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Deformation Detection of Satellite Flight Instruments

Interferometric Measurements in Ultra-High Vacuum with attocube's IDS3010

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Space environment imposes extremely stringent design constraints on observational spacecrafts, especially in terms of thermos-elastic stability, leading to the use of advanced materials and thermal architectures. These constraints also translate into demanding validation processes, including accurate characterizations and thermomechanical model correlations by means of ambient and high vacuum test campaigns.

OHB System AG used attocube's interferometric displacement sensor – the IDS3010 – for an opto-thermo-mechanical model correlation test in high vacuum for the Meteosat Third Generation (MTG) Flexible Combined Imager instrument.

For the test, different zones of the instrument were exposed to controlled thermal fluxes and the resulting relative displacements of the optical elements were measured with a Shack-Hartmann sensor. With the precise measurement of the IDS3010, the stability of the relative position of a flat reference mirror and the IRS instrument was continuously monitored. During a testing period of more than one week in vacuum, a continuous measurement accuracy of less than one arcsecond was achieved by the setup.

Introduction

The MTG Imager satellite will outperform the current Meteosat Second Generation Satellite. Its main mission will be to ensure the continuity of the weather forecast services with unprecedented spatial resolution measurements and a faster Earth half disc repeat cycle. The MTG Imager satellite will carry the flexible combined imager instrument (to replace the Spinning Enhanced Visible and Infrared Imager SEVIRI currently on board the Meteosat Second Generation satellite) and the lightning imager (depicted by the four small baffles visible in Figure 1 below). The MTG project is developed under ESA contract and Thales Alenia Space prime contractorship.

OHB System AG performed these opto-thermo-mechanical measurements on the MTG flexible combined imager instrument in high-vacuum conditions (10^{-6} mbar) with several thermal boundary conditions. The complete sequence of tests lasted more than one week in vacuum. The instrument's deformation measurements required an accurate monitoring of the stability of the relative position of a flat reference mirror with respect to the flexible combined imager instrument.

Figure 1: Artist view of the satellite. Picture provided by ESA.

Setup

attocube's interferometric displacement sensor (IDS) is capable of measuring nanometer deformations of, e.g., space components under extreme environments such as high vacuum. The IDS has three individual measurement axes, which allows the user to extract important information about the angular movements of the satellite structure when submitted to temperature excursions. The complete test setup is shown in Figure 3. The attocube sensor heads were mounted on the purple stainless steel structure.

A Shack-Hartmann wavefront sensor was mounted in place of the later detectors of the new imager system; the flat reference mirror was positioned in front of the instrument baffle to reflect the light coming from the Shack-Hartmann sensor back to itself through the whole instrument. By monitoring the variations of the wavefront error, one can determine the movements of each individual optical component of the instrument, allowing subsequent thermos-mechanical model correlations.

In order to make sure that the measured variations of the wavefront error are not due to movements of the flat reference mirror, four IDS3010 were used to monitor the alignment stability of this flat reference mirror with respect to the instrument. To this aim, a total of four focused sensor heads were placed at a distance of 48 mm behind the flat reference mirror. Additionally, four collimated sensor heads are pointing at corner cube retroreflectors with a distance of 2.7 m, which are mounted on a bracket on the instrument, as can be seen in Figure 3. These angular stability values were measured every second with an accuracy better than one arcsecond. The stability was detected over the complete test period of 11 days.

LabVIEW libraries were used to develop a custom monitoring software, allowing OHB System to store the monitoring data in the preferred format for further data processing.

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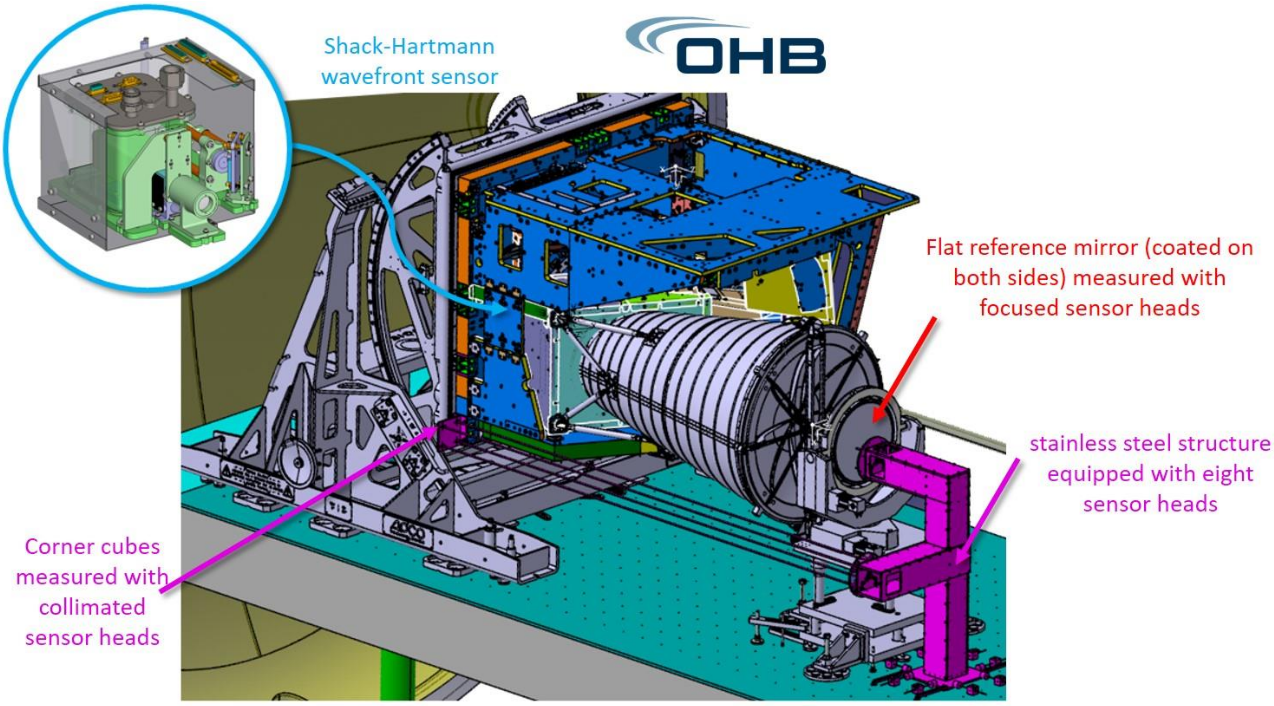

Figure 3: The sketch shows the experimental setup with the Meteosat Third Generation Flexible Combined Imager (MTG-FCI) instrument. In purple, the interferometric components: sensor head holder and the corner cube holders. Information provided by OHB System AG.

Measurement Results

Preliminary tests were required to calibrate the IDS3010 lever arms (distances between each sensor head and resulting lever arms for angular calculations, nominally 100 mm). For that purpose, the motorized gimbal of the flat reference mirror was used to generate arbitrary angular movements. These angles were measured both by the IDS' sensors and by a calibrated auto-collimator used as a reference, as can be seen in Figure 4. The IDS' measurement showed an outstanding linearity (< 0.1 %) over ± 720 arcseconds, while the calibration of the sensor heads proved to be very easy.

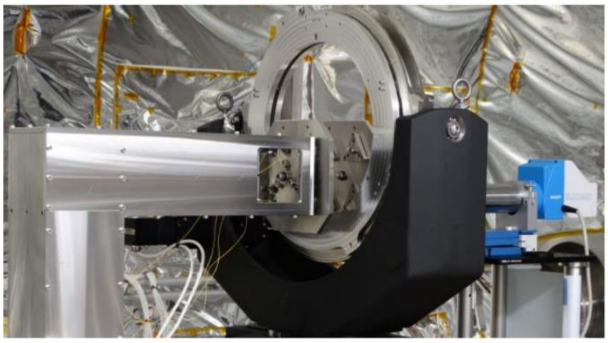

Figure 4: Calibration setup with autocollimator. Image provided by OHB System AG.

Once aligned with the MTG flexible combined imager instrument, another cross-calibration between the Shack-Hartmann sensor and the IDS sensors was performed to compensate for the clocking of the IDS3010 with respect to the wavefront sensor.

Conclusion

The goal of the measurement was to monitor the stability of the reference mirror with respect to the satellite instrument over more than one week in vacuum conditions, with an accuracy better than one arcsecond.

With the shown setup, the angular accuracy of attocube's sensors was even better than one arcsecond. Theoretical calculations showed a potential resolution of 0.021 arcsec (equal to 5.8 µ°), but the readout was limited by the test setup.

M. Cortese:

"The design, procurement, assembly, monitoring software development and calibration took only 1.5 months from kick-off to readiness at the test facility. With the versatile and off-the-shelf high-vacuum compatible sensors, in a very short time frame we were able to develop an emergency solution to the original measurement tool that turned out not to be sufficiently reliable short before our test campaign. This allowed OHN to react immediately, keep program schedules, and maintain its booked test facility slot seamlessly."