Mechanical Analysis and Testing of the ASPECT Payload for Milani CubeSat

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ABSTRACT

Hera is the European component of the international Asteroid Impact and Deflection Assessment (AIDA) project. In early 2027, HERA intends to deploy two CubeSats, named Milani and Juventas in the near proximity of the binary asteroid Didymos. Milani is a 6U CubeSat and has 6-DOF maneuvering capabilities, to control both its attitude and translational motion. Utilizing the hyperspectral imager ASPECT built by VTT, Milani intends to provide a detailed mineralogical map of Didymos' (primary of the binary system) and Dimorphos' (secondary) surfaces.

The ASPECT miniaturized hyperspectral imager covers the optical spectrum from visible to the shortwave infrared (SWIR) range. There are four measurement channels on the instrument, one for visible light (VIS), two for near-infrared (NIR), and one for SWIR. SWIR is a single-point spectrometer, while VIS and NIR are imaging spectrometers. Asteroids' surfaces will also be characterized by ASPECT in terms of space weathering, shock effects, surface material transfer, and roughness. There will be finer detail images of selected features, such as the spacecraft's impact on Dimorphos in 2022, where DART (Double Asteroid Redirection Test) was launched.

A summary of the FEA analysis and vibration testing for the ASPECT instrument is presented in this paper. As per the ESA specification guidelines, shock response analysis was the most critical module to assess. Mode shapes were calculated as a pre-requisite to the shock response analysis, modal analysis being the most fundamental of all dynamic analyses. Modal analysis was carried out for the X, Y, and Z axis non simultaneously. The fundamental frequency from the first mode shape was around 850 Hz which was within the acceptable range.
The shock response of the ASPECT structure was then investigated with a response spectrum analysis. The maximum stress within ASPECT components was below the specific material ultimate strength values. The peak stresses and maximum deformation occur at the PCB support struts as can be seen in Figure 1.

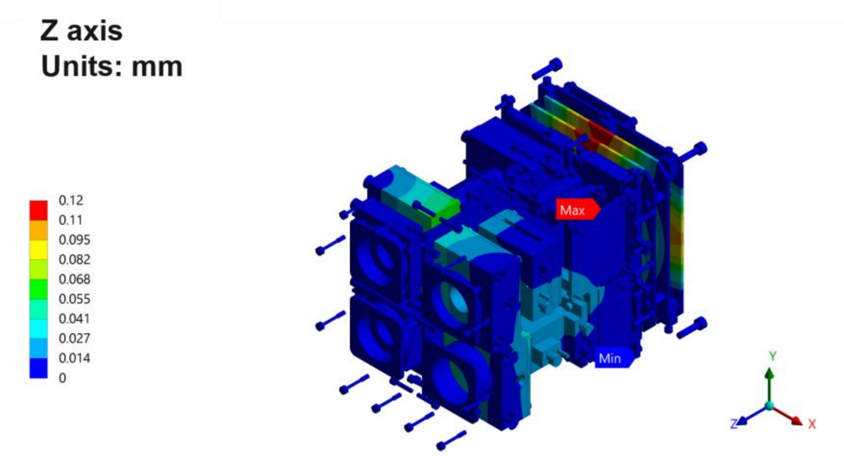

Figure 1: ASPECT displacement for Z-axis loading

The predicted MOS (Margin of Safety) for all the critical components is also above 1 as shown in Figure 2.

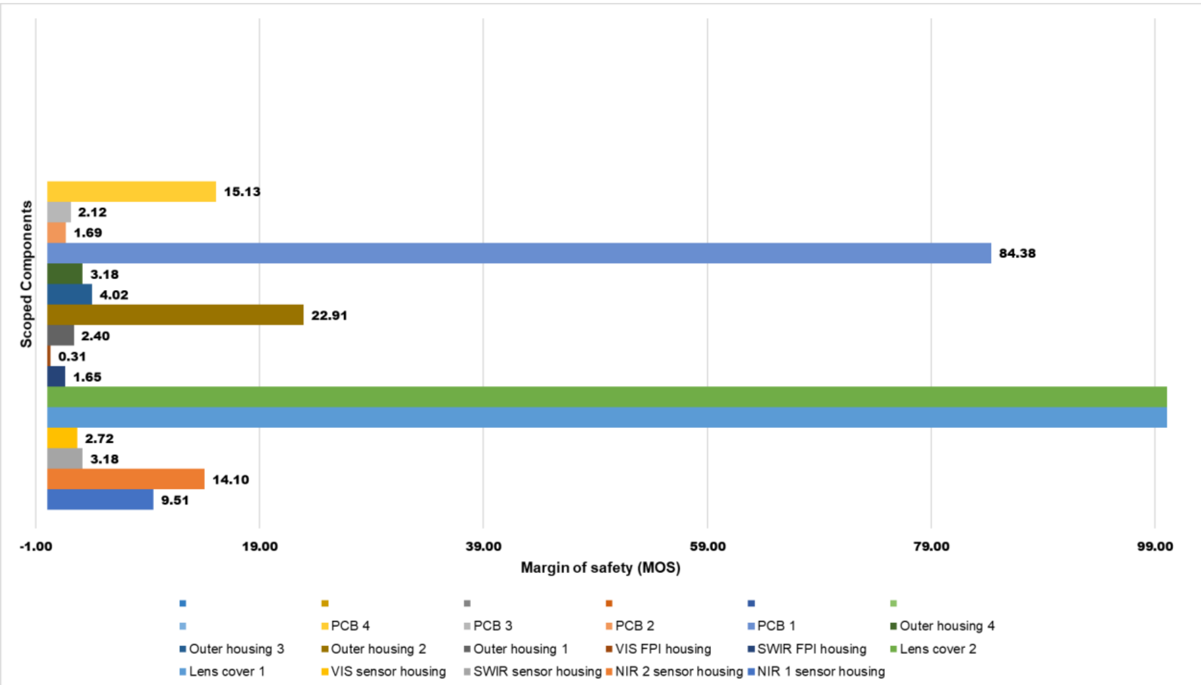

Figure 2: ASPECT MOS

A critical design component for ASPECT is the tuneable Fabry Perot Interferometer (FPI). Detailed vibration tests were performed on the FPI assembly consisting of the Fabry, housing, and attachment screws. Three steps involving an LLSS (low-level sine sweep), random vibration test, and shock response tests were conducted on the FPI assembly. A frequency sweep was used to quickly observe the instrument's response in the frequency range of the operational environment. Each main axis is tested individually LLSS to find structures' natural frequency. The fundamental frequency was then used as a base for a random vibration test to simulate launch vibrations. These were tested at three stages of amplification: -6, -3, and -0 decibels. The levels for the shock response tests varied from 500-1500 g. No noticeable damage was observed on the structure post the three test stages. Furthermore, another set of LLSS tests was performed to ensure that the natural frequency did not vary by more than 15 %.

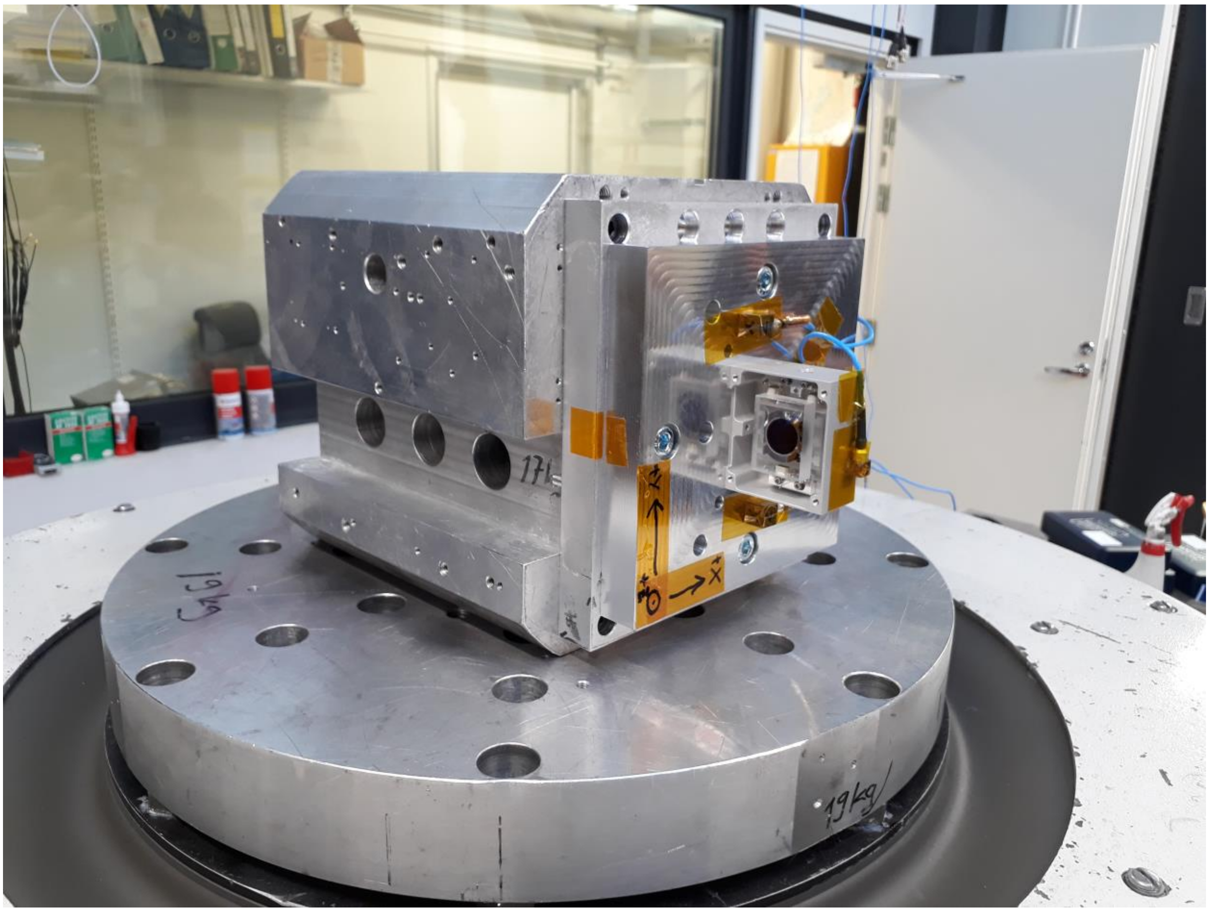

Figure 3: FPI vibration test assembly