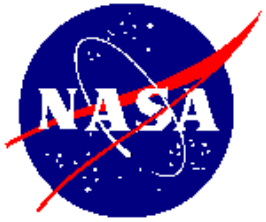


Tin Whisker Observations on Pure Tin-Plated Ceramic Chip Capacitors

Presentation to:

American Electroplaters and Surface Finishers (AESF) Society
SUR/FIN Conference
Chicago, IL
June 25, 2002

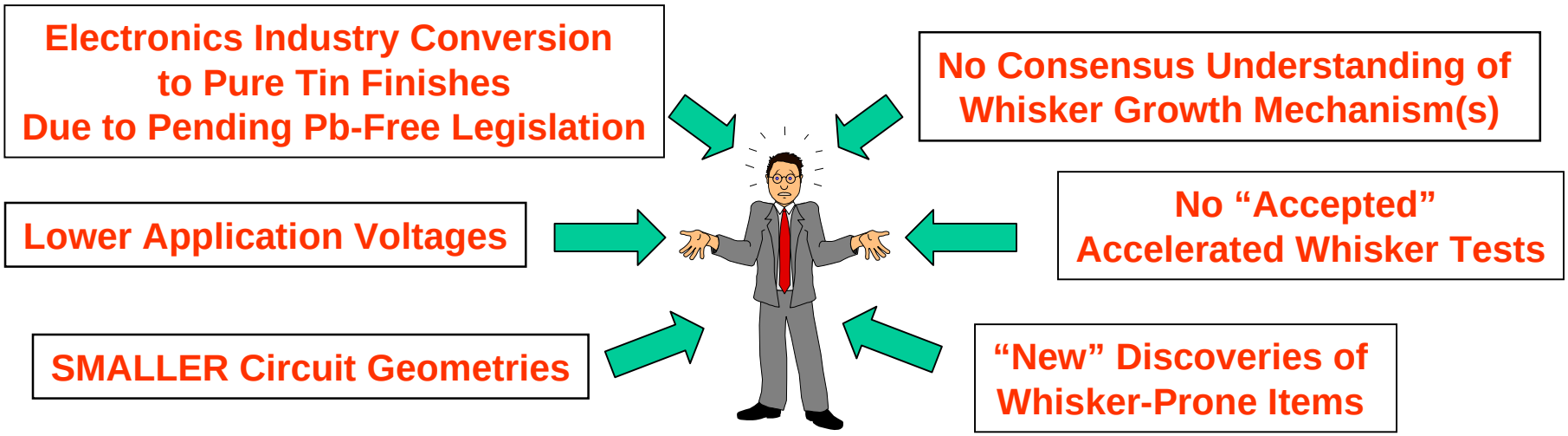
Jay Brusse
QSS Group, Inc. @ NASA Goddard Space Flight Center

Outline

- Quick Overview of Tin Whiskers
  - Examples
  - Failure Modes
  - “Public Domain” Field Failure Experience
- Multilayer Ceramic Capacitors (MLCCs)
  - Typical Construction/Sizes
  - 4 Examples of MLCCs with Tin Whiskers
- Conclusions
- Recommendations
- “NEW” Observations/Discoveries about Tin Whiskers

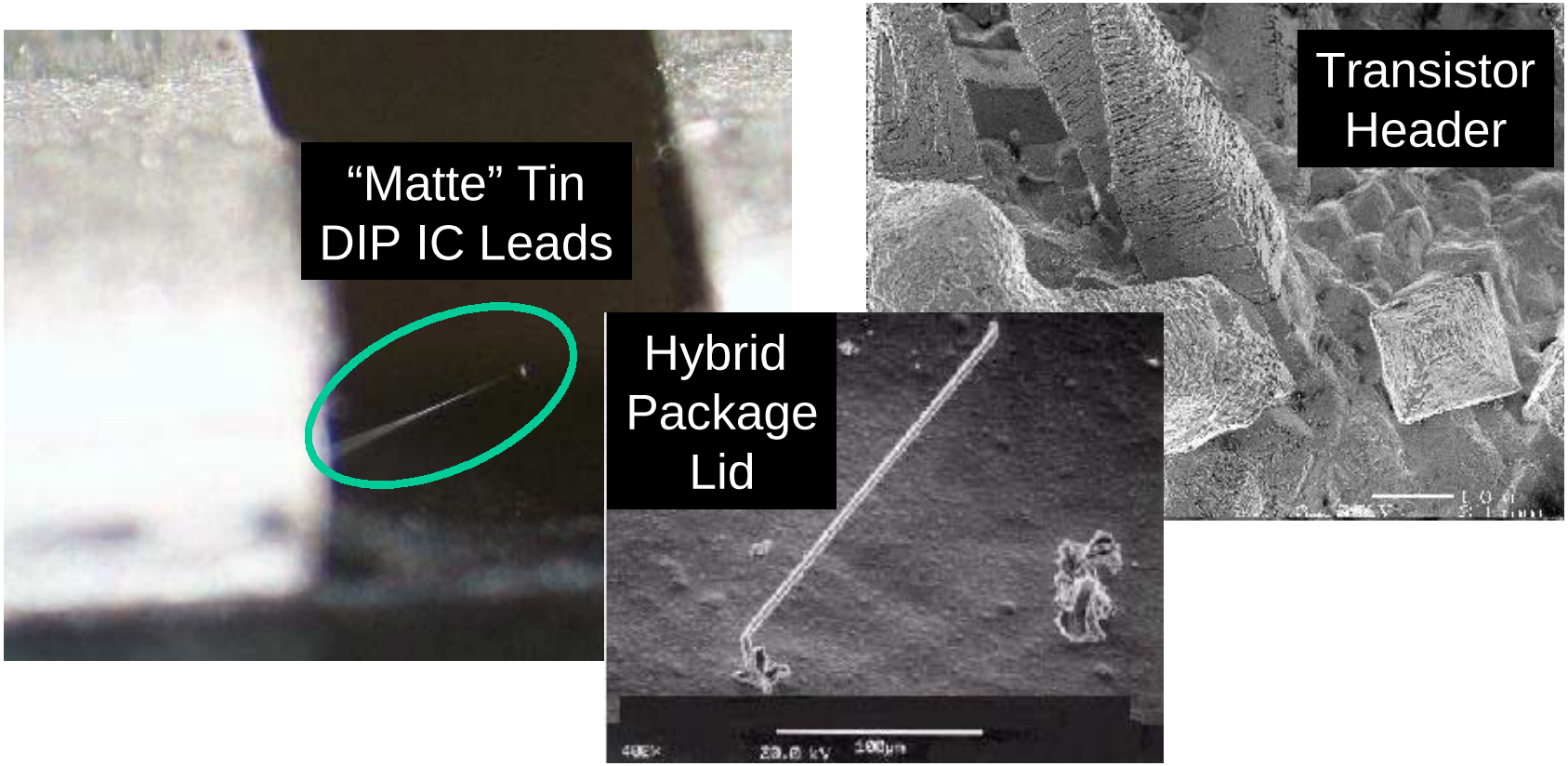
Why **ANOTHER** Paper on Tin Whiskers?

- **The PAST:**
  - Tin Whiskers Known for ~60 Years
  - HUNDREDS of Independent Studies
  - Numerous Disparities Exist in Published Literature
- **The PRESENT:** Combination of CONCERNING Factors



Examples of EEE Components with Tin Whiskers

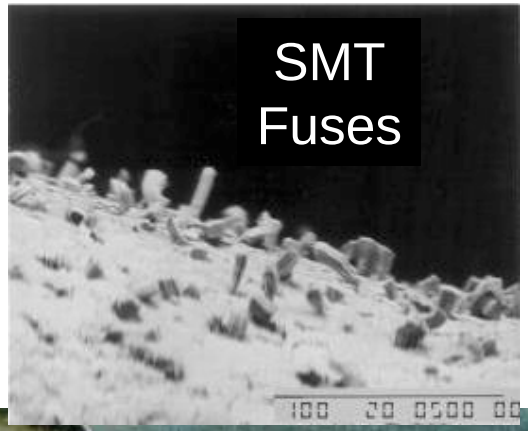
Active Components

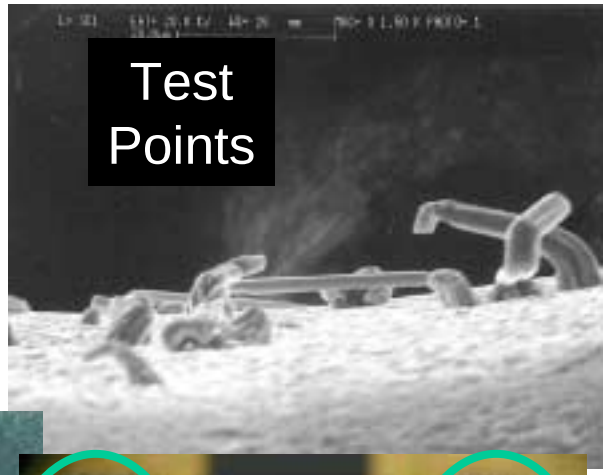


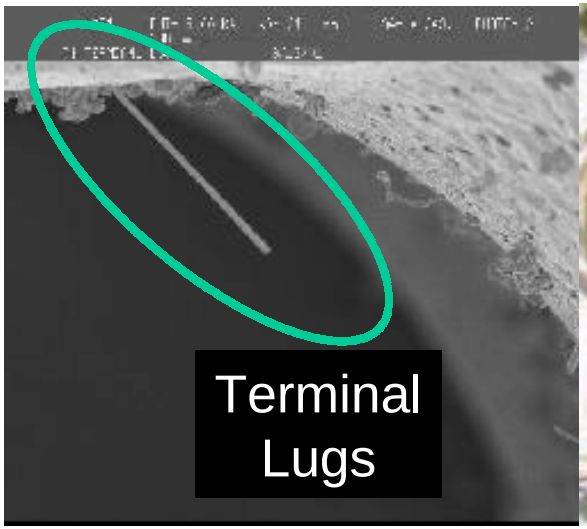
MORE Examples of EEE Components with Tin Whiskers

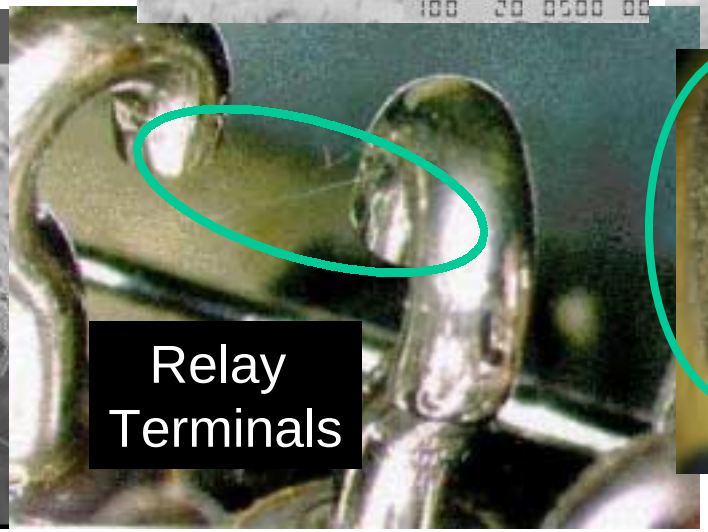
PASSIVE Components

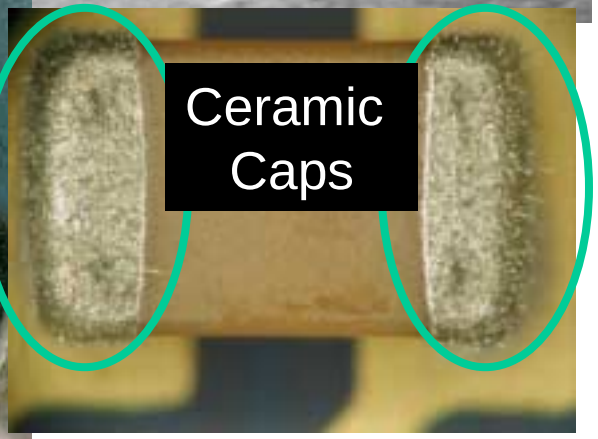
It's about MORE than Just Active Components



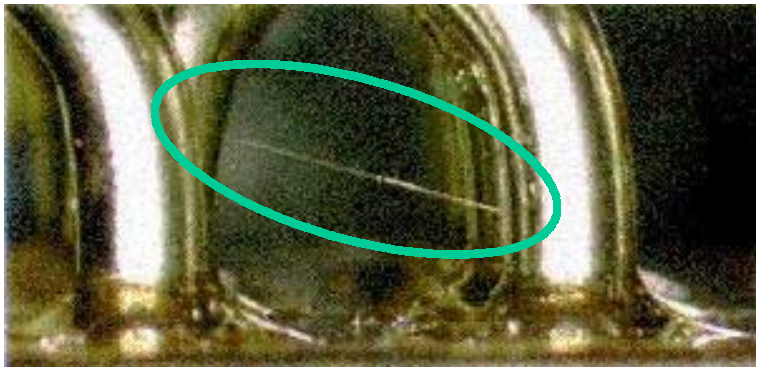






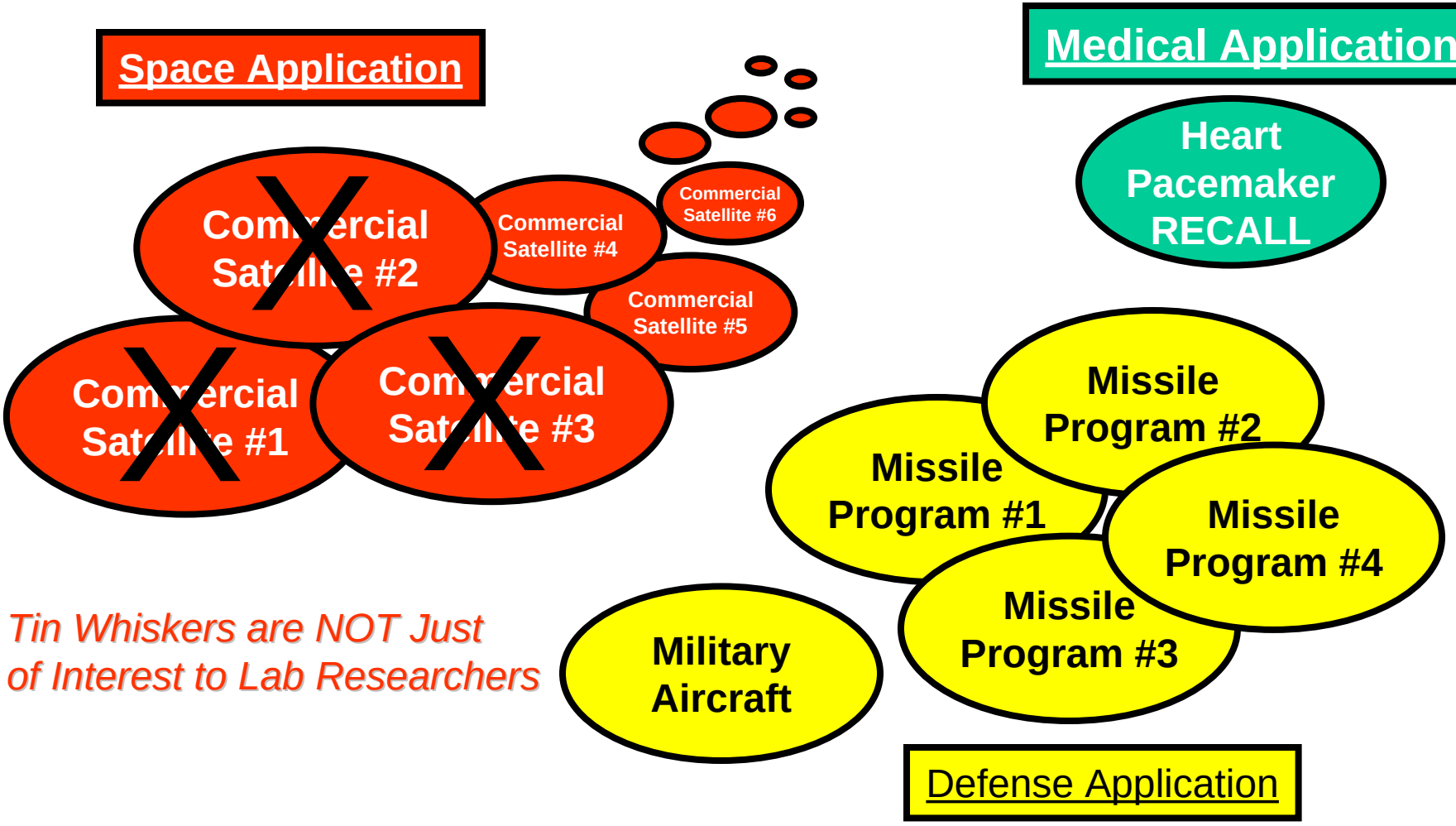


Tin Whisker Failure Modes

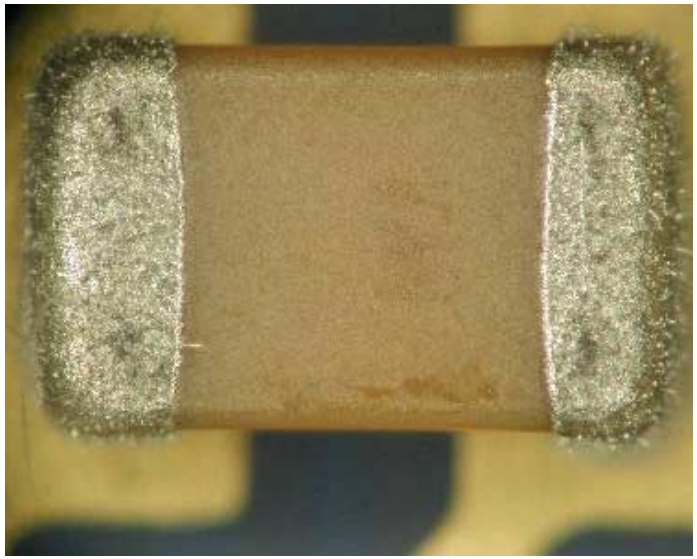


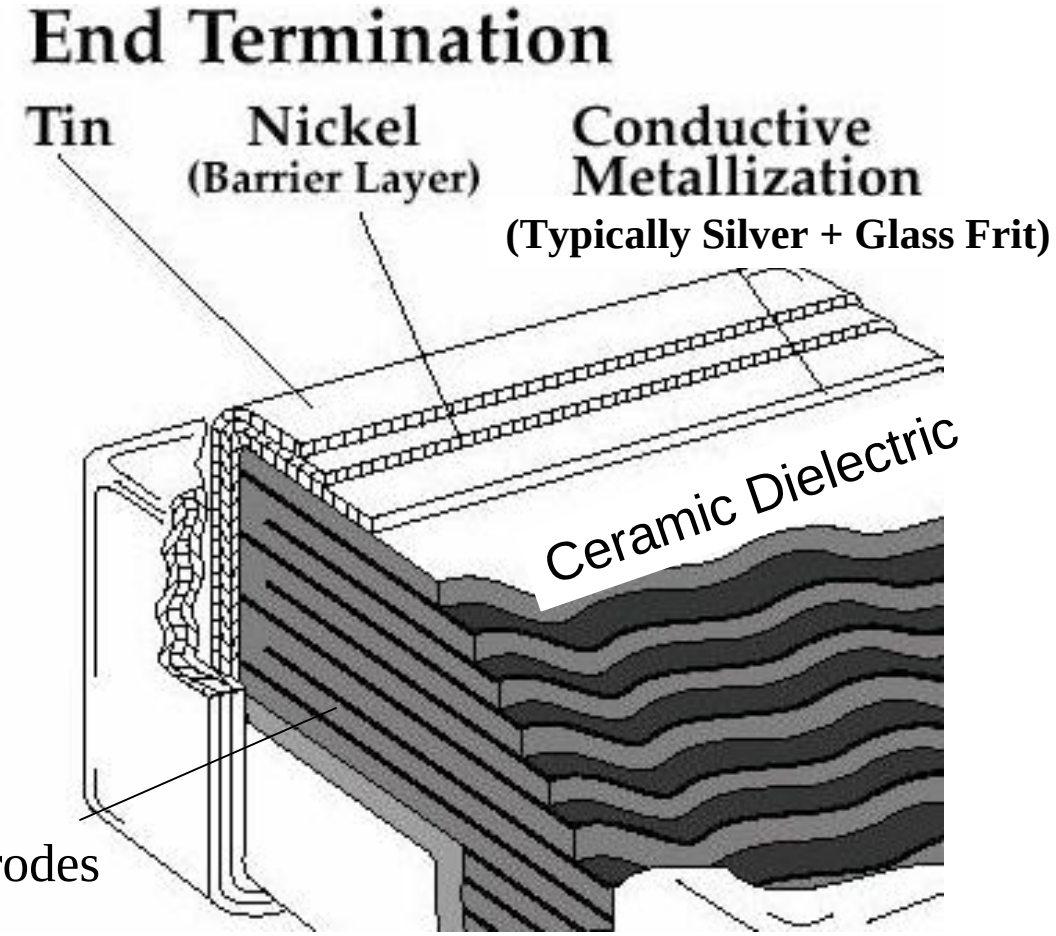
- ***Electrical Short Circuits***
  - Permanent (if current < 10's of mA)
  - Intermittent (if current > 10's of mA)
- ***Debris/Contamination***
  - Interfere with Sensitive Optics or MEMS
  - Can Cause Shorts in Areas Remote From Whisker Origins
- ***METAL VAPOR ARC in VACUUM***
  - When a Tin Whisker Causes a Short in Reduced Atmospheric Pressure, If V > ~18 V and I > 10's of Amps, then Whisker can Vaporize into Highly Conductive Plasma of Tin Ions
  - Plasma can Form Arc Capable of Carrying ***HUNDREDS OF AMPERES***
  - Arc Can Be Sustained by Tin Evaporated from Surrounding Areas

"Reported"
Tin Whisker-Induced Field Problems

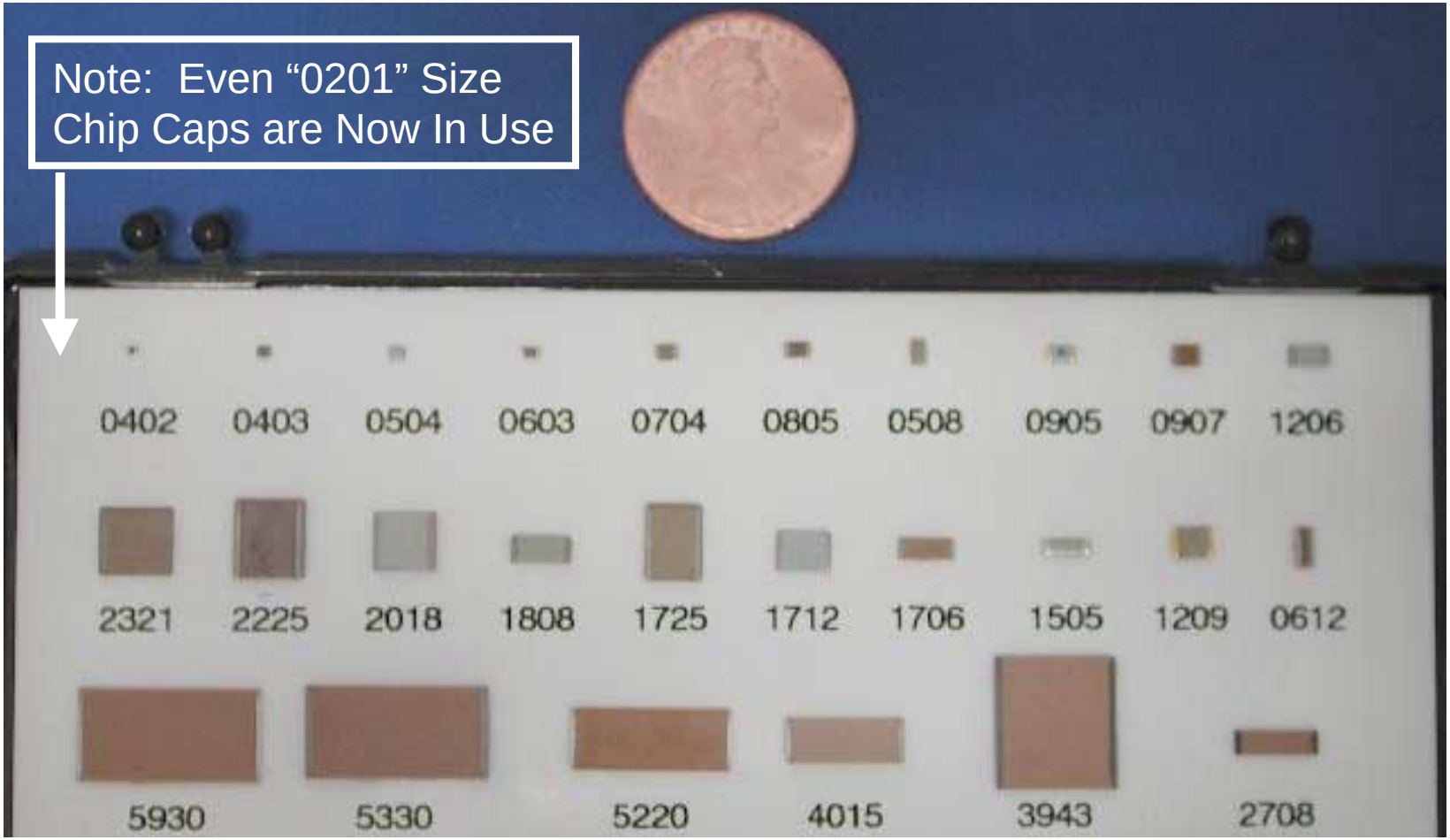


Basic Construction of a Multilayer Ceramic Chip Capacitor (MLCC)





Typical Sizes of MLCCs



Tin Whiskers and Multilayer Ceramic Capacitors (MLCCs)

Past Research

- Two Previous Papers by MLCC Manufacturers (1990 & 1997) Assert *MLCCs Have Following Attributes that make them Highly Resistant to Whisker*

✓ "Large" (>5 μm), Well-Polygonized Tin Grain Structure

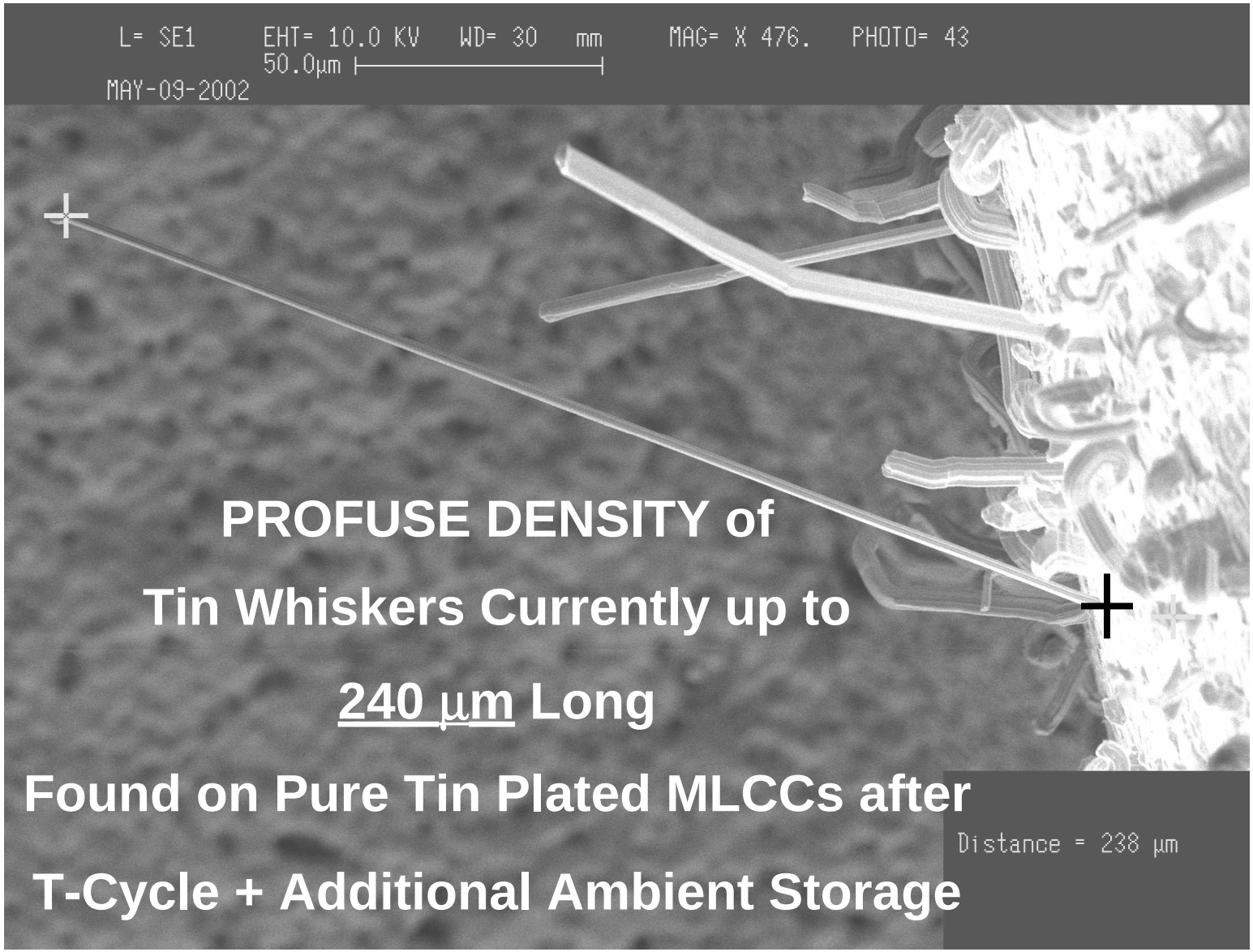
✓ Ni-Underplate (> 2 μm)
Reduces Diffusion that Causes Internal Stress

✓ "Thick" Matte Tin Plating (5 - 10 μm)

✓ Post-Plating Annealing
Promotes Grain Growth & Reduces Residual Stress

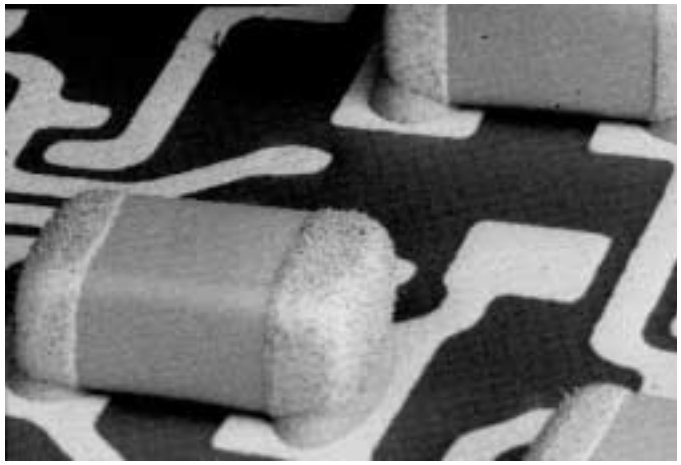
- ONE MLCC Mfr Experiment showed *18 Years WHISKER-FREE* Observations for MLCCs Stored Continuously at 50°C

HOWEVER...


L= SE1 EHT= 10.0 KV WD= 30 mm MAG= X 476. PHOTO= 43
50.0µm
MAY-09-2002
PROFUSE DENSITY of
Tin Whiskers Currently up to
240 µm Long
Found on Pure Tin Plated MLCCs after
T-Cycle + Additional Ambient Storage
Distance = 238 µm

Example #1: Tin Whiskers and MLCCs

MLCC Mfr "A": T-Cycle of MLCCs Inside Hybrid Microcircuit

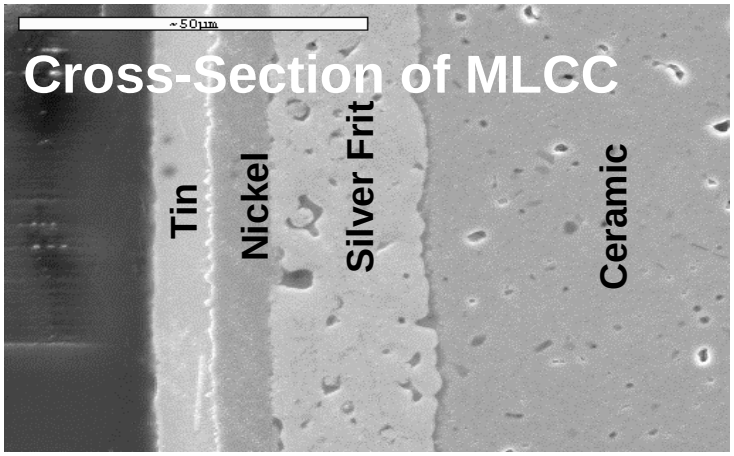


User Application:

- Hybrid Microcircuit (Herm-Sealed)
  - Gold Plated Substrate Pads
  - Substrate Line Spacing 125 µm (min.)
- ORDERED Pd-Ag Terminated MLCC, but Supplier Shipped PURE TIN
- Chip Caps Mounted by Silver Epoxy

MLCC Construction (0805 size):

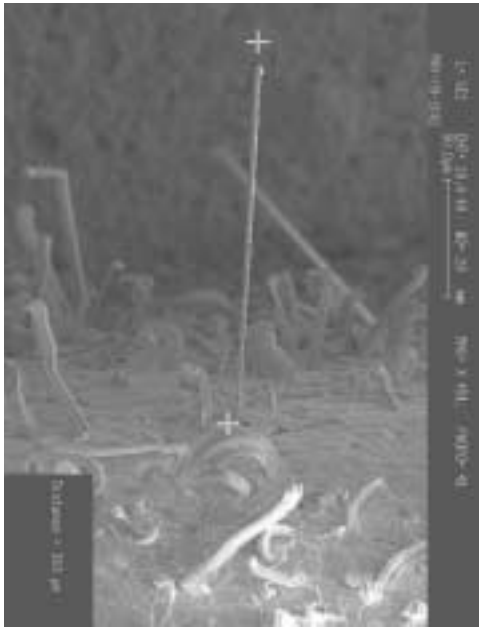
- Barium Titanate Ceramic Body
- Silver Frit Base Termination **17 µm**
- ☑ *Nickel Barrier Layer* **6.5 µm**
- ☑ *Matte Tin-Plated* Final Finish **6.5 µm**
- ☑ Average Grain Size **> 5 µm**



Example #1: Tin Whiskers and MLCCs

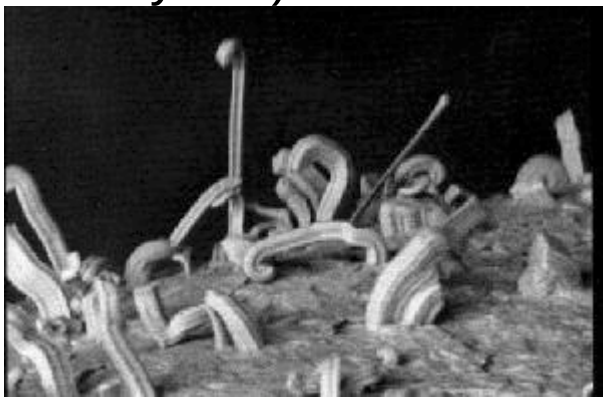
USER TEST ENVIRONMENTS

Condition 1: Temp Cycle: -40°C / +90°C (> 200 Cycles)



Whiskers ~100 µm

Density > 800/mm²



Note: After an ADDITIONAL

1 Year "Ambient" Storage

Whiskers Up to 240 µm

Condition 2:

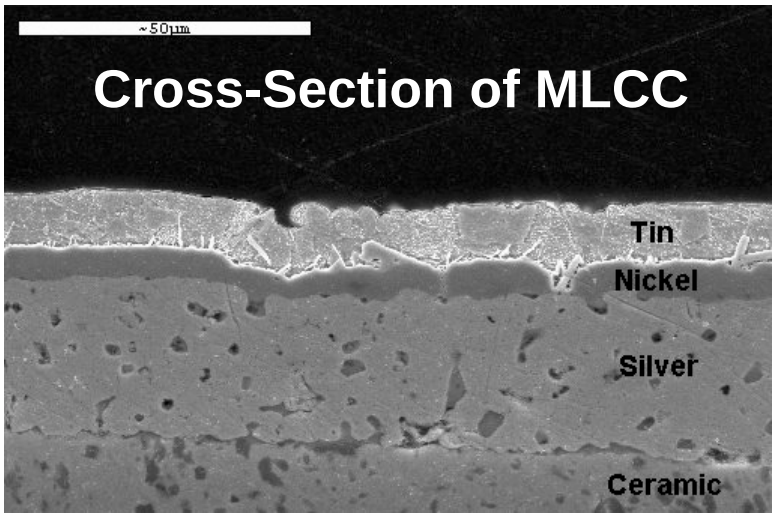
High Temp Storage: +90°C for 400 hrs → ***NO WHISKERS!!!***

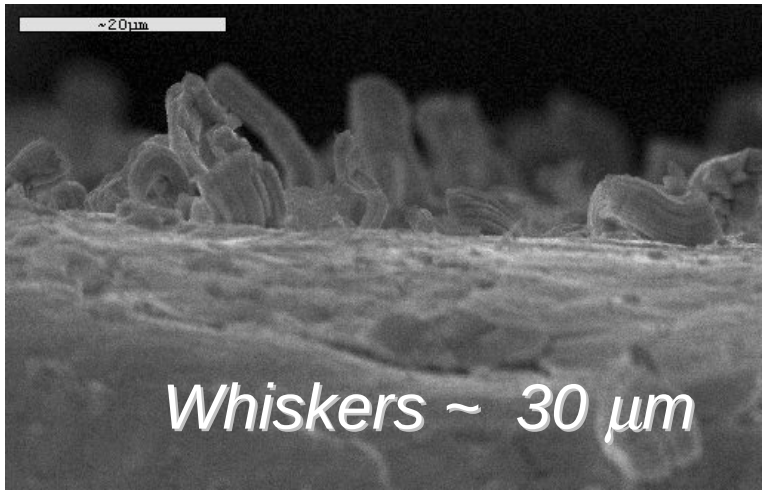
Example #2: Tin Whiskers and MLCCs

MLCC Mfr "B": Simulation of Reflow Temperature Exposure

MLCC Construction:

- Barium Titanate Ceramic Body
- Silver Frit Base Termination ~30 µm
- ☑ *Nickel Barrier Layer* ~ 6 µm
- ☑ *Matte Tin-Plated* Final Finish ~10 µm





Test Condition:

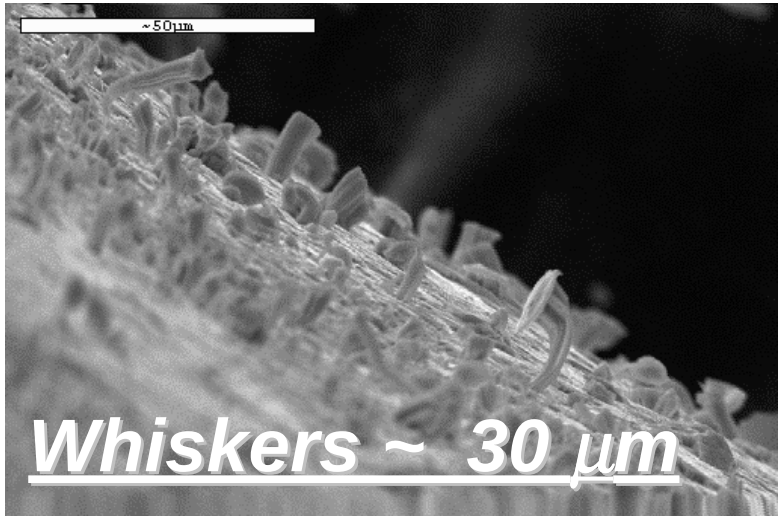
- Heat Treated @ 215°C for 5 Seconds to "Simulate" Reflow Installation
- Temp Cycle Unmounted: -40°C / +90°C for 500+ Cycles

Example #2: Tin Whiskers and MLCCs

MLCC Mfr "C": Thermal Cycle Exposure Testing

MLCC Construction

- Barium Titanate Ceramic Body
- Silver Frit Base Termination
- ☑ *Nickel Barrier Layer*
- ☑ *Matte Tin-Plated* Final Finish



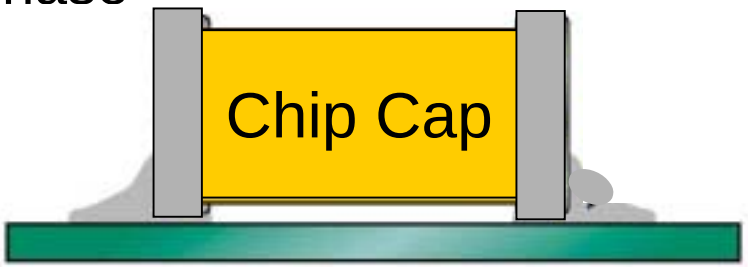
Test Condition:

- NO Heat Treatment to Simulate Installation
- Temp Cycle Unmounted: -40°C / +90°C for 100 Cycles

Example #3: Tin Whiskers and MLCCs

MLCC Mfr "B": Whiskers AFTER Vapor Phase Installation and T-Cycle

- Pure Tin-Plated 2220 and 1812 Size MLCCs Mounted on FR4 Boards via Vapor Phase
  - Solder = Sn63 / Pb37
  - Installation Temp. = 217°C



- Boards Subjected to Thermal Cycle/Shock (-55°C / +100°C) for 50 to 400 Cycles
  - RESULTS: ***Whiskers up to 30 μm***

- Soldering Operations DO NOT Always Reflow ALL Tin Surfaces Nor Mix them with the Mounting Solder

Example #4: Tin Whiskers and MLCCs

MLCC Mfr "D": Anecdotal Info - Whiskers AFTER Ambient Storage

User Application:

- MLCCs for Use Inside of Hybrid Microcircuit
- User Orders Pd-Ag Terminated MLCCs, but Gets ***PURE TIN*** Supplied by Mistake

User Observations:

- After Removing MLCCs from Stock Storage, User Observes ***"Moss-Like" Growths on the Terminations***
  (i.e., Parts were NOT Subjected to Any Environmental Test Conditions)

Conclusions

- Pure Tin-Plated Ceramic Chip Capacitors *ARE* Susceptible to Whisker Formation (contrary to previously published claims)
- Failures Due to Tin Whiskers are *STILL* a Significant Problem. Until Significant Discoveries are Made Regarding Effective Mitigation Practices
  - Problems *WILL INCREASE* with Increased Use of Pure Tin Coatings
  - Failures *ARE STILL OCCURRING*
- Even when PROHIBITED by System Design and Procurement Practices, Components Made with Pure Tin Finishes Continue to Appear in Electronic Equipment
- *Factors Affecting Tin Whisker Formation are NOT Completely Understood.* *Risk Assessment Based* on a SUBSET of Published Literature Can Be DANGEROUS

Recommendations

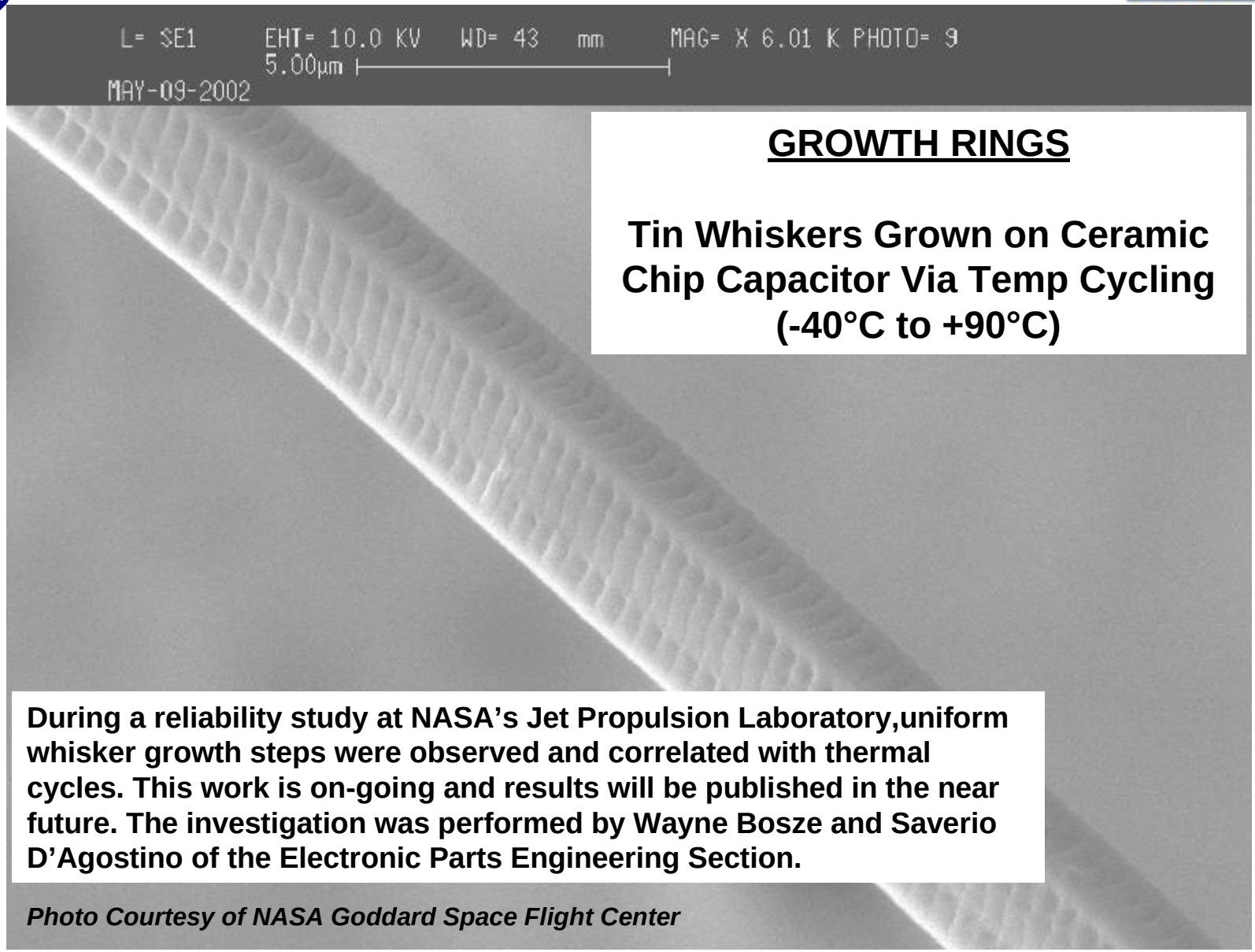
- CONSENSUS Understanding of the Fundamental Mechanism(s) that Drive Whisker Formation is Needed
- "Accelerated" Test Method(s) to Judge Whisker Propensity of a Given Product/Process is Needed
  - *Method Must be Tailorable to Assess a Broad Range of Device Constructions, Materials AND User Applications*
  - *Acceleration Factors MUST be Determined*
- Experiences with Tin (and OTHER Metal Whiskers--Zinc, Cadmium) Need to be Shared MORE Openly
- Electronic System Suppliers, Component Manufacturers and Plating Suppliers Should Develop Practices to Assess and Mitigate the Risk of Tin Whisker Induced Failures in their Products

And Now…..

A "Teaser" of

Some Very

NEW Observations



GROWTH RINGS

Tin Whiskers Grown on Ceramic Chip Capacitor Via Temp Cycling (-40°C to +90°C)

During a reliability study at NASA's Jet Propulsion Laboratory,uniform whisker growth steps were observed and correlated with thermal cycles. This work is on-going and results will be published in the near future. The investigation was performed by Wayne Bosze and Saverio D'Agostino of the Electronic Parts Engineering Section.

Photo Courtesy of NASA Goddard Space Flight Center

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301-286-2019

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Jong Kadesch			**(Orbital Sciences Corporation)**
Nilesh Shah			**(QSS Group, Inc.)**
Wayne Bosze	**&**	**Saverio D'Agostino**	**(Jet Propulsion Laboratory)**

NASA Goddard Tin Whisker WWW Site

http://nepp.nasa.gov/whisker