External Surface Changes Observed on the International Space Station (ISS) Through 2012

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Abstract

As the International Space Station (ISS) surpasses 13 years of on-orbit operation, 11 of those years continuously inhabited, external surfaces of the vehicle have shown a wide variety of visible environmental effects. Throughout, the ISS program has maintained a significant effort to routinely document the vehicle external surface condition and to monitor those changes with time.

The impacts of micrometeoroids and orbital debris, surface changes from molecular contamination of various sources, and the effects of ultraviolet radiation and atomic oxygen have all been noted. The tremendous size and complexity of the ISS vehicle has yielded a wide variety of observations of interest to the spacecraft materials engineer concerning long-term, low earth orbit (LEO) space environmental effects (SEE). In addition, inadvertent materials substitutions have been identified because of these environmental effects, as well as inadequate contamination control practices likely occurring during hardware manufacture and assembly. Some of the observations from our photography are purely artifacts of the unusual lighting conditions and environments that exist in space. A compilation of ISS on-orbit photography representing all of these aspects is presented, demonstrating the various SEE and their impacts as a function of time in LEO, including interpretations of those effects.

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External Surface Changes on ISS

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  All photography courtesy of NASA

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  - **NASA JSC Flight Image Science & Analysis Group.**
  - **Kim DeGroh and Bruce Banks – NASA GRC**
  - **Kent Ross – NASA JSC (Jacobs Eng.)**

External Surface Changes on ISS

Summary of Presentation

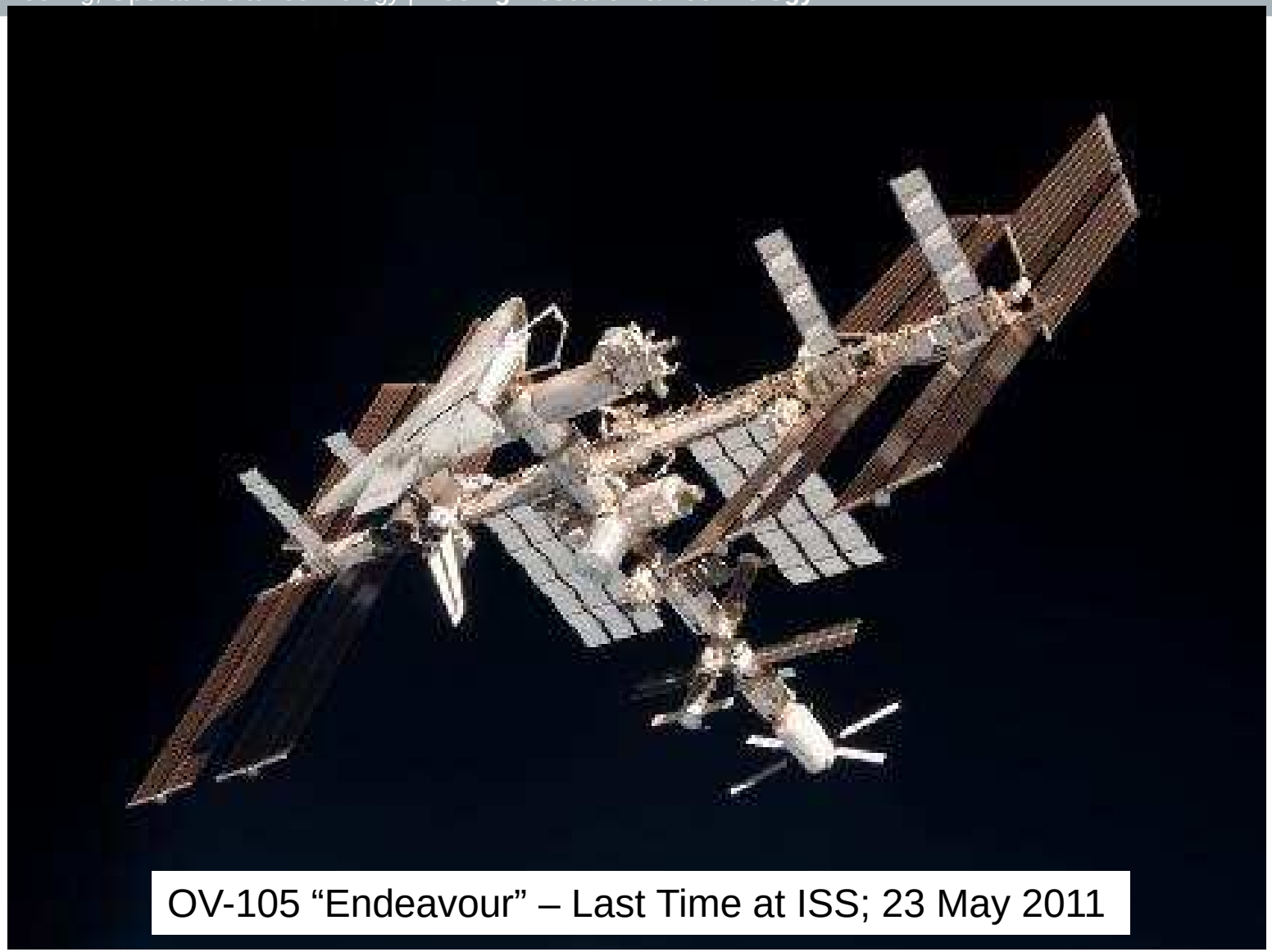
A sampling of ISS on-orbit and post-flight photography showing space environmental effects (SEE) in conjunction with:

- **Basic Materials Selection Issues**
- **Inadvertent Materials Substitution**
- **Materials Handling Issues (Ground Contamination)**
- **Contamination and Micrometeroid/Orbital Debris (MMOD) Impacts**
- **The Imaging Process Itself**

External Surface Changes on ISS

S129E009239

External Surface Changes on ISS



OV-105 “Endeavour” – Last Time at ISS; 23 May 2011

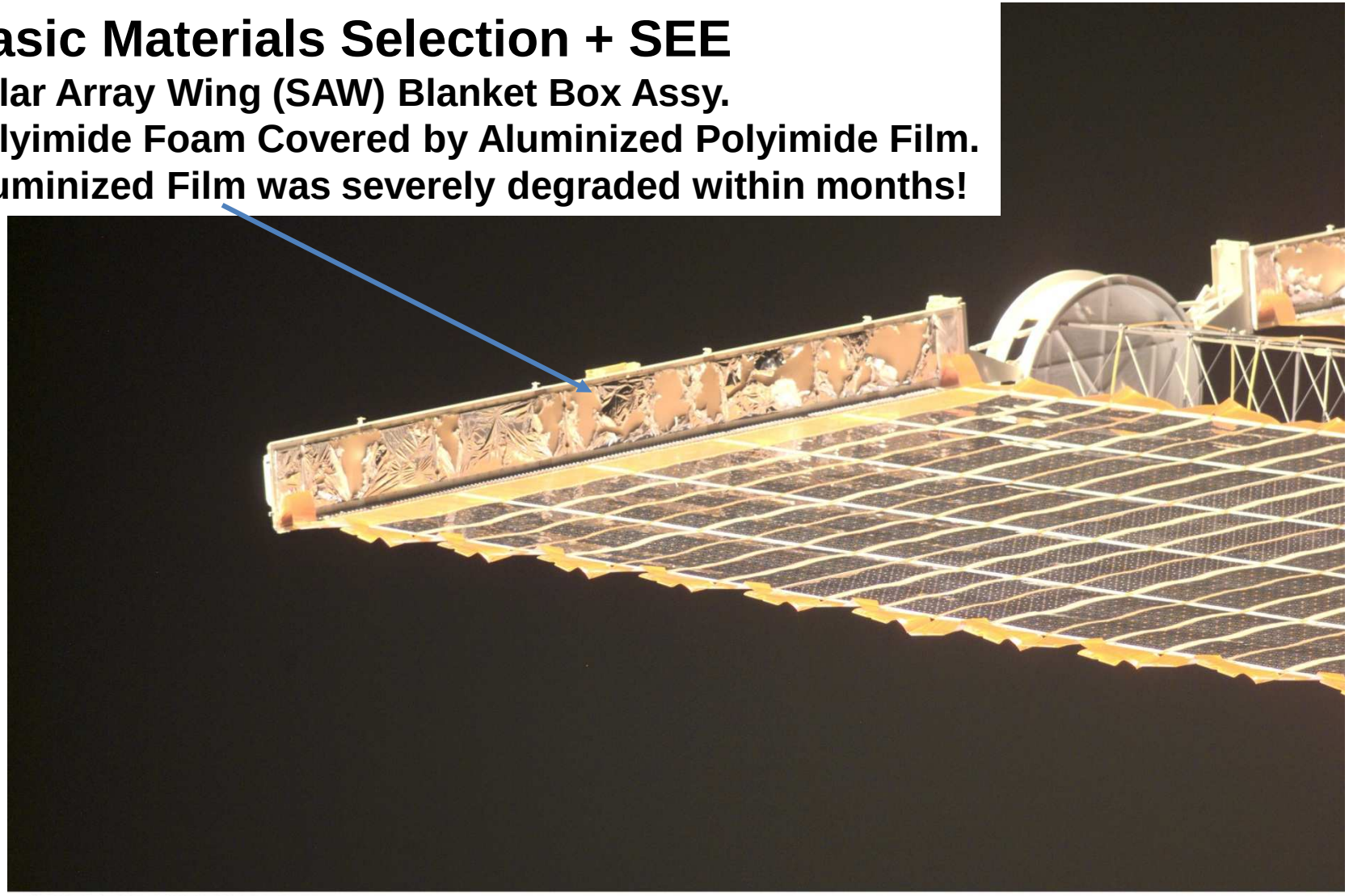
External Surface Changes on ISS

OV-105 “Endeavour” – Last Time at ISS; 23 May 2011

External Surface Changes on ISS

Basic Materials Selection + SEE

Solar Array Wing (SAW) Blanket Box Assy.
Polyimide Foam Covered by Aluminized Polyimide Film.
Aluminized Film was severely degraded within months!



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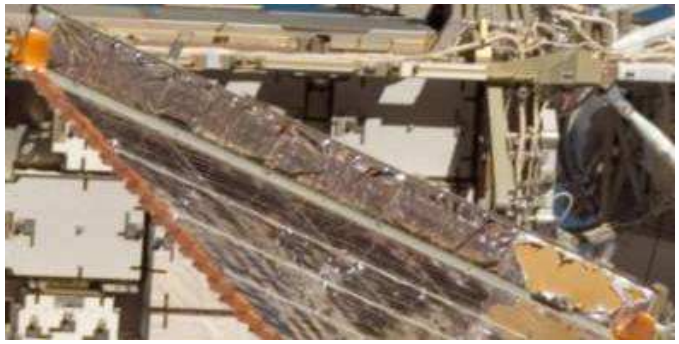
External Surface Changes on ISS

Basic Materials Selection + SEE

Solar Array Wing (SAW) Blanket Box Assy

Not all SAWs were equally affected, plus the damaged occurred quickly and did not continue with time.



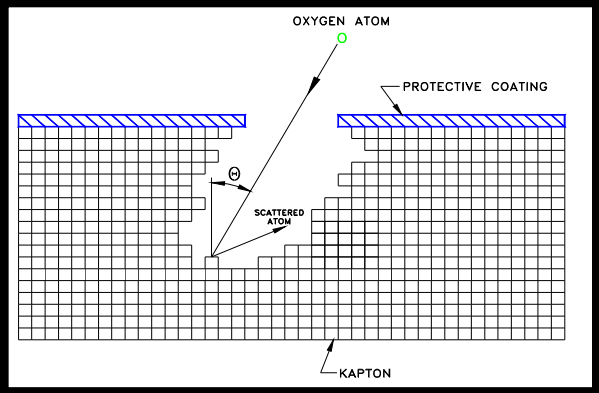
3 Months

38 Months

External Surface Changes on ISS

Monte Carlo Computational Model

Bruce A. Banks (PI)



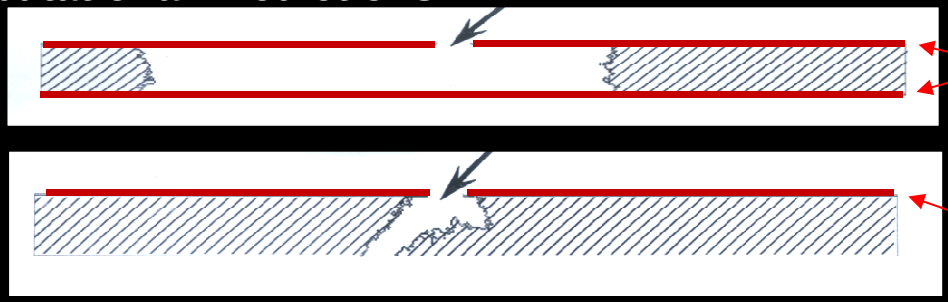
2-D computational modeling of atomic oxygen erosion of polymers

- **Takes into account:**
  - Energy dependence of reaction probability
  - Angle of impact dependence of reaction probability
  - Thermalization of scattered oxygen atoms
  - Partial recombination at surfaces
  - Atomic oxygen scattering distribution functions

⇒ ***MISSE data will be use to tuned the model to more accurately replicate in-space erosion***

ISS Solar Array Blanket Box Cover Erosion

Computational Predictions



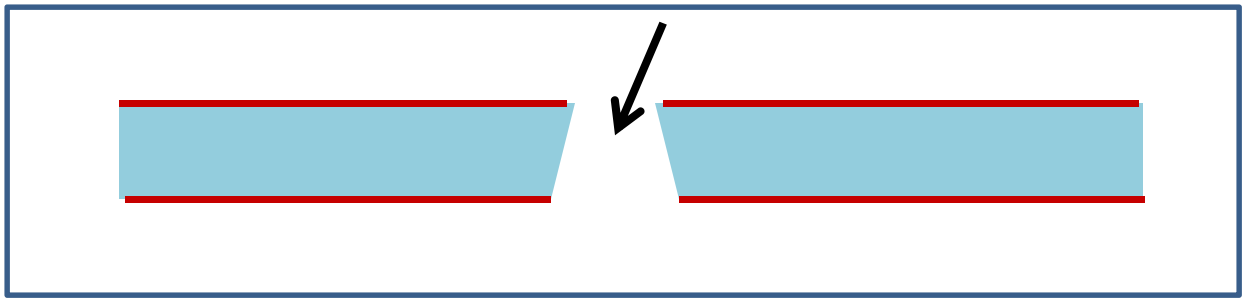
Aluminized on both sides of Kapton *(ISS configuration)*

Aluminized only on exposed side of Kapton

Source: B. A. Banks, K. K. de Groh and S. K. Miller, "Low Earth Orbital Atomic Oxygen Interactions with Spacecraft Materials," Materials Research Society Symposium Proceedings 2004, NN8.1

External Surface Changes on ISS

- **That some areas of the SAW blanket boxes remain intact for years after the initial rapid failures further suggests that MMOD impacts are slow to initiate the damage observed from defects/damage in the surface metallization layer.**



Aluminized on both sides
25 μm Kapton

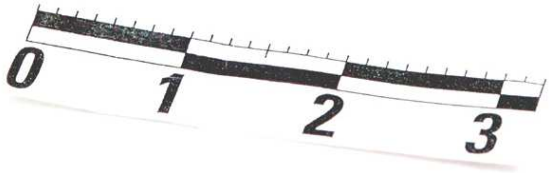
External Surface Changes on ISS

Basic Materials Selection + SEE

Trailing Umbilical System (TUS) Reel Grounding Strap (Tin-Plated)

External Surface Changes on ISS

Basic Materials Selection + SEE



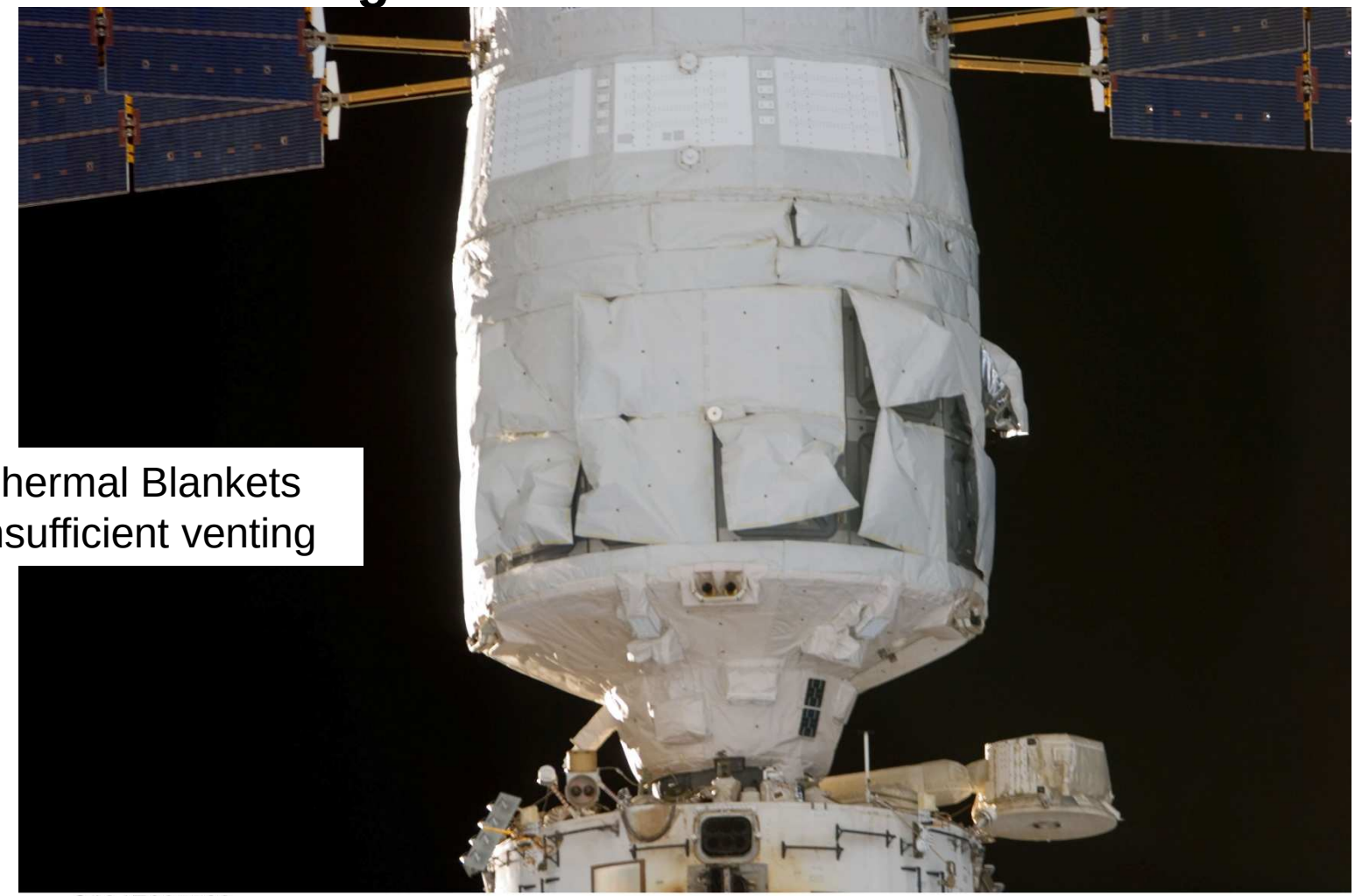
Ground strap removed from Trailing Umbilical System

Detail of tin pest region

Scratches serving as initiation sites; low temperatures on-orbit accelerate phase transformation

External Surface Changes on ISS

Basic Materials Design + SEE

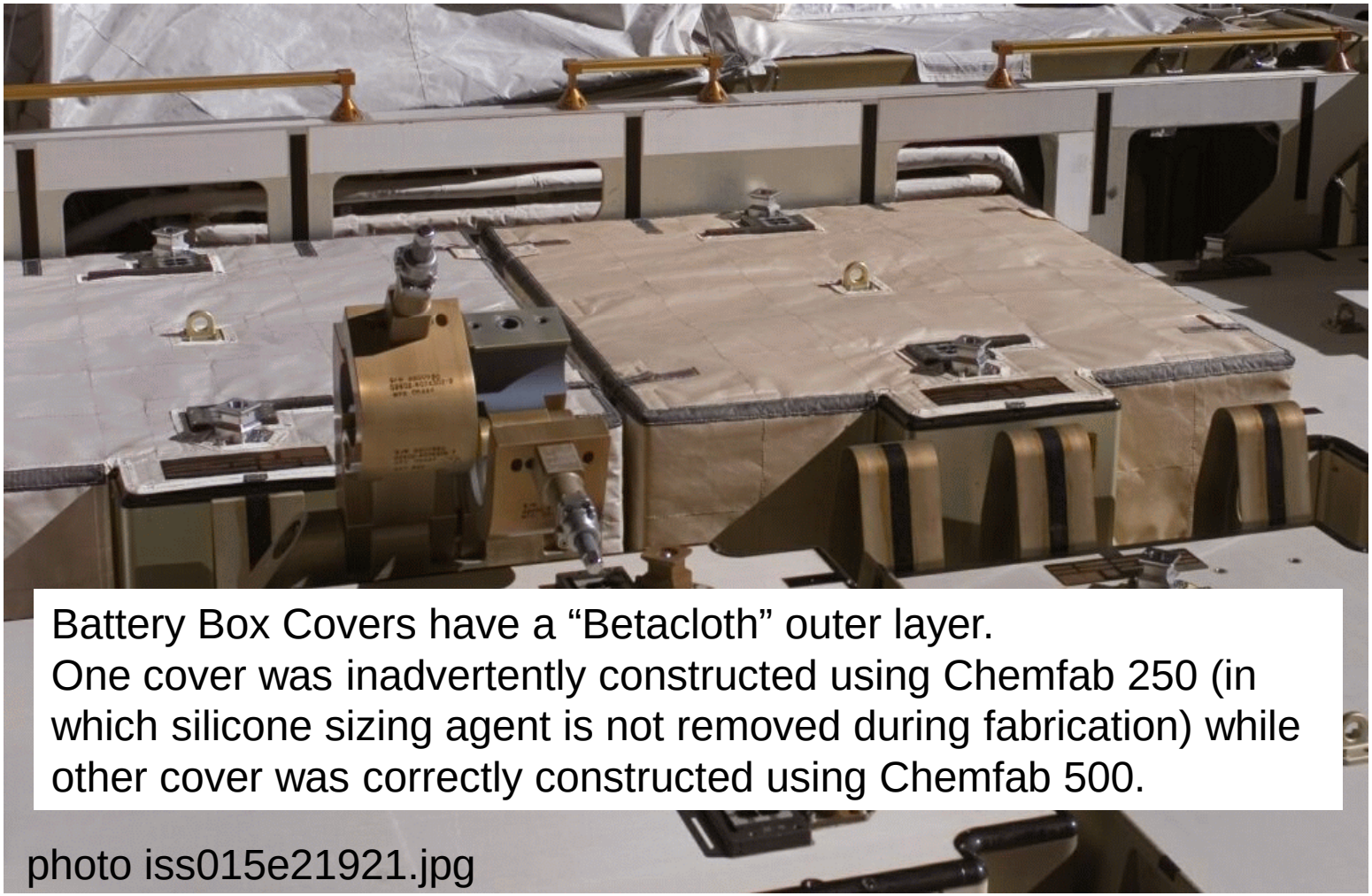


ATV1 Thermal Blankets show insufficient venting

S124E005722

External Surface Changes on ISS

Inadvertent Materials Substitution + SEE

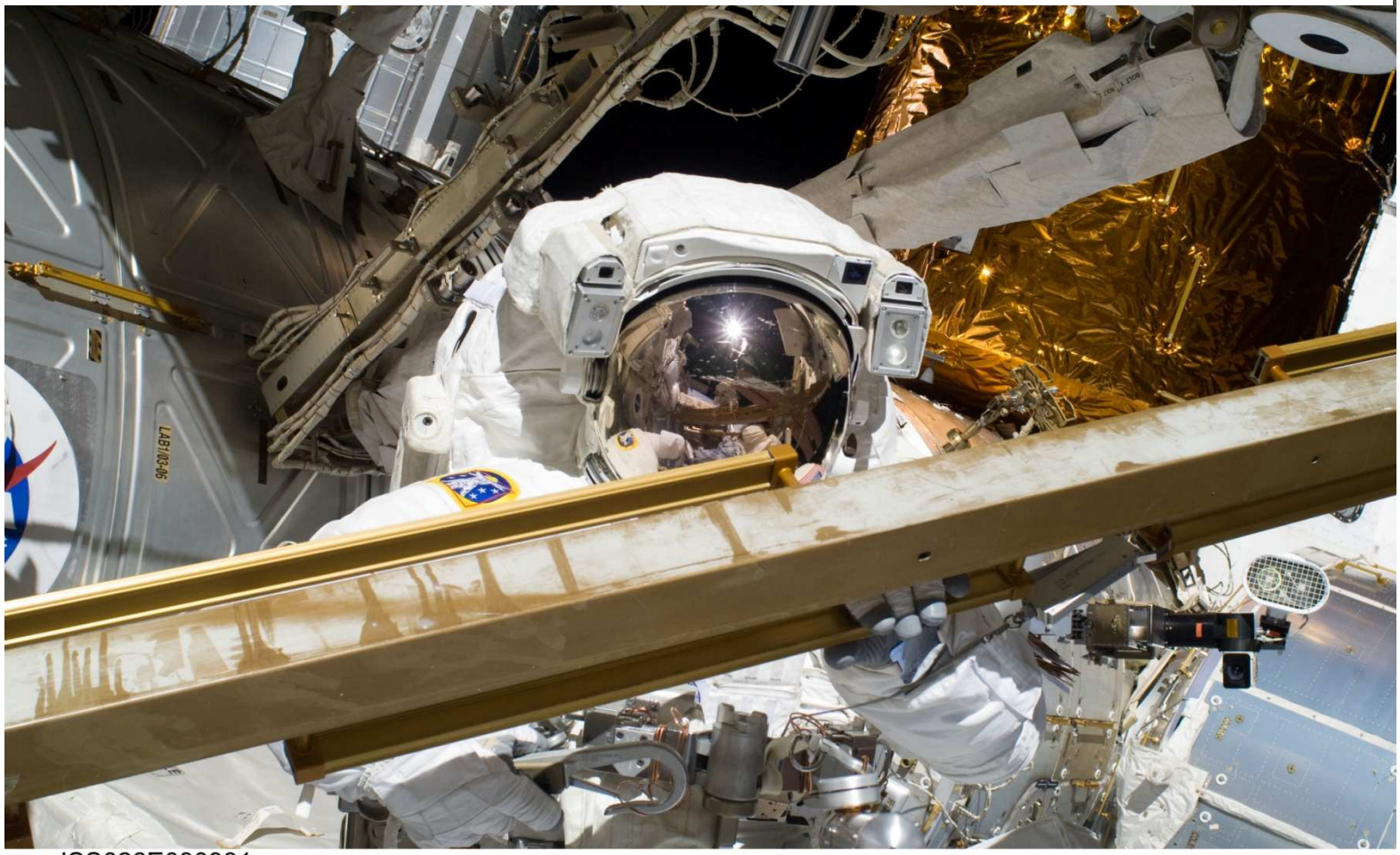


Battery Box Covers have a “Betacloth” outer layer.
One cover was inadvertently constructed using Chemfab 250 (in which silicone sizing agent is not removed during fabrication) while other cover was correctly constructed using Chemfab 500.

photo iss015e21921.jpg

External Surface Changes on ISS

Materials Handling Issues (Ground Contamination)



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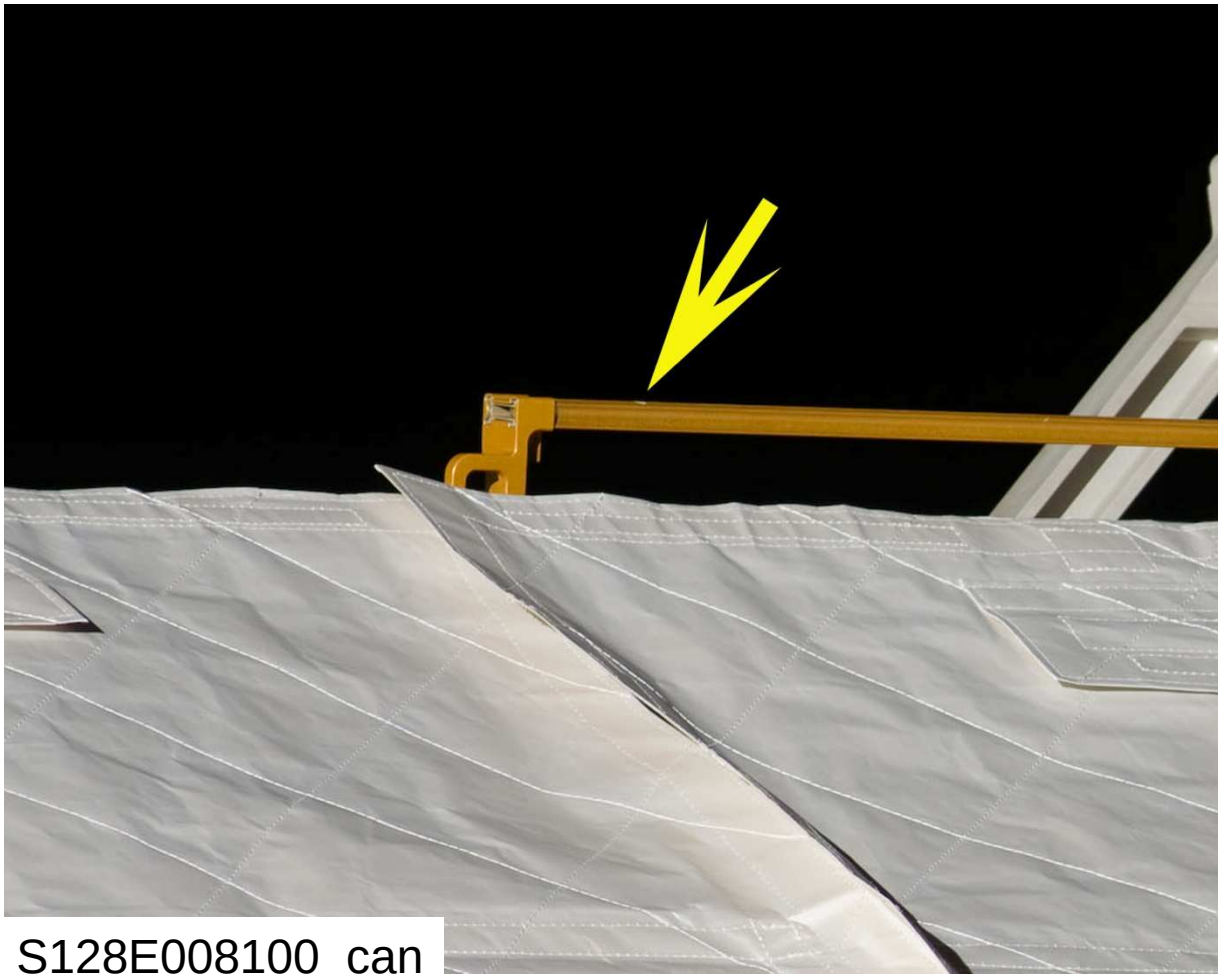
External Surface Changes on ISS

Materials Handling Issues (Ground Contamination)

S122e009382 - cropped

External Surface Changes on ISS

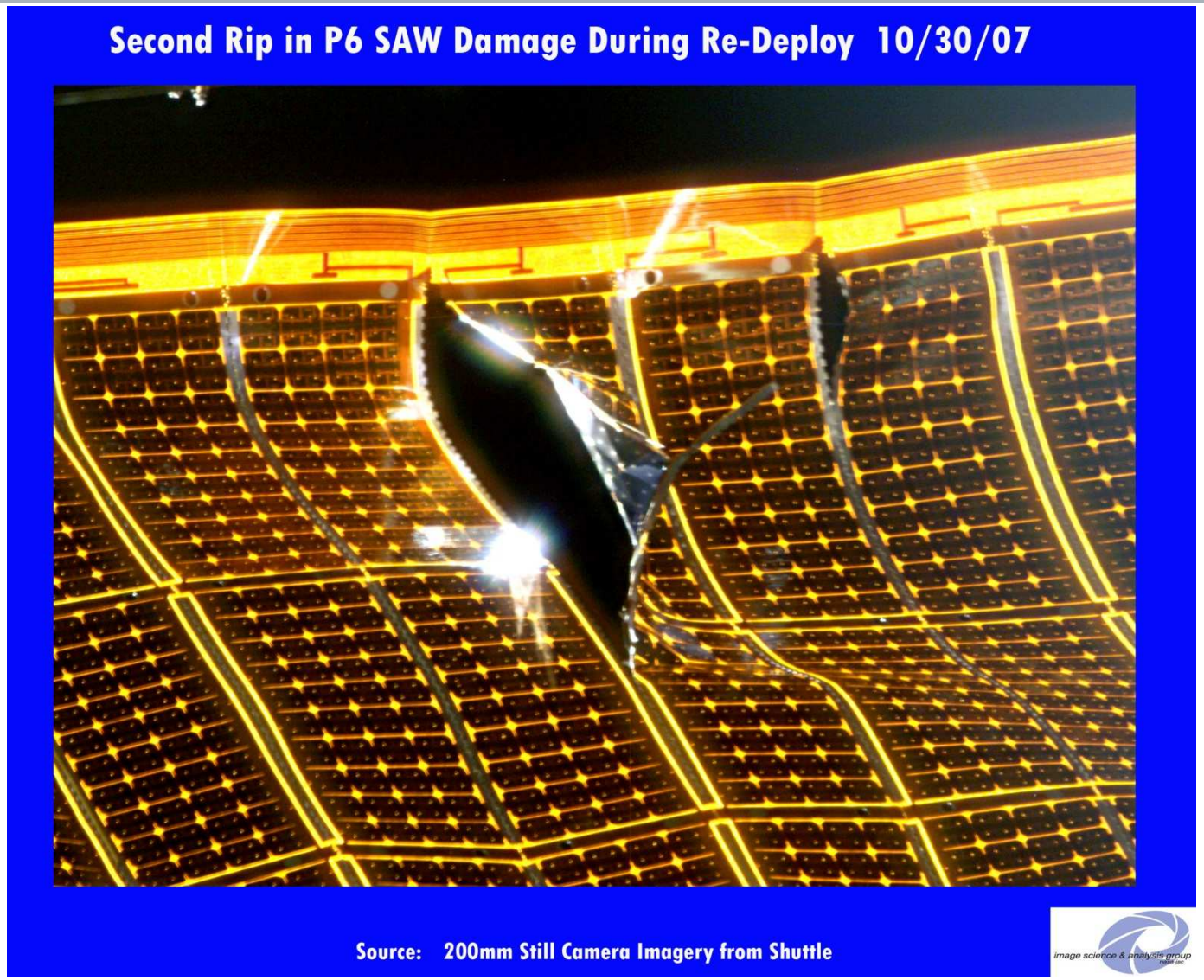
Space Environmental Effects



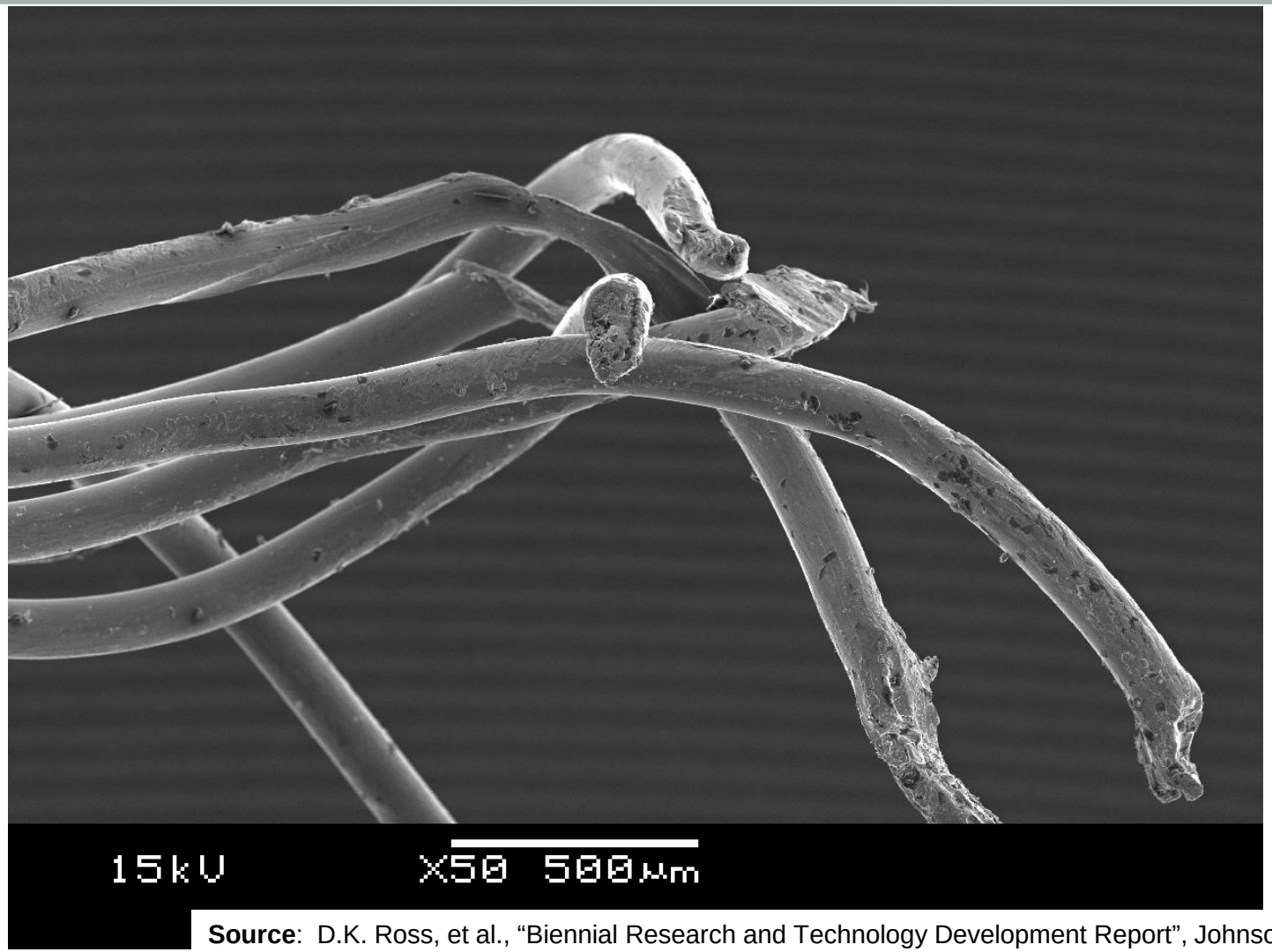
S128E008100_can

MMOD impacts on handrails are becoming increasingly troublesome, causing EVA glove damage

External Surface Changes on ISS

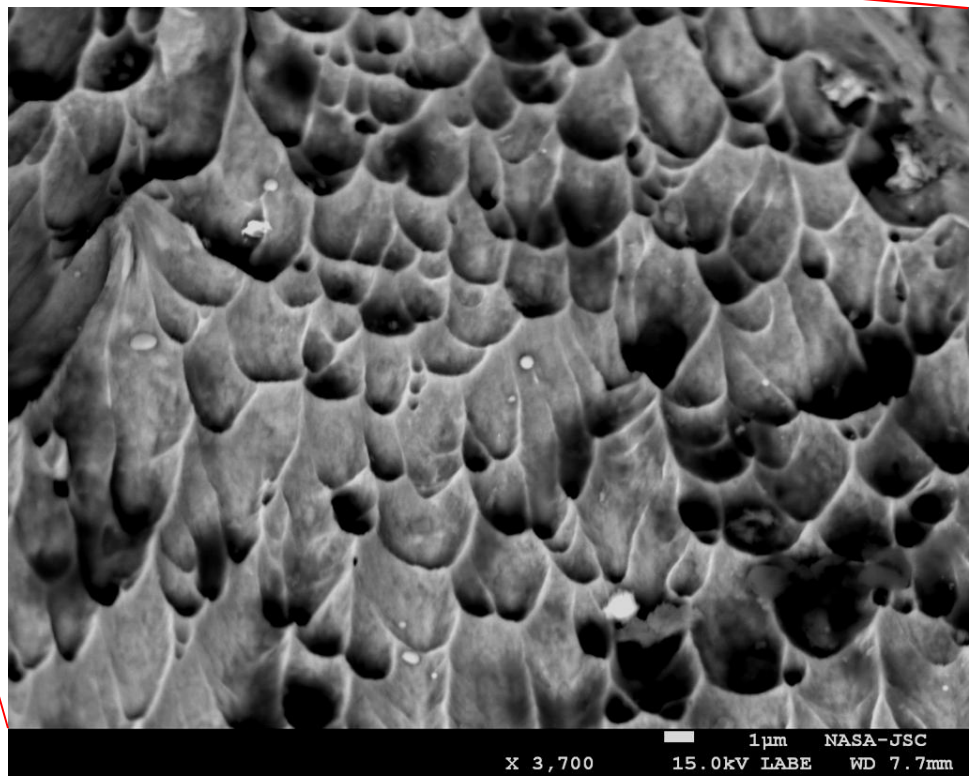


External Surface Changes on ISS

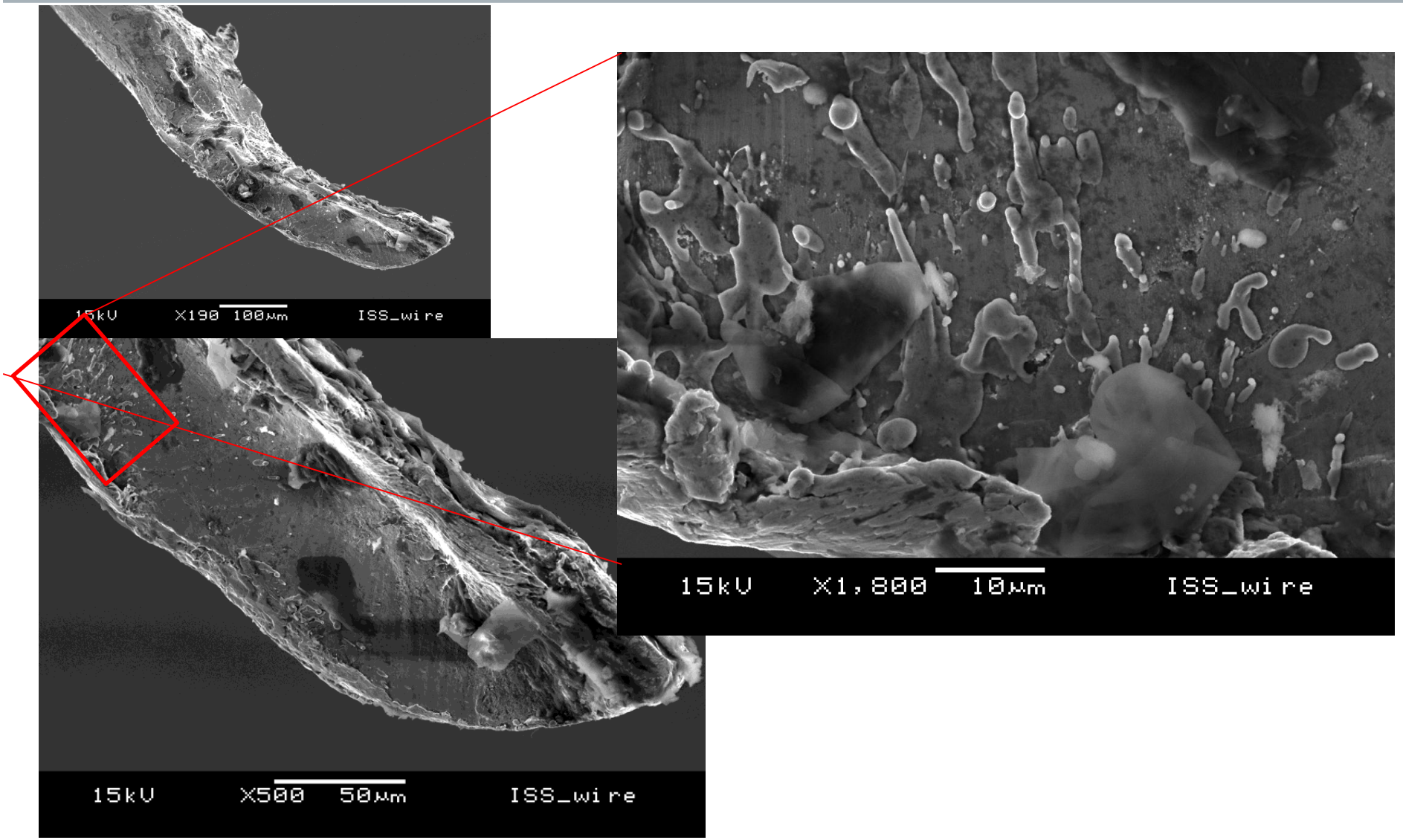


Source: D.K. Ross, et al., “Biennial Research and Technology Development Report”, Johnson Space Center, K. Lulla, editor. NASA TM-2011-216163

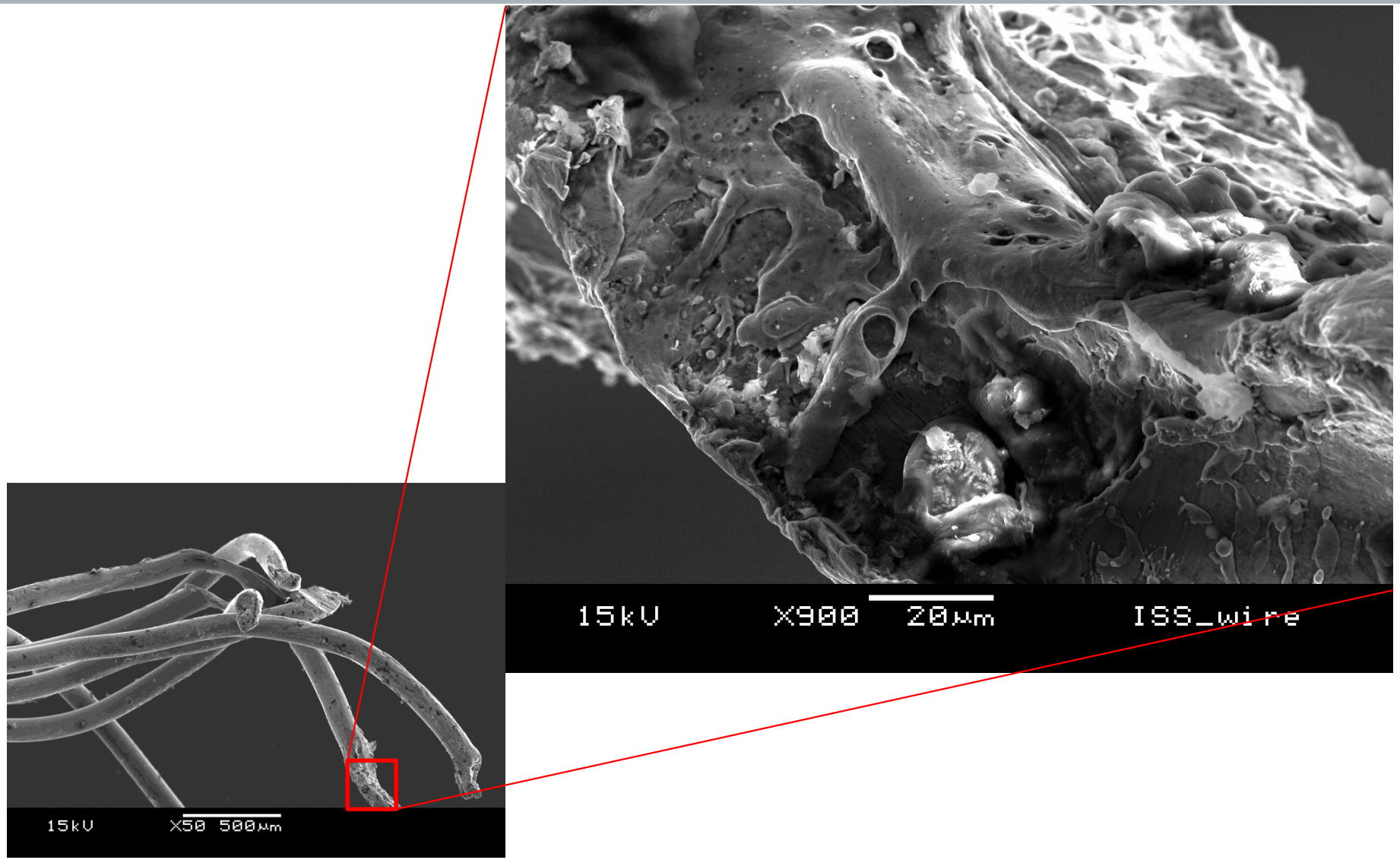
External Surface Changes on ISS



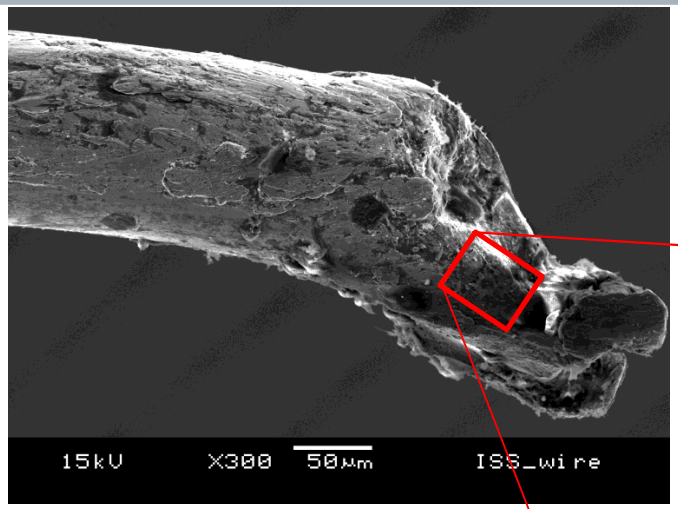
External Surface Changes on ISS

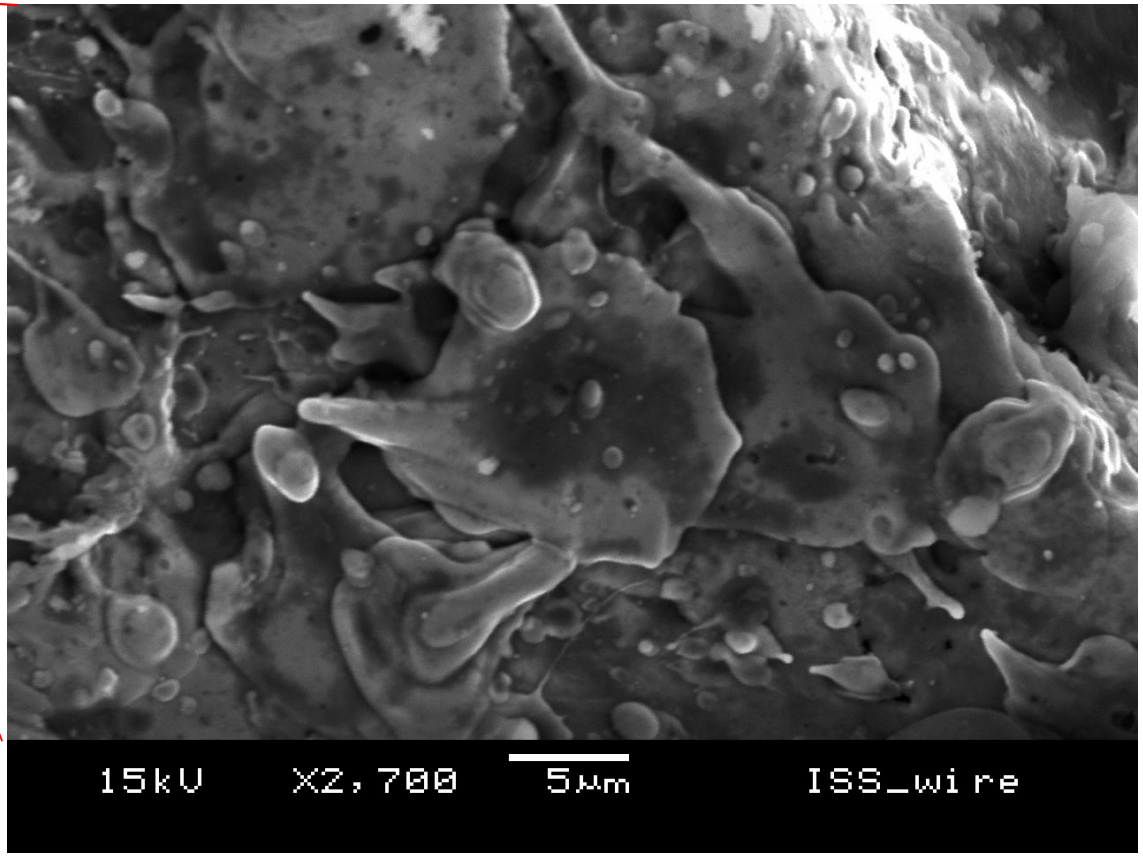


External Surface Changes on ISS

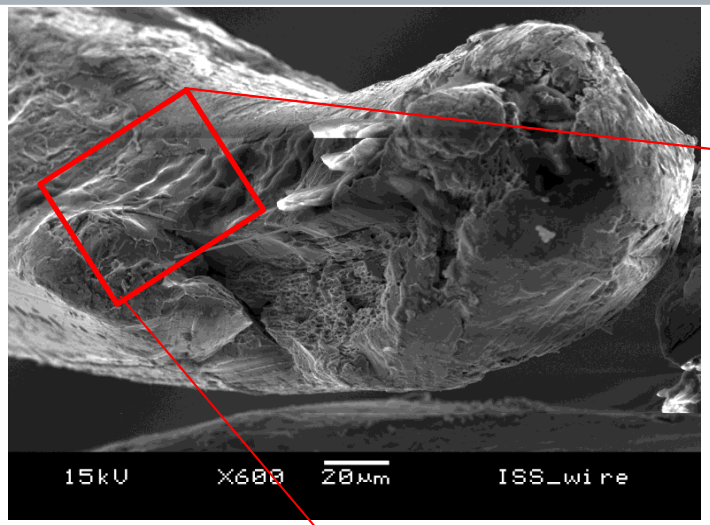


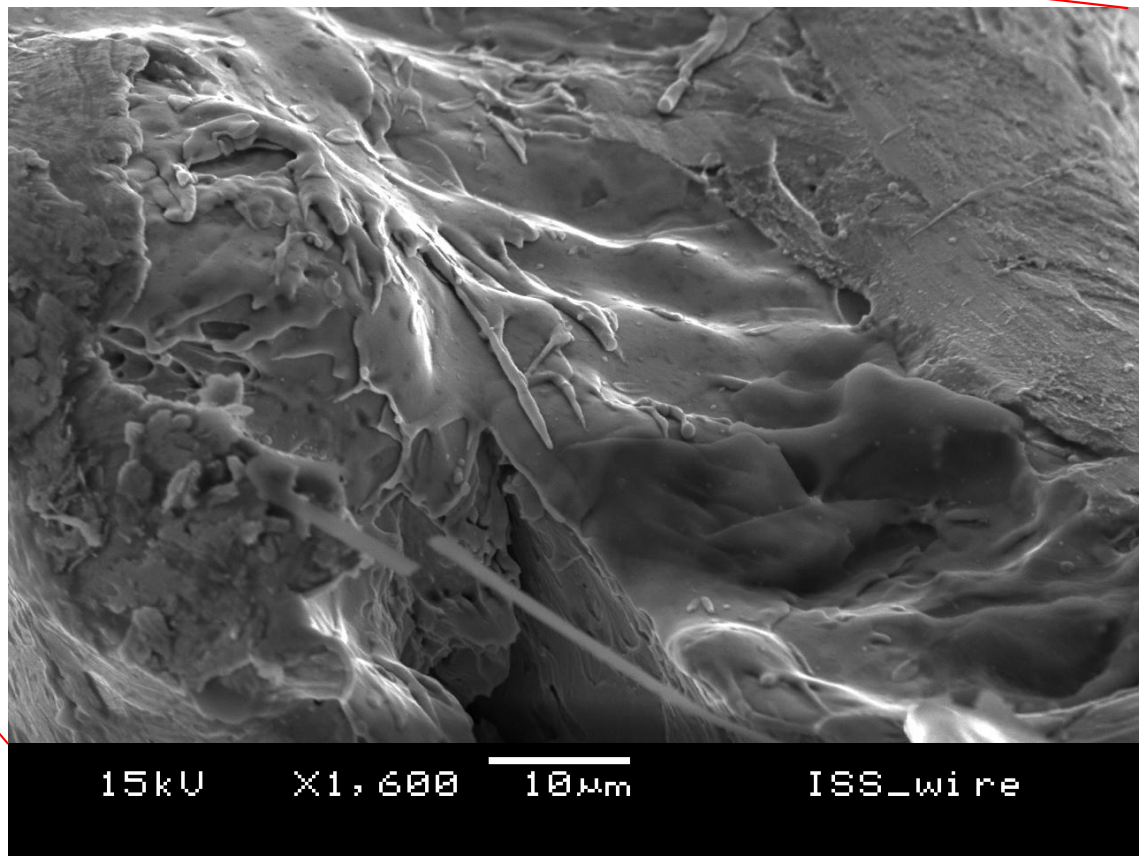
External Surface Changes on ISS



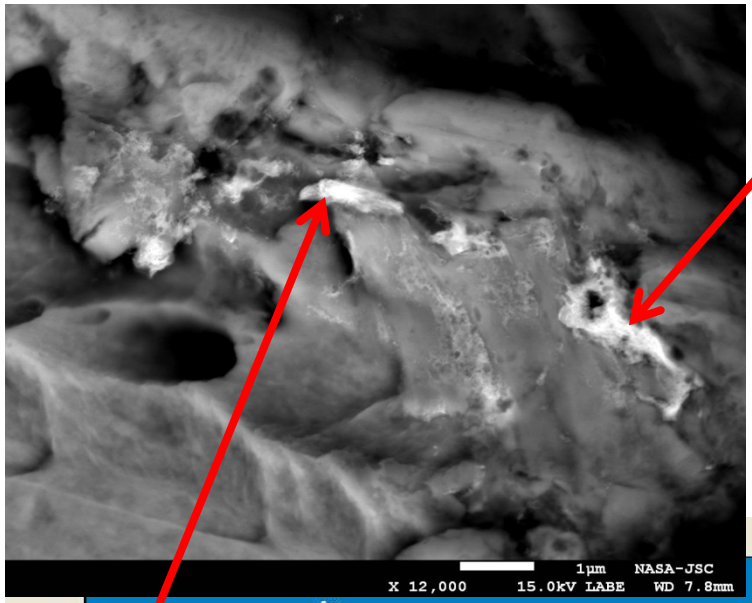


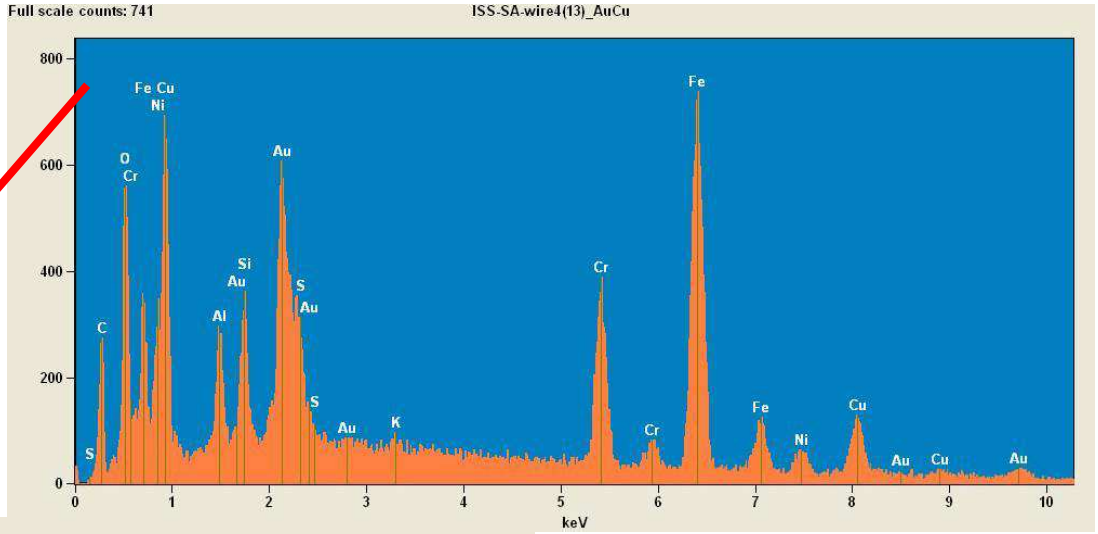
External Surface Changes on ISS

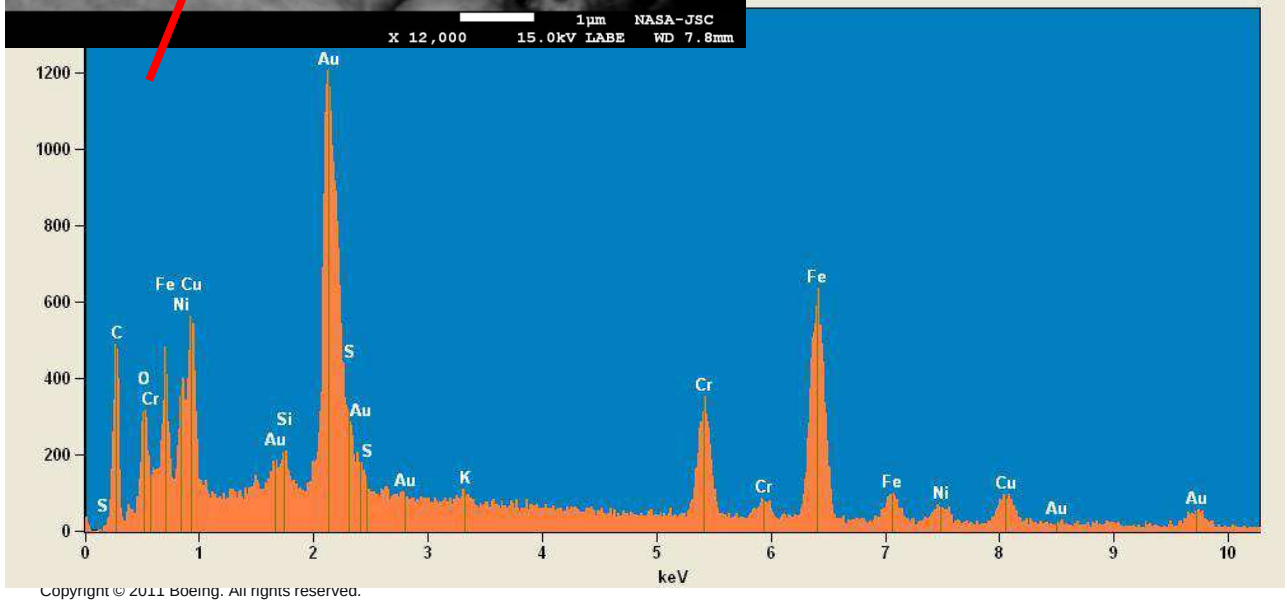




External Surface Changes on ISS



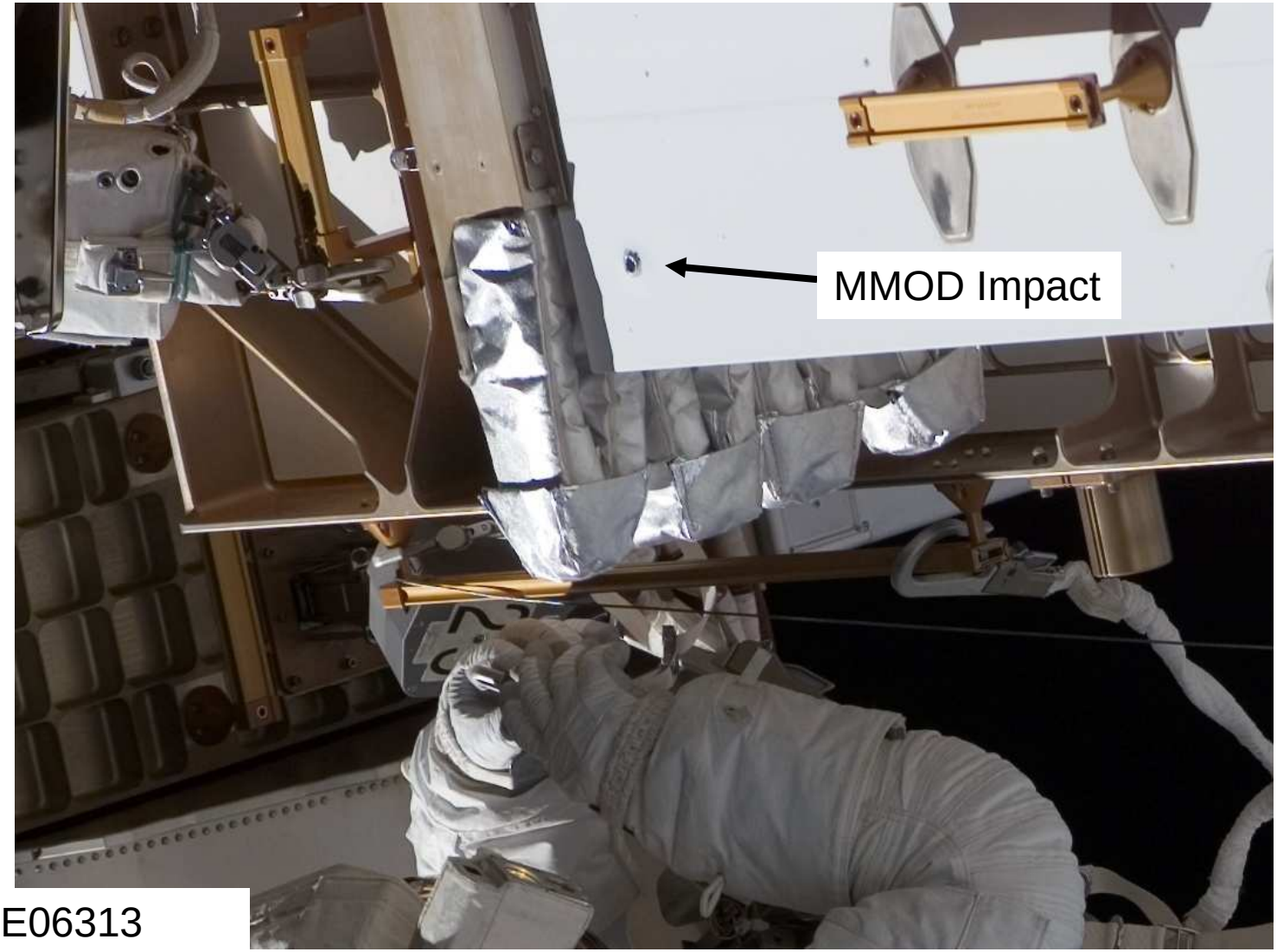




External Surface Changes on ISS

- P6 Guidewire sample observations
  - SEM images reveal abundant evidence of melting and melt mobility on several strands in the guidewire.
  - Several areas of unusual chemical composition were observed in the melt region.
    - Bismuth and Gold/Copper particles.
    - The Fe/Cr/Ni composition of the wire make it difficult to discern some types of micrometeoroids.
  - The evidence suggests that orbital debris impact of sufficient energy damaged wire(s) in the wire bundle.
    - Individual wire(s) breaking would cause the wire bundle to unravel, leading to additional mechanical damages, which lead to eventual complete failure of the guidewire.
    - The failed guidewire snagged into the solar array wing, leading to the damage observed during redeploy.

External Surface Changes on ISS



S118E06313

External Surface Changes on ISS

Space Environmental Effects

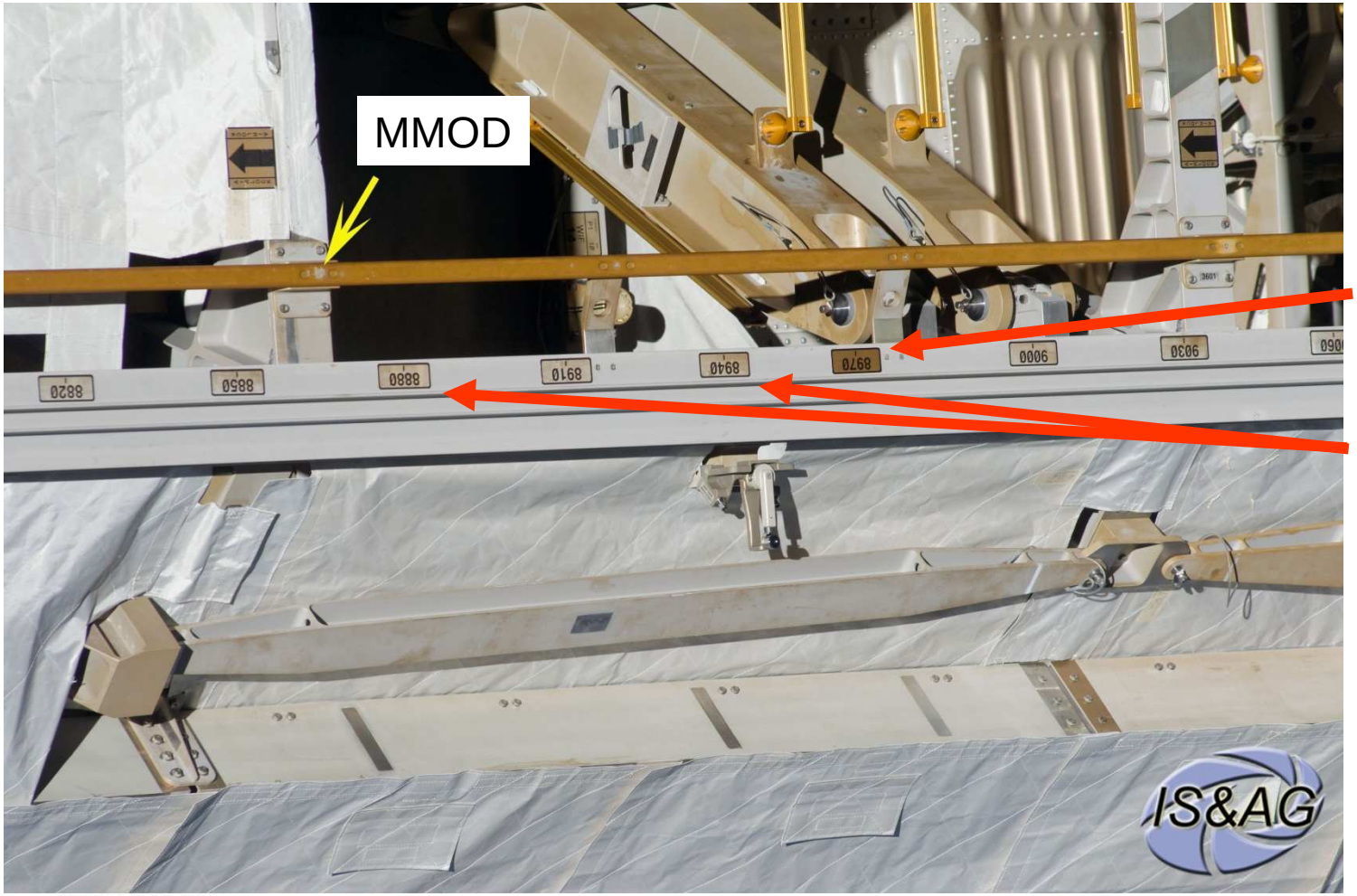
Preflight (closeout) Photo showing anodized foil labels

External Surface Changes on ISS

Space Environmental Effects

External Surface Changes on ISS

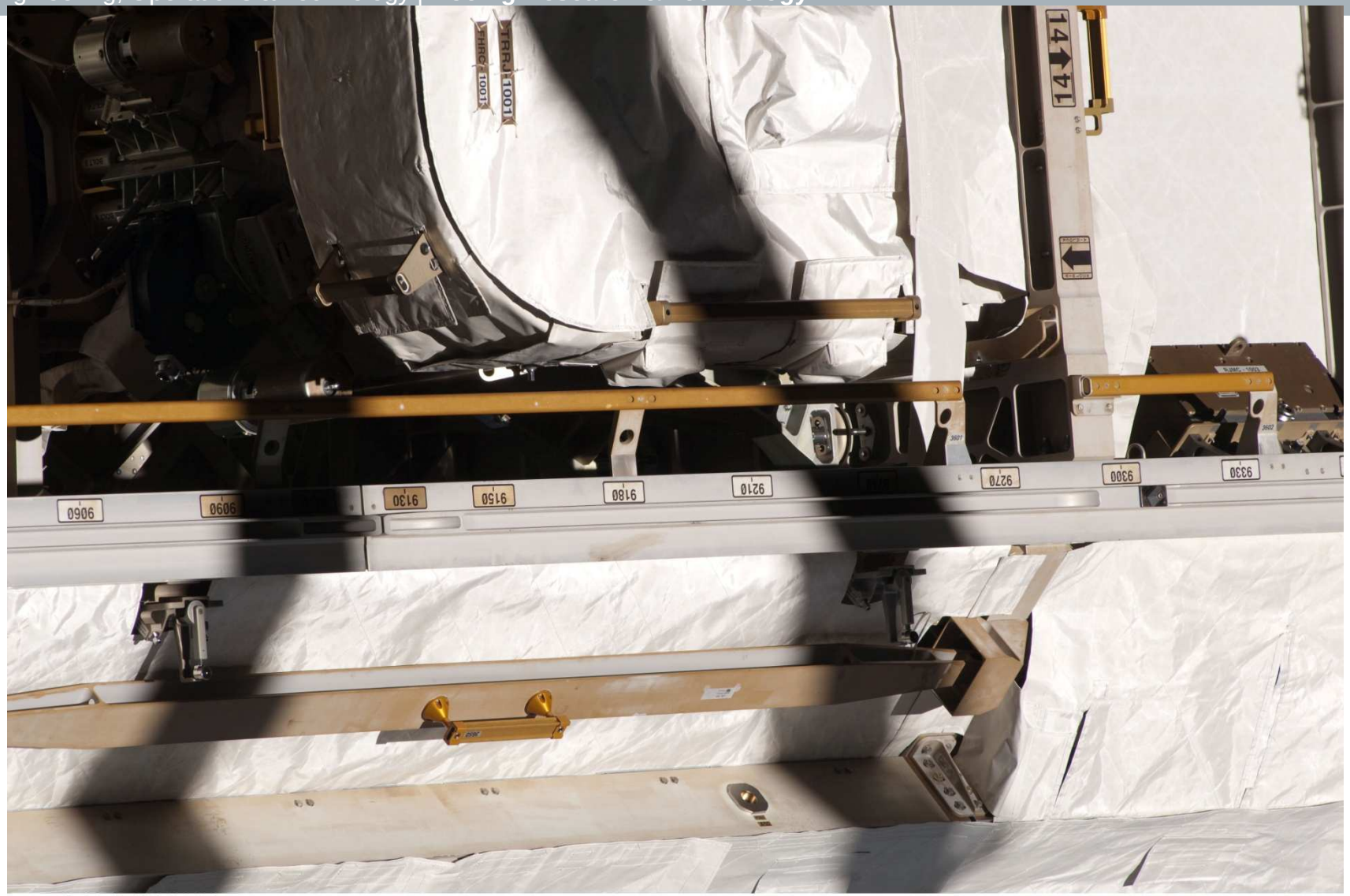
Space Environmental Effects



S128E008103

Anodized aluminum labels, which darkened quickly, have begun to recover their expected appearance with continued AO exposure!

External Surface Changes on ISS



S131E009933

External Surface Changes on ISS

Space Environmental Effects – Frequent and "New" Visiting Vehicles

Soyuz docked to FGB
Outgassing or Thruster Contamination

ISS022E067004

External Surface Changes on ISS

Space Environmental Effects – Frequent and "New" Visiting Vehicles

ISS021E031911

Opposite direction from previous photo

External Surface Changes on ISS

Issues with Imaging

Charged Particle affecting Digital Video Camera Imaging

External Surface Changes on ISS

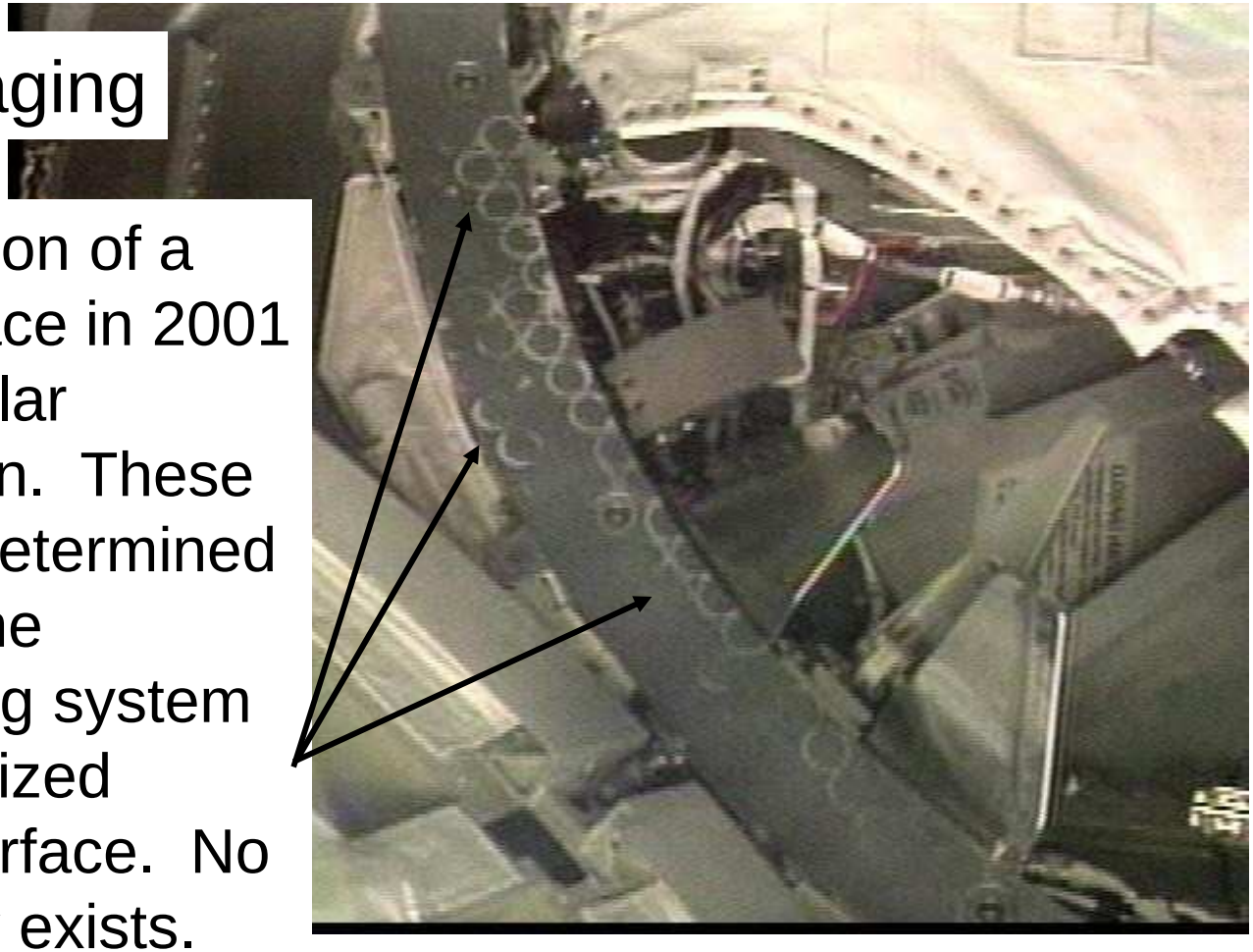
Issues with Imaging - Reflections

ISS023E021963

External Surface Changes on ISS

Issues with Imaging

Pre-berthing inspection of a Node 1 sealing surface in 2001 identified these circular features as a concern. These features were later determined to be reflections of the camera's LED lighting system on the smooth, anodized aluminum sealing surface. No such feature actually exists.



External Surface Changes on ISS

Conclusions

- Some worse-than-expected materials degradation effects have been observed on ISS, but only one has created an operational issue (during P6 redeploy) and some surfaces (as with the anodized aluminum labels) appear to be recovering.
- Inadvertent materials substitutions have been observed, but none have created any operational issues.
- Hardware handling contamination effects have been observed, and although none have created operational issues, there is clearly room for improvement in this regard.
- Even with robust materials selections, space environmental effects will be observed.
- Be cautious when interpreting photography, as lighting conditions and the environment affect interpretation.

External Surface Changes on ISS