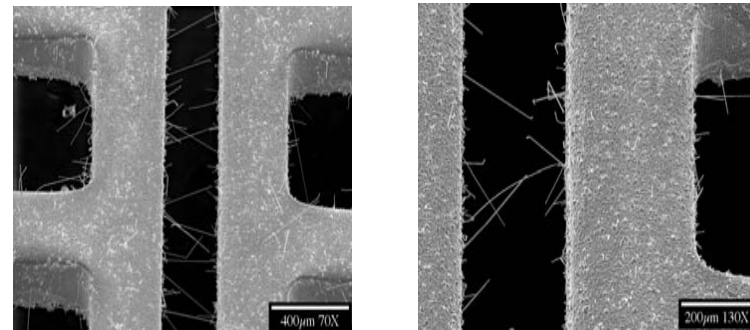
Tin Whiskers — background

- This is the **BIG lead-free concern for the space community**
- In space vacuum whiskers can create plasma arcs able to completely disable spacecraft electronics
- It has been known for over 50 years that pure tin plating is subject to whisker growth
- The underlying causes and processes are still unknown
- Tin has a long history as the plating of choice for solderable terminals in the commercial sector
 - Inexpensive
 - Plentiful
 - Easy to solder to
 - Remains solderable after long storage



Tin Whisker Mitigation

- There is no single technique to mitigate against tin whiskers except **“don’t use pure tin”**
- Use as many as practical of:
 - nickel underplate
 - solder dip
 - reflow
 - conformal coat
- OR Develop whisker-free OR whisker resistant tin platings **BUT HOW?**
- A test for whisker propensity is needed

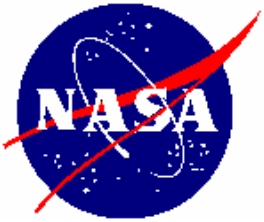


Tin Whiskers on “Matte” Tin-Plated 28-Pin SOIC after 3 Years Ambient Storage (Courtesy of Peter Bush/SUNY Buffalo- 12/03)



Tin Whisker Tests

- **Experimentation by teams from 3 continents**
 - Europe (E4), Asia (JEITA) and America (NEMI)
- **Published results from these groups are very limited**
- **Currently test methods recommended by the National Electronic Manufacturing Initiative (NEMI) have been proposed to JEDEC as the basis for:**
 - A Test method standard
 - A Qualification standard
- **The technical validation for this is very weak**
- **Commercial industry prefers a bad but standard test process to the confusion of approaches being demanded by their customers**
- **It is unclear what the consequences will be but it is likely to increase confidence in and therefore use of pure tin plating**



Whisker Research

- **NASA WWW Site:**
<http://nepp.nasa.gov/whisker>
- **The Most Extensive Collection of Tin Whisker Information Available on the Internet**
- **Videos Added**
- **More Papers and References**
- **Member of NEMI Test Method Forum**
 - Attempting to develop method to accelerate whisker growth
- **Contributor to JG-PP Lead-free Solder Evaluation**
 - NASA GSFC, MSFC and JPL
 - Developing Joint Test Protocol (JTP)

