Pre-flight Calibration and validation test of CMM-1 Fluxgate Magnetometer MAG-O

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Abstract

As one of the objectives for China's First Mars Exploration Mission (CMM-1), the magnetic field in Mars' near space will be measured by the Magnetometer onboard of the Orbiter (MAG-O), which consists of two fluxgate sensors and one electronic box. We conducted pre-flight calibration test to determine the offset drift with temperature and the correction matrix, which composed of sensitivities and non-orthogonality parameters. The characteristics of mutual interference between two sensors are also verified. The results show that MAG-O meets the requirements of CMM-1 mission.

The Instrument

To study the nature of Mars magnetic more accurately, our fluxgate magnetometer with two triaxle fluxgate sensors will be on board the orbiter CMM-1. The hardware of magnetometer benefits from the heritage of the Venus-Express and THEMIS mission. The replacement of analogue parts and the digitization on AC-level in general makes the sensed signal much more robust against changes of the environmental temperature and the supply voltage as well as insensitive to electro-magnetic interference.

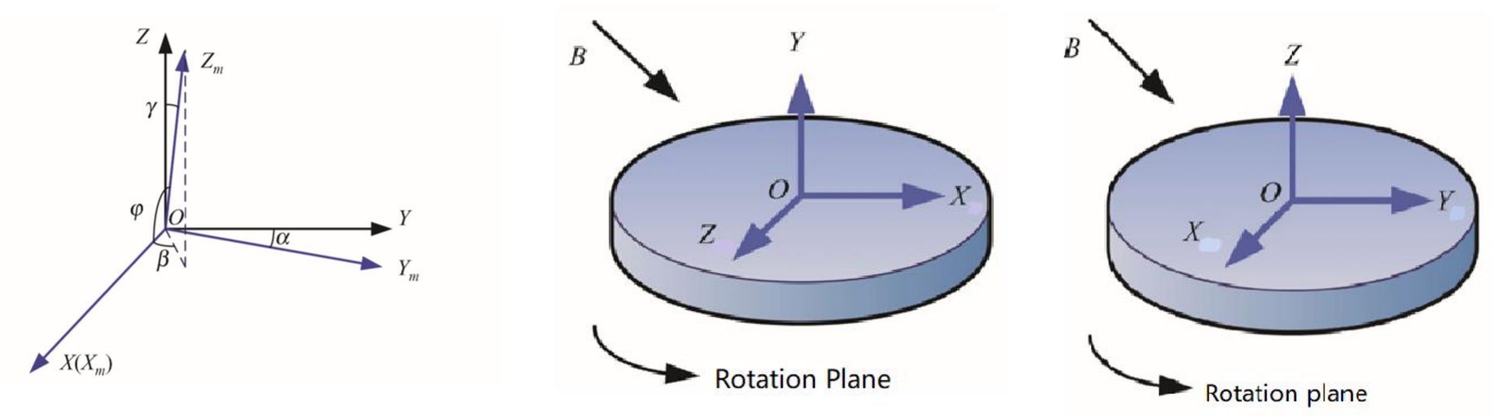
Like many other space magnetic measurement mission, a 3.19 m long carbon fiber deployed boom is used for separating the sensors from the body of spacecraft. The dual-sensor configuration enable separation of stray field effects generated by the spacecraft from the ambient space magnetic field. The outboard sensor (OB) is mounted on the tip of the boom, while the inboard sensor (IB) which near to the spacecraft is far away from it about 0.9 m.

Magnetometer sensors, which are going to be covered by thermal coating, would experience temperature changes from -120℃ to +5℃ as simulated during the mission.

Measurement range	±10000nT
Resolution	1.96pT
Noise density at 1Hz	<10pT $Hz^{-1/2}$
Electronics offset stability(-40℃~45℃)	0.85nT
Linearity error	< 1.6×10^{-4}
Power consumption	3.8W
Mass	
Sensor	250g
Electronics box	1150g

Method and Experiments

Experiment1. Determine of the correction matrix

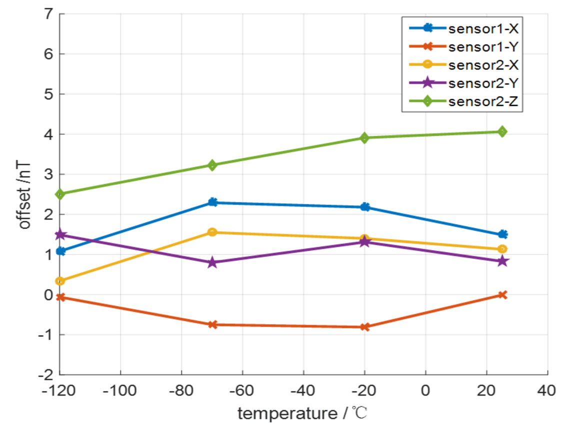


$$\begin{bmatrix}x\\y\\z\end{bmatrix}=\begin{bmatrix}k_x&&\\&k_y&\\&&k_z\end{bmatrix}\begin{bmatrix}1&0&0\\ \sin\alpha&\cos\alpha&0\\ \cos\beta\sin\gamma&\sin\beta\sin\gamma&\cos\gamma\end{bmatrix}\begin{bmatrix}u\\v\\w\end{bmatrix}+\begin{bmatrix}x_0\\y_0\\z_0\end{bmatrix}$$

Experiment2. Offset drift with temperature

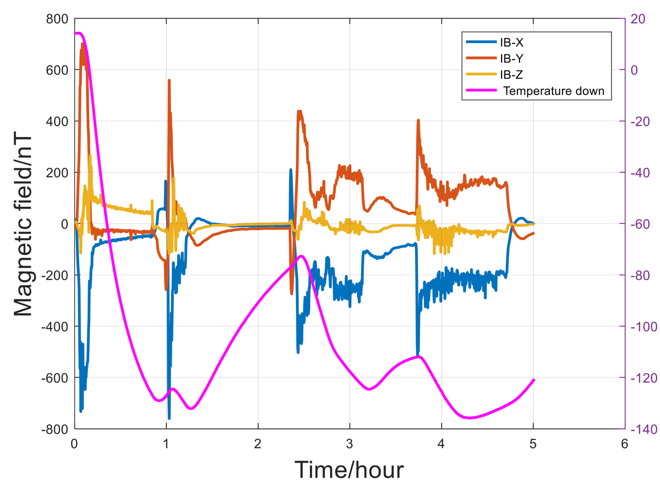
1. Rotate the axes 180° to determine the offset at certain temperature step.

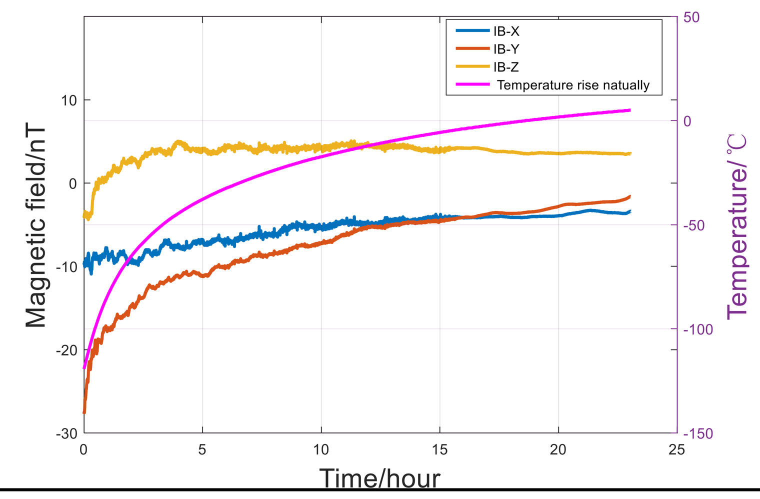
Temperature steps: -120℃, -70℃, -20℃, 25℃. offset $= \frac{M_{0^\circ} + M_{180^\circ}}{2}$



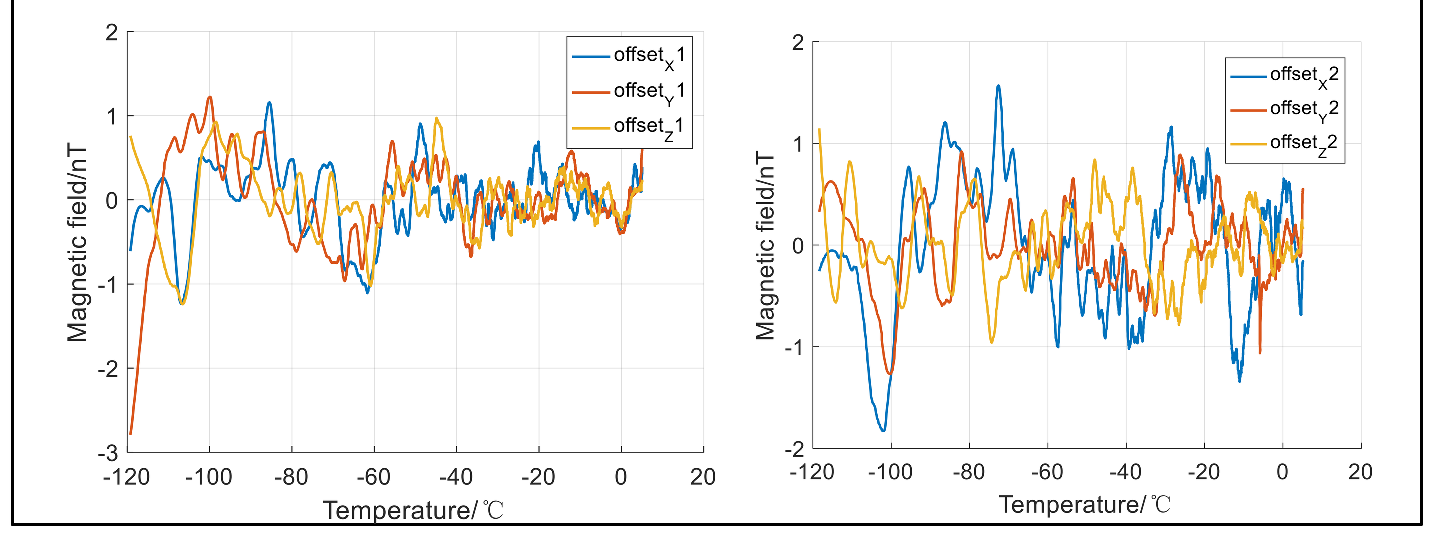
2. Offset stability of the sensors over the whole temperature range (-120℃ to 5℃)

Cooling process and natural heating process:



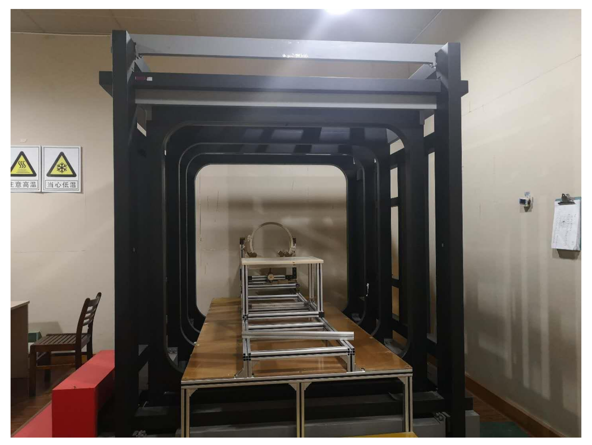


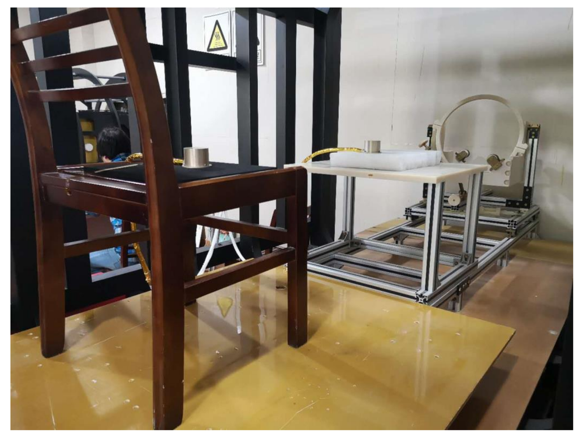
Offset and fluctuations during the temperature rising process

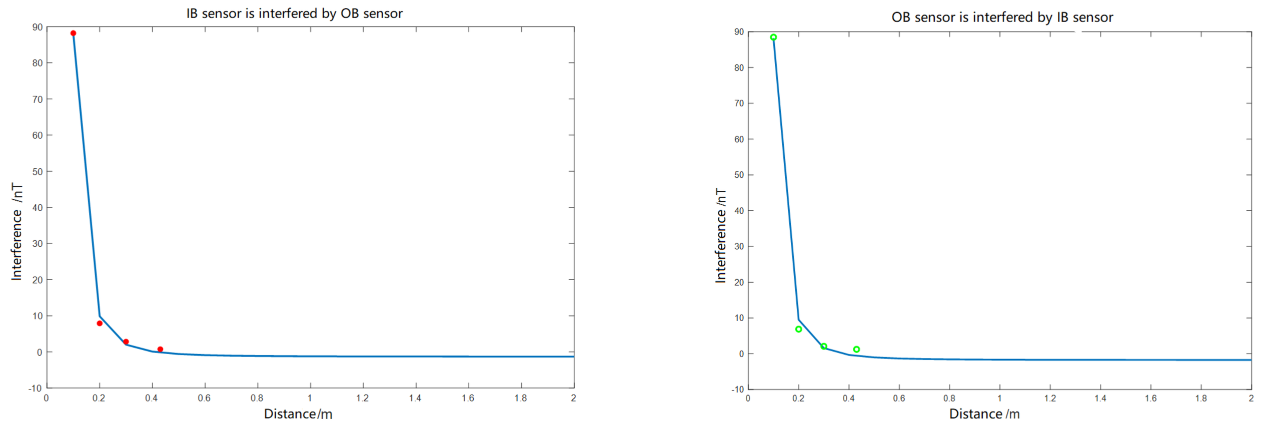


Experiment3. mutual interference of the two sensors

When the magnetometer is working, the internal coil will generate an induced magnetic field, which interferes with the surrounding magnetic field and decays with increasing distance. The actual distance of the inboard sensor and outboard sensor is 0.9 m, we test the mutual interference with 0.1m, 0.2m, 0.3m, 0.43m distance as the limitation of the test facility. Then we get interference at 0.9m through data fitting: $y=a*x^{-3}+b$; x indicate the distance and y is the interference value, and b represents the interference when the two probes are at infinity.







Conclusions

The method, rotating the sensor axes at a 2D plane, to determine the correction matrix proved to be simple and robust. The error of the total magnetic field after correction is less than 1.5nT.

When the temperature was controlled at certain temperature step, the offset stability with temperature is less than 1.55nT over the temperature range from -120℃ to +25 ℃. Full temperature test with temperature rising from -120℃ to 5℃ naturally shows that the fluctuations of the offset plus the residual magnetic are within ±1.5nT (Except for some measurements that are extremely unstable at low temperatures).

From the results of experiment 3, we verify there is almost no mutual interference when the distance between the two sensors is 0.9m.