

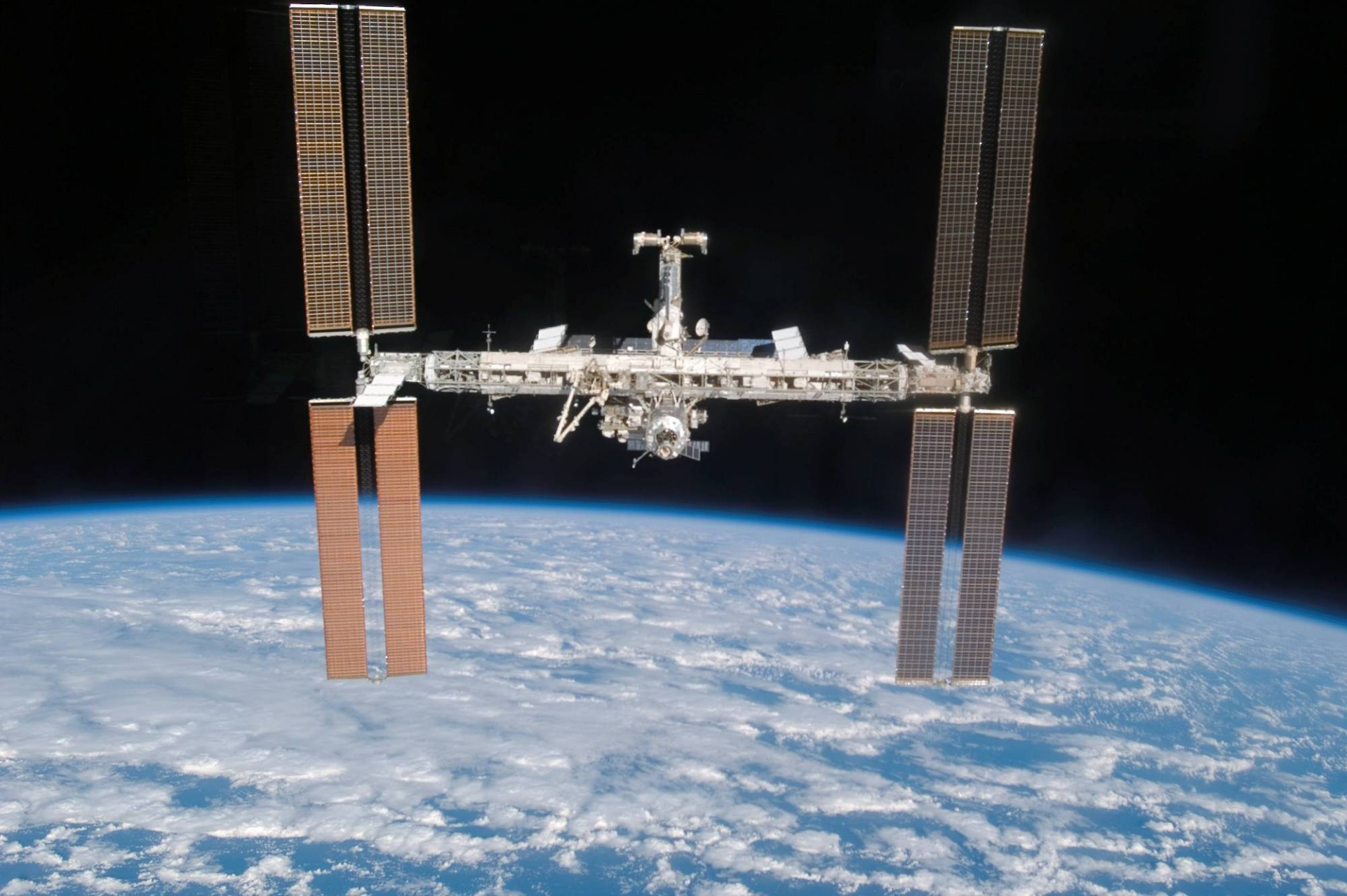
Atomic Oxygen Erosion of EVA-stranded Soft-goods on the ISS

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International Space Station – Flight 13A



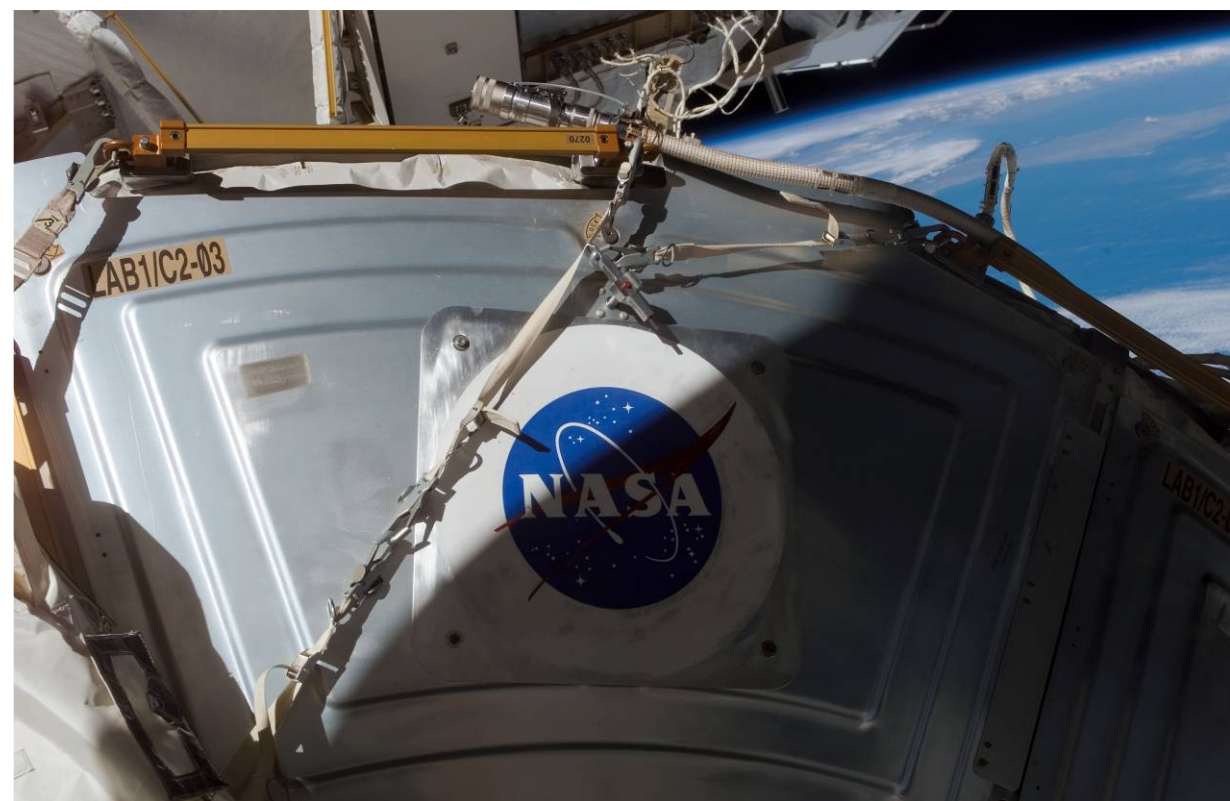
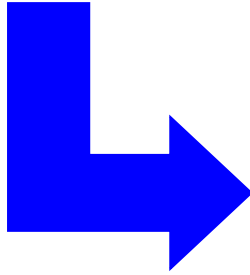
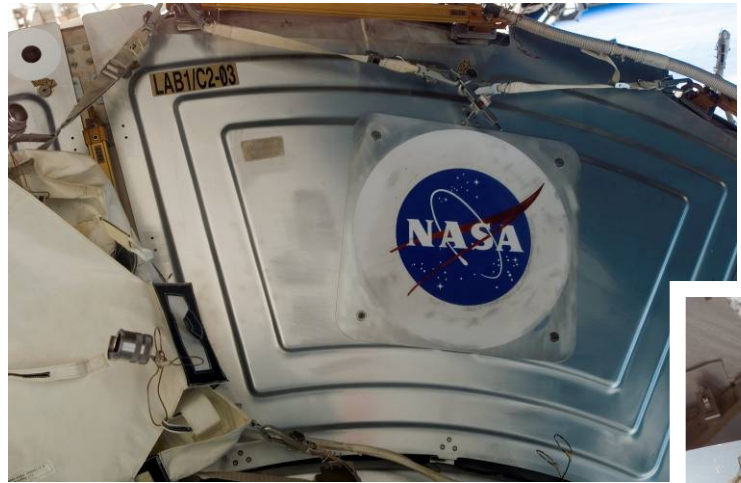


Problems, Problems, Problems

- **Year 2007 was the most challenging for the ISS Program.**
 - ➔ **Russian computer failures on Flight 13A (STS 117).**
 - ➔ **Starboard SARJ anomaly - starting on Flight 13A.**
 - ➔ **EMU Glove cuts exacerbated starting on Flight 13A.**
 - ➔ **Solar Array Wing repair on Flight 10A (STS 120).**
- **During Flight 13A EVA 4 (6/17/07), the EVA crew had difficulty securing the micrometeoroid and orbital debris (MMOD) shields on the Node 1 and US Lab.**



Lab MMOD Shield



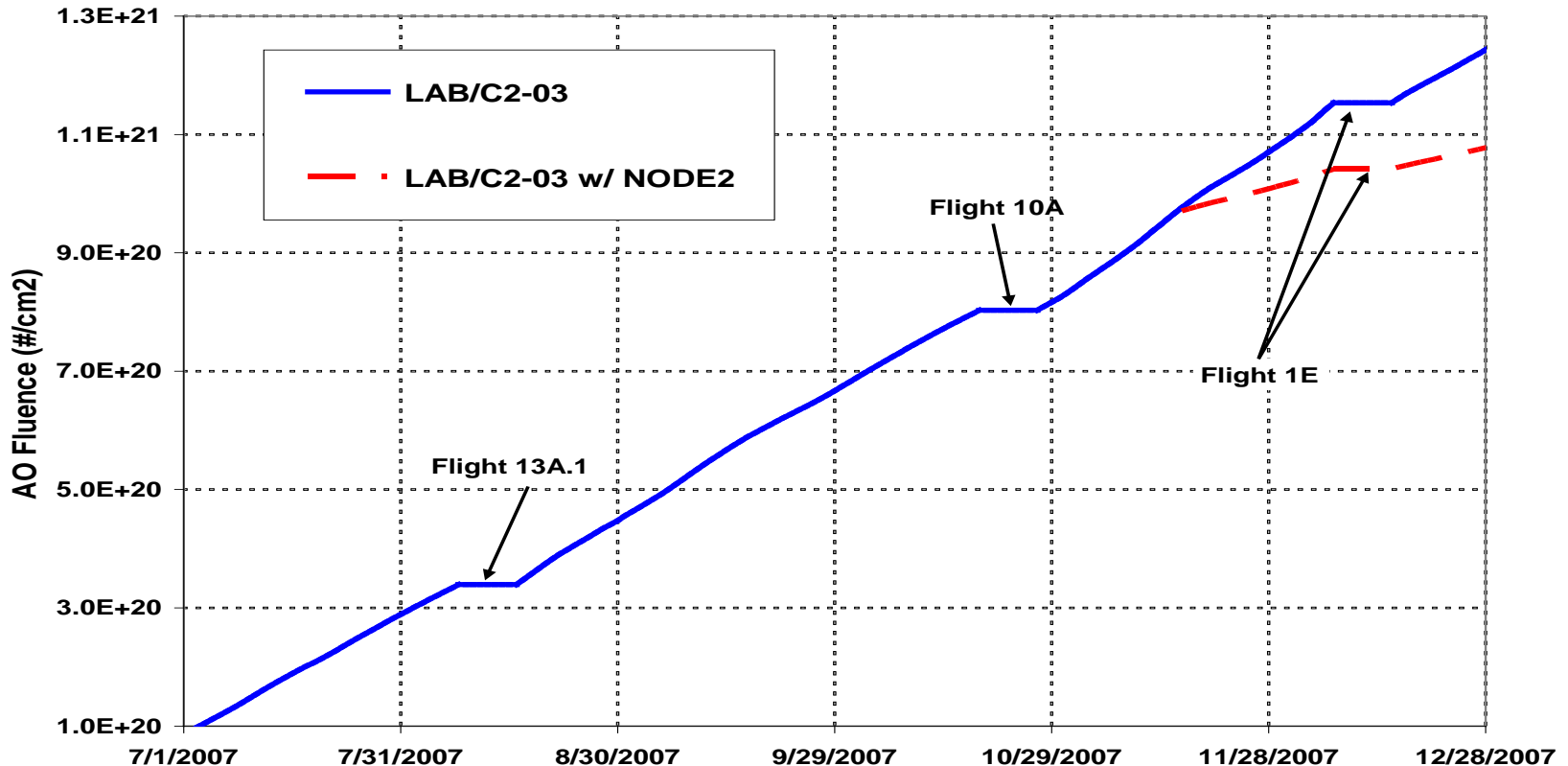


Solution

- **6 Adjustable Equipment Tethers (AETs) used to secure the MMOD shields:**
 - ➔ 3 AETs for Node 1 shield
 - ➔ 3 AETs for US Lab shield
- **Limited life assessments for Nomex based on ES4 test of Nomex at MSFC (Atomic Oxygen Fluence of 1.4×10^{21} atoms/cm²).**
- **Currently Nomex is limited to 2453 hours (~102 days) EVA exposure based on worst case AO Flux (5.0×10^{21} atoms/cm²-yr).**

ISS Program Query

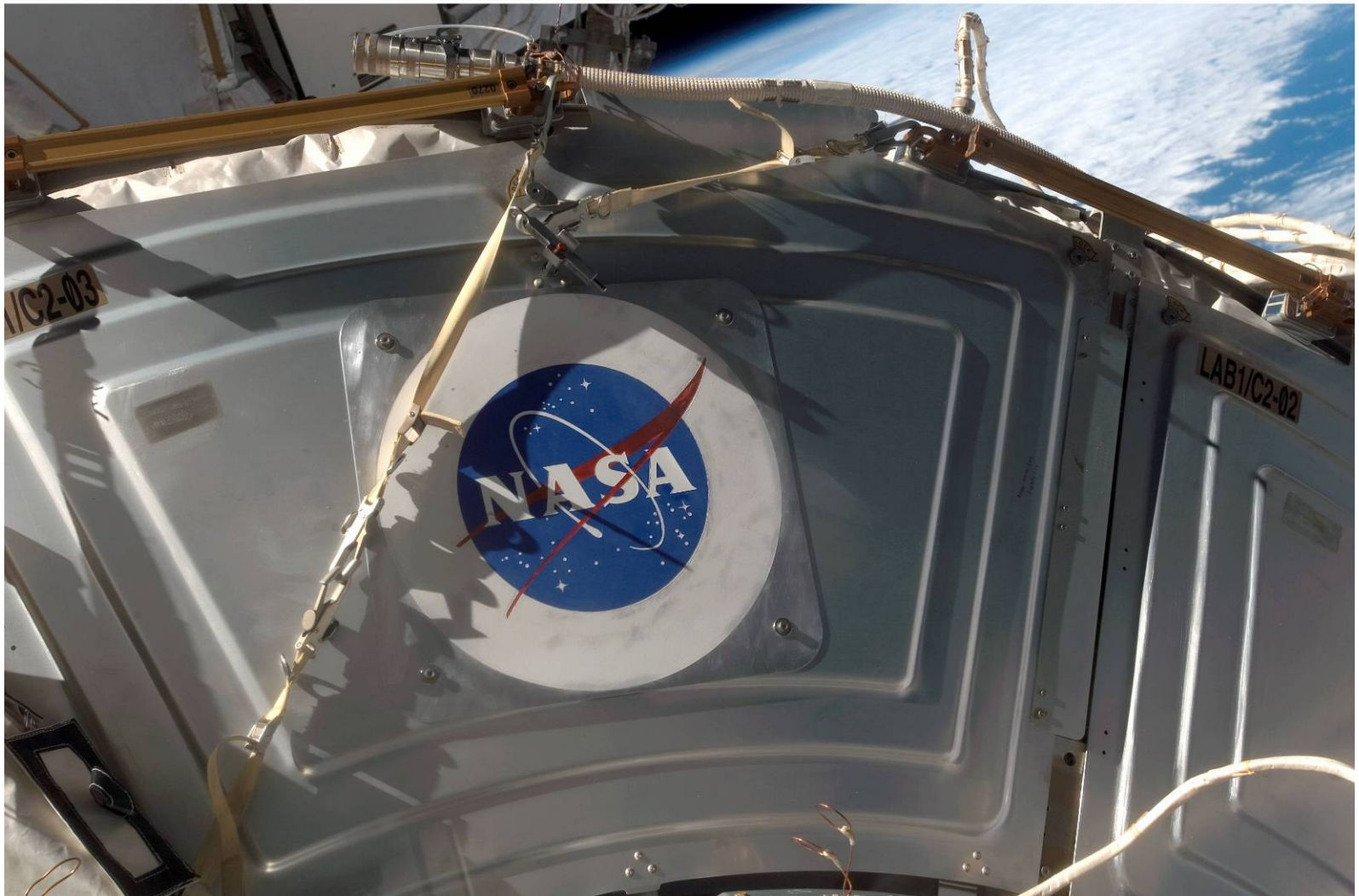
- How Long can AETs be left outside?
- ES4 answer – about eight months.





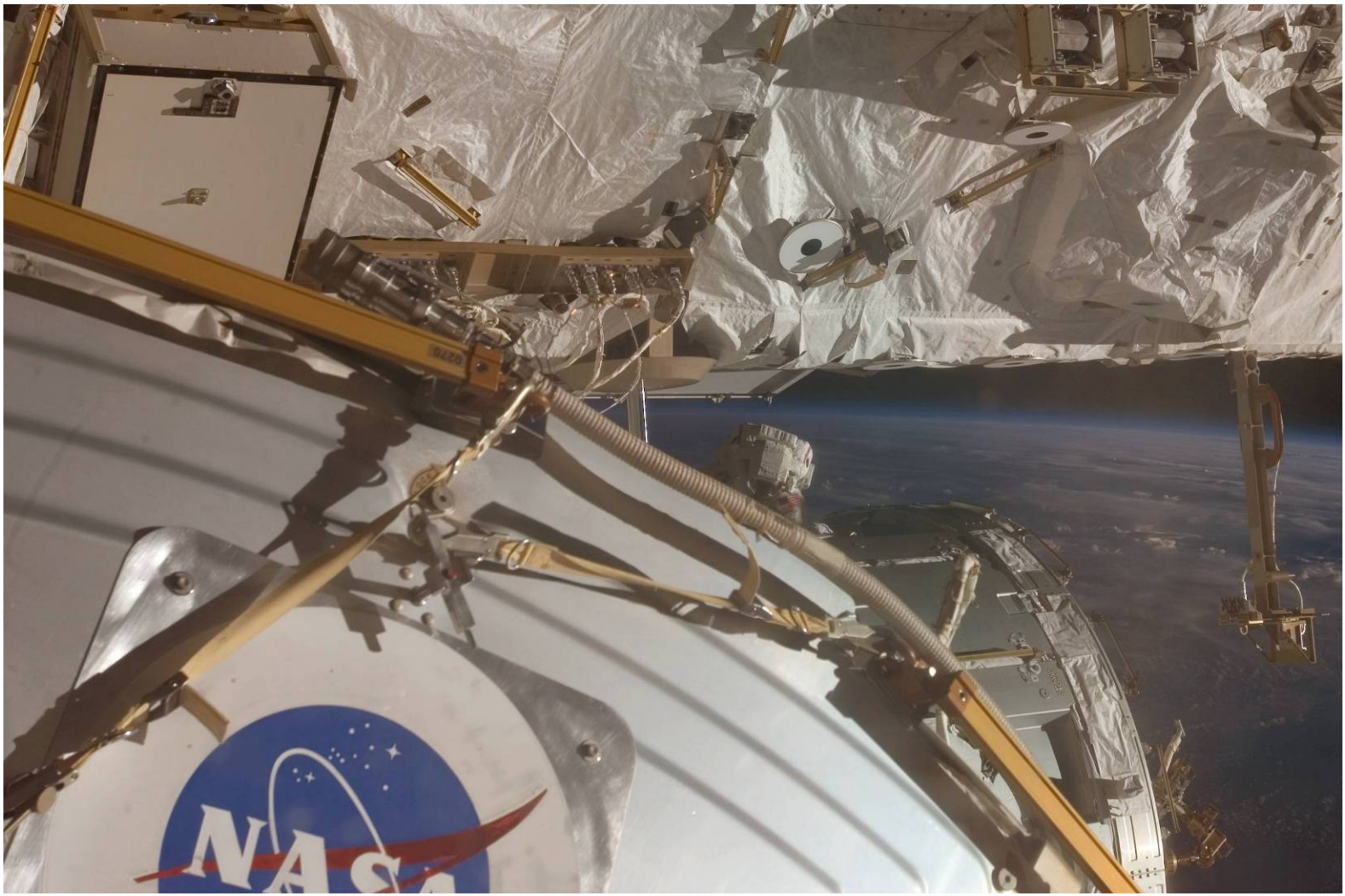
Meanwhile : Flight 13A.1 (STS-118)

S118E07530



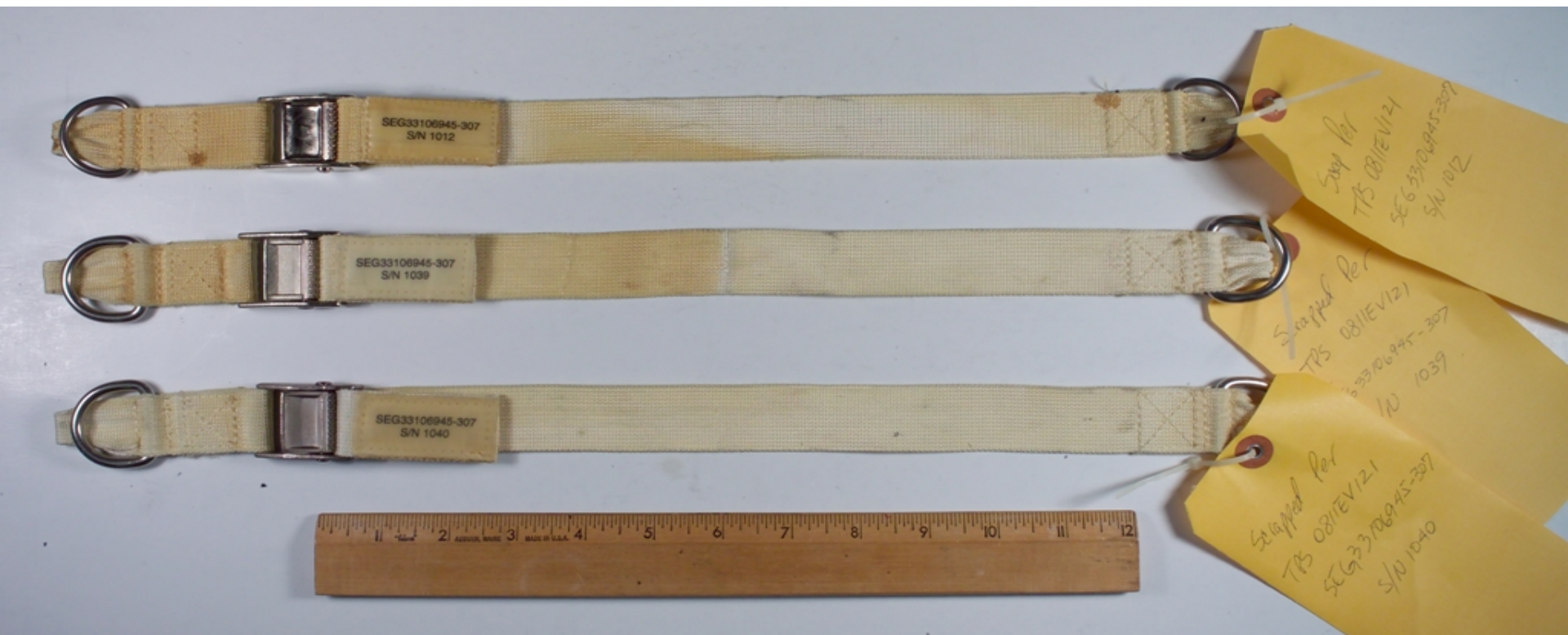


Meanwhile : Flight 10A (STS-120)



Retrieval

- AETs on US Lab MMOD shield removed on Flight 10A (STS-122) EVA 3 (on 2/13/08) and returned to Houston.



Back View



Comparison



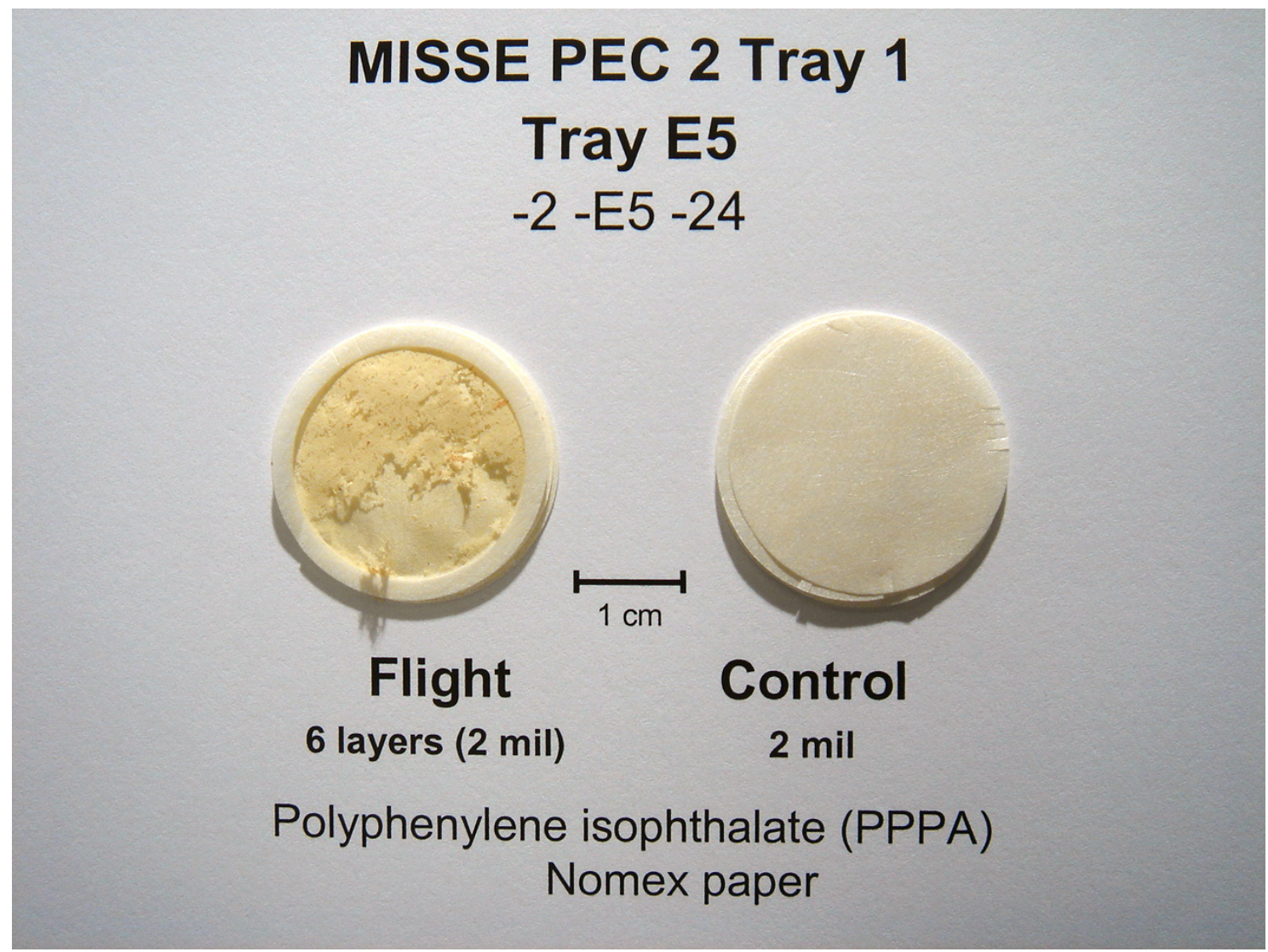
What We Expect for Nomex

AO Erosion
Yield :

**Polyphenylene
 isophthalate
 (Nomex)**

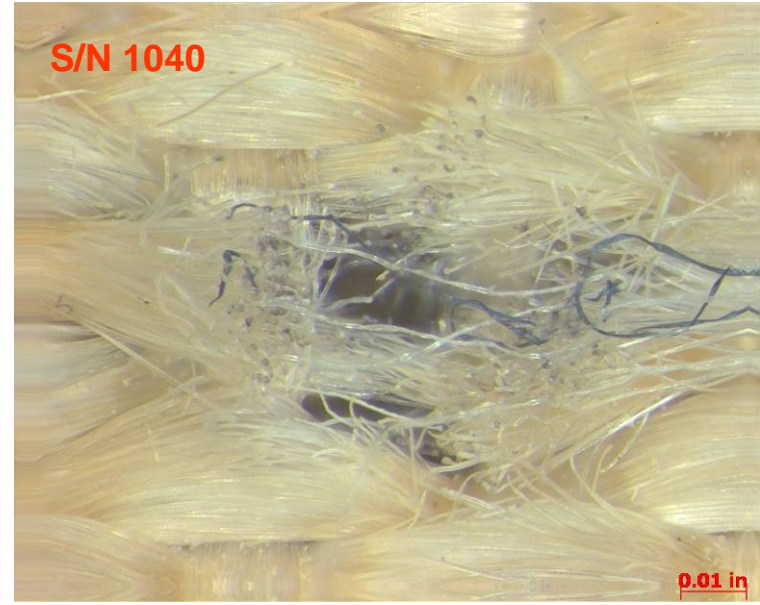
**1.41×10^{-24}
 cm^3 per atom**

**Based on this,
 the AETs
 should show
 ~0.1 mm loss.**

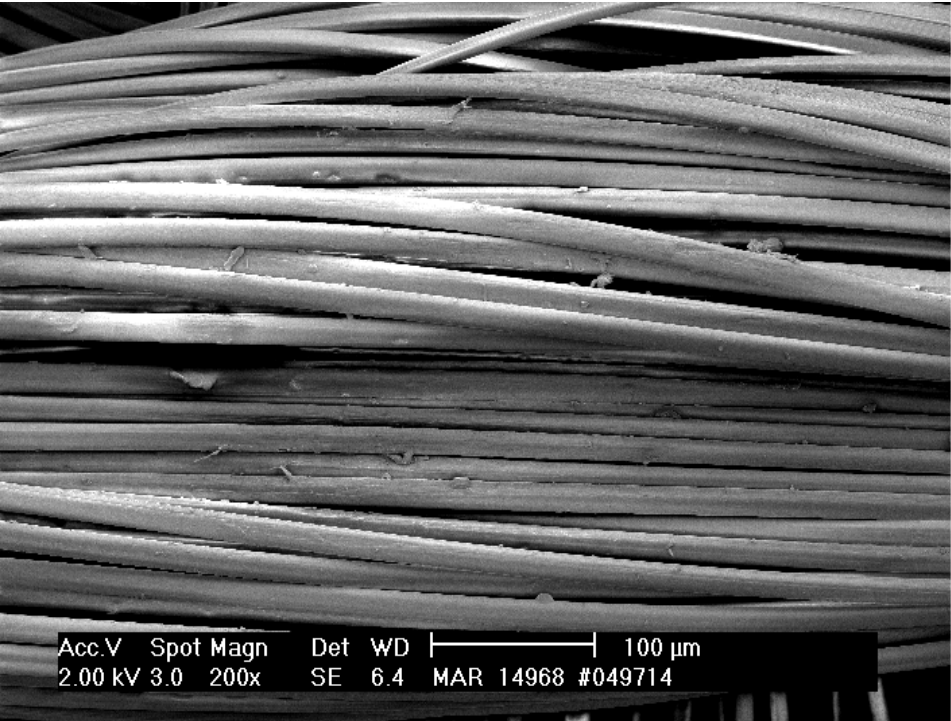


Visual Inspection

- Visual photography taken at 8X showed minimal degradations of Nomex webbing



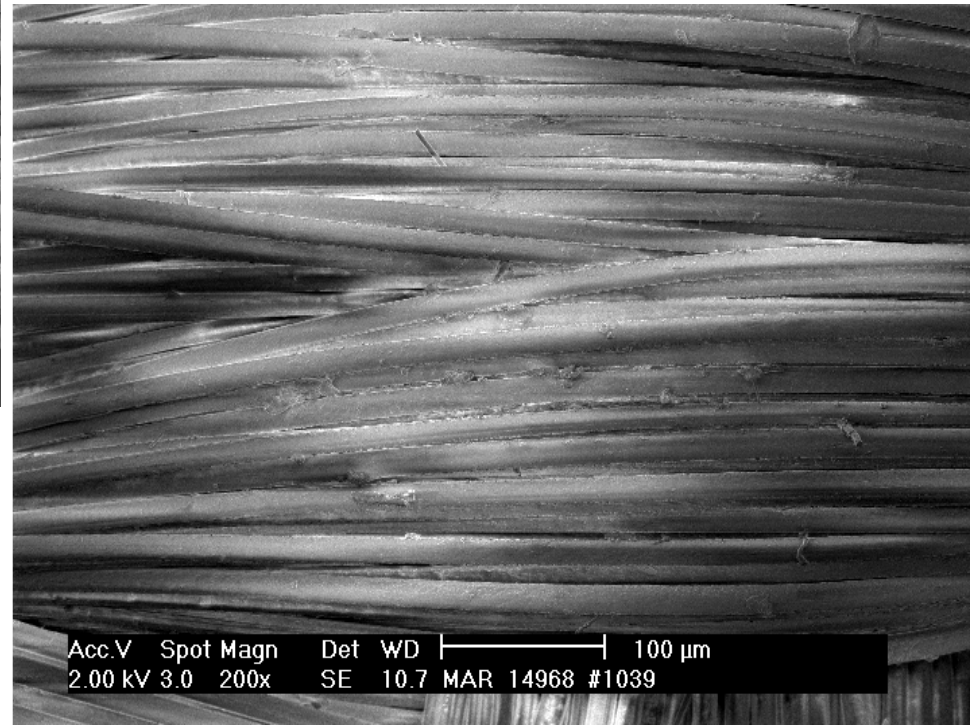
SEMs



Acc.V Spot Magn Det WD | 100 μm
 2.00 kV 3.0 200x SE 6.4 MAR 14968 #049714

Pristine Nomex sample

Sample from AET S/N 1039

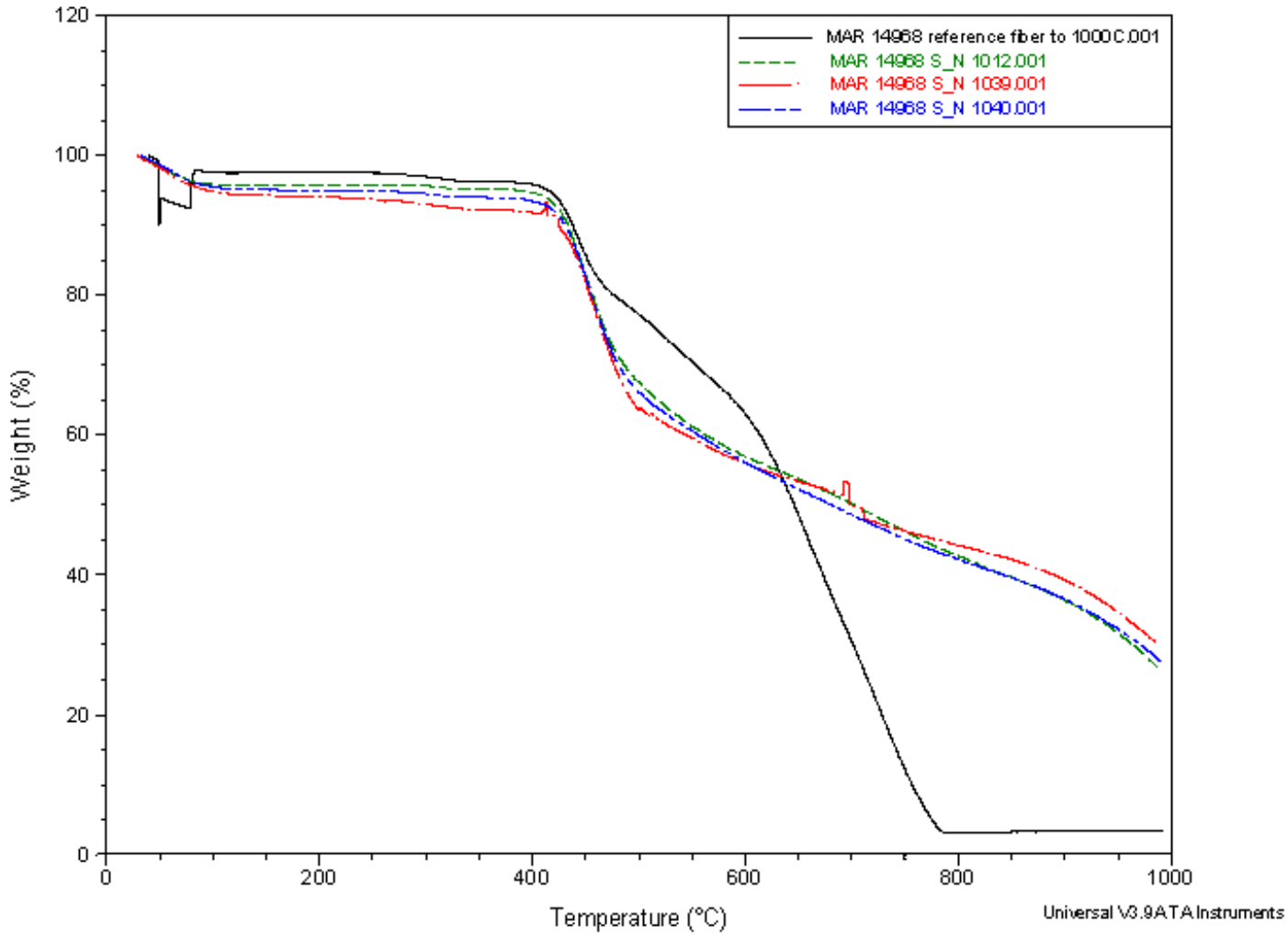


Acc.V Spot Magn Det WD | 100 μm
 2.00 kV 3.0 200x SE 10.7 MAR 14968 #1039



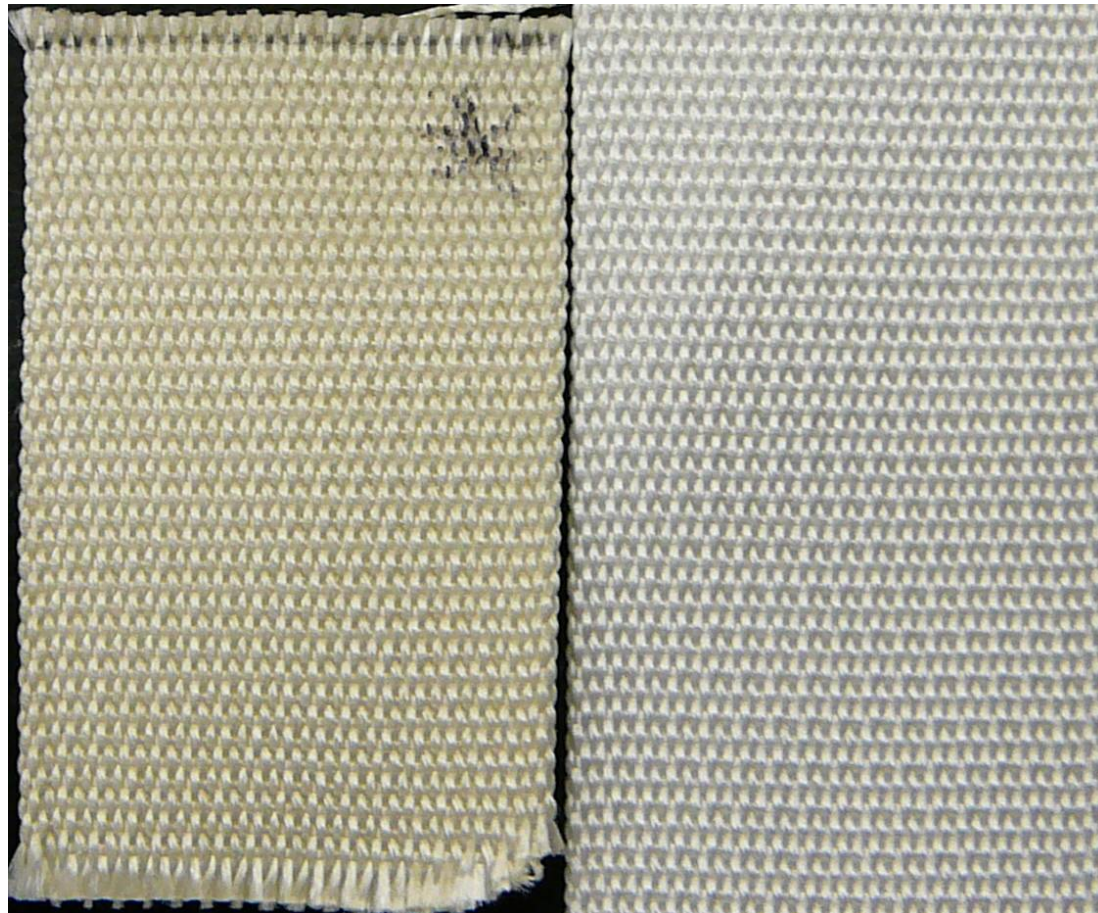
Thermogravimetric (TGA) testing

➤ Pristine Nomex sample versus the on-orbit tethers.



UV Exposure of Nomex

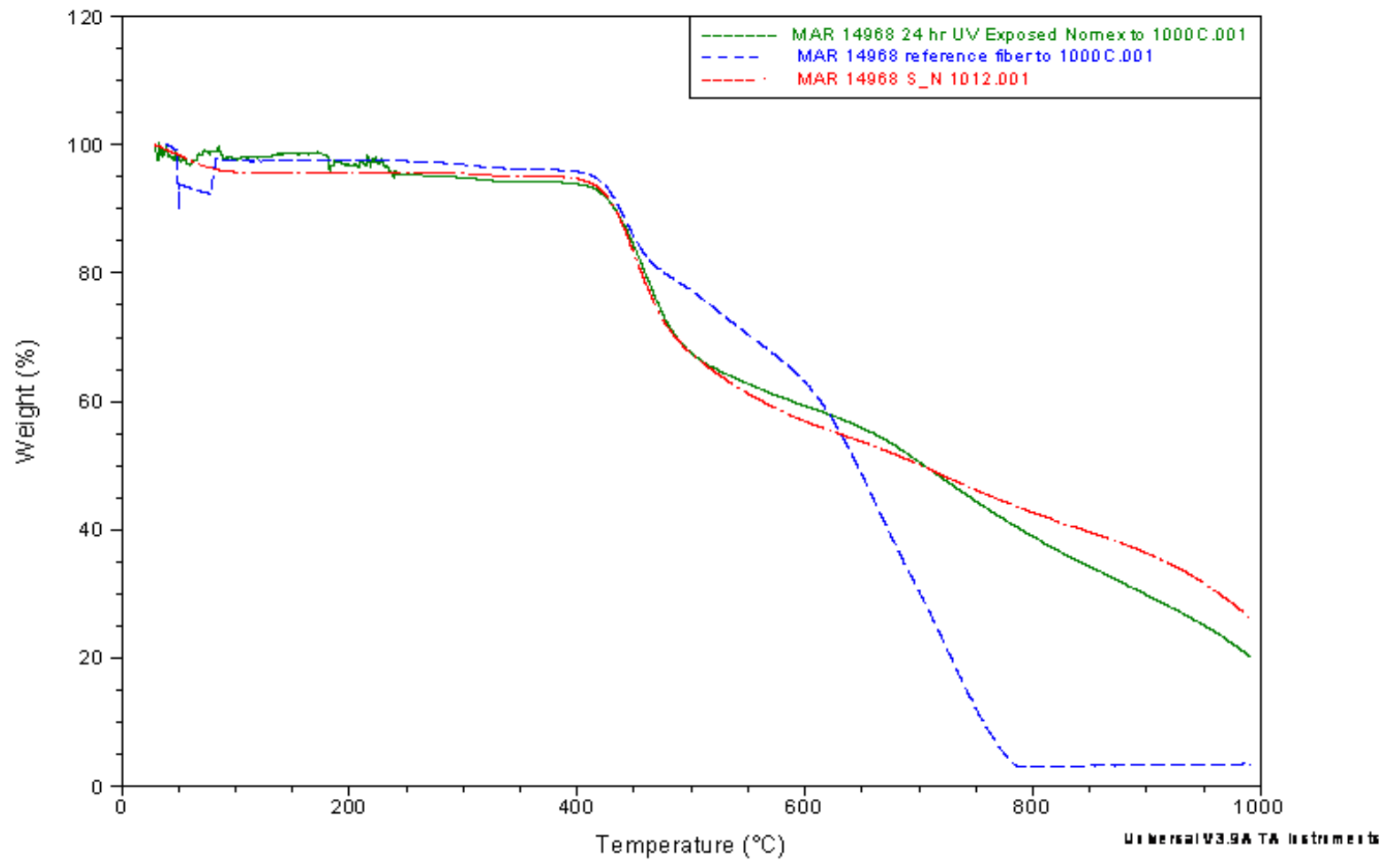
- Pristine Nomex sample exposed to UV in lab.
- Image below shows a sample exposed to UV for 12 hours.





Comparisons w/ UV Sample

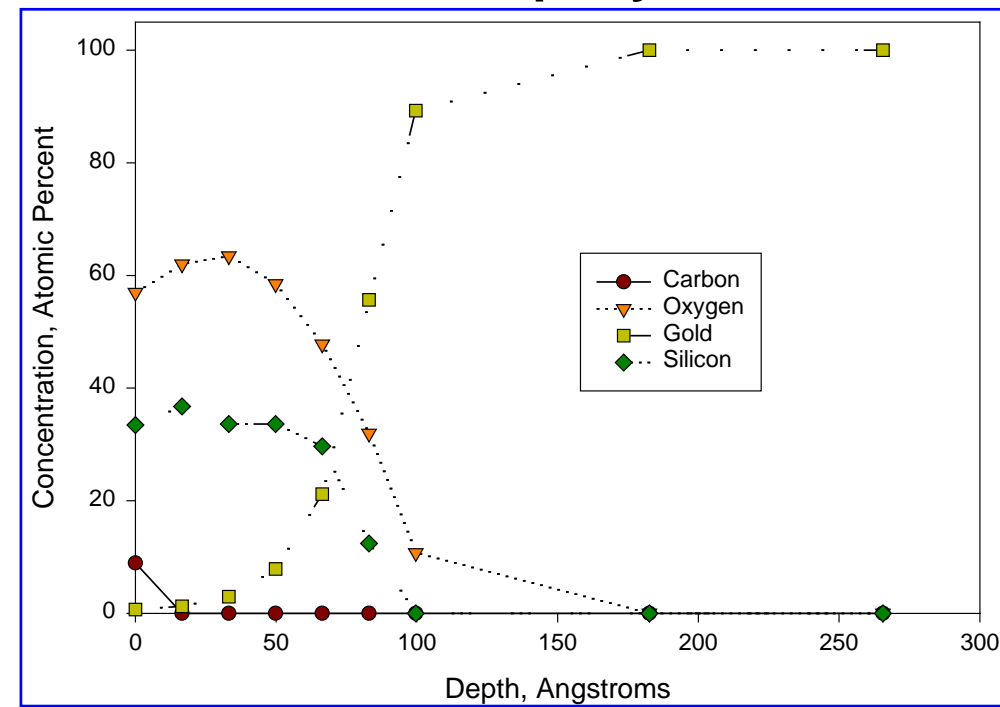
➤ UV altered Nomex closely resembles that of the on-orbit tethers





Another Piece of the Puzzle

- Silicon found from energy dispersive analysis during SEMs on the exposed surfaces of the flown AETs.
- Indicative of on-orbit induced molecular deposition from Orbiter and ISS.
- MISSE and Shuttle-MIR RMEs have shown $\sim 70 \text{ \AA}$ per year silicon consistent with Space Environments' External Contamination models.
- Silicon overcoat will protect carbon-bearing materials from AO.





What Next?

- **Report to ISS M&P Systems Manager, ISS Vehicle, and EVA Tools Panel.**
- **Node 1 MMOD Panel AETs to be retrieved next year.**
- **EVA community looking to extend life of ISS support tools/equipment to 2020.**
- **XPS/Depth profiling of flown AETs?**
- **Load testing of controlled samples – exposed vs. non-exposed?**



Special Thanks to

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