KPLO Magnetometer Data Processing and Current Status. Wooin Jo[1], Ho Jin[1], Khan-Hyuk Kim[1], Ian Garrick-Bethell[2], Hyeonhu Park[1], Junhyun Lee[1], Yunho Jang[1], Hyeonji Kang[1], Seul-Min Baek[3], and Jo-Ryeong Yim[4], [1]Kyung Hee University, South Korea (whdndls99@khu.ac.kr), [2]University of California, Santa Cruz, [3]Korea Astronomy and Space science Institute, South Korea, [4]Korea Aerospace Research Institute, South Korea

Introduction: The Korea Pathfinder Lunar Orbiter (KPLO) launched on 5 August 2022, has reached the Moon after finishing a 4.5-month Ballistic Lunar Transfer (BLT). KPLO is now orbiting the Moon at an altitude of 100 km $\pm$ 30 km. KPLO contains five payloads developed by Korean universities and research institutes including KARI and one payload from NASA: Lunar Terrain Imager (LUTI), Disruption Tolerant Networking (DTN), Wide-Field Polarimetric Camera (PolCam), KPLO Magnetometer (KMAG), KPLO Gamma Ray Spectrometer (KGRS), and ShadowCam. KMAG, developed by Kyung Hee University, is a magnetic field measurement instrument that consists of 3 magnetometers (MAGs) inside a 1.2-meter boom structure. Each MAG is a triaxial fluxgate designed to measure a ±1000 nT range of DC magnetic fields with 0.2 nT resolution [1]. The scientific objectives are the investigation of the lunar magnetic field and near-Moon space environment.

For these investigations, we are carrying out data processing. This requires several calibrations, similar to previous missions, including estimation of offsets and removal of the ambient field. The public data set will be released by the Korea Aerospace Research Institute (KARI) Planetary Data System (KPDS) compliant with the PDS4 standard [2]. In this presentation, we introduce the KMAG Science Operation Center (SOC) that generates the data products for each step defined by the level of data processing.

Data level: Data level: There are three major data levels: Raw, Partially Processed (PP), and Calibrated (CAL) data. KMAG SOC produces these calibrated data sets from the raw Telemetry (TM) data received from KARI. Raw data (the level-0) is generated by binary parsing and data extraction process from the TM data. PP data (level-1) means that a coordinate transformation, attitude correction and offset adjustment has been applied to the raw data. In the last step, the CAL data is produced by correcting for the temperature effect and ambient field. It is defined as level-2 data, i.e., end-user data.

Data Processing: During KPLO initial operations, KMAG observed magnetic fields in interplanetary space and in the near-Moon space. Therefore, we have been able to test all steps of our pre-built data processing pipeline (Fig 1). For the Level 1 data processing stage, we require ancillary data such as time, ephemeris, and attitude information, which are provided in the form of SPICE kernel by NAIF and KARI [3]. The data is processed in the following steps.

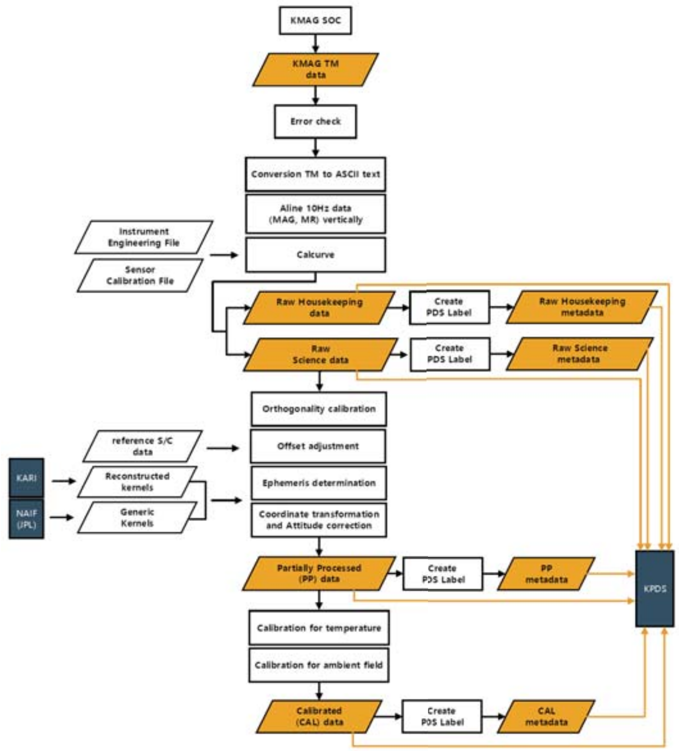

Figure 1. KMAG data products processing pipeline. Partially and fully calibrated data files contain magnetic field vectors in several appropriate coordinate systems in the time-series.

Orthogonality correction. The sensor orthogonality is an important factor for raw data correction, which is in the sensor frame. Using an orthogonality correction equation obtained from ground testing, the standard deviation of the magnetic field was decreased by 0.04 nT on average.

Reference data. For the validation of the KMAG data and the data processing pipelines, we used the DSCOVR spacecraft, which observes the vector magnetic field at Lagrange point L1, as the sample reference.

Offset estimation. After launch, the offset value was larger than we expected. The offset determination is still an ongoing issue. Our initial analysis method used a comparison with reference data to estimate the offset reliability.

Coordinate transformation and attitude correction. To produce PP data, finally, transformation to generic coordinate systems is necessary: Geocentric Solar Magnetospheric (GSM), Geocentric Solar Ecliptic (GSE), Selenocentric Solar Ecliptic (SSE), and Mean Earth/Polar Axis (ME) coordinate systems. For this process, we used the frame kernels provided by NAIF and KARI [3] and the new frame kernels which was made by KMAG SOC for specific coordinates. In order to validate these frame kernels and software, we tested the coordinate transformation pipeline using DSCOVR and KAGUYA data. It was confirmed that the conversion proceeded well. Table 1 and Figure 2 show the results of level 1 data processing after converting KMAG raw data based on GSE coordinates. Finally, we derived the PP data in specific coordinate systems as an end-user request. Although more precise calibration processes are left, the KMAG data shows that it is reasonable and reliable to use for science investigations.

Table 1. Mean and standard deviation of KMAG PP data and DSCOVR data in GSE coordinate systems on September 6, 2022.

Magnetic field	$m_{kmag,gse}$	$\sigma_{kmag,gse}$	$m_{dscovr,gse}$	$\sigma_{dscovr\ gse}$
B_x	-2.9 nT	1.4 nT	-2.8 nT	1.3 nT
B_y	2.9 nT	1.9 nT	3.0 nT	1.7 nT
B_z	0.7 nT	2.5 nT	0.7 nT	2.5 nT

Discussion: In the BLT cruise phase, KMAG on-orbit calibration processes were performed successfully. The level 1 data processing pipeline has been verified and confirmed by way of comparison with DSCOVR. But there still remain some issues such as spatial distortion effect of spacecraft body, removing unwanted disturbances by artificial events and long-term stability. Because KMAG has three fluxgate magnetometers in the boom and one AMR sensor inside the spacecraft body, we are analyzing the data to distinguish the noise signal with a multi-sensing method. For a more reliable quality of data products, we are studying more delicate calibration with ICA numerical methods and machine learning etc.

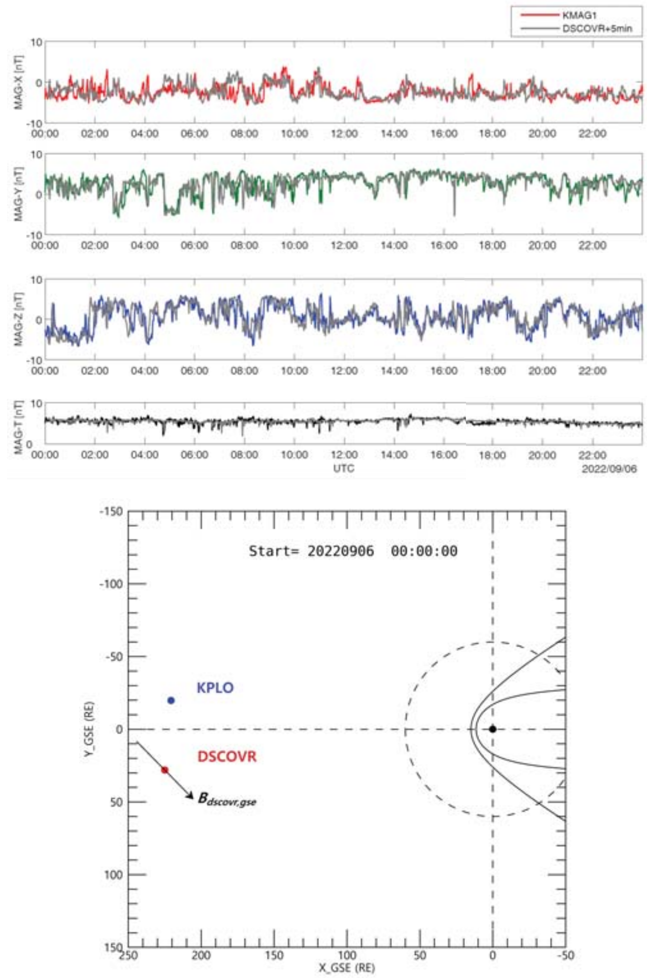

Figure 2. Comparison results of KMAG PP data and DSCOVR (5 min. time-shift) in GSE coordinate systems on September 6, 2022, when KPLO passed the L_1 point closely.

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