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Introduction
Swarm mission constellation, launched into orbit on November 22, 2013, consists of three satellites that precisely measure magnetic signal of the Earth. Each of the three satellites is equipped with three μASC Camera Head Units (CHU) mounted on a common optical bench (OB), which has a purpose of transference of the precisely determined attitude from the star trackers to the vector magnetometer (VFM) measurements. Although pre-launch analyses were made to minimize thermal and mechanical instabilities of the OB, significant signal with thermal signature is discovered when comparing relative attitude between the three CHU's. These misalignments between CHU's, and consequently geomagnetic reference frame, are found to be correlated with the optical bench temperature variation.

In this paper, we investigate the propagation of thermal effects into the μASC attitude observations and demonstrate how thermally induced attitude variation can be predicted and corrected in the Swarm data processing. The results after applying thermal model significantly improves attitude determination which, after correction, meets the requirements of Swarm satellite mission. This study demonstrates the importance of the OB pre-launch analysis to ensure minimum thermal gradient on satellite optical system and therefore maximum attitude accuracy.

Swarm optical Bench

Swarm optical bench (OB) is an ultra-stable silicon carbide-carbon fiber compound structure installed on a deployable conical tube of square cross section. Its purpose is transference of the precisely determined attitude using star trackers to the magnetometer field components.

Observed thermo-elastic instabilities

The three CHU's are placed on OB and arranged with the Inter Boresight Angle (IBA) of around 90° from each other. Ideally, IBA is expected to be constant. However, IBA variation shows periodicity, which is correlated with temperatures measured on three Swarm satellites.

The fixed frame is defined as: Each rotation is described by:

\[ X_f = \frac{x}{p_z} \times \frac{x}{p_z} \times \frac{x}{p_z} \quad Y_f = \frac{y}{p_z} \times \frac{y}{p_z} \times \frac{y}{p_z} \]

Thermal model is found by Singular Value Decomposition (SVD) fitting of IBA orbital averages and observed temperatures, and it describes how each CHU moves relative to its pre-light calibrated frame due to the thermal gradients. It is defined as:

\[ R_{CHU \text{corrected}} = R_3(y) R_2(x) R_1(z) R_{CHU} \]

micro Advanced Stellar Compass μASC

- Designed and produced by the Measurement and Instrumentation (DTU)
- to date one of the most successful star tracker worldwide
- autonomously calculates attitude based on all bright stars in the CHUs
- Running a single CHU, μASC can provide 22 true solutions per second
- absolute accuracy of < 1 arc second
- operating on many satellite missions without a single hardware or functional failure

References


European Geosciences Union, General Assembly 2018, Vienna, Austria, 08 – 13 April 2018

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