Status of the Mercury Thermal Radiometer and Thermal Infrared Spectrometer (MERTIS) for BepiColombo H. Hiesinger[1], J. Helbert[2], M. D'Amore[2], A. Maturilli[2], G. Peter[3], I. Walter[3], I. Weber[1], K. Bauch[1], A. Morlok[1], MERTIS Co-I Team; [1]Institut für Planetologie, Westfälische Wilhelms-Universität, Wilhelm-Klemm-Str. 10, 48149 Münster, Germany (hiesinger@uni-muenster.de), [2]DLR Inst. für Planetenforschung, Berlin, [3]DLR Inst. für Opt. Informationssysteme, Berlin, Germany.

Introduction: The Mercury Radiometer and Thermal Infrared Spectrometer (MERTIS) is one of the instruments on board the European/Japanese BepiColombo mission (Fig. 1). BepiColombo, consisting of the Mercury Transfer Module (MTM), the Mercury Planetary Orbiter (MPO), the Mercury Magnetospheric Orbiter (MMO), and a sunshield, has been completely integrated and tested, and awaits shipping to the launch pad in French-Guyana in March 2018. After launch in October 2018 and several Earth, Venus, and Mercury flybys, BepiColombo will go into orbit around Mercury in December 2025. MERTIS has been delivered to ESA in 2013 and since then has been fully integrated and successfully tested on the spacecraft. MERTIS is a highly miniaturized innovative instrument to investigate the surface composition and mineralogy of planet Mercury. The scientific objectives of MERTIS are 1.) Study of Mercury's surface composition, 2.) Identification of rock-forming minerals, 3.) Global mapping of the surface mineralogy, and 4.) Study of surface temperature variations and thermal inertia.

Figure 1: The BepiColombo MPO during early integration with the radiator panel facing to the right. The MERTIS planet baffle is visible at the bottom planet facing panel.

Instrument: The instrument consists of an uncooled grating push-broom IR-spectrometer (TIS) for the wavelength region of 7-14 μm (78 spectral channels) and a radiometer (TIR) for wavelengths of 7-40 μm (2 spectral channels) [1,2]. This thermal infrared range is particularly well suited to study the surface composition of Mercury because numerous rock-forming minerals have diagnostic spectral features at these wavelengths, i.e., the Christiansen Feature (CF), Reststrahlen Bands (RB), and the Transparency Feature (TF). Feldspars, for example, can be easily detected and distinguished by the characteristic position of their CF. MERTIS will also allow us to identify and map occurrences of elemental sulfur, pyroxenes, olivines, and other complex minerals. MERTIS will globally map the surface at a spatial resolution of about 500 m and for approximately 5-10% of the surface at a resolution of up to 280 m [3]. MERTIS features more than 10 miniaturized, highly integrated subsystems, including mirror optics, two IR detectors (bolometer and radiometer) with read-out electronics, two actuators (pointing unit and shutter), two on-board blackbody calibration targets at 300 and 700 K, two baffles (planet, space), heater, temperature sensors, and two cold redundant instrument controllers and power supplies (Fig. 2). MERTIS has a mass of less than 3.1 kg and during nominal science operations has a power consumption of 7.9 - 9.9 W and exceeds all previously defined science requirements (Tab. 1). Further technical information can be found in [3].

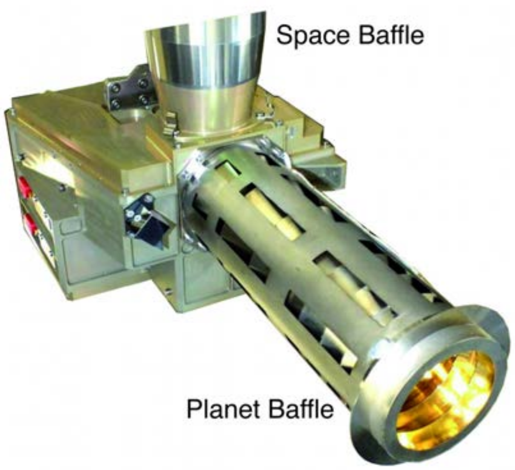

Figure 2: The MERTIS flight model (FM). The housing has dimensions of about 180x180x130 mm; the planet baffle is about 200 mm long

Ongoing Work: *Operations:* We are currently preparing for launch and the Near-Earth commissioning phase, as well as planning for Venus flybys, and the first year of Mercury observations. For the Mercury observations, we are developing a Science Activity Plan (SAP), which will be verified with our Science Traceability Matrix. This requires a definition of hierarchic observation sequences and the implementation of our operations concept into ESA planning tools.

Data Compression: In addition, the limited BepiColombo downlink capabilities in combination with the large MERTIS data volume makes it necessary to develop a data compression algorithm to maximize science return. Thus, we tested several such algorithms (Discrete Cosine-Transformation, Hadamard-Transformation, Haar-Wavelet-Transformation). We found that calculating differences between two consecutive images will result in a loss-less compression rate of 4 for MERTIS test data and this option has been implemented into the onboard software and successfully tested with data from the MERTIS flight spare (FS) model. A significantly higher lossy data compression is possible when truncating the data by 2 bits, which mostly carry noise. However, in this case, the signal-to-noise ratio will be reduced to less than 10%.

Ground Reference Model: The MERTIS FS is stored at DLR in Berlin and serves as ground reference model for testing software procedures and instrument performance. For this purpose, we developed and built a nitrogen-purged chamber with two black bodies (high and low T) that allow us to simulate observations at Mercury. The set-up is fully functional and will support our launch and Near-Earth commissioning activities.

Laboratory studies: Both laboratories, i.e., the Infrared & Raman for Interplanetary Spectroscopy (IRIS) laboratory in Münster and the Planetary Spectroscopy Laboratory (PSL) in Berlin have been updated and are regularly producing reference spectra of Mercury-relevant materials to be incorporated in the Berlin Emissivity Database (BED) [4-8]. In both locations, P/T effects on the spectral information are currently studied [9-11] and in Münster we are simulating effects of space weathering via laser experiments, ion bombardment, and impact shock experiments [12]. We also developed thermal models for the lunar surface, which we can now apply to the mercurian surface [13-14].

	Sub-Unit	Subject	Target perfomance	Minimal required performance	Science goal
1	Spectrometer	Spectral range	7-14 μm	7.2-13 μm	1,2
2	Spectrometer	Spectral resolution	90 nm	200 nm	1,2
3	Spectrometer	S/N ratio at Christiansen feature (7.5 μm)	>200	> 100	2
4	Spectrometer	Spatial resolution at 400 km apoherm	< 300 m	< 500 m	2,3
5	Spectrometer	Spatial resolution for global mapping	< 500 m	500 m	2,3
6	Spectrometer	Coverage with more 500-1000 m resolution	100%	95%	2,3
7	Spectrometer	Coverage with better than 500 m resolution	10%	5%	2,3
8	Radiometer	NETD at 100 K surface temperature	≤ 1 K	≤ 3 K	4
9	Radiometer	Spatial resolution at 400 km apoherm	≤ 2000 m	≤ 5000 m	4
10	both	Operation period	Continuous operation with priorities according to observation conditions	Operation during the periherm on dayside	3

Table 1: MERTIS science performance. Target performance must be reached to meet 100% of science goals. If the instrument only fulfills the minimum requirements, some science goals might be affected. Green colors indicate that a requirement is fully met; MERTIS spectral resolution exceeds the minimum requirement, but does not reach the target performance.

References: [1] Hiesinger et al. (2010) Planet. Space Sci. 58; [2] Peter et al. (2013) Proc. SPIE 8867; [3] Hiesinger et al. (2014) LPSC 45; [4] Maturilli et al. (2008) Planet. Space Sci. 56; [5] Morlok et al. (2014) LPSC 45; [6] Morlok et al. (2017) Icarus 296; [7] Morlok et al. (2016) Icarus 278; [8] Helbert et al. (2013) EPSL, 371; [9] Helbert et al. (2013) EPSL, 369; [10] Reitze et al. (2017) EGU, 17491; [11] Weber et al. (2016) Met. Planet. Sci. 51; [12] Stojic et al. (2016) LPSC 47, 2332; [13] Bauch et al. (2014) Planet. Space Sci. 101; [14] Bauch et al. (2016) EGU 16736.