BC-SIM-TR-019 STC ICO2 REPORT Issue 1.0

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Approvation

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Change Log

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0	0	01/07/2020	All	Draft
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1. Introduction

1.1. Scope

The present document has been issued to describe the ICO#2 (Instrument Check Out) Tests of STC, channel of the Spectrometers and Imagers for MPO BepiColombo Integrated Observatory SYStem (SIMBIO-SYS). The tests phase was performed during 2019-11-27.

1.2. Reference Documents

[RD. 1]	BC-SIM-TN-003 Reports and Note Layout and Flow
	(10.20371/INAF/TechRep/36)
[RD. 2]	BC-SIM-GAF-MA-002 rev.8_SIMBIO-SYS FM User Manual, 2017
[RD. 3]	BC-SIM-GAF-MA-002 rev.10 SIMBIO-SYS FM User Manual
[RD. 4]	STC FPA Delivery Review Board (DRB) Data Package FM (BC-SIM-RVS-DP-021)
	(10.20371/INAF/TechRep/36)
[RD. 5]	BC-SIM-TN-001-FOPs_Decription_Draft_ver0_20Dec2019
	(10.20371/INAF/TechRep/15)
[RD. 6]	BC-SIM-PL-004-Checkout_02_Test_Summary_Issue_1_05Nov2019
	(10.20371/INAF/TechRep/100)
[RD. 7]	BC-SIM-TR-017 EGSE ICO#02 report
	(10.20371/INAF/TechRep/123**)**
[RD. 8]	BC-SIM-TR-003-STC_NECP_Report
	(10.20371/INAF/TechRep/26)
[RD. 9]	BC-SIM-TR-007 STC Delta-NECP REPORT
	(10.20371/INAF/TechRep/71)
[RD. 10]	BC-SIM-TR-007_STC_ICO1_Report
	(10.20371/INAF/TechRep/89)
[RD. 11]	BC-SIM-TR-XXX General SIMBIO – ICO1
	(10.20371/INAF/TechRep/98)
[RD. 12]	SIMIONI, E., et al. CMOS detectors: lessons learned during the STC stereo channel preflight calibration. In: International Conference on Space Optics—ICSO 2016. International Society for Optics and Photonics, 2017. p. 105622M
	(10.1117/12.2296147)
[RD. 13]	BC-SIM-TR-003_-_STC_NECP_report
	(10.20371/INAF/TechRep/26)
[RD. 14]	BC-SIM-TN-004_-_SIMBIO-SYS_FOP_update_after_NECP
	(10.20371/INAF/TechRep/58)
[RD. 15]	BC-SIM-TR-018_-_HRIC ICO2 Report (10.20371/INAF/TechRep/100)

1.3. Acronyms

ACK	Acknowledgment
ADC	Analogical Digit Converter
APID	Application Process IDentifier
ASW	Application SoftWare
CM	Color Mode
CSV	Comma Separated Values
DSNU	Dark Signal not Uniformity
FOP	Flight Operation Procedure
FPA	Focal Plane Assembly
HK	Housekeeping
HRIC	High spatial Resolution Imaging Channel
ICO	Instrument Checkout
IT	Integration Time
ME	Main Electronics
NECP	Near Earth Commissioning Phase
OBCP	On-Board Control Procedure
OB	Optical Bench
OBSW	On Board Software
ODS	Offset Dark Subtraction
PDOR	Payload Direct Operation Request
PDS	Planetary Data System
PE	Proximity Electronics
PNG	Portable Network Graphics
PSC	Packet Sequence Control
RT	Repetition Time
SIMBIO-SYS	Spectrometers and Imagers for MPO BepiColombo Integrated Observatory SYStem
SSC	Source Sequence Count
SSMM	Solid State Mass Memory
STC	STereo imaging Channel
S/C	Space-Craft
TC	TeleCommand
TEC	Thermo-Electric Cooler
TM	Telemetry
VIHI	VIsible and Hyper-spectral Imaging channel
XML	eXtensible Markup Language

1.4. Document Format and Repository

This document is compliant with the SIMBIO-SYS Report and Note Layout and Flow **[RD. 1]** and will be archived both on the INAF Open Access repository and the SIMBIO-SYS team Archive.

1.5. Document Organization

This document is organized in sections whose topics are listed as follows:

- *Section 2* – Definitions and assumptions
- *Section 3* – ICO2 objective, with a brief description of the test executed reported in details in the following sections.
- *Section 4* – "Functional test" description including commanding and HK interpretation and discussion.
- *Section 5* – "Nominal Test" description including commanding and HK interpretation and discussion.
- *Section 6* – "Science All FPA" test description.
- *Section 7* – Description of the test reports in attachment.

2. Definitions and assumptions

In this section the main physical and technical terms are defined.

2.1. STC Sensors

Param.	Param. Name	Unit	Calibration
NSS21040	Temperature FPA1	K	CSSP0020TM
NSS21041	Temperature FPA2	K	CSSP0021TM
NSS21042	Temperature PE	K	CSSP0022TM
NSS21043	Focal Plane Assembly (FPA) (former Temp ch-Fw)	K	CSSP0023TM
NSS21044	STC Optical Bench (OB) (former Temp ch-Bw)	K	CSSP0024TM
NSS21050	PE 3.3V Measured	V	CSSP0025TM
NSS21051	TEC Current	A	CSSP0026TM

Table 1 Main SIMB STC Housekeeping (Packed ID YSS40002) including temperature sensors of STC on the FPA, PE, the backside of the detector and the STC OB as Reported in [RD. 2].

The position of the STC temperature sensors are shown in Figure 1 (a,b) and Figure 2 (a) extracted by [RD. 2] and [RD. 4].

The STC Temperature FPA1 and FPA2 sensors, (often abbreviated TFPA1 and TFPA2 respectively), are located next to the detector surface (see Figure 2). Their temperature readings increase when the detector is switched on, then their values lower when the TEC is switched on to cool the detector; their temperature values are also used as a feedback for the TEC.

The Temp Channel-Fw and Temp Channel-Bw were initially located on the optical bench near the folding mirrors of the Forward and Backward channels (defined, in a later stage, Ch-2 and Ch-1 or Channel-High and Channel-Low respectively). The Temp Channel-**F**w (defined nowadays as **F**PA Package) sensor was, at a later time, located on the hot side of the FPA package, thus it is expected to have values corresponding to instrument temperature; the Temp Channel-**B**w (defined nowadays STC-Optical **B**ench) is located on the back of one of the folding mirrors as in Figure 1(b) gives a measurement of the OB temperature in the front part of the STC Channel-Low and near the VIHI PE, as shown in Figure 1(c).

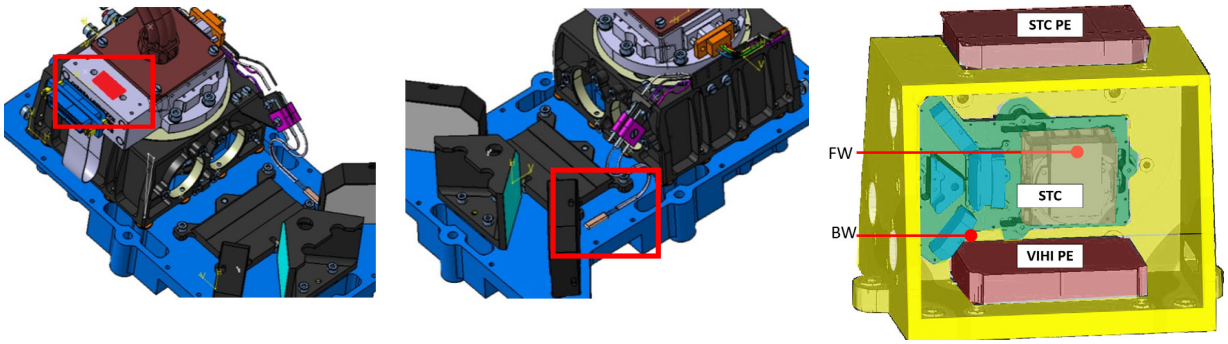


Figure 1 In (a) the location of the "STC Temperature FPA Package (fw)" (NSS21043) temperature sensor (red rectangle). As highlighted in the 3D CAD model (no pictures are available, it is not present in the original CAD model), this sensor is placed onto the FPA package, in the same position where the corresponding sensor is placed on the HRIC FPA. In (b) the location of the "STC Temperature Optical Bench (bw)" (NSS21044) temperature sensor, as shown in the 3D CAD model (no picture available). In (c) the overview of the layout of SIMBIO-SYS showing VIHI and STC PE respect the Temperatures sensors.

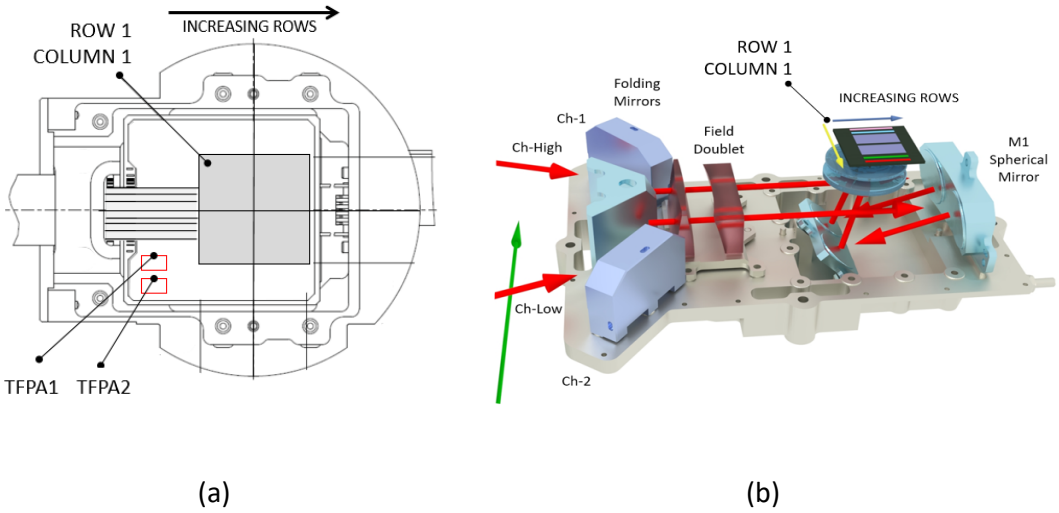


Figure 2 In (a) Location of the "STC-FPA Temperature sensors" next to the FPA (see the red rectangles). They are called TFPA1 (upper one) and TFPA2 (bottom one) and are associated respectively with the NSS21040 and NSS21041[RD. 4]. In (b) STC schematic optical layout where the origin of the detector reference system is indicated. In green an along-track direction. In red the optical path. Image shows the correspondence Ch-2 / Channel-Low and Ch1 /Channel High

3. STC-ICO#2 Tests

As reported in planning documentation [RD. 6], the SIMBIO-SYS ICO2 had the scope to verify the health status of the instrument at channel and system level 1 year after launch. Few functional and performance tests are planned to monitor the evolution of some key instrument parameters.
The tests performed are reported in Table 2.

Test name	Monitoring	UTC first Image
STC Functional Test	PE,TEC, memory, acquisition, capability	2019-11-27T06:43:50.102154
STC Performance Test	DC Verification	2019-11-27T07:03:00.103517

Table 2. Table of the Tests as reported in [RD. 6].

Performance Tests are divided in two phases:

- **Nominal Tests**
  dedicated to DC measurement in GM.
- **All Fpa 2.0**
  dedicated to different large regions of the detector and to test compression.

The two tests are described in Section 5 and 6 respectively.

During the Functional Tests, differently from NECP phase (see **[RD. 8**]) the switch on of the Channels was performed after:

- the update of the nominal parameters (see details in **[RD. 2]**) for the gentle activation of the TEC
- the updated of the temperature threshold of the SIMBIO-SYS heating procedures performed by the S/C (see **[RD. 6]**)

Both the issues (described in next sub-sessions) were correctly adopted to avoid anomalies of the TEC current (reported as Issue 1 in [RD. 11]) in the case of a difference in temperature greater than 10K between CF and TEC SetPoint.

3.1. TEC Parameters

As performed in the previous ICO#1 test (see **[RD. 10]** for details), during the switch on of the ME (before the beginning of the ICO) the STC TEC parameters were updated substituting the default values with the nominal ones (**[RD. 3**).
Differently from other uploaded parameters (i.e. VIHI Bias Detector parameters which remain in the PE RAM until the PE is switched off), when the TEC parameters have been

uploaded, they are written in the CPCU RAM, so they remain available up to the next SIMBIO-SYS switch off (see [RD. 2] Section 8.3.1.10 and 8.3.1.16).

The summary of the parameters used for STC in the NECP phase and in the ICO1 and ICO2 phases is reported in following table.

Name	Data-kind	Meaning	NECP Phase Nominal	ICO1 Phase	ICO2 Phase
NP	[16 bit uint]	Proportional gain	77	128	77
NI	[16 bit uint]	integral gain	33	229	33
N_E	[16 bit uint] (only 12 lsb's may be not zero)	PI operation threshold	112 (10K)	34(3K)	112 (10K)
NSS	[16 bit uint] (only 14 lsb's may be not zero)	Soft start Ramp slope	12289	5	12289
BSS o BSTART	[2 bits]	- bit 15= 0/1 : anti- windup ON/OFF; - bit 14= 0/1 : P-only/ramp soft start	11	11	11
T_REF	[16 bit uint]	Reference FPA commanded temperature (only 12 lsb's may be not zero)	2799 (268 K)	2799 (268 K)	2799 (268 K)

Table 3 *TEC Soft-Start parameters*

Once the ME was switched on (with the updated parameters) all the functional tests were commanded by a sequence of the FOP SS-TST-020 (see **[RD. 14]**).

3.2. Heating and Cold Fingers

This section discusses the trend of the STC Cold Finger (CF) temperature sensor named MPO-TEMP-SIMBIO-STC-CF and identified as NRUD2087 (see [RD. 9] for a detailed description of the sensors and their positions).
STC CF temperature trend during ICO2 is shown in Figure 3. For the sake of completeness , we report the trends of the CFs of all the three channels of SIMBIOSYS. HKs were acquired with a sample rate of 1 minute.

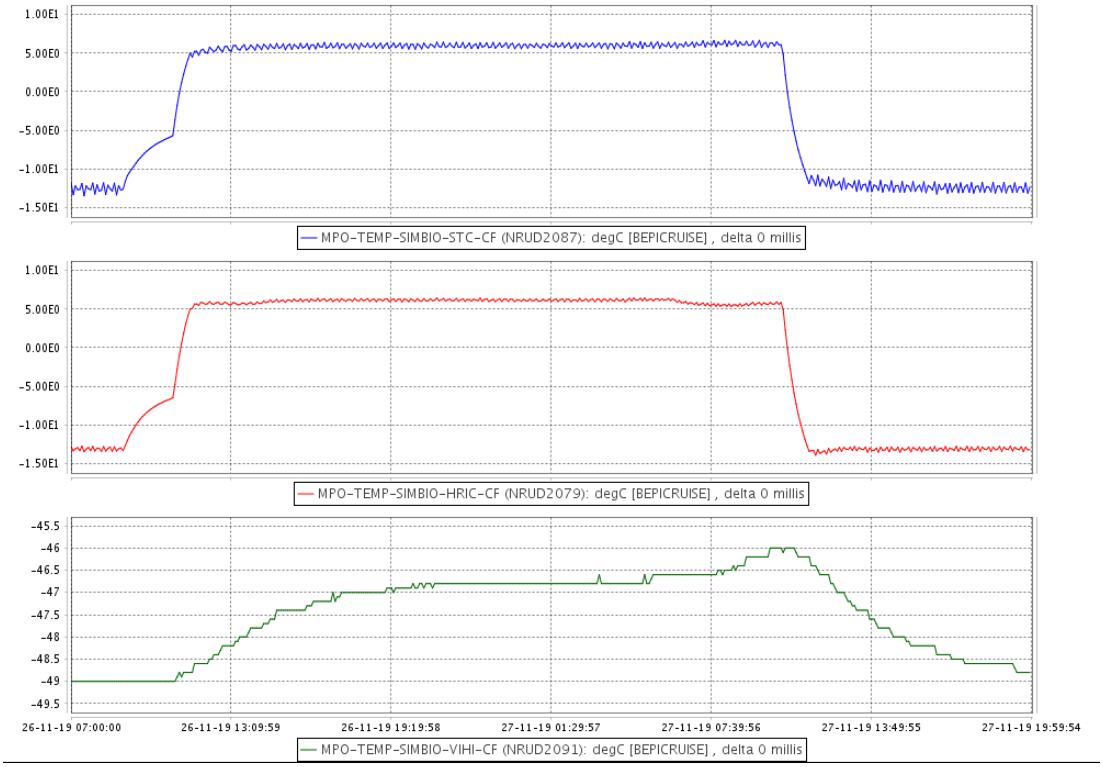


Figure 3 Measurement for STC (blu), HRIC (red) and VIHI (green) Cold Fingers during ICO2 phase. Temperature is reported in °C.

The cold fingers have reached the temperature thresholds after 2 h of heating. **As required by the team, the temperature range was increased compared to previous ICOs (from +4/+5°C to +5/+6 °C) in manner to guarantee the nominal gentle activation of the imaging channels TEC.**

This allowed the instrument to avoid the anomalies reported as Issue 1 in [RD. 11]).

The redundant heater of the imaging channels (NPWD1023) remained switched on for all the duration of the test while the nominal line (NPWD0923) was cyclically switched on and off to maintain the CF in the temperature ranges required by the thermal settings.

The on/off cycles are reported in **Figure 4** which shows, for each epoch of the ICO2 tests, the duration (time between an off-on switch and the following one) of the main heater cycle. As for previous ICO (ICO1) the duration has initially measured around 14.5 minutes. During the increasing curve of the CF (163 minutes), the Heater was always switched on. During the operative phase, the cycle can be considered decreased to 9.5 minutes. After the decreasing curve of the CF (68 minutes) it return to be as initially at 14.5 minutes. The trend respects all the characteristics measured for the ICO01 (a part the length of the TEST).

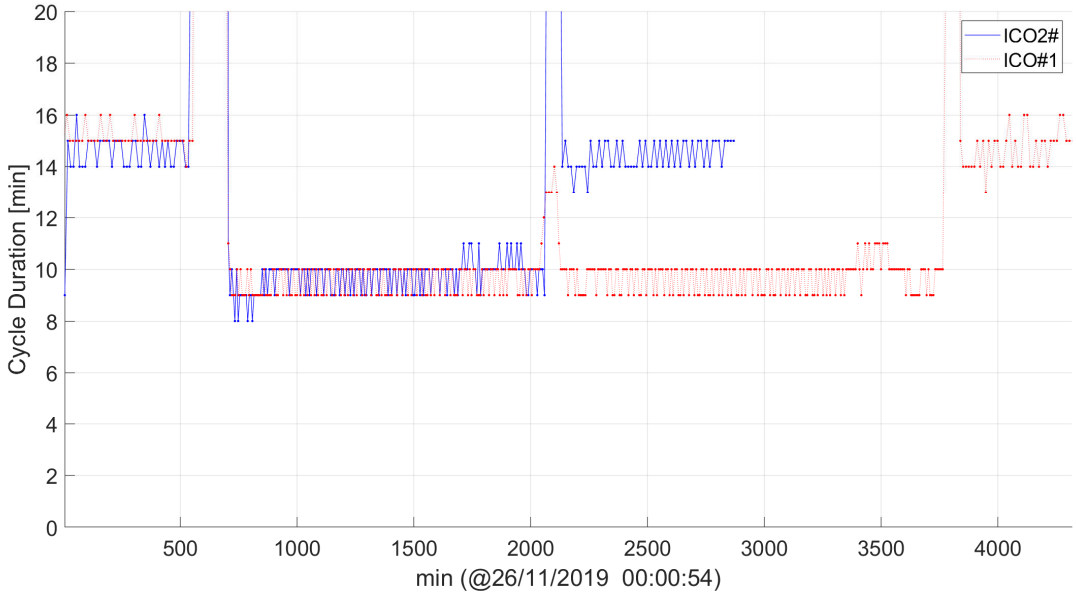


Figure 4 Cycle on-off duration during the ICO5 phase for the main heater (id HK: NPWD0923). Blu line represents the ICO2 measurement. In red is overlapped the ICO1 measurement (as function of the time respect the ME switch on).

4. STC Functional Test

4.1. Test description

During ICO#02 the STC functionality has been verified by means of dedicated Functional Test procedures with the aim of verifying:

- o PE, TEC and detector activation
- o memory/registers status
- o science acquisition capability

The STC functionality will be tested by means of the following TCs sequence:

- PE switch-on
- Detector switch-on
- TEC switch-on (nominal TEC parameters)
- Test of the reading and writing of a specific memory address
- The following science acquisitions:
  - o a ten of GM compressed acquisitions with low RT,
  - o a ten of GM compressed acquisitions with high RT,
  - o a ten of CM compressed acquisitions with low RT,
  - o a ten of CM compressed acquisitions with high RT
- TEC switch-off
- Detector switch-off

- PE switch-off

4.2. Commanding

During ICO#2 ESA performed the SIMBIO-SYS heating procedure. Consequently, the TEC nominal parameters (reported in **[RD. 2]** and with more details in Table 3 of **[RD. 10]**) were updated and all the STC tests went ahead with no other anomalies detected.
Once the ME was switched on (with the updated parameters) all the functional tests were commanded by a new version of FOP SS-TST-020 whose details and updates can be found in **[RD. 14**].
During Functional Test (at 06:28:05) an out-of-limit on NSS21010 "STC last event TC Timer Ovrf." was relieved.
This was simultaneous to event YSS40800 SIMB "HK discarded to SPW error" and YSS40408 "SIMB PE HK Frame Restart".
All science TCs planned were nominally executed. The summary of the TCs and the consequent images dataset generated is reported in Table 4 and Table 5.

Timeline	Relative	TC	Scope	Notes
0:00:00	00:00:00	ZSS00329	Set HK to 1 s	
0:00:05	00:00:05	ZSS17210	Send SIMB STC Detector On/Off	Switch On STC PE (Channel) (to restore after ASW update with TEC initialization).
0:00:10	00:00:05	ZSS17203	Send SIMB STC Thermal Control On/Off	TEC set point: 268K
0:00:15	00:00:05	ZSS17206	Send SIMB STC Read Addr	Read memory present status
0:00:30	00:00:15	ZSS17206	Send SIMB STC Read Addr	
0:00:35	00:00:05	ZSS17207	Send SIMB STC Write Addr	Test Writing Memory
0:00:40	00:00:05	ZSS17204	Send SIMB STC Confirm Command	
0:00:45	00:00:05	ZSS17207	Send SIMB STC Write Addr	Test STC science test pattern
0:00:50	00:00:05	ZSS17204	Send SIMB STC Confirm Command	
0:15:50	00:15:00	ZSS17202	Start STC Science (GM Mean)	
0:16:10	00:00:20	ZSS17202	Start STC Science (GM Max)	
0:18:20	00:02:10	ZSS17202	Start STC Science (CM-Mean)	Science
0:18:30	00:00:10	ZSS17202	Start STC Science (CM-Max)	
0:18:54	00:00:24	ZSS17209	Send SIMB STC Stop Science	End test.
0:18:59	00:00:05	ZSS00329	Set HK to 10 s	

Table 4 Timeline of the Functional Tests with the references to the commanded ZSS (see Errore. L'origine riferimento non è stata trovata.**]** for more details).

The resulting database derived by EGSE telemetry to raw pipeline is reported in Table 4.

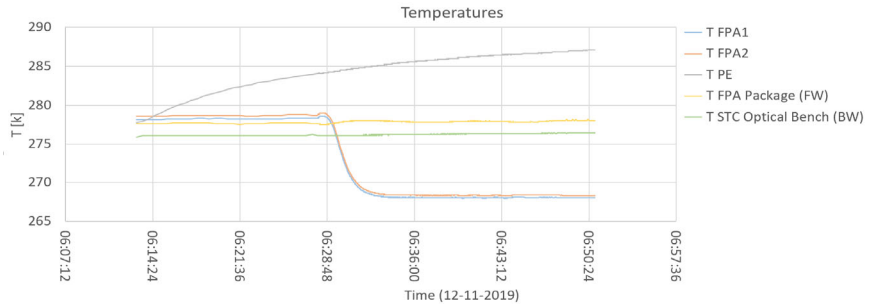
EGSE_NTC [#]	First_Acq [UTC]	Duration [s]	NACQ [#]	DimX [px]	IT [ms]	RT [s]	Windows
1	2019-11-27T06:43:50.102154Z	18	10	896	0.096	2	GM
2	2019-11-27T06:44:10.102154Z	123	11	896	1.4976	12.3	GM
3	2019-11-27T06:46:25.401698Z	4.4	12	896	5.2992	0.4	CM

4	2019-11-27T06:46:30.201716Z	22.5	12	896	37.7952	2.05	CM

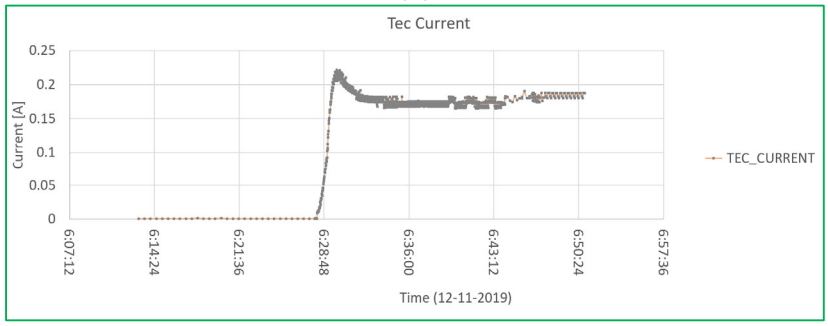
Table 5 Resulting database of the ICO1 Functional Test. All TCs were commanded with the CBD = 64x64 and, nominally, the IBR was set to 32 for the GM and 63 for the CM.

4.3. HKs interpretation and discussion

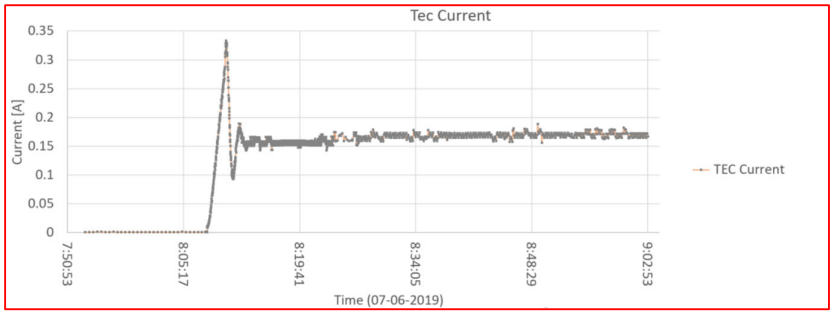
Uploading the nominal TEC activation parameters allowed its "gentle" activation determining a graceful cool-down of the FPA temperature and so avoiding a OOL current peak. Figure 5 b) and c) show a comparison between the STC TEC current profile and the ICO1 one (for details se Section 4.3 of [RD. 10]). **ICO1 and ICO2 commanded the same TEC parameters but different CF threshold**.



(a)



(b)



(c)

Figure 5 Temperatures (a) and TEC current values (b) evolution over the Functional Tests of ICO2. For HK description details see **Table 1**. In (c) TEC current values evolution over the Functional Tests of ICO01 reported for comparison.

4.4. Image analysis

Science data acquired during Functional Tests has no anomalies from an operational point of view.
The main Dark parameters (such as mean and std of the signal) confirm the ones acquired during ICO1 (see [RD. 10]).
A first reduction of the dataset is shown in Figure 6. The image shows, for each acquisition, the mean value of the windows included in the 4 TCs. Right y-axis (yellow) reports the distance between each acquisition and the previous one.
As expected for the firsts two TCs (GM) the signal results nominally constant for all the 3 windows considered (WINX+PANH+PANL). In the case of the CM the peak-issue (see [RD. 12]) brings to a not constant level of the dark in the case of long times between the acquisitions.
The issue will be resolved during the Scientific Phase of the Mission in two way: the Offset Dark Subtraction (ODS) Calibration and the Mitigation Strategy

Offset Dark Subtraction (ODS)

The ODS Calibration approach assumes that each acquisition strategy includes the acquisition of an additive minimal window (called win-X) in the dark coated part of the FPA. The DC will be calibrated by subtracting the offset measured by averaging the dark present on the winx (assuming a uniform offset of DC over all the FPA).
ODS Calibration can, in this way, guarantee to have a correct measurement of the dark both at the beginning or at the end of the acquisition sequences.

Mitigation Strategy

Unlike the ODC calibration, the Mitigation strategy is nowadays under analysis in order to avoid entirely the issue: the peaks are linked to the waiting time before the acquisition; this means that an acquisition with a high data rate before the planned one should avoid the increase of DC and should allow to take advantage of all the dynamical range. This strategy was tested in d-Necp phase (see [RD. 9] for details) without conclusive results and new verification tests are planned for ICO03 phase.

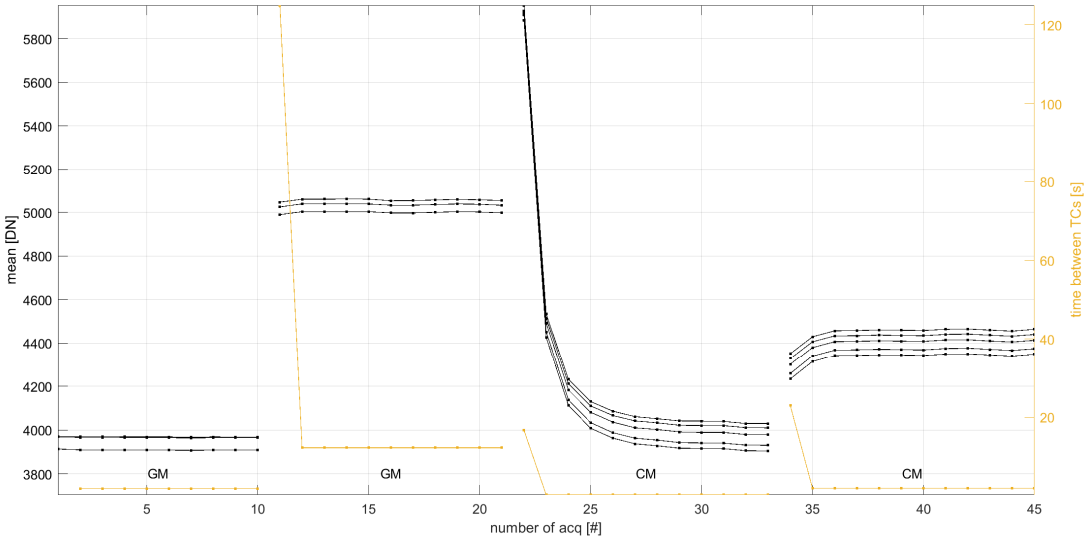


Figure 6 The figure reports the reduction in mean of the images of the Functional tests. Right y-axis (yellow) report the distance between each acquisition and the previous one.

Inverse peak of the 2 set of images of the CM needs more investigations but confirm the behavior measured at the first check out (see [RD. 10]).

5. STC Nominal Test

5.1. Test description

During ICO#02 the STC performance has been verified by means of a minimal Performance test procedures with the aim of verifying of DC behavior for the nominal IT and Repetition Time (RT). Same IT and RT were commanded during NECP phase ([RD. 13]) and ICO1 ([RD. 10]).

5.2. Commanding

This test has been performed through the execution of 1 pre-defined PORs named:
“BPSS00309 - SIMBIO-SYS - STC_Nominal_Test ICO2”
See [RD. 12] for more details.

The POR repeats the acquisitions performed during ICO1 performance tests (see Table 6 of [RD. 10]) limiting the acquisitions to the GM mode and avoiding the CM.

The POR executes the acquisition of sets of 10 images in GM mode for each IT considered. The test is performed for 2 different RT. These assumptions divide the POR in two phases (see the timeline in Table 6.). Each phase commands the integration of 21 different ITs in manner to obtain for the GM two different dark curves for the low and high repetition times defined.

Timeline	Fop Names	Mode	NTCs	Min IT	Max It	RT
			[#]	[ms]	[ms]	[s]
00:00:00	ASSF307/317	GM	21	0	9600	Where possible 0.45
00:04:58	ASSF307/317	GM	21	0	9600	Where possible 7

Table 6 Timeline of the 2 phases TCs of the PERFORMANCE TEST with the references to the commanded FOPs (see [RD. 14] for more details). All phases commands 21 TCs with different ITs. In the same phase the RT commanded is constant a part for the stellar integration times (FOP-317 and 318). Table reports the relative time respect the first TC of the test and the FCPs commanded, for more details see [RD. 14].

The resulting database derived by EGSE telemetry (see [RD. 7])to raw pipeline is reported in Table 7.

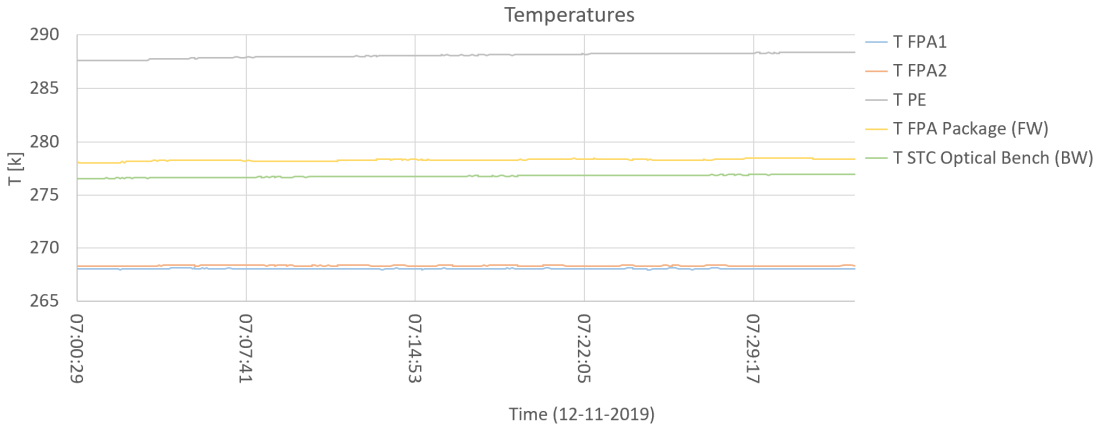
EGSE_NTC [#]	First_Acq [UTC]	Duration [s]	DimX [px]	IT [ms]	RT [s]	Windows
1	2019-11-27T07:03:00.103517Z	4.05	896	0	0.44999	GM
2	2019-11-27T07:03:07.103547Z	4.05	896	0.0096	0.45	GM
3	2019-11-27T07:03:14.103593Z	4.05	896	0.0576	0.45	GM
4	2019-11-27T07:03:21.103516Z	4.05	896	0.1056	0.44999	GM
5	2019-11-27T07:03:28.103577Z	4.05	896	0.192	0.44999	GM
6	2019-11-27T07:03:35.103470Z	4.05	896	0.288	0.44999	GM
7	2019-11-27T07:03:42.103531Z	4.05	896	0.336	0.45	GM
8	2019-11-27T07:03:49.103516Z	4.05	896	0.48	0.44999	GM
9	2019-11-27T07:03:56.103547Z	4.05	896	0.576	0.44998	GM
10	2019-11-27T07:04:03.103485Z	4.05	896	0.96	0.44998	GM
11	2019-11-27T07:04:10.103424Z	4.05	896	2.4	0.45	GM
12	2019-11-27T07:04:17.103394Z	4.05	896	3.36	0.45	GM
13	2019-11-27T07:04:24.103272Z	4.05	896	4.8	0.45001	GM
14	2019-11-27T07:04:31.103363Z	4.05	896	9.6	0.45	GM
15	2019-11-27T07:04:38.103363Z	4.05	896	30	0.44999	GM
16	2019-11-27T07:04:45.103348Z	4.05	896	150	0.45004	GM
17	2019-11-27T07:04:52.103271Z	4.05	896	270	0.44999	GM
18	2019-11-27T07:04:59.103302Z	7.02	896	480	0.78	GM
19	2019-11-27T07:05:09.103164Z	11.3	896	960	1.26	GM
20	2019-11-27T07:05:24.103164Z	45.9	896	4800	5.1	GM
21	2019-11-27T07:06:17.103011Z	89.1	896	9600	9.9	GM
22	2019-11-27T07:07:58.102797Z	63	896	0	7	GM
23	2019-11-27T07:09:10.102537Z	63	896	0.0096	7	GM
24	2019-11-27T07:10:22.102322Z	63	896	0.0576	7	GM
25	2019-11-27T07:11:34.102139Z	63	896	0.1056	7	GM
26	2019-11-27T07:12:46.101909Z	63	896	0.192	7	GM
27	2019-11-27T07:13:58.101679Z	63	896	0.288	7	GM
28	2019-11-27T07:15:10.101480Z	63	896	0.336	7	GM
29	2019-11-27T07:16:22.101251Z	63	896	0.48	7	GM

30	2019-11-27T07:17:34.101128Z	63	896	0.576	7	GM
31	2019-11-27T07:18:46.100777Z	63	896	0.96	7	GM
32	2019-11-27T07:19:58.100547Z	63	896	2.4	7	GM
33	2019-11-27T07:21:10.100516Z	63	896	3.36	7	GM
34	2019-11-27T07:22:22.100347Z	63	896	4.8	7	GM
35	2019-11-27T07:23:34.105031Z	63	896	9.6	7	GM
36	2019-11-27T07:24:46.104710Z	63	896	30	7	GM
37	2019-11-27T07:25:58.104541Z	63	896	150	7	GM
38	2019-11-27T07:27:10.104449Z	63	896	270	7	GM
39	2019-11-27T07:28:22.104204Z	63	896	480	7	GM
40	2019-11-27T07:29:34.104021Z	63	896	960	7	GM
41	2019-11-27T07:30:46.103730Z	63	896	4800	7	GM
42	2019-11-27T07:31:58.103546Z	89.1	896	9600	9.9	GM

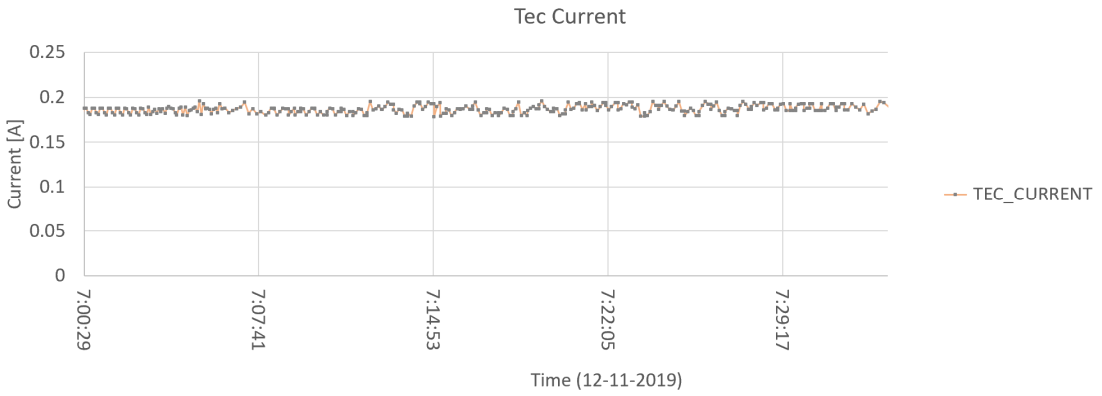
Table 7 Database derived by EGSE. All TCs commanded 10 acquisitions with IBR=0 and CBD=64x64.

5.3. HKs interpretation and discussion

Figure 7 shows the trends of the main temperatures and current (Table 1) of STC. The performance test was executed after the functional test starting from a Stand-By mode of the instrument. No switch other on/off was executed during this test.



(a)



(b)

Figure 7 Temperatures and TEC current values evolution over the Performance Tests of ICO1.

5.4. Image analysis

The Science data acquired during the Performance Tests has no anomalies from an operational point of view.
A first reduction of the dataset is shown in Figure 8. The images show for each acquisition the mean value of the windows included in the 4 TCs. Right y-axis (yellow) reports the distance in time between each acquisition.
The figure shows in red even the exponential models (see [RD. 12] for details) estimated for each set of acquisition. Each signal trend can be modelled by solving nonlinear least-squares curve fitting based on the code described in [RD. 10] following the equation:

$$s_{(n_{acq})} = A - B\, e^{-\frac{\tau}{n_{acq}}}$$

Where:
s is the mean signal on the considered window.
n_{acq} is the number of the consecutive acquisition.
$A \geq 0$ is the peak value in DN.
$\tau > 0$ is the velocity term.
$B \geq 0$ define the stabilization value to be considered as $A - B$.

The model guarantees a mean std of the residuals of 6.8 DN which reaches the worst value of 24 DN in the case of maximum IT commanded. The values are both in the limit of the RON.

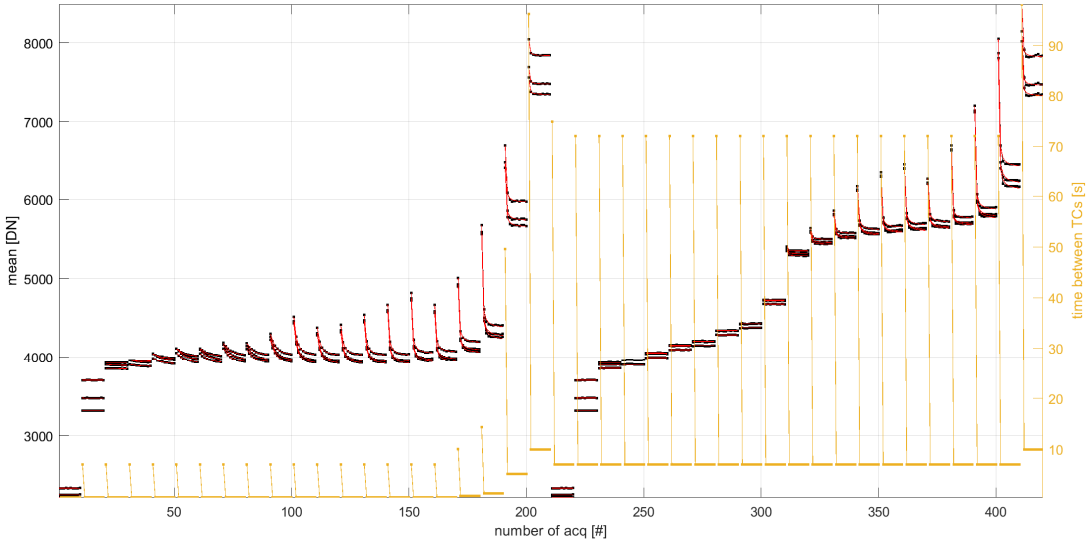


Figure 8 The figure reports the reduction in mean of the images of the Performance tests for the GM. Red lines represent the exponential curves which model by nonlinear fit each set of acquisition. Right y-axis (yellow) report the distance between each acquisition and the previous one.

With the exponential model, it is possible to define the DC for the low and high repetition times commanded. The tests should be executed for each ICO in manner to measure the stability of the curves.

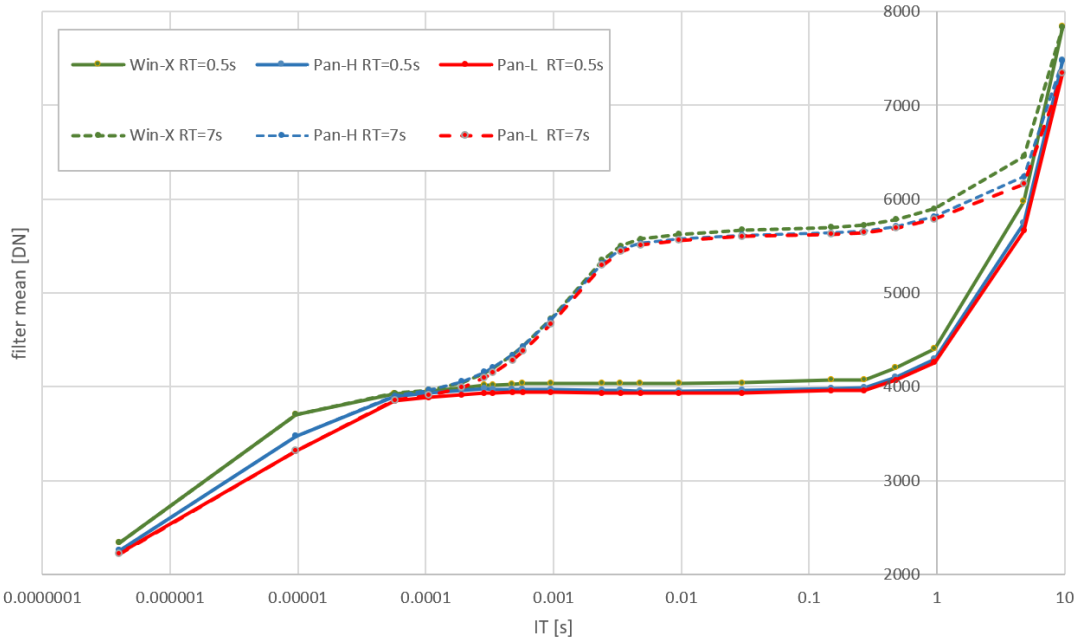


Figure 9 The figure reports the reduction by exponential model of the images of the Performance tests for the GM. Continuous lines represent the DC for the first TC (low RT) while dotted line represent the DC for the 2nd TC (high RT).

The two DC curves are comparable with the ones acquired during ICO1 as shown in Figure 10.

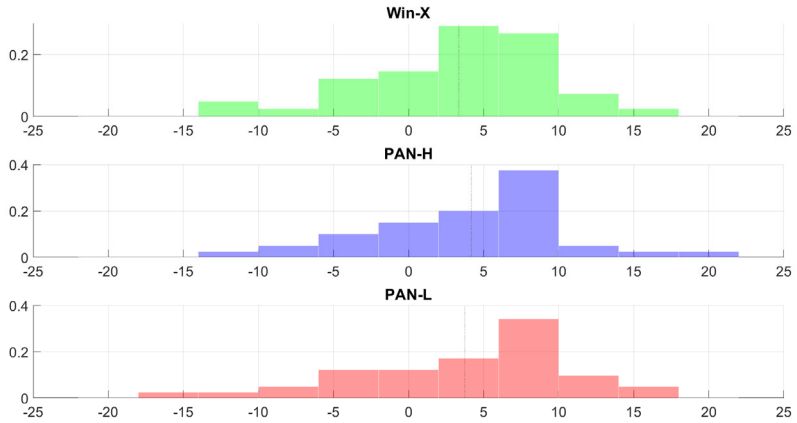


Figure 10 The figures report the normalized histograms of the differences between the asymptotic means in [DN] obtained by ICO1 and the ones obtained during ICO2

6. STC All FPA 2.0

6.1. Test description

The aim of the test is the monitoring of dark, DSNU, RON and IBR effect on the dark.
For this reason the test is divided in two phases:

- Large FPA Acquisitions (LFA)
- IBR FPA Acquisition (IFA)

Most of the DV is dedicated to LFA.
The LFA performs a DSNU, RON measurements by means of several acquisitions of large detector regions. The different regions have been defined with the aim of covering the whole detector and finalizing the tests performed during Delta-Necp ([RD. 9]).

Differently from what was commanded during the on-ground calibration phase, STC Dark was measured for fixed values of the RT to analyze the impact of low RTs (0.7s where possible or 1.2s) and high RTs (5 s).
The IT=0 and 500, raw values corresponding to 400 ns and 4.8 ms, have been tested in 5 main configurations (each with for two different values of the RTs):

- "Left" side of the detector (the first 576 columns of the FPA).
  Hereafter "SurfBndLft".

- "Right" side of the detector (the last 576 columns of the FPA). Hereafter "SurfBndRgh".
- "Central" part of the detector (middle 1024 columns of the FPA). Hereafter "SurfBndCen".
- "Half High" part of the detector (the first 1024 rows of the FPA). Hereafter "SurfHalfHi".
- "Half Low" part of the detector (the last 1024 rows of the FPA). Hereafter "SurfHalfLO"

The latter phase of the test (IFA) is a limited set of acquisition to analyze the effect of the different compression level in the GM.

6.2. Commanding

This test has been performed through the execution of a PORs named:
"BPSS00288 - SIMBIOSYS_STC_all_fpa ICO2"
See [RD. 6] for more details.

A detailed timeline of the test is shown in Table 8 for LFA phase and Table 9 for IFA phase.

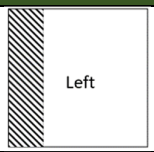
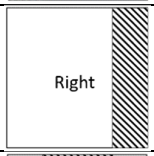
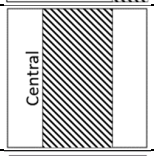
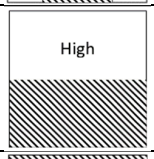
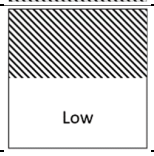
Timing	ID FOPs	Name FOP	FPA Region	Parameters
00:00:00	ASSF322A	STC OUTF SurfBndLft v03		IT=0;RT=0.7s, Width= 576 px
00:00:30	ASSF322A	STC OUTF SurfBndLft v03		IT=500;RT=0.7s, Width= 576 px
00:01:00	ASSF322A	STC OUTF SurfBndLft v03		IT=0;RT=5s, Width= 576 px
00:01:30	ASSF322A	STC OUTF SurfBndLft v03		IT=500;RT=5s, Width= 576 px
00:02:00	ASSF323A	STC OUTF SurfBndRgh v03		IT=0;RT=0.7s, Width= 576 px
00:02:30	ASSF323A	STC OUTF SurfBndRgh v03		IT=500;RT=0.7s, Width= 576 px
00:03:00	ASSF323A	STC OUTF SurfBndRgh v03		IT=0;RT=5s, Width= 576 px
00:03:30	ASSF323A	STC OUTF SurfBndRgh v03		IT=500;RT=5s, Width= 576 px
00:04:00	ASSF321A	STC OUTF SurfBndCen v03		IT=0;RT=1.2s, Width= 1024 px
00:04:30	ASSF321A	STC OUTF SurfBndCen v03		IT=500;RT=1.2s, Width= 1024 px
00:05:00	ASSF321A	STC OUTF SurfBndCen v03		IT=0;RT=5s, Width= 1024 px
00:05:30	ASSF321A	STC OUTF SurfBndCen v03		IT=500;RT=5s, Width= 1024 px
00:06:00	ASSF324A	STC OUTF SurfHalfHi v03		IT=0;RT=1.2s
00:06:30	ASSF324A	STC OUTF SurfHalfHi v03		IT=500;RT=1.2s
00:07:00	ASSF324A	STC OUTF SurfHalfHi v03		IT=0;RT=5s
00:07:30	ASSF324A	STC OUTF SurfHalfHi v03		IT=500;RT=5s
00:08:00	ASSF325A	STC OUTF SurfHalfLO v03		IT=0;RT=1.2s
00:08:30	ASSF325A	STC OUTF SurfHalfLO v03		IT=500;RT=1.2s
00:09:00	ASSF325A	STC OUTF SurfHalfLO v03		IT=0;RT=5s
00:09:30	ASSF325A	STC OUTF SurfHalfLO v03		IT=500;RT=5s

Table 8 Timeline of the ALL_FPA LFA test with the references to the commanded FOPs (see [RD. 14] for more details). All TCs were commanded 5 consecutive acquisitions. RTs are reported in seconds, ITs are reported in RAW format (IT=0

and 500, raw values corresponding to 400ns and 4.8 ms). Table reports the FCP commanded, for more details see **Errore. L'origine riferimento non è stata trovata.**].

Timing	ID FOPs	Name FOP	RT	IBR
00:10:00	ASSF307A	STC Sci SurfNomnl GM	0.3	0,0,0
00:10:02	ASSF307A	STC Sci SurfNomnl GM	1	63,63,63
00:10:05	ASSF307A	STC Sci SurfNomnl, GM	1	63,63,32
00:10:08	ASSF325A	STC Sci SurfNomnl GM	1	0,0,0
00:10:11	ASSF307A	STC Sci SurfNomnl GM	1	63,63,8
00:10:14	ASSF307A	STC Sci SurfNomnl GM	1	63,63,2

Table 9 Timeline of the ALL_FPA IFA with the references to the commanded FOPs (see RD9 for more details). All TCs were commanded 2 consecutive acquisitions. IT was always commanded to 104 (raw). RTs are reported in seconds. Table reports the FCP commanded, for more details see **Errore. L'origine riferimento non è stata trovata.**].

The resulting database derived by EGSE telemetry to raw pipeline is reported in Table 10 for LFA and Table 11 for IFA.

EGSE_NTC [#]	First_Acq [UTC]	Duration [s]	NACQ [#]	DimX [px]	IT [ms]	RT [s]
43	2019-11-27T08:23:00.105242Z	2.8	5	640	0	0.69996
44	2019-11-27T08:23:30.105028Z	2.8	5	640	4.8	0.70008
45	2019-11-27T08:24:00.105074Z	20	5	640	0	5
46	2019-11-27T08:24:30.104921Z	20	5	640	4.8	5
47	2019-11-27T08:25:00.104860Z	2.8	5	640	0	0.69997
48	2019-11-27T08:25:30.129716Z	2.8	5	640	4.8	0.70002
49	2019-11-27T08:26:00.104752Z	20	5	640	0	5
50	2019-11-27T08:26:30.104600Z	20	5	640	4.8	5
51	2019-11-27T08:27:00.104553Z	4.8	5	1024	0	1.2
52	2019-11-27T08:27:30.104462Z	4.8	5	1024	4.8	1.2
53	2019-11-27T08:28:00.104324Z	20	5	1024	0	5
54	2019-11-27T08:28:30.104293Z	20	5	1024	4.8	5
55	2019-11-27T08:29:00.104217Z	4.8	5	2048	0	1.2
56	2019-11-27T08:29:30.104216Z	4.8	5	2048	4.8	1.2
57	2019-11-27T08:30:00.103957Z	20	5	2048	0	5
58	2019-11-27T08:30:30.103941Z	20	5	2048	4.8	5
59	2019-11-27T08:31:00.103880Z	4.8	5	2048	0	1.2
60	2019-11-27T08:31:30.103819Z	4.8	5	2048	4.8	1.2
61	2019-11-27T08:32:00.103696Z	20	5	2048	0	5
62	2019-11-27T08:32:30.103696Z	20	5	2048	4.8	5

Table 10 Database derived by EGSE for the ALLFPA LFA phase. All TCs commanded 5 consecutive acquisitions with IBR=0 and CBD=128x128..

EGSE_NTC [#]	First_Acq [UTC]	Duration [s]	NACQ [#]	DimX [px]	IT [ms]	RT [s]	IBR

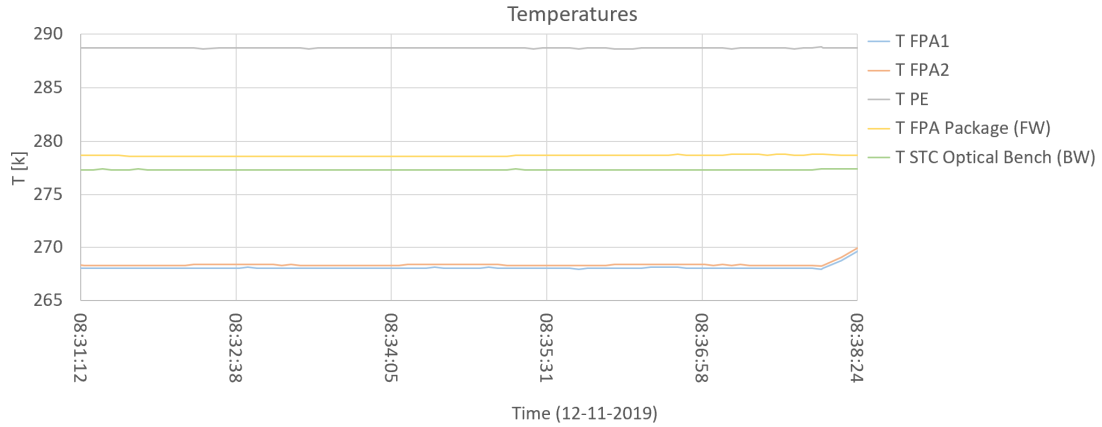
63	2019-11-27T08:33:00.103650Z	0.3	2	896	0.9984	0.30002	0,0,0
64	2019-11-27T08:33:02.103574Z	1	2	896	0.9984	1	63,63,63
65	2019-11-27T08:33:05.103635Z	1	2	896	0.9984	0.99998	63,63,32
66	2019-11-27T08:33:08.103543Z	1	2	896	0.9984	1	0,0,0
67	2019-11-27T08:33:11.103558Z	1	2	896	0.9984	0.99989	63,63,8
68	2019-11-27T08:33:14.103497Z	1	2	896	0.9984	1.0001	63,63,2

Table 11 Database derived by EGSE for the ALLFPA IFA phase. All TCs commanded 2 consecutive acquisitions of GM with IBR=0 and CBD=64x64.

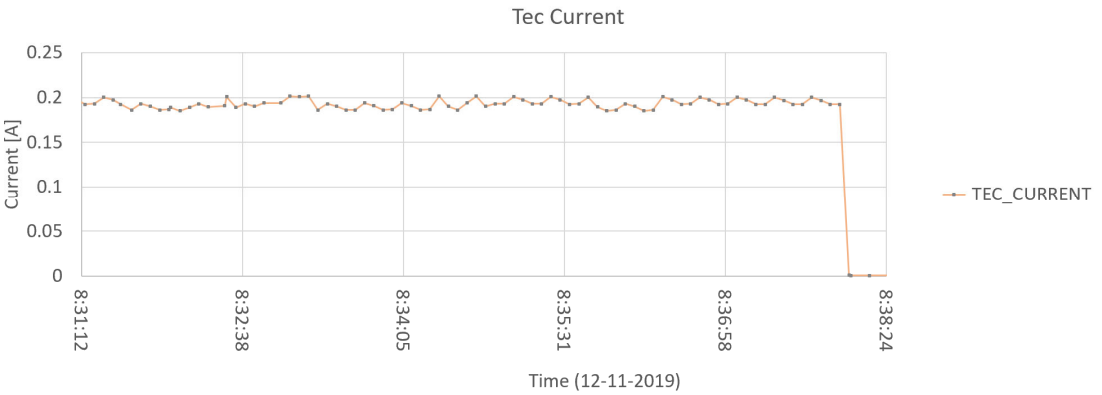
6.3. HKs interpretation and discussion

6.3.1. TEC and Temperatures HKs

Figure 11 shows the trends of the main temperatures and current (Table 1) of STC. The performance test was executed after the functional test without starting from a Stand-By mode of the instrument. Channel switch-off was executed at the end of this test.



(a)



(b)

Figure 11 Temperatures and TEC current values evolution over the ALL_FPA test of ICO2.

The Science data acquired during Performance Tests has no anomalies from an operational point of view.

6.3.2. Science Data: Large FPA Acquisitions

A first reduction of the dataset is shown in Figure 12. The images show for each acquisition the mean value of the windows included in the 4 TCs. Right y-axis (yellow) reports the distance in time between each acquisition.
The figure shows even the exponential models (see [RD. 12] for details) estimated for each set of acquisition. Each signal trend can be modelled by solving nonlinear least-squares curve fitting based on code described in [RD. 10] following the equation:

$$s_{(n_{acq})} = A - B\, e^{-\frac{\tau}{n_{acq}}}$$

Where:
s is the mean signal on the considered window.
n_{acq} is the number of the consecutive acquisition.
$A \geq 0$ is the peak value in DN.
$\tau > 0$ is the velocity term.
$B \geq 0$ define the stabilization value to be considered as $A - B$.

The model guarantees a mean std of the residuals of 6.3 DN which reach the worst value of 10.99 DN in the case of maximal integration time commanded. The values are both in the limit of the RON.

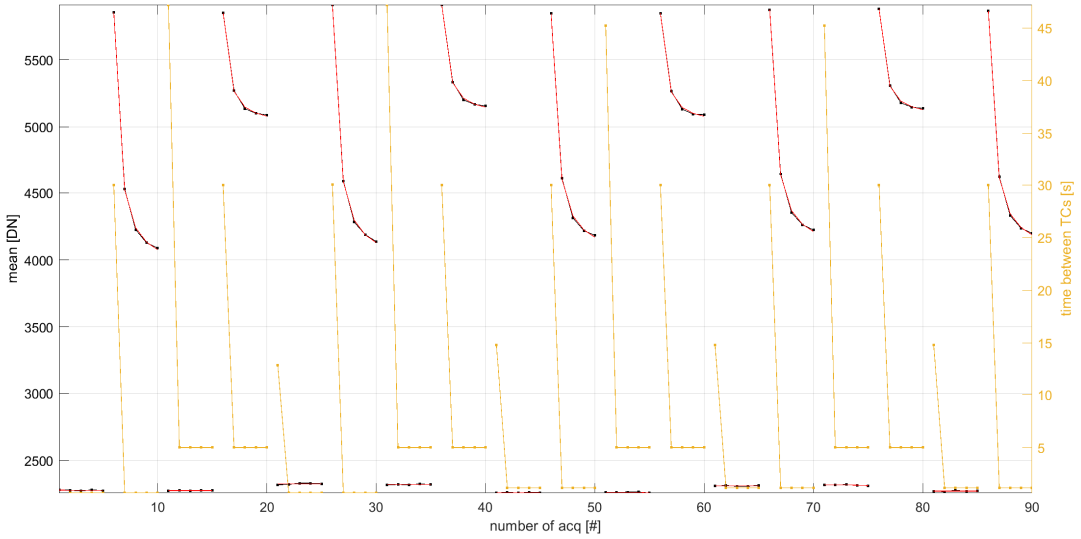
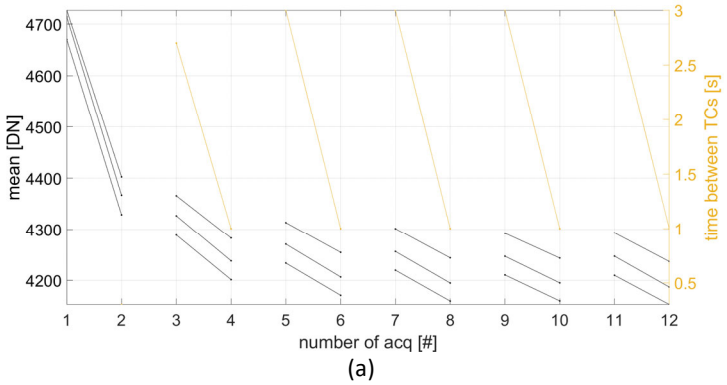


Figure 12 The figure reports the reduction in mean of the images of the ALLFPA2.0 Test LPA. Red lines represent the exponential curves which model by nonlinear fit each set of acquisition. Right y-axis (yellow) reports the distance between each acquisition and the previous one.

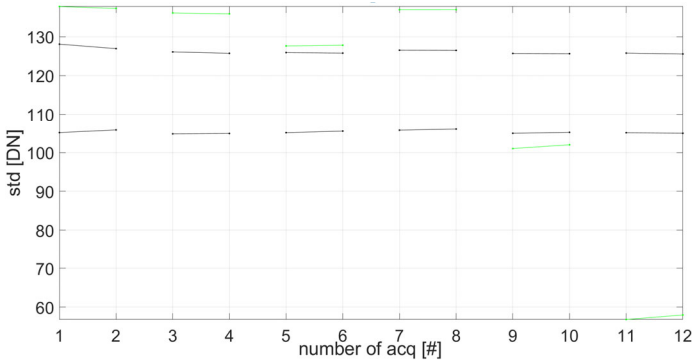
With the exponential model it is possible to define the Dark Current for the low and high repetition times commanded.

6.3.3. Science Data: IBR FPA Acquisitions (IFA)

The IFA images were reduced in mean and std avoiding the exponential fit considering the limited number of acquisitions: two images are acquired for each IBR configuration.



(a)



(b)

Figure 13 The figures reports the reduction in mean (a) and std (b) of the images of the ALLFPA2.0 Test IPA for the GM. Right y-axis (yellow) of (a) figure reports the distance between each acquisition and the previous one.

The std images shows the impact of the compression on the PANL (green lines) for the different compression factor considered (0, 63, 32, 0, 8, 2).
The test has the scope to understand the effect of the IBR on the mean and the std of the images in relation with compression/decompression on ground tests.

6.3.3.1. Compression/Decompression Simulation

Different simulations were performed on-ground by the applying the SIMBIO-SYS compressor/decompressor simulator to in-flight dark frames from STC in order to evaluate the level of degradation introduced as a function of the inverse bit rate (IBR) parameter. The simulations (limited to nominal CBD=64x64) report in Figure 14 for each window of the GM the effect of the IBR parameters on Mean Squared Error (MSE), Mean Absolute Error (MAE), Maximum Absolute Error (MxAE), and Mean of subtraction
Mean of subtraction should foresee a difference less than 0.5 DN for IBR greater than 8.

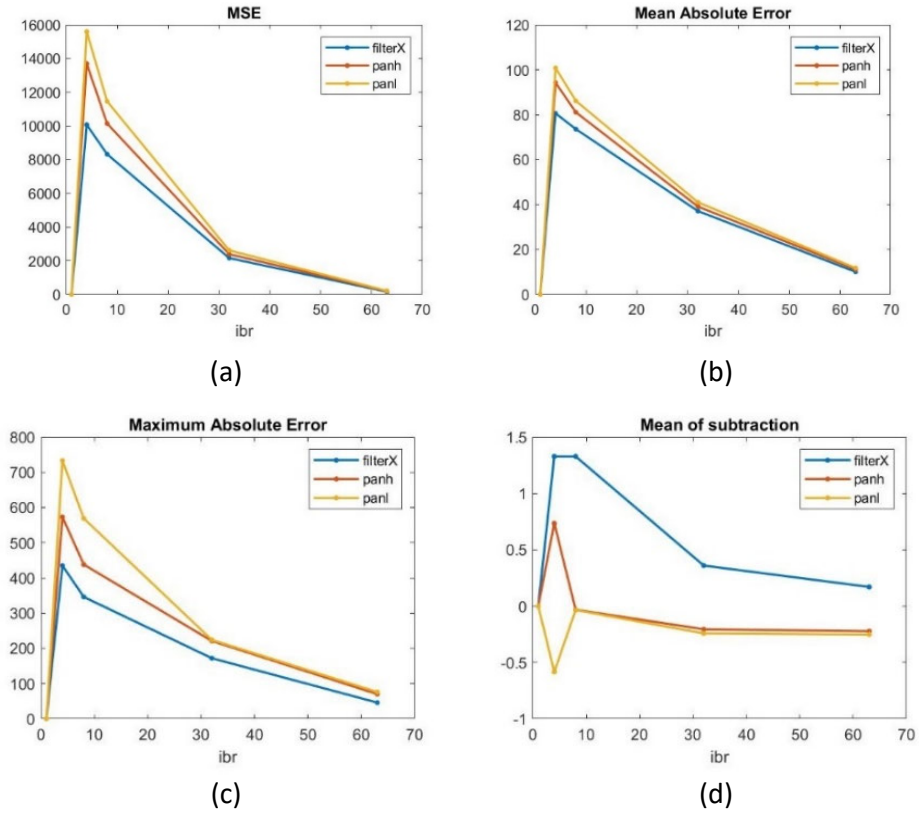


Figure 14 Simulations performed for GM with CBD 64x64 and IBR covering the values: 1 (lossless), 4, 8, 32 and 63. The plots describe Peak Signal-to-Noise Ratio (PSNR), Mean Squared Error (MSE), Mean Absolute Error (MAE), Maximum Absolute Error (MxAE), Mean of subtraction, Correlation Coefficient.

6.3.3.2. Inflight Image reduction

Considering that the offset which affect the detector should be supposed uniform, all the FPA images are analyzed after the subtraction of the mean value of the win-x (mitigated) which is not compressed during these tests. Figure 15 shows the PANL images associated as last for each TCs. Each image is compressed with a different IBR and the offset measured on the wins is than subtracted.

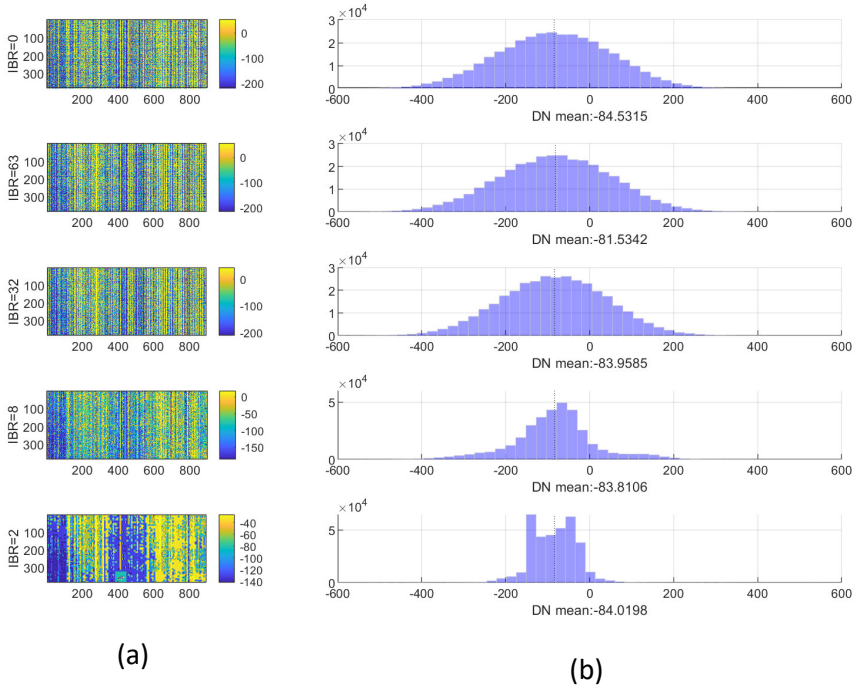


Figure 15 In (a) the PANL images acquired with different IBR (reported on the ylabel). To all the images the mean value of the winx is subtracted to avoid the presence of the RT-linked offset . In (b) statistical analysis and mean value of each one of these images.

Figure 15 (b) shows that compression has a low impact on the mean of the image. The difference with respect the bit packing case reaches its maximum value (3 DN) for IBR=63 while can be considered less than 0.8 DN for the other compression factors. These values are reported in Table 12; the table reports the mean error both in case of the first and second (and last) acquisition of each TC.

The same analysis is applied not only the hole PAN image but even to all the strips which compose the windows in manner to have a statistical measurement of the compression effect on a single strip: the image considered is composed by 6x7 strips with a dimension of 64x128 pixels. This means that the test supplies a set of 42 windows with the same dimension of winx on which verify the effect of compression on the mean values. The table reports the mean difference and ($\pm$) the standard deviation measured on the bench of strips.

The test shows how for little strips it is possible to reach a maximal variation in the mean of the window due to the compression of 6 DN.

IBR	Mean on Image		Mean on Strips	
#	[DN]		[DN]	
	first	second	first	second
63	4.78	3	4.79±1.5	3.0±1.03
32	2.11	0.57	2.12±0.7	0.57±0.92
8	-0.08	0.72	-0.07±2.6	0.72±2.91
2	-1.5	0.51	-1.50±3.2	0.51±5.06

Table 12 Table shows the difference of the mean of a window compressed respect with the not compressed one. Two cases are considered (the hole PANL image and the statistics of the strips which compose it).

This test (compared with Section 6.3.3.1) highlighted two issues:

- A difference in the first and second images which cannot be justified considering the uniformity of the reset
- A inflight difference in mean (6 DN) not confirmed by on ground simulation. Same issue was relieved during the same ICO HRIC Channel as reported in **[RD. 15]**.

The second misalignment (6DN) is in line with what observed during Nominal Test (Section 5) and highlighted by Figure 10. It seems to underling a difference in between the two ICOs.
The noise highlighted in dark measurement by HRIC channel required deeper investigations of STC data. It was measured even for STC Channel and it justifies all the misalignment between acquisition in the order of 6 DN.
Unique case of long acquisitions for STC is limited to orbit test during Delta-Necp (see [RD. 16]). A deeper analysis was performed on this test (as reported in Figure 10). The plot shows the averages of the PANL filter during test, composed of different continuous commands with different IT and RT .

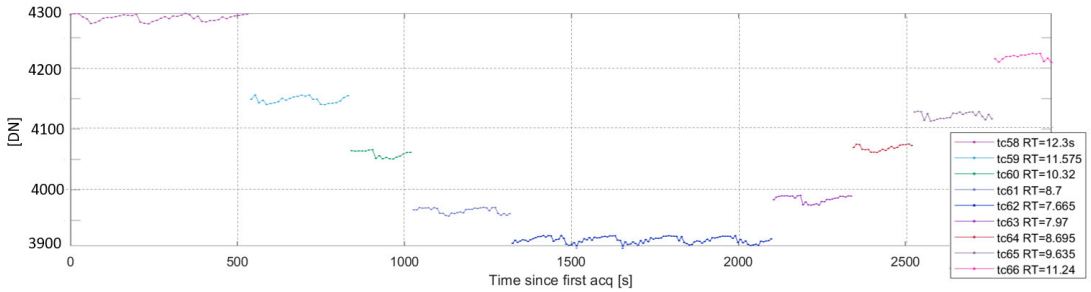


Figure 16 *Frames average vs Time respect with the first acquisition. Each orbit section is depicted here with a different color. In the legend the RTs are reported in seconds. All acquisitions shown the same carry wave on the DC measurement.*

The evident carry wave, which has no impact on the STC calibration thanks to the ODS Calibration (see 4.4) is defined, in these case, by a period of $T = 183 \pm 11.4$ s and an amplitude of 6 DN (± 0.146 % of the signal).
If due to a thermal issue, this carrier wave should be read as a fluctuation of the FPA temperature corresponding to ± 14.6 mK.
Furter investigations will be performed in next ICOs to understand this behavior.

7. Attached documents

In this section the attached documents are enumerated with corresponding links.
The Documents represent two kind of reports: the former traces the HKs and the main fast reduction of all the acquisitions (Performance Report). The latter indicates the Timing Issue linked to the SC and ME delays to each TCs. It covers the time between 2019-11-27T06:43:50.102154 (first TC of the ICO1 phase) and 2019-11-27T08:33:15.103573 (last acquisition of the ICO1 phase). Fast reading tables are reported in Annex section. For more details a deeper description is reported in next sessions.

Section	Name Report	Link
4	20210705ICO2_v2_Functional_STC	
5-6	20210705ICO2_v2_Performance_STC	

Table 13 Performance report file attachment covering the period including dNECP. The Log file is divided in sheets as EGSE structure in four different folder representing the different test..

Name Report	Link
20210714_TimingReport_NECP2ICO2	

Table 14 Timing Report file attachment covering the period including ICO2.

7.1. Performance Report

From the xml files, which include the HKs data, a series of useful quantities have been extracted. The report attached to Table 13 (see Attached Documents Section) includes all the following parameter for each acquisition:

Column	Name	Description
A	ACQ NUM	Number of the acquisition science the first on of the test
B	TC	ID of the TC corresponding to the folder in simbio server (i.e. science001)
C	last_image	Boolean flag defining if the acquisition is or not the last of the TC considered.
D	start_obs	UTC time of the acquisition

E-J	name_WX	Names of the windows acquired as reported in the xml files.
K	start_obs_et_[s]	UTC time of the in seconds
L	IT_[s]	Integration time of the WIN1 acquisition as reported in xml files.It correspond to the Integration time (IT) for each image acquired for a specific telecommand
M	RT_mean_[s]	Repetition time **evaluated** as the mean time between the first and last acquisition of the TC. In case of 1 acquisition it is not evaluated.
N	WT_[s]	Waiting Time of an acquisition. Derived by the time distance since and the previous acquisition (even if associate to another TC).
O-S	TXXXX_[K]	Temperature HKs (FPA1, FPA2, Channel1, Channel2 and PE temperature) as reported in the xml file
T-AK	mean_Wx_[DN]	For each window acquired is reported the mean of the windows in DN.
	mean64_Wx_[DN]	For each window acquired is reported the mean of the last 64 column of the window in DN.
	DSNU_Wx	For each window acquired is the standard deviation (Dark Signal Non Uniformity (DSNU)) of the window in DN.

Table 15 Columns description of the Performance Report file

7.2. TIMING LOG Report

This report (in attachment at Table 14) allows to check the delay time between the commanded timeline and the executed one due to granularity of the TC at satellite level and to the management of the TC by SIMBIO-SYS ME.
The report is based on the crossing of two documents:

- STACK report: xml file provided by ESOC
- LOGEVENT: provided by EGSE reporting the acceptance and execution time by SIMBIO-ME.

The report includes information extracted by the two documents descripted in previous section. Columns name, descriptions and sources are reported in next table.

Name	Description	Source
NAME_LOG_EVENT	Name of the LogEvent file	LOGEVENT
NAME_STACK_XML	Name of the ESOC STACK file	STACK
EVENTLOG_SEQ_NUMBER	Event sequence number associate to the ZSS an reported in the EventLog as described in previous paragraphs.	LOGEVENT
STACK_ROW	Row of the STACK file	STACK
FOP	FOP corresponding to the Sequence Name in the Stack file (see previous paragraphs).	STACK
ZSS	FOP corresponding to the Command Name in the Stack file (see previous paragraphs).	STACK
NOTES	Description of the ZSS (see previous paragraphs)	LOGEVENT
CHANNEL	Channel identify the Channel of the TC which means H for HRIC,S for STC,V for VIHI and M for the ME	
ISSCIENCE	Boolean flag true for the 6 TCs of SCIENCE and false everywhere else. Science TCs for the three channels are: ZSS17102, ZSS171B2 (for HRIC), ZSS17202, ZSS172B2 (for STC)	

	ZSS17302,ZSS173B2 (for VIHI).	
ACCEPTED_TIME_LOGEVENT	Acceptance time by ME (see previous paragraphs).	LOGEVENT
FAILURE_TIME	Failure time (where happens) by ME (see previous paragraphs).	LOGEVENT
EXECUTED_TIME_LOGEVENT	Execution time by ME (see previous paragraphs).	LOGEVENT
EXECUTED_TIME_STACK	Execution time by satellite. It should correspond to ACCEPTED_TIME_LOGEVENT	STACK
ACCEPTED/ EXECUTED/ FAILED	Boolean report of the result of the execution	LOGEVENT
DELAY_IN_EXECUTION_s	Delay in time execution (in seconds) due to ME issues.	LOGEVENT
DELAY_IN_FAILURE_s	Delay in failure (in seconds where happens) due to ME issues.	LOGEVENT
RT_SEC	Where the FOP is a Science TC. Repetition Time commanded is here reported.	STACK
PSSDESCXXX/ PSSVALSXXX	For each PSS are reported the Description (including PSS id) and the value commanded	STACK

Table 16 Table reports names, description and source of all the columns of the TimingLog file.