

L= SE1

EHT= 10.0 KV

WD= 34 mm

MAG= X 112.

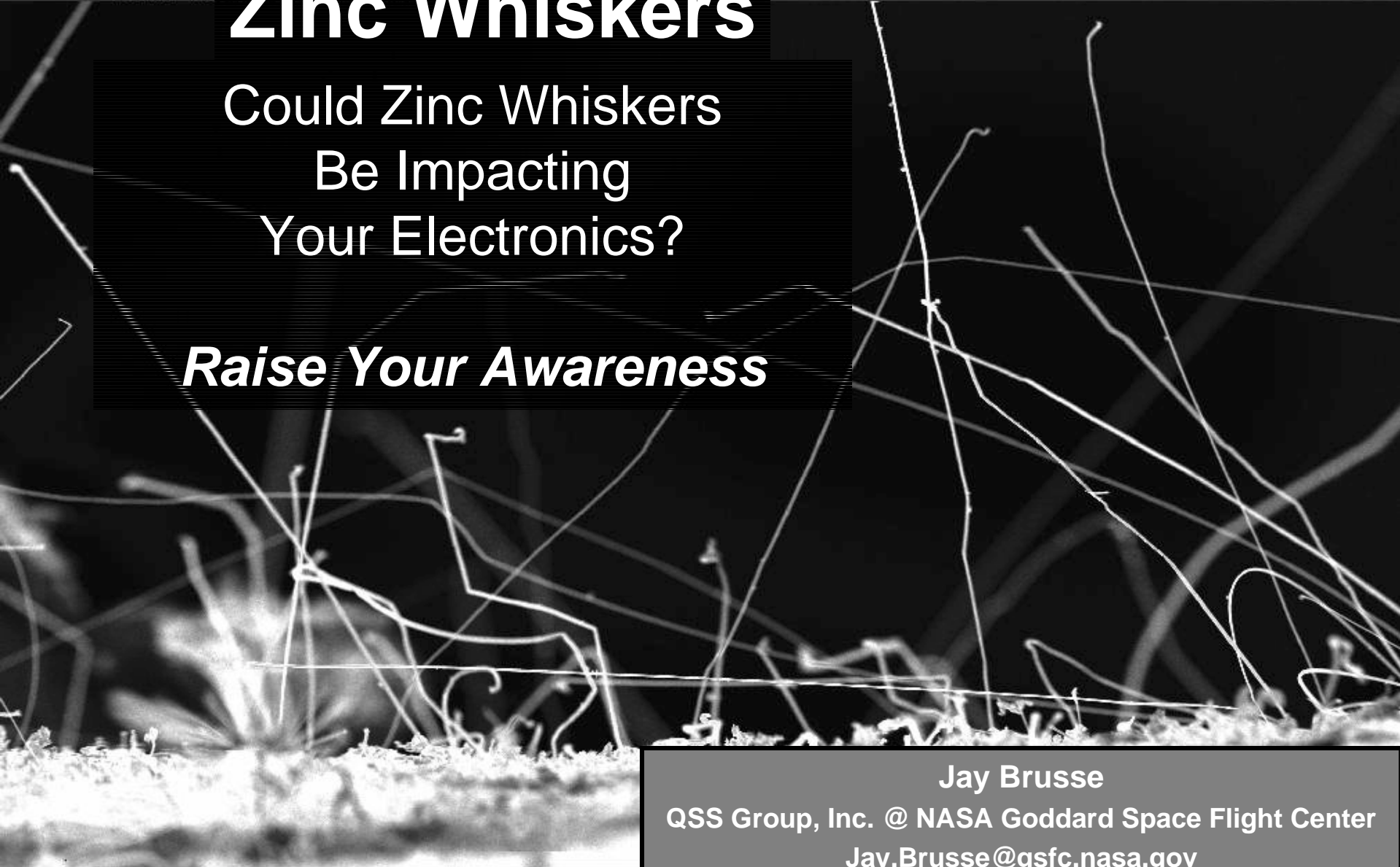
PHOTO= 15

ZINC WHISKERS

# Zinc Whiskers

Could Zinc Whiskers  
Be Impacting  
Your Electronics?

*Raise Your Awareness*

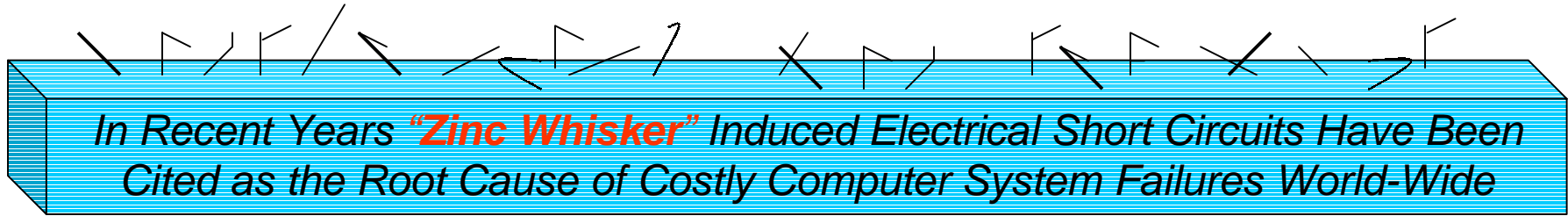


Jay Brusse

QSS Group, Inc. @ NASA Goddard Space Flight Center

Jay.Brusse@gsfc.nasa.gov

April 2, 2003



**Zinc whiskers** are tiny conductive filaments of zinc typically less than a **few millimeters (mm) long** and only a few thousandths of a millimeter in diameter. They grow from metal surfaces (e.g., steel) that have been electroplated (galvanized) with zinc for corrosion protection. The growth process consists of an **unpredictable incubation period** (months or perhaps even years) followed by a period of growth at rates **as high as 1 mm/year**.

Zinc whiskers are conductive and therefore they will cause **electrical shorts** if they manage to bridge tightly-spaced electrical conductors. Now that zinc whisker-induced shorts have been so convincingly demonstrated, some former "seemingly inexplicable" shorts are now regarded as explainable as having been caused by zinc whiskers. In recent years many computer equipment failures (servers, routers, switches, etc.) ranging from **nuisance glitches to catastrophic system failures** have been attributed to zinc whiskers. A search of the web shows that the most often reported source for zinc whiskers is the bottom surface of **zinc-plated raised ("access") floor tiles** commonly used in computer room construction. Other sources of zinc whiskers include zinc-plated floor supports/rails, computer equipment racks and hardware such as screws, nuts, washers and bus rails.

Zinc whisker sources on the underside of floor tiles are a long distance from electronic equipment in floor racks. However, experience demonstrates that whiskers are broken free during floor-bumping activities including construction and maintenance, and become entrained in the air flow used for cooling, and then deposit into the distant electronic equipment, as well as into people's lungs.

***Sometimes Zinc Whiskers find their way INSIDE equipment cabinets.***

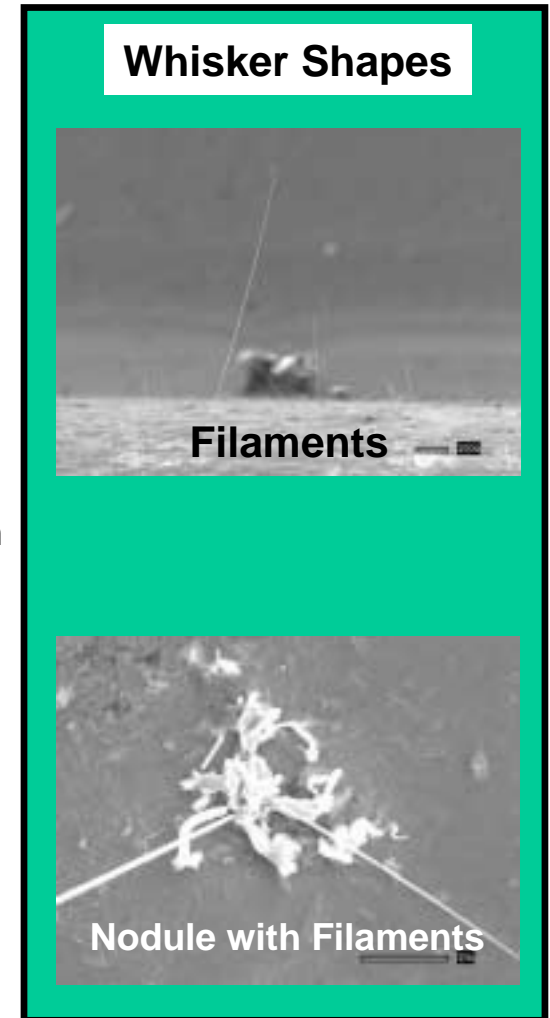
***Are You at Risk?***



***Read on to Raise Your Awareness about Zinc Whiskers...***

# Zinc Whisker: Facts & Attributes

- Zinc Whiskers are NOT a newly discovered phenomenon  
They were first reported in the 1940s!!!
- Physical Attributes (typical)
  - **Length:** a few millimeters or less
  - **Diameter:** a few microns (thousandths of a millimeter)
  - **Shapes:** straight or kinked filaments, nodules
  - **Texture:** fluted and/or striated along axis of growth
  - **Conductive:** can carry tens of milliamperes before melting
- Growth Behavior
  - **Mechanism of Growth:** UNCONFIRMED, as is also the case for tin whiskers. However, the most plausible mechanism for tin whiskers is that they grow to relieve compressive stress within the film, and that may be the case also for zinc whiskers
  - **Incubation:** ranges from days to **years**
  - **Growth rate:** typically less than 1 mm/year
- Failure Modes:
  - **Intermittent Shorts** if available current > tens of milliamperes
  - **Permanent Shorts** if available current < tens of milliamperes
  - **Metal Vapor Arcs** initiated in vacuum when  $V >$  dozens of volts and  $I >$  tens of Amperes. Such arcs are capable of sustaining **HUNDREDS of AMPERES**



# Some Sources of Zinc Whiskers

*Metals Electroplated with Zinc*

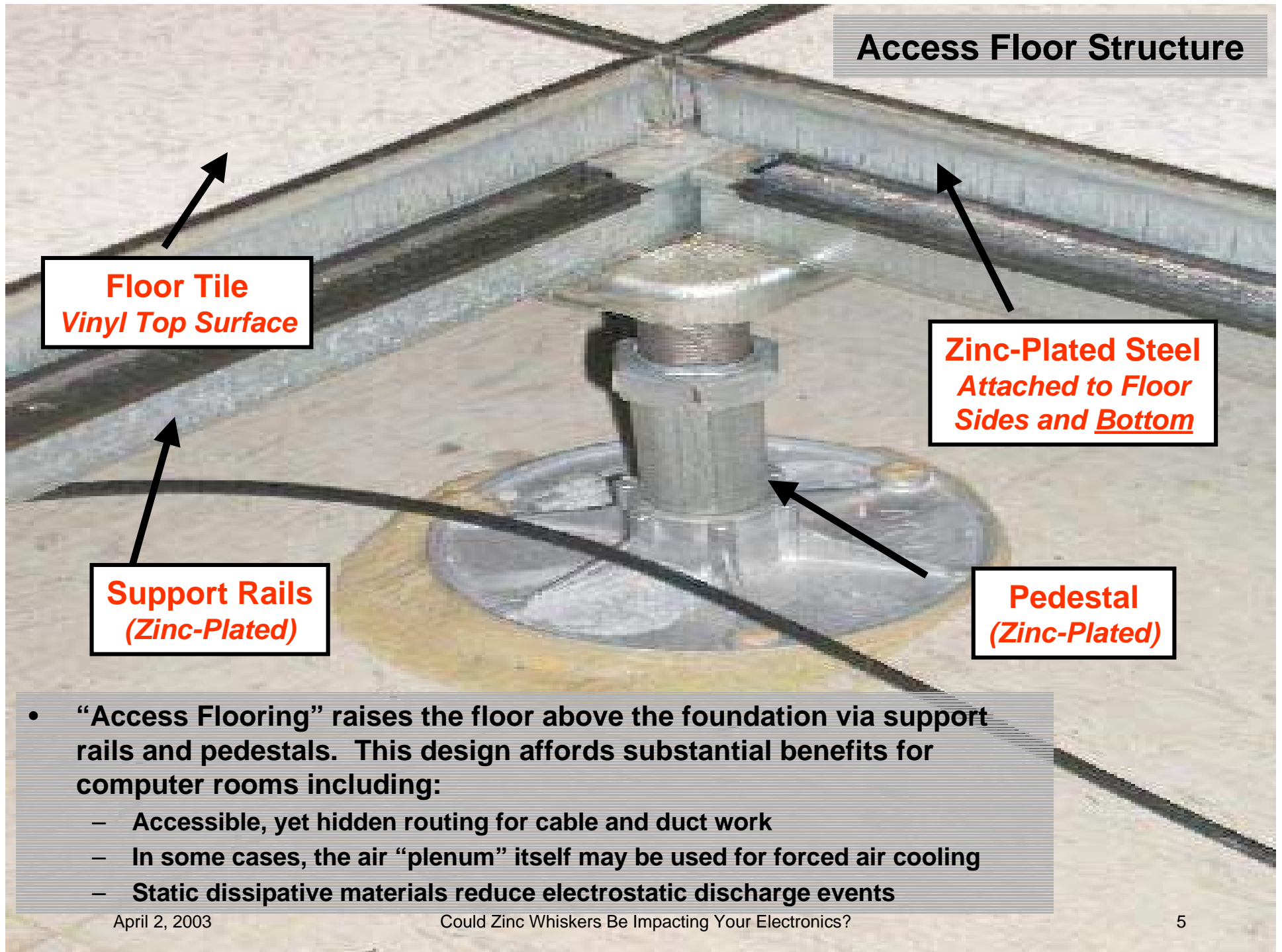
- **Mechanical Hardware**

- Nuts
- Screws
- Washers

- **Equipment Racks**

- Cabinets
- Chassis
- Bus Rails

- ***Access Floor Tiles***





One Type of Access Floor Tile  
Susceptible to Zinc Whiskers

~ 1mm Thick Sheet of Steel  
Electroplated with Zinc  
Glued to Wood Core Fiber Board

1" Thick Wood Core

- In this Image a Chisel and Sheet Metal Cutters were Used to Separate the Zinc-Electroplated Steel Understructure from the Wood Core. This process was Done **CAREFULLY** in Order to Collect Samples Suitable for Microscope Inspection to Document ***Incredible Zinc Whisker Growths***



# “Naked Eye” Whisker Inspection

- Seeing Zinc Whiskers with the Naked-Eye Can be **EXTREMELY DIFFICULT**
- Some Suggestions for Initial Inspection
  - URGENT! Perform Inspection OUTSIDE of Areas where Sensitive Computer Equipment is Operated*
  - Select Floor Tiles that are Unlikely to have been Removed Recently for Access/Maintenance
  - CAREFULLY Remove Floor Tile so as NOT to Disturb/Remove Potential Whiskers
  - Place Floor Tile with Metal-Side UP. If tile has been placed metal side down, then whiskers will be squashed
  - Dim “ambient” light (If Possible)
  - Shine a bright light (laser pointer is also very effective) **PARALLEL** to floor surface
  - Inspect with eye **PARALLEL** to floor surface
  - If Whiskers are present, you are likely to see “sparkling” hairs on the surface
  - Blowing GENTLY across the surface may enhance inspection as whiskers will move and twinkle in the light

Bright Light Source  
Shined Parallel to Floor Surface

This inspection technique does NOT guarantee Whisker Detection

Dust-Like Appearance on Surface is Actually Zinc Whisker Infestation  
(Difficult to Photograph without Microscopy)

**CAUTION:** The potential health hazards from exposure to zinc in the form tiny whisker-like filaments is NOT KNOWN to this author. Therefore, appropriate protective measures are encouraged to minimize human exposure. Consult occupational health experts for guidance.

# Zinc-Plated Steel Removed from Access Floor Tile



---

Sample Has Been Mounted to an Aluminum Stage Using Double-Sided Conductive Tape to Facilitate Optical and Scanning Electron Microscope Inspection





Optical Microscope Inspection of  
Zinc-Plated Steel from Access Floor Tile  
(Side and Top Illumination)

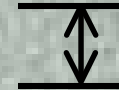
Microscope w/  
“Ring” Light for  
Top Illumination



Side Illumination  
Via “Flex” Light




0.5 mm

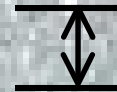


Whiskers are **NOT Easy to See** when  
Looking **PERPENDICULAR** to the Surface

Optical Microscope Inspection of  
Zinc-Plated Steel from Access Floor Tile  
(Side Illumination ONLY)

  
Light Source

0.5 mm



Whiskers are **NOT Easy to See** when  
Looking **PERPENDICULAR** to the Surface

TILTING Specimen to Look  
PARALLEL to Surface  
(Top Illumination - "Ring" Light ONLY)

"Ring" light Illuminates the "Background" as well as the Specimen.  
Too much "reflection" from the background OBSCURES whisker detection

0.5 mm



Whiskers are **STILL NOT Easy to See**  
Because the **Background is Reflecting Back Too Much Light**

TILTING Specimen to Look  
PARALLEL to Surface  
(SIDE “flex light” Illumination ONLY)

**AHA!! There they Are. Side Illumination provides better view due to improved contrast against background. A Dark Backdrop is Very Helpful**

||| →  
Light Source

0.5 mm



Looking **PARALLEL** to the Floor Surface with this lighting and angle of inspection illuminates the whiskers without illuminating the Background which could “hide” the whiskers

L= SE1

EHT= 10.0 KV

WD= 34 mm

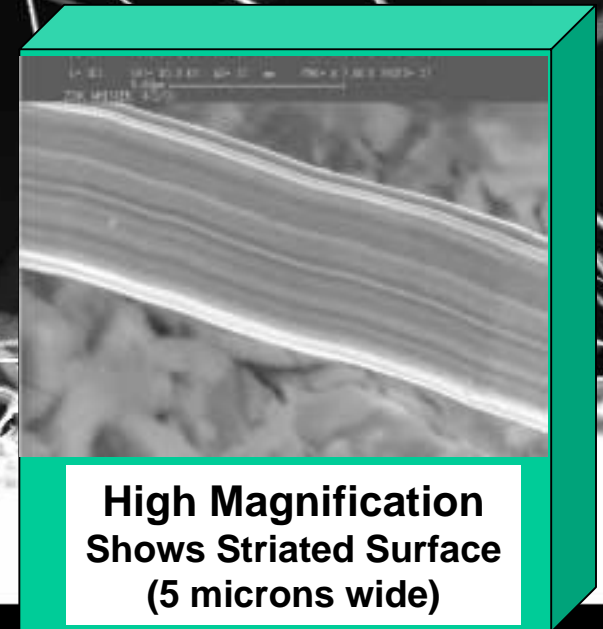
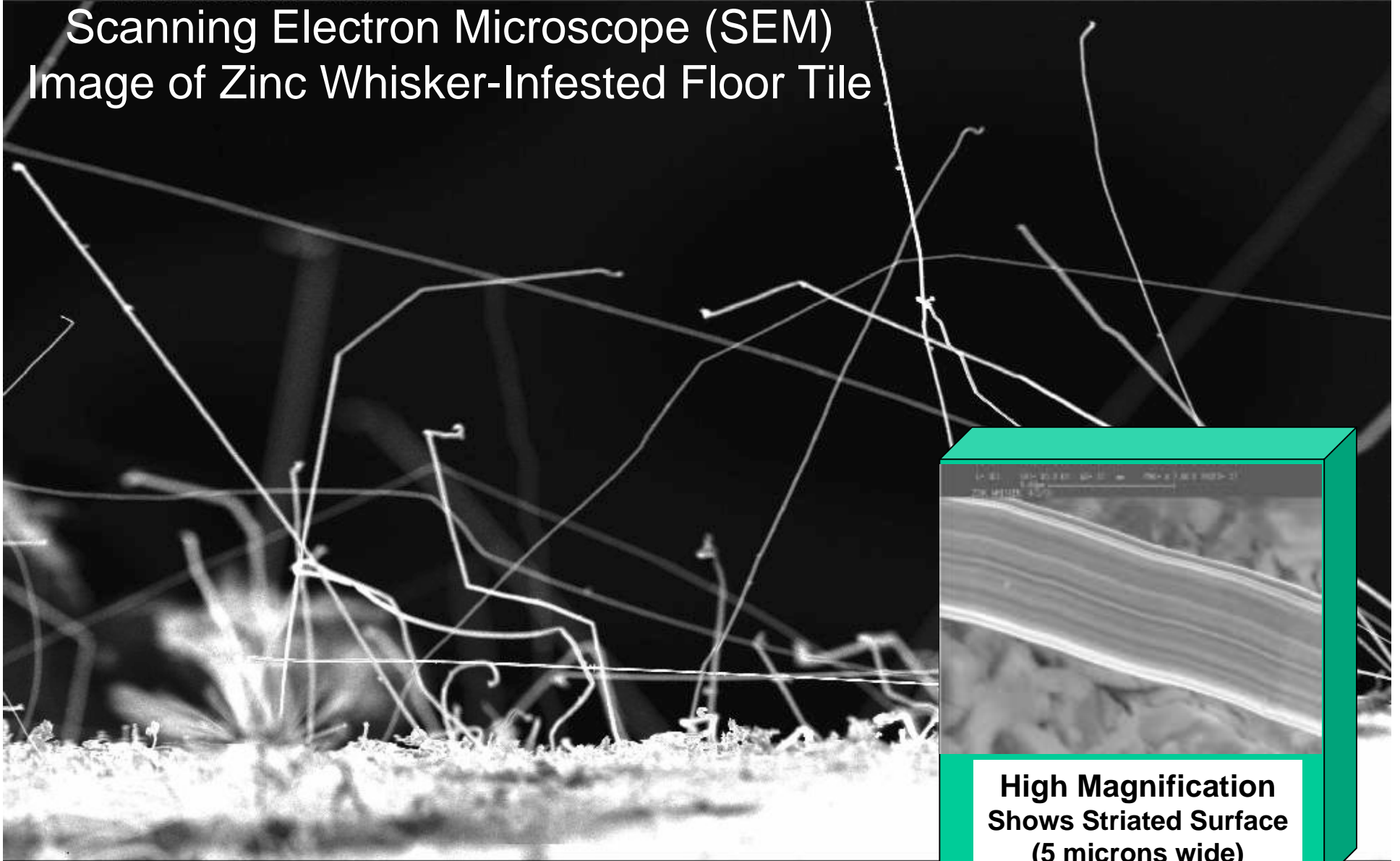
MAG= X 112.

PHOTO= 15

200  $\mu$ m |-----|

ZINC WHISKER, 4/1/03

# Scanning Electron Microscope (SEM) Image of Zinc Whisker-Infested Floor Tile



**High Magnification  
Shows Striated Surface  
(5 microns wide)**

# Why Zinc Whisker Concerns Now?

**FACT:** *Zinc Whiskers were first reported in the 1940s!*

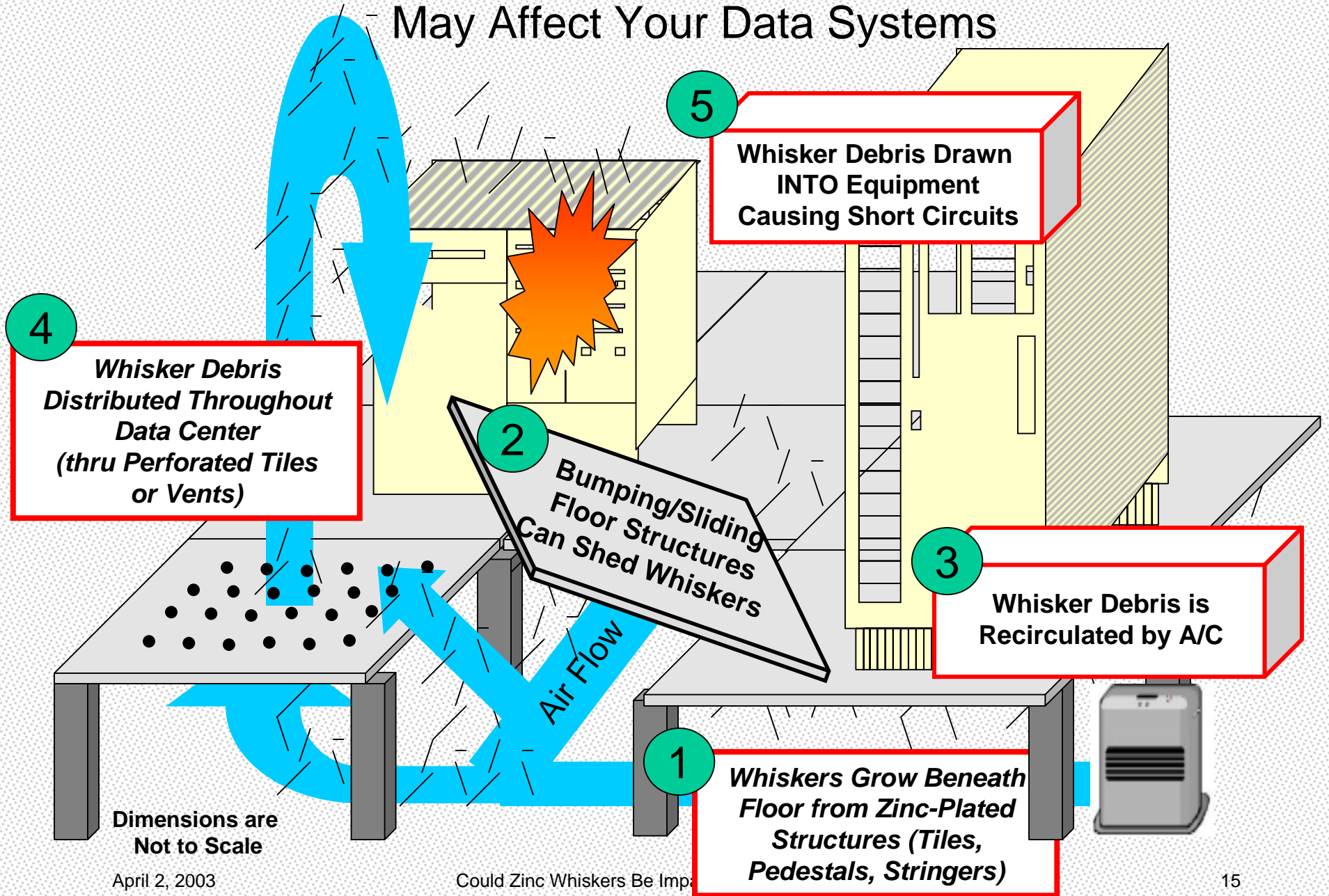
**QUESTION:** *Why are we “Rediscovering” Zinc Whiskers in the 21st Century?*

**ANSWER:** *Many Factors Combine to INCREASE Risk of Whisker Problems*

- ***Miniaturization of Electronic Circuits***
  - Reduction in spacing between conductors NOW makes the same old whiskers a hazard.
  - Former electronics used distinctly wider spacing which these whiskers could not bridge
- ***Reduction of Circuit Voltages and Currents in Many of Today’s Electronics***
  - Available circuit voltage may be insufficient to melt whiskers --> PERMANENT short circuits
- ***TIME!!!***
  - Many Computer Room Floors and Equipment Racks are now 10, 20, 30 YEARS Old... Thus where zinc-plated hardware is in use, whiskers have had sufficient time to grow in potentially hazardous quantities and lengths
- ***More Frequent System Upgrades***
  - Replacement of “older” computer servers, routers etc. involves construction in the computer room which may lead to generation of conductive whisker debris



# One Way Zinc Whiskers May Affect Your Data Systems



# Example of Zinc Whisker-Induced Failures

## Background

- **Affected User: Library Computer Data Center**
  - Library Materials Database
  - Customer Information Database
  - Local Internet Service Provider (ISP)
- **Most Plausible Root Cause of Failure**
  - Thousands of ZINC Whiskers (some >2 mm long) Inadvertently scattered about room during Construction project
  - Whisker debris recirculated into computer servers and routers via A/C and cooling fans
  - **Whisker debris created short circuits**
- **Source of Zinc Whiskers**
  - **Zinc-Plated Access Floor Tiles**
  - Floor Installed ~20 Years Before Failures

## IMPACT

- **10 Catastrophic Server Failures in 2 - 3 months**
  - Power Supply Shorts
  - ~\$20k/each
- **~12 Catastrophic Router Failures in 18 months**
  - \$0.5k - \$1.5k/each
- **Major Disaster Recovery Project**
  - ~\$100k Floor Reconstruction + Equipment Tear Down/Cleanout
- **System DOWN-TIME!!!**

# Raise Your Awareness

- *Zinc Whiskers Have Caused Extensive Failures to Electronic Systems*
  - Potential “Health” Hazard from Breathing Zinc Whisker Debris is Unknown. However, there is a general understanding that needle-shaped particulate material can present a special hazard to lungs regardless of material. Occupational Health experts should be consulted for guidance on appropriate protective measures as required.
- Problem Experiences are on the Rise as Some Previously Inexplicable Failures are Now Being Recognized as Zinc Whisker-Induced Short Circuits
- Detection and Mitigation is Difficult
  - Detection Frequently Requires Trained Expertise, But User-Inspection is Possible with Proper Precautions
  - Mitigation Strategies Often Involve COMPLETE Removal and Replacement of Floor Tiles, Support Structure, Equipment Racks, etc.
  - *Prominent Computer Suppliers have Contracted with a Network of “Disaster Recovery” Companies to Help Diagnose & Root Out Zinc Whisker Contamination*
- The Problems You’ve Been Experiencing May Be Lurking Under Your Feet or Inside Your Equipment Racks... **ZINC WHISKERS**



<http://nepp.nasa.gov/whisker>

Zinc Whisker References

NASA Goddard Space Flight Center  
Tin Whisker Homepage  
(And Other Metal Whiskers)

Home	Basic Info/FAQ	Photo Gallery	Video Gallery	GSFC Experiments	Literature References
Whisker Failures	Whisker Anecdotes	Other Metal Whiskers	Related Links	What's New	Contact Us

Tin Whisker Growing from Pure Tin Plated Relay Terminal



Motion depicted in this image is for simulation purposes only

Photo of the Month

November 2002:

- [Tin Whiskers Growing INSIDE of Hermetically Sealed Relay](#)
- [See Also the Video of these Whiskers Moving Due to Gentle Air Currents](#)



Hot Topics

- G. Galyon, "[Annotated Tin Whisker Bibliography](#)", NEMI Pub., pp 1-21, Feb. 2003
- D. Romm, "[Whisker Evaluation of Tin-Plated Logic Component Leads](#)", Texas Instruments App Note SZZA037A (Feb 2003)
- G. Davy, "[Relay Failure Caused by Tin Whiskers](#)", Oct. 2002
- **More Links to Technical Papers Added (Dec 2002)**
  - GE Power Management, "[Technical Service Bulletin: Tin Whiskers in MOD10 Relays](#)", March 27, 2000
  - C. Stevens, "[Relay Failures Induced by the Growth of Tin Whiskers: A Case Study](#)", IEEE Boston Reliability Chapter 38th Annual Spring Reliability Symposium, May 16, 2001
  - S. Tucker, "[What Nasty Little Things are Lurking Inside Your Data Center?](#)", Unisys World Monthly, November 2002
  - B. Dunn, "[Mechanical and Electrical Characteristics of Tin Whiskers with Special Reference to Spacecraft Systems](#)," *European Space Agency (ESA) Journal*, 12, pp. 1-17, January 14, 1988.
  - B. Dunn, "[A Laboratory Study of Tin Whisker Growth](#)", *European Space Agency (ESA) STR-223*, pp. 1 - 50, September 1987.
  - B.D. Dunn, "[Whisker Formation on Electronic Materials](#)", *ESA Scientific and Technical Review*, vol. 2, no. 1, pp. 1-22, 1976.
- **NEW Tin Whisker Videos (Nov 2002)**
  - Tin Whisker Motion Due to Minor Air Currents
  - Tin Whisker Growth Kinetics
- **Photos of Relay with Tin Whiskers INSIDE Package (Nov 2002)**
- **Tin Whiskers: Attributes & Mitigation (Slides) CARTS Europe (Oct. 2002)**
- **Whisker Observations on Pure Tin-Plated Ceramic Chip Capacitors**
  - [Technical Paper](#) (SUR/FIN Conference, June 2002)

# Additional Zinc Whisker References

[http://nepp.nasa.gov/whisker/other\\_whisker](http://nepp.nasa.gov/whisker/other_whisker)

1. "What Nasty Little Things are Lurking Inside Your Data Center?" (Source: Unisys World Monthly)
2. Apnea Monitor Failures: J. Downs, "The Phenomenon of Zinc Whisker Growth and the Rotary Switch (or, How the Switch Industry Captured the Abominable Snowman)", *Metal Finishing*, August 1994, pp. 23-25
3. How Do Zinc Whiskers Affect Today's Data Centers? (Source: Power Quality Solutions, July 13, 2001)
4. Zinc Whiskers Growing on Raised Floor Tiles are Causing Conductive Contamination Failures and Equipment Shutdowns (Source: The Uptime Institute)
5. Zinc Whiskers on Floor Tiles (Source: Infinite Access Floors)
6. Precautions Against Zinc Whiskers (Source: Compaq)
7. Monitoring Zinc Whiskers (Source: Telstra Research)
8. Zinc Whisker Abatement (Source: Worldwide Environmental Services)
9. Zinc Whisker Contamination: A Paper on the Effect and Abatement of Zinc Whiskers in Data Processing Centers, David Loman (HP Services)
10. Are Zinc Whiskers Growing in Your Computer Room? (Source: Data Clean Corp.)
11. Zinc Whiskers (Source: Infinite Access Floors)

# Contact Information

**Jay Brusse**



Sr. Components Engineer

QSS Group, Inc. at NASA Goddard Space Flight Center

Greenbelt, MD

Jay.Brusse@gsfc.nasa.gov

---

## **NASA Goddard Space Flight Center Whisker Investigation Team:**

**Mike Sampson - NEPAG Manager**

**Henning Leidecker - Chief Parts Engineer**

**Jong Kadesch - Orbital Sciences Corporation**