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.

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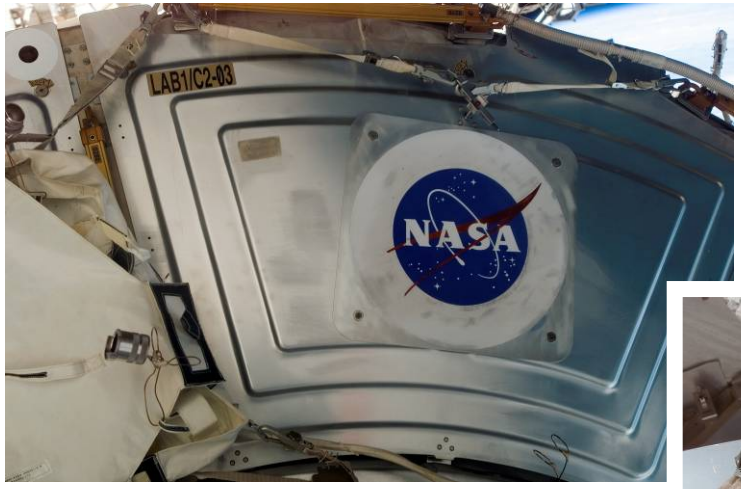
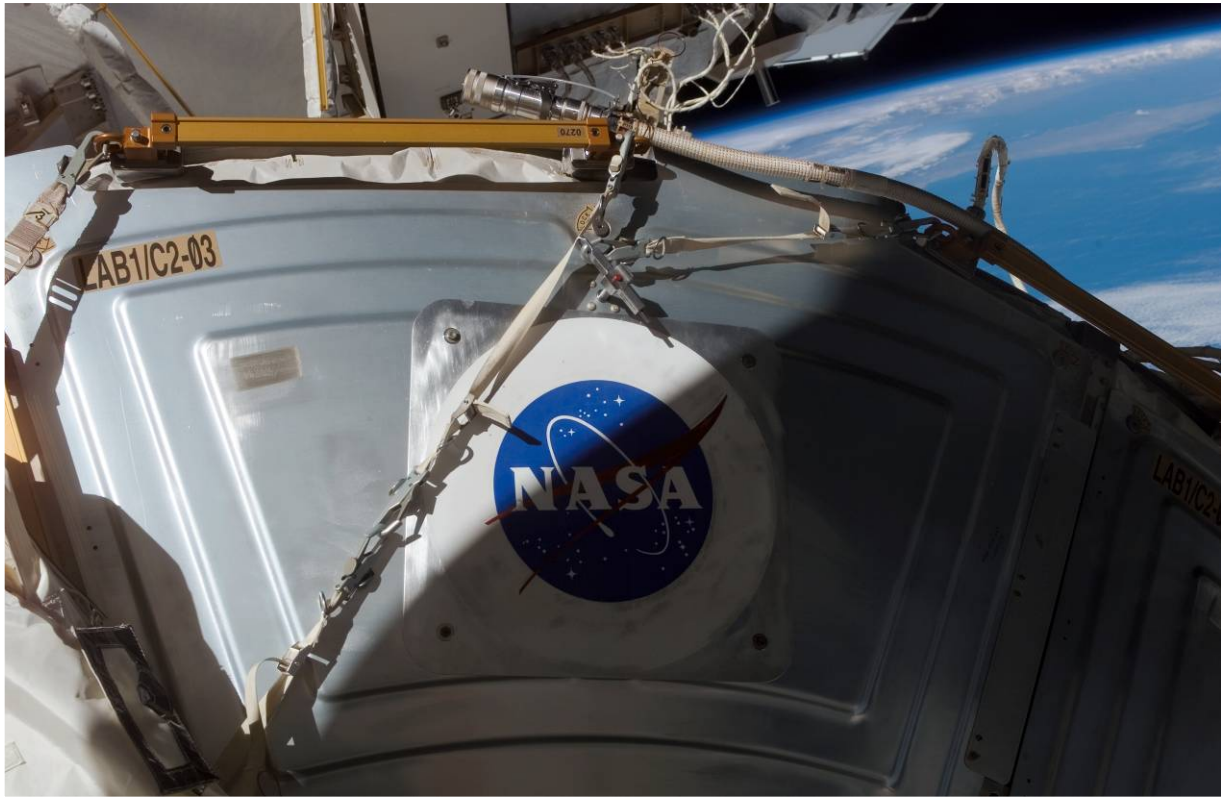
Lab MMOD Shield





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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 x 10^{21} atoms/cm^2) .
- Currently Nomex is limited to 2453 hours (~102 days) EVA exposure based on worst case AO Flux (5.0 x 10^{21} atoms/cm^2-yr).

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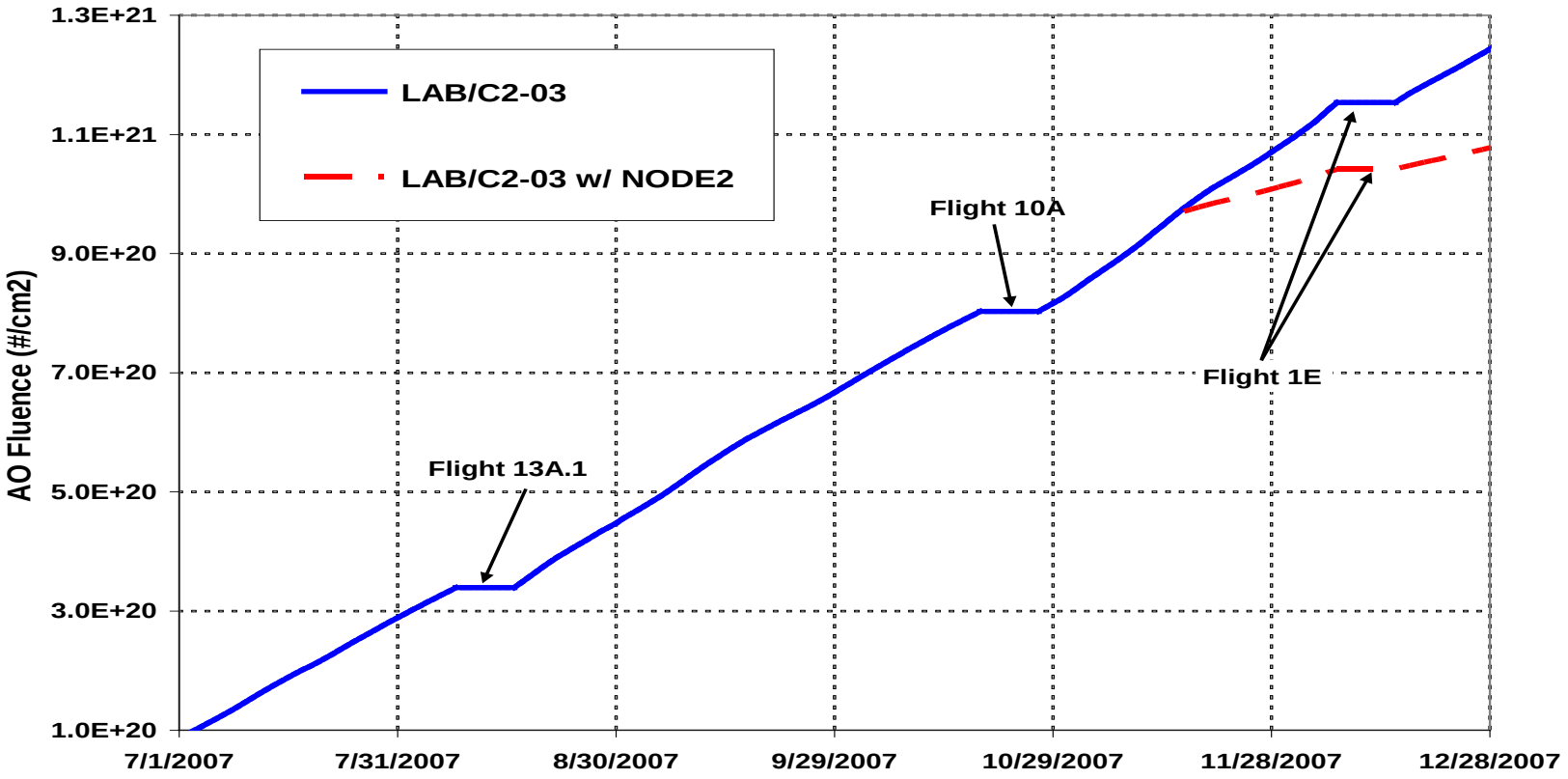
ISS Program Query

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



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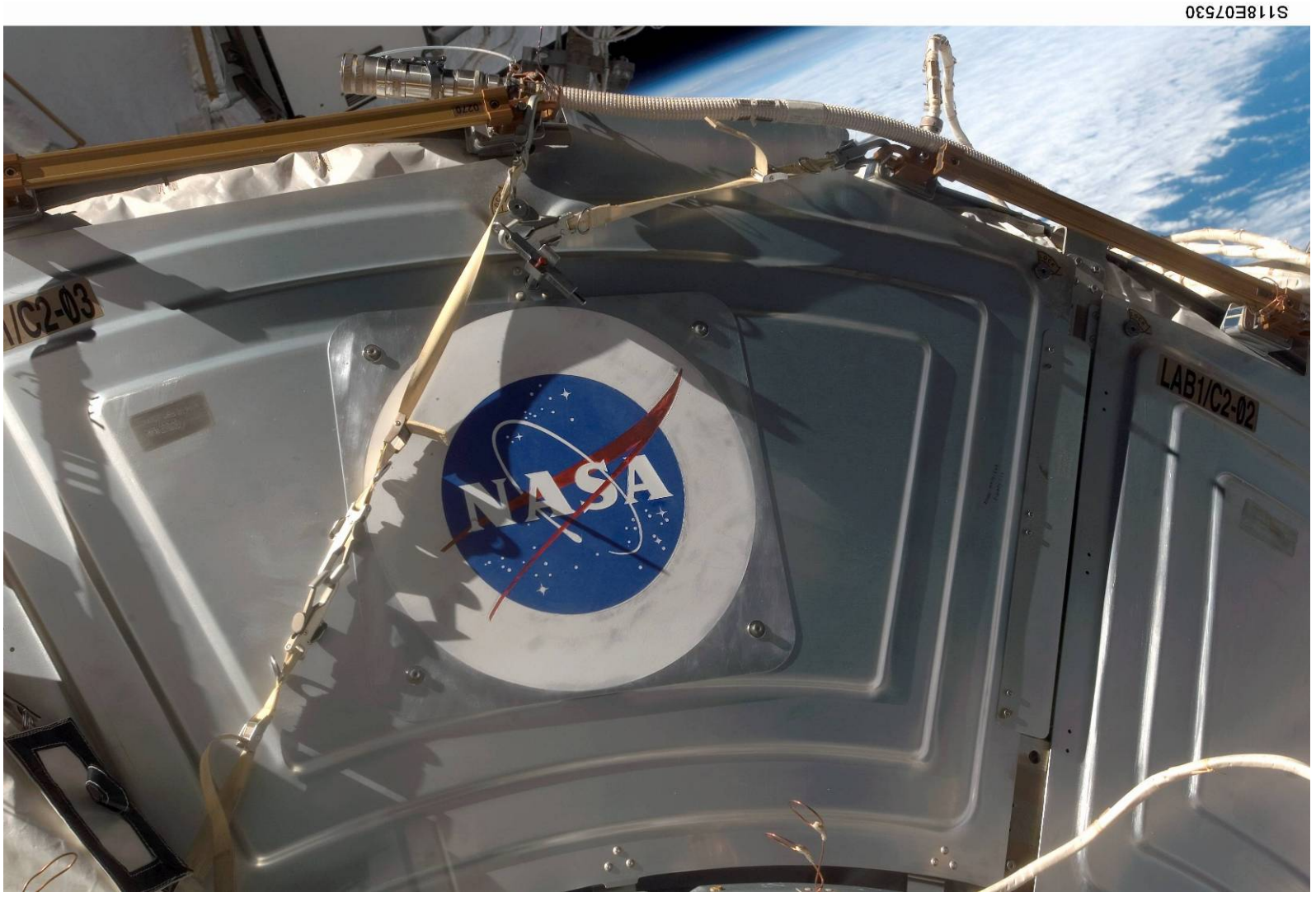
Meanwhile : Flight 13A.1 (STS-118)



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Meanwhile : Flight 10A (STS-120)

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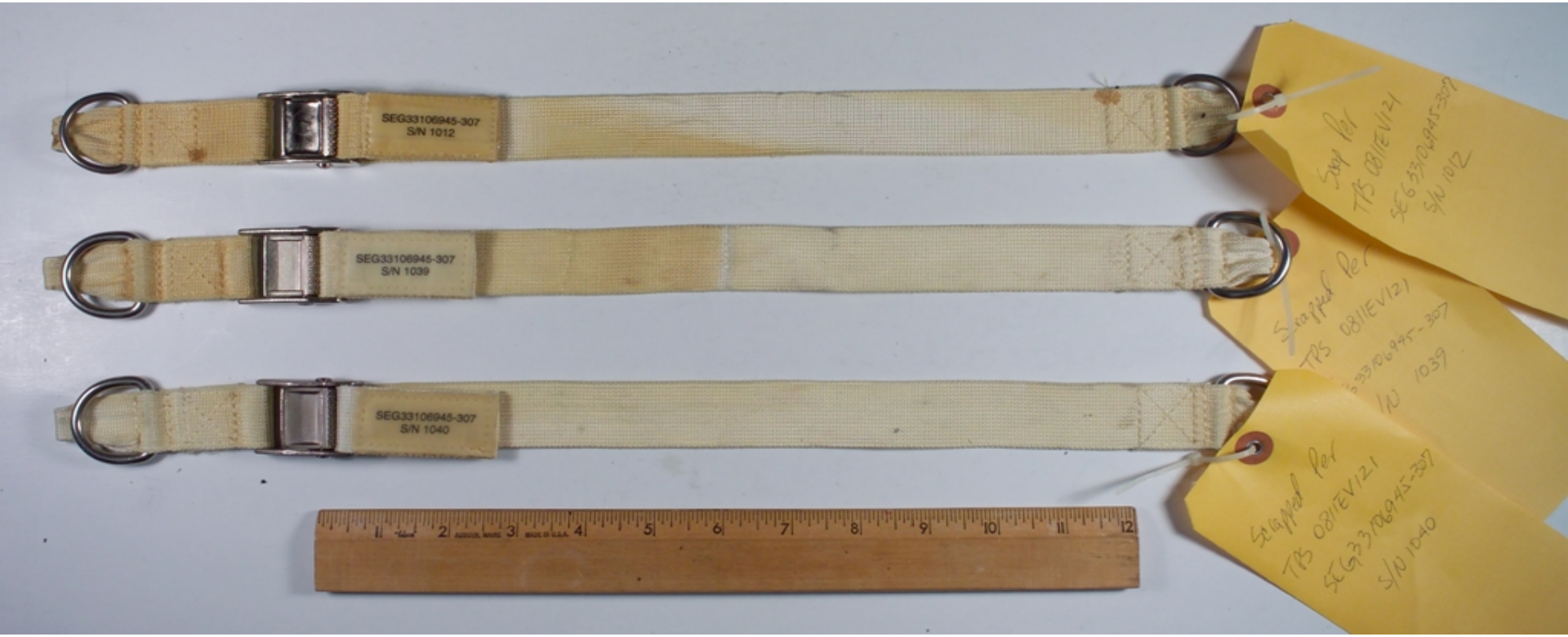
Retrieval

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



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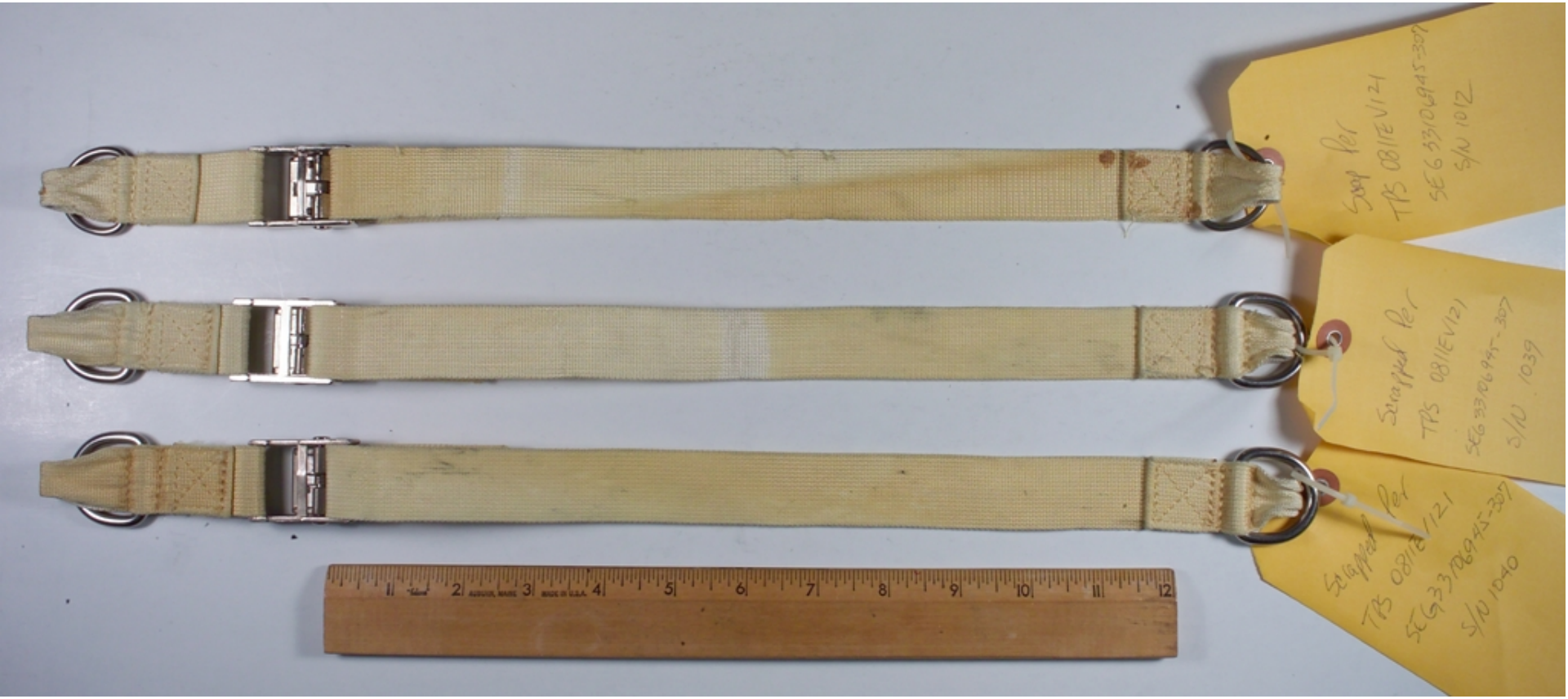
Back View



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Comparison

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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.

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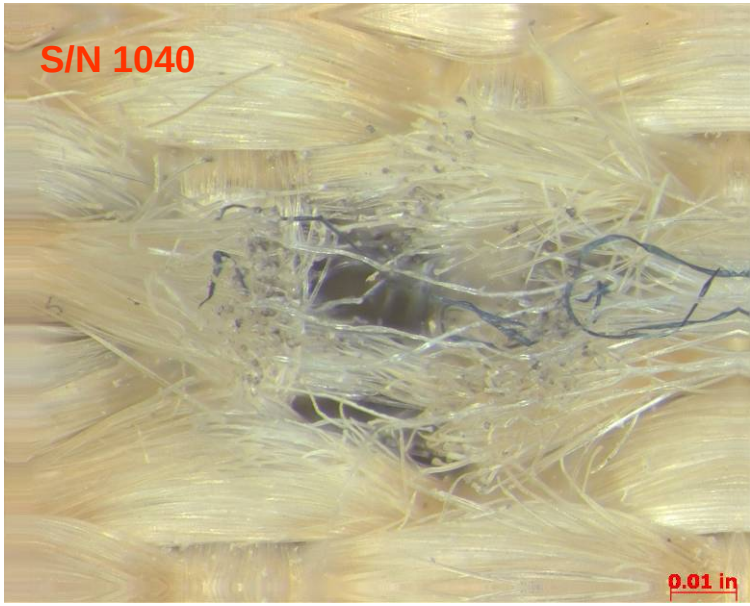
Visual Inspection

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



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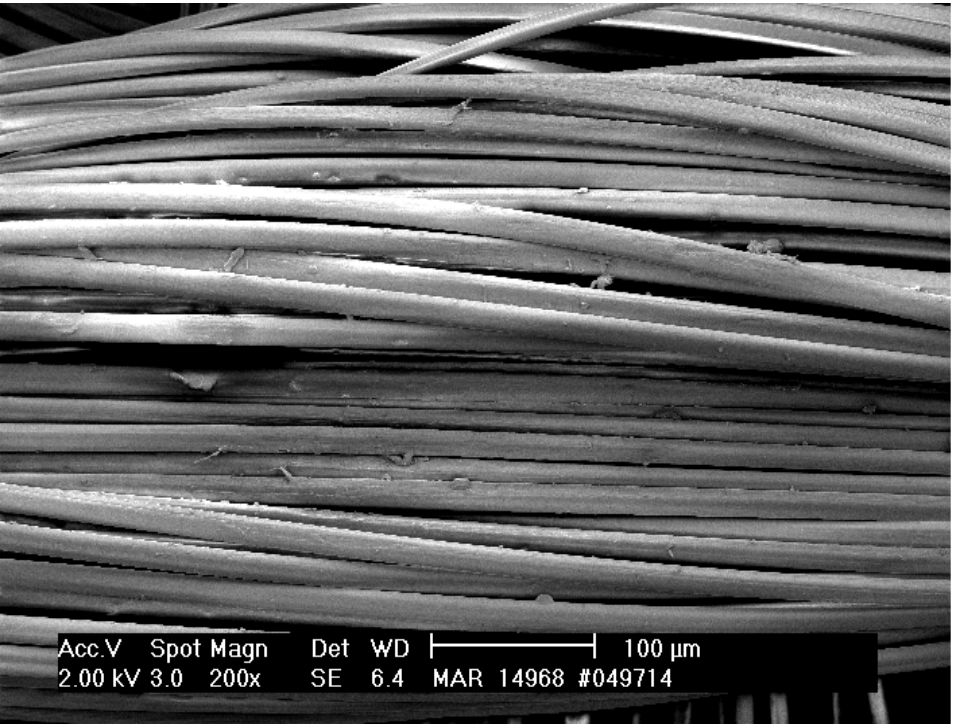
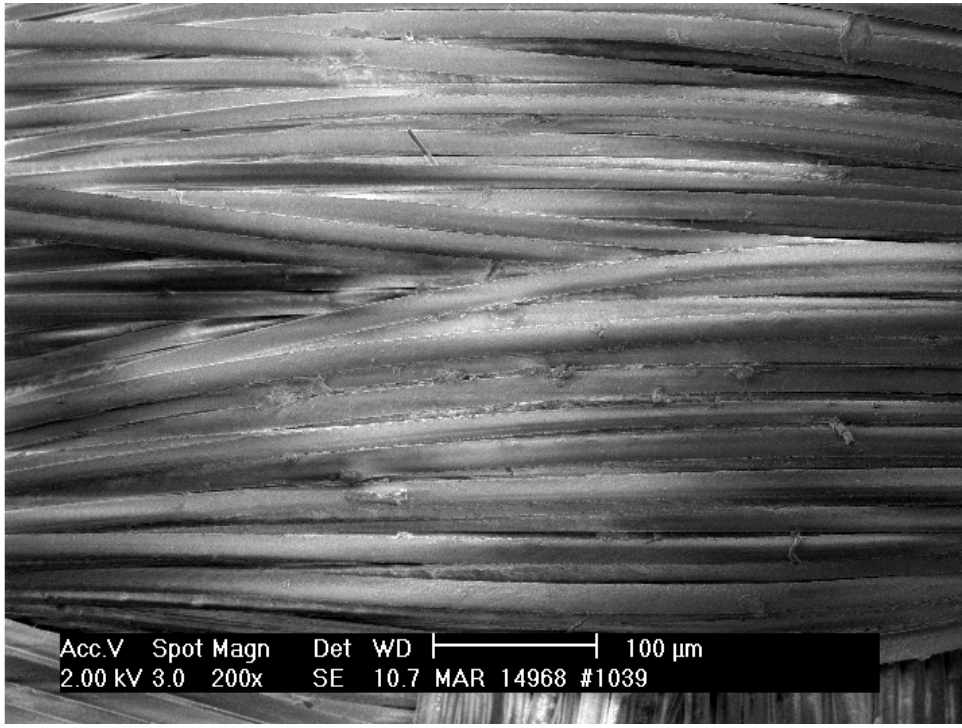
SEMs



Pristine Nomex sample

Sample from AET S/N 1039



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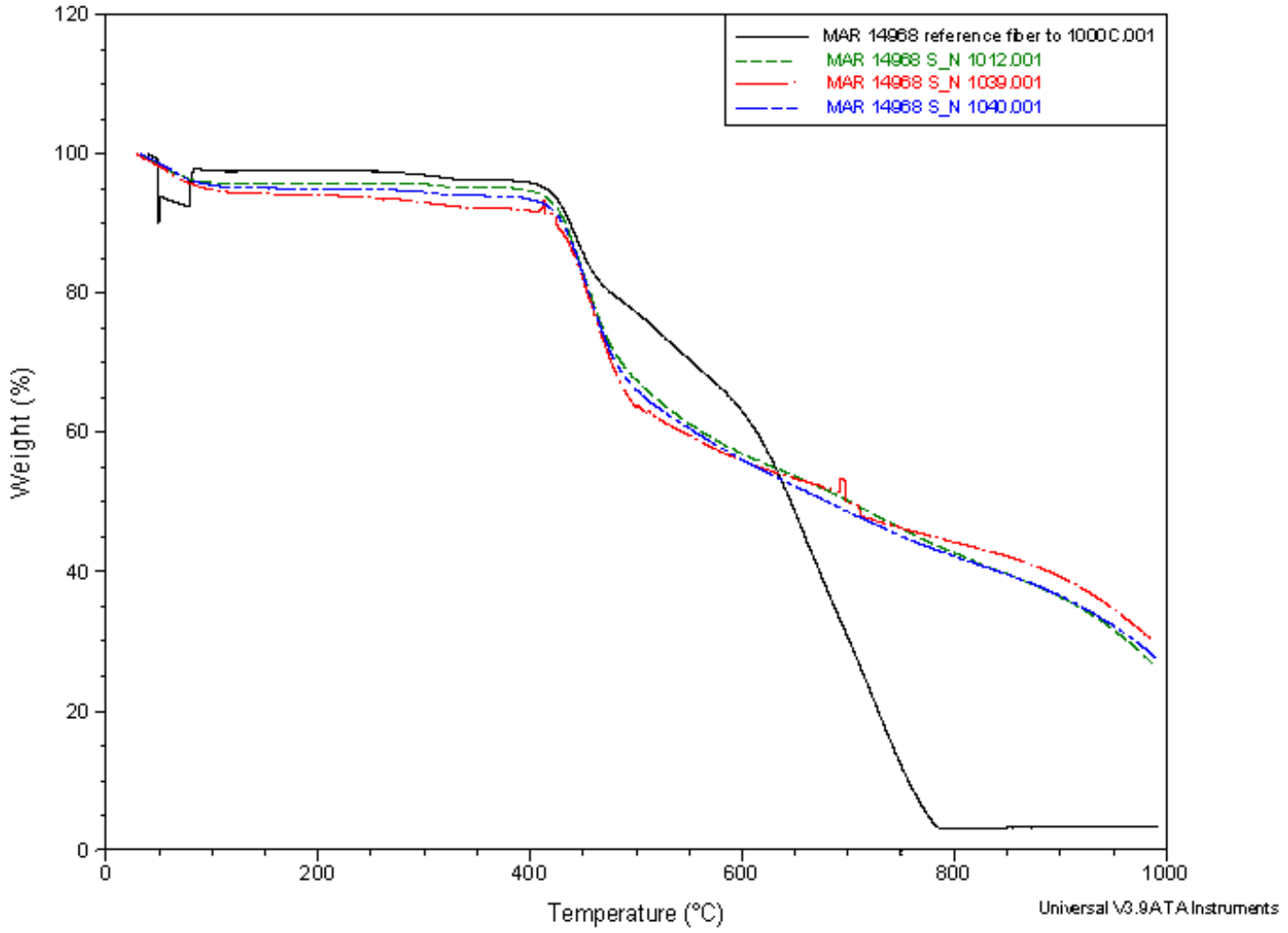
Thermogravimetric (TGA) testing

- **Pristine Nomex sample versus the on-orbit tethers.**



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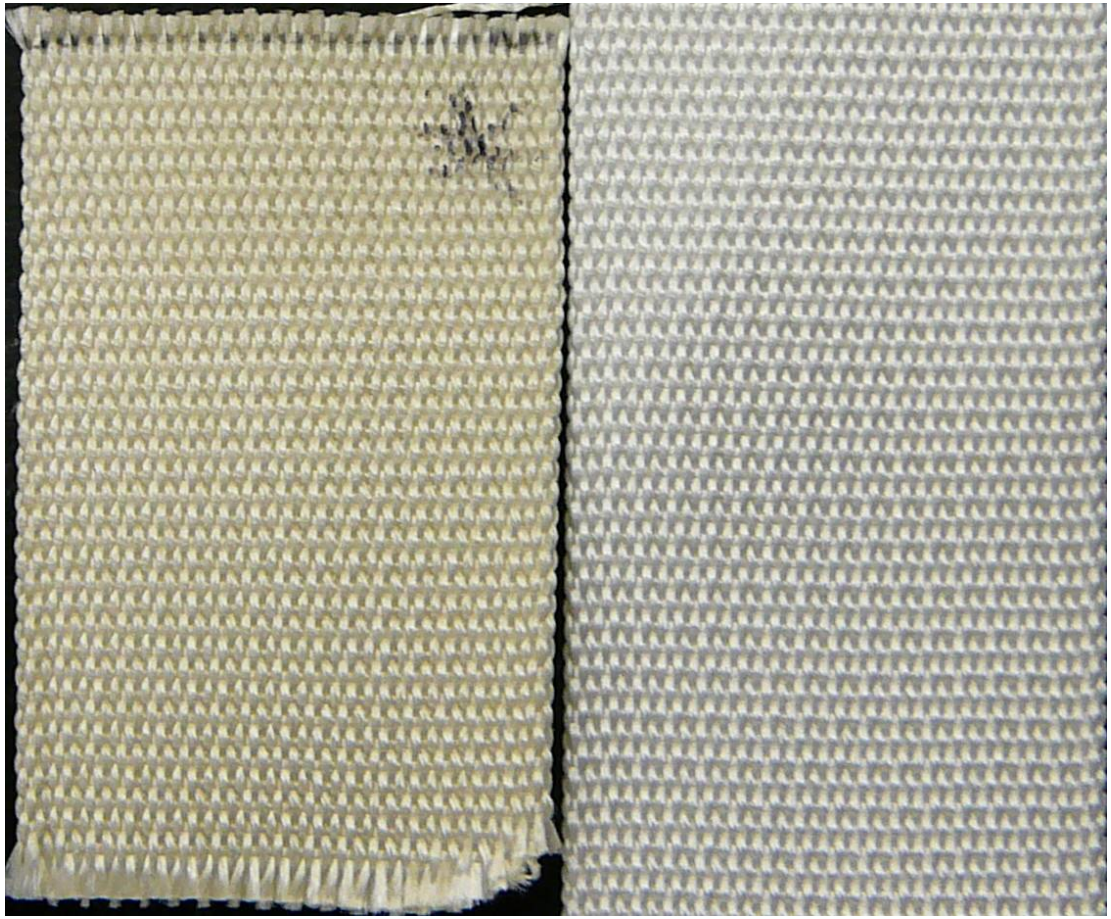
UV Exposure of Nomex

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



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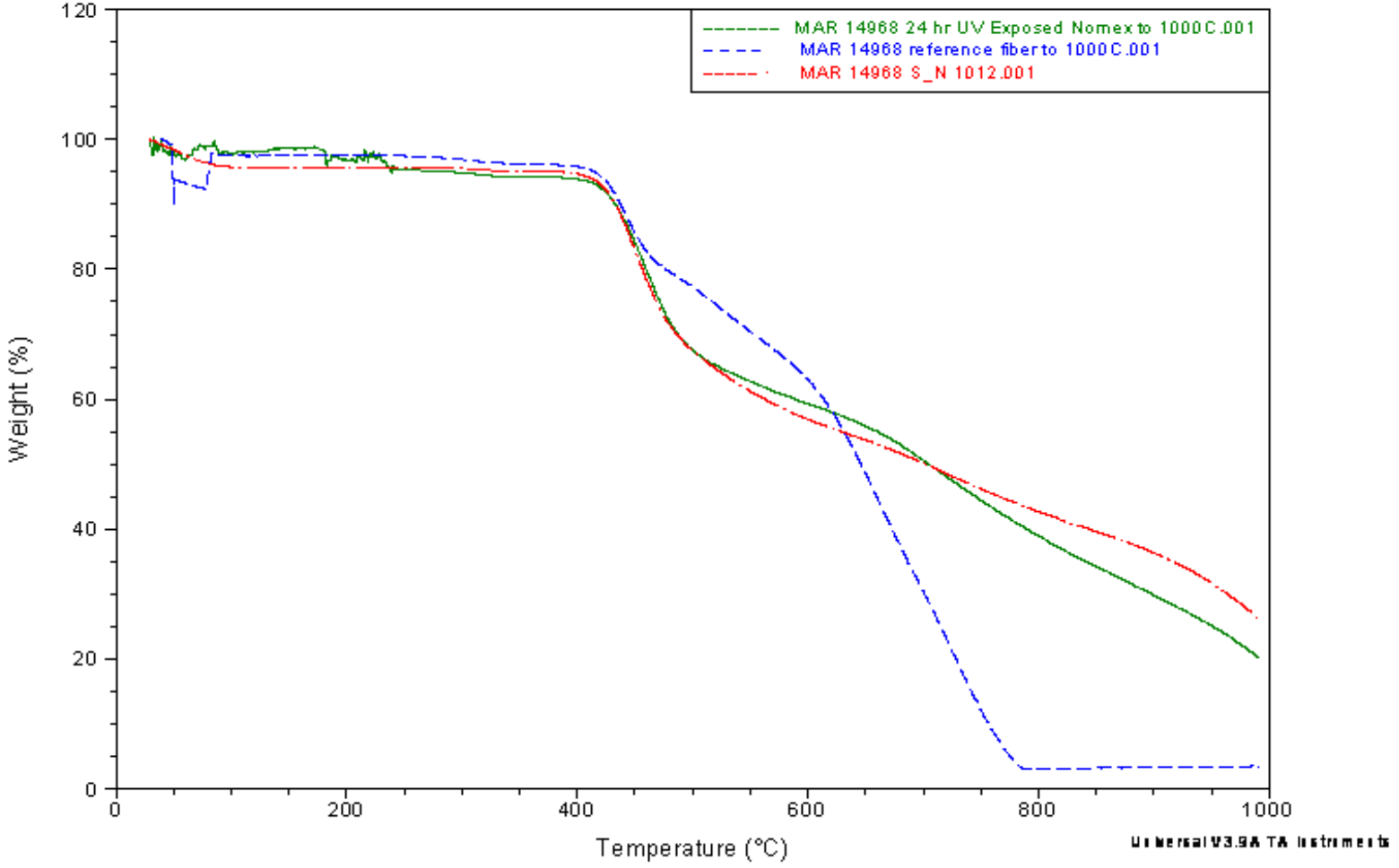
Comparisons w/ UV Sample

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



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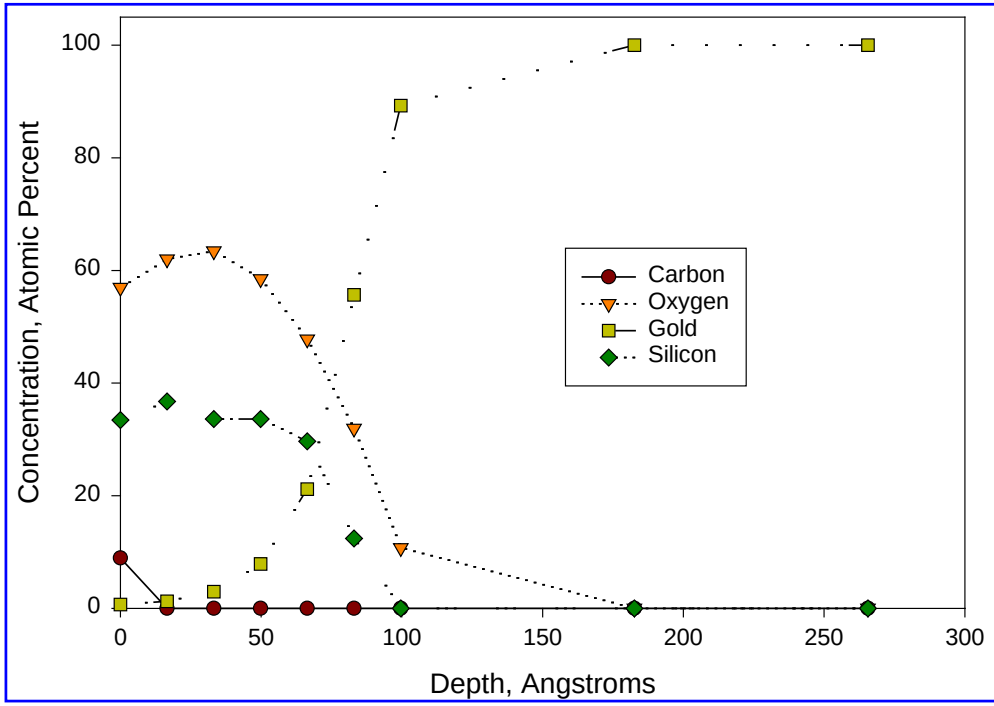
Another Piece of the Puzzle

- 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 ~70 Å per year silicon consistent with Space Environments' External Contamination models.
- Silicon overcoat will protect carbon-bearing materials from AO.



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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?

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