SIMBIO-SYS, the remote sensing instruments on board the BepiColombo mission

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Abstract. The SIMBIO-SYS (Spectrometer and Imaging for MPO BepiColombo Integrated Observatory SYStem) is a complex instrument suite part of the scientific payload of the Mercury Planetary Orbiter for the BepiColombo mission, the last of the cornerstone missions of the European Space Agency (ESA) Horizon + science program. It will explore Mercury, the closest planet to the Sun. The SIMBIO-SYS instrument will provide all the science imaging capability of the BepiColombo MPO spacecraft. It consists of three channels: the STereo imaging Channel (STC), with broad spectral band in the 410-930 nm range and medium spatial resolution (up to 60 m/px), that will provide Digital Terrain Model of the entire surface of the planet with an accuracy better than 80 m; the High Resolution Imaging Channel HRIC), with broad spectral bands in the 530-900 nm range and high spatial resolution (up to 6 m/px), that will provide high resolution images of about 10% of the surface, and the Visible and near-Infrared Hyperspectral Imaging channel (VIHI), with high spectral resolution (up to 6 nm) in the 400-2000 nm range and spatial resolution up to 120 m/px, it will provide the global coverage at 480 m/px with the spectral information, assuming the first orbit around Mercury with periherm at 480 km from the surface.
It has been funded by the two space agencies, ASI (Italian Space Agency) and CNES (French Space Agency) and it is the result of the collaboration between more than 100 scientists and engineers of 12 different countries all over the world, with the Italian prime contractor Leonardo spa. It is the first time that a planetary mission has three remote sensing instruments integrated in a system, sharing the Main Electronics, and under the responsibility of one team.

Introduction

The Spectrometer and Imagers for MPO Bepicolombo Integrated Observatory SYStem (SIMBIO-SYS) is a suite of three independent optical heads that will provide images and spectroscopic observations of Mercury's surface. The SIMBIO-SYS instrument on board the Mercury Planetary Orbiter (MPO), one of the two modules of the BepiColombo mission, is composed of HRIC (High Resolution Imaging Camera), STC (STereo Channel), and VIHI (Visible and Infrared Hyperspectral Imager). The scientific objectives at mission level are to obtain a global mapping of the surface with STC and VIHI in the first 6 months of the 1 year nominal mission. Both channels will provide data on the surface composition, the surface geology as well as Digital Terrain Models (DTMs) of the entire planet.

The observing strategy of SIMBIO-SYS is based on the global mapping requirement and includes high-resolution images of 10% of the surface (HRIC). In the second 6 months, STC and VIHI will fill in gaps possibly left in the global mapping. In this phase, VIHI will observe selected regions at a spatial resolution of a factor of four better than during the previous phase. STC will acquire 4 color images of selected regions.

The BepiColombo mission will arrive at Mercury in December 2025, the instrument commissioning will be in March 2026 with the starting nominal mission in April 2026.

It is the first time that a planetary mission has three remote sensing instruments integrated in a system sharing some hardware components. The Main Electronics (ME) and the onboard software

are the same, allowing for synergistic management of operations, data handling, and compression of all the acquired data. A single factory provided all the detectors that are similar for the three cameras. From an engineering point of view, the systemic approach to the design has had several advantages:

- the technical management structure allowed the management of the developing and testing phases with the main target of optimizing the overall performance and capabilities of SIMBIO-SYS;
- the integration of the common parts allowed a better control and the optimization of the resources as mass and power;
- mechanical, thermal, and electrical interfaces towards the spacecraft have been handled at a unified level.

From a scientific point of view, the systemic approach with the same management will provide many advantages:

- cross-calibration and co-alignment of the three channels is included in the commissioning and operations;
- co-registration and data fusion are easier and included in the scientific activities;
- common science planning is applied.

Scientific objectives

The SIMBIO-SYS integrated package [1](Figure 1) aims to provide answers to almost all the main scientific questions of the BepiColombo mission concerning the Mercury surface and composition, and to provide important contributions to the understanding of its interior and exosphere. The main scientific questions can be summarized in the following topics:

- shape and morphology;
- crustal mineralogy;
- geological mapping and stratigraphy;
- volatiles;
- interior;
- Hermean extreme environment;
- exosphere;
- surface changes;
- opportunity science

Technical description

To fulfil the scientific goals of the mission, in compliance with the limited resources available on the MPO and the harsh operative environment, several solutions and technologies have been implemented, namely:

- A very compact design for HRIC
- A wide spectral coverage wih a single channel instrument for VIHI
- A single detector dual channel design for STC
- A special coating (ITO) and baffle (Stavroudis design) for heat load rejection
- Diamond turned mirrors in RSA905 Aluminum alloy
- Spectral and radiometric in-flight calibration unit with no moving parts
- Large use of composite materials for structural parts
- Capabilities of stereo imaging

In addition, an instrument architecture with three dedicated Proximity Electronics (PE) and a common Main Electronics (ME) was designed, aimed at the best use of the available electrical resources thanks to the sharing of functions among the three channels.

Each channel of the SIMBIO-SYS Flight Model (FM) has been successfully tested and characterized at Leonardo SpA premises by means of two dedicated Optical Ground Support Equipment (OGSE) which have been developed and manufactured for this purpose.

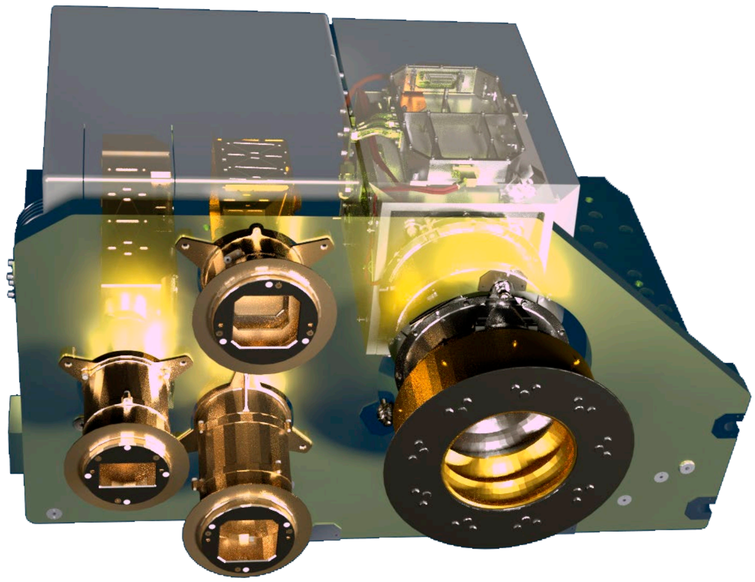

Figure 1: The three channels together representing SIMBIO-SYS, including the Proximity Electronics (PE), on the left VIHI, in the middle STC and on the right HRIC

High Resolution Camera

HRIC is a camera operating in the 530 nm to 900 nm spectral range with 6 m resolution on ground from the orbital altitude of 480 km.

The camera is equipped with a main panchromatic channel and three broadband spectral channels centred at 550 nm, 750 nm and 880 nm with 40 nm bandwidth.

The HRIC optical system [2] is composed of a telescope with a Ritchey-Chretien configuration modified with three-lenses corrector aimed to guarantee the optical quality over the whole squared 1.47° FoV. The instrument has a focal length of 800 mm and is equipped with a dioptric image corrector adapting the FoV to a 2048 x 2048 pixels detector with a pixel size of 10 μm. The focal ratio is F#8.9, to be diffraction limited at 400 nm and to optimize radiometric flux and overall mechanical dimensions. Due to the large amount of heat flux coming from Mercury, the camera aperture is protected from the planet radiation by means of a baffle, in Stavroudis configuration, and a filter, named Thermal Infrared Rejection Device (TIRD), which can be considered as part of the HRIC thermo-optical system.

The selected Stavroudis configuration for the baffle is composed of six elliptical and five hyperbolic internally high-reflecting surfaces interconnected together. All the surfaces have two common foci and this provides the baffle with the geometrical property to reject externally, after a given number of multiple reflections, all the rays impacting on the conical surfaces from an angular direction within the two foci.

Stereo Camera

STC represents one of the first push-frame stereo cameras on board a planetary mission. Based on a new concept, STC integrates the compactness of a single-detector telescope with the photogrammetric capabilities of bidirectional cameras [3]. Two separate incoming optical path oriented at ±20° with respect to nadir allow the instrument to acquire images of the same surface region with a different viewing angle at two very close moments, taking advantage of the along-track movement of the S/C. The optical system is an advanced compact catadioptric layout concept, which consists of a front-end optical separation group of mirrors inclined in order to realize ± 20° stereo channels and a common telescope, based on an off-axis modified 'Schmidt corrector' design.

Visible Infrared Hyperspectral Imager

The VIHI channel has been designed to perform hyperspectral imaging observations of the whole Hermean surface in the VIS-NearIR range [1]. The channel concept is based on a collecting telescope and a diffraction-grating spectrometer ideally joined on the telescope focal plane, where the spectrometer entrance slit is located. The image of the slit is dispersed by the diffraction grating on a bi-dimensional detector. The instantaneous acquisition on the bi-dimensional detector consists of the slit image diffracted by the grating over the spectral range. The image itself is built in time by subsequent slit acquisitions, matching the S/C track speed with the slit size projected on ground (push broom mode). The final result is an hyperspectral cube, which associates a VIS-NearIR spectrum to each pixel on ground. VIHI has been designed to achieve an IFoV of 250 μrad (corresponding to 120m @ 480km altitude) and to cover a spectral range of 400-2000nm with a spectral sampling of 6.25nm.

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