Tin Whiskers and the Lead Free Initiative Summary

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* The information is provided by the National Tin Whisker Consortium. Participants are listed in the vugraphs.   Some pictures are provided by NASA Goddard SFC

Agenda

- Documented Failures – we have a problem
- Basic definitions and examples
- Mitigation Factors
- Lead-Free Soldering vs. Lead-Free Leadframes
- Lead Banning Legislation and History
- Tin Whisker Anecdotes
- Consortium Members
- Risk and Pro-active Solutions
- Q & A

Tin Whiskers at NAWC WD

- NAWC WD has Program Offices which support approximately 20 air and surface launched weapons*
- 5 of these weapon systems have documented Tin Whisker failures that were built in the 1985 to 1992 timeframe. Failure rates varied from 1% to 10%.
- Manufacturers of Microcircuits/Semiconductors <u>BEGAN</u> shifting to Pure Tin in the 1996-97 time frame
- Therefore it can be concluded that future failure rates will be HIGHER

- Raytheon, NAVAIR, et al. recognizes the issue and organizes a National Consortium of government, industry, and academia to understand the problem and to determine Risk and Mitigation Strategies (Formed 5/02).

* Tomahawk, HARM, Sparrow/ESSM, Phoenix, Sidewinder, AMRAAM, Hellfire/TOW/Maverick/Paveway, RAM, JSOW, JDAM, Standard, Stinger/Spike, SLAM-ER/Harpoon/Penguin, JASSM

Documented Failures Attributed to Tin Whisker Shorting

- 6 Satellites (Galaxy – 3 , Solidaridad 1, Direct TV3 and HS 601) 1998-2002
- 5 Navy Missiles 1985-1992
- F-15 Radar
- Patriot Missile
- Heart Pacemakers
- Communications Equipment
- Data Processing Equipment
- Power Switching Equipment

Tin Whiskers and Relay's do not mix

Figure 1 – Failed relay

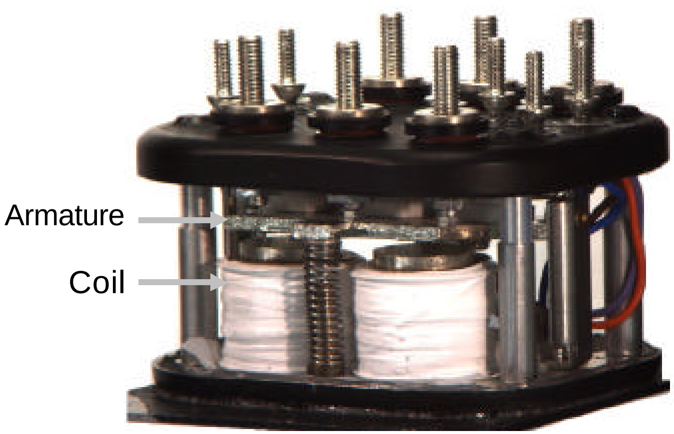
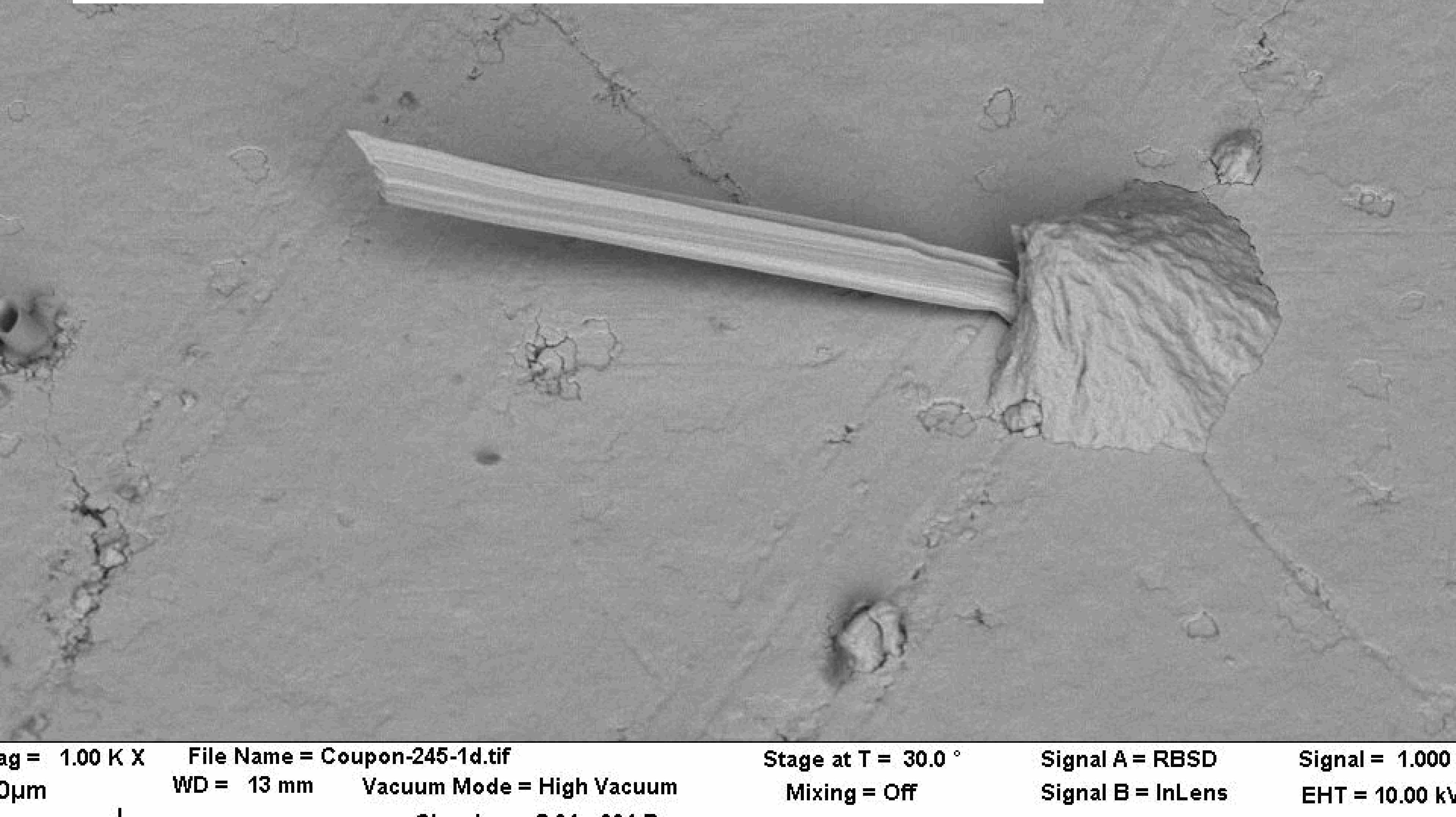


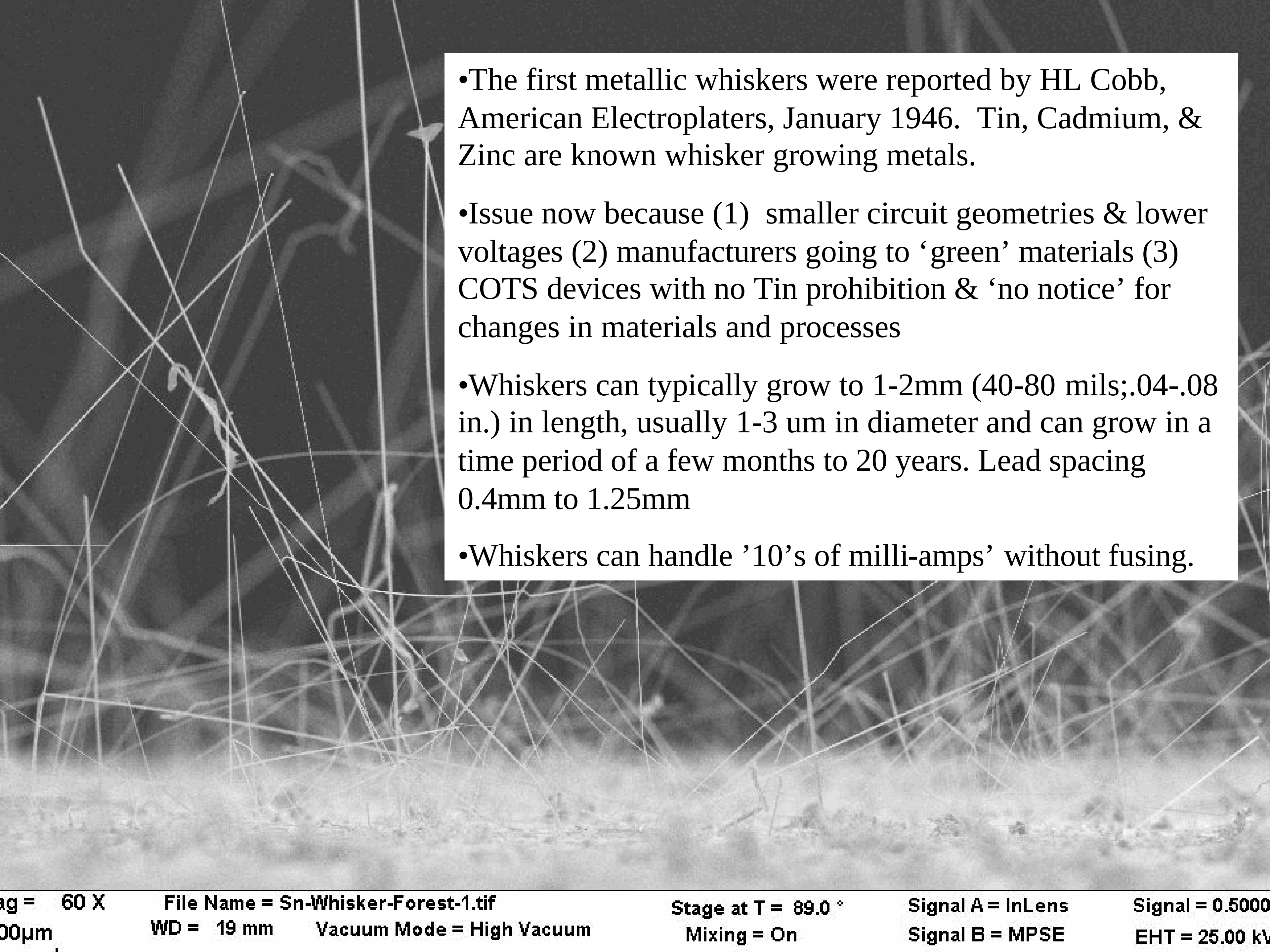
Figure 2 – Opened un-failed relay

3 Relay failures from a Military Aircraft; approximately 10 years old. Failed in 1998. Rated at 25 amps/115 Vac/3 phase

<u>Definition:</u> **A Tin Whisker is a spontaneous filament of crystalline tin emanating from the surface of a plating finish.**

<u>Attributes:</u> **high aspect ratios; can be kinked, bent or twisted; generally have a consistent cross section; rarely branch; may have striations/rings**



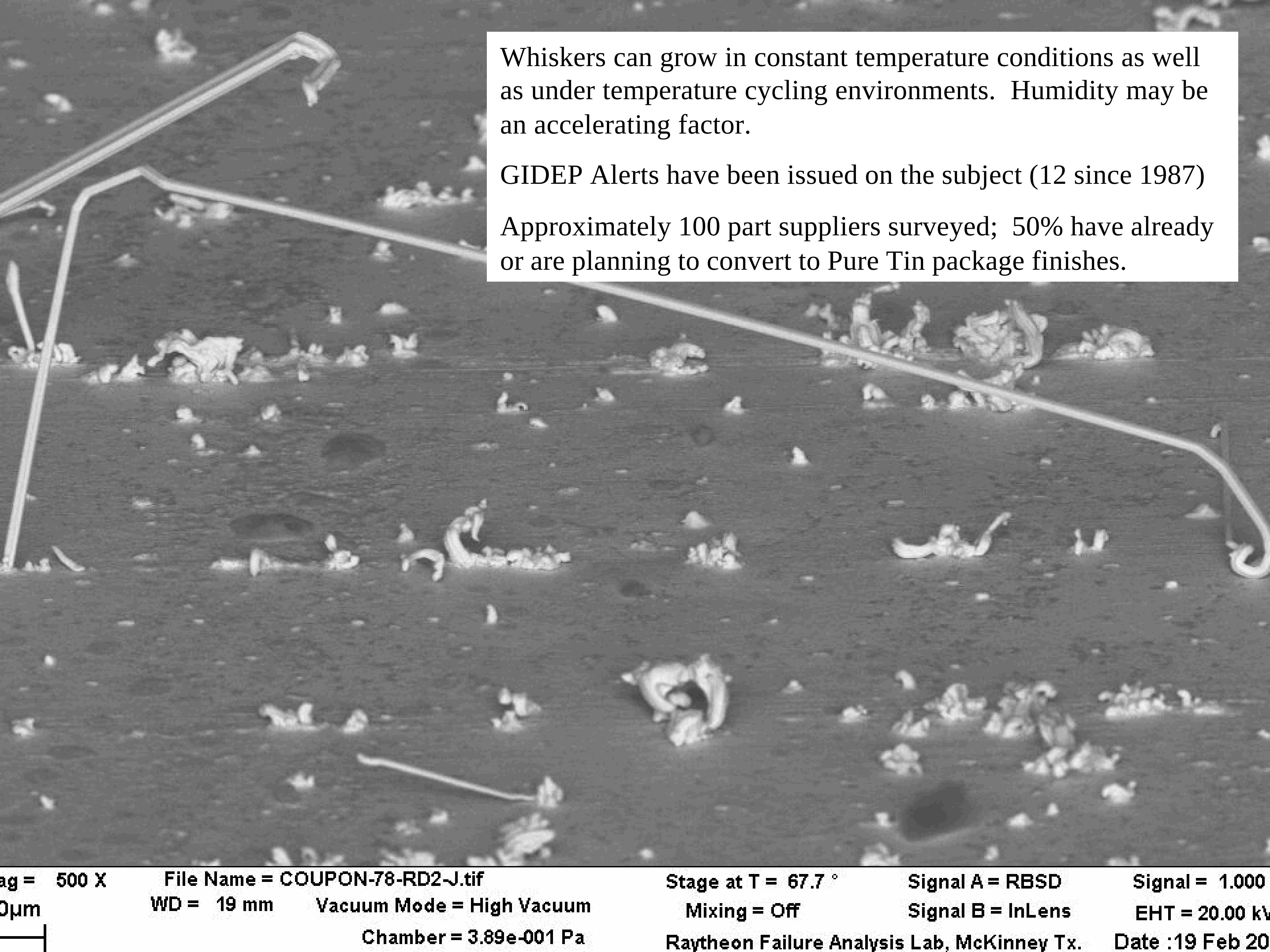


- The first metallic whiskers were reported by HL Cobb, American Electroplaters, January 1946. Tin, Cadmium, & Zinc are known whisker growing metals.
- Issue now because (1) smaller circuit geometries & lower voltages (2) manufacturers going to ‘green’ materials (3) COTS devices with no Tin prohibition & ‘no notice’ for changes in materials and processes
- Whiskers can typically grow to 1-2mm (40-80 mils;.04-.08 in.) in length, usually 1-3 um in diameter and can grow in a time period of a few months to 20 years. Lead spacing 0.4mm to 1.25mm
- Whiskers can handle ’10’s of milli-amps’ without fusing.

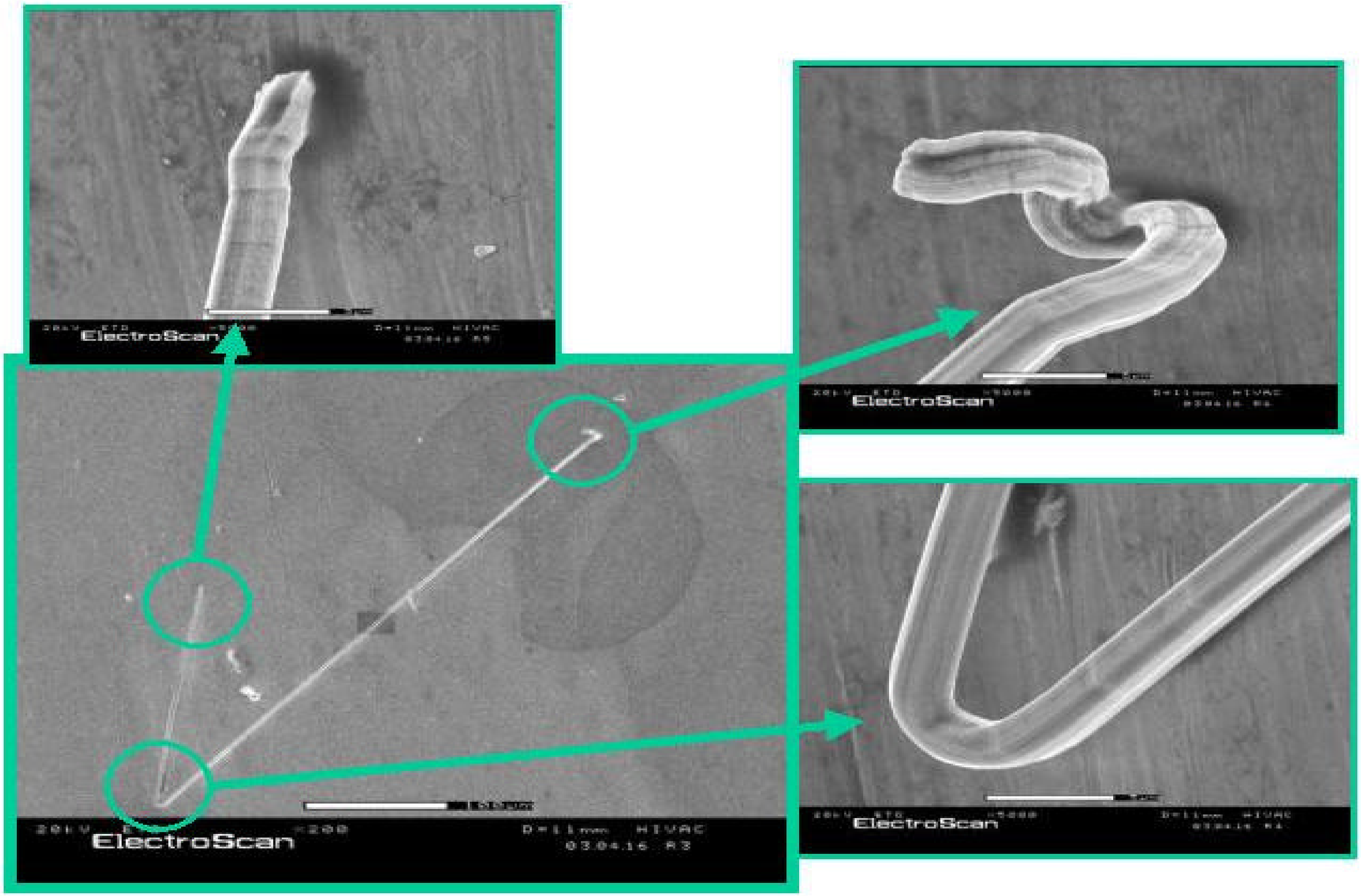
Whiskers can grow in constant temperature conditions as well as under temperature cycling environments. Humidity may be an accelerating factor.

GIDEP Alerts have been issued on the subject (12 since 1987)

Approximately 100 part suppliers surveyed; 50% have already or are planning to convert to Pure Tin package finishes.



<u>Mitigation Factors</u>: annealing (?), re-flowing, conformal coatings (which are also being phased out due to Volatile Organic Compounds), plating with barrier metals, alloying with other metals. Note: there are presently no fully proven avenues of mitigation other than avoidance of use.



Lead Frame Soldering Issues

- Tin Whisker shorting from Matte Tin plated leads
- Higher Soldering Temperatures (240-260 deg C verses 183 deg C for Lead Tin). The most likely replacement is SnAgCu (Tin Silver Copper).
- Changes in the Part Moisture Sensitivity Levels (moisture can cause popcorning, die attach and delamination) for Plastic Packages (PEMs)
- Unknown/Untested Life Cycle Reliability
- Solderability – wetting, cracking, brittleness, etc.

RISKS:

- Mixing Soldering Technologies during assembly, repair, or upgrade
- Difficulty Tracking Parts with differing finishes
- Inability to know what plating is being supplied
- Suppliers are no longer required to provide information on process and material changes.

Lead Banning Legislation History

- 1972 EPA phases out leaded gasoline
- The European Union (EU) has drafted legislation to recycle Waste Electrical and Electronic Equipment (WEEE) and to restrict the use of hazardous substances (ROHS) scheduled to take effect in July 2006
- Japan’s lead free movement has cited the landfill space crisis and the potential for lead leaching into water supplies as their motivation. All electronic assemblies must be recycled as of April 2001.
- There is currently no Lead Elimination legislation enacted or pending in the United States.   US suppliers are switching to lead free soldering and plating finishes because “profit margins are higher for Green Products and materials that convey ‘environmentally safe’ to the consumer”.   The EPA has changed reporting levels from 25K pounds per year to 100 pounds per year.

NAVAIR WEAPONS DIVISION

NAVAIR

Product	Consumption (%)
Storage Batteries	80.81
Paints, Ceramics, Pigments, Chemicals	4.78
Ammunition	4.69
Sheet lead	1.79
Cable covering	1.40
Casting metals	1.13
Brass / bronze billets and ingots	0.72
Pipes, traps, extruded products	0.72
Solder (excluding electronic solder)	0.70
Electronic solder	0.49
Miscellaneous	2.77

Source: Advancing Microelectronics, September/October, 1999. p. 29 [4]

Table 1 Industry Lead (Pb) Users

Note: In the EU starting in 2006 - Electronic Solder (0.49%) will be banned, but Lead Batteries (80%) will be exempt. Reason: “cars can not run without batteries but the electronics industry can manage without lead”. (Chart is based on Consumption)

In Japan, the lead-free movement has cited the landfill space crisis and the potential for lead leaching into water supplies. Japan is simply running out of landfill space, and the Government and industry are looking for ways to reduce the amount of waste. The emphasis in Japan is on recycling electronic components and some manufacturers have already begun implementing recycling programs. However, recycling programs are costly and burdensome, therefore some manufacturers are looking to eliminate lead from most of their products in order to avoid the requirement for recycling. Avoiding the recycling program will not save one cubic inch of space of landfill; nevertheless, the Japanese lead-free movement is still on full steam ahead [3].

In the United States, the EPA considers both lead and silver metals to be toxic and requires for both not to exceed a maximum level of 5.0 mg/l at the landfill water sample test (EPA Solid Waste Testing Manual, Section 7, Table 7-1- Maximum Concentration of contaminants for toxicity characteristics) [1]. There is currently no Pb-elimination legislation enacted/pending in the United States. However, on January 17, 2001, EPA published a rule that classified lead and lead compounds as persistent, bioaccumulative and toxic (PBT) chemicals and lowered the previously existing 25,000 pound and 10,000 pound reporting thresholds requirements on manufacturers to 100 pounds per year for lead and lead compounds [1].

III. A Critical View Of Motivation Factors For The Lead-free Conversion In Electronics

The mere presence of lead does not constitute a hazard for humans. Studies [4] have shown that miners working in Aspen, Colorado lead mines and living with their families on soil around the mine with 20,000 ppm contamination (the EPA accepted levels for most soil is 500 ppm) have a lead blood content approximately 10 times lower than the national standards set by the Centers for Disease Control (CDC). Dr. Laura Turbini, Executive Director of the Centre for Microelectronics Assembly and Packaging (CMAP) at the University of Toronto, conducted a study with 125 volunteers tested at the Aspen mine site. Dr. Turbini documented a blood content for children living near the lead mine of 2.77 micrograms per deciliter and 3.4 micrograms per deciliter for adults. The national average is 4 to 6 micrograms per deciliter and in some places such as downtown Cincinnati Ohio, the average is 17 micrograms per deciliter. The toxic level is 10 micrograms per deciliter, as established by the CDC.

To date, no one has shown that there is a transfer mechanism of lead to human blood from direct contact with electronic components, tin-lead solder paste or component finishing with lead. Nevertheless, the lead-free movement for electronic components continues full steam ahead.

Another reason cited for justifying the lead-free movement is the concern that lead in landfills will leach into the water and produce harmful effects on the aquatic life and environment as well as contaminating potable water supplies. Major contributors to the pollution of landfills (See Table 2 – 1998 EPA Data on Municipal Solid Waste Landfill Leachate Characteristics) are not consumer electronics products themselves but lead-acid batteries (48.1%), TV picture tubes, and computer CRTs (35.8 %)[4]. These products are exempt from current draft legislation or proposed industry regulations. All other lead-containing discarded electronics contribute less than 5% of waste introduced to landfill solid waste. Of that, only about 0.5 to 2% is attributable to the soldering compounds and tin-lead (SnPb) component finishes. Obviously, eliminating them would provide an insignificant improvement to the environment.

Lead-containing Discards	Weight Percent
Lead Acid Batteries	48.1
TV Pictures Tubes and CRTs	35.8
Glass and Ceramics	5.5
Other Consumer Electronics	4.4
Plastics	2.5
Cans / Shipping Containers	1.4
Other	2.3

Source: NUS Corporation [4]

Table 2. 1998 EPA Data on Municipal Solid Waste Landfill Leachate Characteristics.

Note: EU exempts lead acid batteries from the landfill, but prohibits 'consumer electronics' from disposal. (Chart is based on Lead containing Discards as a Weight Percent)

Tin Whiskers Anecdotes

- One vendor is claiming that their products are 'Whisker Free'; in the small print they define 'whisker free' as whiskers that will be less than 2 mils (.002 in.) in length in a 2 year storage period.

- Approximately one half of the part suppliers contacted were NOT even aware that pure Tin has a whiskering propensity.

- NASA contractually forbids any pure tin coated products in their satellites with flow down requirements to subs and has a sampling survey process – Results: 1-2% pure tin parts still slip into their systems.

Tin Whisker Consortium Members

- Raytheon (9 different sites) – Group Lead by Bill Rollins (Tucson)
  - wprollins@raytheon.com (520) 794-5203
- CALCE (University of Maryland)
- Boeing (3 sites)
- Honeywell (3 sites)
- Navy (5 sites – China Lake, Dahlgren, Crane, BMPCOE, Corona)
- Army (1 site)
- AF (2 sites)
- Sandia (Albuquerque)
- NASA (2 sites)
- The Aerospace Corporation
- American Competitive Institute (ACI)
- Lockheed Martin
- Delphi Automotive (Kokomo)
- Northrop Grumman
- Johns Hopkins Applied Physics Lab
- NEMI Consortium (National Electronics Manufacturers Initiative)
- GEIA (Government Electronic Industries Association)
- NIST (National Institute of Standards and Technology)

Is this a problem?

- Yes; but we don't know how serious yet. Most historical failure occurred BEFORE pure tin coatings became a widely used material!
  - Remember tin whiskers can easily grow to 1-2 mm (10 mm is the longest) under the right conditions
  - Lead Spacing on the following package types:
    - TQFP (Thin Quad Flat Pack) - 0.4 mm, 0.5 mm, 0.65 mm, 0.8 mm and 1.0 mm lead pitches available (a representative more modern package)
    - SOIC (Standard Outline Integrated Circuit) - 1.25 mm (this is the old lead pitch used on 14 & 16 Pin DIP packages used since the late 1960's.)
  - Remember – pure tin plated Washers, Nuts, Bolts, Fasteners, Metal Shields, Relays can grow whiskers as well as Microcircuits

What can we do to Minimize Risk?

- Avoid the use of Pure Tin coated parts – contract verbage with flow down to subs.
  - Supply Chain Management Track
  - Standard Letter to Suppliers
- 100% in-coming sampling – XRF (X-Ray Fluorescence) seems to be the best and cheapest tool. $60.K each!
- On-site Surveys
- Use Mitigation Strategies (see slide # 9)
- Develop a Project Strategy and Management Plan
- Develop detailed plan of action and milestones
- Provide funding for Tin Whisker Risk Management and Mitigation i.e. Funding for Surveillance
- Communicate and Implement i.e. Awareness Campaigns with the Depots, labs, part suppliers and distributors, contractors and subs.
- Tax Incentives to manufactures whom continue to provide Tin-Lead options?

- Support programs that our working the issue:
  - TMTI (Transformational Manufacturing Technology Initiative) – BMPCOE/ONR
  - Man Tech Risk Mitigation Project – computational modeling (Sandia)
  - EMMA – Electronics Miniaturization for Missile Applications (MANTECH)
  - CALCE – Computer Aided Life Cycle Engineering Consortium (U. of Maryland)

What can we do pro-actively?

- **<u>Post-production:</u>** one system needs to be completely dismantled and every part examined by XRF or SEM/EDS/Auger looking for Tin plated surfaces. Especially if there are systems that have been in storage over 10 years.

- **<u>In Production:</u>** a sample part from every parts bin needs to be examined by XRF or SEM. Nuts, bolts, relays, brackets, microcircuits, semiconductors, etc.

- **<u>Pre-Production:</u>** ensure that the Contract contains language banning or at least identifying Tin Plated surfaces; should provide penalties if discovered after the fact. Conduct on-site surveys and education. If used, use maximum number of mitigation techniques and develop a follow-on plan of action with milestones.