



**AIV, environmental tests and calibration of the IXPE satellite:
a success story despite COVID**

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- IXPE is a NASA SMEX mission to measure the X-ray polarisation of Astrophysical sources, launched on 9 December 2021
- INAF, INFN and ASI contributed the focal plane Instrument of IXPE (three Detector Units and the Detectors Service Unit), NASA MSFC managed the mission and manufactured the three Mirror Module Assemblies, Ball Aerospace is the satellite prime contractor
- IXPE was in Phase D when the COVID pandemic started in spring 2020, the borders shut and international travelling stopped. At that time we had just completed the Instrument AIV (Detector Units with Detectors Service Unit). We had to re-organise the satellite AIV, environmental tests and telescope calibration due to the restrictions in place
- Here we describe the operative solutions found to overcome the COVID restrictions and successfully complete the activities listed above, and the lessons learned from this experience

International travelling stopped between the end of the Instrument AIV (in Italy) and the start of the Satellite AIV (in the U.S.)

- **Installing the X-ray sources in the FCWs**
 - Each Detector Unit (DU) contains four ^{55}Fe sources in custom holders for on-board calibration
 - DUs could not be shipped with the ^{55}Fe sources installed. The Italian Team (I2T) planned to install the sources in the holders after shipment at Ball
 - Remote training of the MSFC and Ball personnel to perform this activity on our behalf. We provided dummy holders and sources for this goal
- **AIT/V of the Instrument with the Spacecraft**
 - According to the plan, the Ball personnel performed the integration (mechanical and electrical) of the Instrument with the Satellite and ran the satellite level tests
 - I2T could not attend the activities and provided remote feedback by analysing the data
- **Environmental Tests at satellite level**
 - Modal, Vibration and Shock tests; Thermovacuum test
 - I2T could not be on site and had to remotely analyse the data for feedback, inspection and verification
- **Calibration of the Telescope (Detector Unit + Mirror Module Assembly)**
 - Due to schedule constraints, we calibrated the spare units (DU FM1 and MMA-4) at the Stray Light Test Facility of MSFC
 - The MSFC personnel was already trained with an Engineering Model shipped from Italy
 - The Italian Team analysed the data and provided immediate feedback during the measurements

All Instrument activities at satellite level needed to be reorganized to cope with the COVID travel restrictions

- **AIT Working Teams (AWT)**
 - Four AWT composed of U.S. and Italian personnel to cover all topics (PA/QA, operations and electrical integration, thermo-mechanical integration, data analysis) relevant for the activities
 - Weekly meeting to discuss the progress of the activities
 - Daily meeting to plan the activities during Integration, Environmental Tests and Calibration
 - Frequent communication to provide feedback based on data analysis (Environmental Tests and Telescope Calibration)
- **Documentation**
 - Dedicated protocols to install the sources and adapt the procedures to the new test condition
- **Training with engineering models**
 - DU EM shipped to Ball and used by the personnel to test the installation of X-ray sources and the AIT/V procedures
- **Operators training and mission rehearsals**
 - On-line courses to train the operators (Integration and Commissioning)
 - At the end of the training, ASI authorized the Ball personnel to use the Instrument
 - Mission Rehearsals to test the Commissioning plan, software and activities

Operative Solutions to reorganize all Instrument activities at satellite level to cope with the COVID travel restrictions

- **Engineering Models are fundamental training benches, especially for dry runs**
- **Integrated Working Teams can be exploited to overcome travel restrictions**
 - Efficient communication is fundamental for this approach
 - Periodic teleconferences to discuss the activities and the progress
 - We had trouble using webcams in the laboratory due to poor network connection. This would have simplified the training and inspection
- **Rehearsals (mostly supported by the DU EM) have been vastly used in IXPE for**
 - Preparation of project reviews
 - Training of operators
 - Test of Commissioning activities:
 - Commissioning Plan
 - Telecommand scripts
 - MOC software and procedures
 - Typical U.S. approach to rehearsals mainly include simulation of ordinary planned activity, we introduced the response to unexpected anomalies during a Commissioning rehearsal

NASA acknowledges our contribution to complete the AIV and Calibration under COVID restrictions