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IASI-A end of life tests: main results

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ABSTRACT

Since 2018, three IASI instruments have been operated simultaneously on board Metop-A, B and C satellites. For Metop-A, operated since October 2006, 2021 marked the end of life process. However before saying goodbye to the spacecraft, and given that all its subsystems were healthy, an End Of Life test campaign at satellite and instrument levels was decided. On IASI, we took advantage of this particular phase to propose tests that would not had been considered normally on an operational satellite due to service outages and risk of damaging the instrument. The duration of these End Of Life campaign was more than 3 months to allow an important number of tests, dedicated to various purposes.

After iterations between industry, partners and product experts, several tests were selected by the agencies. These tests can be sorted in two categories: technologies and science tests.

The EOL campaign finished on time on December 2021. The tests are fruitful and after reviewing the outcomes we are now able to present the most significant results. In order to give a clear overview of the End of life test campaign on IASI A, this article will address the objectives of the tests, their progress and main results but also some feedbacks of the EOL process itself.

Keywords: IASI, End of life, test, Metop, operation

1. INTRODUCTION

This paper will describe briefly the tests done on IASI during the end of life and their main results. The content will be divided in 2 parts, one dedicated to the instrument behavior (technological tests) and one dedicated to science tests.

Some results are still preliminary because of the deeper investigations needed to have complete analysis.

1.1 IASI mission

The mission objectives assigned to IASI are to meet the basic requirements of both the operational numerical weather prediction community and the community interested in the climatology. IASI measurements are used by the research community interested in the atmospheric chemistry. IASI provide improved infrared soundings of the temperature and moisture profiles in the troposphere and the lower stratosphere as well as some of the chemical components playing a key role in the tropospheric chemistry and the additional greenhouse effect.

The meteorological mission supported by IASI consists in the determination of the atmosphere characteristics (vertical profile of temperature and concentrations of atmospheric constituents) from the high spectral resolution spectra sent to the Earth by IASI in the thermal infrared [645- 2760 cm-1]

1.2 How it works… briefly

The IASI instrument is based on a spectro interferometer, working on a Michelson basis.

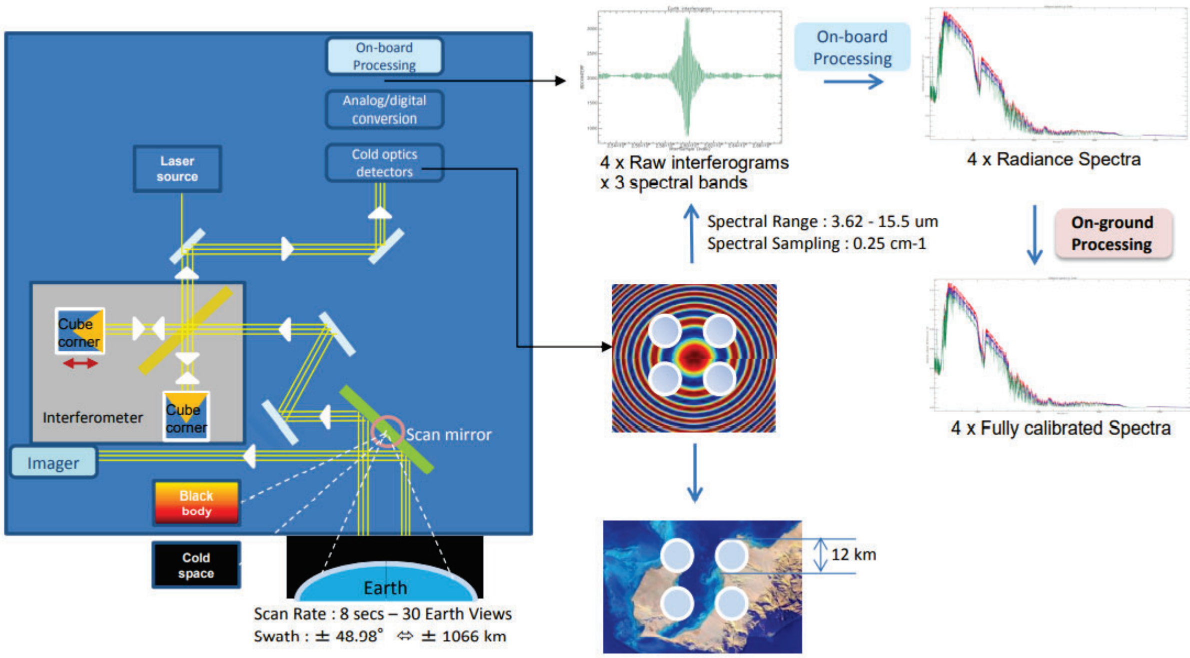

Figure 1: Process of the IASI measurement

More information available in [1] and [2]

2. TECHNOLOGICAL TESTS

2.1 IASI-EOL-13: IASI REDUNDANCIES

2.1.1 Objective and progress of the test

The purpose of the test was to check the remaining redundancies of the instrument that have never been exercised in space before; potentially some knowledge could be gained about the ageing effect after a long stay in space in cold configuration (non-powered).

The two redundancies tested was the power of the laser 2 (use for metrology) and the DPC5 (calculator for the science data)

2.1.2 Main results

The behavior of the 2 redundancies has been exactly the one expected:

- The power of the laser 2 was compatible with the one used for operational mode

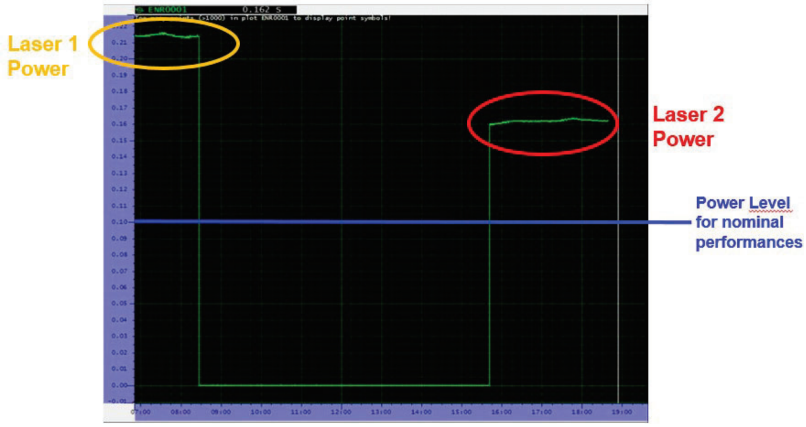

Figure 2: Output power of the metrology signal measured for laser 1 and 2

- The behavior of the new DPC was similar to the nominal ones

2.2 IASI-EOL-16: INVESTIGATION ON CSQ ANOMALIES

2.2.1 Objective and progress of the test

During the life of IASI-A, a major anomaly occurred and decision has been taken to move to side B. This anomaly was a very high increase of the CSQ flags (Cube corner Speed Quality error) which detects an instability of the cube corner speed during the interferogram acquisition. After moving to side B this anomaly disappeared.

The objective of the test was to characterize more finely the CSQ anomaly on nominal and on redundant sides, by testing several values for the low and high CSQ detection thresholds. The objective was to obtain a more precise knowledge of the amplitude and sign of position errors causing the appearance of CSQs and to provide work around solutions for IASI-B or IASI-C in case of similar anomalies.

Because of various problems during the test process, exploitable data are only available for side B.

2.2.2 Main results

After the test, completion of statistics have been done on the percentage of acquisition for which a CSQ anomaly appeared depending on the threshold.

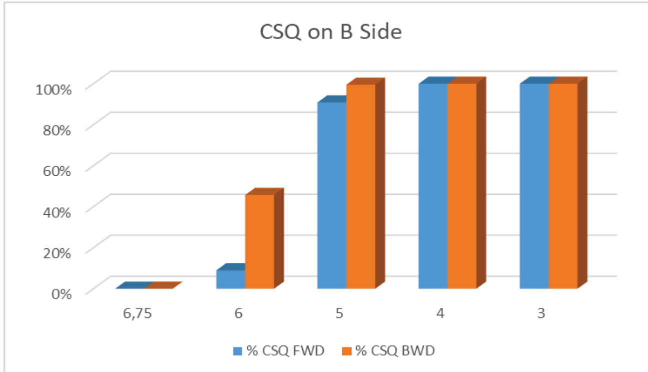

Figure 3: CSQ on B side

Looking at these data several points can be noticed and investigated:

- The value of the nominal threshold (6.75) seems to be close to the transition between a nominal behaviour and a high CSQ rate behaviour.
- There is a brutal transition between nominal and anomaly behaviour
- The transition is not the same for forward and backward

All these behaviors are compatible with the ones seen on earth before the launch so we can't say if there is a problem due to ageing on the mechanism, but if there is, this effect is very small after 15 years in orbit.

2.3 IASI-EOL- 01 / 02: LFD RELEASE and CD stop

2.3.1 Objective and progress of the test

The Locking Filtering Device (LFD) was implemented on IASI to ensure a decoupling between the platform and the instrument in order to prevent micro-vibrations coming from the METOP platform and impacting the quality of IASI data. However, this option was never exercised and there was no in-orbit experience of IASI in this configuration prior to the test.

The objective was to test the deployment of all the 3 LFDs, taking into account that there is no direct way to validate the success of the release of the LFD. After a long stay in space, the release might be partial and very slow because of the aging of the elastomer materials.

Then we stop the compensation device in order to give more chance to see the effect of the LFD release. Indeed the Compensation Device (CD) was introduced in the IASI design to compensate the dynamics perturbations generated by the Corner Cube Functional Device (CCFD) in the configuration where the LFD are deployed; in this configuration, the interface between IASI and the satellite PLM is non-rigid.

2.3.2 Main results

The release of the LFD Shape Memory Alloy (SMA) run as expected. The variation of the SMA temperature showed a plateau, confirming the phase transition and thus the elongation of the material.

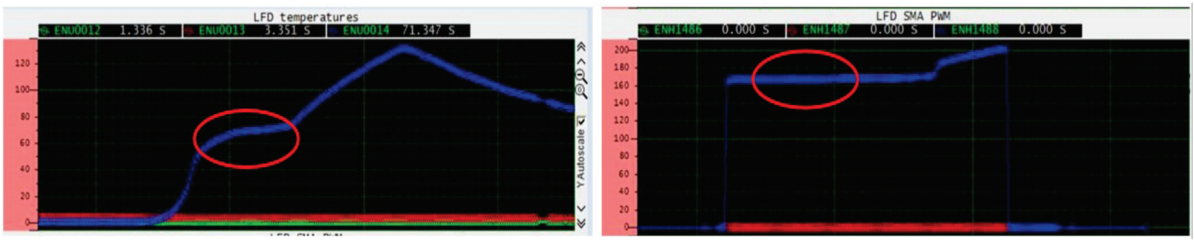

Figure 4: LFD temperature (left) and LFD SMA (right)

However we didn't see any effect on the SCAO side after the LFD release even when the CD has been turn of. There is 2 hypothesis. First one the elastomer material which had been squeezed for many years in space, had lost elasticity and the capacity to expend the mechanism. Second hypothesis: the expansion was too slow to be noticeable within the duration of the test.

At the end of the test, a small impact on the noise correlation matrix can be seen.

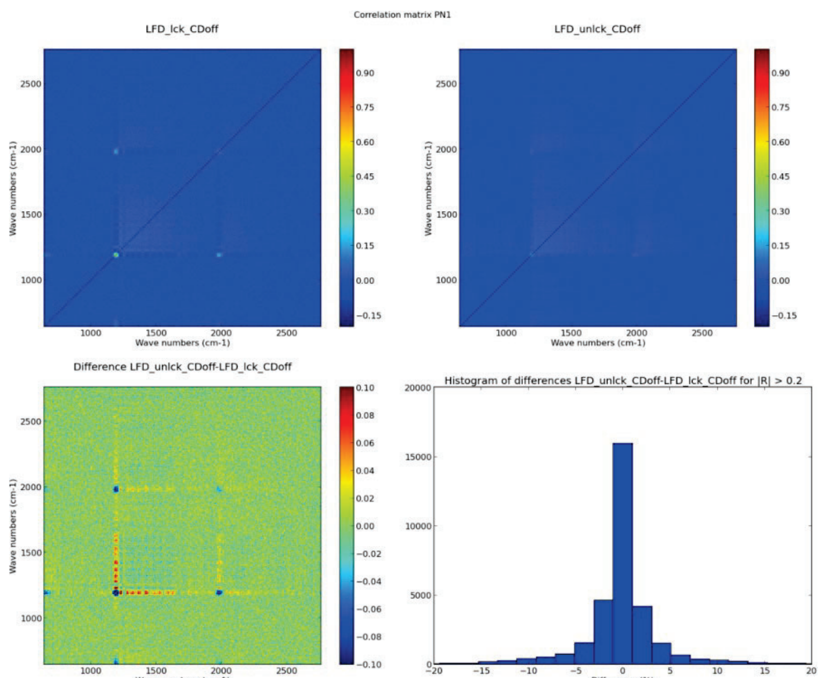

Figure 5: NCMs LFD locked / CD Off VS LFD unlocked / CD Off

These differences seem to demonstrate that the release of the LFDs tend to slightly decrease the level of micro-vibrations observed on IASI instrument.

3. SCIENCE TESTS

3.1 IASI-EOL-15: Local improvement of spatial sampling

3.1.1 Objective and progress of the test

The objective of the test was to reduce the swath by dividing by 8 the spacing between consecutive FOR (from ~48 km to ~6 km) and therefore increase the spatial density of the soundings.

For that the behavior of the scan mechanism has been modified in order to increase the spatial density of the sounding. These modifications had'nt modified the quality of the SCAN behavior

3.1.2 Main results

The scientific results of this test aren't available until now but some studies to assess the quality of the data have been done to be sure that scientific analysis based on these data are manageable.

We first seen that during the test the behavior of the SCAN remain compliant with the requirements: the SCAN has been controlled has expected and the behavior was stable.

All quality criteria suggest that the data are of sufficient quality (equivalent to the nominal quality) to be used for scientific analyses:

- The geolocation performances are still accurate
- The variability of two consecutive FORs during the test exhibits atmospheric signatures exceeding noise level. A significant improvement of the spatial resolution of L1 spectra is therefore expected from this test

3.2 IASI-EOL-18: NEDT improvement in B1 on 1 sounder pixel

3.2.1 Objective and progress of the test

The objective of the test was to reduce the temperature of the detectors and check the improvement of radiometric noise in spectral band B1. The decrease of temperature is obtained by switching off 3 of the 4 pixels of the sounder.

The idea was to be able to deliver some data closer to the performances expected for IASI-NG

3.2.2 Main results

As planned the focal plane reach a temperature 3 degrees lower than the usual one and the NEDT became smaller by a percentage of 20% on B1. For B2 and B3 there is no huge improvement because, as expected, B2 and B3 are less sensitive to the temperature.

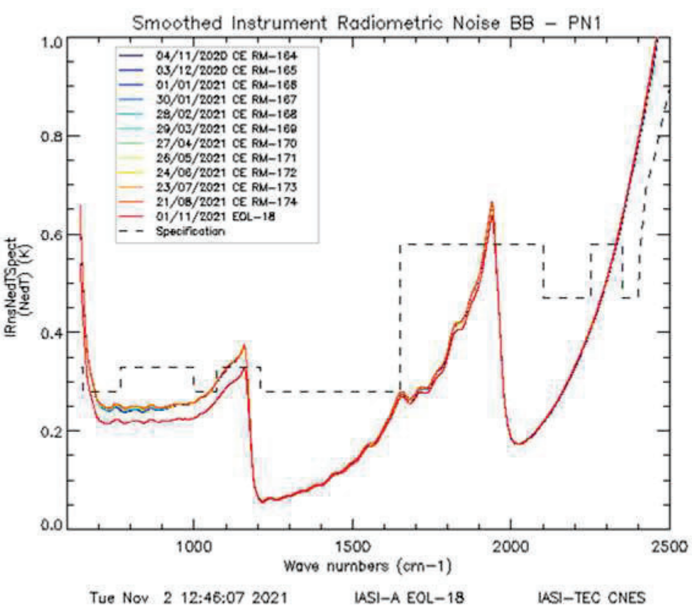

Figure 6: L0 radiometric noise after the decrease of the temperature

3.3 IASI-EOL-03: Inter calibration of Metop-A, B & C

3.3.1 Objective and progress of the test

The purpose of the test was to use the opportunity given by the deorbiting of Metop-A and the change of the geometric configuration of the METOP constellation to acquire Simultaneous Nadir Observations (SNO) data by IASI-A and IASI-B or by IASI-A and IASI-C over the Earth poles.

The duration of this test was short: only 8 days, so there were few Common Nadir Observations between IASI-A and IASI-B or IASI-C.

3.3.2 Main results

The comparison has been done using 28 mean spectra for IASI-A and IASI-B in the process and 23 between IASI-A and IASI-C. The inter-comparisons is < 0.1K

3.4 IASI-EOL-17: IASI limb pointing

3.4.1 Objective and progress of the test

The backflip maneuver of METOP-A planned at the end of the EOL test campaign, gave the opportunity to acquire measurements of the atmosphere in Earth Limb directions which has a potential scientific interest and can provide a comparison between IASI and other limb atmospheric sounders. The acquisitions of measurements in the Earth Limb direction provided opportunities to test or validate the spectroscopy and radiance modelling in new conditions, especially in non-local thermodynamical equilibrium state.

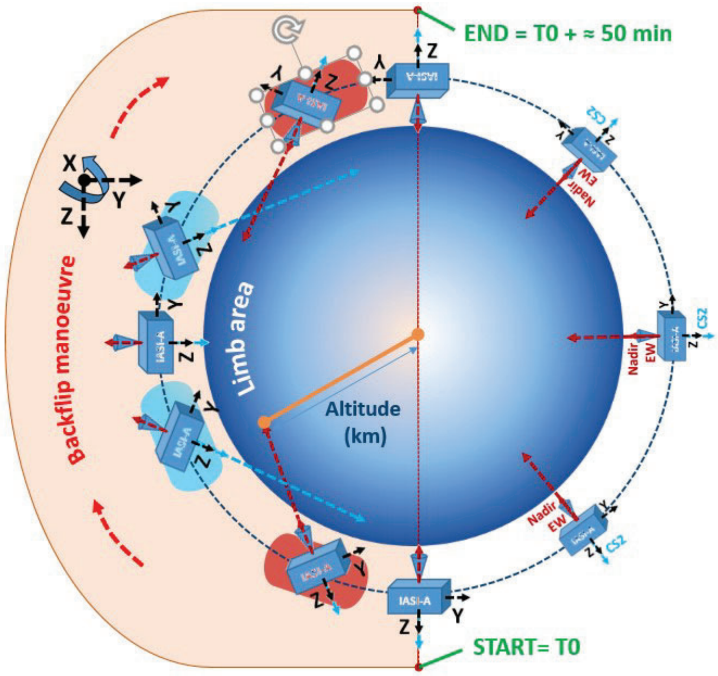

Figure 7: graphic of the EOL-17 test using alternatively Nadir views and CS2 views

3.4.2 Main results

The analysis of this test is still in progress

4. CONCLUSION

As described previously this end of life test campaign has been fruitful from both technical and scientific points of view. It has been a good opportunity to create link between the different teams of the project working together on a daily basis.

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