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IXPE ITALIAN CONTRIBUTION

Instrument Delta E2E Test Report

AT-003

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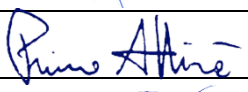
Primo Attinà	Italian PM	
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1. TABLE OF ANNEX INTRODUCTION

1.1 Scope

This document describes the test set-up, the methods, the procedures and the results of the Delta Instrument End to End Test. The aim of this test is to verify the functionality and the performance of the Instrument after the rework of the DSU PFM in the disposition of the Non Conformance Report I2C-OHBI-ISE-NCR-076 (see [AD 17]). We test the Instrument in a representative configuration: DSU PFM with DU FM1, DU FM3 and DU FM4.

We used the electrical ground support equipment (EGSE) and the TSC interface to send sequences of telecommand to configure and perform functional tests and to retrieve the telemetry produced by the Instrument. The EGSE collects both data fluxes: scientific and ancillary (Housekeeping). All the functionalities have been validated in flight-like conditions of data stream and activities. For this test we followed the procedures contained in [AD 16].

1.2 Applicability

This document forms, with its applicable documents, the binding document for the Italian Team in charge of the development and implementation of Instrument models needed for the realization of the IXPE mission.

This document is applicable in the framework of phase C/D activities.

1.3 Document Roadmap

Chapter	Content
1	Introduction to the document & explanation of its contents and scope.
2	List of the documentation linked to the procedure
3	Description of the experimental set-up
4	Participants
5	Constraints
6	Test success criteria
7	Preliminary procedures
8	Test Results

9	Anomalies
10	Conclusions
11	List of acronyms

2. LINKED DOCUMENTS

2.1 Applicable Documents

[AD 1]	I2C-INFN-ISE-TEC-004	DU User Manual, i02p03, 28 Oct 2019
[AD 2]	I2C-OHBI-IOP-TEC-004	PFM DSU User Manual, Issue: 01, 9 Dec 2019
[AD 3]	I2C-OHBI-ISE-TEC-007	IXPE EGSE USER MANUAL, Issue: 2, Date: 10 May 2019
[AD 4]	I2C-IAPS-ISE-SPC-004	Instrument Test Specifications, i04p01, 2 May 2019
[AD 5]	I2C-IAPS-ISE-REP-002	Instrument Design Report, i03p00, 30 Apr 2019
[AD 6]	I2C-OHBI-ISE-REP-008	DSU Design Report, Issue:03, 11/06/2018
[AD 7]	I2C-OHBI-ISE-REP-009	IXPE DSU/DU EGSE Design Report, Issue:4, 01/03/2019
[AD 8]	I2C-OHBI-ISE-TEC-009	DSU FPGA DESIGN DESCRIPTION, Issue: 01, 09 Sep 2019
[AD 9]	I2C-OHBI-ISE-ICD-002	Electrical Interface Control Document (EICD), issue 5, 19 Aug 2019
[AD 10]	I2C-IAPS-IPA-PLN-003	Instrument PA Plan, i04p01, 30 Mar 2018
[AD 11]	I2C-IAPS-ISE-SPC-001	Instrument Technical Specification, i07p00, 30 Apr 2019
[AD 12]	I2C-OHBI-ISE-ICD-003	IXPE DSU-DU EGSE Interface Control Document, i04p00, 11 Mar 2019
[AD 13]	I2C-OHBI-ISW-ICD-002	IXPE Software Telemetry-Telecommand Definitions, Issue: 4, 11 Feb 2020
[AD 14]	I2C-IAPS-ISE-PRC-019	Instrument E2E Test Procedures, issue 2
[AD 15]	I2C-IAPS-ISE-REP-010	Instrument End to End Test Report, i01p00, 27 Feb 2020
[AD 16]	I2C-IAPS-ISE-PRC-021	Instrument Functional Test and Comprehensive Performance Test, i01p00
[AD 17]	I2C-OHBI-ISE-NCR-076	PFM DSU - DUs switch on failure @hot plateau during TVTC test

2.2 Reference Documents

[RD 1]	I2C-IAPS-ISE-REP-012	Instrument Calibration Equipment ICE, i01p00,
[RD 2]	I2C-OHBI-AIT-REP-012	DU FCW FM2 INTEGRATION AND TEST REPORT, Issue 1, 6 Aug 2019
[RD 3]	I2C-OHBI-AIT-REP-014	DU FCW FM4 INTEGRATION AND TEST REPORT, Issue 1, 8 Aug 2019
[RD 4]	I2C-OHBI-AIT-REP-011	DU FCW FM1 INTEGRATION AND TEST REPORT, Issue 1, 31 May 2019
[RD 5]	I2C-OHBI-AIT-REP-013	DU FCW FM3 INTEGRATION AND TEST REPORT, Issue 1, 02 Sep 2019
[RD 6]	I2C-IAPS-ISE-VCD-001	Instrument Verification Control Document, i02p00
[RD 7]	I2C-IAPS-ISE-TEC-004	Instrument Timing Management, Issue 1

2.3 Standards/Handbooks

[SD 1] ECSS-E-ST-10-03C Space Engineering - Testing

3. DESCRIPTION OF THE EXPERIMENTAL SET-UP

The activities are conducted at IAPS/INAF facility inside an ISO 7 cleanroom, the setup is composed by:

- Electrical Ground Support Equipment
- Assembly and calibration equipment (ACE)
- Test Harness
- X-Ray tubes
- Metrological tools

3.1 The Electrical Ground Support Equipment (EGSE)

In this scenario the IXPE Instrument EGSE is used to test the whole Instrument, composed of the DSU PFM and three DU FMs: DU FM1, DU FM3 and DU FM4. EGSE provides the missing interfaces normally provided by the Spacecraft (Figure 3-1).

As such the EGSE for DSU testing performs:

- the simulation of the missing I/F normally provided by the S/C:
  - TM/TC packet management
  - Scientific data acquisition and verification with a dedicated tool that can validate the received science data
  - Pulse-per-second generation
  - Power supply

The main EGSE elements involved in this test context are identified in the following image:

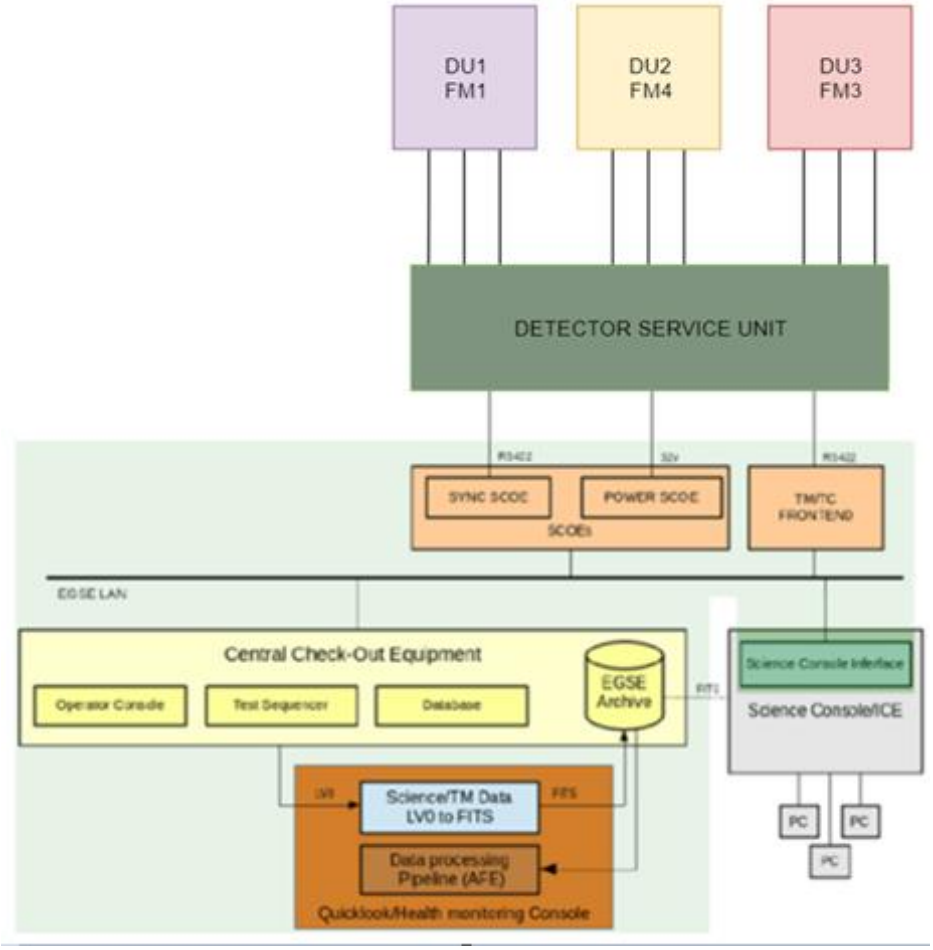

Figure 3-1 DSU EGSE logical breakdown

- The Central Check-Out Equipment (CCOE) is the core of the DSU EGSE, from which all testing is prepared, controlled (Test Sequencer) and results archived (EGSE Archive). It presents the main man machine interface (Operator console), and single point of control, for the supporting of all aspects of the test of the DSU.
- The TM/TC Data Frontend Equipment (TM/TC FE) handles the Telemetry and Telecommand communication between the DSU under test and the missing UUT TM/TC interfaces.
- The Specific Check-Out Equipment (SCOEs) provides the DSU under test with the missing interfaces with UUT, such as synchronization signal and power for the unit itself.
- The Quicklook/Health monitoring console contains a Data Processing Pipeline (AFE) and Science/TM data converter that produces LV0a FITS file from the acquired data of the UUT.
- The Science Console I/F allows the basic control of the DU testing. The EGSE archived data are also available to the Science Console, not part of this contract, for further analysis.

3.2 The AIV/T Calibration Equipment (ACE)

The Assembly and Calibration Equipment is the facility assembled for the ground activity of AIV-T at instrument level. The facility is equipped with X-Ray sources needed during end to end tests activities for the evaluation of scientific performance of entire instrument. The facility is located at IAPS/INAF in a ISO 7 cleanroom.

3.3 Detector Service Unit

The equipment under test is the IXPE Detectors Service Unit Protoflight model (DSU PFM). The Figure 3-2 shows the external DSU connectors configuration positioned on front (S/C side) and back (DUs side) panels; the position of the unit bonding stud is also shown.

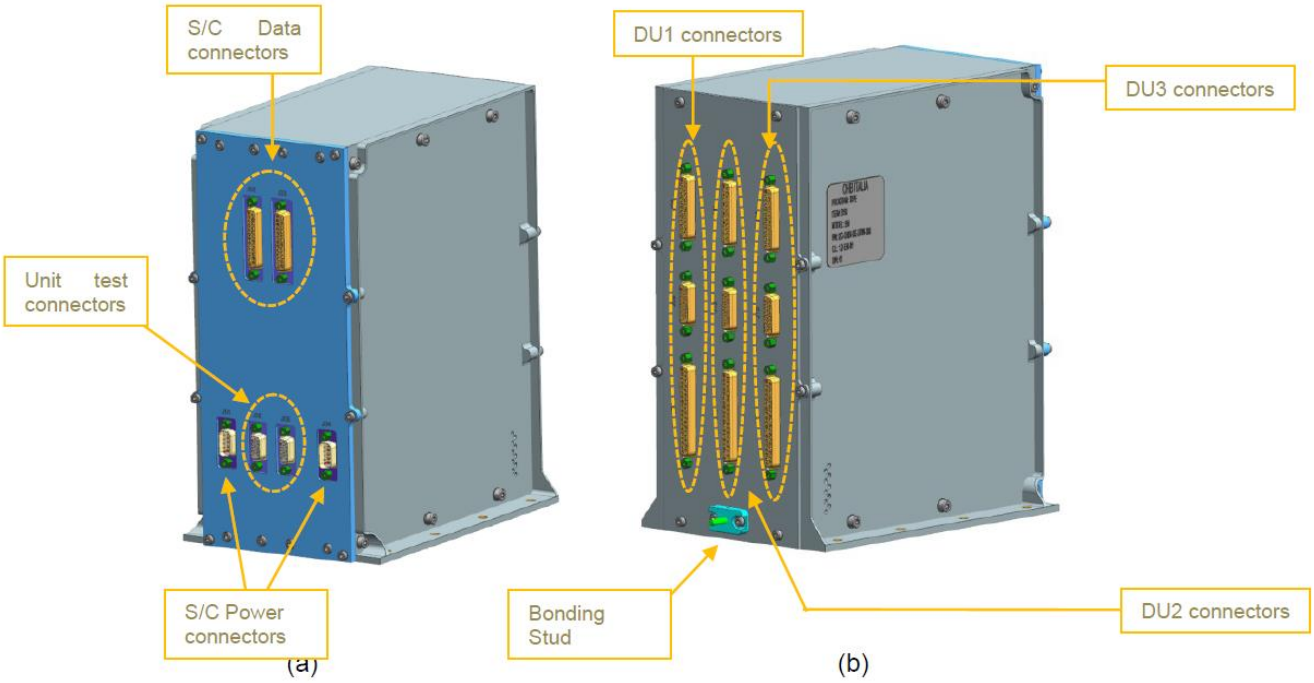

Figure 3-2 DSU PFM mechanical box: front (a) and rear (b) view

3.4 Detector Unit

The Detector Unit (DU) is the unit containing the polarization sensitive sensor (Gas Pixel Detector, GPD) and all the electric boards, thermal and mechanical items required by the GPD. The flight model of the Detector Unit, hereafter DU FM, is

connected to the DSU PFM using the three interfaces: Power, Data and FCW. In Figure 3-3 is reported the rendering of the rear view of DU with the 4 interfaces in evidence.

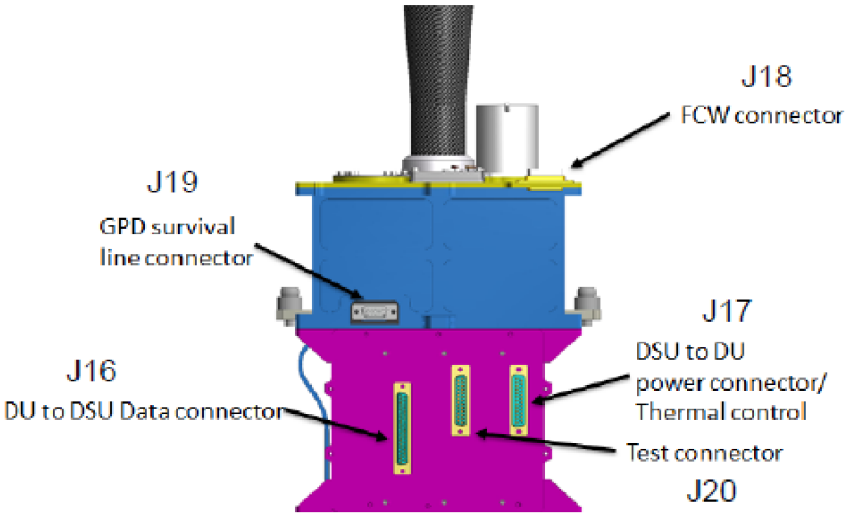

Figure 3-3 DU FM mechanical box: rear view

3.5 Heritage

INAF personnel started training with the EGSE since the beginning of 2019, when the first EGSE was delivered to INFN-Pisa for the integration of the DUs. The training followed during the dry run of ICE before starting the calibration of the DU FMs. In this test we followed the procedures included in [AD 16].

3.6 Electrical Interfaces

The electrical interfaces are described in User Manual ([AD 2] and [AD 3]) and ICD ([AD 10]).

The DSU interfaces can be divided into two subgroups:

- External I/Fs
- Internal I/Fs

The DSU external interfaces with S/C are the following:

- A. Nominal Power Supply
  - Power line: 32V + RTN (From IXPE S/C to DSU)
- B. Redundant Power Supply
  - Power line: 32V + RTN (From IXPE S/C to DSU)

- C. Nominal I/O digital data interface
  - CMDs & TOD (From IXPE S/C to DSU)
  - PPS (From IXPE S/C to DSU)
  - H&S (From DSU to IXPE S/C)
  - Science Data (From DSU to IXPE S/C)
- D. Redundant I/O digital data interface
  - CMDs & TOD (From IXPE S/C to DSU)
  - PPS (From IXPE S/C to DSU)
  - H&S (From DSU to IXPE S/C)
  - Science Data, Clock and Enable (From DSU to IXPE S/C)

For each of the above interfaces (A, B, C, D) the DSU provides a dedicated connector (see Figure 3-3).

The DSU internal interfaces are the ones between the DSU and the DU, namely:

- DU Data link
  - CCI Command Control Interface
  - SDI Serial Data Interface
  - RESET and auxiliary
  - PPS Pulse per Second
  - 1MHz clock
- DU Power
  - Power supply rails (+5V and +25V)
  - Heater supply rails
  - Peltier supply rails
  - Temperature sensors (PT1000)
- DU Filter & Calibration Wheel
  - Motor phases (Nom / Red)
  - Motor Temperature sensors (PT100) (Nom / Red)
  - Hall sensors
  - Potentiometer

Details about connectors, cables and pin allocation of electrical and power interfaces are reported in [AD 7] about interfaces between EGSE and DSU and [AD 10] about interfaces between DSU and DU

3.7 Grounding

The Figure 3-4 shows the system grounding diagram, with the internal redundancy and the board division; cables and relevant shielding are also shown. The S/C will be simulated by EGSE during functional tests.

The DSU grounding has the following characteristics:

- A star point inside DSU
- DSU secondary returns connected together near the DC/DC transformer
- In the digital lines, cable shields are connected to the driver (TX) ground; on receiver side, shield is floating
- Cables between DSU and DU have over shields connected to chassis (360° conn.)

- 3 cables between DSU and each DU (Data, Power, FCW)
- DSU secondary ground (nominal & redundant) are connected together on backplane ground plane.

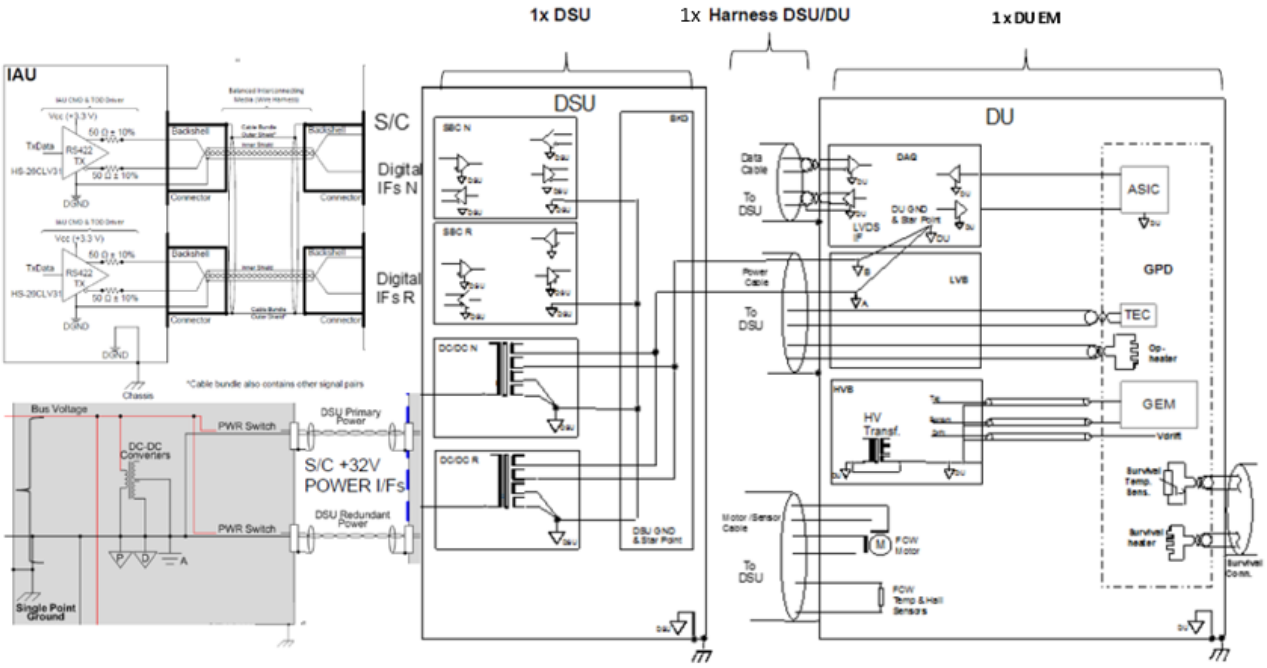

Figure 3-4 Instrument grounding scheme.

The ACE setup reproduce in part the grounding scheme required by the instrument, in particular DSU and DU are bonded to the Optical Bench (conductive surface) and in continuity to the Grounding Box of clean room. Following in Figure 3-5 Grounding of the ACE is reported the block scheme of grounding circuit.

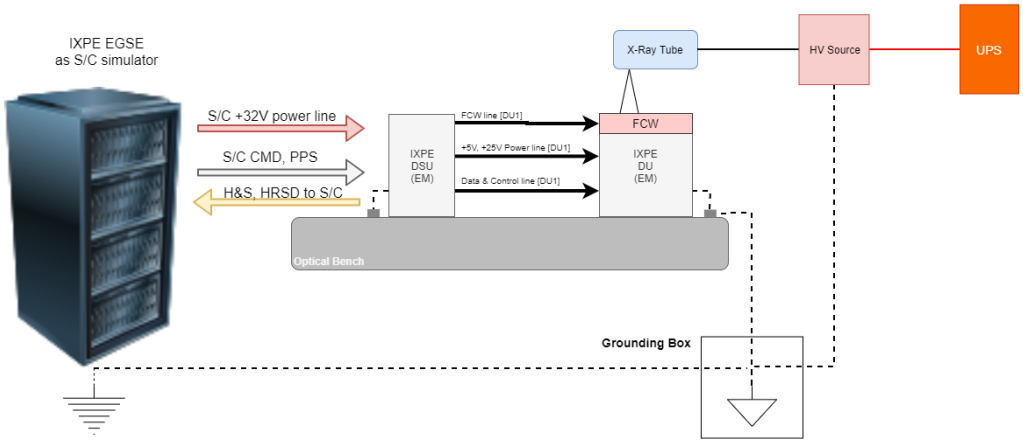

Figure 3-5 Grounding of the ACE

3.8 Mechanical Ground Support Equipment

A description of the mechanical interfaces in the ACE is reported in [RD 1].

During the tests 3 DUs and the DSU are accommodated on the same optical bench. Such bench is provided of an aluminum structure on top where three X-ray tube sources (Figure 4-6) can be fixed. Any tube is collimated by a cylinder tube with a pinhole at the end. Each cylinder tube has the capability, by X and Y motorised stages, to center the axes tube respect to the X-Ray flow. During the alignment procedure the X-Ray flux is aligned to the normal of the ASIC plane. It is possible to measure directly, by a portable measuring arm, the coordinated of the two axes.

The DSU is operated on the same optical bench and is located at almost 1m distance from the EGSE (Figure 3-7).

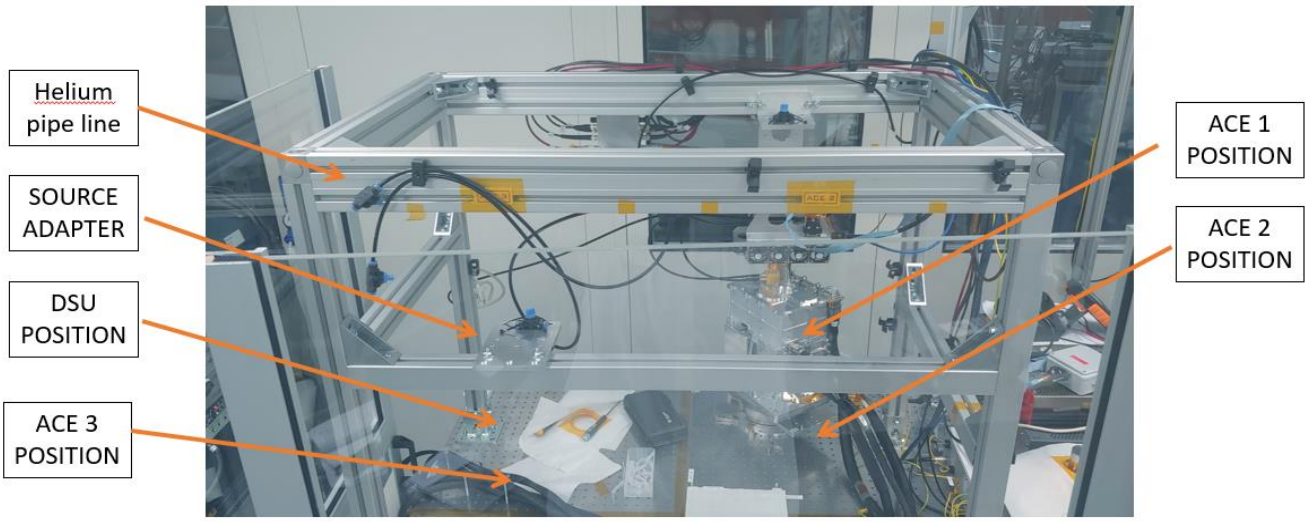

Figure 3-6 ACE E2E description

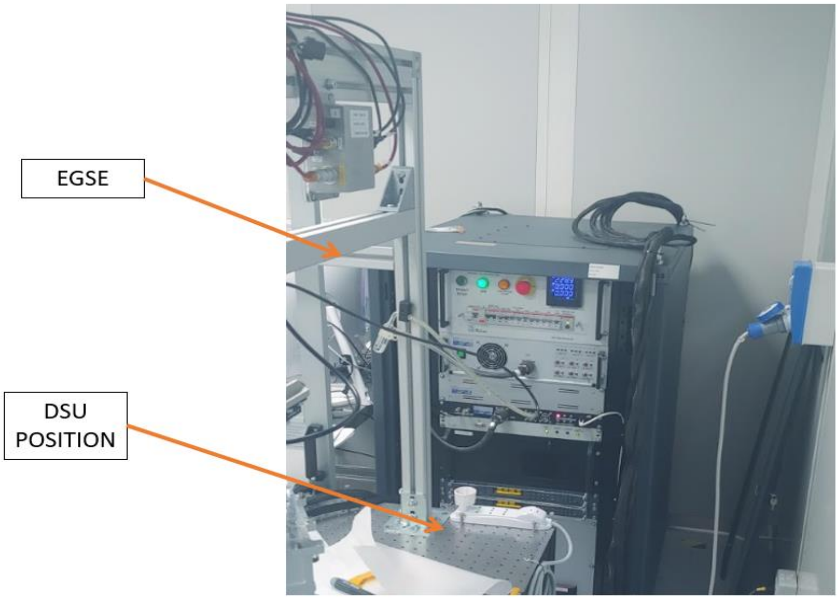

Figure 3-7 DSU and EGSE position

3.9 List of SW for the End to End Test

All the SWs used during the E2E test are maintained under control configuration in the official repository (

https://bitbucket.org/%7Bdfa78ca9-2a91-4797-a98c-786a3460c452%7D/).

Software	Version
build_ixpe_tmparser	18-02-2020 version
build_ixpe_correction	18-02-2020 version
gpdsw	18-02-2020 version
dqmpipeline	18-02-2020 version
ixpehealth	18-02-2020 version

4. PARTICIPANTS

The E2E Test and the data analysis are under INAF responsibility. INAF conducted the test and set up the facility as described in this procedure. Tests have been performed under QA surveillance, in compliance with the PA Plan [AD 10]. INAF QA witnessed the test in order to ensure that the procedure is strictly followed and the step-by step sheets are comprehensively filled and signed by relevant personnel, test facility and required tools are conform to the requirements.

5. CONSTRAINTS

During the test described in the current document, we equipped the DU FMs and the DSU PFM with connector savers. The data will be analyzed using the software listed in section 3.9.

6. TEST SUCCESS CRITERIA

We list in Table 6-1 the tests and their success criteria.

Table 6-1 Success criteria

Functionalities	**Success Criteria**
DSU POWER ON/OFF	- Boot OK - Boot Report Telemetry generation OK - Safe/Stand-By operative mode OK - HK apid 1200 generation
DSU - HKs checks and rates management	- HK apid 1200 generation - HKs rates change OK - main parameters within the limits

DSU - memory checks and management	- Maintenance operative mode OK - read/write MRAM with dedicated TC OK
DU 5V Power ON/OFF	- BEE 5V ON success - HK apid 1321 generation - HK apid 1324 generation - main parameters within the limits
DU - HKs check and rates management	- HK apid 1321 generation - HK apid 1324 generation - HKs rates change OK - main parameters within the limits
DU - Configuration	- TC BEE setup success - HK apid 1324 checks OK - main parameters within the limits
Instrument Observation - DU pixel scan (Charge Injection)	– TC Pixel Mask Procedure OK – Events acquisition (Packets 1119 generation) – Packets 1203 generation (scientific Ratemeters) – Scientific Data quality success
FCW rotation	- Position OK - power consumption OK
DU Thermal Control	- Peltier OK - Heater OK
HV Management	- HV Power ON OK - HV ramp up procedure OK - HV ramp down procedure OK - main parameters in the limits
Instrument Observation - Nominal acquisition	– Events acquisition (Packets 1118 generation) – Packets 1203 generation (scientific Ratemeters) – Scientific Data quality success – Orphan Removal ON
Instrument SAA Mode	– Events inhibition – HV ramp down – HV ramp up after SAA

Instrument Timing Management	– TOD receiving ok – PPS management ok – Timing test internal trigger ok (DSU on board management) – checks time-tag events ok
Performance Test	– Completion of orbital cycles including Observation and SAA operative modes

7. PRELIMINARY PROCEDURES

STEP	Operation	Expected value	Measured Value	Remarks
1.	Check environmental conditions of test facility	OK		
1.1	Record temperature of the test facility	19°C < T < 25°C	OK	
1.2	Record relative humidity of the test facility	45% < T < 65%	OK	
2.	Unpack (if needed) and check EGSE readiness for test	OK	OK	
3.	Unpack (if needed) and check harness readiness for test	OK	OK	
4.	Unpack (if needed) and check DSU unit readiness for test	OK	OK	
5.	Prepare the test setup implementing the connection between DSU and EGSE with the relative test harness as described in [AD 13]	OK	OK	
6.	Prepare the test setup implementing the connection between DSU and DU with the relative test harness as described in [AD 10]	OK	OK	
7.	Check the test setup grounding	OK	OK	See Figure 3-5 for EUT grounding scheme
7.1	Check DSU grounding measuring DC electrical resistance of unit bonding with respect to laboratory earth	< 1Ω	0.7	
7.2	Check DUs grounding measuring DC electrical resistance of unit bonding with respect to laboratory earth	< 1Ω	0.7	
7.3	Check EGSE grounding measuring DC electrical resistance of unit bonding with respect to laboratory earth	< 1Ω	0.7	

8. TEST RESULTS

The "as run" procedure of the Delta End to End Test, for both Nominal and Redundant sections of the DSU PFM, is the file I2C-IAPS-ISE-PRC-021_i01p00_Instrument_FT_CPT_AS RUN.pdf .

9. ANOMALIES

No NCRs for the Instrument have been issued at the end of the Delta End to End Test.

Similarly to the End to End Test (see [AD 15] for more details), during the test, we found a misalignment on the DU-DSU SDI interface. In some cases, the DUs produce events with wrong roi indexes. These events cause a block on the DSU processing algorithm (orphan pixel removal). When this block occurs the DSU SW resets the SDI interface after 1 second and automatically restart the acquisition. Consequently, no operations are needed from ground. During orbital cycles we detected 4 of these process blocks over 108×10^6 events on the main section and 1 over 19×10^6 events on the redundant section.

10. CONCLUSIONS

During the Delta End to End Test we tested the IXPE Instrument in a representative configuration, composed of the DSU PFM, the DU FM1, DU FM3 and DU FM4, after the rework of the DSU PFM in the disposition of the Non Conformance Report I2C-OHBI-ISE-NCR-076 (see [AD 17]). We verified that the DU FM1, DU FM3 and DU FM4 can be successfully connected to the DSU PFM for electrical, telecommand and telemetry interfaces. In addition, we verified that the operative modes designed for the DUs in orbit can be successfully employed and the orbital cycles, composed of OBSERVATION, passage in the SAA and calibration using the FCW, can be successfully reproduced.

At the completion of the Delta End to End Test we declare that the Instrument is still compliant to the requirements reported in the [RD 6]. No open issues nor NCRs have been found for the Instrument related to the Delta End to End Test.

11. LIST OF ACRONYMS

ADC	Analog to Digital Converter
AIT	Assembly, Integration and Test
BB	Breadboard
CPU	Central Processing Unit
ECSS	European Cooperation for Space Standardization
EGSE	Electrical Ground Support Equipment
EM	Engineering Model
ELM	Electrical Model Model
FDIR	Fault Detection, Isolation and Recovery
FFT	Full Functional Test
FM	Flight Model
GSE	Ground Support Equipment
H/W	Hardware
HK	Housekeeping
IF	Interface
MGSE	Mechanical Ground Support Equipment
MoI	Moment of Inertia
N/A	Not Applicable
OCOE	Overall Checkout Equipment
PA	Product Assurance

PFM	Proto Flight Model
RD-n	Reference Document n
RTDB	Run Time Database
FR	Flight Representative
S/C	Spacecraft
SFT	Short Functional Test
S/W	Software
SMM	Structural Mathematical Model
STM	Structural Thermal Model
TBC	To Be Confirmed
TBD	To Be Defined
TBW	To Be Written
TC	Tele Command
TLM	Telemetry

APPENDICES : Annex 1

1. POTENTIOMETER VALUES FOR THE DU FMS

In table below are reported the values of potentiometers collected during FCWs verification tests.

		DU FM1	DU FM2	DU FM3	DU FM4
		FCW sn2	FCW sn4	FCW sn1	FCW sn3
Position	Item	Potentiometer	Potentiometer	Potentiometer	Potentiometer
0	OPEN	1.71 V	1.71 V	1.70 V	1.68 V
1	GRAY	2.44 V	2.44 V	2.42 V	2.40 V
2	SOURCE A	3.16 V	3.16 V	3.14 V	3.12 V
3	SOURCE C	3.88 V	3.88 V	3.86 V	3.85 V
4	CLOSED	4.61 V	4.60 V	4.59 V	4.58 V
5	SOURCE D	0.26 V	0.25 V	0.25 V	0.22 V
6	SOURCE B	0.99 V	0.98 V	0.98 V	0.95 V

According to I2C-OHBI-AIT-REP-012, I2C-OHBI-AIT-REP-014, I2C-OHBI-AIT-REP-011 and I2C-OHBI-AIT-REP-013, the measured output voltages are within the expected value with a tolerance of ±20%.

END OF DOCUMENT