ARIETIS and ARIETIS-NS gyros test results and qualification status

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Abstract

ARIETIS and ARIETIS-NS are two gyroscopes for space applications developed by Innalabs based on its proprietary CVG technology. ARIETIS is an ITAR free, Rad-Hard 3-axis gyroscope whose main applications are Earth Observation, Science missions, Telecom, as well as Navigation, Earth Observation, as well as Science missions. It uses class 1 EEE components and meets ESA ECSS standards. ARIETIS-NS is an ITAR free, rad and Single Event Effects (SEEs) tolerant 3-axis gyroscope. It is developed following ECSS standard with the exception of using commercial EEE components that are upscreened by means of radiation testing. ARIETIS-NS is intended for commercial satellites (both LEO and GEO), constellations and mega-constellations, but it has also been selected for science and exploration missions.

ARIETIS and ARIETIS-NS are both based on InnaLabs proprietary Coriolis Vibratory Gyroscope (CVG) technology which is currently used in Space on board both LEO and GEO applications. InnaLabs CVG gyros have already cumulated more than 3,000,000 hours in flight with no failures and no deviation from the specified performance, confirming the suitability of the technology to space environment.

After a brief description of the InnaLabs CVG basic principles and an overview of the CVG technical strengths in comparison to competing technologies, this paper describes the specification. key design features, and budgets of both ARIETIS and ARIETIS-NS. Both gyros are able to provide high performance (ARW <0.005 deg/√hr) and high reliability (~1000 FITs) in a very compact design (~1.2 kg for ARIETIS-NS and ~3kg for ARIETIS) and very low power consumption (<6W). To achieve this, several targeted enhancements and optimisations to InnaLabs gyroscope's design have been introduced, mainly in the component selection, the control loops, the compensation algorithms, and a smaller Sensing Element design.

ARIETIS-NS has recently completed qualification where multiple qualification models were used to characterize different configurations of the product. Qualification test results will be presented to show the gyro compliance to the specification in terms of performance and compatibility to both mechanical and thermal environment. ARIETIS is at the start of the qualification campaign with the qualification model currently under MAIT. Several ARIETIS engineering models have been built and tested and test results are presented in the paper.

1 INTRODUCTION

InnaLabs CVG gyro technology, design, and performance was first described in 2013 [1]. It belongs to the vast group of Coriolis gyroscopes, namely CVGs (Coriolis Vibratory Gyroscope), and as does HRGs (Hemispheric Resonator Gyros), to a sub-category of operating axisymmetric balanced resonators. The design, originally intended for stabilization market and tactical applications was updated to cover North finding applications to provide a lower noise solution especially at lower frequencies [2].

Innalabs CVG gyro technology was originally designed not considering space as a key application, nevertheless the key elements of the technology, i.e. a metal resonator vibrating in vacuum condition makes it very suitable for such environment. Commercial customers selected Innalabs CVG gyros for Low Earth Orbit (LEO) Earth Observation and GEO telecom applications. As of 2023, 100 gyros are flying in space and more than 3,000,000 hours of operational time in spaceflight were accumulated with no failures and no deviation from the specified performance. In flight experience confirms that the technology is well suited to space environment.

Based on such experience, Innalabs engaged with the European Space Agency (ESA) and Enterprise Ireland (the Irish government agency that is responsible for space activities in Ireland) in order to develop gyroscopes qualified to European Space Standards (ECSS) based on Innalabs CVG gyro technology. Thanks to the support of ESA and EI, two different products were developed.

ARIETIS is a rad-hard 3-axis gyro that use Hi-Rel components (i.e. electronic components that are designed and qualified for space application). ARIETIS design concept was first presented in [7]. Preliminary test results from ARIETIS breadboards were presented in [8] to confirm that product specification was met. Finally, a summary of design and preliminary test results of ARIETIS was presented in [10]. ARIETIS Engineering Qualification Model (EQM) is currently in the MAIT process, with qualification planned to be started in Q4 2023.

ARIETIS-NS is a rad-tolerant 3-axis gyro that use commercial components that are subject to Lot Acceptance tests by means of total dose and single event radiation tests. ARIETIS and ARIETIS-NS show a number of similarities [9]: both use the same CVG sensor, while deviating from Innalabs non-space gyros [1] by using an FPGA based digital design rather than an analogue one. Main difference between the products are related to the type of electronic components used (Hi-Rel for ARIETIS and mostly commercial for ARIETIS-NS) and the fact that ARIETIS-NS is industrialized for serial production to cover large constellations as well. ARIETIS-NS design was first introduced in [10], whereas partial test results were presented in [11]. A summary of ARIETIS-NS qualification test is presented in [12]. Since the release of those papers, Innalabs has completed qualification testing of ARIETIS-NS and flight models are expected to be shipped over the next few weeks.

2 InnaLabs CVG Technology and sensor design

InnaLabs gyros belong to the vast group of Coriolis gyroscopes, namely CVGs (Coriolis Vibratory Gyroscope), and as HRGs (Hemispheric Resonator Gyros), to a sub-category of operating axisymmetric balanced resonators.

The Sensing Element (SE) features a cylindrical high-quality metal resonator whose primary and secondary resonant mode have matching frequencies. These two modes are operated by means of 8 rectangular piezo elements shown in Figure 1. They are attached to the outside of the flat bottom surface of the resonator as per a specific configuration described in [3]. The resonator is secured to a mounting base and is hermetically sealed under vacuum to form a sensing element with a total volume of ~15 cm3 (0.9 cubic inches).

To reduce dimensions and improve mechanical and thermal decoupling, the original resonator mounting base design has been optimised to include three flexible structures (the isolators), which are equally distributed about the resonator principal axis. This new and unique sensing element configuration is shown in Figure 1 and described in more detail in [4].

Figure 1. InnaLabs CVG Sensing Element (SE)

The three SE isolators are identical and homogeneous, with physical properties such that any of the translational and rotational resonances have a roll-off frequency above 600 Hz with a reduced quality factor ($Q < 10$).

Wire bonding connections connect electrically each piezo element to glass to metal sealed pins, in turn connected to an external proximity board attached to the bottom of the sensing element mounting base. Referring to [1], a closed-loop electronics system executes what is called a Force to Rebalance mode of operation (FTR) which is described in detail in [5]. One resonant mode (referred to as the excitation mode, or the primary mode) is energised to a set amplitude, and the second resonant mode with matched frequency is used to sense inertial rotations applied to the resonator (referred to as the detection mode, or the secondary mode). When the SE is rotated about its principal axis, the induced Coriolis forces transfer energy from the primary mode to the secondary mode, and the force generated by the control closed-loop electronics to null mode 2 is proportional to the input rotation rate.

Reference [5] presents a simplified/reference version of vibratory gyroscope control system with high-level functional blocks. Such approach is used as well in Innalabs gyros. Input/Output signals, denoted Adet (Antinode Detection), Ndet (Node Detection), Aexc (Antinode Excitation), and Nexc (Node Excitation), as well as the 4 standard control loop blocks using these signals specific to Coriolis gyroscopes, can be recognised.

InnaLabs CVG SE presented in Figure 1 has been exposed to a design and qualification process aligned to ESA ECSS standards. This started with an assessment of the suitability of each process and materials being used to all targeted space applications, followed by a qualification of each CVG SE parts and processes (soldering, brazing, welding, etc.) individually, and completed by a qualification at SE level prior to final qualification at system level. Radiation testing of the sensing element was performed as described in Reference[7], showing no impact on sensing element behavior for radiations of 170 krad.

As part of the test plan, performance tests, magnetic susceptibility tests (±10 Gauss), gravity susceptibility tests (±1 g), and micro-vibrations susceptibility tests (sine sweep of ≤0.5 g) were conducted on selected units, followed by mechanical environments survivability tests and life testing exceeding the expected flight loads for the various space missions considered.

In relation to mechanical environments survivability, 26.25g sine sweep from 5Hz up to 100Hz at 2 Oct/min were applied along 3 orthogonal directions. These were followed by random vibrations of 24.3grms within a frequency range of 20Hz to 2kHz. Which were then completed with SRS shock levels of 1500g from 1.5kHz to 10kHz. Life testing consisted of 500 thermal cycling with a temperature range of -45°C to +95°C and a temperature slope of ±2°C/min. All these tests were performed in laboratory conditions. The tests qualified Innalabs CVG sensor to space standards.

3 ARIETIS AND ARIETIS-NS GYRO DESIGN

This section summarises the main design features of ARIETIS and ARIETIS-NS. For a more detail description please see [10] for ARIETIS and [12] for ARIETIS-NS. ARIETIS FPGA architecture and challenges in the development of the FPGA code are also described in [13]

3.1 ARIETIS Rad-Hard gyro

ARIETIS is shown in Figure 2. It is a Rad-Hard, high to medium performance, high-reliability, ITAR-free non-redundant 3-axis Gyro (or Rate Measurement Unit). It is used by the AOCS system to sense the angular rates about three orthogonal axes. The gyro design is based on ECSS standards and uses Class 1 EEE parts. Its output noise is very low over the entire measurement bandwidth, and for this reason, it is particularly suited for use in applications as Earth Observation and Science missions. Additionally, it also performs within requirements for GEO applications.

Figure 2. ARIETIS gyro.

Figure 3 shows ARIETIS functional diagram with key components and interface to the system. In particular it can be seen that the core gyro functionality needs 3 elements: i) the gyro sensing elements (one per each axis), ii) the control loops within the FPGA that maintain vibration within the sensing element in the prescribed amplitude and direction, and iii) DAC to convert FPGA output in signals useful for the sensing elements, and ADC that convert sensing element outputs into digital format for the FPGA.

For what concerns power supply board interfaces, ARIETIS offers power ON and OFF telecommand, as well as providing thermistor, status ON/OFF and status of one secondary power. All power interfaces are redundant.

For what concerns data interfaces, besides the main redundant RS422 interface, ARIETIS offers a stimulus interface for ground testing and an optional analogue output (intended to be used for Fault Detection, Isolation, and Recovery purpose at satellite level).

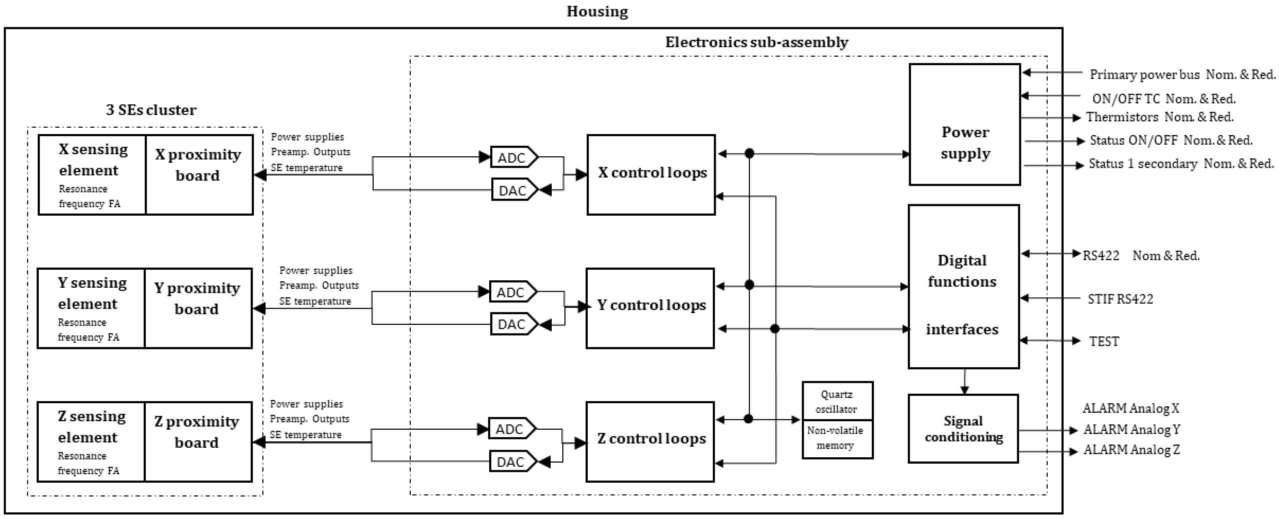

Figure 3 – ARIETIS functional diagram

3.2 ARIETIS-NS Rad-Tolerant gyro

ARIETIS-NS shown in Figure 4 is a rad-tolerant, high to medium performance, high-reliability, ITAR-free non-redundant 3-axis Gyros, Its target applications are LEO and GEO missions. The product is industrialized for high production rate to support use in constellations and megaconstellations.

This product is derived from ARIETIS as both use the same sensing element and the same overall gyro architecture with digital control loops implemented in an FPGA. However ARIETIS-NS is not fitted with Class 1 components. Its design is based on the following principles:

- Utilisation of up screened COTS EEE parts selected by means of Radiation Lot Acceptance Tests, including Total Ionising Dose (TID), Total Non Ionising Dose (TNID) for optical parts, destructive and non-destructive Single Event Effects (SEE)
- PCB procured based on IPC standard rather than ECSS standards.
- sensing element mounted directly on the gyro baseplate.
- Simple functional architecture with only one operating mode after power on
- Simple Power Supply Board
- Design and industrialized for high production rate.

Two versions of ARIETIS-NS are proposed:

- ARIETIS-NS-LEO, whose housing has been optimised to reduce mass in a more benign radiation environment such as LEO applications. It can also be used for science/exploration applications when the radiation environment is benign.
- ARIETIS-NS-GEO, whose housing provides radiation protection in harsher radiation environments such as GEO applications.

Both ARIETIS-NS-LEO and ARIETIS-NS-GEO versions are proposed with various data interfaces. They share the same EEE components for what concerns the sensing elements control electronics and the only difference between the two models is the thickness of the box to withstand different radiation environments.

Figure 4 presents a preliminary view of ARIETIS-NS LEO:

Figure 4. ARIETIS-NS in LEO configuration.

Figure 5 provides a functional diagram of ARIETIS-NS gyro unit. It can be seen that the functional architecture is very similar to the one of ARIETIS presented in Figure 3. Main differences are i) the much simpler interfaces on the power supply boards, where only primary power bus and thermistor are present and ii) no optional analogue output for the gyro.

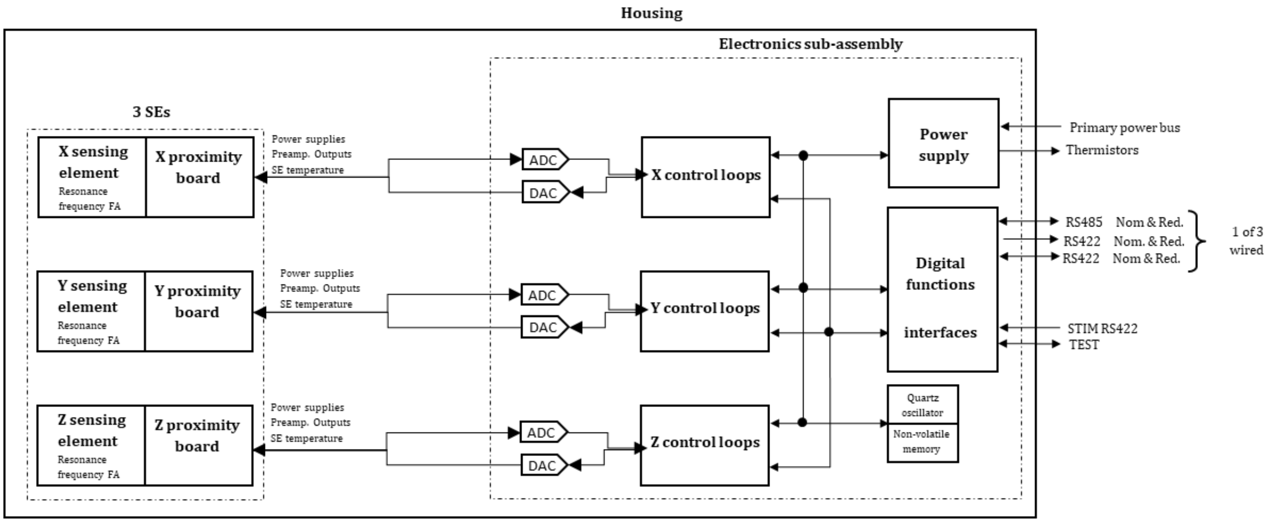

Figure 5. ARIETIS-NS, functional diagram.

3.3 Specifications

As a result of the many commonalities between ARIETIS and ARIETIS-NS described above, the two gyros have very similar performance specifications. The differences emerge with the size and mass (the use of COTS EEE parts in ARIETIS-NS allows for a more compact design), as well as for environmental specifications (the use of a cluster on dampers in ARIETIS allows for more demanding mechanical loads). But both gyros are designed for high reliability as well as long duration in both ground storage and lifetime in flight.

Table 1 – ARIETIS and ARIETIS-NS specification

Parameter	ARIETIS Value	ARIETIS-NS Value
INTERFACE		
TM/TC user interface	RS422 redundant TM output rate 8 to 32Hz	RS422 (transmitter only or bidirectional) or RS485 redundant. TM output rate up to 500Hz
Ground test interface	RS422 receiver only – not redundant	RS422 receiver only – not redundant
Power Input	28V (regulated or unregulated) redundant. Power on and power off command	28V (regulated or unregulated) - not redundant.
ENVIRONMENT		
Operating Temperature Range	[-20°C; +50°C]	[-15°C; +55°C]
Qualification Temperature Range	[-30°C; +60°C]	[-25°C; +65°C]
Random vibration	26.2g rms	18g rms
Shock	2000g / 2000Hz	1500g / 1500Hz

Parameter	ARIETIS Value	ARIETIS-NS Value
Radiation	Hi-Rel EEE qualified to 50krad TID / 60MeV SEE	mostly COTS EEE screened to: • 30krad TID • SEL free till 60MeV • SET behaviour characterised.
PERFORMANCES		
measurement range	[-3°/s; +3°/s] fine mode [-48°/s; +48°/s] coarse mode	[-12°/s; +12°/s]
Bandwidth	4 Hz (can be adapted)	5 Hz or 155 Hz
ARW	<0.005 °/√h	<0.005 °/√h
Bias Instability	< 0.1 °/hr	< 0.1 °/hr
bias - Ground BOL	10°/h (3σ)	10°/h (3σ)
SF stability EOL	3000 ppm (3σ) if scale factor calibration active	3000 ppm (3σ) if scale factor calibration active
Magnetic sensitivity	1°/h/Gauss (up to 15 Gauss)	1°/h/Gauss (up to 15 Gauss)
Reliability	1000 FIT (FIDES)	1000 FIT (FIDES)
life	up to 6 years on ground and 16 years in flight	up to 6 years on ground and 16 years in flight
BUDGETS		
Mass	2.7 kg	1.3 kg (LEO - 2mm thick housing) 2.3 kg (GEO - 8mm thick housing)
Envelop	186 x 186 x 81 mm	130 x 130 x 65 mm (LEO - 2mm thick housing) 142 x 142 x 73 mm (GEO - 8mm thick housing)
Max Power consumption	8W	6W

4 DEVELOPMENT, VERIFICATION, AND QUALIFICATION APPROACH

Development and verification of ARIETIS and ARIETIS-NS relied on a number of HW models that were built and tested over the last few years. The design verification relied on multiple iterations of the product Hardware: Breadboard (BB), Engineering Model (EM) and Engineering Qualification Model (EQM). ARIETIS and ARIETIS-NS Breadboard (BB) configuration and results are presented in [10].

4.1 ARIETIS Development Models

For what concerns ARIETIS, 3 Engineering Models (EMs) have been built. The EMs are identical in functionality and performance to the flight models, with the exception that PCB are procured in lower quality and mostly COTS EEE are used. One Engineering Model has been shipped to the PLATO mission for testing in the avionic testbench. Such activities, as per Figure 6 demonstrated the correct integration of ARIETIS in with PLATO main on board computer and power distribution subsystem.

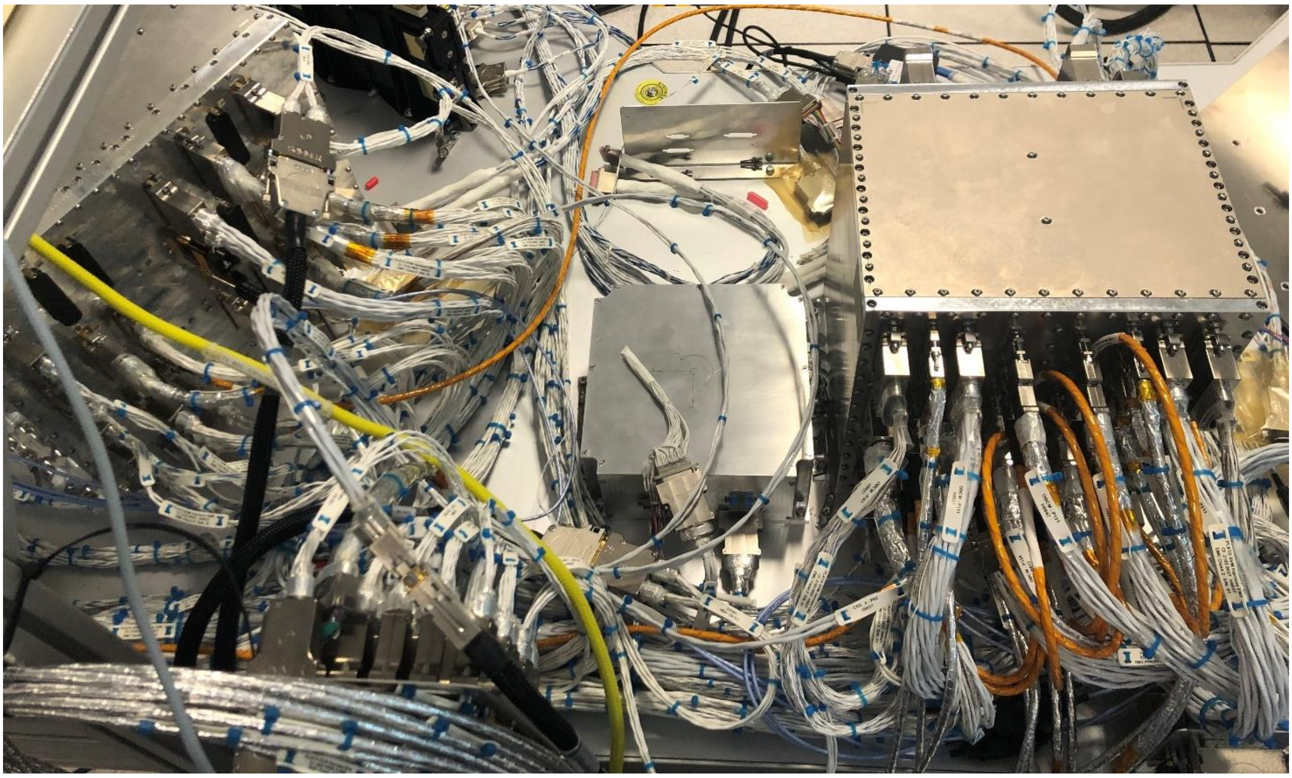

Figure 6. ARIETIS (centre of the picture) integrated in PLATO Avionic Test Bench (photo courtesy of Thales Alenia Space)

An Engineering Qualification Model (EQM) is currently in manufacturing and will be used for ARIETIS qualification, starting in Q4 2023. The EQM is identical to the Flight Models (FM) except that on the qualification units the rad-hard electronics components are not necessarily procured in class 1. ARIETIS has already been selected on a number of missions, including PLATO, LSTM, ARIEL. As these missions require slightly different configurations on ARIETIS, a PFM approach will be used to qualify mission specific configurations.

As the manufacturing of ARIETIS EQM is not complete yet, ARIETIS test results shown in the sequel are referred to the Engineering Models.

4.2 ARIETIS-NS Development Models

Around 10 ARIETIS-NS Engineering Models were built for verification tests ahead of CDR and for integration test within customer avionic test benches. Following successful testing of such models, a number of EQMs were built.

ARIETIS-NS product qualification used 3 EQMs with various configurations in order to cover several type of missions: both LEO (thin box) and GEO (tick box) configuration with multiple data interface solutions have been tested. See Figure 7 for a picture with 3x ARIETIS-NS EQM in Innalabs thermal chamber.

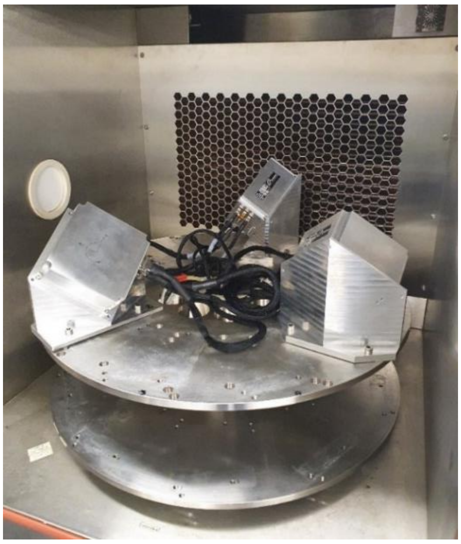

Figure 7. ARIETIS-NS EQMs in thermal chamber for performance testing

ARIETIS-NS has already been selected on a number of missions, including HERA. Qualification campaign already covered a number of configurations, but more specific tests are planned to be performed at PFM level for several customers which have mission specific needs.

4.3 Qualification Plan

Both ARIETIS and ARIETIS-NS have been developed following ECSS rules and as such the qualification campaign is almost identical for both products. The qualification sequence includes performance testing (Figure 7), mechanical environment testing (sine, random vibration, and shock test, see Figure 8), thermal vacuum testing, and EMC (Figure 9). The complete qualification sequence is available in Table 2

ARIETIS-NS completed the qualification test sequence with the exception of life tests, whereas ARIETIS is planned to start it in Q4 2023.

Table 2. Qualification sequence for ARIETIS and ARIETIS-NS

Test Item
Board level tests
Board electrical tests
Environment stress screening
EMC workmanship tests (PSB only)
General tests
Physical properties
Electrical Verification Test
Compensation
Initial Functional and performance (FFT)
Mechanical env. tests
Sine vibration
Random vibration
Performance basic check (RFT)
Shock
Intermediate Functional and performance (FFT)

Thermal environment test
Thermal vacuum
Performance basic check (RFT)
Thermal ambient
Performance basic check (RFT)
EMC
EMC - Conducted Emissions
EMC - Conducted Susceptibility
EMC - Radiated Emission
EMC - Radiated Susceptibility
EMC - Magnetic susceptibility (AC/DC)
EMC -Magnetic Moment
EMC - ESD
General tests (Part 2)
Final Functional and performance
Life Test
Accelerated life test (only for ARIETIS-NS)

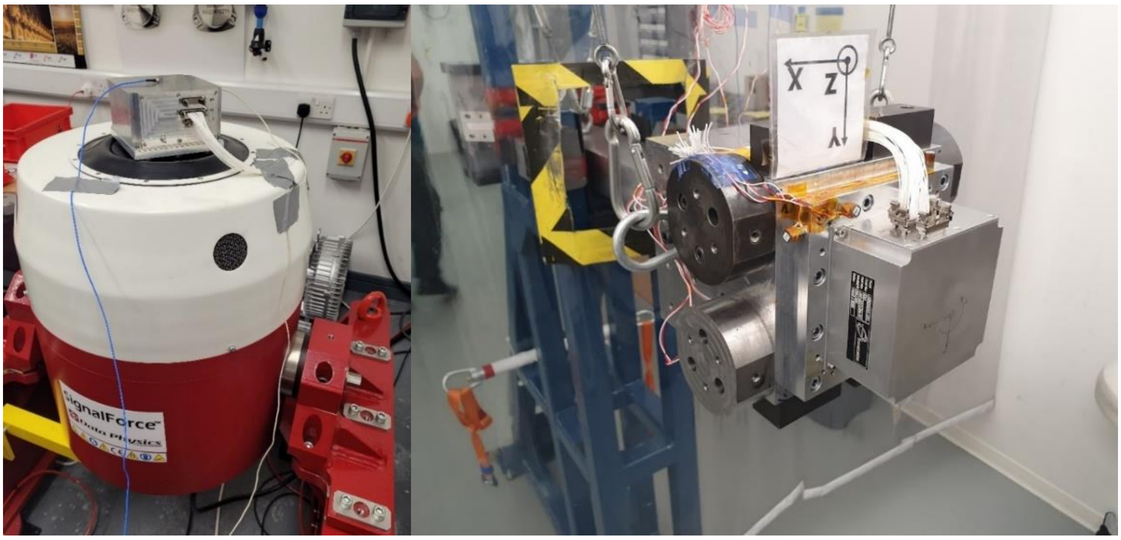

Figure 8. ARIETIS-NS EQM vibration test at InnaLabs facilities (left) and shock test (right)

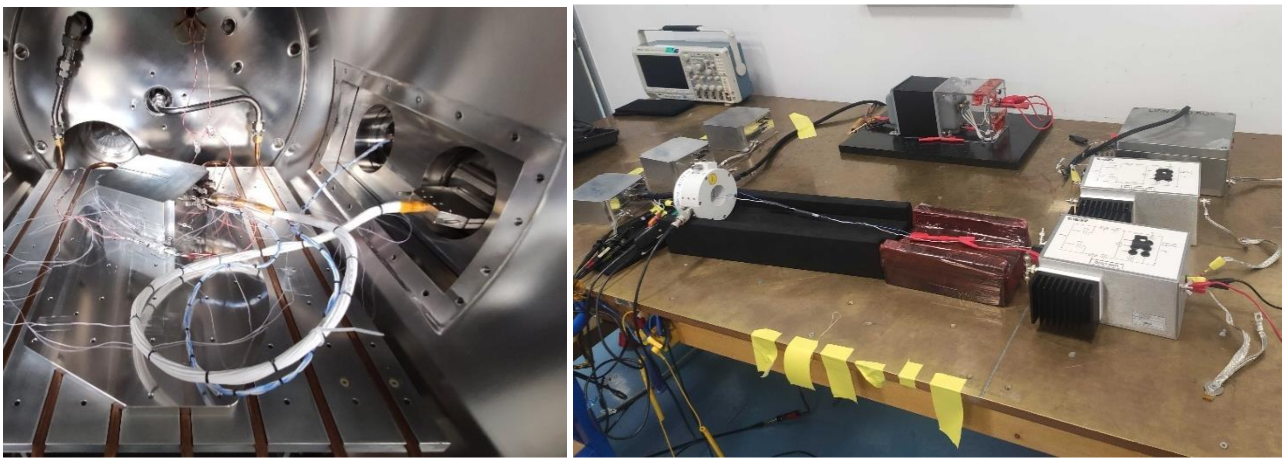

Figure 9. EQM under Thermal-Vacuum test (left) and with their LISN under EMC testing (right)

5 ARIETIS TEST RESULTS

This section recollects the main performance test results performed on ARIETIS to show compliance with specification provided in Table 1.

5.1 Bias stability over temperature

Figure 10 shows ARIETIS in Innalabs thermal chamber that includes a rate table, where most performance tests are performed. Figure 11is showing a typical result for bias stability over temperature. The bias is assessed by recording the static gyroscope output over temperature and subtracting local earth rotation projection, the raw data are then averaged by a 10 sec moving average. The temperature profile follows a 1.5 thermal cycles between 5°C and 4°C. For the test, the maximum bias is within 10°/hr and the bias stability is 1.74°/hr (1σ).

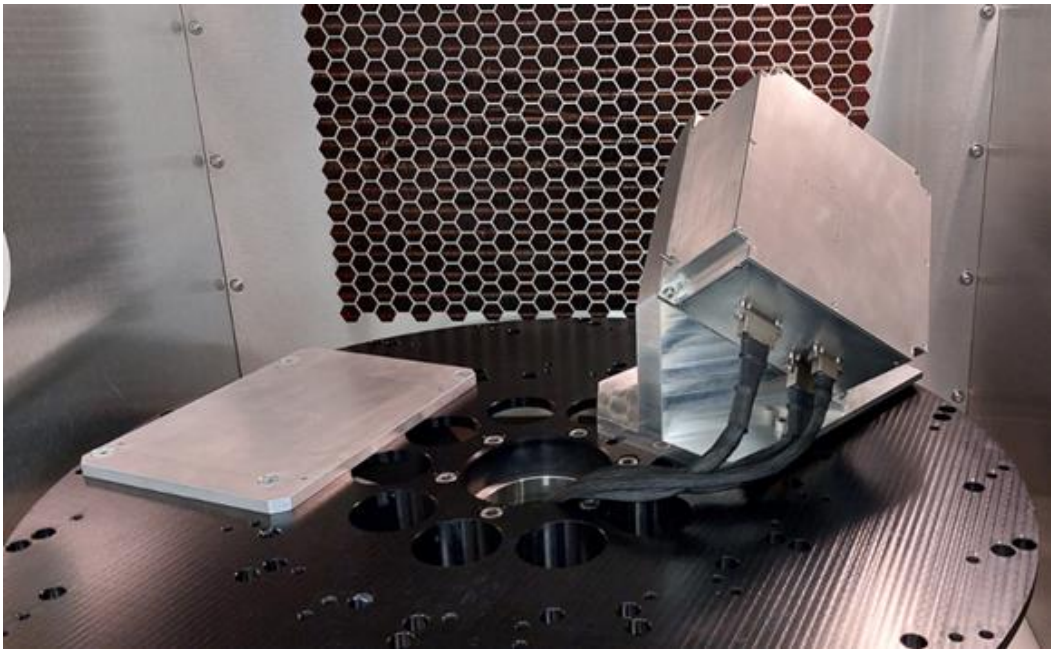

Figure 10. ARIETIS in bias performance test in Innalabs thermal chamber

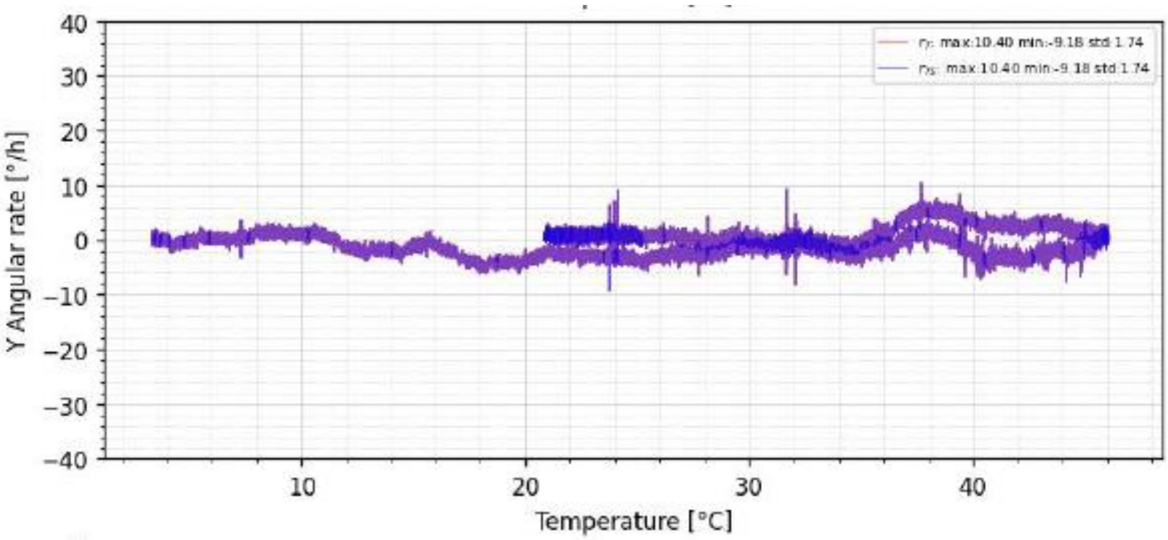

Figure 11. ARIETIS bias stability over temperature

5.2 Allan variance

Figure 12 shows ARIETIS tested for noise, including Allan Variance, over a marble plinth connected to bedrock. No temperature control of the equipment or of the room is performed.

Figure 13 gives the Allan Variance plot of an Engineering model 3 axes measured at ambient temperature in laboratory conditions (temperature not controlled). The achieved bias in-run stability vary between 0.02 and 0.04 °/hr (1σ) and the Angular Random Walk (ARW) spans between 0.00073 °/√hr (-1/2 slope) for the Y axis and 0.0024 °/√hr for the Z axis. This show significant margin with respect to the 0.005 °/√hr specification and show that some additional work is needed to make sure all axis behave in a similar way.A detailed description of the Allan Variance noise analysis method can be found in [5].The test was performed on a gyro with bandwidth of ~4Hz.

Figure 12. ARIETIS Allan Variance evaluation over marble plinth

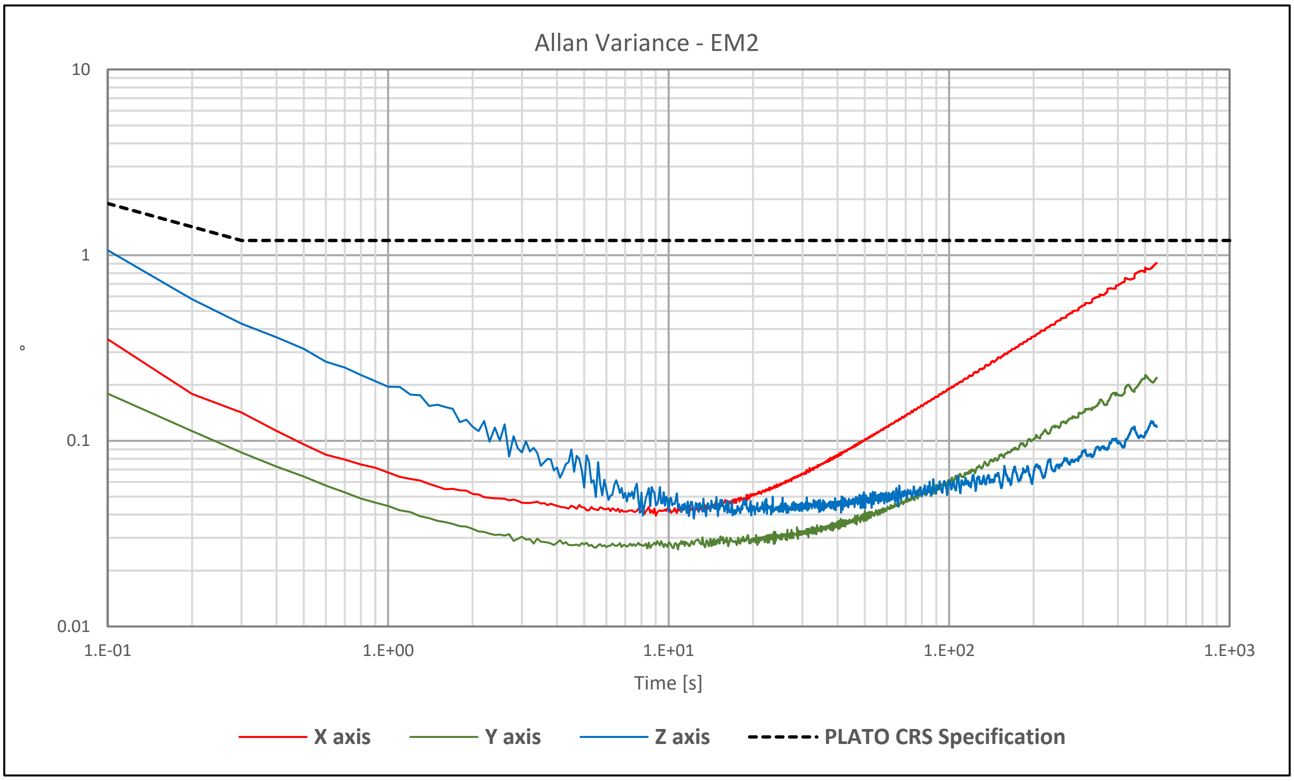

Figure 13. ARIETIS Allan variance

6 ARIETIS-NS TEST RESULTS

This section recollects the main qualification test results to show compliance with specification provided in Table 1.

6.1 Bias stability over temperature

Figure 14 is showing a typical result for bias stability over temperature for the initial and post-shock full performance test. The bias is assessed by recording the static gyroscope output over temperature and subtracting local earth rotation projection, the raw data are then averaged by a 10 sec moving average. The temperature profile follows a 1.5 thermal cycles between -10°C and 60°C with 5°C/hr temperature ramps and 4 hours dwell time at extreme temperatures.

For the initial testing, the maximum bias is 4.5°/hr and the bias stability is 1.3°/hr (1σ). After shock, the maximum bias is 5.7°/hr and the bias stability remains 1.3°/hr (1σ). When comparing the initial and the post shock curves, the bias has shifted by around 4 to 5 °/hr.

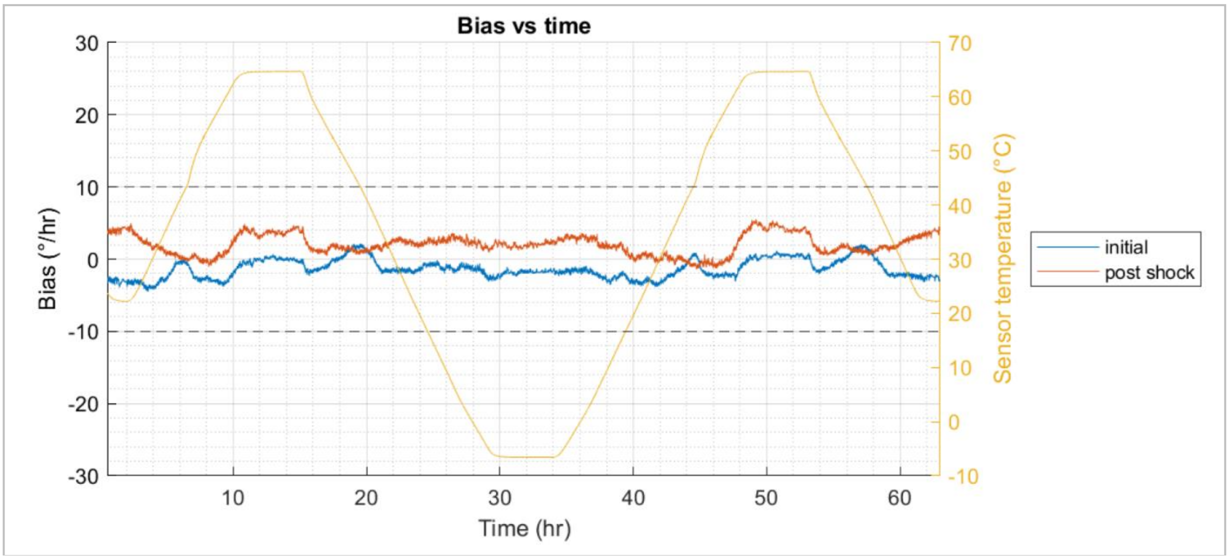

Figure 14. ARIETIS-NS bias stability over temperature (pre and post shock tests)

6.2 Scale factor stability over temperature

Figure 15 is presenting the scale factor error stability over temperature. The scale factor is continuously measured by successive positive and negative rotation steps of 7°/s of 30s each. The temperature profile follows a 1.5 thermal cycles between -10 and 60°C with 5°C/hr temperature ramps and 2 hours dwell time at extreme temperatures. For this axis, the scale factor error stability was reaching 167 ppm (1σ). Note that early Innalabs gyro (as presented in [1]) show scale factor stability in the order of few thousands ppm. Scale factor self calibration allows a scale factor performance that is one order of magnitude better than previous gyros.

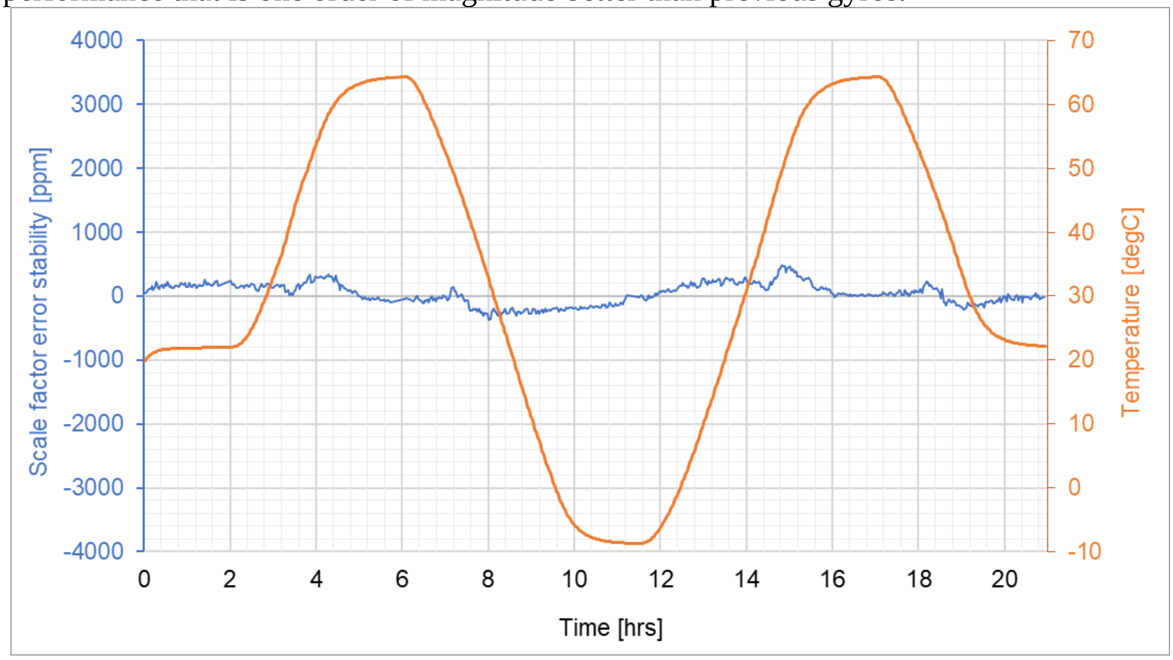

Figure 15. ARIETIS-NS Scale factor stability over temperature

6.3 Allan variance

Figure 16 gives an Allan Variance plot measured at ambient temperature in laboratory conditions (temperature not controlled) for a test duration of 12 hours on an EQM. The achieved bias in-run stability is 0.043 °/hr (1σ) and the Angular Random Walk (ARW) is 0.0028 °/√hr (-1/2 slope).

A detailed description of the Allan Variance noise analysis method can be found in [5].The test was performed on a gyro with bandwidth of 5Hz.

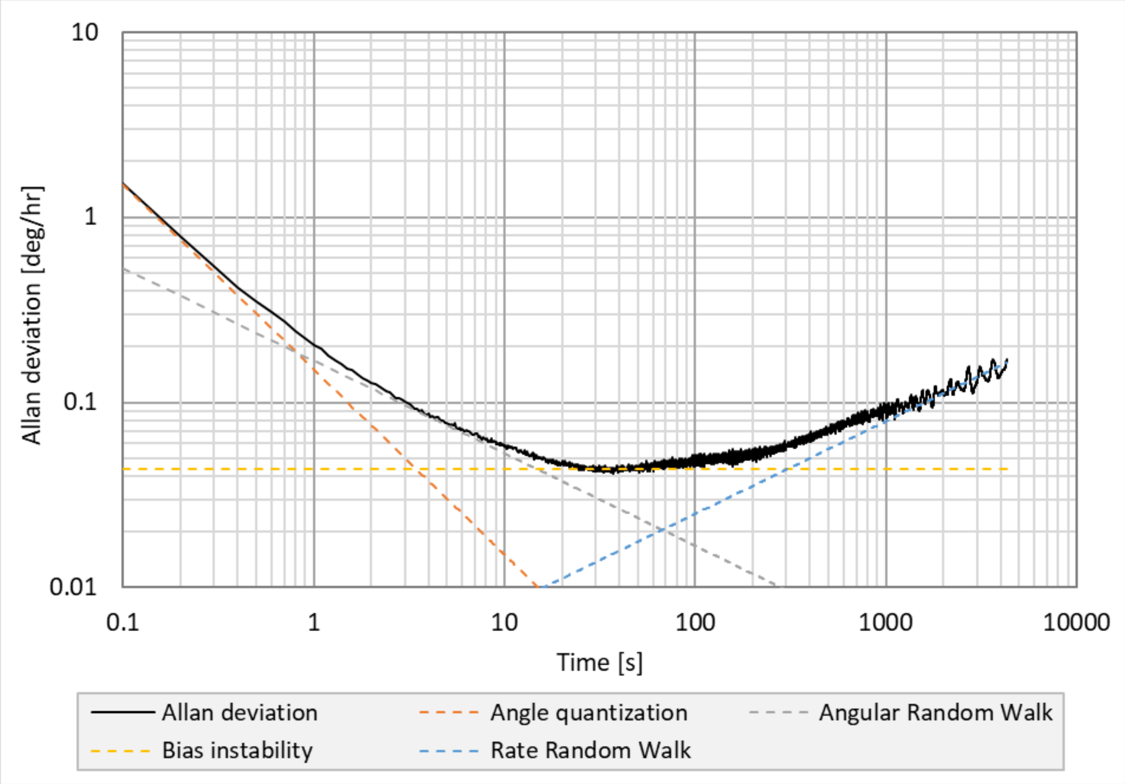

Figure 16. ARIETIS-NS Allan variance

6.4 Environmental tests

ARIETIS-NS was tested under sine vibration at 26.25g. Random vibration profile for both in-plane and out-of-plane is as per Figure 17. Shock profile tested (along the 3 axes) is as per Figure 18. As per Figure 14, gyro performance is within specification when comparing behavior before and after the environmental qualification testing.

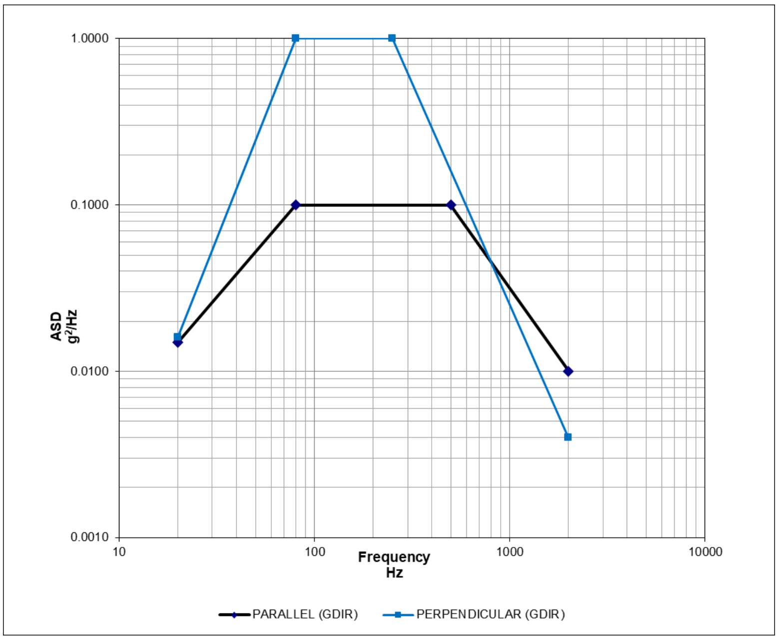

Figure 17. ARIETIS-NS Out-Of-Plane and In-Plane random vibration profile.

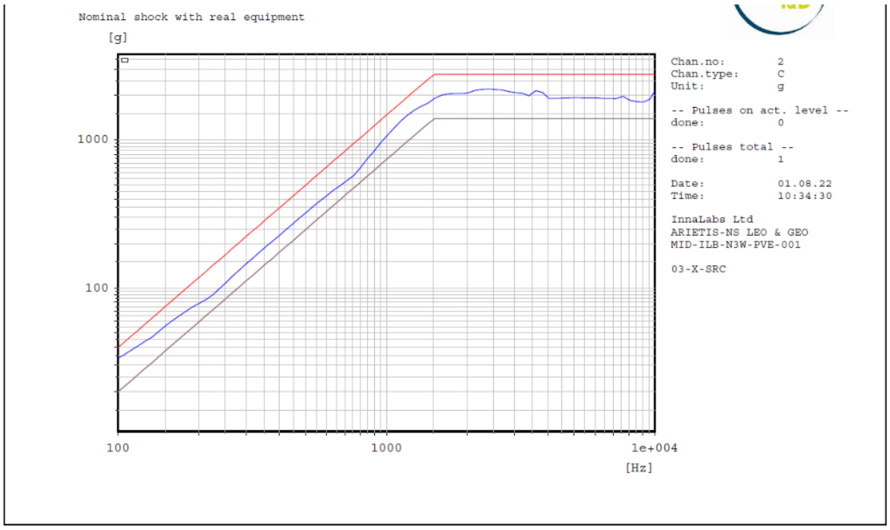

Figure 18. ARIETIS-NS Shock profile tested

6.5 Thermal Vacuum tests

A Thermal Vacuum test consisting of 15 cycles was run on each qualification model. Test profile with ON-OFF approach is presented in Figure 19. Bias performance over the test is presented in Figure 20. Figure 20 also shows a comparison between bias stability during thermal vacuum test and bias tests at ambient pressure. As Innalabs CVG sensors already operate under vacuum and ARIETIS-NS has a low power consumption, bias performance under thermal cycle is identical if tested under vacuum or under ambient pressure.

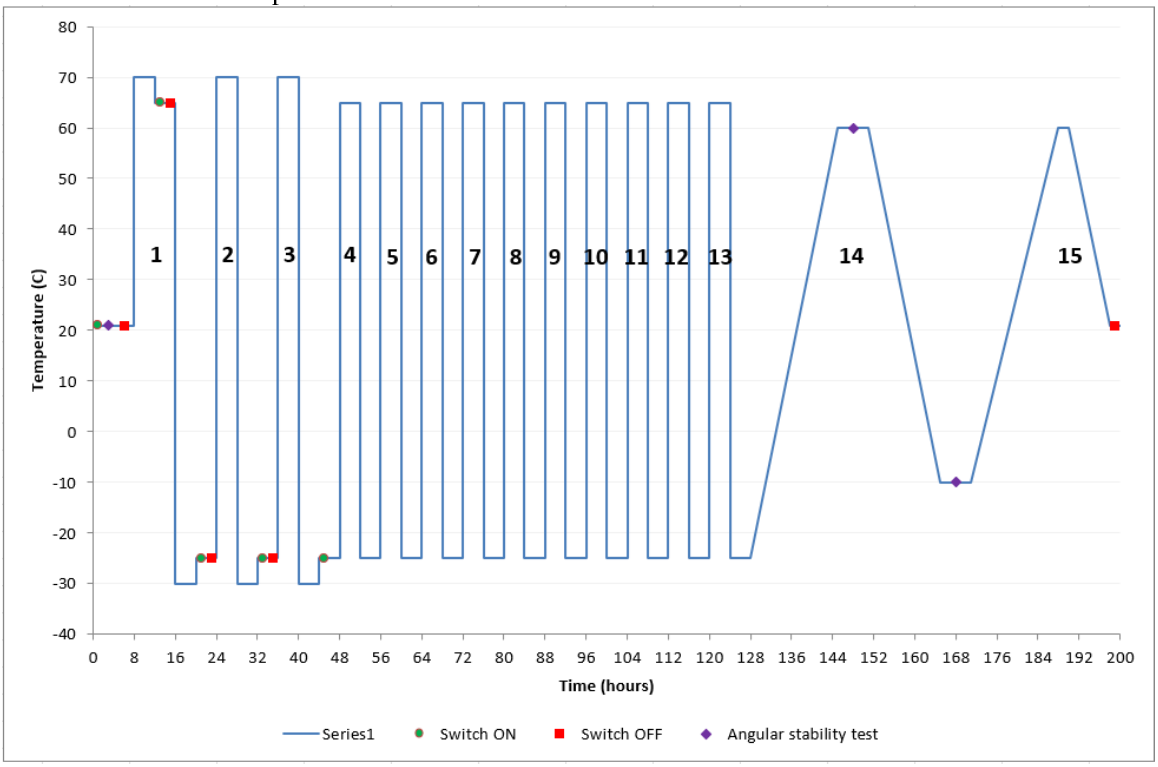

Figure 19. ARIETIS-NS Thermal Vacuum Test profile

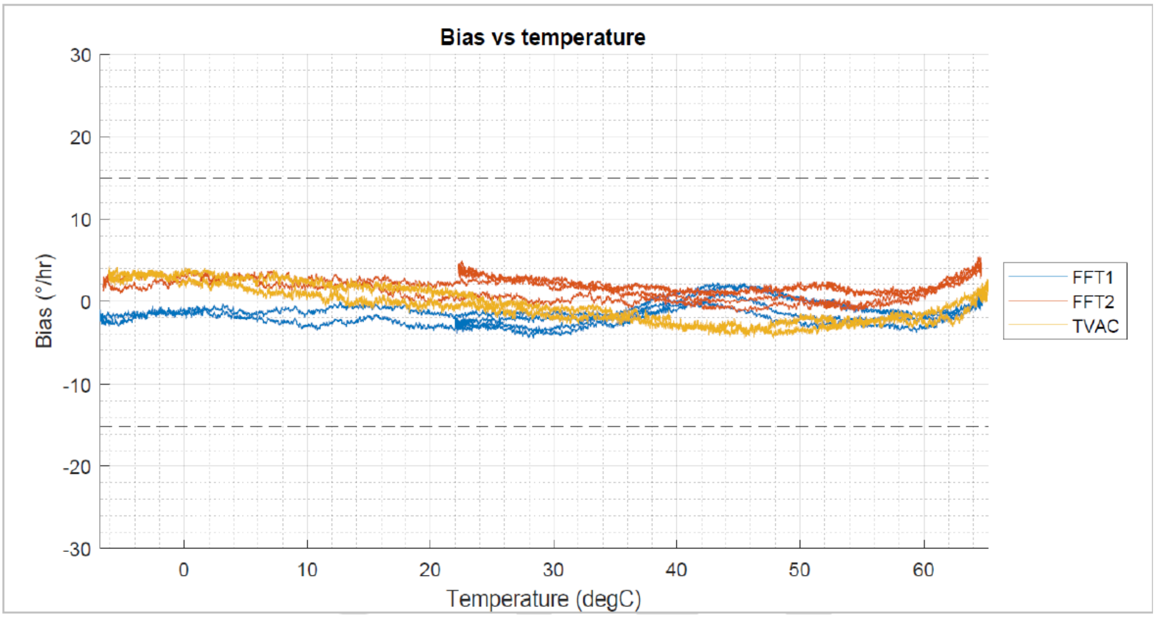

Figure 20. ARIETIS-NS bias output during thermal vacuum (TVAC) in comparison to thermal test at ambient pressure (FFT1 and FFT2)

6.6 EMC tests

ARIETIS-NS was subject to a complete EMC test campaign as per Table 2. As an example of test result, a summary of RE is reported in Figure 21

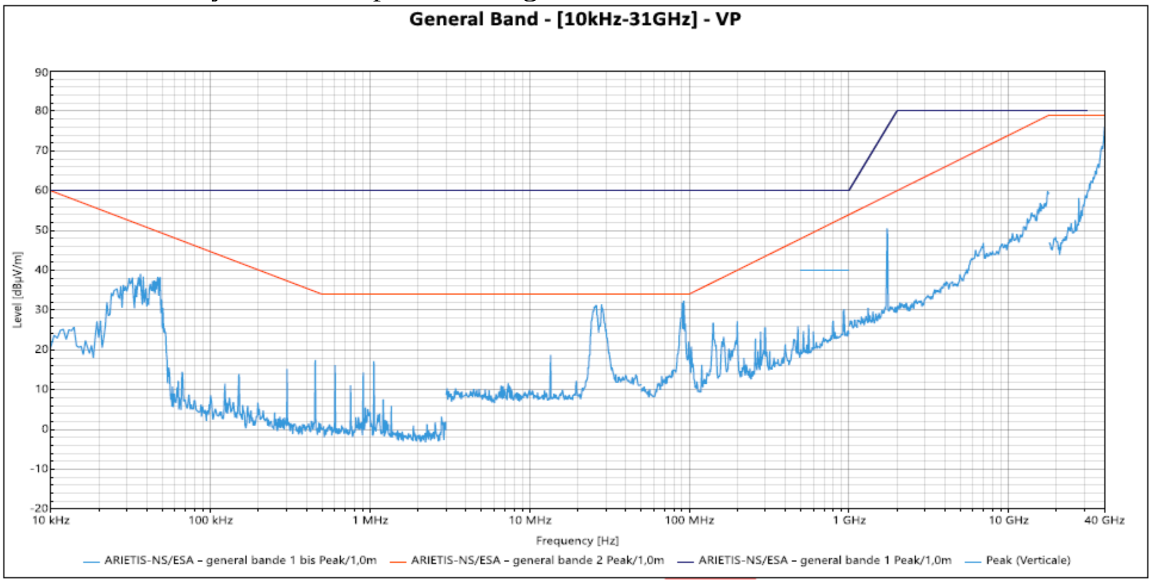

Figure 21. ARIETIS-NS RE test results

7 CONCLUSION

Based on its proprietary CVG technology, InnaLabs developed two 3-axes gyros for space applications, ARIETIS Rad-Hard gyro and ARIETIS-NS rad-tolerant. Both gyros have already been selected for ESA missions (ARIETIS as Coarse Rate Sensor on Plato and as main gyro on LSTM and ARIEL, ARIETIS-NS as main gyro on Hera) and ARIETIS-NS has been selected for multiple

platforms in both LEO and GEO. The two equipment share similar performance specification as the main difference between the two is the Product Assurance approach and the type of EEE used.
At Engineering Model level, ARIETIS shows that noise and bias performance exceed specification, with significant margins in case of noise. Minor evolution of the products were introduced for the Engineering Qualification Model that is currently in manufacturing and that will be used for formal qualification of the product.
ARIETIS-NS design is now frozen, engineering models were shipped to a number of customers, qualification finished and flight models will be shipped in a few weeks. Qualification tests show that the gyro meet specification, sometimes with significant margins. Life tests will be performed over summer 2023 to confirm end of life performance.

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