	Istituto di Astrofisica e Planetologia Spaziali **Institute For Space Astrophysics and Planetology**	

SERENA Science Operations Review

SERENA NPA-IS

(Neutral Particle Analyzer- Ion Spectrometer)

bepicolombo

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DISTRIBUTION

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CHANGE LOG

date	issue	revision	Section	reason for change
				1st Draft. Starting from a previous version of “Flight Operations” Deliverable
15/10/2015	2	0		Merged with Power Constraints in a new deliverable.
30/10/2015	2	1		Splitted again, now only Science Operations. Power Constraint Analysis again in another document

Contents

ACRONYMS

TBW

1 Introduction

This document describes the global set of operative rules, constraints, features and top level procedures for the execution of SERENA operations, and it describes the scientific rationale behind the optimal observing strategy. The SERENA instrument is composed by four units, ELENA, STROFIO and PICAM may operate independently, while MIPA is dependent by ELENA powering; SERENA has a good flexibility in order to operate in different modes and configurations that could fit the allocated power and telemetry budget. Nevertheless for reaching the full science goals, the four units should operate at the same time, when compatible with system constraints. The scientific objectives of SERENA are listed in Table 1.

2 Applicable Documents

- AD 1 SERENA Calibration Plan
  BC-SRN-RP-00028_03_4_SERENA_Science_Perf_Report

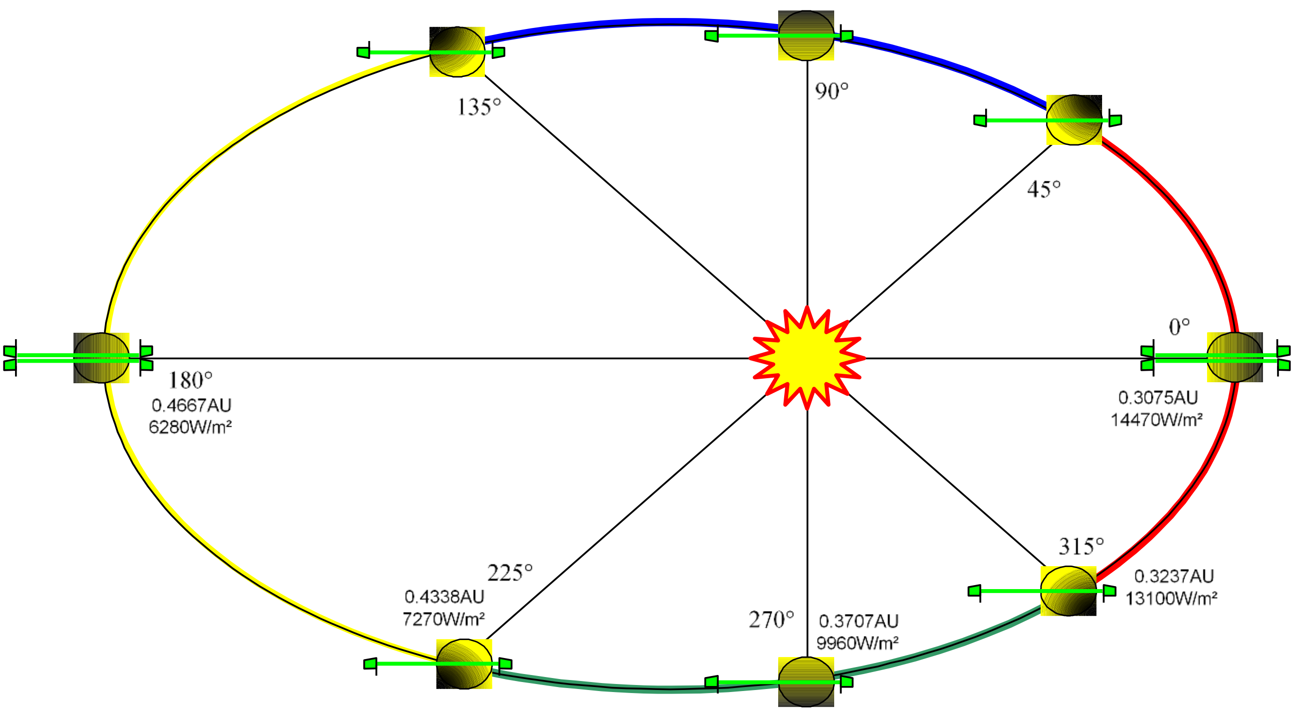
- AD 2 Tech.note - BepiColombo Radiation Analysis
  BC-ASD-TN-00027 EADS Astrium GmbH

  INPUTS:

- AD 3 ASI Contract
- AD 4 Scientific Requirements (WP 2200)
- AD 5 ELENA layout (SEE SERENA EID-B)
- AD 6 Strofio layout (SEE SERENA EID-B)
- AD 7 PICAM layout (SEE SERENA EID-B)
- AD 8 MIPA layout (SEE SERENA EID-B)

3 Mission Phases.

The mission phases for SERENA are defined by dividing the orbit of Mercury around the Sun into 4 parts of 90 degrees each: A, Summer (from -45° to 45° of TAA); B, Fall (45° to 135°), C, Winter (135° to 225°); D, Spring (225° to 315°). Phase A lasts 14.5 days, phase B and D last 21 days, phase C lasts 31 days. Figure 1 shows the four Mercury phases. For each Mercury phase, 2 mission phases are defined based on the MPO position along its orbit: phase "p" (periherm) from -90° to 90° of true anomaly angle (TAA); phase "a" (apoherm) from 90° to 270°. Hence, a total of 8 phases are defined: Aa, Ap, Ba, Bp, Ca, Cp, Da, Dp. Additionally, phases B and D may be subdivided into "early" (first half) and "late" (second half) B and D; in this way, there is a correlation between the mission phase and whether the MPO is in the day side or not. MPO is in the dayside in phases Aa, EBa,



LBp, Cp, EDp, LDa, and it is in the nightside in the other phases.

Figure 1 MPO configurations during 1 Mercurian year. Red: A; Blue: B; Yellow: C; Green: D

4 SERENA Experiment Operations

SERENA is an instrument composed of 4 units devoted to neutral and ionized particles detection, plus a System Control Unit (SCU) to provide whole package instrument functionality control, memory and computational capability
Following the power-up of the instrument, the HW-SW initialisations and tests are carried out. The test results can be provided by requesting specific boot report TM. The Main IFE controller is put into STAND-BY state. The reception of dedicated ON/OFF command from

the S/C SpaceWire I/F to the power control register will allow to control and power any sub-unit. Compressor unit is a specific sub-unit residing in the SCU itself and it can be powered on as any other Sensor unit. Boot behaviour is described in paragraph 3.7.1.4 of EIDB. The default logic for the SERENA state transitions is that any automatism can be disabled and the modes trajectory is defined by a sequence of ground commands. The transition from one state to another (except power off /on) always goes via STAND-BY state.

4.1 SERENA Modes Summary

Regardless of the Compression/DPU SCU state, the following SERENA operational modes can be commanded:

- INIT & TEST
- DIAGNOSTIC
- STAND-BY
- CALIBRATION
- SCIENCE

When automatism are enabled the default logic for the SCU mode transitions is that they can be operated with no human action, but the control logic may be bypassed all the time by ground control. The transition from one mode to another mode (except power off /on) always goes via STAND-BY Mode.
SCU System will switch mode by first closing current acquisition mode and dumping all complete information, then switching into standby mode, then setting up the new mode necessary configuration parameters and then finally switching it into the target mode.
The transition:
SCI-Mode_X -> STAND-BY -> SCI-Mode_Y
Is the normal commanding sequence required to go from one mode science Mode_X to another. By the way the instrument can accept a direct SCI-Mode_X -> SCI-Mode_Y command directly and in which the passage to the STAND-BY is made transparent for the User.

4.2 INIT & TEST

This mode is automatically entered by power-on/reset.
INIT & TEST concerns the SCU HW-SW initialisation performed at the boot. The result of the initialization is made available in a specific RAM table. If the booting test procedures success, SCU switches autonomously to STAND-BY mode and the test results can be provided by requesting specific boot report TM. Conversely if errors are detected SCU goes automatically in DIAGNOSTIC mode.

4.3 DIAGNOSTIC MODE

This mode is used for diagnostic purposes, only housekeeping packets are transmitted. Regardless of the Sensor head powering condition, the “diagnostic” mode is the basic mode for performing checks and testing operation on power-up. SCU will be switched into a survival mode with minimum performances and operability of the unit. Only H/K and diagnostic dumps for health monitoring will be provided and transmitted.

4.4 STAND-BY MODE

This is the default mode, in which SCU is switched following a reset or a power-up. From this mode, the DPU SCU can be switched to any other scientific or diagnostic mode by means of dedicated TCs. Only housekeeping telemetry will be supported while in this mode.

4.5 CALIBRATION

The complete calibration of the whole package at LBR TM budget. TM bandwidth will be dedicated to the data produced by collecting from a specific sensor in turn, the maximum quantity of data fixed according to the predefined TM allocation table. This mode can benefit of the DSP Compressor. Other sensor must stay in STAND-BY or being OFF.

4.6 SCIENCE MODE

The SCIENCE mode is the native mode for returning science products for the SERENA suite. It provides one or more science modes with different power and telemetry budget defined for each unit. It foresees several categories of science returning modes each providing different sorted list of products according to the output TM regime. They may be grouped in some sub-modes.

4.6.1 Nominal Science

This scientific sub-mode is a combination of modes for the 4 units that stays inside the nominal TM budget. It’s the nominal one and shall be normally used for all types of scientific observations. All or a few sensor units can be active and producing science data. TM will be produced by collecting from the sensor head fixed quantity of data according to the predefined TM allocation table.

4.6.2 High Science

This scientific sub-mode is an upgrade of the nominal science case. It’s a combination of modes of the units that exceeds the nominal TM budget. It’s reserved for specific and time-limited science cases. It takes into account of specific condition in which a more relevant bandwidth of the S/C is made available for SCU. All or a few sensor units can be active and produce science data.
TM will be produced collecting from the sensor heads fixed quantity of data according to the predefined TM allocation table.

4.6.3 Full Science (Nominal/High Science Compression)

These scientific modes for the 4 SERENA units take full benefit of the availability of the compression functionality and they can provide a considerable larger amount of science even with the same TM allocation bandwidth (LBR/HBR) of the nominal /high science modes.

4.6.4 SUB-SyS CAL

This scientific mode is fully devoted to support calibration or diagnostic purposes.
Multi sensors calibration may be accounted as standard Nominal/High and Full Science modes by tailoring their calibration bandwidth to those of the related scientific modes.

INIT&TEST	RST	RST	RST	RST	RST	RST	RST
DIAGNOSTIC	TC AE	X	TC AEC	AEC	AEC	AEC	AEC
STAND_BY	TC AN	TC	X	TC AN AE	TC AN AE	TC AN AE	TC AN AE
SCIENCE	X	X	TC AN	X	X	X	X
COMP. NOM-SCI	X	X	TC AN	X	X	AN	X
COMP. HI-SCI	X	X	TC AN	X	AN	X	X
CALIBRATION	X	X	TC AN	X	X	X	X

TC = Commanded by TeleCommand
AN = Autonomous Nominal
AE = Autonomous due to Error
AEC = Autonomous due to Critical Error
RST = ReSeT (autonomous or commanded)
X = not allowed
Note that:
(1) The Autonomous Nominal transitions “Standby to Science or Standby to Calibration” occur when instrument is commanded to go to a specific science mode when is NOT in standby. In this case the control system performs first a transition to Stand-by then to the required mode.
(2) The Autonomous Nominal transitions “Science Compressed Nom to Science Compressed High” (and back), when this automatism has been enabled, occurs without affecting the TM bandwidth allocated for SERENA.

(3) The Autonomous Nominal transitions “Science to Standby” occurs in the presence of a major fault or in the end of acquisition (single or multiple sequences snapshots).

(4) A Critical error transition condition AEC is originated by a detection of a critical error like program memory corruption (checksum), or anomalous power consumption detection of some module (latch-up). All the other less severe error conditions maps to A

S/W Memory Allocation

Table 1

MEM ID	**UNIT**	**TYPE**	**MEM OFFSET (Byte)**	**MEM SIZE (Bytes)**	**Comment**
200	SCU	16b	0x0000	256k	Prog Mem Area
201	SCU	16b	0x0000	456k	SRAM Prog & Data Area
202	SCU	16b	0x72000	568k	SRAM Scratch Data Area
203	SCU-DSP	16b	0x00000	2M	Prog Mem Area
204	SCU-DSP	16b	0x00000	320k	SRAM Prog & Data Area
205	SCU-DSP	16b	0x00000	1M	SRAM Scratch Data Area
206	PICAM	8b	0x00000	768k	Prog & Data Area**
207	ELENA	8b	0x00000	256k	SRAM Prog & Data Area*
208	MIPA	8b	0x00000	8k	SRAM Prog & Data Area
209	STROFIO	16b	0x00000	16k	SRAM Prog & Data Area

*ELENA Note:
Three types of ELENA memory are accessible:

Memory Type	Size	Memory Access	Address Range
Program RAM	64kx8	Check/Dump/Load	0x00000 - 0x0FFFF
Extended RAM	64kx8	Check/Dump/Load	0x10000 - 0x1FFFF
EEPROM	128kx8	Check/Dump	0x20000 - 0x3FFFF

**PICAM Note:
Four types of PICAM memory are accessible:

Memory Type	Size	Memory Access	Address Range
Program RAM	32kx8	Check/Dump/Load	0x00000 - 0x07FFF
Extended RAM	**8kx8**	**Check/Dump/Load**	**0x0C000 - 0x0DFFF**
EEPROM	128kx8	Check/Dump	0x20000 - 0x3FFFF
Mass RAM	512kx8	Check/Dump	0x40000 - 0xBFFFF

Boot Behaviour

After power up, the SCU operates as follows.
“Stand-by state” is the default mode in which SERENA is switched on following a reset or a power-up. From this mode, the unit can be switched into any other scientific or diagnostic mode by means of dedicated TCs. Only housekeeping telemetry will be supported while in this mode.
If a “Diagnostic TM” SCU mode is commanded, the unit will be switched into a survival mode with minimum performances and operability. In this condition, no usual science

telemetry will be provided by the experiment even if any sensor head would be put in ON state. Only H/K and diagnostic dumps for health checking will be provided and transmitted.
If a “Low TM” SCU mode is commanded, the unit will be kept into its nominal state to provide science support. Science data will be collected from the activated sensor heads, and according the normal operations TM polling tables, eventually Loss-Less data compressed, organized into science packets and transmitted to S/C.
If a “Burst TM” SCU mode is commanded, the system will power up and initialize the DSP compressor. In this mode the nominal performances of the IFE will be increased taking benefit of the DSP performances to support also Lossy data compression. However, if during burst the booting procedure problems in the health checking of the DSP are identified the DSP is put in a partial mode in which a limited set of functionality is available for diagnostic, while the main IFE system will be left into its nominal state for autonomous S/C I/F and TM dumping.

4.6.5 S/W Maintenance Concept

The SERENA on-board software maintenance (OBSM) capability provides a means of adapting the real mission conditions scenario to the real-time status of the hardware and to any operational difficulties that instrument might encounter during its operating lifetimes. The need for On-Board Software Maintenance can arise at any time, from immediately after launch if the spacecraft's post-launch status calls for operational adaptations, until the end of the mission when ageing of the in-orbit hardware leads to a greater probability of failures. Even if the need of OBSM services are not used regularly, an adequate infrastructure must be available on the ground throughout the mission to correct, add to or re-design the on-board software whenever the need arises.
The re-programmable SERENA on-board S/W on SCU, ELENA and PICAM resides on EEPROMs as listed in table 3.7.1.3. Such blocks contain XORCRC 16 checksum tables for each of their 1kbytes content. Re-programmability may occur only in the so-called DIAGNOSTIC Mode.

5 Requirements for the Flight Operations

The generation of requirements for SERENA flight operations follows this general concept: the scientific team, in collaboration with PIs, identifies the scientific objectives that can be achieved either with a specific instrument or with a suite of them. Then the scientific team identifies, for each scientific objective, the proper operative modes for the sensor (or suite of sensors).

The second task for the scientific team is to give to each scientific objective a priority value, so that, in case of conflict due to resource limitations, it would be possible to decide which operative mode to run first. This general philosophy guide the decisions of the SCI OPS team, but it cannot be applied straightforward without the help of the scientific team because it is not possible to give but approximate values for the priority table. Scientific objective table (example) is given in table 1, priorities have been omitted as they can change. The timeline that has been proposed to and discussed with ESA during the SERENA science operation WG in IFSI (Sept 2011) is table 2. Performance parameters to fulfil the science requirements

The Scientific Performance Requirements, according to the scientific requirements are evaluated in

Table 1: Scientific objectives

Scientific Topic	Geometrical factor	Energy Energy resolution	Mass resolution		FOV Angular resolution		Time resolution	SERENA sensor#	Synergies with other BC instruments#
1. Chemical and elemental composition of the exosphere	10^{-1} (counts/s)(cm^3)*	< 1 eV NA	>60		- NA		NA	**STROFIO**	MPO/PHEBUS
2a. Neutral gas density asymmetries Latitude	10^{-1} (counts/s)(cm^3)*	< 1 eV NA	>60		- NA		ΔT<10 m	**STROFIO**	MPO/PHEBUS MMO/MSASI
2b, c. Neutral gas density asymmetries Day/night Dawn/dusk	10^{-1} (counts/s)(cm^3)*	< 1 eV NA	>60		- NA		ΔT>orbit	**STROFIO**	MPO/PHEBUS MMO/MSASI
2d Neutral gas density asymmetries Altitude	10^{-1} (counts/s)(cm^3)*	< 1 eV NA	>60		- NA		NA	**STROFIO**	**MPO/PHEBUS** MMO/MSASI
2e Neutral gas density asymmetries Temporal variation vs SW	10^{-1} (counts/s)(cm^3)*	< 1 eV NA	>60		- NA		ΔT<10 m	**STROFIO**	MPO/PHEBUS MMO/MSASI MIPA MMO/MPPE MMO/MGF MPO/SIXS

3. Exo-ionosphere composition	≥10^{-5} cm^2 sr**	>10 eV NA	>50		- NA		NA	**PICAM**	MMO/MPPE
4a. Exo-ionosphere spatial and energy distribution	≥10^{-4} cm^2 sr**	>10 eV ΔE/E < 30%	>40		- Δα < 15º x60		ΔT<3 m	**PICAM**	MPO/MAG MMO/MPPE MMO/MGF MMO/PWI
4b. Exo-ionosphere spatial and energy distribution Temporal variation vs SW	≥10^{-4} cm^2 sr**	>10 eV ΔE/E < 30%	>40		- Δα < 15º x60		ΔT<3 m	**PICAM**	MIPA MPO/MAG MPO/SIXS MMO/MPPE MMO/MGF MMO/PWI
5a. Plasma precipitation rate SW	10^{-6}≤GF≤10^{-3} cm^2 sr ***	0.5-10 keV ΔE/E <30%	H^+ identification		2π FOV in the orbit plane Δα < 25º x60°		ΔT< 1 m	**MIPA** **ELENA B-U**	**MPO/MAG** MMO/MPPE MMO/MGF MMO/PWI MPO/SIXS
5b. Plasma precipitation rate SW distribution in the inner magnetosphere	10^{-6}≤GF≤10^{-3} cm^2 sr ***	0.5-10 keV ΔE/E <30%	H^+ identification		2π FOV in the orbit plane Δα < 25º		ΔT< 1 m	**MIPA**	**MPO/MAG** MMO/MPPE MMO/MGF MMO/PWI MPO/SIXS
5c. Plasma precipitation rate Heavy ions	≥10^{-5} cm^2 sr	0.5-50 keV ΔE/E <30%	>10		2π FOV in the orbit plane Δα < 25º x60°		ΔT< 1 m	MIPA PICAM	**MPO/MAG** MMO/MPPE MMO/MGF MMO/PWI

									MPO/SIXS MPO/MIXS
6b. Surface emission rate and release processes. SW - back-scattering emission	$\geq 10^{-5}$ cm^2 sr	100-1000s eV NA	H		5^ox60^o (nadir centred) $\Delta\alpha < 15^o$		ΔT< 3 m	**ELENA B-U**	**MPO/MAG** MMO/MPPE MPO/SIXS MMO/MGF MMO/PWI
	$10^{-6} \leq GF \leq 10^{-3}$ cm^2 sr ***	0.5-10 keV ΔE/E <30%	Mainly H^+		2π FOV in the orbit plane $\Delta\alpha < 25^o$		ΔT< 3 m	MIPA	
6c b-u. Time-averaged emissivity of surface features	$\geq 10^{-5}$ cm^2 sr	20 -100s eV NA	NA		5^ox60^o $\Delta\alpha < 8^o$		ΔT< 10 m	**ELENA B-U**	MPO/MIXS MPO/MERTIS MPO/Simbio Sys
6d. Surface emission rate and release processes. Surface MIV	10^{-1} (counts/s)(cm^3)*	< 1 eV NA	>60		- NA		ΔT< 5 m	**STROFIO**	MMO/MDM MPO/Symbio-Sys MPO/MIXS MPO/MERTIS
6e. Surface emission rate and release processes. PSD	10^{-1} (counts/s)(cm^3)*	< 1 eV NA	>60		- NA		ΔT <10 m	**STROFIO**	MPO/PHEBUS MMO/MSASI
7b. Particle loss rate from Mercury's environment Exospheric charge-exchange	$\geq 10^{-5}$ cm^2 sr	0.5-5 keV	Hydrogen/ heavy particles discrimination		5^ox20^o (toward horizon) $\Delta\alpha < 8^o$		ΔT< 3 m	**ELENA B-U**	**MMO/MPPE**

7c. Particle loss rate from Mercury's environment *Loss of planetary ions*	$\geq 10^{-4}$ cm^2 sr	0.5-10 keV $\Delta E/E <$ 30%	>50		Hemispheric FOV $\Delta\alpha < 15^o$ x60		$\Delta T <$ 5 m	**PICAM** MIPA	**MPO/MAG** MMO/MPPE MMO/MGF MMO/PWI

* STROFIO does not measure particle flux, but density. Hence, the concept of geometrical factor is not applicable. In this case, we require at least S/N=3 (at 10 cm^{-3}) that will be achieved by increasing the integration time.

** The minimum requested GF_{min} for low energy ions is estimated from the minimum detectable density, D_{min}:

$GF_{min}=1/(D_{min} \cdot v/4\pi/C_{min})$

Where v is the typical velocity of exo-ionosphere ions (about 10^7 cm/s i.e. 100 eV for AMU 23) and C_{min} is the minimum counts per s (we consider C_{min}=10/s for 3, no time resolution, and C_{min}=100/s for 4)

*** In the case of SW fluxes we need to avoid saturation of the instrument; hence, a GF upper limit is requested, too.

bold format means highly needed measurement.

ESA in agreement with SERENA
ESA with more restrictive operated than SERENA
SERENA more resctritive than ESA

Mercury Year 1	AA				AP				BA				BP				CA				CP				DA				DP			
	Orbits		Obj.	Mode	Orbits		Obj.	Mode	Orbits		Obj.	Mode	Orbits		Obj.	Mode	Orbits		Obj.	Mode	Orbits		Obj.	Mode	Orbits		Obj.	Mode	Orbits		Obj.	Mode
STROFIO	all	100	2a, 2b, 2c, 2d, 2e, 6a, 6c, 6d, 6e	**N**	all	100	1, 2a, 2b, 2c, 2e, 2d, 6a, 6c, 6d	N	all	100	2a, 2d, 2e, 6d, 6e	N	all	100	1, 2a, 2d, 2e, 6a, 6c, 6d, 6e	N	all	100	2a, 2b, 2c, 2d, 2e, 6d	N	all	100	1, 2a, 2b, 2c, 2d, 2e, 6a, 6c, 6d, 6e	N	all	100	2a, 2d, 2e, 6d, 6e	N	all	100	1, 2a, 2d, 2e, 6a, 6c, 6d, 6e	N
ELENA	all	100	6a, 6b, 6c, 7a	**H**	all	50	6a, 6b, 6c, 7a	**N**	50% 50%	80	7a	N L	50% 50%	95	6a, 6b, 6c, 7a	N L	all	60	7b	H	all	100	6a, 6b, 6c, 7a	H	50% 50%	80	7b	N L	50% 50%	95	6a, 6b, 6c, 7a	L N
PICAM	all	65	4, 5b	IM_HT_HR	5/6 1/6	75	3, 4, 5b	MC_HR_LE MD_MR_HE	all	70	4, 5b,7c	IM_HT_HR	5/6 1/6	90	3, 4, 5b	MC_HR_LE MD_MR_HE	5/6 1/6	80	4, 5b, 7c	IM_HR_HT MC_HR_LE	5/6 1/6	100	3, 4, 5b	MC_HR_LE MD_MR_HE	all	80	4, 5b,7c	**IM_HT_HR**	5/6 1/6	90	3, 4, 5b	MC_HR_LE MD_MR_HE
MIPA	all	100	5a, 5b, 6a, 6b	5	3/6	60	5a, 5b, 6a, 6b	5	3/6	70	5b, 7c	6	3/6	80	5a, 5b, 6a, 6b	5	all	65	5b, 7c	6	all	80	5a, 5b, 6a, 6b	5	3/6	80	5b, 7c	6	3/6	80	5a, 5b, 6a, 6b	5

Mercury Year 2	AA				AP				BA				BP				CA				CP				DA				DP			
	Orbits		Obj.	Mode	Orbits		Obj.	Mode	Orbits		Obj.	Mode	Orbits		Obj.	Mode	Orbits		Obj.	Mode	Orbits		Obj.	Mode	Orbits		Obj.	Mode	Orbits		Obj.	Mode
STROFIO	all		2a, 2b, 2c, 2d, 2e, 6a, 6d, 6e	N	3/6		2a, 2b, 2c, 2d, 2e, 6d	N	3/6		2a, 2d, 2e, 6d	N	3/6		2a, 2d, 2e, 6d	N	2/6		2a, 2b, 2c, 2d, 2e, 6d	N	all		2a, 2b, 2c, 2d, 2e, 6a, 6d, 6e	N	3/6		2a, 2d, 2e, 6d	N	3/6		2a, 2d, 2e, 6d	N
ELENA	all		6a, 6b, 7a	N	3/6		7a	N:F1-3	3/6		7b	N:F5	3/6		7a	N:F1-3	all		7b	N:F5	all		6a, 6b, 7a	N	3/6		7b	N:F5	3/6		7a	N:F1-3
PICAM	2/8		4, 5b	**IM_HR**	3/6		4, 5b	**IM_HR**	3/6		4, 5b, 7c	**IM_HR**	3/6		4, 5b	**IM_HR**	all		4, 5b, 7c	**IM_HR**	2/8		4, 5b	**IM_HR**	3/6		4, 5b, 7c	**IM_HR**	3/6		4, 5b	**IM_HR**
MIPA	all		5a, 5b, 6a, 6b	5	3/6		5b	6	3/6		5b, 7c	6	3/6		5b	6	all		5b, 7c	6	all		5a, 5b, 6a, 6b	5	3/6		5b, 7c	6	3/6		5b	6

Mercury Year 3-4	AA				AP				BA				BP				CA				CP				DA				DP			
	Orbits		Obj.	Mode	Orbits		Obj.	Mode	Orbits		Obj.	Mode	Orbits		Obj.	Mode	Orbits		Obj.	Mode	Orbits		Obj.	Mode	Orbits		Obj.	Mode	Orbits		Obj.	Mode
STROFIO	2/6		2a, 2b, 2c, 6e	N	3/6		2a, 2b, 2c, 6d	N	2/6		2a	N	3/6		2a	N	2/6		2a, 2b, 2c, 6d	N	2/6		2a, 2b, 2c, 6e	N	2/6		2a	N	3/6		2a	N
ELENA	2/6			N	3/6			N	2/6			N	3/6			N	all		7b	N	2/6			N	2/6			N	3/6			N
PICAM	2/6		4, 5b	**IM_HR**	3/6		4, 5b	**IM_HR**	2/6		4, 5b	**IM_HR**	3/6		4, 5b	**IM_HR**	all		4, 5b, 7c	**IM_HR**	2/6		4, 5b	**IM_HR**	2/6		4, 5b	**IM_HR**	3/6		4, 5b	**IM_HR**
MIPA	2/6		5b	6	3/6		5b	6	2/6		5b	6	3/6		5b	6	all		5b, 7c	6	2/6		5b	6	2/6		5b	6	3/6		5b	6

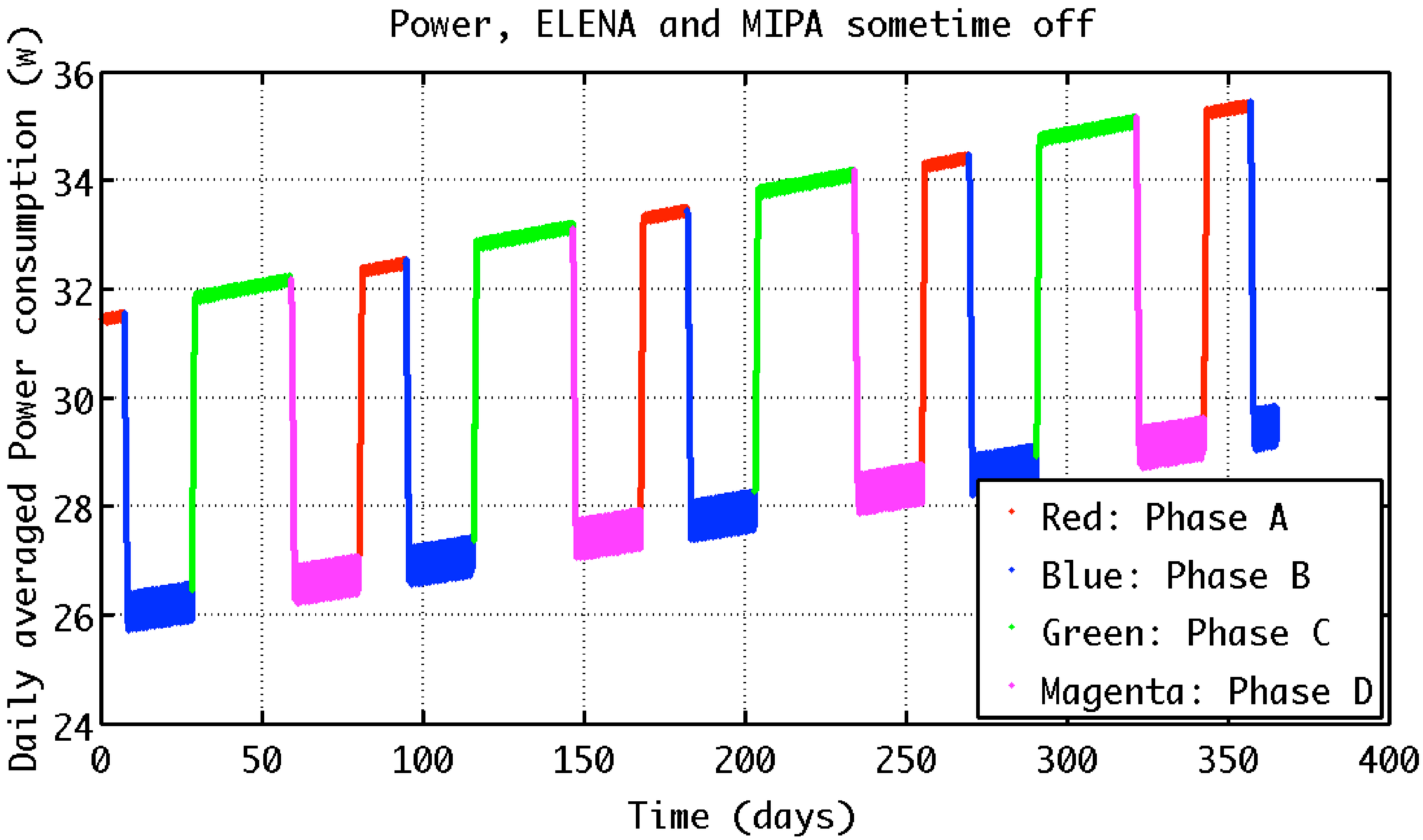

Power, ELENA and MIPA sometime off
Daily averaged Power consumption (W)
36
34
32
30
28
26
24
0
50
100
150
200
250
300
350
400
Time (days)
Red: Phase A
Blue: Phase B
Green: Phase C
Magenta: Phase D

Table 2: instruments timeline (phases Aa, Ap .. etc refer to the following figure).

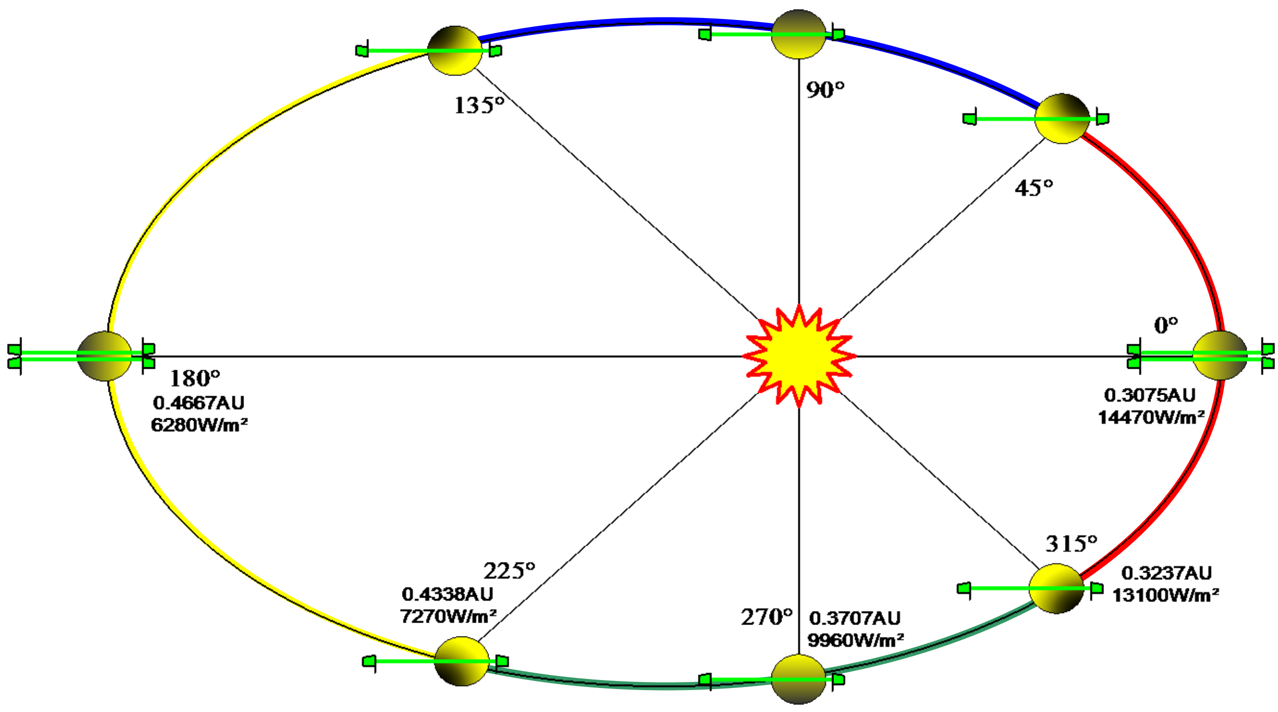


Figure 0: Mission phases (Aa= perihelion, apoherm, Ap= perihelio, periherm, etc.)

5.1 Support in the identification of the observable objectives (WP2100)

The estimation of ELENA performances has been revised after the unit calibration. The shuttering mechanism, providing ToF (velocity) measurement of detected particles, is not operating in the nominal mode. The power consumption has been revised, as well as the scientific objectives. The TLM prediction has been revised showing some contingency with respect to the previous calculation.

5.2 Optimization of the observational strategy

Here will be discussed how it can be compatible with the power and TM resources allocated.
There are two main constraints that prevent SERENA to operate with all sensors at full nominal mode together and continuously: data volume limitation and power limitation.
The first constraint has been found to be less problematic than the second because:
The team estimated that the nominal mode for all instrument during all periods where the relative scientific objective (s) priority is high or medium is about 120 Gb, i.e. the data volume that has been given to ESA as an estimate of SERENA need.
In case of data volume limitation, it is always possible to run any instrument (most of) in the same operative mode but with a compressed data return. This will have a moderate impact on science return

The 120 Gb figure has been estimate in the absence of any power limitation, but actually it may happen that power limitation will shorten the time of scientific operations and hence the overall data volume

The data volume and telemetry data rate can be estimated with high accuracy and it is stable with time, while the power budget can vary along the mission timeline.

The following table is an estimate of current power budget:

Table 3

Revision: 18 September 2014 — **ALL VALUES in tables are AVERAGE power consumption**

SCU ELENA

	Unit	Nominal (EOL/BOL) [W]		Calibration (EOL/BOL) [W]		Burst (EOL/BOL) [W]		Diagnostic (EOL/BOL) [W]	
Notes:	SCU	4.6	4.2	4.6	4.2	4.6	4.2	4.6	4.2
	ELENA with MIPA OFF	11	10	10.8	9.8	11	10	10.8	9.8
	ELENA with MIPA ON	12	10.91	11.8	10.71	12	10.91	11.8	10.71
DCDC for MIPA is	ELENA with SCU and MIPA OFF	15.6	14.2	15.4	14	15.6	14.2	15.4	14
hosted on Elena Main Board EOL = BOL +10%	ELENA with SCU and MIPA ON	16.6	15.11	16.4	14.91	16.6	15.11	16.4	14.91

STROFIO

	Unit	Nominal (EOL/BOL) [W]		Calibration (EOL/BOL) [W]		Burst (EOL/BOL) [W]		Diagnostic (EOL/BOL) [W]	
	STROFIO	7.5	6.58	7.5	6.58	8.44	7.52	5.5	5

PICAM

	Unit	Nominal (EOL/BOL) [W]		Calibration (EOL/BOL) [W]		Burst (EOL/BOL) [W]		Diagnostic (EOL/BOL) [W]	
Notes	PICAM H orbits	9.5	8.6	6.7	6.1	9.5	8.6	4.4	4
EOL = BOL +10%, H = Hadamard mode, S = Single pulse mode	PICAM S orbits (around 50% of orbits)	7.5	6.8						

MIPA

	Unit	Nominal (EOL/BOL) [W]		Calibration (EOL/BOL) [W]		Burst (EOL/BOL) [W]		Diagnostic (EOL/BOL) [W]	
DCDC for MIPA is hosted on Elena	MIPA	3.5	2.6	3.5	2.6	3.5	2.6	3.5	2.6

TOTAL

	Unit	Nominal (EOL/BOL) [W]		Calibration (EOL/BOL) [W]		Burst (EOL/BOL) [W]		Diagnostic (EOL/BOL) [W]	
Note Picam S orbits considered	SCU + All units	**35.1**	**31.1**	**34.1**	**30.2**	**38**	**33.8**	**29.8**	**26.5**
considered		**37.1**	**32.9**						

Basing on the above table and using the timeline as in table 2 the team produced an estimate of the power consumption of SERENA along the mission timeline (figure 1).

Figure 1

5.3 Simulation of orbital sequences

5.3.1 Telemetry and power simulation

A basic simulation of power and telemetry has been performed by using the above-discussed tables. Power consumption is given in figure 1, telemetry data rate is given in figure 2.

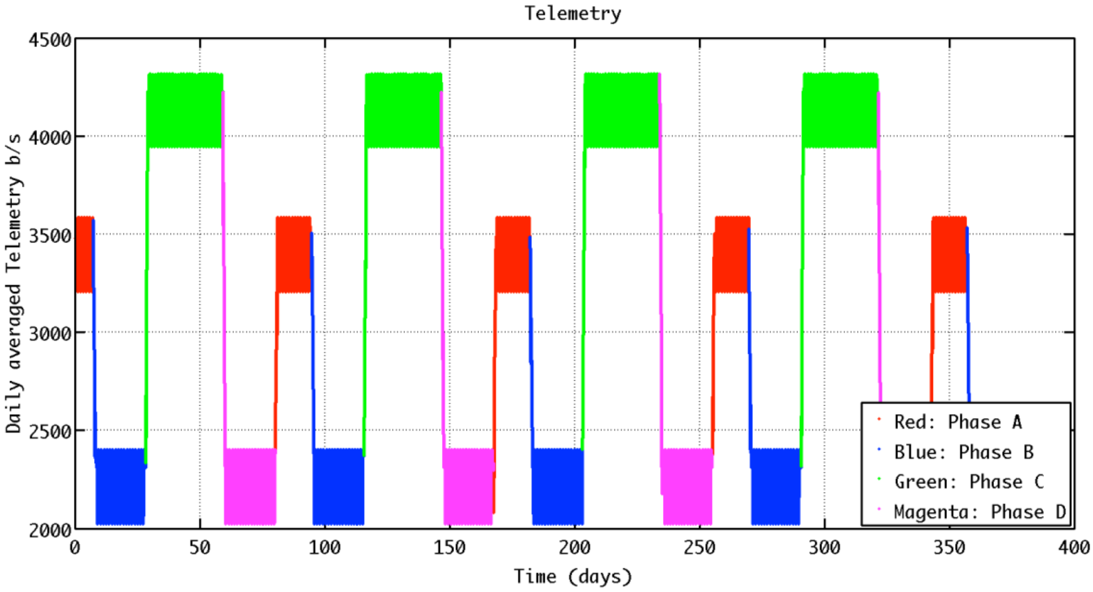


Figure 2

5.4 Compatibility of the operations plan with the scientific requirements

5.4.1 ELENA

The operation plan for ELENA has been tested against the scientific requirements. In figure 3, we show the estimated counts for 1°x1° surface elements (latitude / longitude), due to ion sputtering, for single ToF channel (worst case). The top panel is in a local time reference frame. The two bulges are the intense areas of ion precipitation (cusps), from where an intense ion sputtering neutral flux is foreseen. If we want to study the surface properties, we have to switch to a surface-fixed reference frame (bottom panel). Due to the complex 2/3 resonances of the orbital and rotational periods of Mercury, which are also related to the BepiColombo MPO orbit phase, the coverage in this reference frame is not uniform. The predicted coverage allows performing a surface characterization; however, any further shortening of ELENA operative time will results in a serious downgrade of the science return.

The est

imate in the figures is based on the predicted count-rate in the ELENA ToF channel with smaller signal (worst case). The signal (due to ion sputtering) can be up to a factor 10 higher in other ToF channels. Please note also that the signal due to ion backscattering (which is a secondary scientific target) is considerably higher (up to a factor 1000 larger than that estimated in the figures 3 and 4).

The precipitation pattern used in this simulation is a hyper-simplified case where the cusps are modelled as ellipses. The actual precipitation areas are presumably less uniform (and probably larger).
The analysis discussed here refers to the case of an instrument with ToF resolution and for Ion sputtering signal. Since the actual instrument will have no ToF resolution, these numbers should be scaled to backscattering signal (1000 times larger) and accumulated into only one ToF channel. Hence, the analysis show that the signal is very high in any emitting region.

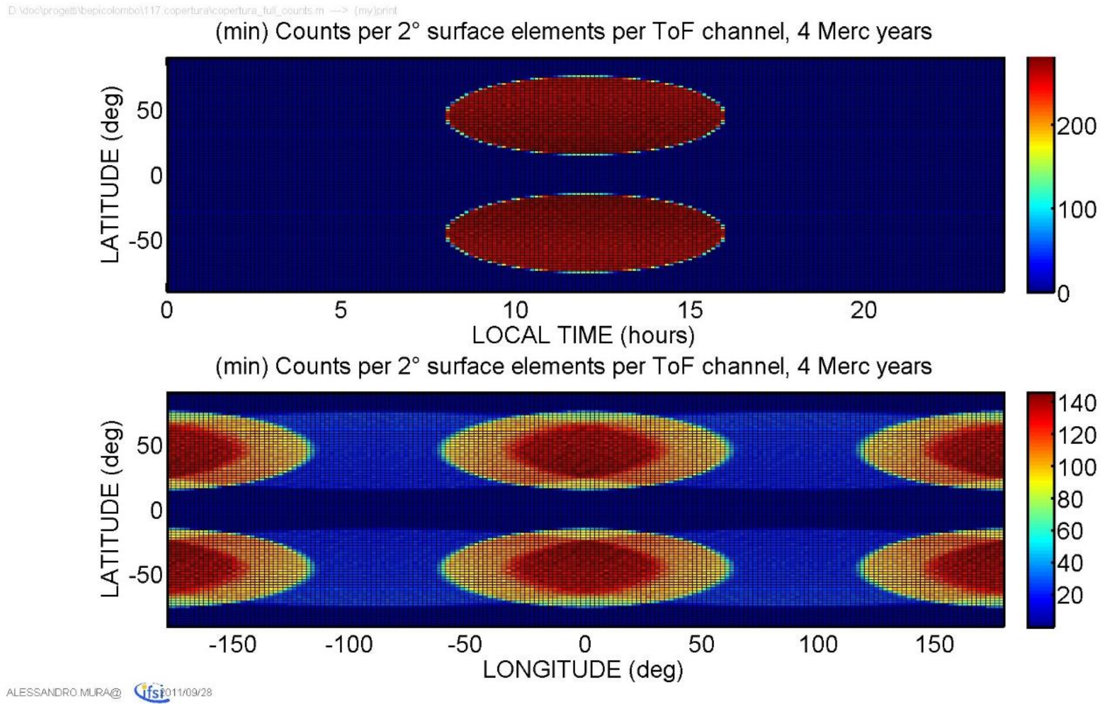


Figure 3

In figure 4, we show a similar plot as in figure 3, where the perihelion activity is reduced due to power limitation. If we switch off ELENA at the perihelion (few days) we obtain a decreased scientific return because the surface coverage is smaller.

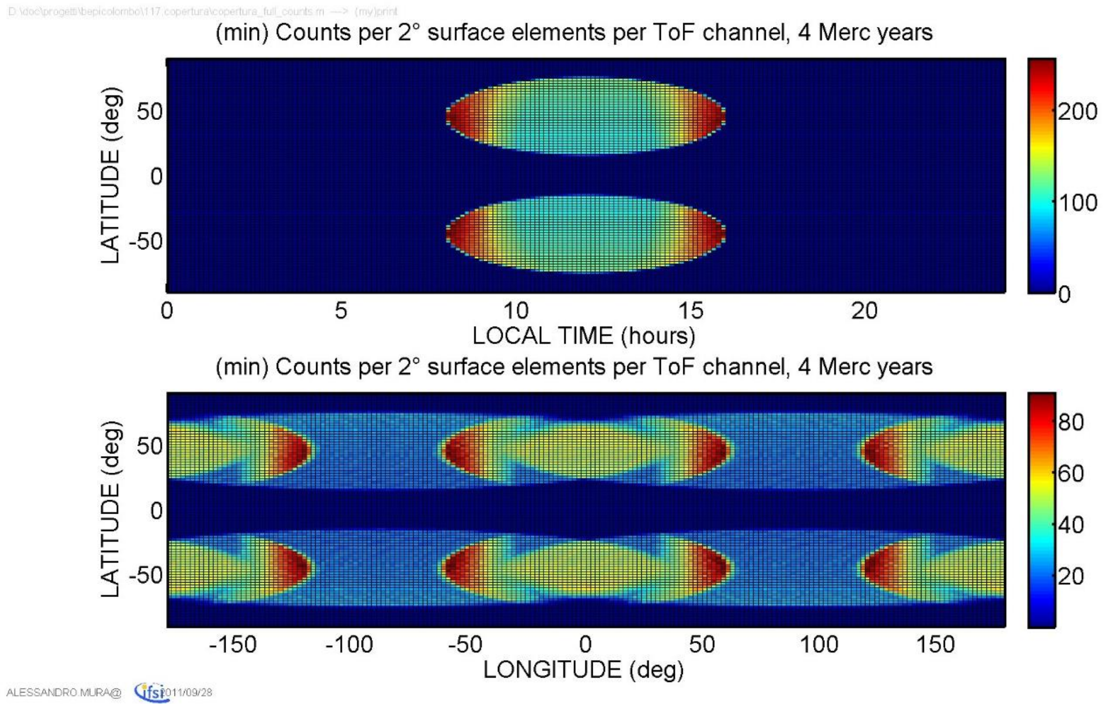


Figure 4

ELENA Signal to Noise Ratio (SNR)

UV light is probably the major cause of false counts for ELENA, and the S/N ratio in such case has been estimated in different orbital conditions by using data from ELENA calibration campaign during 2015. Measured count-rates for ions (used to simulated neutral Backscattering) and UVs have been used. This data has been rescaled to simulate the real signal at Mercury.

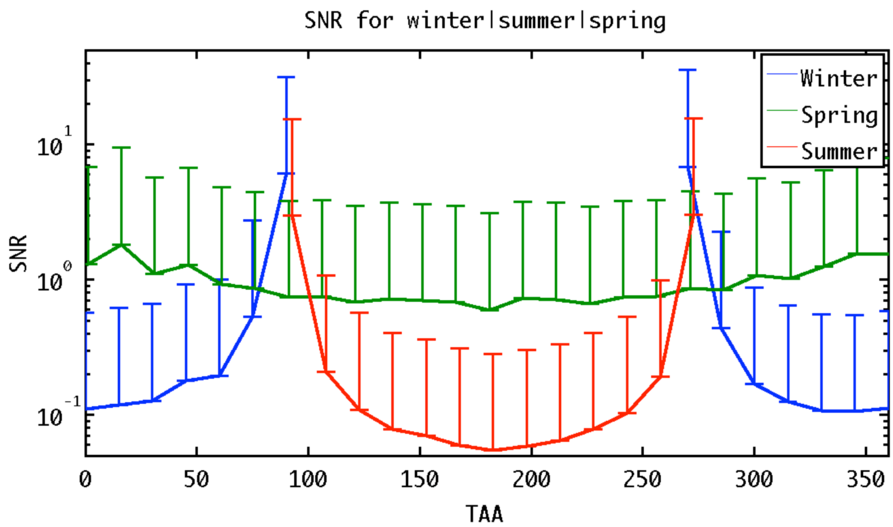


Figure 5

The figure shows the *signal-to-noise* ratio for ELENA, assuming backscattering as signal and UV contamination as noise, for three different orbits: at aphelion (winter; blue), at

perihelion (Summer, red) and at terminator (Spring, greed). Red and blue lines are not continuous, as the snr is not calculated in the nightside, because we assume that the main noise there is not due to UV. The snr is not very high. In the “terminator” case, the mean snr is approximately 1, and may be up to 10.
The snr in the night side may be larger, but is presently not estimated.
This shows that detailed analysis and simulation of the UV noise is needed in order to allow (partial) removal of this signal.

5.4.2 STROFIO

TBW

5.4.2.1 STROFIO SNR

TBW

5.4.3 MIPA

TBW

5.4.3.1 MIPA SNR

TBW

5.4.4 PICAM

TBW

5.4.4.1 PICAM SNR

TBW

6 Power Limitations

Here will be described the refinement of science operations activity due to power limitations. The foreseen power consumption largely exceeds the ESA allocation for SERENA on board BC. Even if at the present time the power consumption estimate can vary (for example, because of the ELENA chosen frequency, which has big impact on the piezo power consumption), it is necessary to investigate and develop a plan to recover the lack of electric power. The recovery plan has to be discussed among the scientific community involved (since it will in any case impact on the science return) and the (co) PIs.
Preliminarily, it is clear that at least two straightforward strategies can be identified (here are given only as example for further discussion):

1) linear time cut: respect to the proposed timeline (see table 2), each instrument will proportionally reduce the observation time until the average power will be in the allocated budget. For example, if instrument A is to be on 6 hours around periherm, a 50% cut will result in a 3 hours operation (still around periherm).
2) instrument cut: alternatively, some instrument will be completely turned off.

As an example, case 1 will reduce the average power but non necessarily the peak one, while case 2 will reduce both but probably has a bigger impact on science.

It is clear that those are only hypothesis that need to be discussed at the next SOWG (Madrid, ESAC, Nov 2012). Some other hypothesis, as well as the obtained timeline of telemetry and power, will be presented in that meeting. This section will be updated with the results of the meeting discussion.

7 Activity summary

7.1 Activity Summary: Kick Off - Nov 2012

In the following we list the on-going and performed activity up to Nov 2012.

7.1.1 Adequacy of on-board storage and data transmission resources

Checks for different observation strategies. MTBW

7.1.2 Analysis of the temporal profile and along the orbit

This is discussed in section 6.

7.1.3 Simulation of measured signal and the telemetry budget in light and on ground.

Development of ELENA SCOE, see the attached report in Annex 4.
Data processing of ELENA measurement data using the acquisitions done with digital oscilloscope.
Development of the hardware interface with the ELENA electronic boards using the arduino board is ongoing.

7.1.4 Scientific visualization tools

Generation of the requirements and data development of the GSE inherent to the sensors (see also WP 2210).
Collaboration with FMI institute to add specific SERENA data analysis software.
In order to analyse incoming SERENA data with the official SERENA EGSE.
Data archives of SERENA data packets taken during test session measurements were monitored with yet existent tools on the EGSE and then saved, packet data reduction and offline analysis with specific software is on-going.

7.1.5 Communications to the meeting SOWG (Science Operations Working Group)

Preparation for next SOWG in Madrid (Nov 2012).

7.1.6 Contribution to the documentation requirements for SERENA GSE of phase B2, C and D produced by the FMI

Developing software for the interpretation and the scientific analysis of the data produced by the SERENA subsystem prototypes

7.1.7 Contributing to documentation of phases B2, C and D of the SERENA development

Delivery of the Draft of the SERENA Ground Operations Plan.
Participations in the BepiColombo SFT System Functional Test (debugging and formal run). Compilation of test reports, attached to this document as Annex A.

Participation in site to the BepiColombo EMC test, compilation of the SERENA test report, attached as Annex B.

7.1.8 Publications and / or internal notes

SERENA poster @ EGU Vienna

7.1.9 Contribution to the preparation of periodic ASI reports

TBW

7.2 Activity summary: Nov 2012 - Jan 2014

In the following we list the on-going and performed activity up to Gen 2014.

7.2.1 Adequacy of on-board storage and data transmission resources

Checks for different observation strategies. TBW

7.2.2 Simulation of measured signal and the telemetry budget in light and on ground.

Development of ELENA SCOE.

7.2.3 Scientific visualization tools

Generation of the requirements and data development of the GSE inherent to the sensors (see also WP 2210). The cooperation with FMI institute has succeeded in adding specific SERENA ELENA data analysis software functions in the egse in order to analyse incoming SERENA data with the official SERENA EGSE.

Data archives of SERENA data packets taken during test session measurements were monitored with yet existent tools on the EGSE and then saved, packet data reduction and offline analysis with specific software was developed.

7.2.4 Communications to the meetings

SOWG (Science Operations Working Group) and DHAWG meeting in Madrid (Nov 2012) and in ESTEC (Mar 2013).

7.2.5 Contribution to the documentation requirements for SERENA GSE of phase B2, C and D produced by the FMI

Advances in the developing software for the interpretation and the scientific analysis of the data produced by the SERENA subsystem prototypes and ELENA.

7.2.6 Publications and / or internal notes

ELENA Data Handling and commanding BC-SRN-TN-34000 (see document in annex).
Presentation to the HEWG 4 workshop in Key Largo (Florida, USA) May 2013

http://colombo.iaps.inaf.it/hewg-serena2013/5_16_afternoon/SERENADataHandlingStatusAndDevelopment-Lazzarotto-v3.pdf
poster presentation at the European Ground System Architecture Workshop (ESAW) 2013 held at ESOC on 18th and 19th June 2013.

7.2.7 Contribution to the preparation of periodic ASI reports

7.3 Activity summary: Jan 2014 - Oct 2015

In the following we list the on-going and performed activity up to Oct 2015.

7.3.1 Adequacy of on-board storage and data transmission resources

Checks for different observation strategies, in particular the RAW (event by event) mode for ELENA has been intensively studied and modification have been proposed.

7.3.2 Simulation of measured signal and the telemetry budget in light and on ground.

Development of ELENA SCOE. Calibration tests of ELENA at the Bern facility have been analyzed.

7.3.3 Scientific visualization tools

Generation of the requirements and data development of the GSE inherent to the sensors (see also WP 2210). The cooperation with FMI institute has succeeded in adding specific SERENA ELENA data analysis software functions in the egse in order to analyse incoming SERENA data with the official SERENA EGSE.
Data archives of SERENA data packets taken during test session measurements were monitored with yet existent tools on the EGSE and then saved, packet data reduction and offline analysis with specific software was developed.

7.3.4 Communications to the meetings

SOWG (Science Operations Working Group), Tuesday, 27 January 2015
DHAWG Meeting #4 held on 27-Jan-2015 at ESTEC and DHAWG meeting in Madrid (Nov 2012) and in ESTEC (Mar 2013).
BepiColombo SWT meeting Japan, Sept. 2014.

7.3.5 Publications and / or internal notes

7.3.6 Contribution to the preparation of periodic ASI reports

8 Other Notes

The following documents were used by the **ESA** BC SGS to add the comments previously described:

Number	Title/Description, date	
JOINT_MMO&MPO	SERENA-MMO_Joint_investigation_1_1	
SPR	BC-SRN-RP-00028_04_3_SERENA_SPR.pdf	
STROFIO_FOP	15000-MOP-01 R0 Strofio Flight Operations	
EIDB1	BC-EST-RS-02522-SERENA-EIDB-Iss1dr-120117	
WS_Annex13	BC-SGSPIWorkshop_Annex13-SERENA-DHA	
STROFIO_DESIGN	BC-SRN-DD-50001-01-00_STROFIO_Design_report	
Ame20111117	Email from Alessandro Mura, 2011 November 17	

9 References

TBW