Application Note MS35

Interferometric Deformation Detection of Satellite Flight Instruments

attocube
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The space environment imposes extremely stringent design constraints on observation spacecrafts, especially in terms of thermo-elastic stability, leading to the use of advanced materials and thermal architectures. These constrains also translate into demanding validation processes including accurate characterizations and thermo-mechanical models correlations by means of ambient and high vacuum test campaigns.

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

The test consisted in injecting controlled thermal fluxes in different zones of the instrument and monitor its subsequent optical elements relative displacements 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 with an accuracy of less than 1 arcsecond during the whole duration of the test which lasted more than a week in vacuum in total.

Introduction

The MTG Imager satellite will outperform the currently in use Meteosat Second Generation Satellite. Its main mission will be to ensure the continuity of the weather forecasts services with unprecedented spatial resolution measurements and faster Earth half disc repeat cycle. The MTG Imager satellite will carry both the flexible combined imager instrument (to replace Spinning Enhanced Visible and Infrared Imager (SEVIRI) currently on board the Meteosat Second Generation satellite) and the lightning imager (4 small baffles visible on the picture below). The MTG project is developed under ESA contract and Thales Alenia Space prime contractorship.

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

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 test lasted more than one week in vacuum. The instrument deformations' measurements required an accurate monitoring of the stability of the relative position of a reference flat mirror with respect of the flexible combined imager instrument.

The setup

attocube's interferometric displacement sensor (IDS), shown in Figure 2 together with fiber-based sensor heads, 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.

Figure 2: attocube's displacement sensor with 1 pm resolution and sensor head with fiber

The complete test setup is shown on 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 flexible combined imager instrument detectors, 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 components of the instrument, allowing subsequent thermo-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 with respect to the instrument, four IDS3010 were used to monitor the alignment stability of this flat reference mirror with respect to the instrument (in total 4 focused sensor heads at 48mm behind the flat reference mirror and 4 collimated sensor heads pointing at retroreflectors on a bracket mounted on the instrument at a distance of 2.7m). These angular stability values were measured every second with an accuracy better than 1 arcsecond. The stability was detected over the complete test period of 11 days.

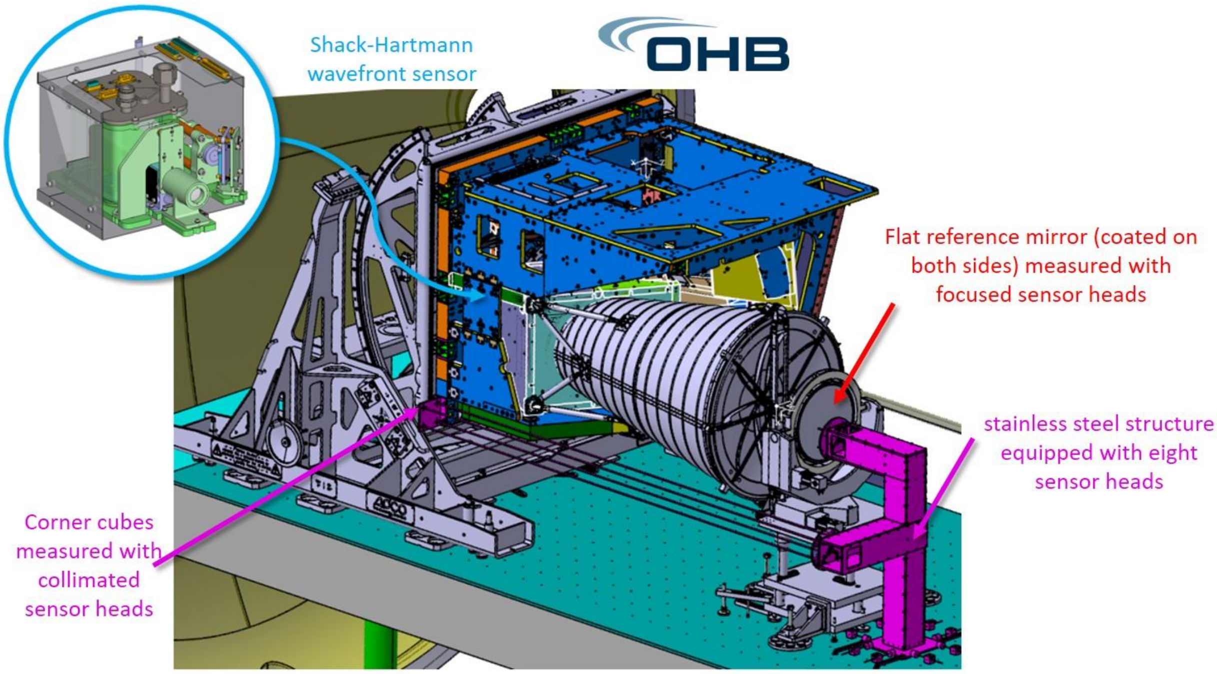

Figure 3: The sketch shows the experimental setup with the Meteosat Third Generation Flexible Combined Imager (MTG-FCI) instrument. In purple, the interferometric components: sensor head holder and the corner cube holders. All information are provided by OHB System AG.

The 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.

Calibration and Performance Tests

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 IDS3010 sensors and a calibrated autocollimator used as a reference. The IDS3010 sensors showed an outstanding linearity (<0.1%) over ±720 arcseconds and were very easy to calibrate.

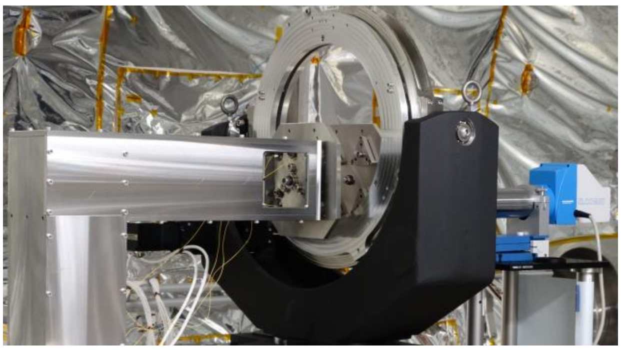

Figure 4: Calibration setup with autocollimator. Picture is provided by OHB.

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

Results

The goal of the measurements was to monitor the stability of the reference mirror with respect to the satellite instrument over more than a week in continuous with an accuracy of less than 1 arcsecond.

With the shown setup, the angular accuracy of the attocube 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 vibrations.

M.Cortese:

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