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STC Observation Strategy Report (Issue 1.0)

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1	**06.2020**	Table 3 at page 14-15 aligned to nominal definitions	**Issue 1 Revision 4**

Contents

1. INTRODUCTION

1.1. Scope

This document aim is to collect information and concepts necessary to define an observation strategy for STC and plan its observations.

1.2. Reference Documents

RD1 BC-EST-RS-01140 Experiment Interface Document Part A 2010
RD2 SIMBIOSYS Experiment Interface Document Part B
RD3 BC-ESC-RP-05500_BC_CREMA
RD4 BC-SIM-GAF-MA-002 6 User Manual
RD5 bc_mpo_mlt_50037_20260314_20280529_v01.orb
RD6 Slemer, A., Zusi, M., Simioni, E., Da Deppo, V., Re, C., Lucchetti, A., ... & Capria, M. T. (2019). Development of a simulator of the SIMBIOSYS suite onboard the BepiColombo mission. Monthly Notices of the Royal Astronomical Society.

RD 7 Slemer, A., Da Deppo, V., Simioni, E., Re, C., Dami, M., Borrelli, D., ... & Naletto, G. (2019). Radiometric calibration of the SIMBIO-SYS STereo imaging Channel. CEAS Space Journal, 1-12.
RD8 BC-SIM-OPD-TN-13
RD9 BepiColombo FOP Issue 3.2

1.3. Acronyms

AT	Along Track	**HR**	High resolution
CM	Colour Mapping	**IT**	Integration Time
CBD	Compression Box Dimension	**LR**	Low resolution
CT	Cross track	**RT**	Repetition Time
DV	Data Volume	**SM**	Stereo Mapping
FOPs	Flight Operation Procedures	**S/C**	Spacecraft
FSA	Filter Strip Assembly	**TA**	True Anomaly
FPA	Focal Plane Assembly	**WX**	Window X
GM	Global Mapping		

2. CONSTRAINTS FROM THE MISSION DESIGN

In this section the main physical and technical terms are defined. The physical and instrumental assumptions are also included.

2.1. The orbit of Mercury and related parameters

The orbital period of Mercury (one Hermean year) around the Sun is 88.0 Earth days, while the rotation period around its axis is 58.6 Earth days thus a 3:2 spin-orbit resonance is present. Every two Hermean years (176 days) the same side of the planet faces the Sun at perihelion, and the planet rotates 3 times around its axis. Figure 1 and Figure 2 represent, respectively, one orbit of Mercury around the Sun and the subsequent orbit. In the figures a reference meridian has been defined and its orientation has been drawn as a red segment to visualize the planet rotation about its axis and the corresponding orientation wrt the Sun. After one orbit around the Sun (see Figure 1) the reference meridian has rotated by one full revolution plus 180°; note that at day 58 the orientation is the same as that at day 0, and the planet has experienced a full rotation about its rotation axis. After the second orbit around the Sun (see Figure 2) the reference meridian will be at the same orientation of day 0 and the planet has done 3 full rotations around its axis.

The Mercury orbital plane is inclined by 7° with respect to the ecliptic plane, while the rotation axis is almost perpendicular, i.e. the axis tilt is 0.034°. Orbital eccentricity is 0.2056.

The mean radius of the planet is 2439.7±1 km. One degree on the surface at the equator corresponds to 42.58 km.

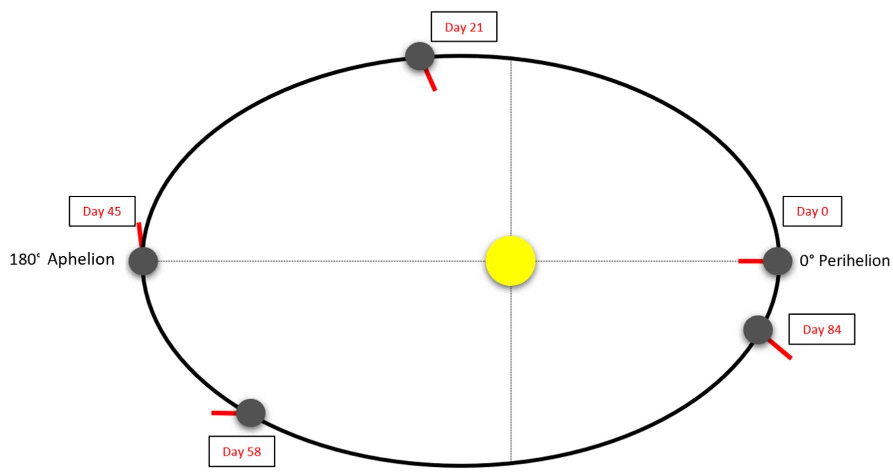


Figure 1 *One Mercury orbit around the Sun is depicted starting from perihelion (day 0). The evolution of the orientation along the orbit of a reference meridian (the red segment) on the planet is shown.*

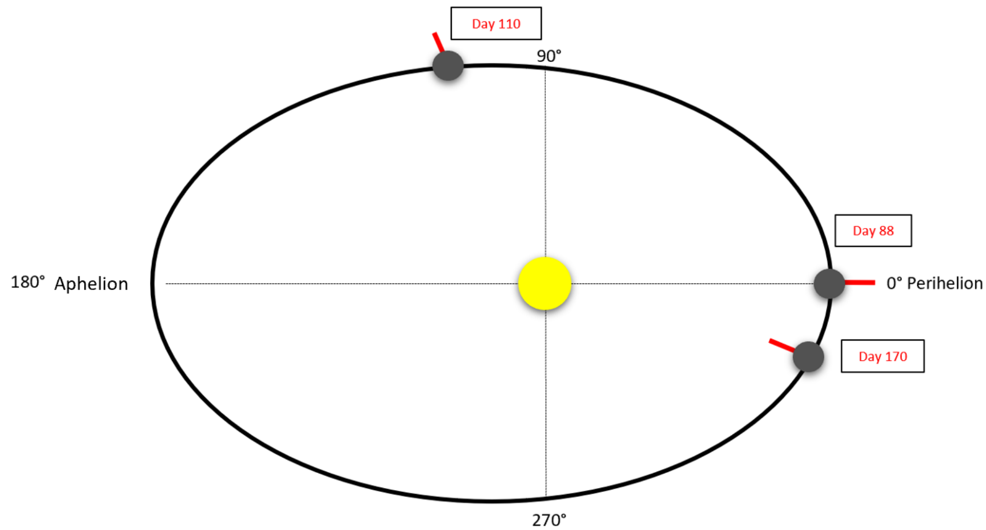


Figure 2 *A second Mercury orbit around the Sun is depicted starting at perihelion (day 88). The evolution of orientation along the orbit of the reference meridian (the red segment) on the planet is shown.*

The longitude convention for Mercury assumes the zero of longitude at one of the two hottest points on the surface. However, when this area was first visited by Mariner 10, this zero meridian was in darkness, so it was impossible to select a feature on the surface to define the exact position of the meridian. Therefore, a small crater further west was chosen, called Hun Kal, which provides the exact reference point for measuring longitude. The center of Hun Kal defines the 20° West meridian.

2.2. The orbit of the Mercury Planetary Orbiter

The Mercury Planetary Orbiter (MPO) spacecraft is three-axis stabilized, with the Z axis pointing along the nadir direction. The orbit of the spacecraft is polar, inertial and elliptical. See **Figure 3** for a schematic visualization of the MPO orbit orientation wrt to the planet orbit around the Sun.

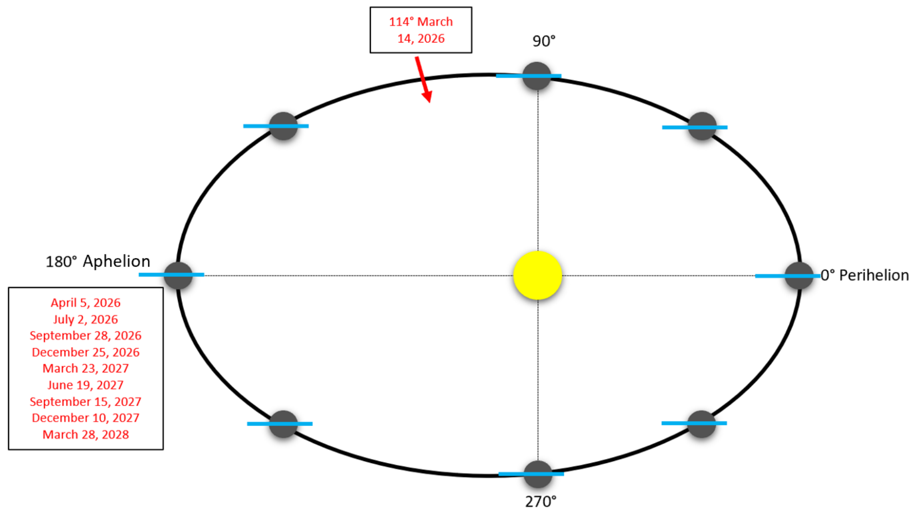


Figure 3 *Mercury orbit around the Sun together with the projection of MPO (polar, inertial and elliptical) orbit (blue segment) around the planet. The date of the beginning of the scientific mission and the dates of the aphelion passages occurring during the nominal and extended mission are highlighted in red.*

	MPO
hp (km)	480
ha (km)	1500
a (km)	3430
e	0.148688
T (h)	2.362
vp (km/s)	2.944
va (km/s)	2.182
$i(°)$	90.0
$\Omega(°)$	67.8
$\omega(°)$	16.0

Table 1 - *Initial orbital elements of MPO (20 Mar 2026).*

The S/C orbital plane is perpendicular to the Mercury equator, the periherm position is opposite to the Sun at perihelion while it is subsolar (same direction as the Sun) at aphelion. Table 1 shows the initial (20 March 2026) orbital elements of MPO in the Mercury equatorial system (beta angle=0°) (see **RD3** Section 2.3). At this time, the argument of periherm is +16° (16° N) with a periherm altitude of 480 km and an apoherm one of 1500 km. The altitude at the equator is 495 km at the ascending node and 1474 km at the descending node; the altitude at the North Pole is 782 km while at the South Pole is 1058 km. The period of the orbit is 2.362 h. Successive MPO ground tracks are separated by 0.595 deg (25.3 km) at the equator due to the rotation of Mercury.

After half a year, the argument of periherm is 0° and the coverage is symmetrical with an altitude of 914 km over both poles. In **Figure 4** the variation of MPO altitude with respect to true latitude for a periherm argument of 16° (beginning of science phase) and of 0° (after six months) is shown.

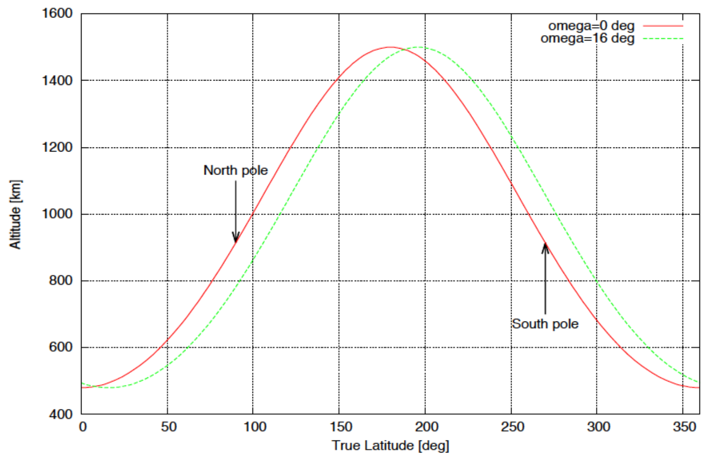


Figure 4 - *Variation of MPO altitude with respect to true latitude for a periherm argument of 16° (green curve, beginning of science phase) and of 0° (red curve, after six months).*

Along the operative phase (TA=138°-222°), the planet covers a mean of 0.28°of TA for each S/C orbit.

The observation strategy discussed in this document is based on the ORBNUM file (RD5) that lists 8199 scientific phase orbits from March 14, 2026 to May 29, 2028. In Figure 5 the projection at the periherm of the nadir direction on the surface of the planet for the science phase orbits is plotted with respect to the latitude and longitude of Mercury surface.

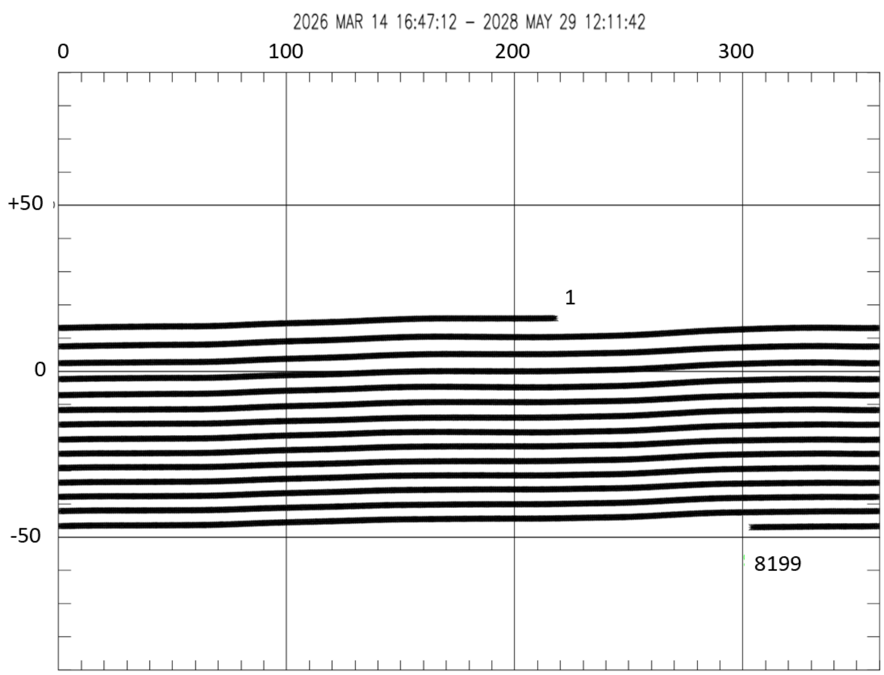


Figure 5 *Coordinates on the surface of Mercury of the sub-nadiral point at the periherm for the science phase orbits and extended mission.*

In Appendix A1 the scientific orbits are listed and classified, on the basis of the true anomaly, as:

- High Resolution orbits (HR*n*, where *n* is a progressive number), with TA between 138° and 222° (around the aphelion),
- Low Resolution orbits (LR*n*)), with TA between 278° and 82° (around the perihelium), not considered in current strategy report because STC will not acquire images in these orbits,
- Terminator orbits (T) in spring/autumn phases, with TA between 82°-138° and 222°-278, not considered in current strategy report because STC will not acquire images in these orbits.

Note that the phase HR2 is hereafter considered as "first" aphelion (when the Global Mapping phase will start). The phase HR1, dedicated to calibration is hereafter considered as "aphelion 0".

2.3. Scientific requirements

In RD2 it has been stated that STC is required to perform a global mapping of the Hermean surface and determine the location, size and height of the major structures with a best resolution of 60 m (at the periherm on the equator). This will allow the reconstruction of a global Digital Terrain Model (DTM), in order to map the global heights distribution of the planet's surface to a vertical accuracy of 80 m (at the periherm). The global mapping should be ideally completed in the first six months of the Scientific Phase ($\frac{2}{3}$ of the Hermean year). After the Orbit Insertion (TA 67°) and the separation of the two modules MMO and MOSIF (respectively 20-26 December 2025), the Global Mapping Phase will start (at first aphelion hereafter HR2), allowing to extend the commissioning phase till the end of HR1, i.e. for TA values between 200° and 222°.

2.4. Mission analysis

The science observation strategy of STC can be based on a cycle of two orbital periods, each one lasting 176 Earth days (88 x 2), corresponding to a day-night period (1 Herman day = 1 sol). In one orbital period half of the planet can be imaged. The observation strategy can be defined for one orbital period, and in the following period the opposite hemisphere can be imaged because the same observation conditions repeat (the planet has rotated by 180°).

An orbital period can be divided in different phases: low resolution (LR) mapping phase (15 + 15 days, true anomaly 278°-82°, i.e. 278°-360° and 0°-82°), and high resolution (HR) mapping phase (30 days, true anomaly 138°- 222°). The plots in the **Figure 6** and **Figure 7** refer to these periods. A reference meridian is drawn in red, the spacecraft orbit in blue.

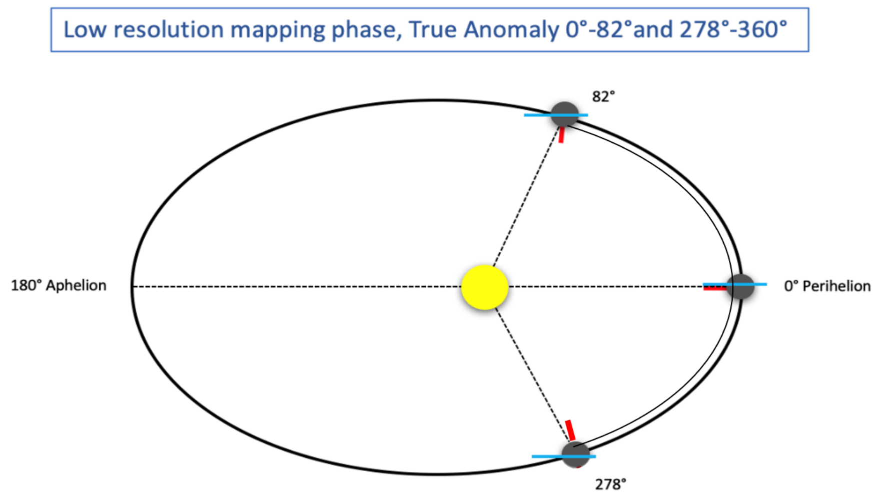


Figure 6 *Low resolution mapping phase. The spacecraft orbit is drawn in light blue, a reference meridian on the planet in red.*

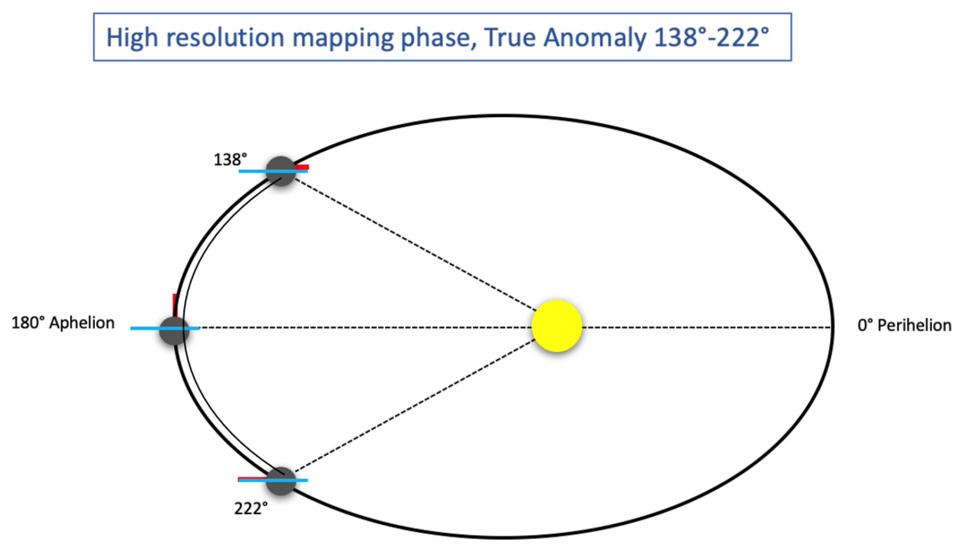


Figure 7 *High resolution mapping phase. The spacecraft orbit is drawn in light blue, a reference meridian on the planet in red.*

3. CONSTRAINTS FROM THE INSTRUMENT DESIGN

3.1. Field of view

STC is composed of two sub-channels (i.e. High (-H) and Low (-L)). The angle between each sub-channel line of sight and the instrument boresight is nominally 20° (see **Figure 8**).

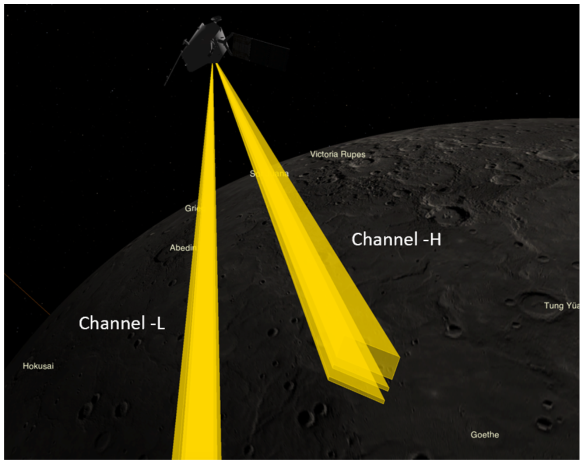


Figure 8 *Screenshot of Cosmographia Tools showing the two sub-channels FoVs of STC. For the sub-channel-H, it is possible to note the FoVs of the Panchromatic filter (greater one) and the 2 colour filters.*

The two sub-channels images are acquired on the same detector (2048 x 2048 pixels). The field of view (FoV) of each sub-channel is rectangular, being 5.386° in the cross-track (CT) direction and 4.8° in the along-track (AT) direction including gaps (**Figure 9** and **Figure 10** and Table 2). 3 filter strips for each sub-channel, one panchromatic and 2 colour, form a window (Filter Strip Assembly) mounted in front of the detector.

The 4 colour filters are centered at the wavelengths of 420 nm, 550 nm, 750 nm and 920 nm and have a bandwidth of 20 nm; the maximum FoV is 5.39° x 0.38° (896 x 64 pixels).

The panchromatic filters are centered at the wavelength of 700 nm and have a bandwidth of 200 nm; the FoV is on average 5.38° x 2.31° (896 x 384 pixels); the angle between each panchromatic filter line of sight and the instrument boresight is 21.375°. The instantaneous field of view (IFoV) of each pixel depends on its position with respect to the boresight of the channel; it is on average 105 x 105 µrad.

On the detector, an area 128x64 pixels wide, called Window X, is acquired for calibration purposes.

Although the maximum FoV of 5.38° corresponds to 896 pixels only for the central 768 pixels (corresponding to 4.61°) the radiometric calibration is guaranteed.

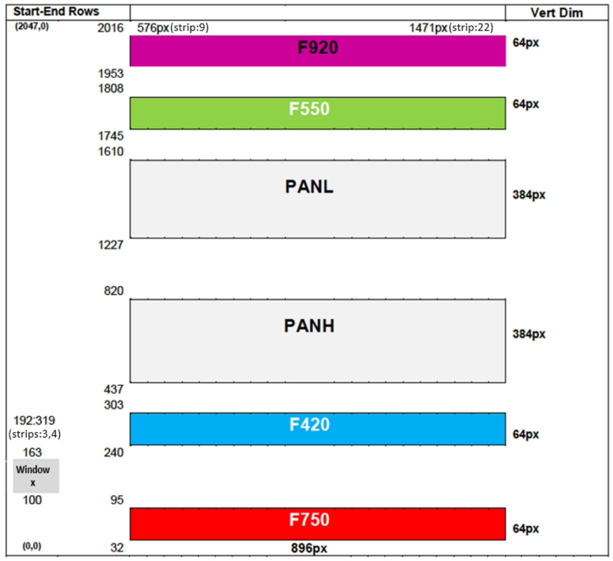
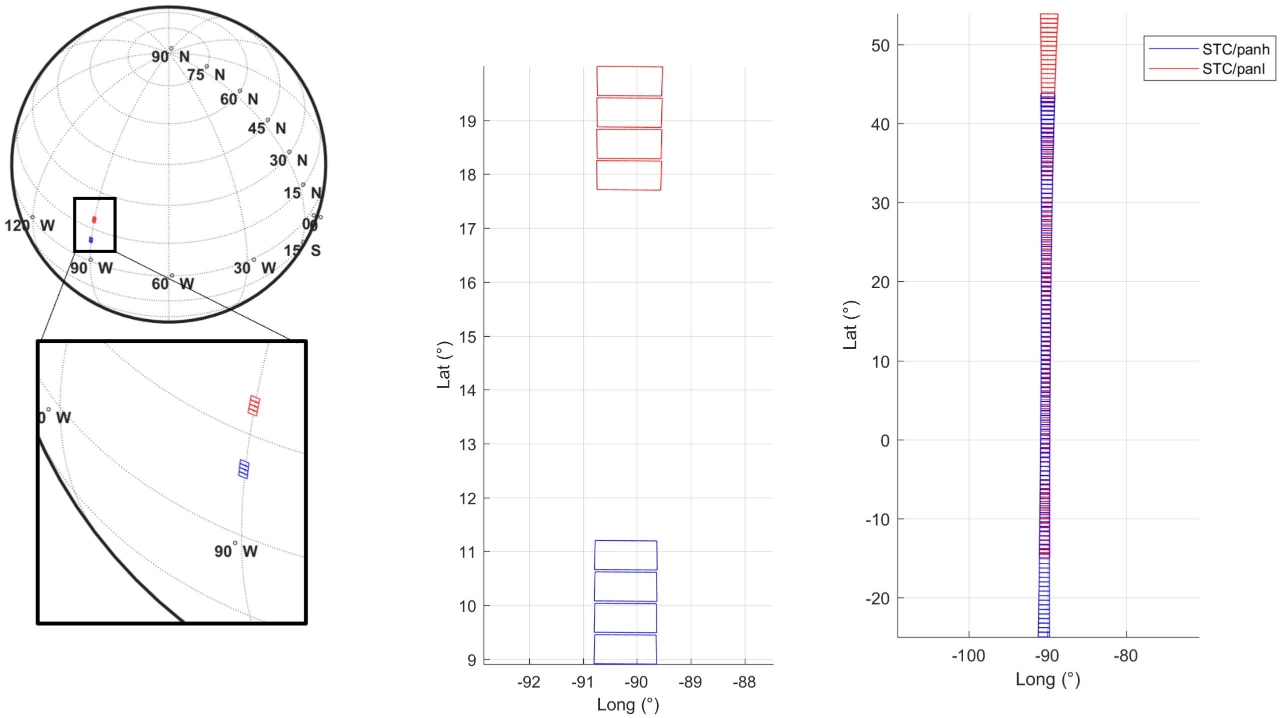


Figure 9 - *Position of the filter regions on the detector. Vertical coordinates are expressed in pixels. Horizontal coordinates are expressed in pixels and in "strips" (1 strip=64 pixels)*

	Raw Definition		Dimension	Bsight Dir	FoV	Angle Definition (vs Nadir)		Angle Definition (vs +-20°)		Bsight (vs ±20°)
	Starting	End				Starting	End	Starting	End	
	[px]	[px]	[px]	[°]	[°]	[°]				[°]
F750	32	95	64	17.95	0.38	17.76	18.14	-2.24	-1.86	-2.05
GAP	96	239	144	18.585	0.87	18.15	19.02	-1.85	-0.98	-1.42
F420	240	303	64	19.22	0.38	19.03	19.41	-0.97	-0.59	-0.78
GAP	304	436	133	20.2975	0.81	19.89	20.70	-0.11	0.70	0.30
PANH	437	820	384	21.375	2.31	20.22	22.53	0.22	2.53	1.38
GAP	821	1226	406	-	-	-	-	-	-	
PANL	1227	1610	384	21.375	2.31	20.22	22.53	0.22	2.53	1.38
GAP	1611	1744	134	20.2975	0.81	19.89	20.70	-0.11	0.70	0.30
F550	1745	1808	64	19.22	0.38	19.03	19.41	-0.97	-0.59	-0.78
GAP	1809	1952	144	18.585	0.87	18.15	19.02	-1.85	-0.98	-1.42
F920	1953	2016	64	17.95	0.38	17.76	18.14	-2.24	-1.86	-2.05

Table 2 - *Definition of the starting and ending vertical coordinates of the filter region on the detector in terms of pixels and FoV. The FoV is defined for each pixel row both in the nadiral reference system (angles on ground) and in the local sub-channel reference system where -H and -L are considered with a nadiral angle of 20°. All filters are considered horizontally starting from pixel 576 to 1472 with a FoV of 5.38° centred in the nadir direction.*



(a) (b) (c)

Figure 10 – *Projection on the surface of Mercury, at the aphelion 0 orbit (HR1), of the footprints (FoVs) of the panchromatic filter of SIMBIOSYS: STC –PAN H and -L (respectively in blue and red). Simulations: in a) projection on the Mercury sphere and in b) equirectangular projection, of 4 consecutive acquisitions with a repetition time of 10 s (which does not guarantee the AT overlapping). In (c) same simulation but extended to 10 minutes around the periherm of the orbit.*

3.2. Pixel ground size

The pixel ground size is the size of the projection of the IFoV of every pixel on the surface of the planet: this size depends on the altitude of the orbit, the position of the pixel with respect to the FoV and the filter considered.

A summary of the main values in term of pixel dimensions and swaths variation during the different years of Mercury is reported in **Table 3**. The swaths are evaluated through spice kernels (**RD6**) as the dimension of the area defined by the intercepts between the planet spheroid and the bounds of the FoVs of the panchromatic filters. The pixel dimension is reported in both the along track and cross track dimensions as mean value of the pixel size on the FoV of the same filters.

		Pixel On ground				Swath			
SwatAphelion phase	Date	Periherm		Poles		Periherm		Poles	
		AT [m]	CT [m]	AT [m]	CT [m]	AT [km]	CT [km]	AT [km]	CT [km]
HR1	4-APR-2026	72.9	53.9	116.7	84.4	28.0	41.4	44.8	64.8

HR2	1-JUL-2026	66.1	49.1	123.3	88.9	25.4	37.7	47.3	68.3
HR3	27-SEP-2026	60.1	44.7	132.3	95.0	23.1	34.3	50.8	73.0
HR4	24-DEC-2026	54.5	40.7	144.6	103.0	20.9	31.3	55.5	79.1
HR5	22-MAR-2027	49.9	37.3	157.6	111.5	19.2	28.6	60.5	85.6

Table 3 *Swaths and pixels on ground (mean on the panchromatic FoVs) for each aphelion orbit during the nominal duration of the mission. The table shows for each aphelion orbit the pixel dimension and the swath along track and cross track of the PANH filter considering two defined orbit points: the periherm, i.e. when the distance between the spacecraft and the planet is at a minimum, and the so-called "Poles Configuration", when the sub-nadiral S/C point is at latitude +83°. In the evaluation, it has been assumed that the Cross Track FoV is the nominal one (768 px). It will change during GM phase to minimize DV.*

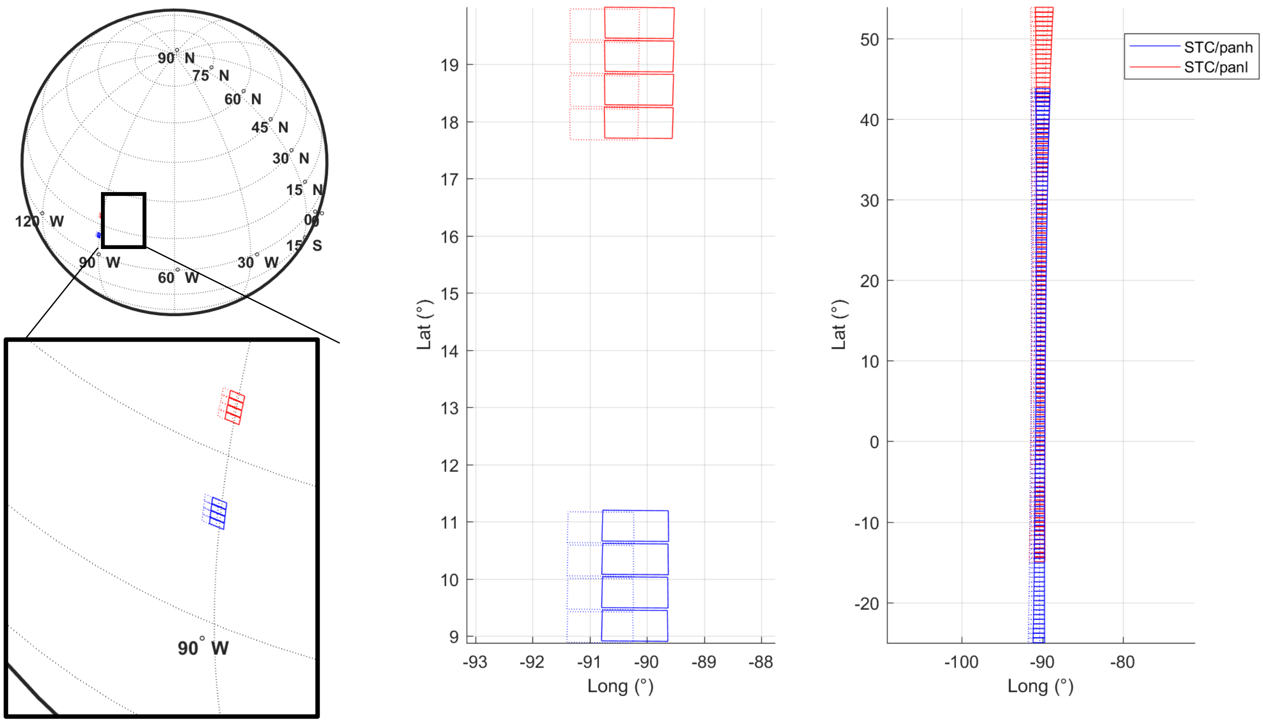
3.3. Ground track

The projections of the sub-channels and filters FoVs on the surface of Mercury could be approximated as rectangular areas (**Figure 10**). We will define as horizontal and vertical ground tracks, representative of the instantaneous projection of a sub-channel, the horizontal and vertical central dimensions of these rectangles.

The on-ground projections of the STC-PAN-H and PAN-L sub-channels FOVs for 2 consecutive orbits are shown in **Figure 11** and **Figure 12**. They represent the projections for two cases: acquisition around the periherm where the subnadiral lat. Is +16° (**Figure 11**), and acquisition around the polar region, where the sub-nadiral latitude is 83° (**Figure 12**), both at the beginning of the scientific phase (HR1).

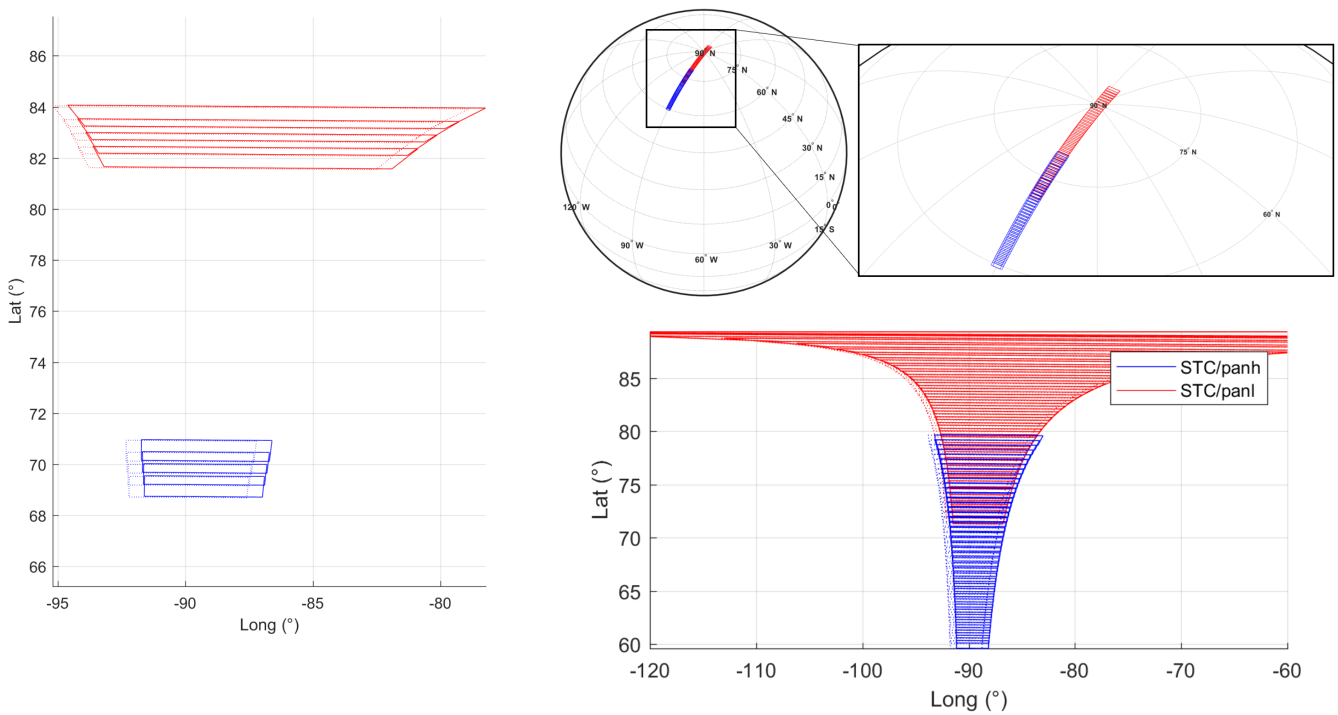
In both cases: in a) the projection on the Mercury sphere is shown, in b) the equirectangular projection of 4 consecutive acquisitions with a repetition time of 10 s (which does not guarantee the AT overlapping), in (c) same simulation but extended to 10 minutes around the same orbit point.

From these plots it is evident that the superposition between the images taken during consecutive orbits is rapidly increasing going from the equator toward higher latitudes.



(a) (b) (c)

Figure 11 – *STC-PANH and PANL FoV projection on the Mercury surface at first aphelion orbit around periherm (lat. +16°). On-ground projection for 2 consecutive orbits of the footprints of the panchromatic filter of SIMBIOSYS STC -H and -L (respectively in blue and red). Projection on the Mercury sphere in a) and equirectangular projection in b) of 4 consecutive acquisitions with a repetition time of 10 sec (which does not guarantee the along track overlapping). In (c) same simulation as in b), but extended to 10 minutes.*



(a) (b)

Figure 12 *STC-PANH and PANL FoV projection on the Mercury surface at aphelion 0 orbit around sub-nadiral latitude +83° (polar region)***.** *On-ground FoV projection for 2 consecutive orbits on the surface of Mercury of the panchromatic filters of SIMBIOSYS STC -H and -L (respectively in blue and red). In (a) simulation of 4 consecutive acquisitions with a repetition time of 10 s (which around the poles guarantees the along track overlapping). Cross track overlapping is almost complete. In (b) same simulation but extended to 7 minutes projected on the Mercury sphere (upper images) and with the equirectangular projection (bottom image).*

Figure 13 gives a different representation of this superposition between consecutive orbits, showing the percentage of superposition of the first orbit with the second one (red line), with the third one (blue line) and with the fourth one (green line) with respect to the latitude. It appears that, while this percentage grows quickly going toward the poles, on the equator it tends to be around 50%.

From the same image it is evident that over the 50° of latitude it is possible to reach the 15% of overlapping cross track by acquiring with the maximum FoV dimensions and working 1 time every 3 orbits.

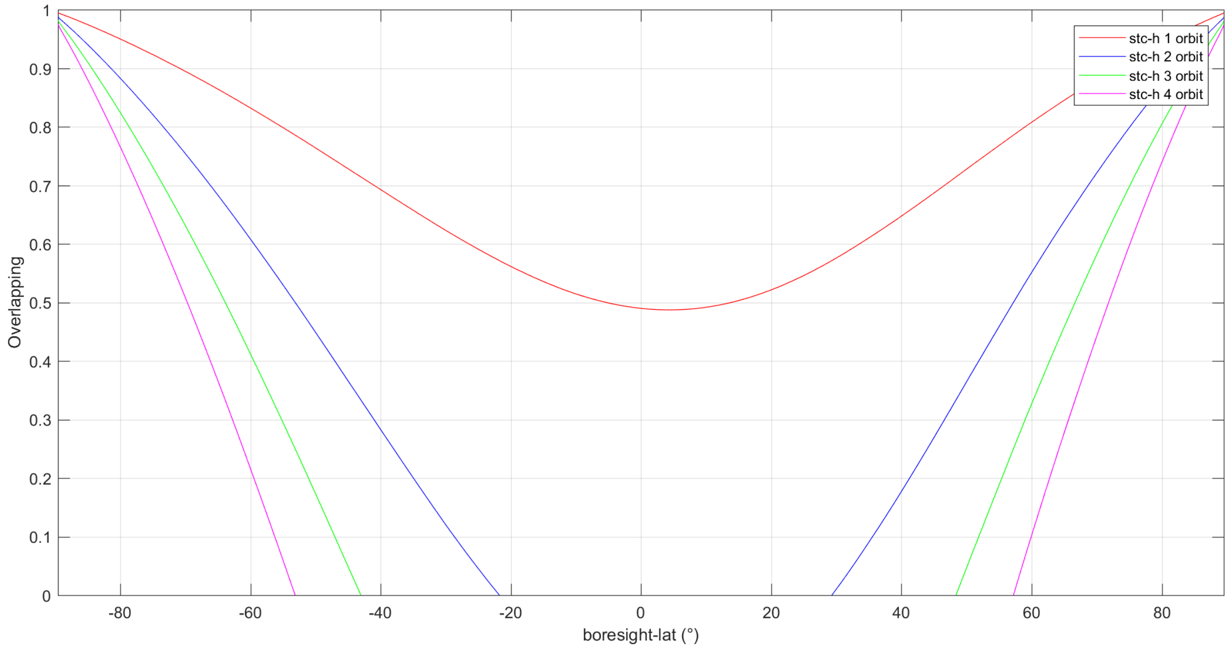


Figure 13 – *Percentage of superposition (for the maximum cross track window size, 768 pixels), with respect to the boresight latitude, of the FoV of one orbit with the consecutive one (red line) and with the following three (blue and green and magenta lines), at the beginning of the mission (HR1).*

4. OPTIMAL STEREO ACQUISITION AND CONFIGURATION

4.1. Percentage of overlapping

Concerning the stereo acquisition of the STC channel during the global mapping phase, the percentage of overlapping (AT) between consecutive acquisitions of each channel should be greater than 10%. In Colour Mode (lower FoV dimension) the minimum required overlapping AT is 15%, as shown in Table 4.

Mode	Overlapping	Min Value [%]	Min Value [px]
Stereo	Along Track	10%	38.4
	Cross Track	15%	78.6
Colour	Along Track	15%	9.6
	Cross Track	-	

Table 4 *Minimum foreseen overlapping, expressed in percentage wrt filter dimension and in pixel, for the main acquisition modes of STC.*

This amount of overlapping would be useful for the alignment of the images acquired in subsequent acquisitions, allowing the identification of a number of tie points in the overlapping area able to accomplish a stable image mosaicking. The availability of a continuous mosaicking of the PAN acquisitions would be important in order to guarantee a stable image block both for the 2D and 3D mapping.
For 3D-reconstruction purposes, the main process consists in the identification of the corresponding image points and in accurately measuring the image coordinates of these points in the overlapping areas within the stereo pair.

On the other side, the processing of a stereo pair at once could give origin to DTMs affected by vertical and lateral offsets between each other. This situation would be caused by the fact that these offsets or tilts are not well constrained by the limited surface coverage of the images. In fact, an absolute positioning of the DTMs is typically well constrained if large regional blocks of images are available.
Considering the across track configuration, even in this case, in order to guarantee a sufficient number of interesting points in the overlapping areas of images to be mosaicked, a minimum overlapping of the 15% between two consecutive orbits for each latitude considered as assumption in this analysis. In this case, we have also to consider the possibility to exploit the overlapping areas in order to adjust the pointing errors between two consecutive orbits.
In any case, an acquisition with the complete FoV could increase the accuracy in the global mosaicking. A good strategy could be (within the limit of the available data volume), for example, to perform this kind of acquisitions for each orbit when the sub-mode, and consequently the cross-track window, changes.
In the acquisition sequence, the repetition time in a science telecommand (TC) must be longer than the sum of the integration time and the maximum between the readout time and the Main Electronics Central Unit processing time.

A Track Dim [px]	Cross-Track FoV [°]	Minimum RT [ms]
896	5.39	0.367
768	4.62	0.315
640	3.85	0.263
512	3.08	0.211
384	2.31	0.160
256	1.54	0.15
128	0.77	0.15

Table 5- *Minimum Repetition Times (RT) allowed (see* **RD8** *for more details). The estimations are defined considering a compression IBR=32 (compression factor = 7), which means a data rate of 2 bit/px. CBD (Compression Box Dimension, see* **RD4***) is defined as 64x64.*

4.2. Illumination conditions

The illumination condition within a stereo pair is a factor that might be relevant in DTM generation, affecting both accuracy and DTM completeness. The performed tests suggest that the range of illumination angles from 50° up to 70° provides better accuracy and coverage of the 3D products while at the same time fulfilling some of the requirements of the scientific community working on 2D images.

4.3. Image compression

In the tests performed on the data produced during the Stereo Validation procedures, several DTMs have been generated by matching the two images of the pair in all the combinations of the compression ratio. The results showed that the increase of the DTM degradation with the compression factor is mild for low compression factors. Combining two images with different compression factors, the result is in most cases marginally better than considering two images both compressed with the same factor. This means that the possibility to acquire stereo images with different compression factors could be useful in order to reduce the data volume, for instance to be used to increase the overlapping percentage, while preserving the accuracy of the DTMs to be produced.

4.4. Windows X

The window X (WX) is a window of minimum dimensions (HxW=64 px X128 px) which is located in a not illuminated area of the detector. The DN values of the WX are acquired while STC acquires images in the Global Mapping phase (2 Panchromatic filters) or in Colour Mode (2 or 4 broad band filters).

The WX acquisitions are important to improve the photometric calibration (**RD 7**).

A maximum of 6 windows can be commanded and acquired at the same time. For this reason, the WX will be not acquired when all the 6 filters of STC are used at the same time. This could happen when the scope of the acquisition will be only to check the geometrical properties (i.e. in the case of geometrical calibration when photometric calibration will be neglected) or when the dark response of the instrument will be well known.

5. OBSERVATION STRATEGY

5.1. Segmented Orbit Strategy

Due to the flexibility of its design, in order to properly operate STC various parameters must be defined: filters combination, size in pixels of the window to be acquired for each filter, repetition time, compression factor. In order to save the data volume and simplify the instrument operations and its implementation in the telecommands it is convenient to divide a spacecraft orbit around Mercury in a number of segments. For each segment the values of the parameters defining a single acquisition is kept fixed. Due to the evolution of the parameters characterizing the orbit of the spacecraft and the different scientific requirements during the phases of the mission, different sets of segments are suitably defined for all the scientific phases.

Note: The number of the segments could be increased in order to optimize the use of the IT and overlapping percentage.

In this report, we assume that the MPO orbit is divided in 11 segments. In 9 of them STC will work acquiring both the sub-channels. In the last 2 segments (near the poles when the nadir of SIMBIO-SYS is pointing to latitudes greater or less than $\pm 83°$), only one sub-channel will work, i.e. the one looking at the illuminated Mercury surface.

5.2. Definitions

An acquisition cycle of STC will give, as a result, one or more rectangular frames (**dataframes**) corresponding to a subset (**window**) on the detector. The window is a matrix of W pixels (defined CT) x H pixels (defined AT). The number of pixels acquired AT is constrained by the filter being used (396 or 64, respectively panchromatic and colour), while the number of pixels acquired cross-track can be predefined. Constraints coming from the compression algorithm being used impose that the number of pixels both along and cross track be a multiple of 64/128 (nominally 64). Constraints coming from the way in which the information is physically read on the detector impose that:

- the minimum allowed CT size be 128 pixels.

- the CT dimension must be a multiple of the CBD (nominally 64 px)

- the AT dimension must be a multiple of the CBD (nominally 64 px)

An **operating mode** is defined by a given set of values for the filters combination, the repetition time, the CT window size and the compression factor. The number of frames that are contemporarily acquired during an acquisition cycle depends on the operating mode and, consequently, on the number of filters and sub-channels used. In an acquisition cycle the frames acquired contemporarily can have different sizes; the collection of these frames is called **dataframe**.

5.3. Compression

The compression algorithm that is used in the onboard software allows to obtain bit packing, reversible (lossless or error-free) compression and irreversible (lossy) compression. The parameter defining the way in which the algorithm is applied is *IBR (Inverse Bit Rate)*, that can assume the values from 0 to 63:

- *ibr* = 0 means bit packing,
- *ibr* = 1 means lossless compression,
- *ibr* values comprised between 3 and 63 mean lossy compression.

The *ibr* factor defines the actual compression ratio and bit rate, following the expressions :

Bit rate = *ibr*/16

Compression ratio = ADC_bits/(*ibr*/16)

where ADC_bits = 14, while 1 pixel for SIMBIO-SYS is 14 bits.

The *IBR* values defining the lossy compression are here reported as example:

ibr =8 <=> 0.5 bit/pixel <=> compression factor = 28

ibr=16 <=> 1 bit/pixel <=> compression factor = 14

ibr=32 <=> 2 bit/pixel <=> compression factor = 7

ibr=63 <=> 3,9375 bit/pixel <=> compression factor = 3.56

In the following, we will use both the concepts of bit rate and compression ratio in evaluating the data volume.

5.4. Parameters defining the operations

In the following table the allowed values for the parameters defining the operations of STC are shown.

The main STC acquisition parameters are the following:

- IBR (Inverse Bit Rate): defines the compression used by ME to post process the images
- RT (Repetition Time) expected by the velocity of the boresight intersection with the planet (and consecutively by the height of the S/C) and by the along track overlapping required for the acquisition
- PCT (Pixels Cross Track): is the cross-track dimension of the filters acquired. It depends primarily on the latitude of the acquisition and is defined to guarantee the cross track overlapping between two consecutive orbits. The size of the windows is constrained by the requirement of the compressor unit (sizes multiples of the nominally CBD=64x64 or of greater 64x128 AT x CT). Another requirement, deriving from the way in which the detector is read, imposes that the minimum cross-track window has to be 128.
- IT (Integration Time): it is defined by the latitude, the height of the S/C and the T.A. and is furthermore evaluated as the minimum between the smearing and the integration time needed to achieve the upper bound (90%) of the linearity range (see **RD8**). For the global mapping (GM) the nominal IT is the minimum between the ITs of the two panchromatic filters and the smearing.

Sub-channels combination	-H + -L, -H, -L
Filters combination	P_H+P_L, P_H, P_L, C_H+C_L, C_H, C_L, P_H+P_L+ C_H+C_L **(*)**
Cross track window (pixels)	128,192,256,320,384,448,512,576,640,704,768,832,896

Along-track window (pixels)	64, 384
Repetition time (sec)	0.15-15
Compression ratio	Bit-packing, lossless, 3.597 (bit rate 3.8921 bit/px, *ibr* 63), 7 (bit rate 2 bit/px, *ibr* 32), 14 (bit rate 1 bit/px, *ibr* 16), 28 (bit rate 0.5 bit/px, *ibr* 8)

Table 6- *Range of possible values for the parameters defining the operations of the two sub-channels.*

(*) It must be noted that, due to the necessity to acquire the filter X and the limitation in the number of dataframes that can be acquired contemporarily, it is generally not possible to acquire the two panchromatic filters together with all of the 4 colour filters unless photometric calibration is neglected.

P_H and P_L are the two panchromatic filters, C_H are the two colour filters on -H while C_L are the two colour filters on -L. The maximum number of windows which can be read in one acquisition is 6 (Window-X included). The repetition time can be chosen in the range between 0.15 – 15 seconds; the minimum value (0.15 sec) is imposed by the detector characteristics and usage. A more detailed definition of the RT will be provided in the next section.

5.5. STC OPERATIVE MODES

In the STC on-board software only one scientific operative mode (*Science mode*) is defined, but to take into account how the resources are used during the operations of STC it is convenient to define group modes and sub-modes. In Table 7 the operating scientific mode groups of STC and their characteristics are listed. The columns in the table have the following meaning: name of the mode group; filters combination on the sub-channels; repetition time; compression ratio; along-track window size in pixels; sub-modes corresponding to the group mode; cross-track window size in pixels for each sub-mode, data volume in Mb for 2 channels, data volume in Mb for one channel, peak data rate in Mbps, assuming as example an overlapping of 10% for GM and 15% for CM (see **Table 4**).

Science mode group	Filters	RT	Compression ratio	AT dimension	Sub-mode	CT dimension	Mb/Acq 2 Ch	Mb/Acq 1 Ch	Peak Data Rate (Mbps)
Stereo mapping	P_H and/or P_L	5s-15s	7 (2 bits/pix) (nominal) Could be different for each sub-channel	384	**1**	896	1.4	0.7	0.3
					2	768	1.2	0.61	
					3	640	1	0.51	
					4	512	0.8	0.41	
					5	384	0.61	0.31	
					6	256	0.41	0.21	
					7	128	0.21	0.11	
Colour mapping	C_H or/and C_L	0.8-5s	3.56 (4 bits/pix)	64	**1**	896	0.95	0.49	
					2	768	0.82	0.43	

			Could be different for each sub-channel		**3**	640	0.69	0.36	1.2
					4	512	0.56	0.29	
					5	384	0.43	0.23	
					6	256	0.29	0.16	
					7	128	0.16	0.098	
Inflight Calibration	P_H+P_L + C_H+C_L or P_H+P_L and C_H+C_L **(*)**	TBD	Lossless	64, 384					
User defined	any combination	TBD	any	64, 384		see tab. 5			

Table 7 - *STC operating modes and sub-modes. The table shows for each science mode group the limits of the RT during the nominal mission phase, the nominal compression factor, the window dimension AT and all the sub-modes for the CT dimension together with the DV of each acquisition but in the case of the use of one channel or two.*

(*) It must be noted that, due to the necessity to acquire the window X and the limitation in the number of dataframes that can be acquired contemporarily, it is not possible to acquire the two panchromatic filters together with all of the 4 colour filters for photometric purpose.

5.5.1. Stereo Mapping

***Stereo mapping* (SM)** is the mode defined to perform the global stereo mapping of Mercury surface and the stereo reconstruction of pre-defined targets.

Both the panchromatic filters will be used simultaneously for most of the orbits, or individually at the pole regions where the boresight of one of the sub-channels looks at the dark side of the planet. The sub-modes have been defined to take into account the variability of the filter-projected FoVs dimensions on the Mercury surface along the orbits due to the latitude of the target region. An orbit arc on the illuminated part of the planet can be divided in segments, spanning from pole to pole. Due to the large cross-track FoV of STC, for some of the segments two sub-modes have been defined, corresponding to a larger or smaller acquired dataframe. A lossy compression algorithm will be used; the compression factor can be different for each sub-channel. By changing the window size and the repetition time, images with the optimal conditions for the stereo reconstruction can be obtained. Differences in the incoming radiance on the two STC channels could have an impact on the quality of the image. Alternated acquisitions (with different integration times) should be considered as a possible solution.

5.5.2. Colour Mapping

***Colour mapping* (CM)** is a mode group aimed at obtaining colour mosaics of given areas. Also for this mode group sub-modes have been defined to take into account the variability of the FoV dimensions on the Mercury surface which could be used to obtain CT mosaicking on continuous orbits. A lossy compression algorithm will be applied.

5.5.3. Stereo Colour Mapping

***Stereo Colour Mapping* (SCM)** is the instrument mode implemented to perform the stereo reconstruction of the targets performing acquisitions both with Panchromatic and Colour filters. As described in par. 4.4, the detector of STC does not allow to acquire 6 windows at the same time, but this problem can be bypassed by acquiring Panchromatic Filters and Colour ones separately.

Considering the limits of the ME (see **RD8**) this strategy can be adopted for all the regions in which a RT>2s guarantees the BBs filter overlapping.

In this case, it is possible to define a different RT for Stereo Mode and Colour Mode maintaining a distance between the TCs of 1 second.

As an example, the repetition of the following sequence will guarantee that no holes will be present in the overlapping of both the panchromatic and colour acquisitions:

- Acquire C_H with low RT.
- Acquire a single P_H

This strategy guarantees the acquisition of Colour Filter and a stereo couple. On the other side, the acquisition of the colour filter will be not co-aligned with the stereo ones, which means that a co-registration procedure would be necessary.

Moreover, it should be considered that the strategy uses a large number of TCs, and could limit any other STC acquisition on the same orbit.

5.5.4. Other Modes

User defined **(UM)** is a completely free mode, in which all the parameters are selectable. This mode is important to guarantee the flexibility of the instrument acquisitions and its capability to react to unforeseen conditions and possibilities.

Inflight calibration **(IC)** is a mode aimed at observing stellar fields in order to perform radiometric and geometric calibration by mapping the distortions along the FoV. The limit on the maximum number of detector windows that can be acquired at the same time (i.e. 6) and the different radiometric sensitivity of each filter limit the possibility to perform radiometric calibration with all the 6 filters at the same time. On the other side, the 6 filters could be acquired in the same time in the geometric calibration phase. All filters acquisition FOPs should be commanded for geometric purpose: this will occur at specific true anomalies along the Mercury orbit (at 90˚ and 270˚). Few dataframes will be acquired each time. Only reversible (lossless) compression will be applied.

6. STEREO MAPPING OF THE SURFACE OF MERCURY

6.1. Stereo Global mapping

A global stereo coverage of the surface of Mercury will be completed by the end of the first 6 months of the Science Phase, assuming that STC will be working almost continuously during the three first high resolution mapping phases (HR1, HR2, HR3, see A1). The rest of the mission will be devoted to a target-driven strategy, in order to fill in holes left in the global coverage or perform a stereo mapping with better conditions on given areas.

It is important to consider that the southern hemisphere is seen in much more favourable conditions towards the end of the mission (see RD3), so any approach must be flexible.

The operative sub-mode group that is used to perform the stereo coverage is *Stereo mapping*. The sequence of sub-modes is defined on the basis of an orbit arc around the illuminated side of the planet, from pole to pole; this arc is subdivided in segments on which the sub-modes are defined (an example can be seen in **Figure 14**).

In the following an example is given of the coverage of one orbit arc during the HR1 and HR2 mission phases. The example is optimized for an along track (vertical) overlapping around 10% and a cross track (horizontal) overlapping (between consecutive orbits) between 20% and 40%. Repetition time and windows size can be chosen with the help of **Figure 15** and **Figure 16**, showing the along track percentage of superposition with different repetition time and the cross-track percentage of superposition with different windows for HR1/HR2. The chosen repetition time in the example is 5 s. The details of the algorithm used to compute the percentage of overlapping can be found in the Appendix 2.

6.1.1. Example: Stereo Global mapping

More details and information on the data volume are given in Table 8 where an example of the possible segmentation of the orbit is proposed. The meaning of the columns is the following: range of latitudes defining the segment; spacecraft altitude at the beginning and at the end of the segment; submode; number of dataframe acquisitions in the segment; data volume in megapixels, uncompressed; data rate in megapixels/second, uncompressed. In this way, we would acquire on every orbit 150.307 Mpix. The corresponding data volume necessary to cover the whole Mercury surface (592 orbits) during the first six months of the mission would be 89 Gpix (uncompressed). The estimated Data Volume will be discussed in Section 6.1.2. A small amount of data volume should be added to these figures, in order to cover the latitude ranges closer to the poles; taking into account the large overlapping of the projected FoVs at high latitudes, only one orbit every three could be acquired in the latitude ranges 80°N - 90°N and 80°S - 90°S.

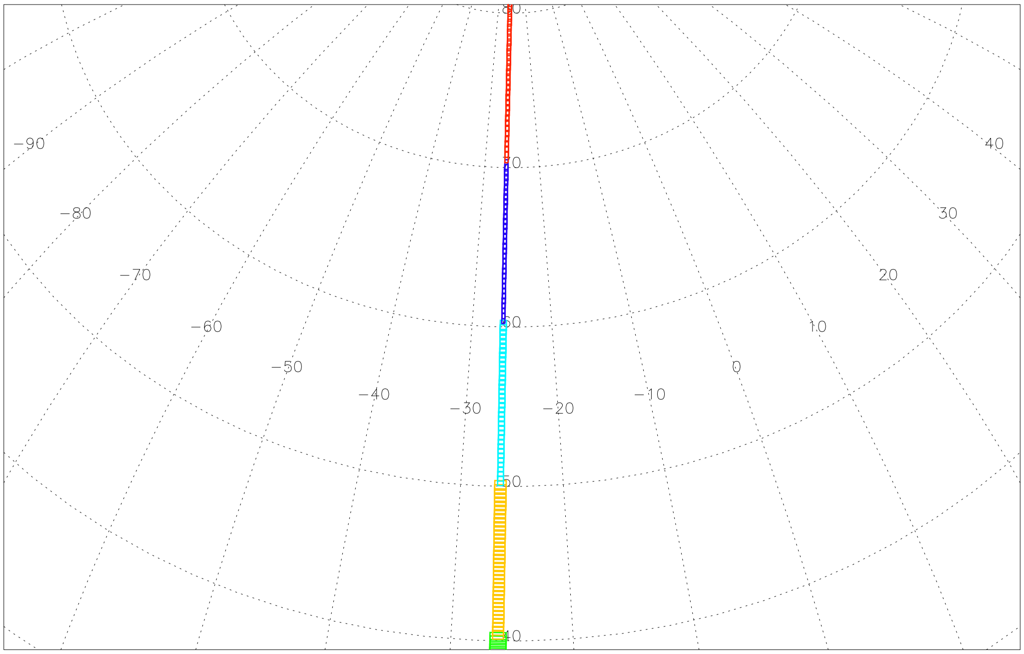


Figure 14– *Segmented orbit strategy applied to an orbit arc: the colours refer to data frames acquired with different repetition times as defined in Table 7. The plot refers to an orbit in the HR1 phase for the sub-channel -H.*

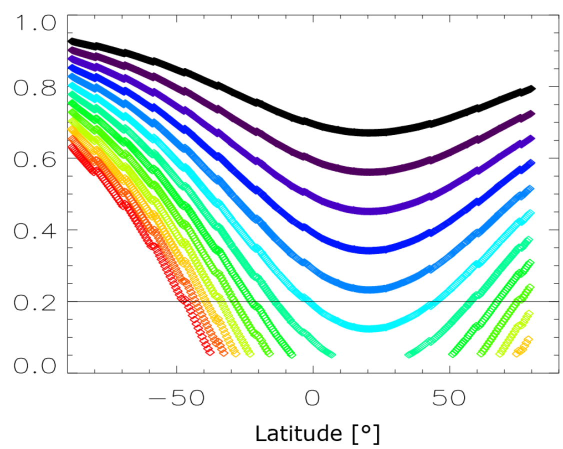


Figure 15 -*Percentage of along track (vertical) overlapping wrt latitude of the FOV of a panchromatic filter along an orbit arc during the phase HR1. Values are shown for different repetition times, starting from 3 sec (black curve) and ending with 15 seconds (red curve).*

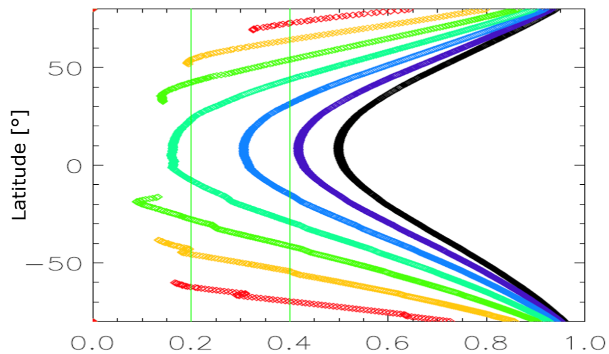


Figure 16 - *Percentage of cross-track superposition wrt latitude of the FOV of a panchromatic filter along two consecutive orbit arcs during the phases HR1/HR2. Values are shown for different window sizes, starting from 896 pixels (black curve), then 768 (violet), 640 (blue), 512 (green mint), 384 (green), 240 (yellow) and 128 (red). A gap in a curve means that there is no superposition.*

Latitudes range	Altitude range (km)	Sub-mode	Number of acquisitions	Data volume (Mpix)	Data rate (Mpix/s)
15°S-30°N	600-528	3	134	65.864	0.098
30°S-15°S 30°N-45°N	686–600 528-560	4	89	34.996	0.079
40°S-30°S 45°N-55°N	765-686 560-597	5	62	18.285	0.059
55°S-40°S 55°N-65°N	896-765 597-643	6	84	16.515	0.039
80°S-55°S 65°N-80°N	1176-896 643-736	7	149	14.647	0.020
Total			**518**	**150.307**	

Table 8- Data volume in megapixels and data rate in megapixels per second for the sub-modes for a possible coverage of an orbit arc with the *Stereo mapping mode* (HR1/HR2).

During the second year of the mission the pixel resolution on the southern hemisphere is higher than at the beginning of the mission (see **RD3** and **Figure 15**). For this reason, the conditions would be optimal for the refinement of the DTM on these areas. It must be noted that a window with a cross-track size of 896 pixels can be necessary in the latitude range 50°S-0° to obtain the desired degree of superposition between consecutive orbits (**Figure 17**).

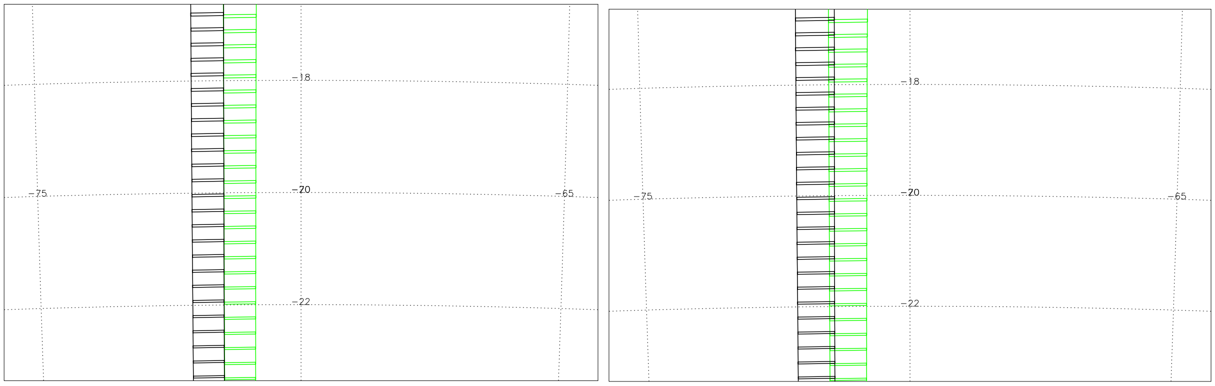


Figure 17 *- HR9 phase, FoV of one panchromatic filter for 2 consecutive orbits with a time step of 3 seconds. The size of the window is 768 pixels (on the left panel) and 896 pixels (on the right panel).*

6.1.2. Stereo Global mapping programming

The following tables show examples of the formal parameters for the HR1, HR2 and HR4 phases. The parameters are evaluated thanks to **RD6**. The definition is reported in Appendix 3. The tables show the variation of the parameters for each of the 11 segments in which the orbit is divided. In this example orbit segmentation is provided on the basis of the subnadiral latitude. The first and last segments represent the ones in which only one channel is acquired. The remaining 9 segments show on the first two columns the latitude coordinates of the sub-nadiral point.

These evaluations are performed as an example, considering an overlapping AT of 10% and CT of 15% and a division of the orbit on 11 segments based on latitudes. A greater number of segments will allow better SNR performance and less DV.

Min Lat	Max Lat	RT [s]	PIX CT [px]	Submode	IT [ms]	Duration [s]	Mb/acq	NACQ	Mb/s	Mb
-80.0		18.52	128.00	7	1.60	490	0.21	27.00	0.01	5.75
-80.0	-62.2	12.79	256.00	6	0.54	415	0.41	33.00	0.03	13.52
-62.2	-44.4	12.92	384.00	5	0.35	370	0.61	29.00	0.05	17.58
-44.4	-26.7	10.36	512.00	4	0.19	325	0.80	32.00	0.08	25.69
-26.7	-8.9	8.83	512.00	4	0.14	330	0.80	38.00	0.09	30.51
-8.9	8.9	8.26	640.00	3	0.23	300	1.00	37.00	0.12	36.98
8.9	26.7	8.32	640.00	3	0.14	305	1.00	37.00	0.12	36.98
26.7	44.4	8.46	512.00	4	0.19	310	0.80	37.00	0.09	29.70
44.4	62.2	9.35	384.00	5	0.35	325	0.61	35.00	0.06	21.22
62.2	80.0	11.26	256.00	6	0.54	350	0.41	32.00	0.04	13.11
80.0		10.75	128.00	7	0.84	375	0.21	35.00	0.02	7.45
									DV	**238.49**

***Table 9**: RT (for an overlapping AT 10%), pixels dimension cross-track (for an overlapping CT 15%), integration times, data rate and data volume for the sub-modes for a possible coverage of an orbit arc with the Stereo mapping mode (the Table refers to the aphelion 0 orbit corresponding to HR1 phase ET_0=2026 APR 4 12:20:30 PM anomaly= 180.101 180.101°).*

Min Lat	Max Lat	RT [s]	PIX CT [px]	Submode	IT [ms]	Duration [s]	Mb/acq	NACQ	Mb/s	Mb
-80.0	-90.0	12.47	128.00	7	0.95	475	0.21	39.00	0.02	8.31
-80.0	-62.2	14.20	256.00	6	0.55	375	0.41	27.00	0.03	11.06
-62.2	-44.4	10.73	384.00	5	0.36	345	0.61	33.00	0.06	20.00
-44.4	-26.7	8.61	512.00	4	0.19	320	0.80	38.00	0.09	30.51
-26.7	-8.9	7.54	640.00	3	0.15	310	1.00	42.00	0.13	41.98
-8.9	8.9	7.33	640.00	3	0.23	295	1.00	41.00	0.14	40.98
8.9	26.7	7.35	640.00	3	0.15	300	1.00	41.00	0.14	40.98
26.7	44.4	7.80	640.00	3	0.19	310	1.00	40.00	0.13	39.98

44.4	62.2	9.19	384.00	5	0.36	325	0.61	36.00	0.07	21.82
62.2	80.0	11.49	256.00	6	0.55	355	0.41	31.00	0.04	12.70
80.0	90.0	11.18	128.00	7	0.91	405	0.21	37.00	0.02	7.88
									DV	276.19

***Table 10**: RT (for an overlapping AT 10%), pixels dimension cross-track (for an overlapping CT 15%), integration times, data rate and data volume for the sub-modes for a possible coverage of an orbit arc with the Stereo mapping mode (the Table refers to the aphelion 0 orbit corresponding to HR2 phase ET_0=2026 JUL 1 16:40:51 anomaly= 180.101°).*

Min Lat	Max Lat	RT [s]	PIX CT [px]	Submode	IT [ms]	Duration [s]	Mb/acq	NACQ	Mb/s	Mb
-80.0	-90.0	10.80	128.00	7	0.82	490	0.21	46.00	0.02	9.80
-80.0	-62.2	9.68	256.00	6	0.54	415	0.41	43.00	0.04	17.61
-62.2	-44.4	7.44	512.00	4	0.36	370	0.80	50.00	0.11	40.14
-44.4	-26.7	6.15	640.00	3	0.19	325	1.00	53.00	0.16	52.97
-26.7	-8.9	5.77	768.00	2	0.14	330	1.20	58.00	0.21	69.37
-8.9	8.9	5.79	768.00	2	0.14	300	1.20	52.00	0.21	62.19
8.9	26.7	5.77	768.00	2	0.14	305	1.20	53.00	0.21	63.39
26.7	44.4	7.30	640.00	3	0.19	310	1.00	43.00	0.14	42.98
44.4	62.2	9.60	384.00	5	0.35	325	0.61	34.00	0.06	20.61
62.2	80.0	13.12	256.00	6	0.54	350	0.41	27.00	0.03	11.06
80.0	90.0	12.17	128.00	7	0.86	375	0.21	31.00	0.02	6.60
									DV	396.72

***Table 11-** RT (for an overlapping AT 10%), pixels dimension cross-track (for an overlapping CT 15%), integration times, data rate and data volume for the sub-modes for a possible coverage of an orbit arc with the Stereo mapping mode (the Table refers to the aphelion orbit corresponding to phase HR4 or ET_0=2026 DEC 24 8:49:55 AM anomaly=179.862° anomaly= 180.198°).*

Assuming that the stereo mosaicking should be based on images with as large as possible cross-track dimension, and taking into account that its impact on the DV is small, we consider the possibility, for the segments near the poles, to acquire images with a larger window size, increasing the overlapping percentage and avoiding to acquire on every orbit. In this case, the impact on the DV of the increasing window size is compensated by the missing orbit acquisition (as discussed in Section 3.3).

During the mission years, the formal parameters will change because the orbital parameters of the spacecraft will change; changes in the true anomaly will impact the incidence angles and the integration time.

As shown in **Figure 18**, the greater impact will be on the Integration Time. The IT assumes a bilobate trend near aphelion (TA=180°), where the two channels are acquiring surface regions with different incidence angles. At the limit of the GM Mercury orbit section (TA=222°) both the channels FoVs cover regions with high incidence angles and the IT is no more dependent on the two different directions of the boresight.

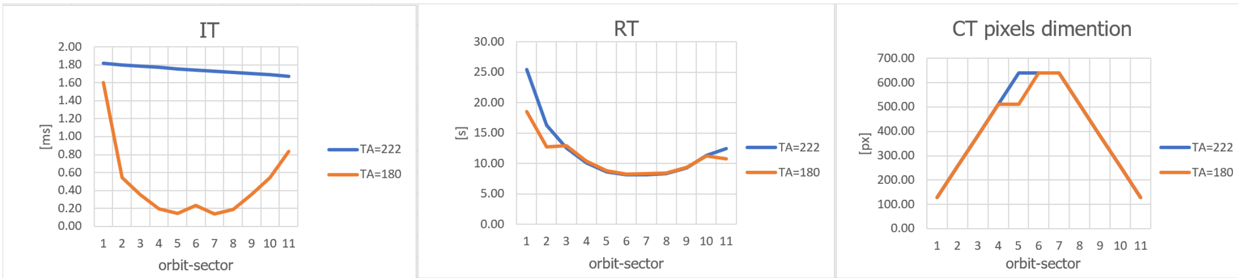


Figure 18 *The three plots show the comparison between the 3 main formal parameters (IT, RT, CTdim) for the HR1 aphelion orbit (TA=180°) and the HR1 last bounds orbit (TA=222°) of the same mercury year.*

Considering that, between the two orbits analyzed, the MPO will cover 151 other orbits, it can be estimated that between one orbit and the following we expect a change ~ 7.6% in the ITs near periherm and 1.5% around the poles.

7. TARGET-DRIVEN STRATEGY

7.1. Stereo Mapping

The *Stereo Mapping* mode can be used in a target-driven strategy not only to complete the global mapping but also to observe areas of particular interest in the best possible conditions.

Stereo Mapping can be performed following two different strategies:

- Acquisition of P_H and subsequent acquisition with P_L
- Acquisition of P_H , acquisition of all the broad band filters $(P_H + P_L)$ and following acquisition with Channel P_L

Note that in different Mercury MTA ranges (in particular for MTA minor or major than 180°) the order of P_H and P_L should be inverted. Each time the MPO will flip around its axis (2 times every mercury year) the channel oriented in the same direction of the S/C velocity will change. This means that P_H will not always be the first channel to be acquired.

Flight Operation Procedures (see **RD9**) defined for the Stereo Mapping mode are reported in Table 12.

FCP-ID	Name	Objectives
SS-FCP-307	SIMBIO-SYS STC Science SURF NOMINAL GM	It commands the acquisition of Global Mapping Mode X+PANH+PANL for low Its.
SS-FCP-301	SIMBIO-SYS STC Science SURF SINGLE PANH	It commands the acquisition of a X+PANH
SS-FCP-302	SIMBIO-SYS STC Science SURF SINGLE PANL	It commands the acquisition of a X+PANL for low Its.

Table 12 *Flight Control Procedures (FCPs) nominally used during Stereo Mapping mode.*

7.1.1. Example: an area of interest in the southern hemisphere

In the following, a possible strategy for the coverage of the area centered on the Dostoevskij crater (latitude 40.0°S-70.0°S, longitude 180.0°-210.0°) is shown. As stated before, the pixel resolution is highest on the Sothern hemisphere during the HR8/HR9 phases of the mission. In order to choose a repetition time and a window size we may use, in a rough approximation, plots such as the ones in **Figure 19** and **Figure 20,** analogous to the **Figure 15** and **Figure 16**.

Selecting a repetition time of 3 seconds and a window size of 768 pixels, the area can be covered with 75 acquisitions (44236800 pixels) on approximately 34 consecutive orbits on the arc segment from 70.0°S to 40.0°S.

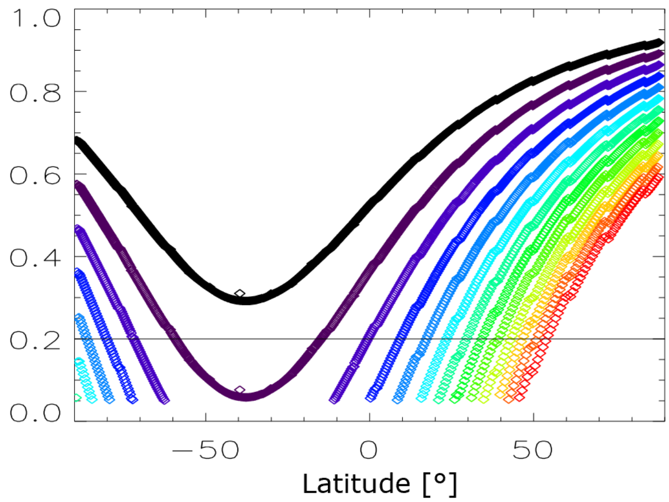


Figure 19 - *Percentage of along track (vertical) overlapping along an orbit arc during the phases HR8/HR9 as function of the latitude. Values are shown for different repetition times, starting from 3 s (black curve) and ending with 15 seconds (red curve). The step is one second. A gap in a curve means that there is no overlapping.*

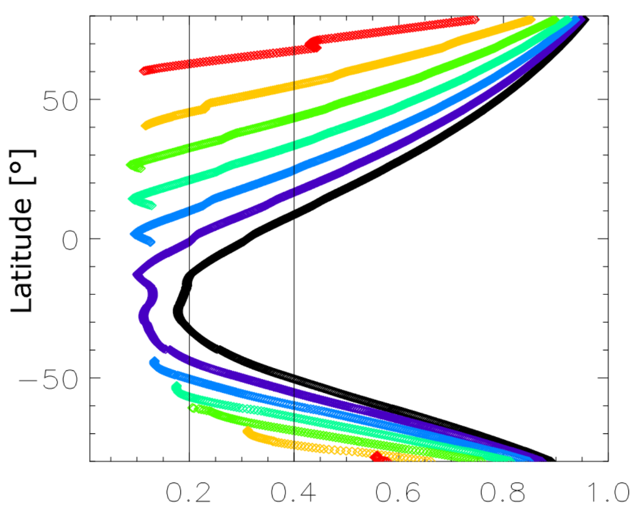


Figure 20- *Percentage of cross track (horizontal) overlapping along an orbit arc during the phases HR8/HR9. Values are shown for different window sizes, starting from 896 pixels (black curve), then 768 (violet), 640 (blue), 512 (green mint), 384 (green), 240 (yellow) and 128 (red). A gap in a curve means that there is no overlapping***.**

7.2. COLOR MAPPING

To acquire color pictures on selected areas of Mercury, the *Color mapping* mode group will be used (Table 7). Depending on the latitude and altitude of the orbit, it will not always be possible to obtain connected data frames.

When planning observations with the colour filters, it is important, considering the coordinates and observation conditions of the target, to check if the SNR is enough and if the conditions to avoid the smearing are fulfilled.

Colour Mapping can be performed by following two strategies:

- Acquisition of C_H and subsequent acquisition with Channel C_L
- Acquisition of C_H , acquisition of all the broad band filters ($C_H + C_L$) and subsequent acquisition with Channel C_L

Note that in different Mercury MTA ranges (in particular for MTA minor or major than 180°) the order of C_H and C_L should be inverted. Each time the MPO will flip around its axis (2 times every mercury year) the channel oriented in the same direction as the S/C velocity vector will change. This means that C_H will not always be the first channel to be acquired.

When colour mapping is performed with acquisition of C_H and subsequently C_L , the strategy allows to constraint the cross-track and along-track direction according to the defined FoV and geometry.

The constraints are reported in Table 13.

	Latitude	Height	Pixel on ground	Subnad Latitude	Lat Limits	Dim Limit
Aphelion 0	Periherm	480 km	58 m	16°	8.19°	348.8 km
	Poles	966.7 km	21.8 m	83°	16.4°	698.88 km
Last aphelion	Periherm	327 km	55.4 m	-13.6°	5.6°	237.8 km
	Poles	942 km	166 m	83°	16°	681 km

Table 13 *Limits of the CM strategy in latitude and km for two acquisitions of the phase HR1 corresponding to first periherm and pole and phase HR5 corresponding to the last aphelion of the nominal mission*

The limits shown in Table 13 are the minimal distance between two consecutive CM acquisitions on the same orbit.

The colour mapping will provide target-oriented acquisitions of multiband images with the four broadband filters. To limit the data volume, STC will acquire images with a channel at the time, maintaining an overlapping greater than 15% between two consecutive acquisitions (AT). The images (corrected for phase angle) will provide mosaicked multiband cubes for clustering or spectrophotometric analysis.

Repetition time will be limited in the range 0.8-5 s.

Colour Mapping will utilize 42.6 Gbit (considering a compression factor of 3.75) of Data Volume covering 15% of the Mercury surface.

For the entire mission (see **RD8**), the SNR of all the broad band filters, with the exception of the less efficient F420, spans from about 100 (near poles) to 165 (near the equatorial plane).

Flight Operation Procedures (see **RD9**) defined for the Stereo mapping mode are reported in Table 14.

FCP-ID	Name	Objectives

SS-FCP-308	SIMBIO-SYS STC Science SURF NOMINAL CM	It commands the acquisition of Colour Mode: X+750+420+550+920 for low Its.
SS-FCP-300	SIMBIO-SYS STC Science SURF FREE	User Defined acquisition. It commands the acquisition of a maximum of 6 Windows.
SS-FCP-303	SIMBIO-SYS STC Science SURF SINGLE 750	It commands the acquisition of a X+F750
SS-FCP-304	SIMBIO-SYS STC Science SURF SINGLE 420	It commands the acquisition of a X+F420
SS-FCP-305	SIMBIO-SYS STC Science SURF SINGLE 550	It commands the acquisition of a X+F550
SS-FCP-306	SIMBIO-SYS STC Science SURF SINGLE 920	It commands the acquisition of a X+F920

Table 14 *Flight Control Procedures (FCPs) nominally used during Colour Mapping mode.*

7.2.1. Example: a small target on the southern hemisphere

A typical small target of high interest is a hollow found in an area with a latitude comprised between 64.95°S and 64.87°S and a longitude comprised between 161.69° and 161.86° (**Figure 21**, left panel). From the point of view of the monochrome images and the stereo reconstruction the target is best observed during HR8, on November 29, 2027. The phase angle is 47° and the illumination angle is 67° (**Figure 21**, right panel).

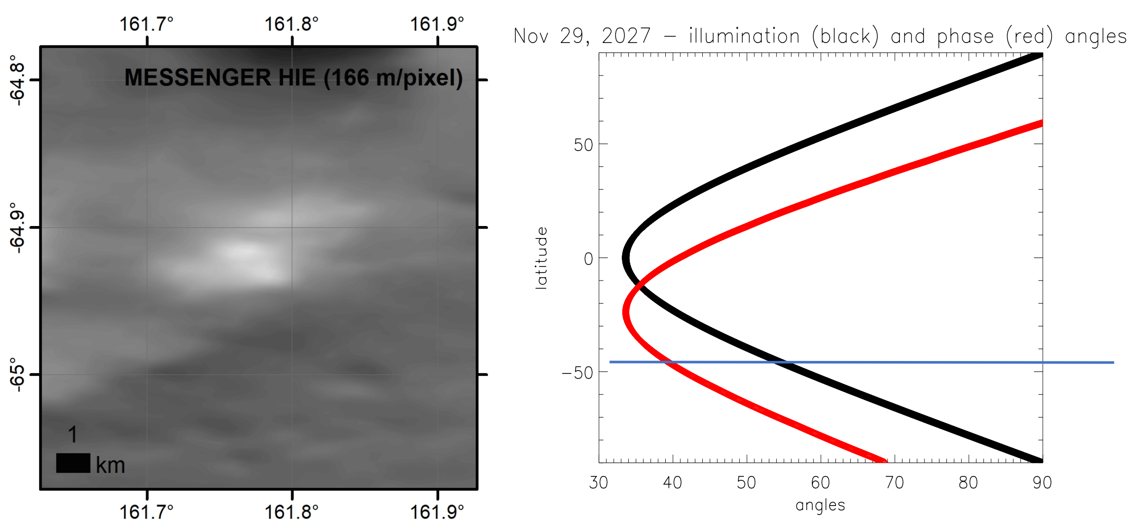


Figure 21 *– Left panel: monochrome image acquired by MDIS on Messenger showing a hollow. Right panel: illumination and phase angles with respect to latitude on November 29, 2027.*

Figure 22 and **Figure 23** can be used to select a RT and a window size.

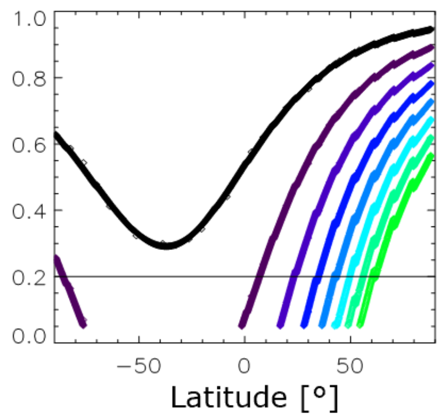


Figure 22– *Percentage of vertical overlapping for the colour filters along an orbit arc during the phase HR8. Values are shown for different repetition times, starting from 0.5 sec (black curve) and ending with 4 seconds (green curve). The step is half second. A gap in a curve means no overlapping.*

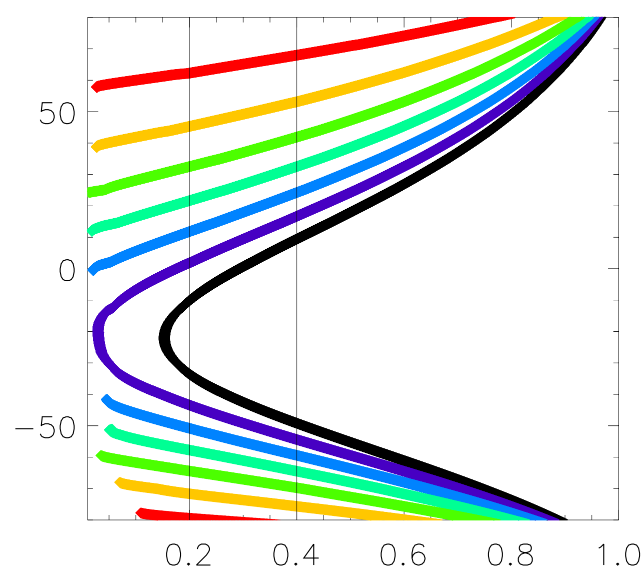


Figure 23*– Percentage of horizontal overlapping along two consecutive orbit arcs for a colour filter during the phase HR8. Values are shown for different window sizes, starting from 896 pixels (black curve), then 768 (violet), 640 (blue), 512 (green mint), 384 (green), 240 (yellow) and 128 (red). A gap in a curve means no overlapping.*

From the figures 23 and 24 it can be seen that the only RT value giving connected frames is 0.5 seconds. The window size could be either 896 or 768 pixels.

8. INFLIGHT CALIBRATION OPERATIONS

Different calibration measurements are foreseen during the BepiColombo mission. Considering the variability of the environment due to Mercury and MPO orbit, most of the tests will be performed periodically during SIMBIO-SYS operation.

STC calibration will be performed in the first part of HR1 phase (Mercury aphelion 0).

The in-flight calibrations can be divided in two classes: internal calibrations, that are all channels calibrations performed without any involvement of the S/C; external calibrations, which require S/C resources.

The channel calibrations are:

i. Detector performance: it includes dark count rate, cosmic ray damages, readout noise, thermal effects verification, FPN, spurious charge, and all the blind tests that will be performed every 6 months during the cruise phase and at Mercury on specific orbits, taking advantage of the dark side of the planet.

ii. PSF and radiometric calibrations will be performed on stellar fields. For the Photo Response Not Uniformity measurement, two different strategies are considered: summing of multiple acquisitions of Hermean surface images or a quasi-dithering reduction method proposed for LEO satellites (Mohammadnejad 2011) provided for high-variability IR-CCD.

For the external ones:

i. Absolute radiometric calibration will be performed using spectrophotometric standard stars.

ii. Geometric calibration will be performed on stellar fields. As for the absolute radiometric calibration, periodic measurements will refine the uncertainty introduced by aging and thermal variation of the optical bench.

The external calibration will also be performed after commissioning, due to the fact that the instrument thermal conditions will vary during the mission. The contribution due to thermo-elastic effects (temperature transients) corresponds to distortions between the Star TRackers (STRs) line-of-sights and the payload line-of-sight. This forces the mission control to foresee different calibration phases for each orbit (aphelion, perihelion, TA=45.135°) to cross–verify the SIMBIO-SYS imaging channel orientations with respect to the STRs.

9. APPENDICES

9.1. APPENDIX 1: Mapping phases

Time	orbit	Anomaly	longitude	phase
14 Mar– 20 Mar 2026	1-62	114-138		T
20 Mar - 19 Apr	63-360	138-222	0-180S	HR1
19 Apr – 3 May	361-510	222-278		T
3 May – 1 Jun	511-806	278-82		LR1
1 Jun – 16 Jun	807-956	82-138		T
16 Jun – 16 Jul	957-1253	138-222	180-0	HR2
16 Jul – 30 Jul	1254-1406	222-278		T
30 Jul – 28 Aug	1407-1699	278-82		LR2
28 Aug – 12 Sep	1700-1850	82-138		T
12 Sep - 11 Oct	1851-2147	138-222	0-180S	HR3
11 Oct – 26 Oct	2148-2299	222-278		T
26 Oct – 24 Nov	2300-2593	278-82		LR3
24 Nov – 9 Dic	2594-2026	82-138		T
9 Dic – 7 Jan 2027	2027-3041	138-222	180-0	HR4
7 Jan – 22 Jan	3042-3192	222-278		T
22 Jan – 20 Feb	3193-3487	278-82		LR4
20 Feb – 7 Mar	3488-3638	82-138		T
7 Mar – 5 Apr	3639-3935	138-222	0-180S	HR5
5 Apr – 20 Apr	3936-4086	222-278		T
20 Apr – 19 May	4087-4401	278-82		LR5
19 May – 3 Jun	4402-4532	82-138		T
3 Jun – 2 Jul	4533-4819	138-222	180-0	HR6
2 Jul – 17 Jul	4820-4980	222-278		T
17 Jul – 15 Aug	4981-5275	278-82		LR6
15 Aug – 30 Aug	5276-5427	82-138		T
30 Aug – 28 Sep	5428-5723	138-222	0-180S	HR7
28 Sep – 13 Oct	5724-5874	222-278		T
13 Oct – 11 Nov	5875-6169	278-82		LR7
11 Nov – 26 Nov	6170-6320	82-138		T
26 Nov – 25 Dic	6321-6617	138-222	180-0	HR8

25 Dic – 9 Jan 2028	6618-6768	222-278		T
9 Jan – 7 Feb	6769-7062	278-82		LR8
7 Feb – 22 Feb	7063-7214	82-138		T
22 Feb – 22 Mar	7215-7510	138-222	0-180S	HR9
22 Mar – 6 Apr	7511-7662	222-278		T
6 Apr – 5 May	7663-7956	278-82		LR9
5 May – 20 May	7957-8108	82-138		T
20 May – 29 May	8109-8199	138-163	2.2-304.	HR10

Tab. A1 *: the phases of the mission are listed, together with the corresponding time range, anomaly range, longitude range and orbit numbers. HR is a high resolution mapping phase, while LR is a low resolution mapping phase.*

9.2. APPENDIX 3: ORBIT FORMAL PARAMETERS EVALUATION

The main parameters to be defined for each sub-mode of the global mapping are evaluated to optimize the overlapping percentage (as defined in Appendix 2) and Data Volume.

Main parameters defined in each FOP in an STC orbit are:

Parameter		Dependence	Description
IBR	Inverse Bit Rate	user	Nominally 32
RT	Repetition Time	by S/C height	is the minimum repetition time operable in order to reach a minimum along-track 10% overlapping for all the orbit segments considered and for both channels The Repetition time is considered as the minimum between the two channels on the orbit sector (OS), following the equation: $$RT = \min_{CH/CL}(\min_{OS}(R\frac{\Delta Lat}{v_{BO}}(1-over)))$$ Where v_{BO} is the velocity of the Boresight on the planetary surface ΔLat is the Along Track coverage of the filter considered $over$ if the overlapping factor (nominally 0.1 for the Global Mapping)
PCT	Pixels Cross Track	by latitude and height	is the minimum dimension of the panchromatic windows in order to guarantee a minimum 15% cross-track overlapping between two consecutive orbits. CT dimension is then evaluated as the maximum between the two channels on the orbit sector (OS), following the equation: $$CTdim^{*} = \max_{CH/CL}(\max_{OS}(\frac{v_{r\_orbit}}{(1-overCT)}\frac{896}{\Delta Long}))$$ Where v_{r_orbit} is the rotation velocity of the planet (in °/MPOorbit) $\Delta Long$ is the Cross Track coverage of the filter considered. $over$CT if the overlapping factor cross track (nominally 0.10 for the Global Mapping) * CTdim must be approximated by excess considering that it must be a multiple of 128.
IT	Integration Time	by latitude, height and T.A.	is defined as the minimum between the smearing and the integration time needed to achieve the upper bound (90%) of the linearity range (see **RD8**). For the global mapping (GM) the nominal IT is the

			minimum between the ITs of the two panchromatic filters and the smearing.