Performance Verification of the MSS-1 and CSES-2 Flight Models

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The sensor heading of the Coupled Dark State Magnetometer flight models for the Macao Science Satellite 1 and the China Seismo-Electromagnetic Satellite 2 was examined in the absolute area of the Conrad Observatory. The Coupled Dark State Magnetometer is an optically pumped scalar magnetometer based on two-photon spectroscopy of free alkali atoms.

The Macao Science Satellite 1 (MSS-1) was proposed and is led by the State Key Laboratory of Lunar and Planetary Science at the Macau University of Science and Technology (MUST). It is the world's first scientific exploration satellite to be placed in a near-equatorial orbit to study the geomagnetic field, and specifically the South Atlantic Anomaly, from space. The satellite successfully launched on May 21st 2023. The China Seismo-Electromagnetic Satellites (CSES) are scientific missions dedicated to the investigation and monitoring of variations of electromagnetic fields and waves as well as plasma parameters and particle fluxes in the near-Earth space. The first CSES satellite (CSES-1) was launched in February 2018, CSES-2 is scheduled for launch in 2024.

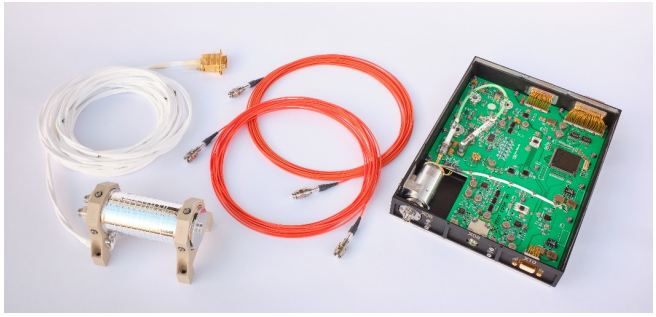

Figure 1: The Coupled Dark State Magnetometer (CDSM) developed for the Macao Science Satellite 1. Laser light, produced in the electronics unit (right), is guided to the sensor unit (left) through one of the fibers (middle). The light is then returned through the second fiber and processed in the electronics.

Both satellites carry an optical magnetometer built by the Space Research Institute of the Austrian Academy of Sciences in Graz, in close cooperation with the Institute of Experimental Physics of the Graz University of Technology (Pollinger et al., 2018, https://doi:10.1088/1361-6501/aacde4). The sensor heading of the fully assembled CDSM flight models was characterized in Earth's field (approx. 48,800 nT). The sensor heading is the deviation of the CDSM reading from the actual magnetic field strength, so to say the accuracy, as a function of the orientation of the sensor with respect to the magnetic field direction. It consists of two parts: A potential stray field of the sensor materials and the measurement principle intrinsic shift. The "actual" magnetic field strength was derived from the observatory reference magnetometer, a GEM Systems GP20 Potassium magnetometer. The CDSM sensor was mounted on a manual rotation device with which the sensor can be rotated around two axes. This gives the opportunity to gain a three-dimensional model of the sensor heading characteristic, which is later used to correct the data gathered in flight.

Figure 2: CSES-2 flight model sensor mounted on the (white) manual rotation frame in the absolute area of COBS.

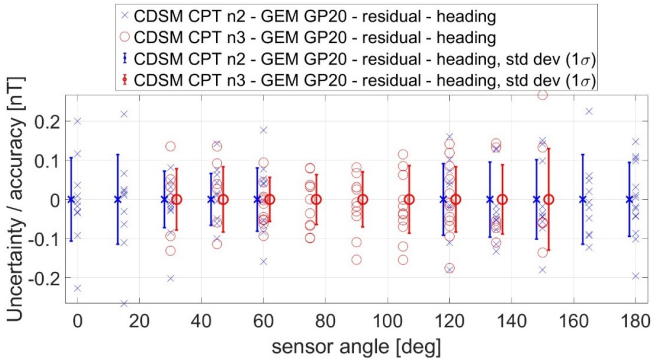

Figure 3: Uncertainty of CDSM after removal of the stray field of sensor materials and application of measurement principle intrinsic heading correction. The sensor angle is the angle between the magnetic field direction and the optical axis of the sensor.

The COBS campaigns showed, that both the FM sensor for the MSS-1 and the FM sensor for the CSES-2 do fulfil the accuracy requirement of 0.3 nT (1σ).

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