ARIETIS-NS: Preliminary qualification results of an innovative 3-Axis Space Rad-Tolerant Gyro

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ADCSS 2022
26/10/2022

InnaLabs Company History Timelines

2011

Oct 2011 InnaLabs Limited is formed

2012

New Factory opens in Aug 2012 in Dublin

2014

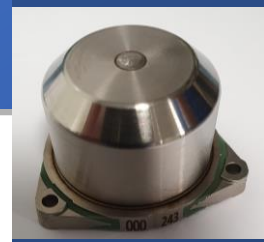
New Gyro Technology Released. First CVG gyros are available to the market

2016

Q Flex Accelerometer family released to the market

2018

Technology selected by ESA for Space development contracts



2020

ESA and European Primes support next generation Space Gyroscopes

2021

Innalabs wins contract to deliver gyros for several missions: HERA, PLATO, LSTM & ARIEL

2022 / 25

Strategic PLAN to move up the value chain by developing Inertial Systems IMU using our own SMART sensors

InnaLabs Manufacturing Capabilities

- **6.000 m² of production area**
- **Clean Rooms**
  - ISO – Class 7
  - ISO - Class 5

  ISO 9001 2015 CERTIFIED
- **Latest state of the art Equipment**
  - Rate Tables
  - Temperature Chambers
  - Shakers
  - High Precision Soldering, Welding and Etching Laser Machines
- **Production Capacity**
  - Gyroscopes – 1000 axes/month
  - Accelerometers – 850 units/month

InnaLabs Space Products

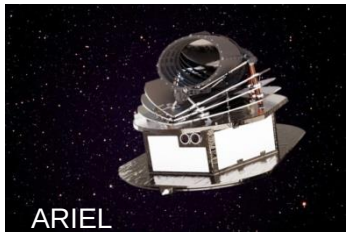
GYROS

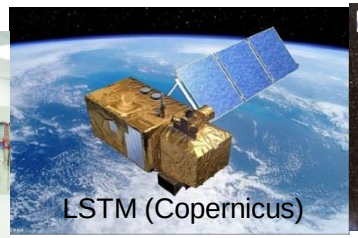
InnaLabs gyro have already accumulated >2,500,000 hours in flight

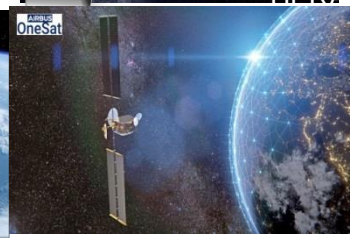
ARIETIS: Rad-Hard

ARIETIS-NS: upscreened COTS

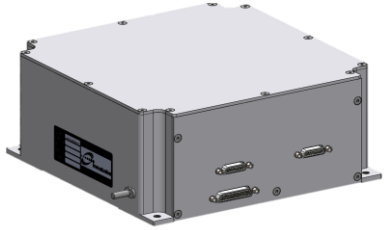
CVG-NS: full COTS solution







ACCELEROMETERS



InnaLabs accelerometers are TRL9 in launchers.

Rad-Hard version being developed

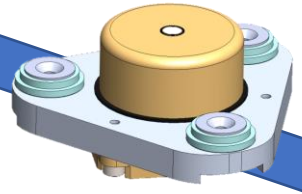
IMU for space applications being developed

InnaLabs CVG Space Heritage

2016

COTS CVG gyro in LEO, **>2,500,000hr** in space since 2016 (19 satellites, 76 × 1-axis gyros, 500km SSO)

CVG sensor used in 3rd party GEO/MEO product (now TRL9, 1st launch in 2022)



2018

Contract to develop the ARIETIS Rad-Hard Space Gyro and ARIETIS-NS Rad-Tolerant Space Gyro by ESA.

2021

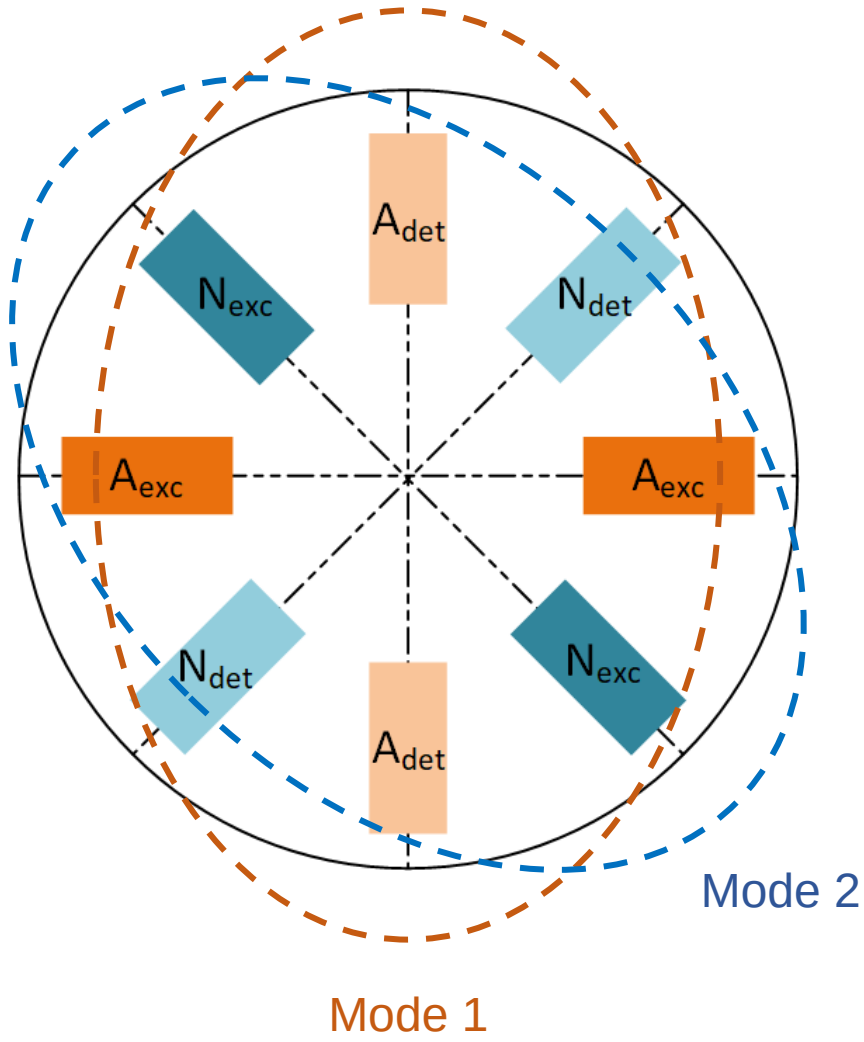
ARIETIS-NS selected by several customers and EM delivered.

2022

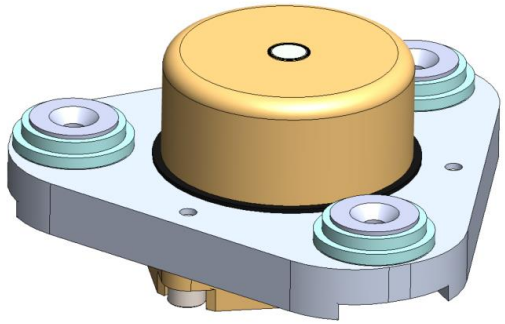
ARIETIS-NS CDR closeout and Qualification Testing

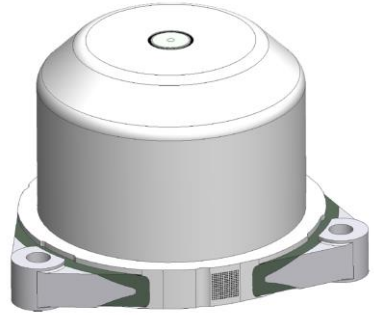
InnaLabs Coriolis Vibratory Gyroscope

- Initially developed in the early 2010 and used across all InnaLabs gyro references since, InnaLabs CVG is based on an axisymmetric resonator made of high-quality metal
- Mode 1 and mode 2 are operated by means of 8 piezo elements
- The nature of the technology, i.e. a metal resonator that needs to operate in vacuum conditions to have the needed Q factor, makes CVG ideal for space applications. No issue with radiations, no moving parts, robust to high shock and vibration environment



InnaLabs CVG element evolution

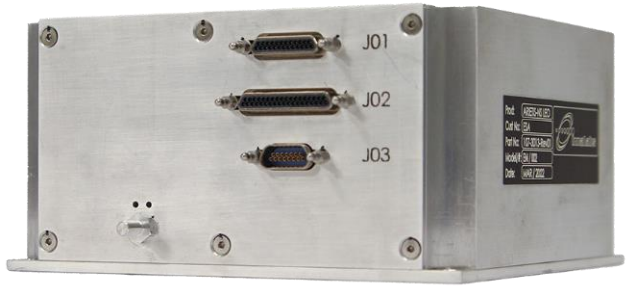




	CVG-1	CVG-2
Size	**Ø 65 mm** x 25 mm	**Ø 45 mm** x 25 mm
Mass	100 grams	65 grams
Damper	External damper flange	**Integrated damper**
Magnetic susceptibility	< 5 °/hr/G	< 1°/hr/G
Qualification	Product qualification for land application	**Space qualification** (ECSS standards) for product, process and parts

Arietis-NS design approach

- 3 axis non redundant **rad-tolerant** medium to high performance gyroscope
  - In terms of performance covers the vast majority of space applications.



- Sensing elements operated through **digital control loops** implemented in FPGAs (contrary to analogue design for other Innalabs products)
  - Use of FPGA allows for new functionalities not present in other Innalabs gyros, including Scale Factor Self Calibration (SFSC)

- **Up screened COTS EEE** parts selected by means of Radiation Lot Acceptance Tests, both Total Ionising Dose (TID) and Single Event Effects (SEE)
  - With the same electronics, two different versions LEO and GEO are created

- **Simplified Functional architecture** simplified with only one operation mode after power
  - Shares functional architecture with ARIETIS, rad-hard space qualified gyro

- Designed for **high production rate**

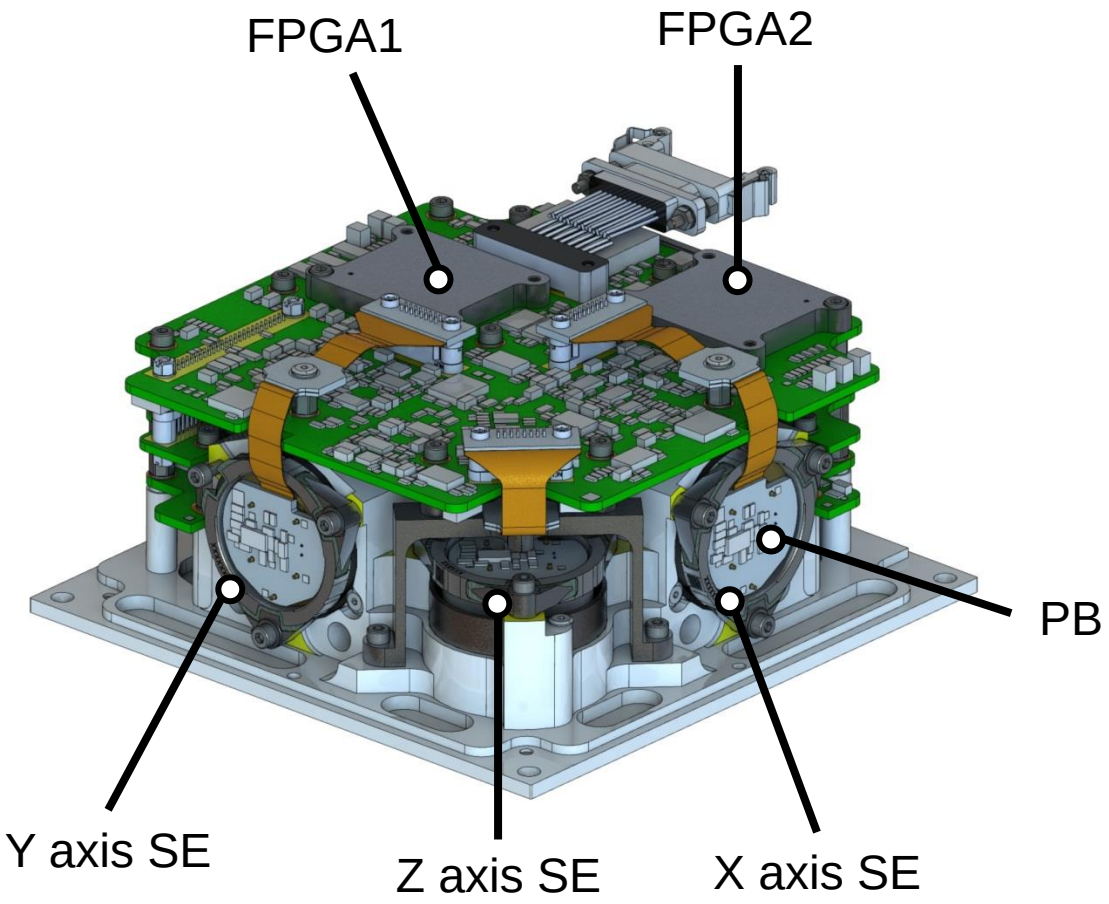
ARIETIS-NS Specification

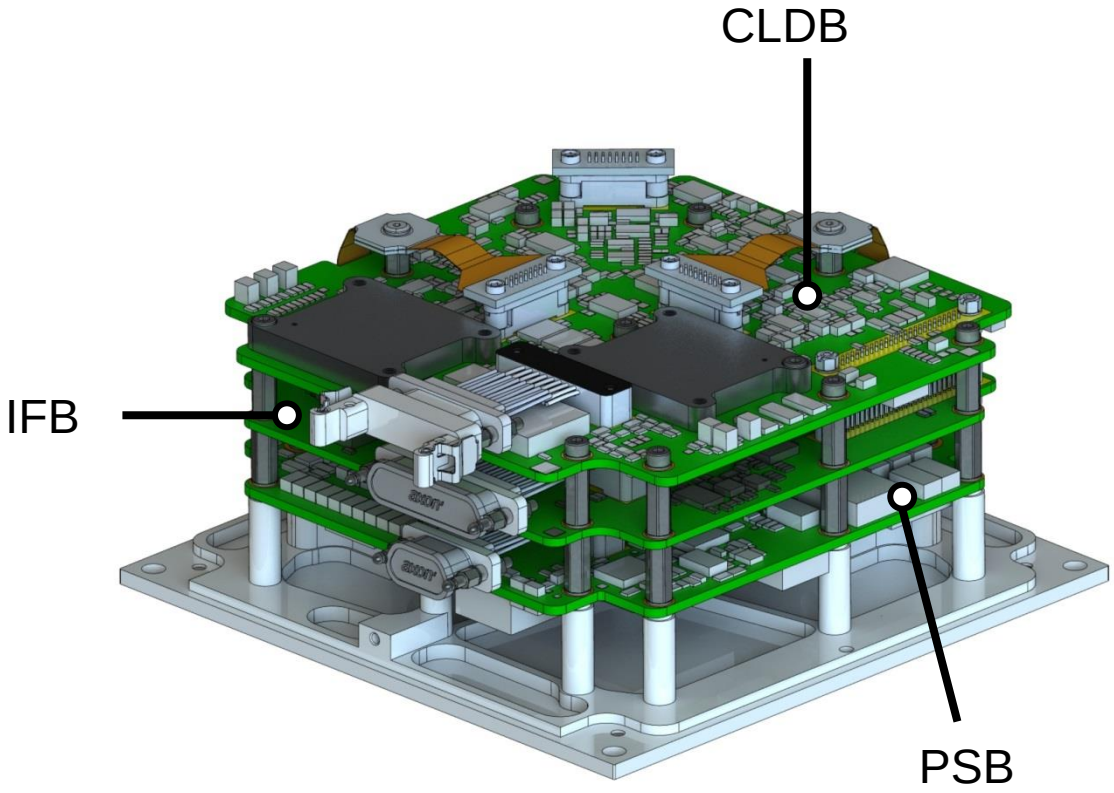
INTERFACE	
TM/TC user interface	RS422 (transmitter only or bidirectional) or RS485 redundant TM output rate up to 500Hz
Ground test interface	RS422 receiver only – not redundant
Power Input	28V (regulated or unregulated) - not redundant.
ENVIRONMENT	
Qualification Temperature Range	[-25°C; +65°C]
Sine vibration level	26.25g
Random vibration level	18.3 g_{rms}
Shock	1500g @ 1500Hz
Radiation	Mostly COTS EEE screened to: • 30krad TID • SEL free till 60MeV.cm^2.mg^{-1} • SET behaviour characterised.

ARIETIS-NS Specification

PERFORMANCES	
Measurement range	[-12°/s; +12°/s]
Bandwidth	5 Hz (for low dynamic mission) 155 Hz (for very dynamic missions)
ARW	<0.005 °/√h
Bias instability	< 0.1 °/hr
Bias - BOL	< 10 °/h (3σ)
SF stability EOL	3000 ppm (3σ) with SFSC 3% (3σ) without SFSC
Magnetic sensitivity	1°/h/Gauss (up to 15 Gauss)
Reliability	1000 FIT (FIDES)
Life	Up to 6 years on ground and 16 years in flight
BUDGETS	
Mass	1.3 kg (LEO - 2mm thick housing) 2.3 kg (GEO - 8mm thick housing)
Envelop	130 x 130 x 65 mm (LEO - 2mm thick housing) 142 x 142 x 73 mm (GEO - 8mm thick housing)
Power consumption	< 6W

Arietis-NS internal structure



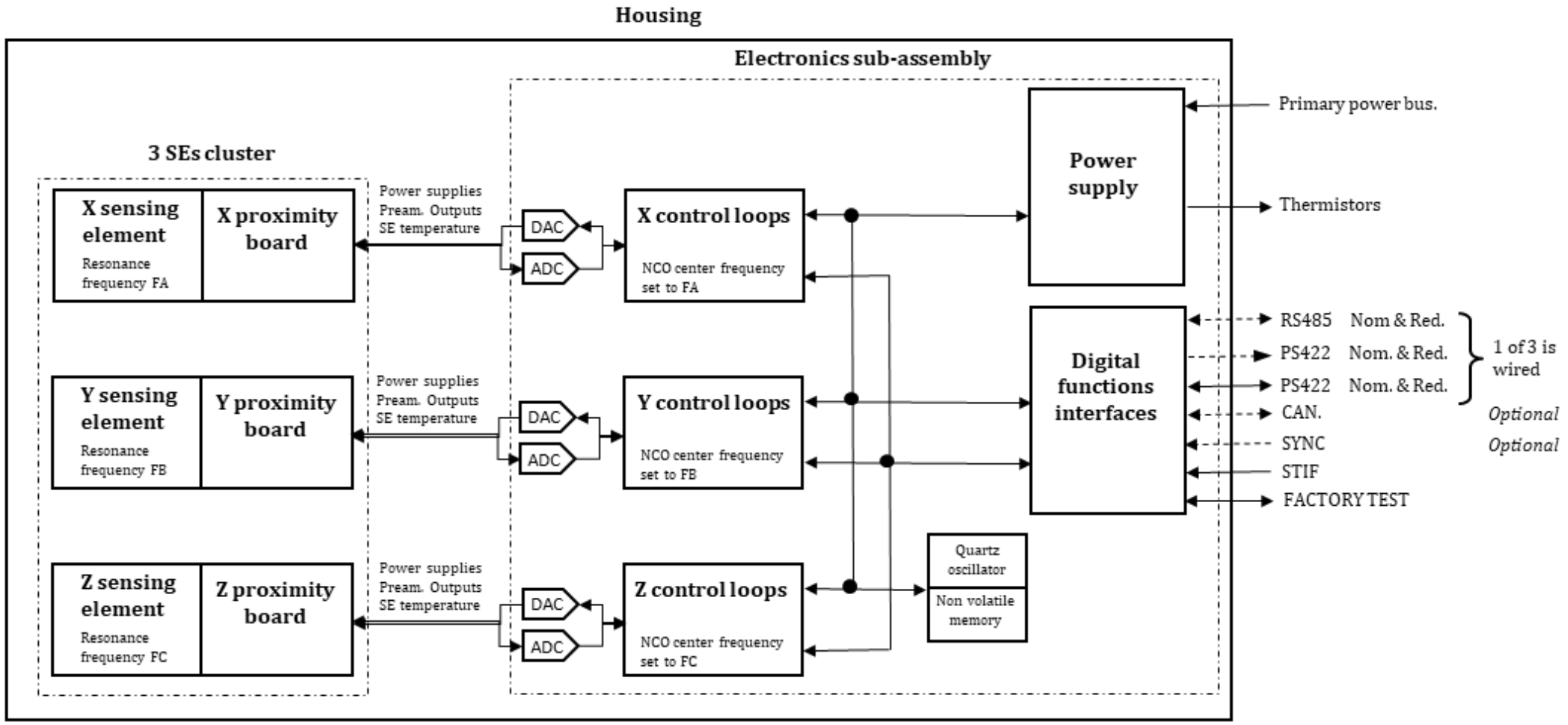


CLDB: Control loop digital board
SE: Sensing element

PB: Proximity board
PSB: Power supply board

IFB: Interface Board

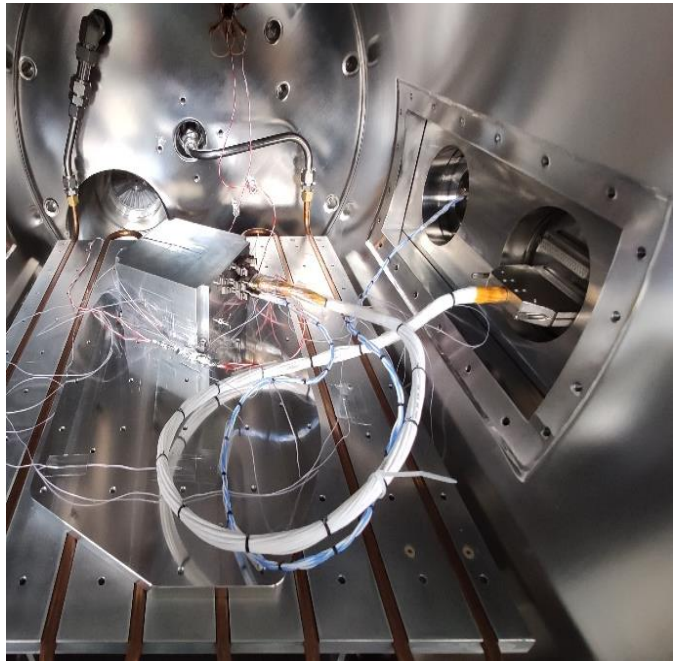
Arietis-NS functional diagram



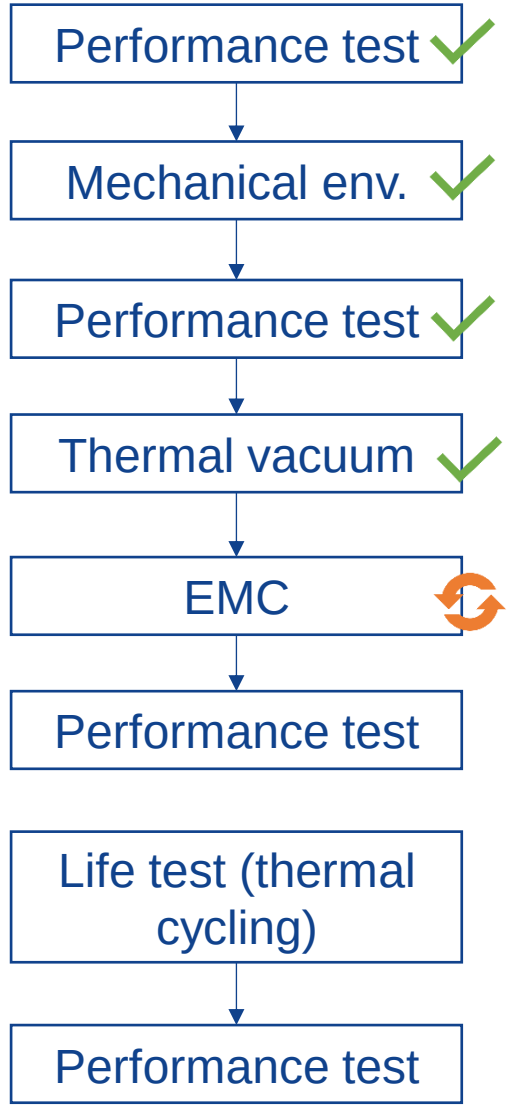
Qualification testing

- Standard ECSS campaign performed.
- 3 different unit with different configurations (LEO, GEO, different data outputs)
- Life test will be performed at the end of the typical ECSS campaign

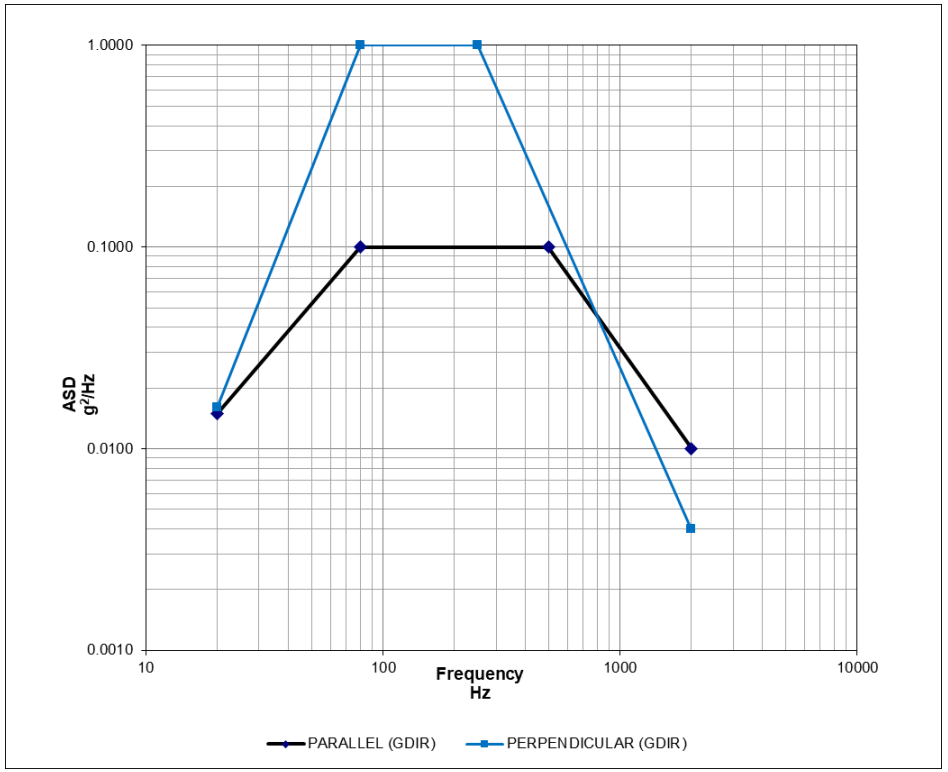
EQM in thermal chamber for performance testing (InnaLabs)



EQM on TVAC chamber (enBio)

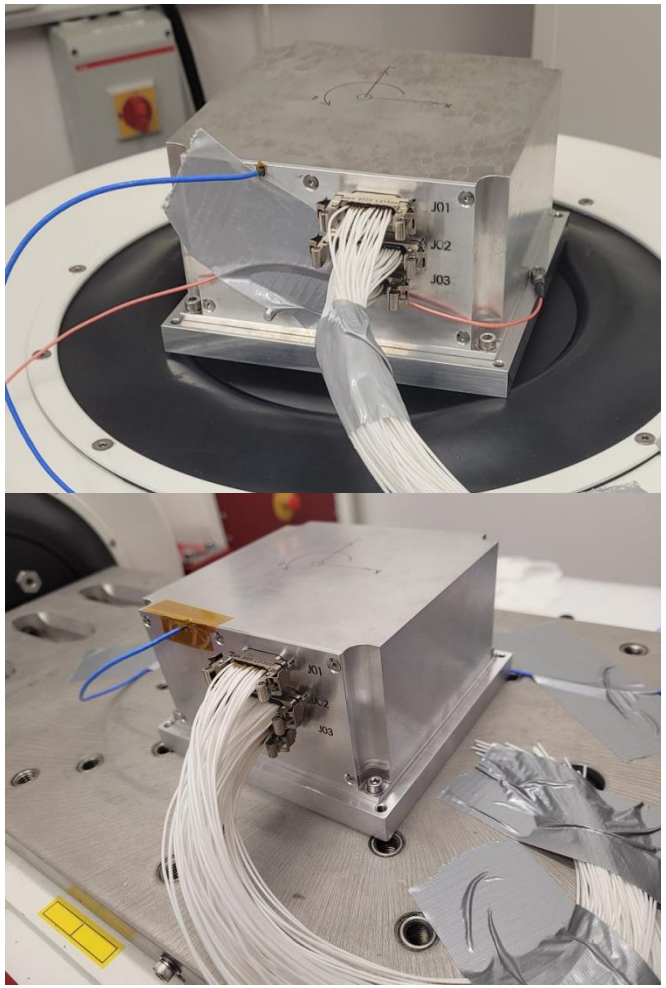


Qualification testing - mechanical



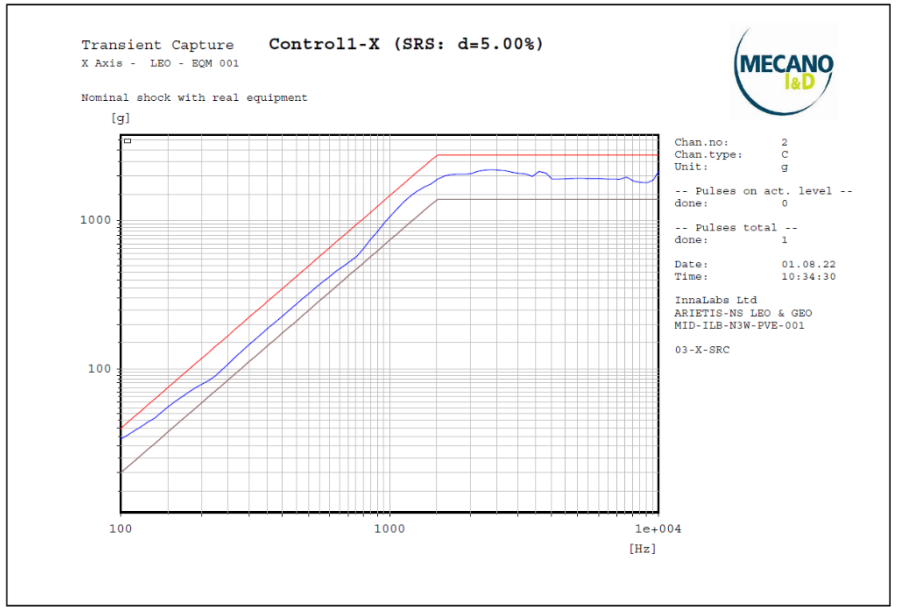
Sine Vibration: 26,25 g

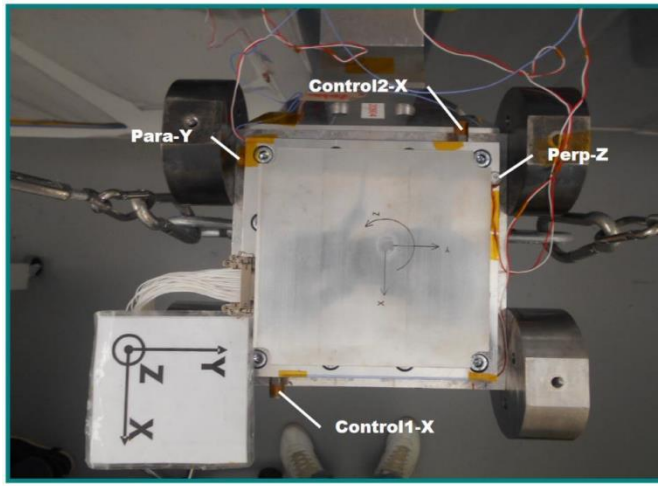
Random Vibration: 18.3 g_{RMS} perpendicular
9.5 g_{RMS} parallel



- Performance test
- Mechanical env.
- Performance test
- Thermal vacuum
- EMC
- Performance test
- Life test (thermal cycling)
- Performance test

Qualification testing - mechanical

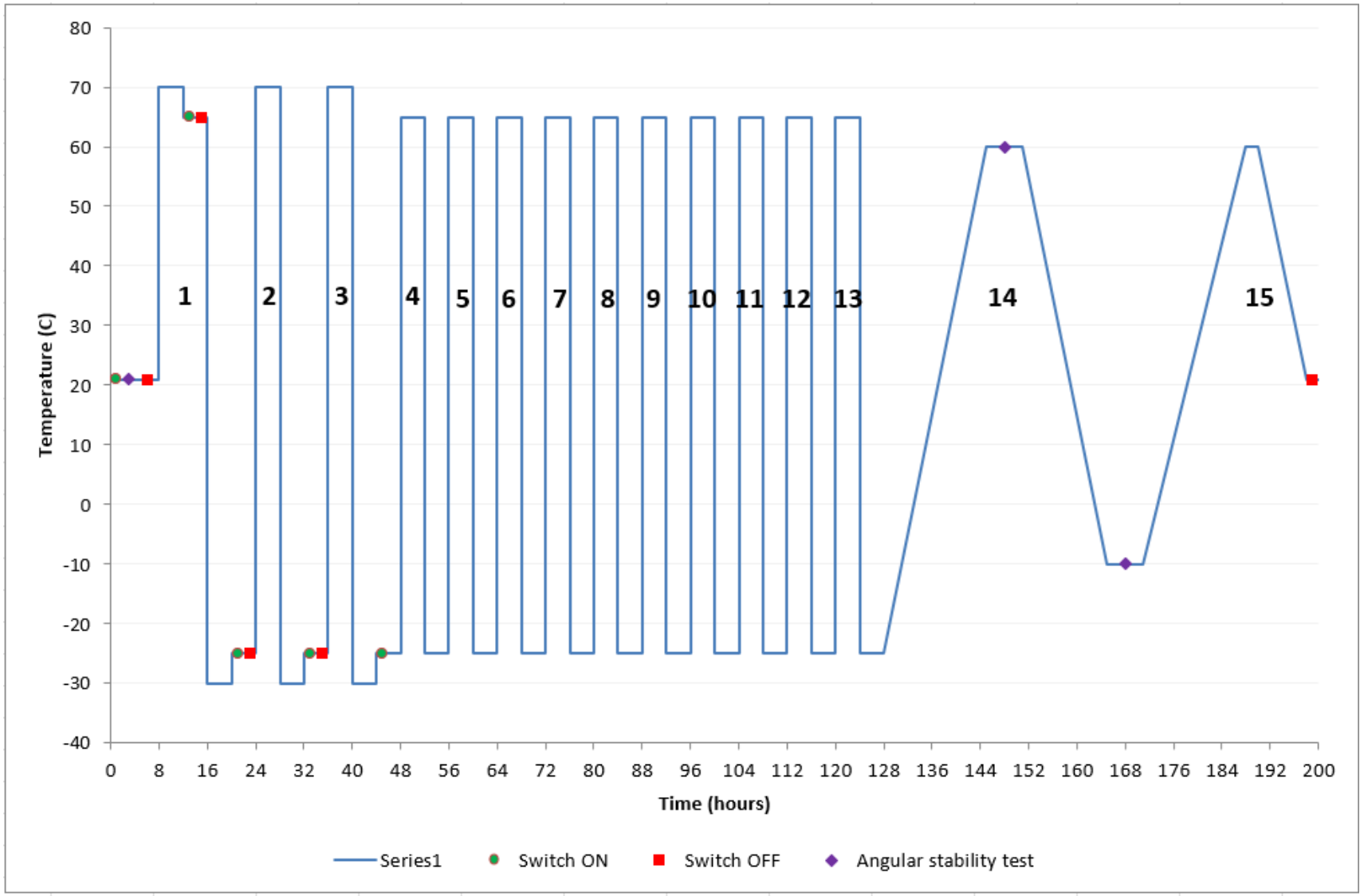




Shock: 1500g @ 1500 Hz SRS

- Performance test
- **Mechanical env.**
- Performance test
- Thermal vacuum
- EMC
- Performance test
- Life test (thermal cycling)
- Performance test

Qualification testing - TVAC

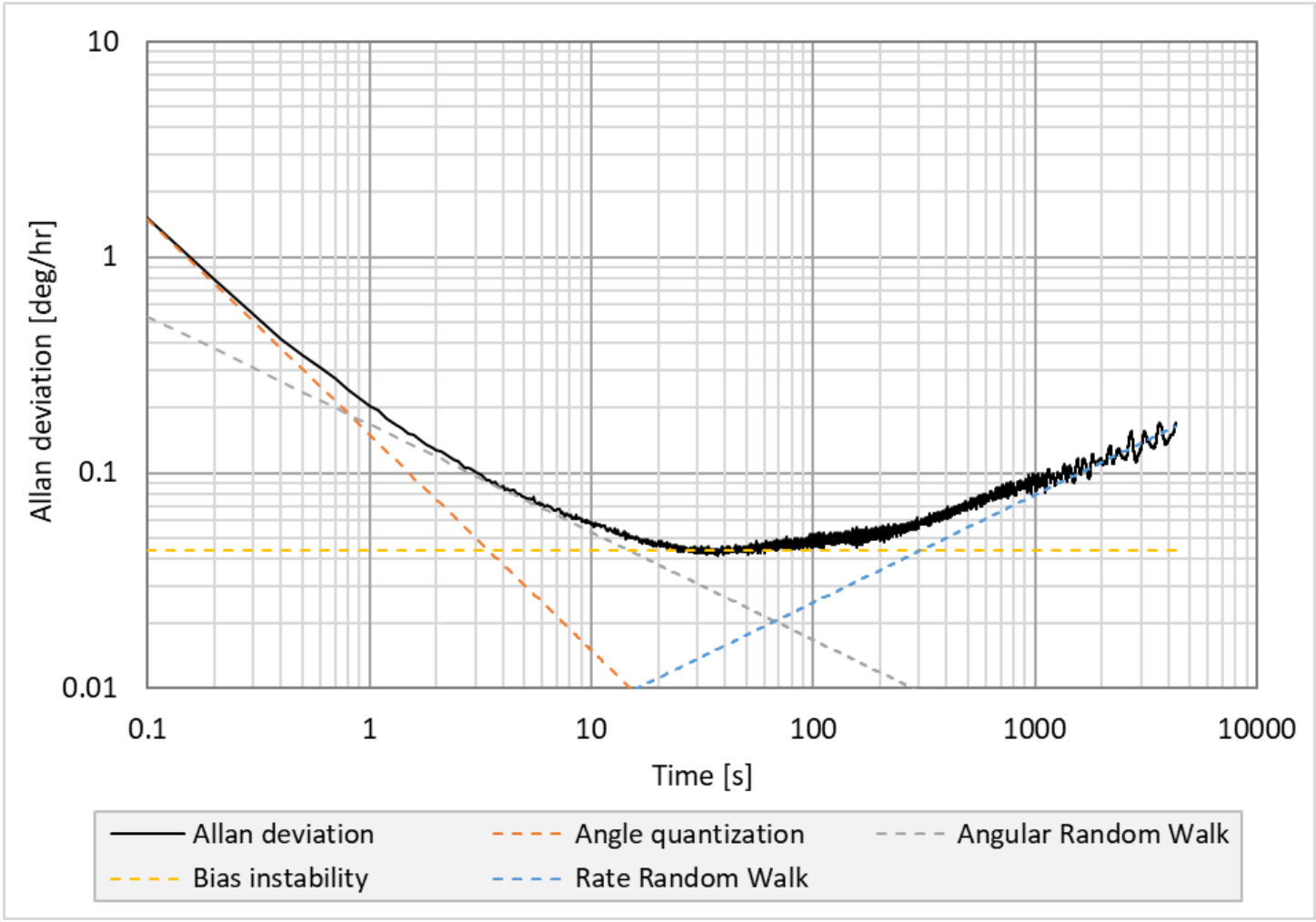


- Performance test
- Mechanical env.
- Performance test
- **Thermal vacuum**
- EMC
- Performance test
- Life test (thermal cycling)
- Performance test

Qualification testing – Noise Performance

Noise measurement

- Based on a 12hrs static measurement on a marble at ambient condition (temperature not controlled)
- **Average angular random walk below 0.003** °/√hr with a minimum of 0.0015 °/√hr
- **Average bias instability is 0.067 °/hr** with a minimum at 0.04 °/hr

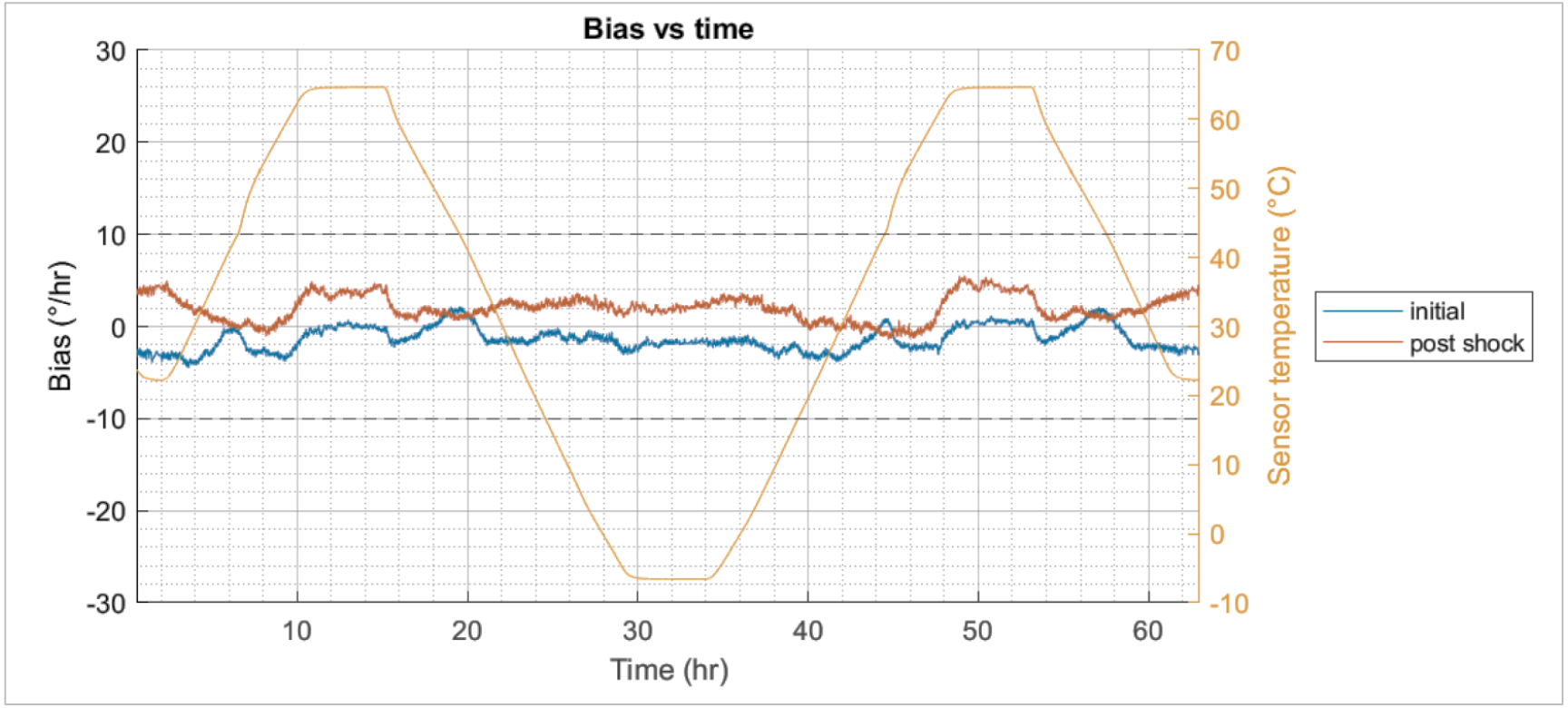


Qualification testing – Bias Performance

Bias stability over temperature & with mechanical environment

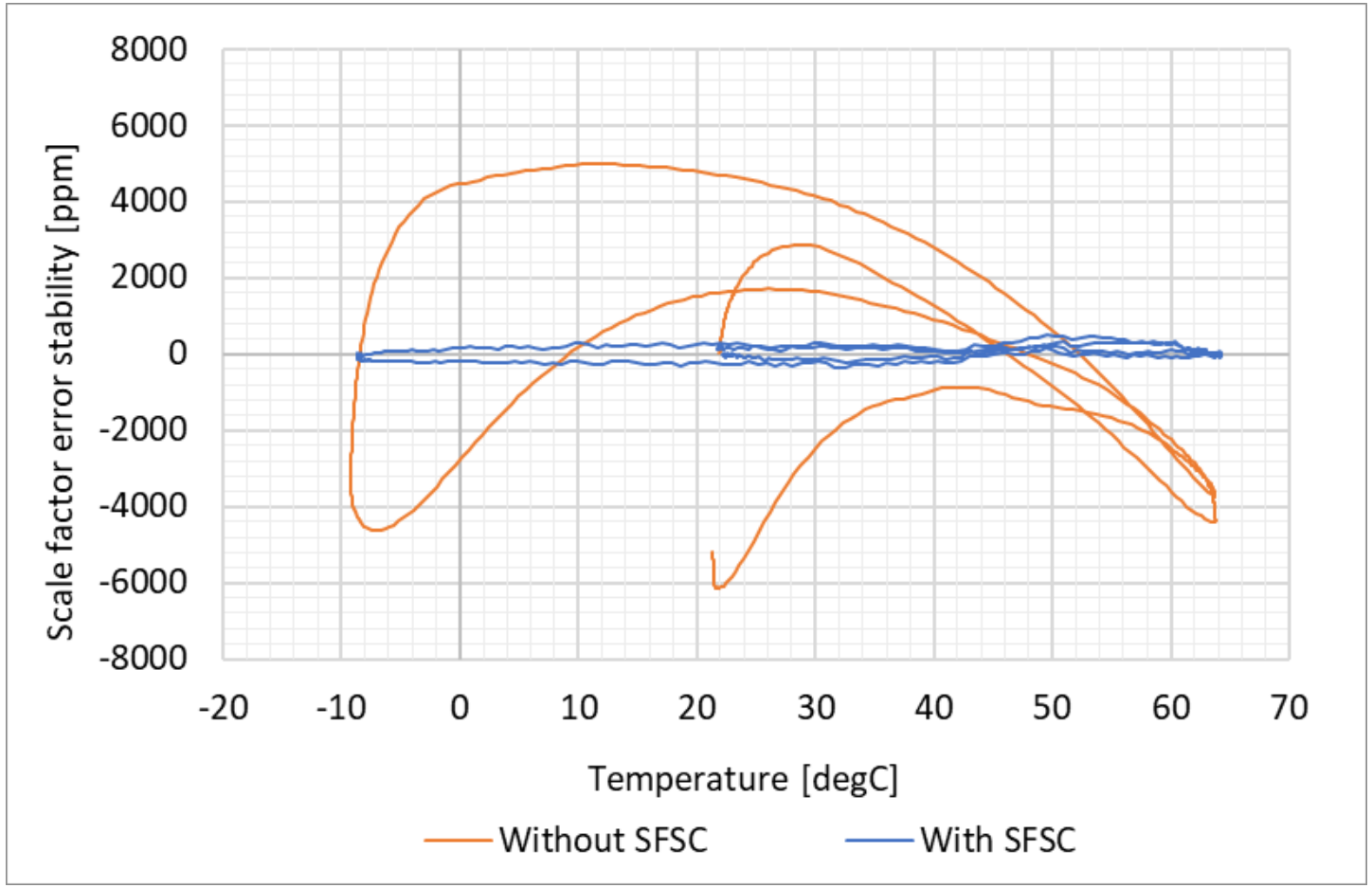
- Bias is measured over -10/60°C temperature range with 5°C/hr ramps and 4 hours dwell time

- Average bias stability over temperature is below 3 °/hr (1σ). After mechanical environment, the absolute bias is drifting by 5 °/hr on average but the stability over temperature remains very close from the initial



Qualification testing – Scale Factor Performance

- Scale Factor Self Calibration (SFSC) is a new patented feature allowed by the digital control loops
- Consists in electromechanical gains measurement on the secondary mode through the injection of a stimuli
- Improve the scale factor error stability over temperature and over time by a factor of at least 10x
- For example, on EQMs (see figure on the right), the scale factor stability is around 200 ppm (1σ) with the SFSC and 3000ppm (1σ) without SFSC



Conclusion

- Innalabs has demonstrated the capability of achieving a **fully digital space CVG based gyro design**
- **ARIETIS-NS design is now frozen**, engineering models released, qualification ongoing and flight model currently being built
- Several configurations have been created to **meet various mission profiles**
- All tests (on Engineering Models and Qualification Models) show that **the gyro meet specification**, in certain cases with significant margins.
- ARIETIS-NS has already been selected for telecom, earth observation, science and exploration missions (including ESA HERA mission). Customers span Europe, North America, Asia.
- Thanks to the European Space Agency and Enterprise Ireland for the support in the development and qualification of ARIETIS-NS