Measures for Micro Meteoroids and Orbital Debris in Cooler Driver Harnesses of the Soft X-ray Spectrometer onboard ASTRO-H

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The Soft X-ray Spectrometer (SXS)[1)] onboard the 6th Japanese X-ray satellite ASTRO-H[2)] covers an 0.3–12 keV band with an unprecedentedly high energy resolution of 7 eV (the target value is 4 eV). The performance of X-ray spectroscopy is achieved using micro-calorimeter technology at a low temperature of $\sim$ 50mK, which is maintained through the following cooling chain. Stirling coolers, called Shield Coolers (SCs) and Pre-Coolers (PCs), decrease the temperature from $\sim$ 290K to $\sim$ 20K, and subsequently, a Joule-Thomson cooler (JT) further decreases the temperature to $\sim$ 4.5K. Then, the temperature is cooled down to $\sim$ 1.2K with superfluid helium and/or an Adiabatic Demagnetization Refrigerator (ADR), and finally the temperature is reduced to $\sim$ 50mK using two-stage ADRs at the front end of the chain.

Electric power derived by a satellite bus is supplied to SCs, PCs, and the JT via cooler drivers named SC Driver (SCD), PC Driver (PCD), and JT Driver (JTD), respectively[1)]. The cryo-coolers and cooler drivers are connected by multiple harnesses, and the numbers of particularly important harnesses for driving the cryo-coolers are 4 in SCD, 4 in PCD, and 2 in JTD (10 in total). Because a part of the dewar surface is placed in front of a window of the satellite panel (Fig. 1[2)]), the harnesses are partly exposed to space, and hence, Micro Meteoroids and Orbital Debris (MMODs) of various sizes can collide with the harnesses. If one of the important harnesses is destroyed because of collision with an MMOD, the cooling chain fails to work as required, significantly degrading the SXS performance. Thus, the design needs to satisfy the requirement that the number of MMODs passing through an important harness per year must be lower than 0.1. In the present document, we roughly estimate the probabilities with 1-digit accuracy in cases with and without a Kevlar measure[3)], and we determine whether the requirement can be satisfied.

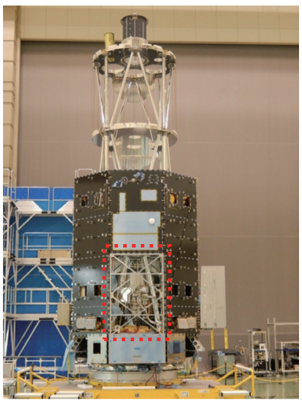

Fig. 1. Flight model of the *ASTRO-H* satellite body in a vibration test, including the engineering model of the SXS dewar[2)] on the inside. The red dotted square shows a window at the satellite panel, through which the harnesses are exposed to the space and MMODs can enter.

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The probability that a harness is penetrated by an MMOD can be estimated by multiplying an area exposed to space, a solid angle against space, and flux of MMODs. In each harness, the part exposed to space commonly has a length of $\sim$ 2 m and a solid angle of $\sim 0.5\pi$ against space, while the sum of widths of important parts driving the cryo-coolers is $\sim$ 1–3 mm (for simplicity, we hereafter employ a width of 3 mm for all the harnesses). According to a debris flux model, MASTER2009[4)], developed by the European Space Agency (ESA), the MMOD flux drastically changes with their sizes. Because the critical MMOD size is determined as the smallest diameter penetrating a harness, the flux depends on the toughness of the harnesses. According to the JAXA space debris protection manual[3)], the critical MMOD size for a commonly used harness cable is $\sim$ 0.2 mm, while that for the same cable covered by a 1-layer Kevlar fiber is calculated to be $\sim$ 0.4 mm. Therefore, the MMOD fluxes can be determined to be $\sim$ 10 and $\sim$ 1 collisions/m^2/year for harnesses without and with the 1-layer Kevlar coverage, respectively.

We calculated the probabilities that one of the important harnesses is penetrated per year. The case without Kevlar coverage has the probability

$$\begin{aligned} &10 \text{ pieces} \times 2\text{ m} \times 0.003\text{ m} \times \frac{0.5\pi}{2\pi} \times 10 \text{ collisions/m}^2\text{/year} \\ &\approx 0.2 \text{ collisions/year}, \end{aligned}$$

while the probability for the case with the 1-layer Kevlar fiber decreases to

$$\begin{aligned} &10 \text{ pieces} \times 2\text{ m} \times 0.003\text{ m} \times \frac{0.5\pi}{2\pi} \times 1 \text{ collisions/m}^2\text{/year} \\ &\approx 0.02 \text{ collisions/year}. \end{aligned}$$

Thus, we successfully confirmed that the design with the 1-layer Kevlar fiber coverage is effective to satisfy the requirement, and we have employed the measures for all the SCD, PCD, and JTD important harnesses.

References
1) K. Mitsuda et al. SPIE **7732**, 773211 (2010)
2) T. Takahashi et al. SPIE, **9144**, 914425 (2014)
3) JAXA space debris protection manual, 2009, JERG-2-144-HB001
4) ESA MASTER: http://www.master-model.de