BC-SIM-TR-018 HRIC
ICO2 REPORT

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Approvation

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Document change record

Issue	Revision	Date	Affected Pages	Change description
1	0	26/01/2022	All	First issue

1 Introduction

1.1 Scope

The present document has been issued to describe the Instrument Check Out Phase (ICO#2) Tests of HRIC, channel of the Spectrometers and Imagers for MPO BepiColombo Integrated Observatory SYStem (SIMBIO-SYS).

1.2 Reference Documents

[RD.1] BC-SIM-TN-003_-_Reports_and_Note_Layout_and_Flow, 10.20371/INAF/TechRep/36

[RD.2] BC-ALS-TN-00099 MPO PFM Monitoring Thermistors Location

[RD.3] BC-SIM-GAF-MA-002 rev.8_SIMBIO-SYS FM User Manual, 2017

[RD.4] BC-SIM-PL-004_-_SIMBIO-SYS_Checkout_02_Test_Summary_Issue1_Revision0, 10.20371/INAF/TechRep/100

[RD.5] BC-SIM-TR-015_-_SIMBIO-SYS_ICO#01_Test_Report_Issue1_Revision0, 10.20371/INAF/TechRep/98

[RD.6] BC-SIM-PL-002_-_SIMBIO-SYS_Checkout_01_Test_Summary_Issue1_Revision0, 10.20371/INAF/TechRep/64

[RD.7] BC-SIM-TR-012_-_HRIC_ICO#01_report, 10.20371/INAF/TechRep/97

[RD.8] BC-SIM-TN-004_-_SIMBIO-SYS_FOP_update_after_NECP, 10.20371/INAF/TechRep/58

[RD.9] BC-SIM-TR-017 Instrument Checkout #2 Data Produced Analysis, 10.20371/INAF/TechRep/123

[RD.10] BC-SIM-IAPSUPA-TR-001 HRIC NECP report, 10.20371/INAF/TechRep/32

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	HouseKepping
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
PDOR	Payload Direct Operation Request
POR	Payload 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	SpaceCraft
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 – sensor definition, with a brief description of the HRIC sensors used to monitor the environment in which the channel executes the tests.
- Section 3 – ICO2-HRIC tests, with a brief description of the executed tests and a report on obtained HKs and data.

2 Definitions and assumptions

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

2.1 HRIC Sensors

Table 1 reports the main HRIC sensors covering the temperature measurement of the Focal Plane Assembly (FPA), the Proximity Electronics (PE), the backside of the detector and the HRIC Optical Bench (OB), the Current and the Voltage measurement of the Thermo-Electric Cooler (TEC) and the PE.

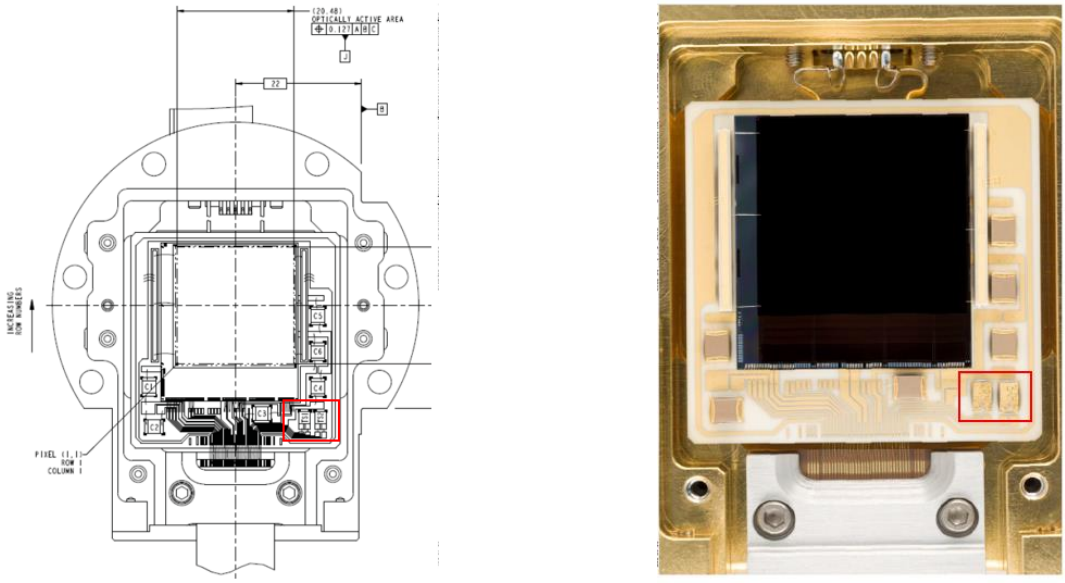
Param.ID	Param Name	Unit	Calibration
NSS11040	HRIC Temperature FPA1	K	CSSP0010TM
NSS11041	HRIC Temperature FPA2	K	CSSP0011TM
NSS11042	HRIC Temperature PE	K	CSSP0012TM
NSS11043	HRIC Temp Tele1	K	CSSP0013TM
NSS11044	HRIC Temp Tele2	K	CSSP0014TM
NSS11050	HRIC PE 3.3V Measured	V	CSSP0015TM
NSS11051	HRIC TEC Current	A	CSSP0016TM
NSS11051	HRIC TEC Current	A	CSSP0016TM

Table 1: Main HRIC temperature sensors of the FPA, PE, the backside of the detector and the HRIC OB as reported in [RD.2]. All HKs are part of the Packet YSS40001.

Table 2 and Figure 1 report the position of the above listed sensors.

Unit	Thermistor ID	T (°C)	Location	Parameter
HRIC Optics 1	PT1000	-40/65	TIRD filter	HRIC_Temp_Tele_1
HRIC Optics 2	PT1000	-40/65	FPA package	HRIC_Temp_Tele_2
HRIC SCA 1	DT470	-40/65	FPA SCA	HRIC_Temp_FPA_1
HRIC SCA 2	DT470	-40/65	FPA SCA	HRIC_Temp_FPA_2
HRIC PE	PT1000	-40/65	PE hot spot	HRIC_Temp_PE

Table 2: HRIC temperature sensor position.



(a) (b)

Figure 1: HRIC-FPA temperature sensors [RD.3] next to the FPA, called SCA1 (on the left) and SCA2 (on the right) and associated respectively to the NSS11040 and NSS11041.

2.2 BepiColombo CF Sensors

HRIC Cold Finger (CF) temperature sensor is placed as indicated in Figure 2.

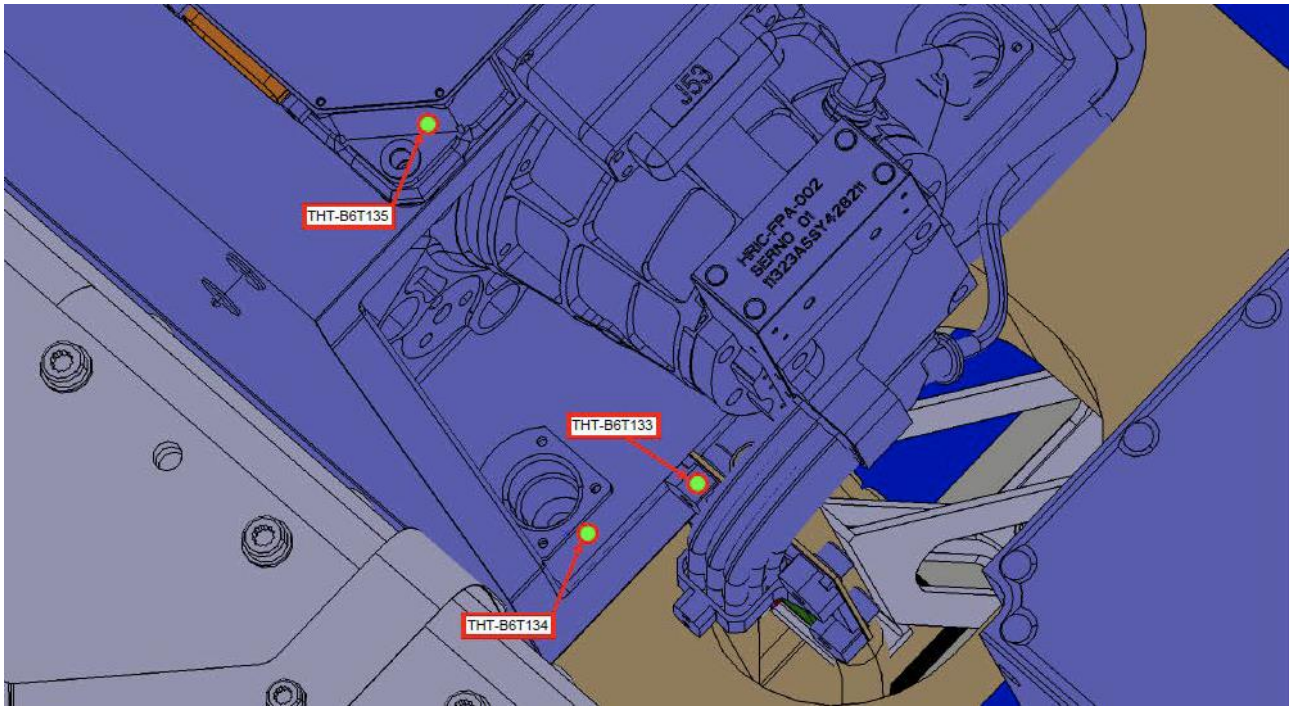


Figure 2: The MPO-TEMP-SIMBIO-HRIC-CF (NRUD2079, here THT-B6T133) as reported in [RD.2].

During the execution of the ICO#02 tests its value was monitored with a 1-minute frequency; the obtained trend is reported in Figure 3.

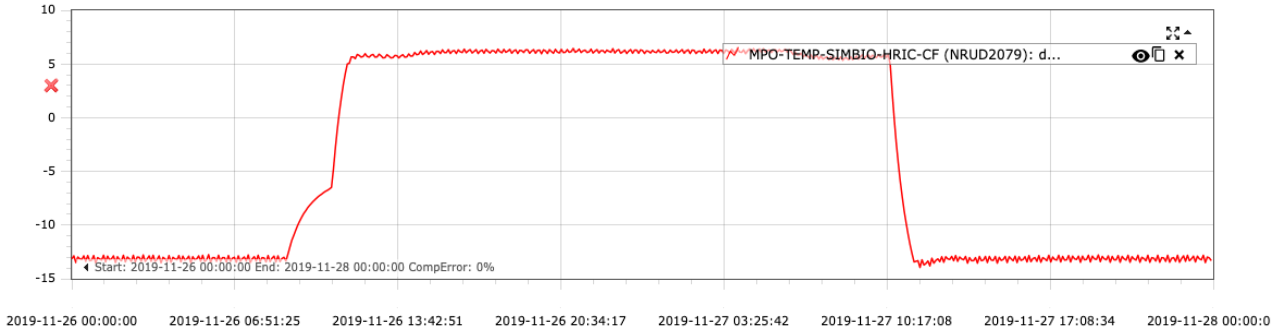


Figure 3: HRIC Cold Finger temperature evolution during the ICO#02 tests. Temperature is reported in °C.

The HRIC CF 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) (see [RD.4]) 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.5].

3 HRIC-ICO2 Tests

As reported in [RD.4], the ICO#02 SIMBIO-SYS tests had the scope to verify the health status of the instrument at channel and system level after 1 year after launch. A functional and a performance test are planned to monitor the evolution of some key instrument parameters (see Table 3 for more details).

Test name	Objective	UTC first Image
Functional	PE, TEC, memory and acquisition capability	2019-11-27T04:35:50.103812
Performance	DC Verification	2019-11-27T05:35:00.102863

Table 3: Table of the Tests as reported in [RD.4].

During Functional Tests, differently from the ICO#01 tests (see [RD.6] and [RD.7]) the switch on of the Channels was performed after two main steps:

1. The usage of S/C Thermal Adjustment settings procedures (i.e., usage of SS-FCP-015 – see [RD.8]) with updated thresholds
2. the upload of the nominal TEC activation parameters (see [RD.3]) to put the instrument in the correct thermal environment (i.e., the one for which the TEC parameters were defined).

With these two steps we avoided the anomalies of the TEC current (reported as Issue 1 of [RD.5]) in the case of a difference in temperature greater than 10K between CF and TEC SetPoint.

The summary of the parameters used for HRIC in all NECP, ICO1 and ICO2 phases is reported in following table.

Name	Data-kind	Meaning	NECP	ICO1	ICO2
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 4: HRIC TEC Soft-Start parameters.

3.1 HRIC Functional Test

3.1.1 Test description

During ICO#02 the HRIC functionality has been verified by means of dedicated Functional Test procedures with the aim of verifying the PE, TEC and detector activation, the memory/registers status, and the science acquisition capability.

In particular, the HRIC functionality will be tested by means of the following TCs sequence:

- PE switch-on
- Detector switch-on
- TEC switch-on (optimized TEC parameters)
- Test of the reading and writing of a specific memory address
- The following science acquisitions (see Table 6**:** for details):
  - 1200 FPAN acquisitions with null integration and RT=1s,
  - 1200 FPAN acquisitions with long integration and RT=1s,
  - 100 FPAN acquisitions with RT=1s,
- TEC switch-off
- Detector switch-off
- PE switch-off

3.1.2 Commanding

Once the ME was switched on all the functional tests were commanded by a Payload Operation Request (POR) whose details and updates can be found in [RD.4]. All planned science TCs were nominally executed. The summary of the TCs and the consequent images dataset generated is reported in Table 5 and Table 6.

Timeline	Relative	TC	Scope	Notes
0:00:00	00:00:00	ZSS00329	Set HK to 1 s	
0:00:05	00:00:05	ZSS17110	Send SIMB HRIC Detector On/Off	Switch On HRIC PE (Channel) (to restore after
0:00:10	00:00:05	ZSS17103	Send SIMB HRIC Thermal Control On/Off	ASW update with correct TEC initialization). TEC set point: 268K
0:15:10	00:15:00	ZSS17106	Send SIMB HRIC Read Addr	Read memory present status
0:15:25	00:00:15	ZSS17106	Send SIMB HRIC Read Addr	
0:15:30	00:00:05	ZSS17107	Send SIMB HRIC Write Addr	Test Writing Memory
0:15:35	00:00:05	ZSS17104	Send SIMB HRIC Confirm Command	
0:15:40	00:00:05	ZSS17107	Send SIMB HRIC Write Addr	Test STC science test pattern

0:15:45	00:00:05	ZSS17104	Send SIMB HRIC Confirm Command	
0:15:50	00:00:05	ZSS17101	Start HRIC Science (Short Int FPAN)	Science
0:35:50	00:20:00	ZSS17109	Stop HRIC Science	
0:35:55	00:00:05	ZSS171B1	Start HRIC Science (Long Int FPAN)	
0:55:55	00:20:00	ZSS17109	Stop HRIC Science	
0:56:00	00:00:05	ZSS17102	Start HRIC Science (Short Int FPAN)	End test.
0:58:00	00:01:55	ZSS00329	Set HK to 10 s	

Table 5: Timeline of the Functional Tests with the references to the commanded ZSS.

The resulting database derived by EGSE telemetry to raw pipeline (see [RD.9]) is reported in Table 6. All science TCs were in continuous mode.

TC#	First_Acq [UTC]	Duration [s]	ACQ#	IT [ms]	RT [s]	Win
1	2019-11-27T04:35:50.103812	1200	1200	0.03840	1	FPAN
2	2019-11-27T04:55:55.102595	1200	1200	314.88	1	FPAN
3	2019-11-27T05:16:00.102294	100	100	0.03840	1	FPAN

Table 6: Resulting database of the ICO#02 Functional Test. All TCs were commanded with the CBD = 128x128 and, nominally, the IBR was set to 32.

3.1.3 HKs interpretation and discussion

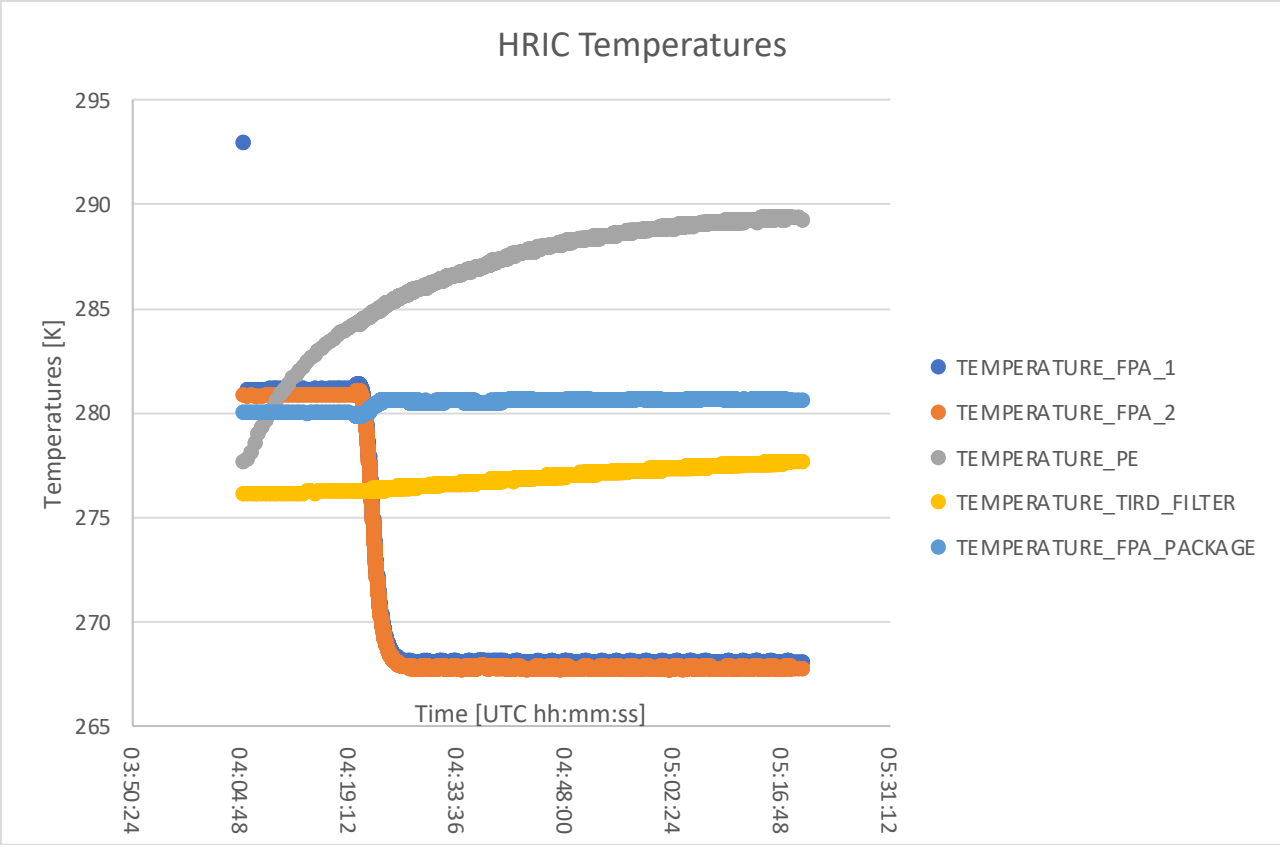


Figure 4: HRIC temperature functional tests.

During the Functional test the temperatures trend for the HRIC channel were nominal. The After the switch on of the channel and the activation of the TEC the 2 FPA temperatures decrease as expected with a DT/s within the limits. The PE temperatures increases as expected due to the power consumption (Figure 4).

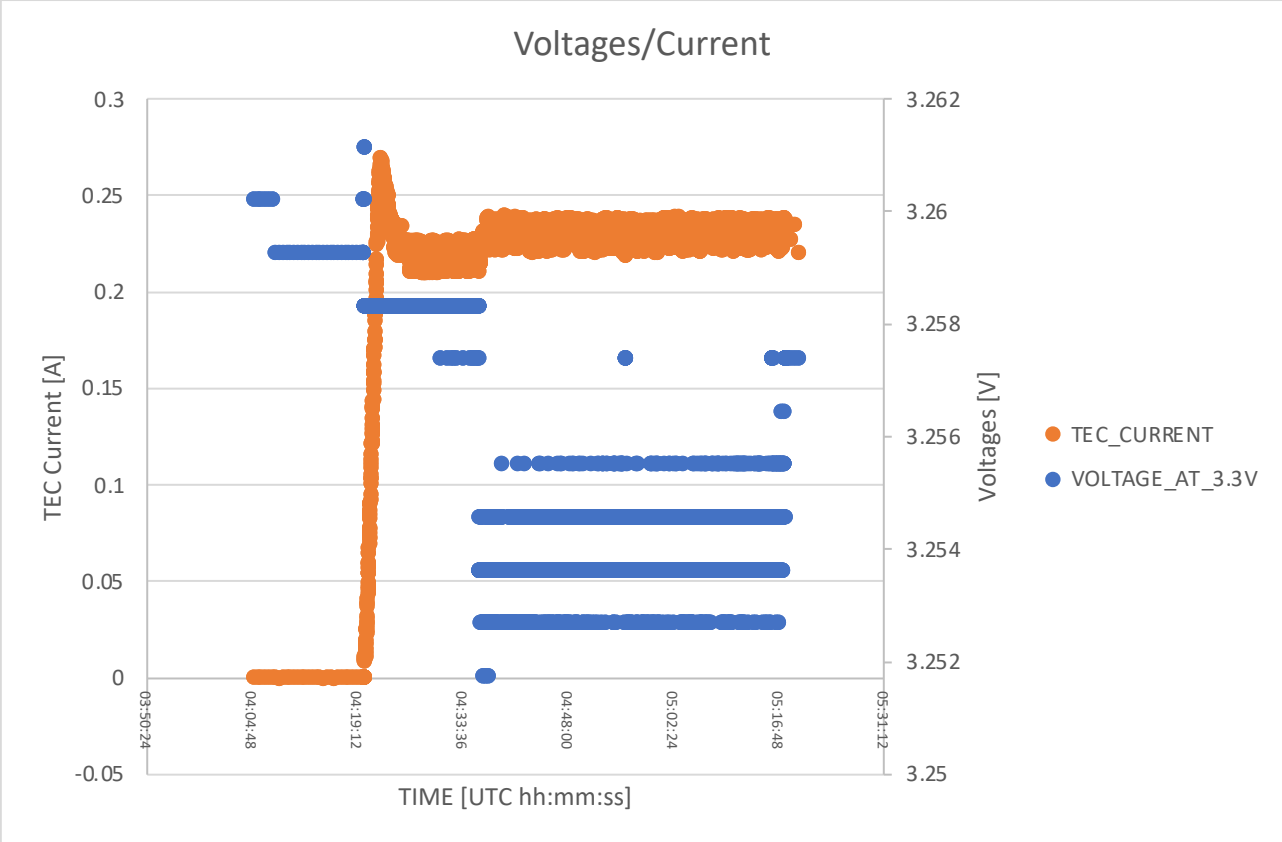


Figure 5: HRIC TEC current (left y-axis) and PE voltages (right y-axis).

During this ICO the interface temperatures were set at the nominal values, imposing the nominal ranges for the hot side of the TEC. With these values for the interfaces temperatures and using the nominal values for the PID TEC controller the behaviour of TEC current and detector temperatures were nominal (Figure 5).

3.1.4 Images Analysis

The analysis of the frames acquired during the functional test show that the signals read from the detector are compatible with the values characterized during the on-ground calibrations. Average Signal Level and Standard deviation measured on the frames are compatibles with the same parameters acquired in similar conditions during the calibration campaign. During the ICO#01 tests (see [RD.7]) but also in NECP (see [RD.10]) were acquired 100 images at short integration time ad 100 images at long integration time. The analysis of the acquired images shows a probable trend vs the number of acquisitions in the average of the acquired frames. In ICO#02 we increased the number of acquired frames to check if this trend is confirmed. The repetition time in both cases was of 1 second.

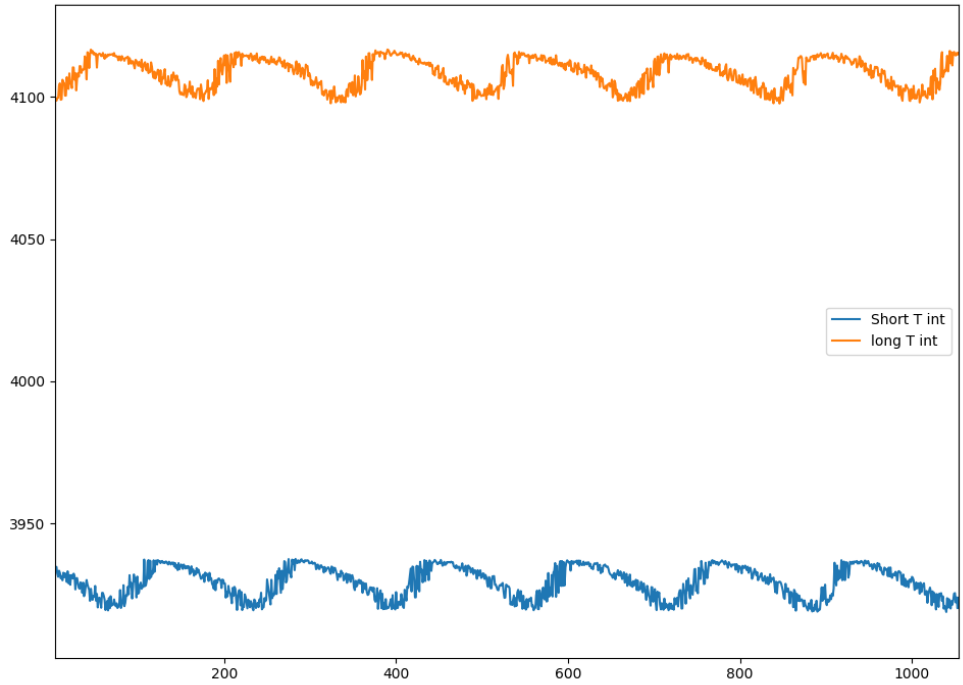


Figure 6: Frame averages vs the number of acquisitions for the short and long integration time. Both the sequence of acquisitions shows a pseudo sinusoidal trend with a period of about 200 s.

For both the measurements at short integration times and long integrations times the average values show a periodic trend with a period of about 200 seconds and a peak valley value of about 20 DN. To check the possible correlation with other functional parameter recorded in HK, in the following are reported the plot of the frame averages versus all the HK parameter reported in the Images header.

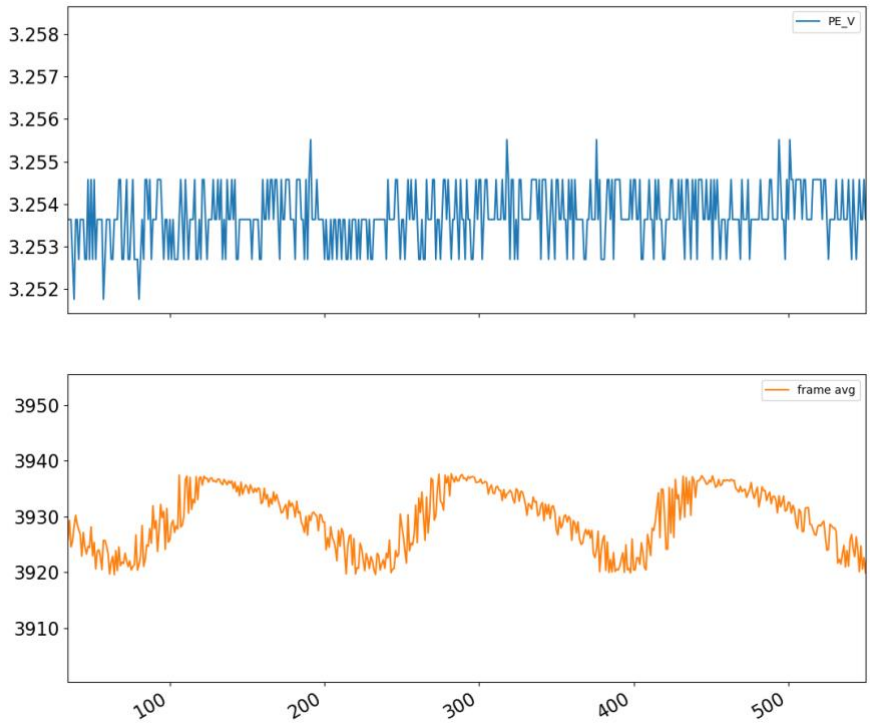


Figure 7: Proximity electronic voltage (above) and Frame averages (below) vs the number of acquisitions.

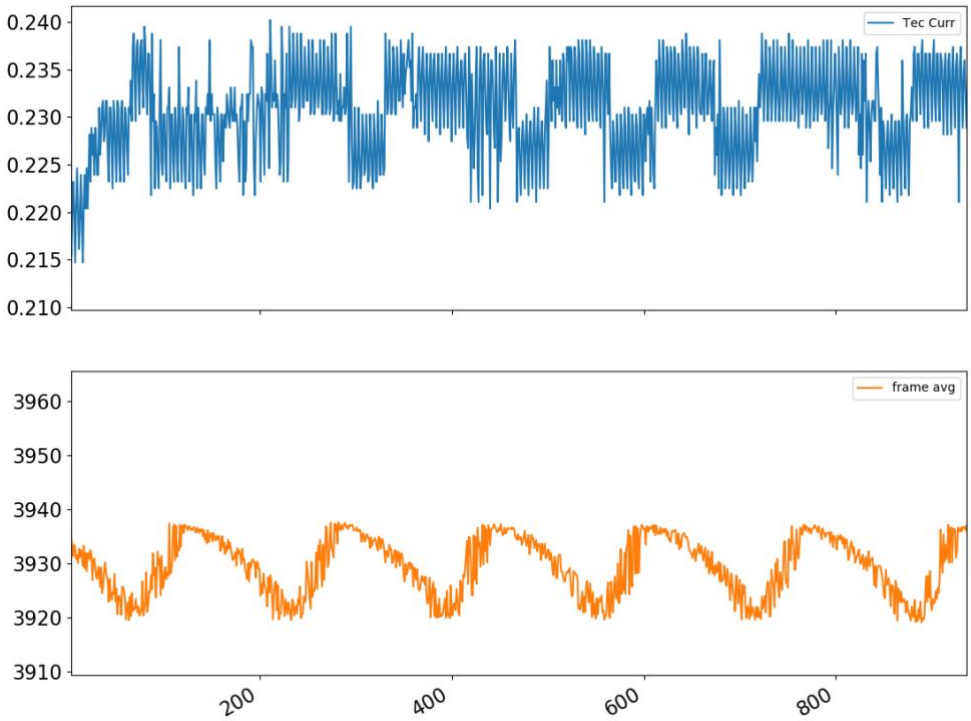


Figure 8: TEC current (above) and Frame averages (below) vs the number of acquisitions.

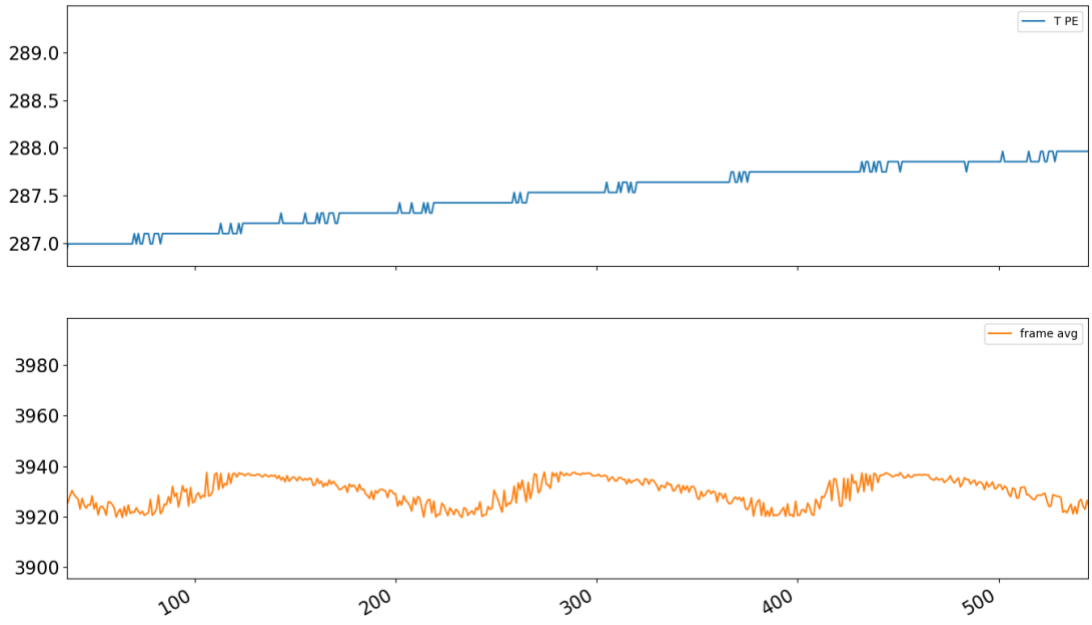


Figure 9: PE temperature (above) and Frames average (below) vs the number of acquisitions.

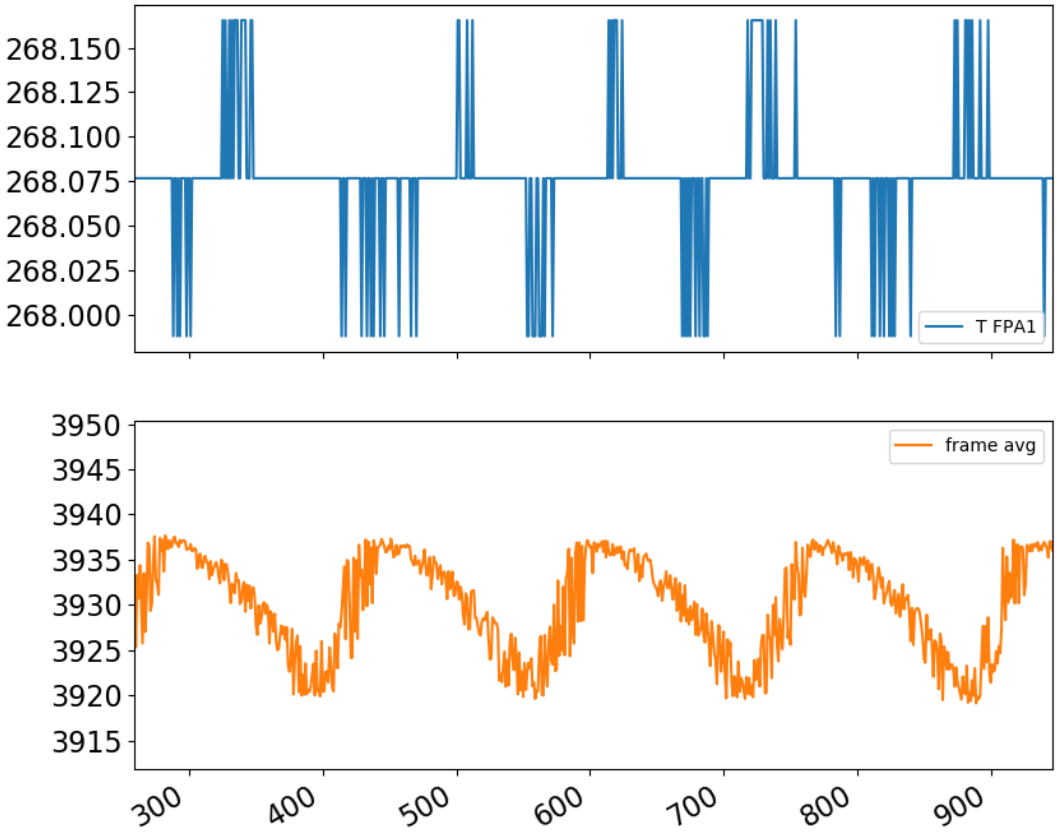


Figure 10: Temperature FPA1 (above) and Frames average (below) vs the number of acquisitions.

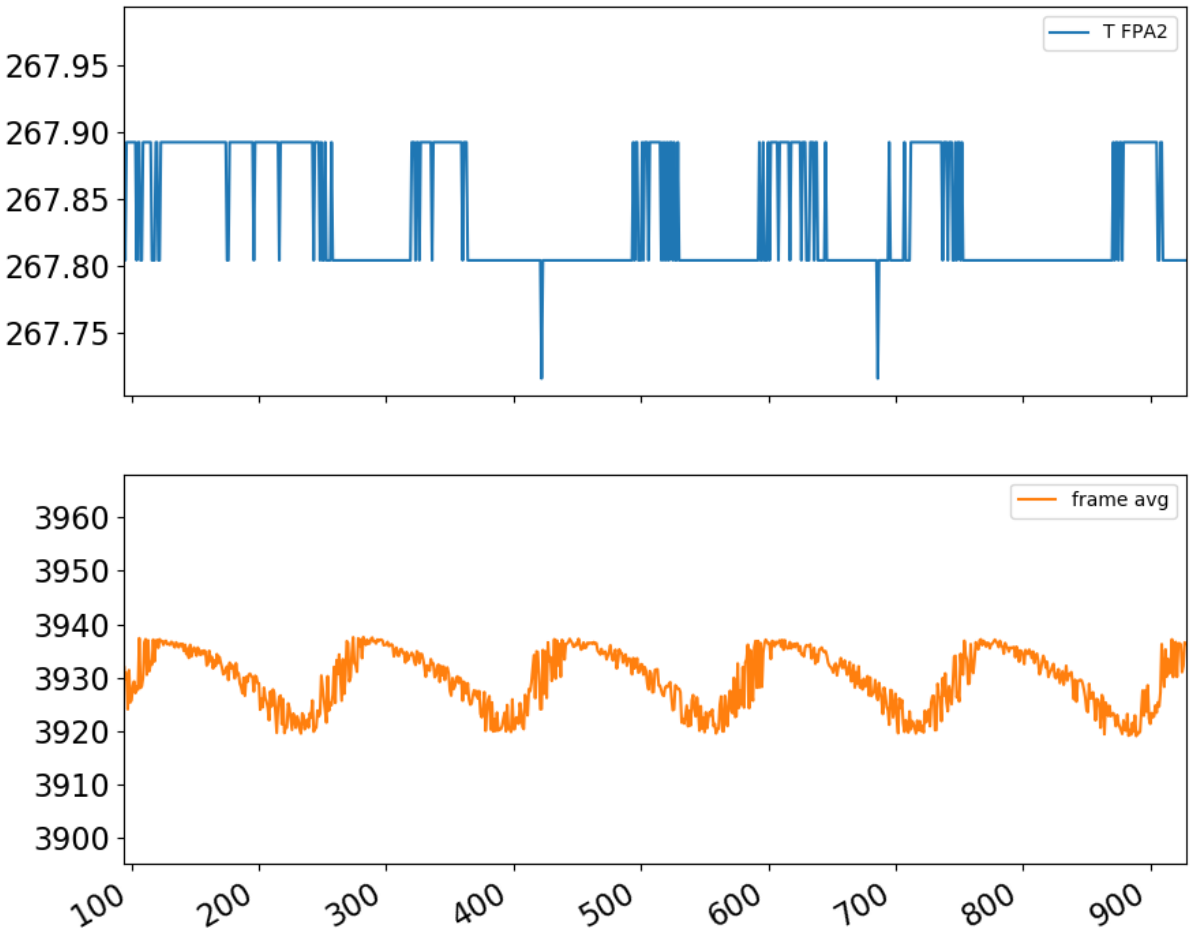


Figure 11: Temperature FPA2 (above) and Frames average (below) vs the number of acquisitions.

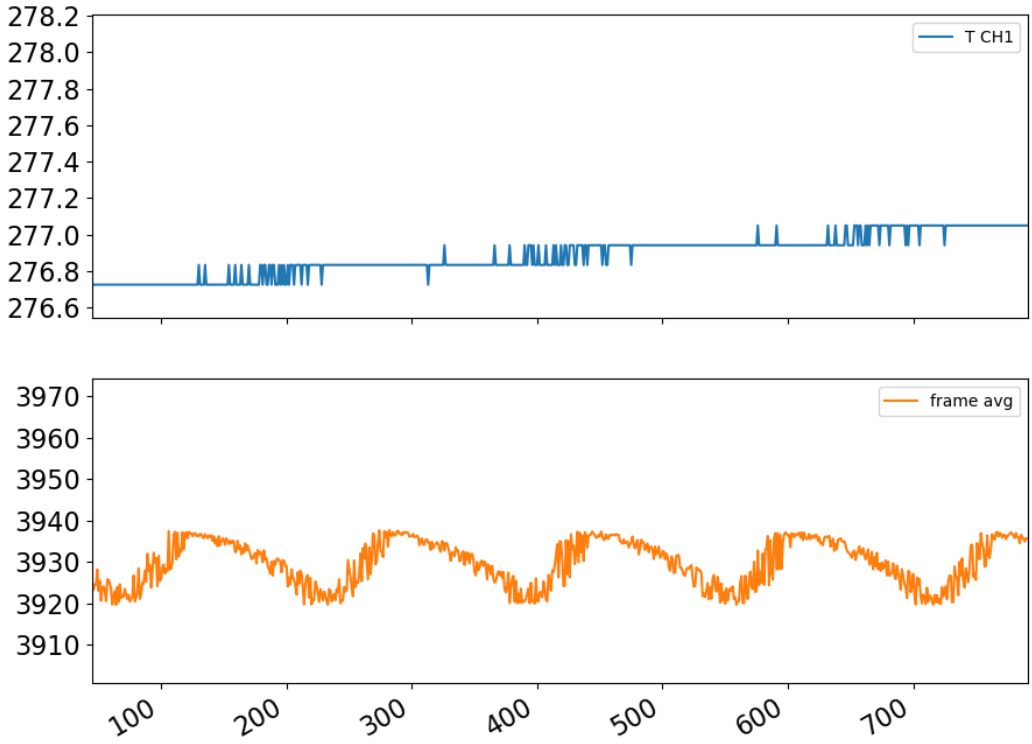


Figure 12: Temperature CH1 (above) and Frames average (below) vs the number of acquisitions.

The analysis of the plots and trends does not show any identifiable correlation with the detector behaviour.

3.2 HRIC Performance Test

3.2.1 Test description

The HRIC performance test in ICO#02 was related in the monitoring of the Dark Current (DC) with respect to the nominal integration times for both the Panchromatic and the Broad Band filters.

3.2.2 Commanding

The test was executed by means of a dedicated POR (see [RD.4] for details) whose science TCs were nominally executed. The summary of the TCs and the consequent images dataset generated is reported in Table 7 and Table 8.

Timeline	FOP Names	TC#	Min IT [ms]	Max It [ms]	RT [s]
00:00:00	ASSF101	13	0	96	1
00:02:10	ASSF201	4	480	5760	Between 2 and 8
00:04:50	ASSF102	13	0	96	1
00:09:10	ASSF201	4	480	5760	Between 2 and 8

Table 7: Timeline of the 4 sets of Science TCs of the PERFORMANCE TEST with the references to the commanded FOPs (see [RD.8] for more details).

The resulting database derived by EGSE telemetry to raw pipeline (see [RD.9]) is reported in Table 8.

TC	First_Acq [UTC]	Duration [s]	IT [ms]	RT [s]	WIN
1	2019-11-27T05:35:00.102863	9.999909043	0.0004	0.999993232	FPAN
2	2019-11-27T05:35:10.102772	10.00001502	0.0096	0.999994887	FPAN
3	2019-11-27T05:35:20.102787	9.999922991	0.0192	0.999984662	FPAN
4	2019-11-27T05:35:30.102710	10.00006104	0.048	1.000001775	FPAN
5	2019-11-27T05:35:40.102771	9.999862909	0.48	0.999986437	FPAN
6	2019-11-27T05:35:50.102634	10.00003004	0.96	0.999984781	FPAN
7	2019-11-27T05:36:00.102664	9.999833107	1.92	0.99999502	FPAN
8	2019-11-27T05:36:10.102497	10.00003004	2.88	1.000005007	FPAN
9	2019-11-27T05:36:20.102527	9.999953985	3.84	1.000001669	FPAN
10	2019-11-27T05:36:30.102481	10	4.8	0.999996556	FPAN
11	2019-11-27T05:36:40.102481	9.999923944	9.6	0.999988106	FPAN
12	2019-11-27T05:36:50.102405	9.999862075	48	0.999993112	FPAN
13	2019-11-27T05:37:00.102267	10.00012195	96	1.00001355	FPAN
14	2019-11-27T05:37:10.102389	19.99987805	480	1.999979668	FPAN
15	2019-11-27T05:37:30.102267	19.99995399	960	1.999986437	FPAN
16	2019-11-27T05:37:50.102221	39.999771	2880	3.999972781	FPAN
17	2019-11-27T05:38:30.101992	79.99975502	5760	7.999962555	FPAN
18	2019-11-27T05:39:50.101747	19.99996901	0.0004	1.999979668	BB
19	2019-11-27T05:40:10.101716	19.99992394	0.0096	1.999981324	BB
20	2019-11-27T05:40:30.101640	19.99986196	0.0192	1.999984662	BB
21	2019-11-27T05:40:50.101502	19.99996901	0.048	1.9999949	BB
22	2019-11-27T05:41:10.101471	19.99987805	0.48	1.999979668	BB
23	2019-11-27T05:41:30.101349	19.99990797	0.96	1.999994887	BB
24	2019-11-27T05:41:50.101257	20	1.92	1.999991563	BB

25	2019-11-27T05:42:10.101257	19.99980199	2.88	1.99998645	BB
26	2019-11-27T05:42:30.101059	19.99998403	3.84	1.999991443	BB
27	2019-11-27T05:42:50.101043	19.99987805	4.8	1.999983112	BB
28	2019-11-27T05:43:10.100921	19.99993896	9.6	1.999998331	BB
29	2019-11-27T05:43:30.100860	19.99993813	48	1.999993232	BB
30	2019-11-27T05:43:50.100798	19.99983299	96	1.999984781	BB
31	2019-11-27T05:44:10.100631	19.99996901	480	1.999999894	BB
32	2019-11-27T05:44:30.100600	39.999771	960	3.999981337	BB
33	2019-11-27T05:45:10.100371	59.99986196	2880	5.999982887	BB
34	2019-11-27T05:46:10.100233	71.99964797	5760	7.999960886	BB

Table 8: Database derived by EGSE. All TCs commanded 10 acquisitions with IBR=0 and CBD=128x128.

3.2.3 HKs interpretation and discussion

The analysis of the HK collected during performance test for HRIC shows a nominal behaviour both for temperatures (Figure 13) and Voltage and TEC current (Figure 14).

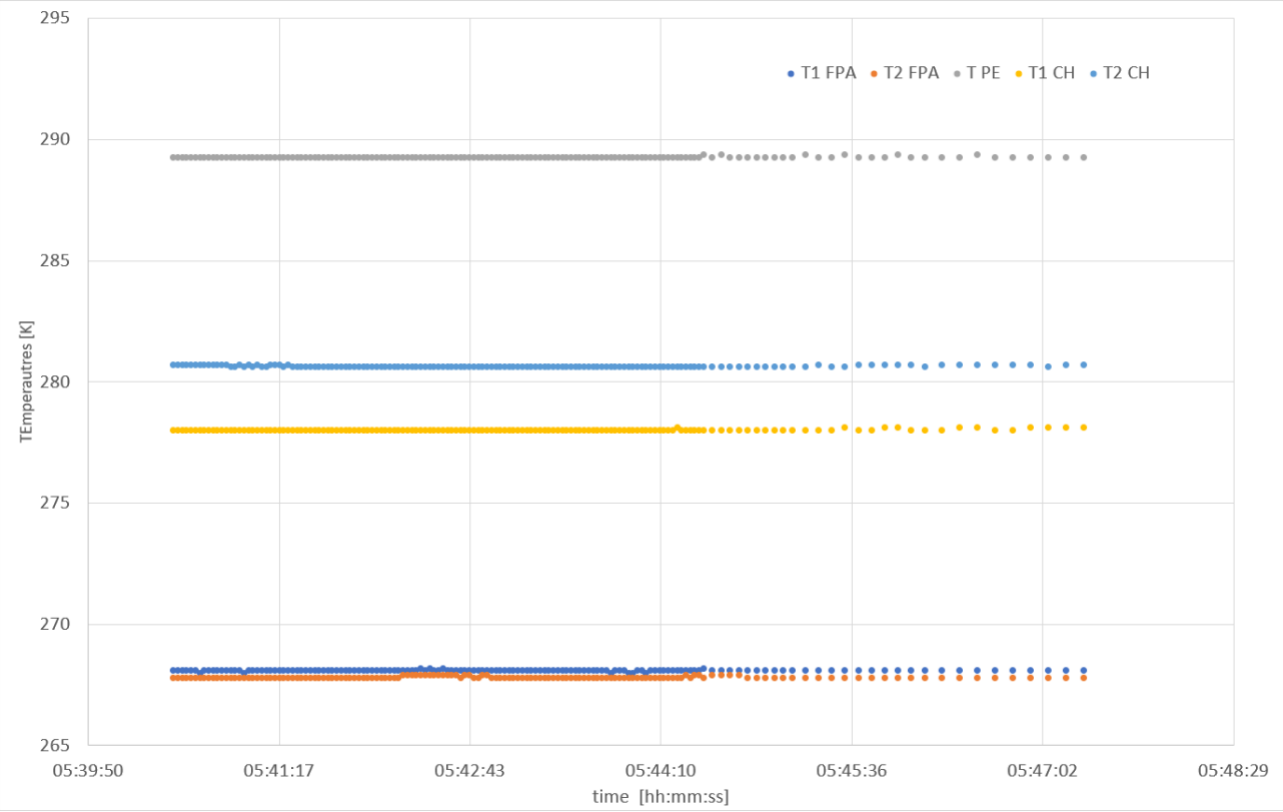


Figure 13: Temperatures of HRIC during performance tests.

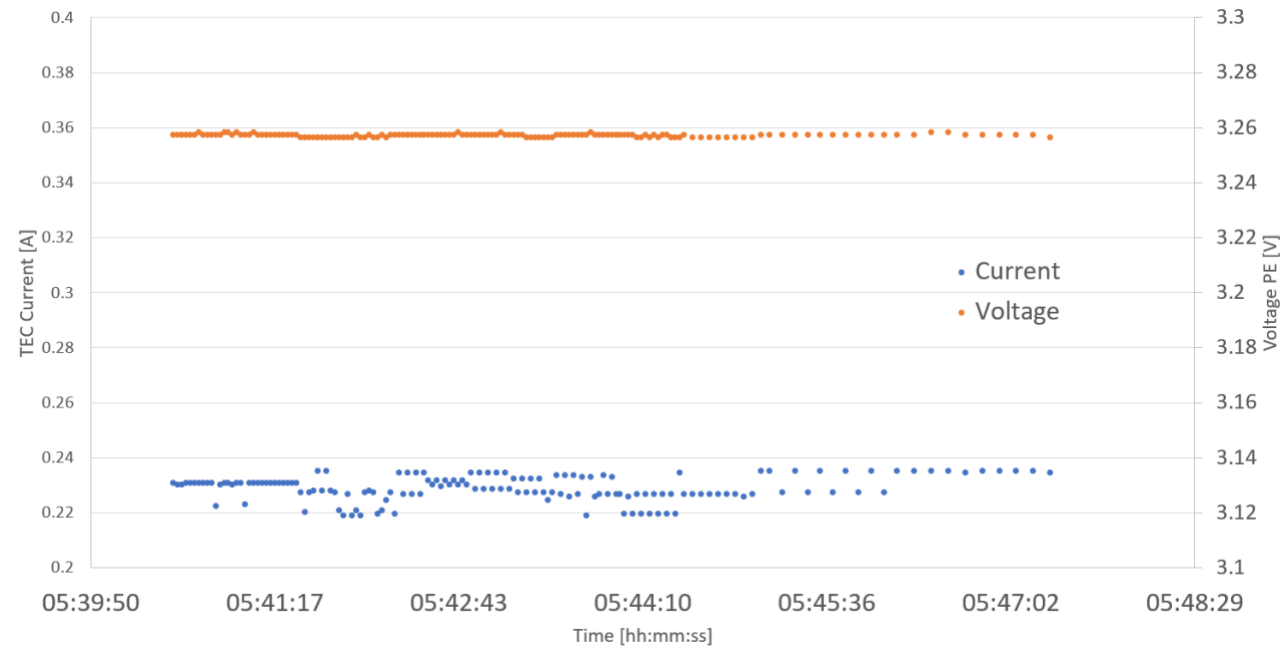


Figure 14: HRIC TEC current (left y-axis) and PE Voltage (right y-axis).

3.2.4 Images analysis

The images were analysed considering the average trend of the DC for the frame. The results are reported in Figure 15.

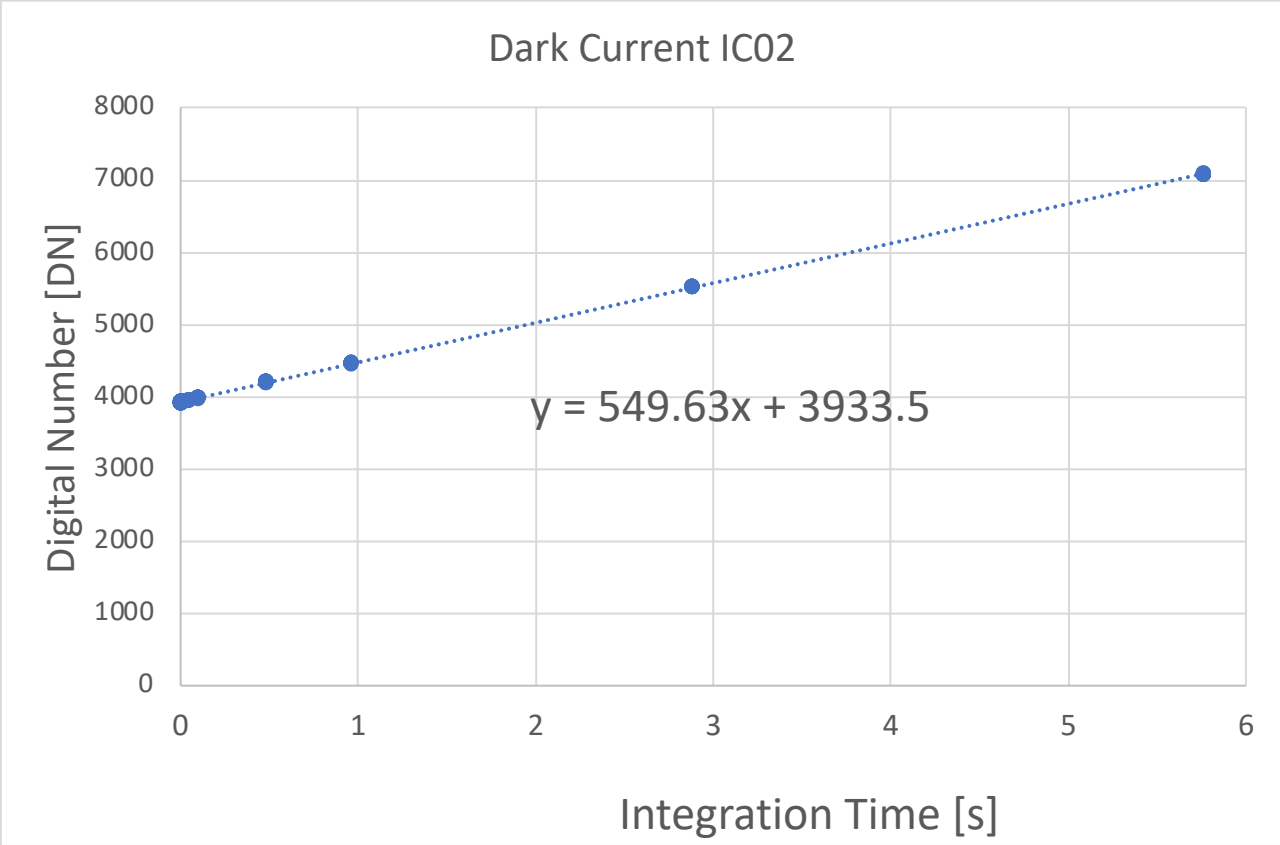


Figure 15: HRIC DC current trend for the FPA during the performance's tests.

A comparison with the values obtained in ICO#01 are reported in Table 9.

ICO	Slope of DC Trend	Intercept of DC trend	Correlation R^2
1	544.36	3929	0.9999
2	549.63	3933	0.9999

Table 9: Dark Current slope and intercept comparison with respect to previous ICOs.