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

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Summary: This paper presents the results of an analysis to calculate the cumulative, effective atomic oxygen (AO) flux impinging on short-duration EVA tethers used to secure panel NOD1/C2-02 and panel LAB/C2-03. Shadowing from the ram reduces the AO flux on much of the Node 1 panel. On the Lab panel, the tethers are essentially in the ram flux. Table 1 summarizes the results of the analysis for Node 1 and the US Lab panels.

	Monthly AO Fluence (ao/cm^2) NOD1/C2-02 Panel	Monthly AO Fluence (ao/cm^2) LAB/C2-03 Panel
June 2007	1.8×10^{19}	7.9×10^{19}
July 2007	4.7×10^{19}	2.9×10^{20}
August 2007	3.8×10^{19}	1.7×10^{20}
September 2007	4.9×10^{19}	2.2×10^{20}
October 2007	3.5×10^{19}	1.6×10^{20}
November 2007	5.8×10^{19}	2.6×10^{20}
December 2007	4.1×10^{19}	1.8×10^{20}

Table 1 – Monthly AO Fluence Values for EVA Tethers

References:

1. NASA TM-2002-211786, NASA Marshall Engineering Thermosphere Model-Version 2.0, J.K. Owens, NASA/MSFC, 2002.
2. NASA Conference Publication 3134, Part 2, Bourassa, R.J., et. al., Atomic Oxygen and Ultraviolet Radiation Mission Total Exposures for LDEF Experiments, LDEF-69 Months in Space, First Post-Retrieval Symposium, June 2-8, 1991, pp. 643-661.

Introduction

This paper presents the results of an analysis to calculate the cumulative, effective atomic oxygen (AO) flux impinging on short-duration EVA tethers used on Flight 13A to secure micrometeoroid and orbital debris (MM/OD) shields on the Node 1 and US Lab elements of the International Space Station (ISS).

Input Data

The following input data were used in this analysis:

- ISS two line element (TLE) sets obtained from the Center for Space Standards & Innovation (www.celestrak.com),
- Observed daily F10.7 cm radio flux values in $W/m^2/Hz$ obtained from NOAA NGDC (www.ngdc.noaa.gov),
- Daily observed Ap geomagnetic index values obtained from NOAA NGDC (www.ngdc.noaa.gov),
- As flown attitude data obtained from JSC ADCO (www.mod.jsc.nasa.gov/df/df64/ADCO-Flight_Info/MCS-flt-info.html),
- Geometry of the attached tethers on the NOD1/C2-02 panel and the LAB1/C2-03 panel (see Figures 1 and 3).

Analysis Approach

Atomic oxygen density as a function of ISS position (latitude, longitude, altitude) is calculated using the MSIS-86 neutral thermosphere code. ISS position as a function of time is calculated from the ISS TLE input data using an in-house driver code developed originally by Rob Suggs (NASA/MSFC). MSIS-86 also requires daily F10.7 cm radio flux data, long term average F10.7 cm radio flux data (F107A), and daily Ap geomagnetic index data as input. F107A average flux values are calculated by taking a 45 day running average of the daily observed F10.7 flux values ending on the day proceeding the day of interest. For days in 2007 beyond the current values in the NOAA NGDC, 2006 values of F10.7 were used. This assumption is felt to be sufficient since the Sun is in a minimal stage of activity. MSIS-86 calculations are generally considered to have a 15% margin of error per NASA TM-2002-211786.

Instantaneous AO density values are calculated every 120 seconds during the orbit. Ram AO flux is then calculated by multiplying the instantaneous AO density by the ISS velocity,

$$v_{ISS} = \sqrt{GM / r\_sat},$$

to determine the instantaneous flux, and then multiplying by 120 seconds to determine the 2-minute AO flux value. Daily and total duration fluences are determined by summing the relevant 2-minute interval AO flux values. *GM* is the gravitational constant and *r_sat* is the distance from the center of the Earth to ISS.

The effective flux to both panels is determined by taking into account the attitude of ISS and the relative orientation of the panels with respect to the velocity vector as a function of time. Only the following principle attitudes were accounted for: +XVV for the majority of the time and –XVV during visits by the Orbiter.

NOD1/C2-02 Panel Analysis

Figure 1 shows the location of the Node 1 C2-02 MM/OD panel (between the US Lab and Node 1). In this location, the majority of the panel is shielded from the AO flux. Figure 2 is a drawing of the short-duration EVA equipment tether (part number SEG-33106945). The hook at each end of the tether is 4 inches long. The hook attached to the handrails on the outer circumference of the Node 1 element places the Nomex portion of the tether in the shadow of the US Lab onto the Node. Hence, the end of the equipment tether attached to the outer handrail may see only occasional AO flux due to any drift of the ISS attitude from +XVV. Table 2 presents the AO fluence per month for the tethers on NOD1/C2-02 through the end of 2007.

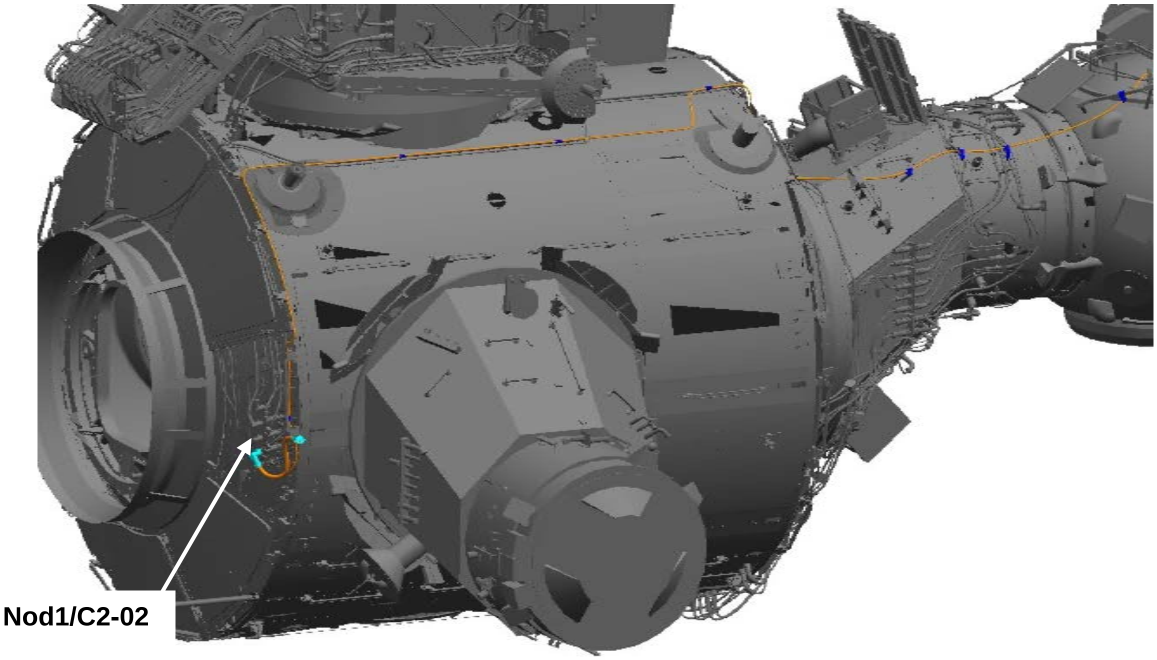

Figure 1 - Node 1 C2-02 Panel

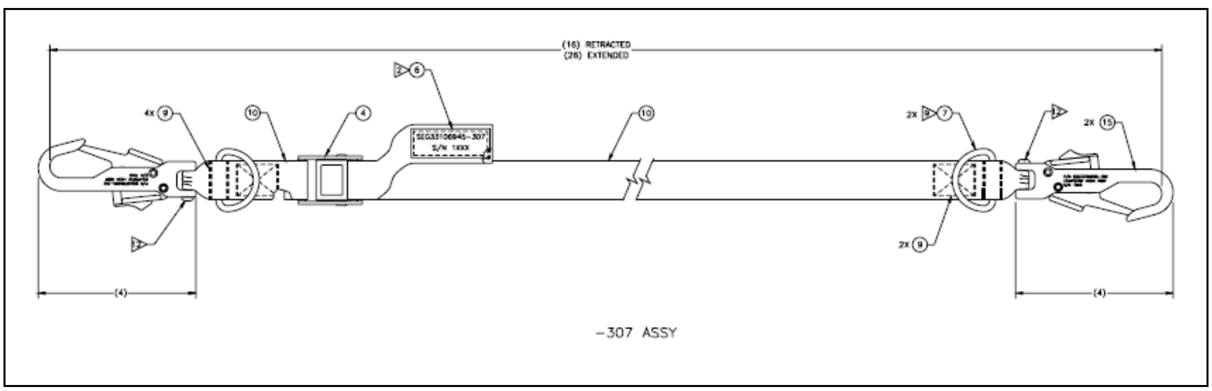

Figure 2 – Short Duration EVA Equipment Tether

	Monthly AO Fluence (ao/cm^2)
June 2007	1.8×10^{19}
July 2007	4.7×10^{19}
August 2007	3.8×10^{19}
September 2007	4.9×10^{19}
October 2007	3.5×10^{19}
November 2007	5.8×10^{19}
December 2007	4.1×10^{19}

Table 2 – NOD1/C2-02 Panel Monthly AO Fluence Values for EVA Tethers

Figure 3 shows the analysis geometry for the Lab C2-03 panel. While there is occasional shadowing of the tethers by PMA2, the tethers are essentially in the ram flux. Table 3 summarizes the results of the analysis for the US Lab.

Figure 3 - US Lab C2-03 Panel

	Monthly AO Fluence (ao/cm^2)
June 2007	7.9×10^{19}
July 2007	2.9×10^{20}
August 2007	1.7×10^{20}
September 2007	2.2×10^{20}
October 2007	1.6×10^{20}
November 2007	2.6×10^{20}
December 2007	1.8×10^{20}

Table 3 – Monthly AO Fluence Values for EVA Tethers

The ram AO flux calculated from MSIS-86 for each orbit segment/attitude combination was summed for the remainder of the 2007 calendar year to give the results shown in Figure 4.

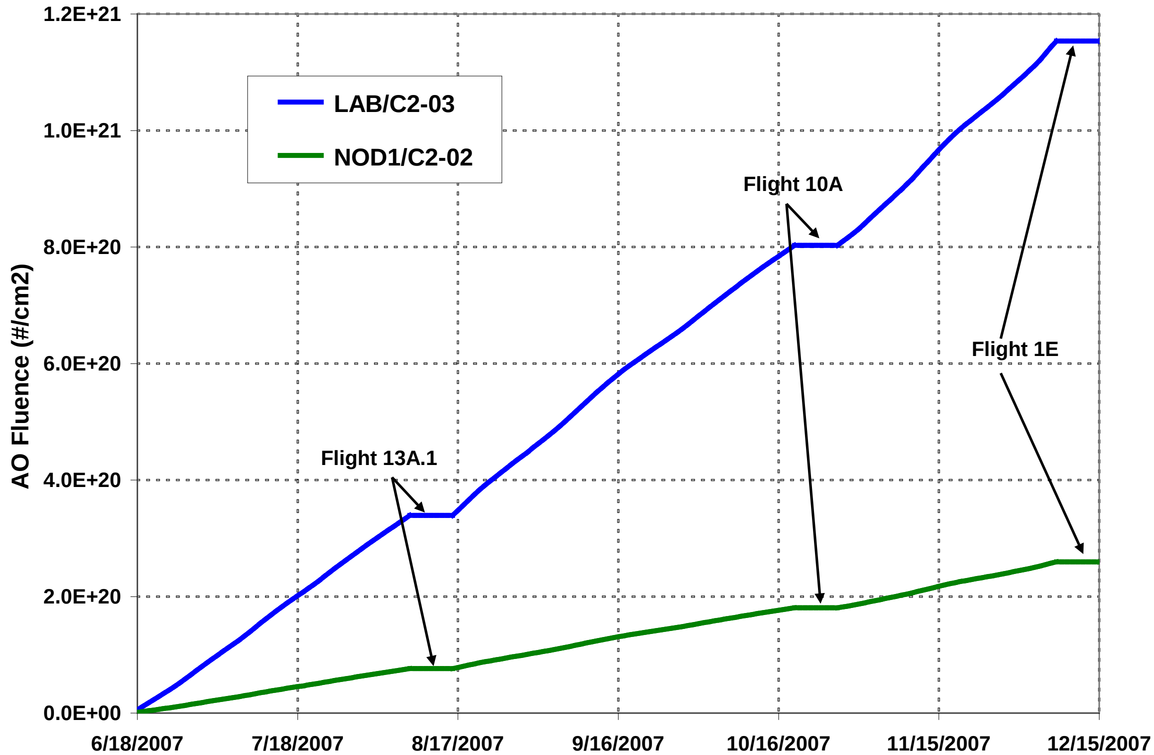

Figure 3 – Cumulative AO Fluence for Tethers on NOD1/C2-02 and LAB/C2-03

Depending upon the attitude of ISS, the AO flux may impinge on the tethers used on the Lab at an angle with respect to the velocity vector. AO flux as a function of angle from ISS ram was determined using data from Bourassa et. al. as shown in figure 4. However, for the outer edge of each tether attached on the LAB/C2-03, the impingement angle is at most 20 degrees from full ram conditions, resulting only in a 10% difference from the full ram values.

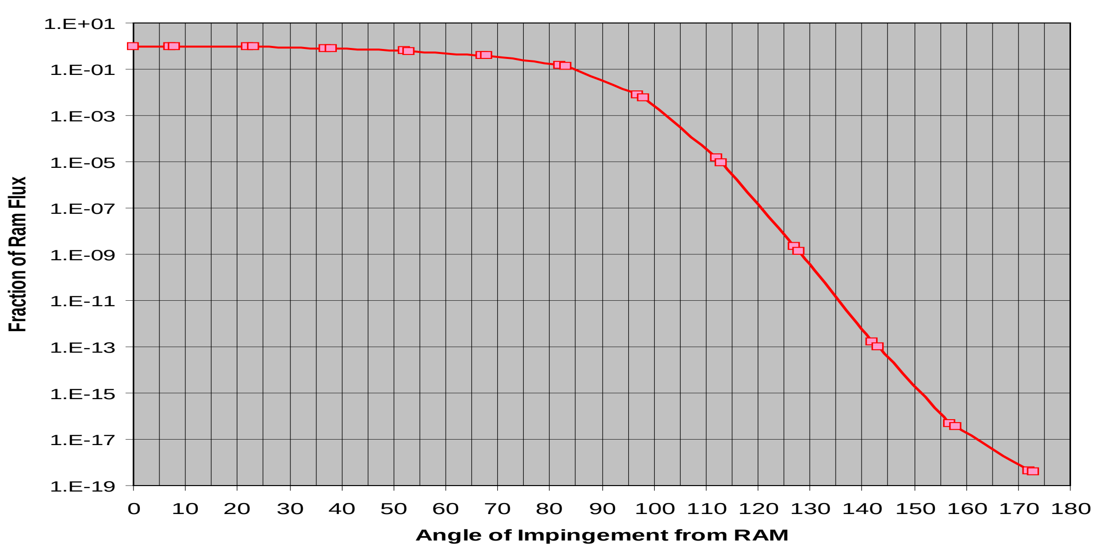

Figure 4 - Fraction of Ram Flux as a Function of Impingement Angle