Maîtrise de la calibration radiométrique absolue des moyens sols optiques entre 0.4 et 2.5µm

SONIA VALLS – THALES ALENIA SPACE

COMET-OEE – ETALONNAGE AU SOL DES INSTRUMENTS OPTIQUES

25/06/2024

Date : 20/06/2024
Ref : Non référencé
Ref Modele : 83230347-DOC-TAS-FR-011

Sommaire

S. Valls, et al., « OGSE absolute radiometric calibration in VIS and NIR", Proc. ICSO 2020, Vol. 11852, 118524B (2021)

CONTEXT

/// OGSE Radiometric calibration purpose

/// Use case : MOTA for MTG-FCI

Date : 20/06/2024
Ref : Non référencé
Ref Modele : 83230347-DOC-TAS-FR-011

OGSE RADIOMETRIC CALIBRATION PURPOSE

/// Final need : Flight instrument calibrated and fully operational

/// On ground calibration required (in addition to in-flight calibration) :

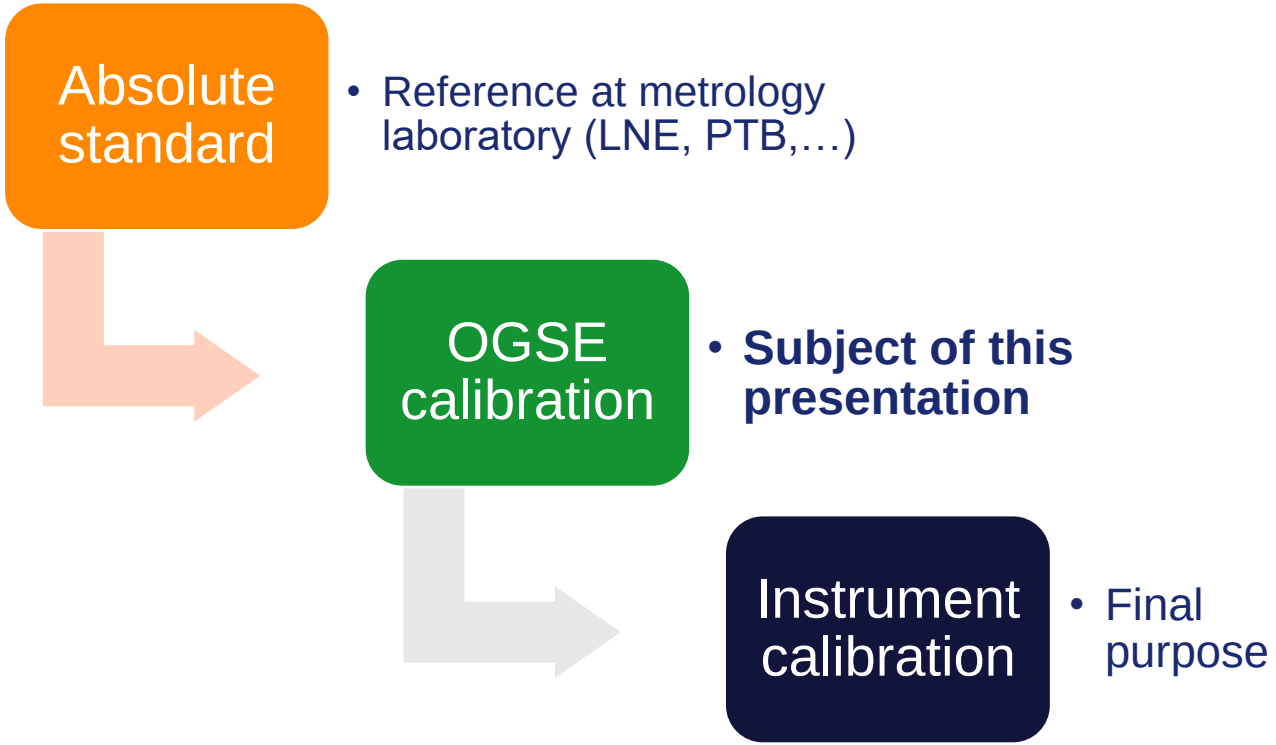
- To validate the performances before launch
- To feed the calibration database

/// On ground calibration of instrument needs :

- Environment representative conditions
- To rely on calibrated OGSE

Date : 20/06/2024
Ref : Non référencé
Ref Modele : 83230347-DOC-TAS-FR-011

OGSE RADIOMETRIC CALIBRATION PURPOSE



Date : 20/06/2024
Ref : Non référencé
Ref Modele : 83230347-DOC-TAS-FR-011

USE CASE : MOTA FOR MTG-FCI

OGSE: Optical ground Support Equipment

MTG-I: Meteosat Third Generation Imager

FCI: Flexible Combined Imager

MOTA : Multi Optical Test Assembly

/// Main instrument for MTG-I is FCI : Imager and Radiometer Instrument

/// Absolute radiometric calibration on-ground requirement :

- 3%
- Over full radiance dynamic
- Over full spectral range

Channel name	central wavelength (nm)	Spectral bandwidth (nm)	Min radiance (W/m².sr.µm)	Max radiance (W/m².sr.µm)
VIS0.4	444	60	5.9	719
VIS0.5	510	40	6.0	722
VIS0.6	640	50	5.2	624
VIS0.8	865	50	3.1	377
VIS0.9	914	20	2.8	220
NIR1.3	1 380	30	1.2	93
NIR1.6	1 610	50	0.8	78
NIR2.2	2 250	50	0.2	22

Date : 20/06/2024
Ref : Non référencé
Ref Modele : 83230347-DOC-TAS-FR-011

USE CASE : MOTA FOR MTG-FCI

OGSE: Optical ground Support Equipment

MTG-I: Meteosat Third Generation Imager

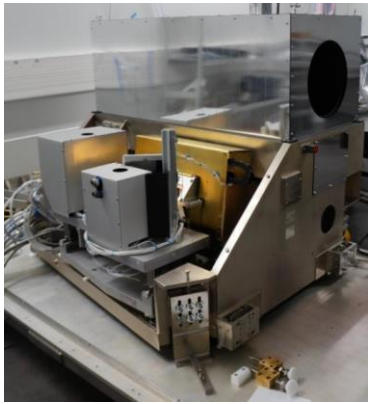
FCI: Flexible Combined Imager

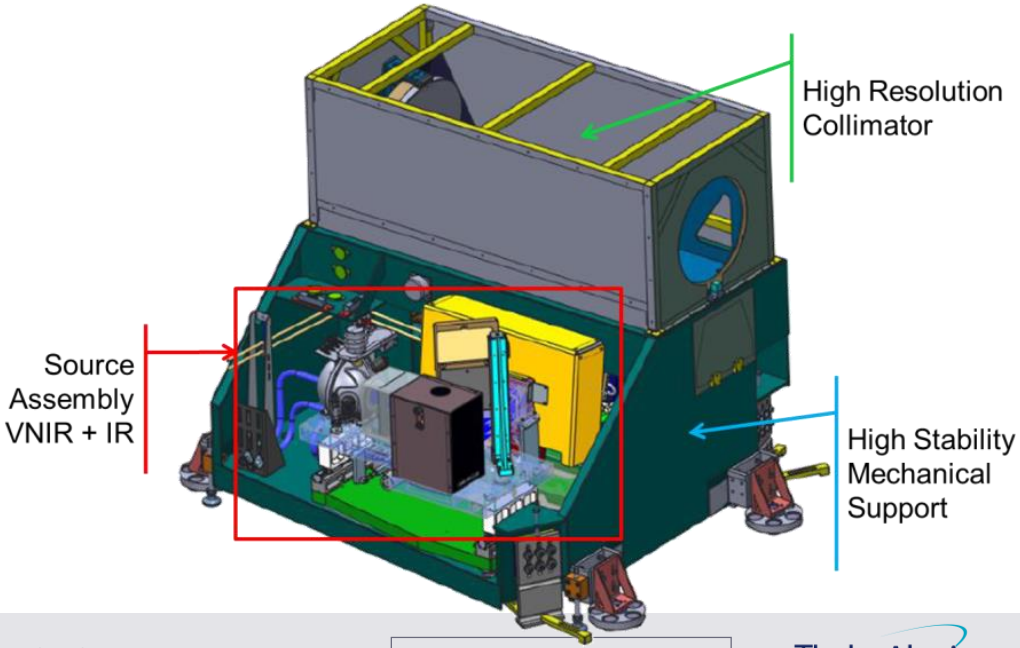
MTF: Modulation Transfer Function

/// MOTA : Multi Optical Test Assembly

/// OGSE dedicated to FCI tests and calibration:

- 440nm – 14.1µm : optical adjustment, MTF characterisation, co-registration, straylight
- 440nm – 2250nm : radiometric relative and absolute calibrations
- Air and vacuum environments
- Large radiance dynamics (2 orders of magnitude)
- High spectral resolution (few nm)





Date : 20/06/2024
Ref : Non référencé
Ref Modele : 83230347-DOC-TAS-FR-011

MANAGEMENT OF MEASUREMENT METHOD

/// Traditional method vs. Transfer method

/// Implementation of spectro-radiometric monitoring

Date : 20/06/2024
Ref : Non référencé
Ref Modele : 83230347-DOC-TAS-FR-011

TRADITIONAL METHOD VS. TRANSFER METHOD

/// Direct calibration (traditional method)

Primary standard
- Metrological laboratory absolute reference

Secondary standard
- Reference detector = **spectro-radiometer**
- Sent to calibration periodically (1 or 2 years)

OGSE
- Calibrated wrt. Secondary standard spectro-radiometer

Monitoring
- OGSE radiance monitored during all Instrument calibration sequence

- Secondary standard absolute calibration 5% to 6% (3σ)

✓ Traditional method

✓ Direct and easy

× Performance limitation for reference detector absolute spectro-radiometric calibration

Date : 20/06/2024
Ref : Non référencé
Ref Modele : 83230347-DOC-TAS-FR-011

TRADITIONAL METHOD VS. TRANSFER METHOD

/// Transfer Method

Primary standard	• Metrological laboratory absolute reference
Secondary standard	• Portable source = **integrating sphere** • Sent to calibration periodically (50h or 6 months)
OGSE	• Calibration transferred from secondary standard to OGSE with spectro-radiometer
Monitoring	• OGSE radiance monitored during all Instrument calibration sequence

- ■ Secondary standard absolute calibration 1.5% to 2.5% (3σ)
- ✓ Spectro-radiometer only contributor: repeatability
- ✗ More hardware needed: secondary standard source + spectro-radiometer

Date : 20/06/2024
Ref : Non référencé
Ref Modele : 83230347-DOC-TAS-FR-011

SPECTRO-RADIOMETRIC MONITORING

MTG: Meteosat Third Generation

FCI: Flexible Combined Imager

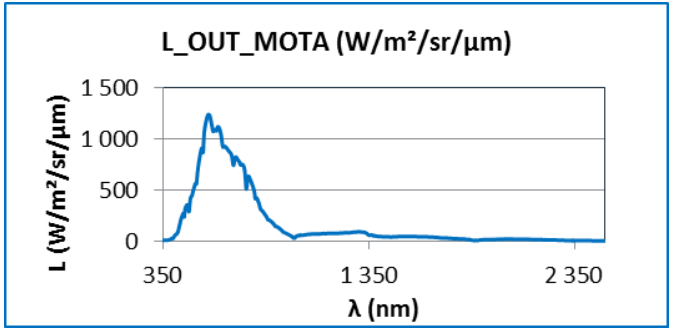
/// MTG-FCI requirements apply on each narrow spectral channel (20 to 60nm)

/// Usual monitoring: photodiode

- Advantage: stability and easy to implement
- Issue: 1 value of integrated radiance over full spectrum ➔ do not detect colour temperature drifts or local spectral variations

/// Implemented new solution: spectro-radiometric monitoring

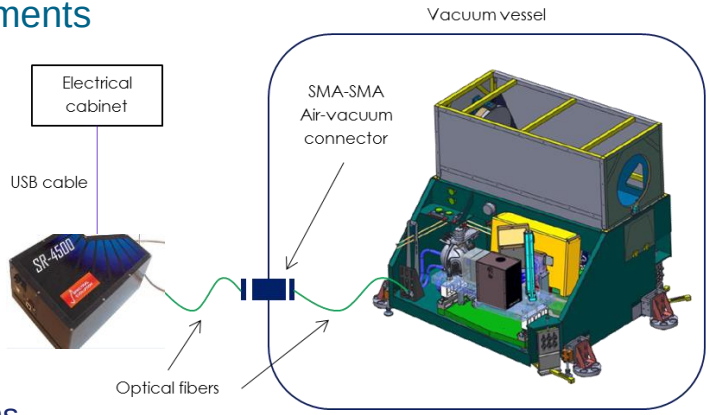
- Monitoring is now a full spectral radiance curve with high spectral resolution



Date : 20/06/2024
Ref : Non référencé
Ref Modele : 83230347-DOC-TAS-FR-011

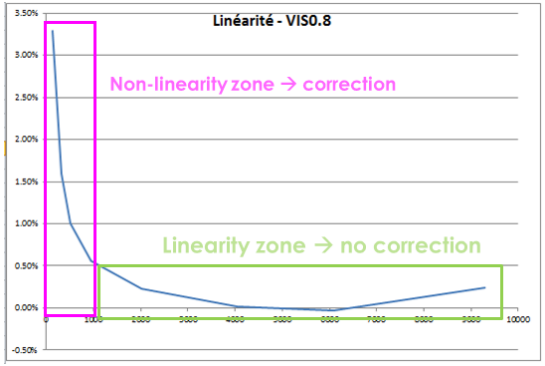
SPECTRO-RADIOMETRIC MONITORING

/// Fibered configuration compatible with air and vacuum environments



/// Spectro-radiometer is SR4500 from Spectral Evolution:

- 3 high performances cooled linear detectors :
  - VIS (350-1000 nm) – 3,5 nm resolution
  - NIR1 (1000-1900nm) – 10 nm resolution
  - NIR2 (1900-2500nm) – 7 nm resolution
- Stability <0.3% on 400-2500nm spectral range and during several months
- Low straylight and high sensitivity: covering whole dynamic



/// In order to reach the performance, non-linearity vs. dynamics has been calibrated for each spectral band

Date : 20/06/2024
Ref : Non référencé
Ref Modele : 83230347-DOC-TAS-FR-011

LIMITATIONS AND IMPROVEMENTS

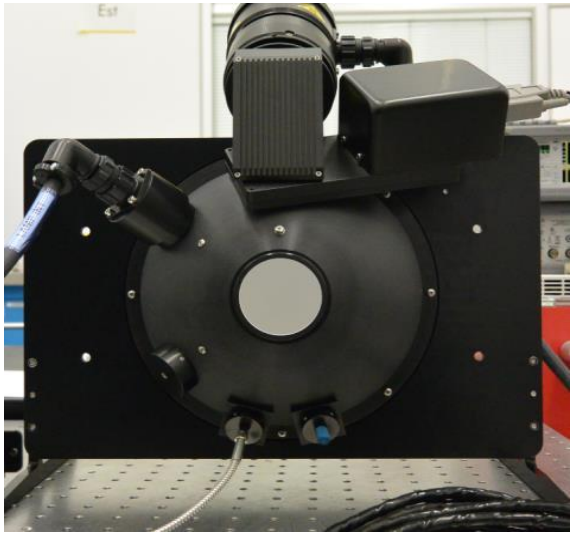
/// Hardware management

/// Environment management:

- air and vacuum
- straylight

Date : 20/06/2024
Ref : Non référencé
Ref Modele : 83230347-DOC-TAS-FR-011

HARDWARE MANAGEMENT



/// Requirements for secondary standard source:

- ISO5 Cleanroom compatibility
- Robust to frequent transports for re-calibrations
- Reproducibility of the configuration of use
- Dimensions and power corresponding to the use case
- Uniformity and stability performances

/// Retained solution :

- Integrating sphere
- Lamp with variable attenuator
- Spectro-radiometric monitoring to follow from metrology to operational use

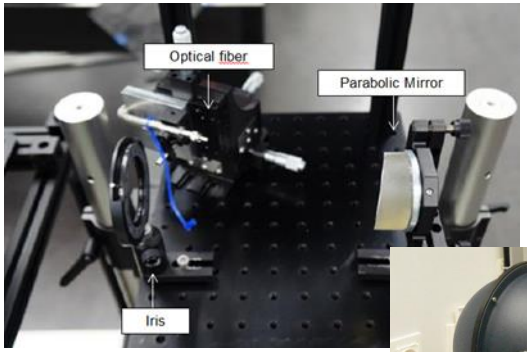
Date : 20/06/2024
Ref : Non référencé
Ref Modele : 83230347-DOC-TAS-FR-011

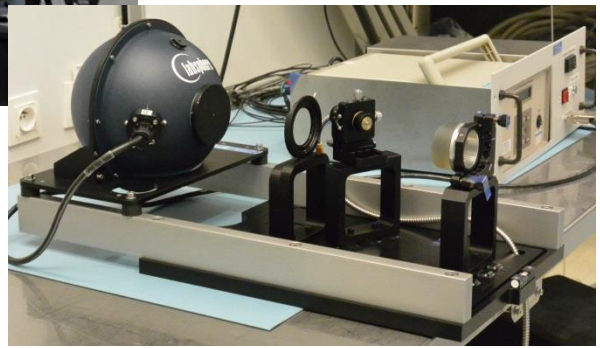
HARDWARE MANAGEMENT

/// Absolute calibration accuracy performance is ensured with high quality hardware: robustness, reproducibility, repeatability

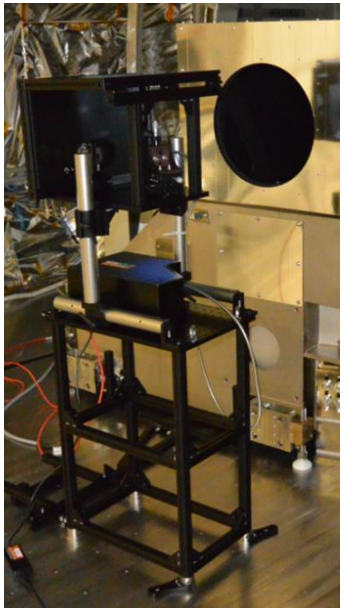
/// Management of hardware and configuration is key skill of AIT team

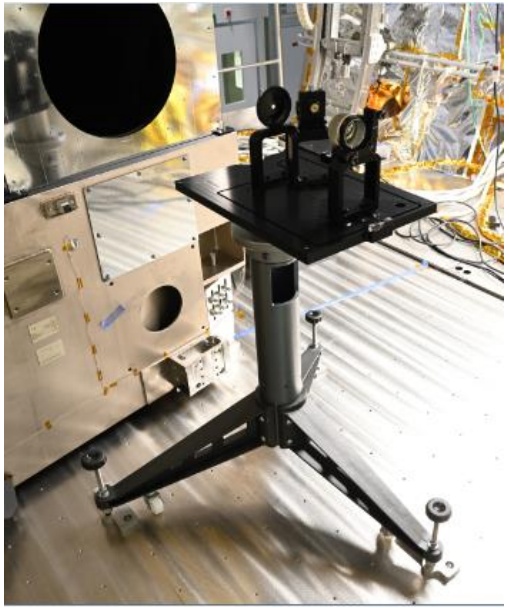
/// Iterative configuration improvements





Radiance head
& 2nd standard





Radiometric calibration bench

Date : 20/06/2024
Ref : Non référencé
Ref Modele : 83230347-DOC-TAS-FR-011

ENVIRONMENT MANAGEMENT: AIR AND VACUUM

OGSE: Optical ground Support Equipment

HR%: Relative Hygrometry

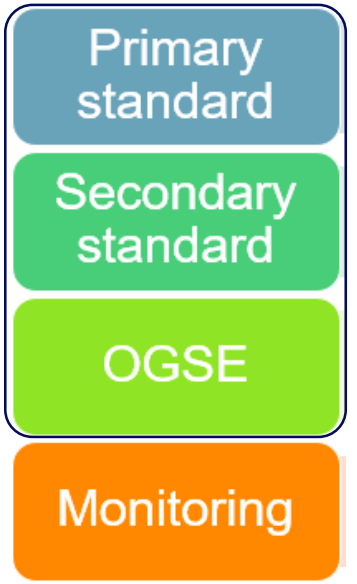
/// Instrument is calibrated under flight-representative environment

➔ OGSE needs to be vacuum compatible but first steps of transfer method has to be run under air environment:

- Primary standard working at ambient
- Spectro-radiometer non vacuum compatible and requires to be close to the sources

/// Air ⇔ vacuum main impact: water vapour absorption in some channels

- HR% measured during secondary standard calibration at metrological laboratory
- HR% measured during transfer measurement between secondary standard and OGSE at Thales Alenia Space
- Deduced correction factor implemented in calibration post-processing

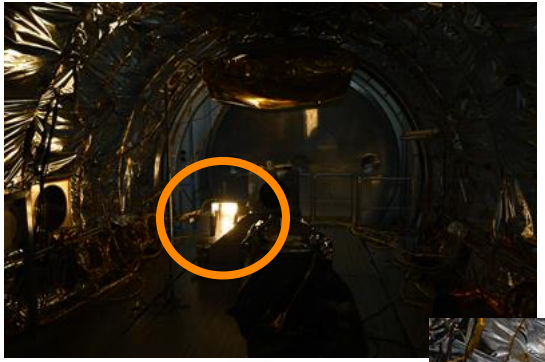


Date : 20/06/2024
Ref : Non référencé
Ref Modele : 83230347-DOC-TAS-FR-011

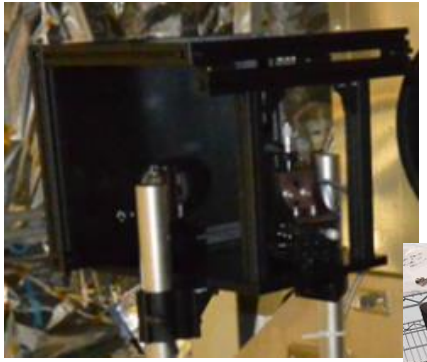
ENVIRONMENT MANAGEMENT: STRAYLIGHT

/// Absolute radiometric calibration requires precise management of straylight in the configuration, especially for low radiance levels

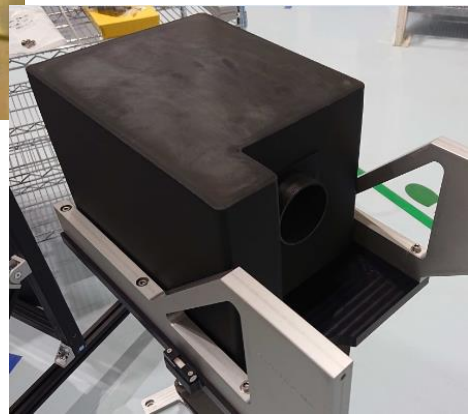
/// Baffles are implemented and optimised for each configuration



MOTA source assembly



Radiance head

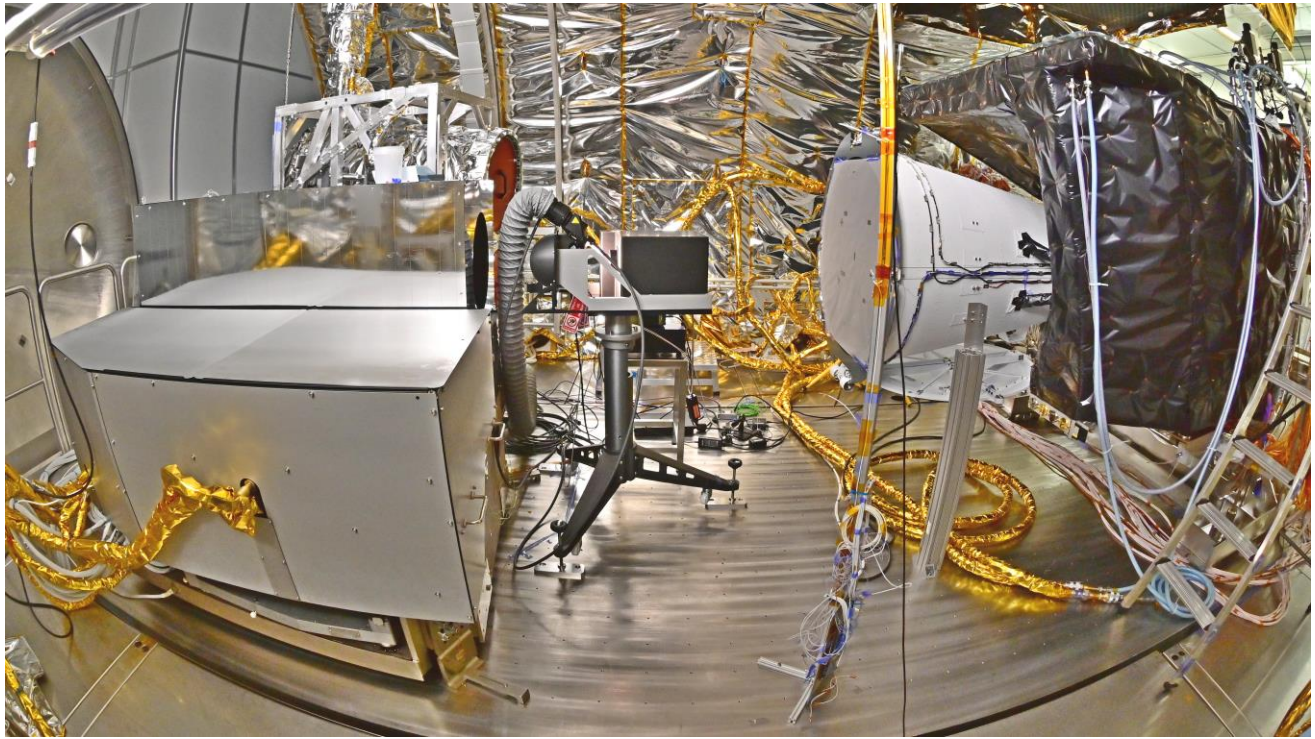


Date : 20/06/2024
Ref : Non référencé
Ref Modele : 83230347-DOC-TAS-FR-011

ENVIRONMENT MANAGEMENT: CONFIGURATION OPTIMISATION

/// MOTA calibration configuration ensures:

- ISO5 compatibility
- Reproducibility
- Compactness
- Ease of use



Date : 20/06/2024
Ref : Non référencé
Ref Modele : 83230347-DOC-TAS-FR-011

CONCLUSION AND WAY-FORWARD

/// An innovative radiometric calibration method has been developed for MTG OGSE:

- Theoretical steps of the transfer method precisely defined
- Spectro-radiometric monitoring during the whole test sequence
- Hardware carefully chosen and improved
- Environments (air & vacuum) properly taken into account
- Configuration iteratively optimised for straylight, repeatability and robustness

➔ Unprecedented level of accuracy reached and confirmed after flight calibration

➔ Industrialisation of the method that can be reused by new teams and adapted for new programs

Date : 20/06/2024
Ref : Non référencé
Ref Modele : 83230347-DOC-TAS-FR-011