Copernicus Sentinel Earth Observation Hyperspectral Instruments - short overview on calibration

Berit Ahlers, Matthias Erdmann (ESA ESTEC); Pepijn Veefkind (KNMI); Marcel Dobber (EUMETSAT)

25th Calcon, Utah 23 Aug 2016

calcon
www.calcon.sdl.usu.edu

KNMI EUMETSAT Copernicus European Space Agency

Initiative headed by the European Commission in partnership with the European Space Agency and EUMETSAT ...

Sentinel-1: Radar Imaging Mission for land and ocean services

Sentinel-2: High resolution wide swath Optical Mission for land services

Sentinel-3: Medium Resolution Optical Imaging and Altimetry Mission

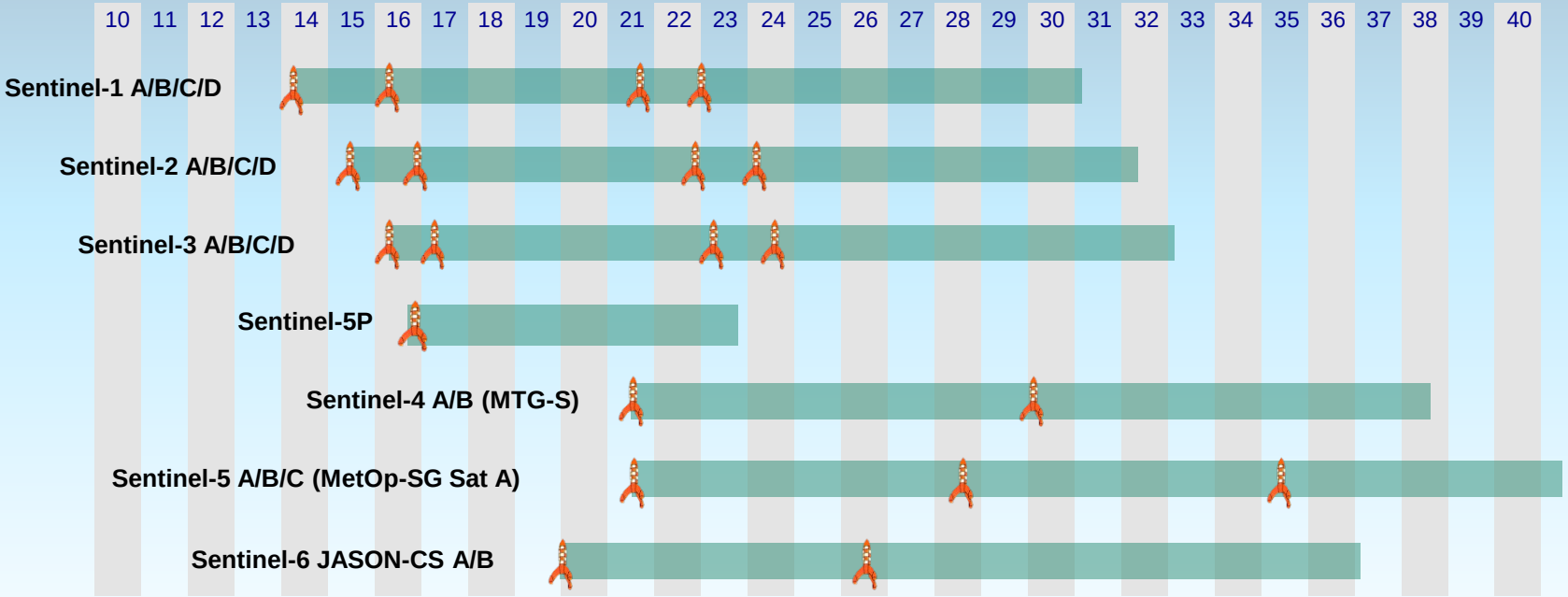
Sentinel-4: Geostationary Atmospheric Chemistry Mission

Sentinel-5P: Low Earth Orbit Atmospheric Chemistry Precursor Mission

Sentinel-5: Low Earth Orbit Atmospheric Chemistry Mission

Sentinel-6, Jason-CS: Altimetry Mission

Sentinels:
7 missions to monitor the Earth



S4, S5, S5p

Sentinel-5 Precursor, developed to reduce data gaps between Envisat, in particular the Sciamachy instrument, and the launch of Sentinel-5, is a joint initiative between ESA and the Netherlands the mission comprises a satellite and a UVNS instrument called TropOMI. TropOMI has been calibrated on-ground last year and will fly in low Earth orbit.

The **Sentinel-4 Ultra-violet / Visible / Near-Infrared** (UVN) sounder covering the needs for continuous monitoring of atmospheric composition in high temporal and spatial resolution from a geostationary orbit, is in phase C.

Sentinel-5, its low Earth orbit 'companion', has finalized the last procurements for its calibration.

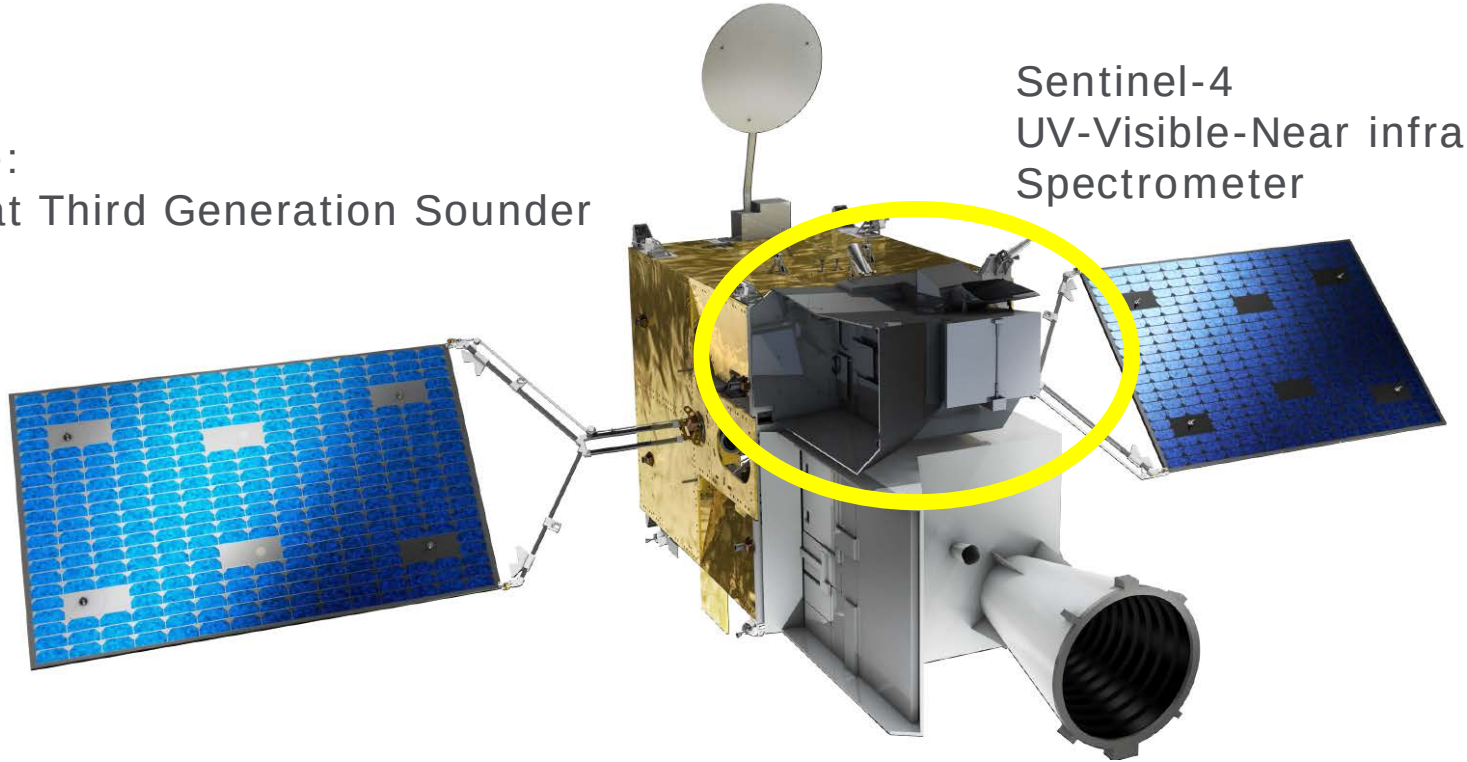
Wavelength coverage

[nm]	S4 (geo)	S5	S5p/TropOMI
UV	-	270-310	270-320
UVVIS	305-500	300-500	320-490
NIR	750-775	685-773	710-775
SWIR1	-	1590-1675	-
SWIR3	-	2305-2385	2305-2385

sentinel-4 on MTG-S

Satellite:
Meteosat Third Generation Sounder

Sentinel-4
UV-Visible-Near infrared (UVN)
Spectrometer

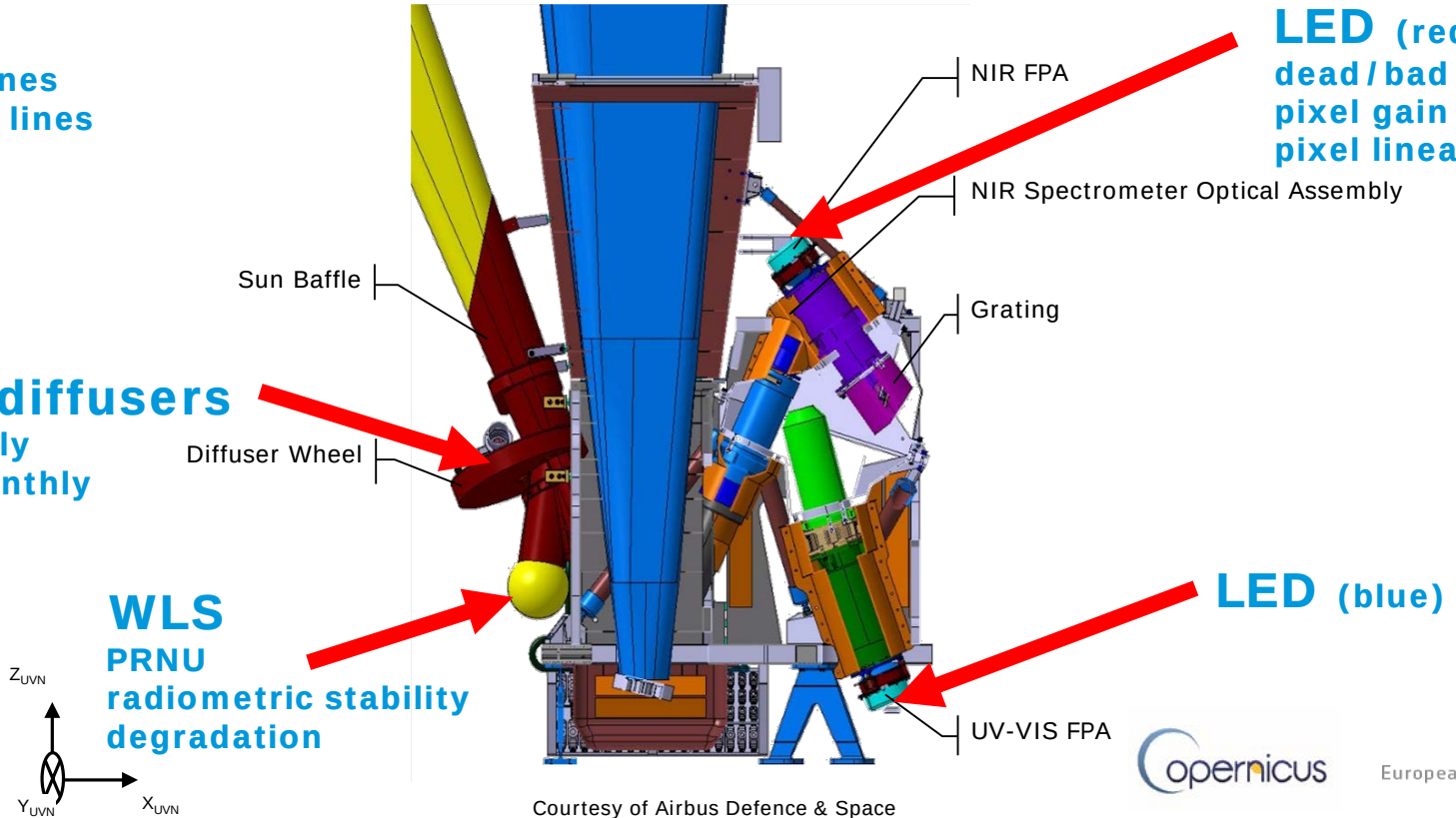


sentinel-4 calibration sources

external
Fraunhofer lines
atmospheric lines
Sun / Moon
zenith sky
stars
OGSE's
vicarious

2 diffusers
daily
monthly

WLS
PRNU
radiometric stability
degradation

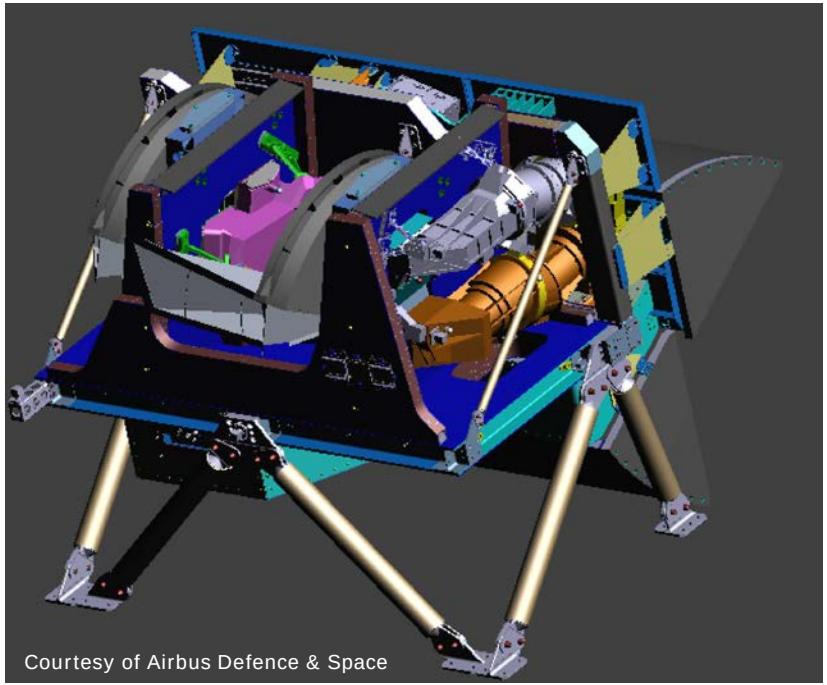


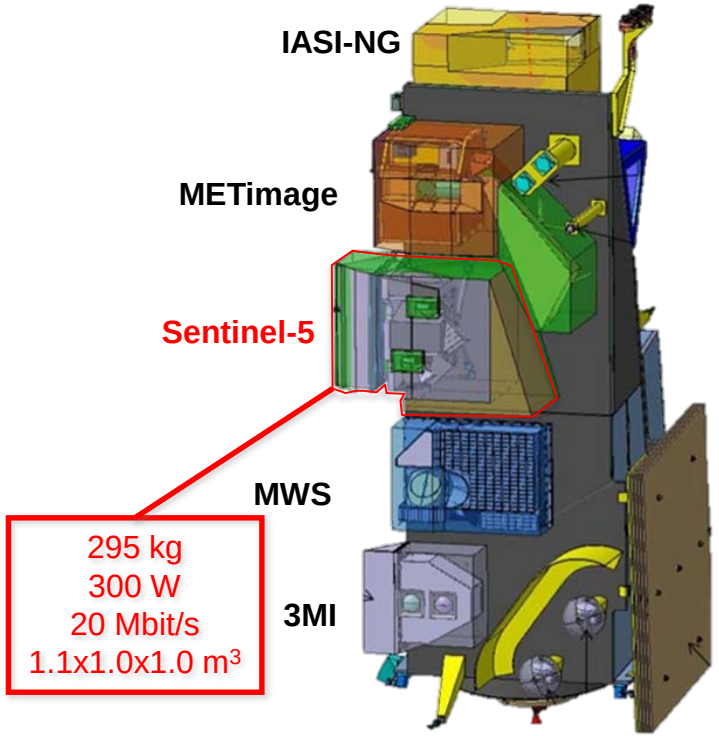
LED (red)
dead / bad pixel
pixel gain
pixel linearity

LED (blue)

Courtesy of Airbus Defence & Space

Sentinel 5 on MetOp-Second Generation-A



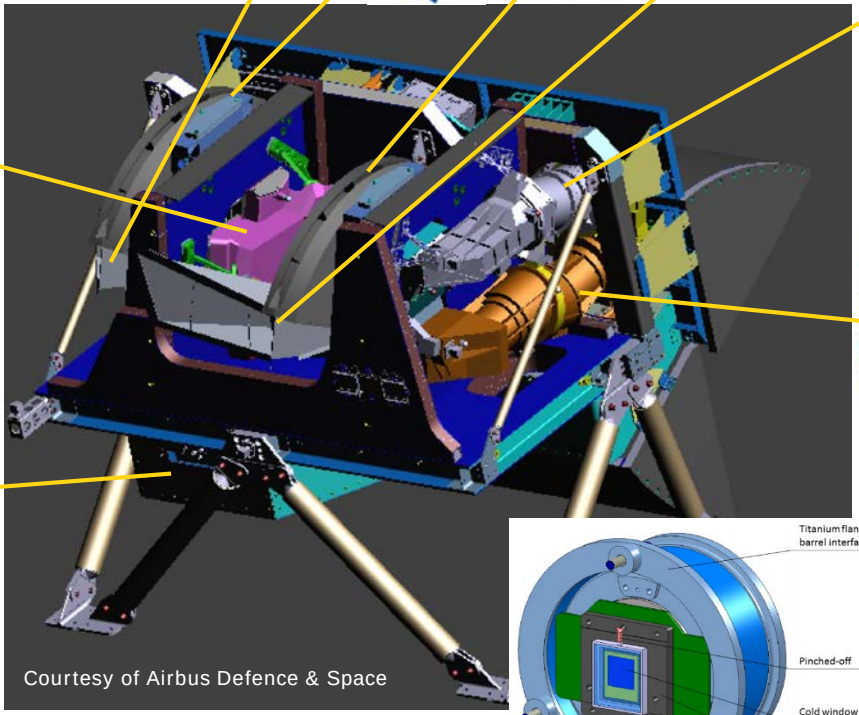


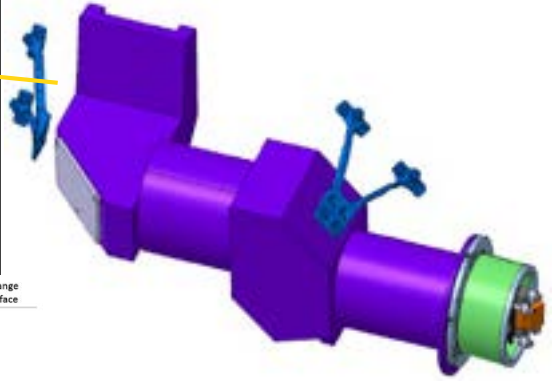
S5

CAS & TSBOA

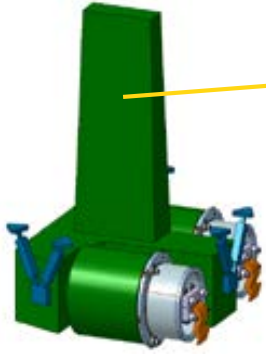
UV2Vis Spectro

UV1 Spectro

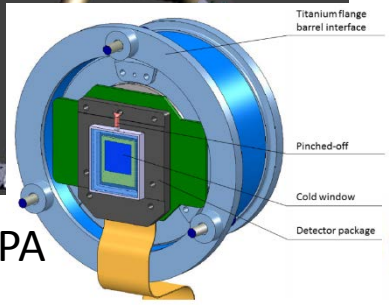




NIR Spectro

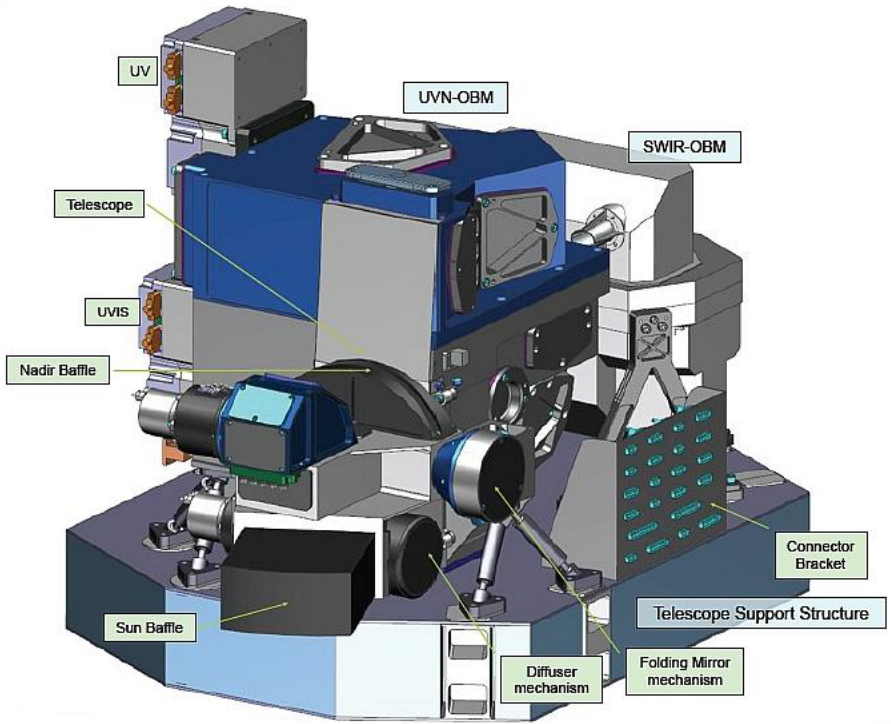


SWIR Spectro



FPA

TropOMI / Sentinel 5 Precursor



TROPOMI

Netherlands Space Office · esa · AIRBUS DEFENCE & SPACE · TNO innovation for life · SRON · Koninklijk Nederlands Meteorologisch Instituut

Copernicus

On-ground calibration

- All measurements done in vacuum under flight representative conditions
- Instrument on cradle in thermal vacuum chamber
- OGSE in front of TVC in cleanroom

S4	S5	S5p / TropOMI
RAL/ UK	RAL/ UK	CSL/ Belgium

S5p TropOMI in TVC on cradle at CSL

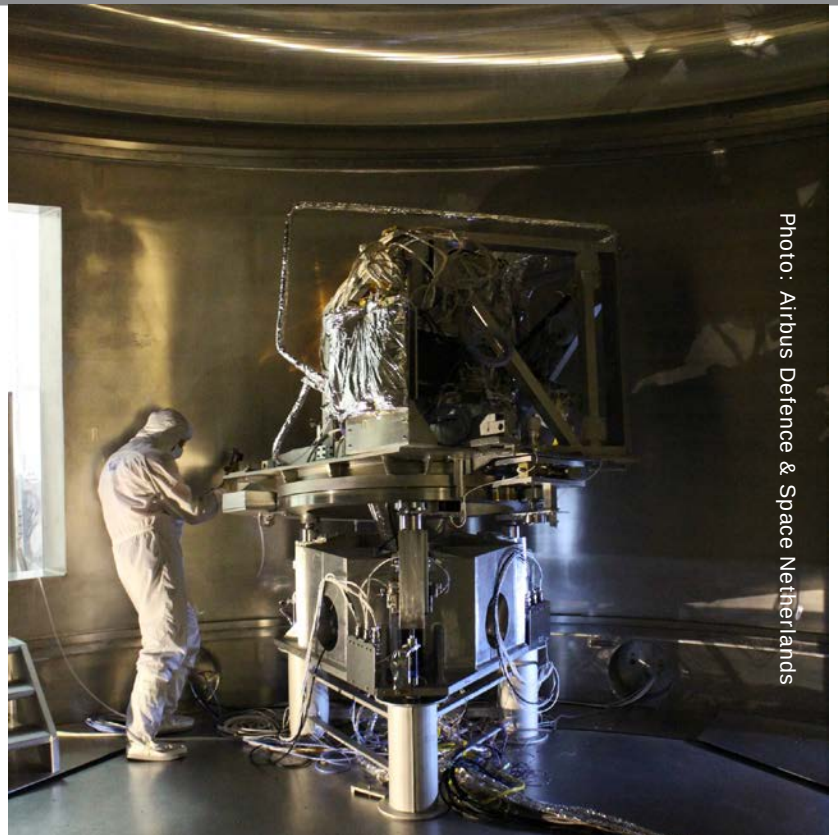


Photo: Airbus Defence & Space Netherlands

TROPOMI

Copernicus

European Space Agency

Rutherford Appleton Laboratories / UK
new building status 17 Feb 2015

RAL Space Calibration facility for
S4/S5 2x 5m

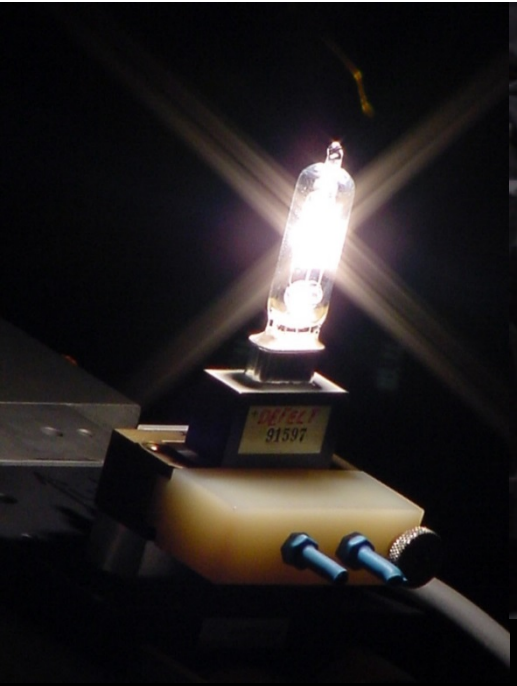
Loading

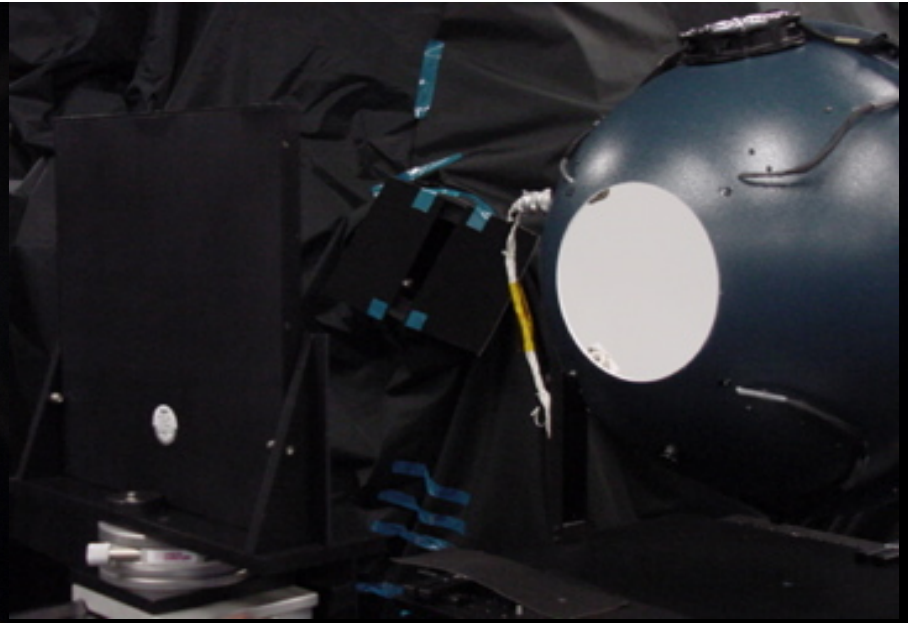
Optical tests

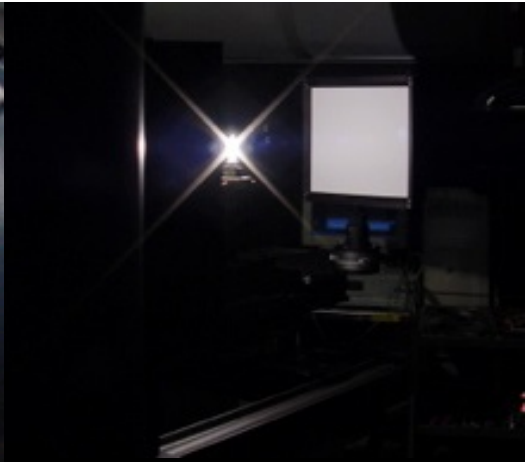
Optical Ground Support Equipment
- radiometric

OGSE	S4	S5	S5p / TropOMI
FEL (+ ext diffuser)	FEL (+diff)	FEL (+ODIFF)	FEL (+diff)
Sun (beam) simulator	SBS	SUSI	Sun simulator
Integrating sphere	ISP (1m)	ISPH (1m)	(0.5m)
OGSE diffuser	Diff (Spectralon)	ODIFF (Spectralon)	300 x 300 mm^2 (Sphere Optics)
Black bodies	NA	x	x

FEL lamp / integrating sphere / diffuser
as part of OGSE

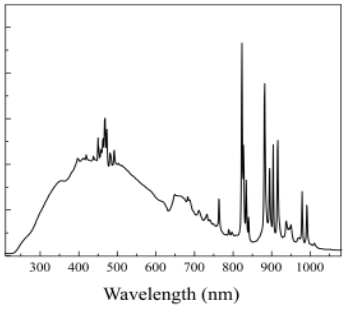






Optical Ground Support Equipment
- white light

OGSE	S4	S5	S5p / TropOMI
Quartz tungsten halogen	x	SM-QTH	x
Xenon	x	SM-XE	300 W/ 1000 W
Polarisation	x	MISC-PM	x



Optical Ground Support Equipment
- spectral/ straylight

OGSE	S4	S5	S5p/TropOMI
Narrow line source	laser	SM-NLS	echelle/ laser
Spectral line source	PtCrNeAr-lamp, M^2	SM-SLS	PtCrNeAr-lamp, HgAr, laser
Laser	Ekspla, M^2	SM-LASER	Ekspla, VSL OPO
Gas cells	not planned	MISC-CELL	CO, CH_4, N_2, N_2.90/CO.10-001
Filter (wheel)	x	MISC-FM	double filter wheel

Optical Ground Support Equipment
- geo

OGSE	S4	S5	S5p / TropOMI
Star stimulus	x	x	x
Geometric	x	GIO-US, GIO-VN, GRO-US, GRO-VN	x
Targets	x	Field targets	x

Ground pixel size

S4 8x8 km^2

S5/S5p 7x7 km^2

On-board calibration sources

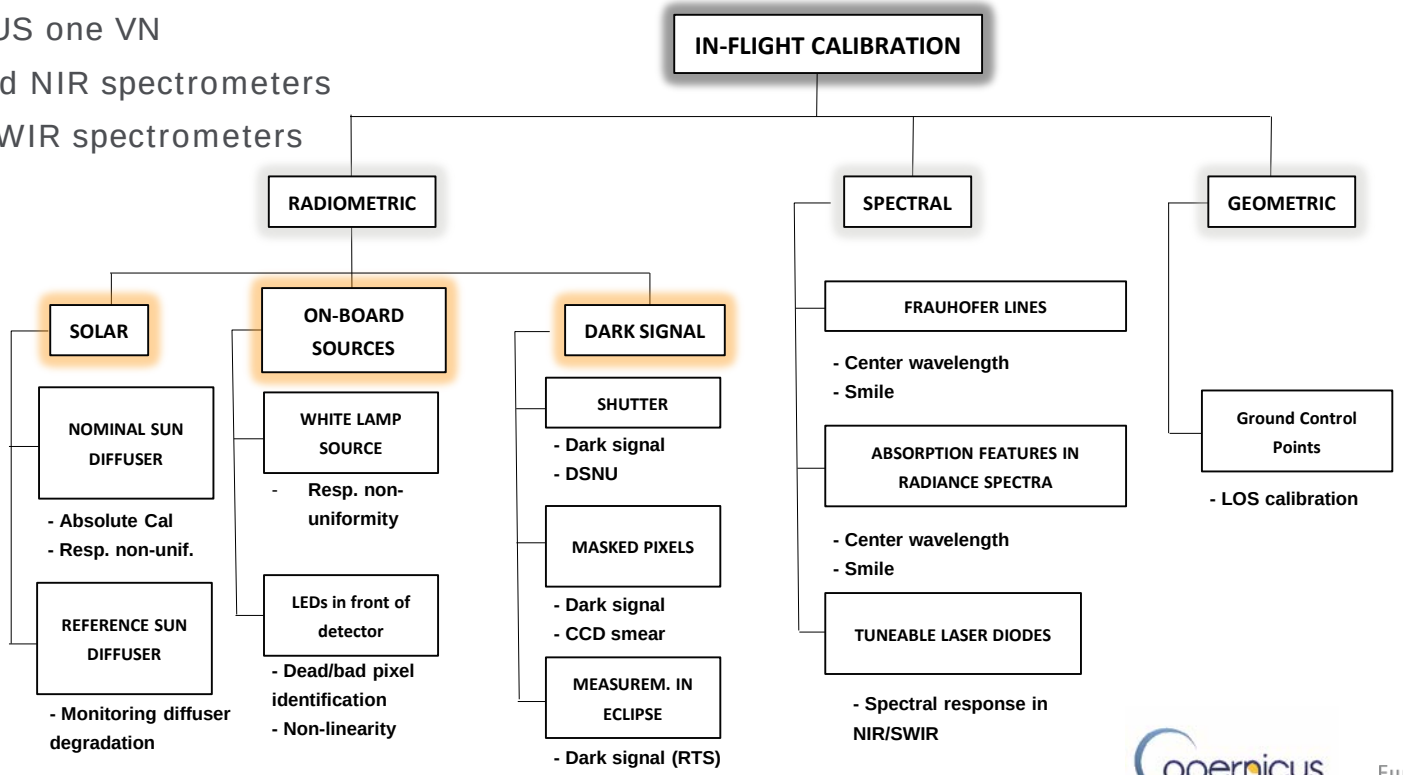
Cal source	S4	S5	S5p/TropOMI
White light	WLS in CAA	WLS in CAS	WLS in CAL
Spectral light	-	Laser diode (SWIR)	SLS in CAL
LED	FPA	FPA	C-LED and D-LED
Diffuser nominal	QVD transm.	HOD-transm.	QVD prism
Diffuser reference	QVD transm.	HOD-Transm.	QVD prism

In flight calibration S5

Two CAS, one US one VN

VN: UV2VIS and NIR spectrometers

US: UV1 and SWIR spectrometers



Thank you for your attention!

Copernicus
www.esa.int/Our_Activities/Observing_the_Earth/Copernicus/Sentinels_-4_-5_and_-5P

TropOMI http://www.tropomi.eu/

KNMI www.knmi.nl

EUMETSAT www.eumetsat.int

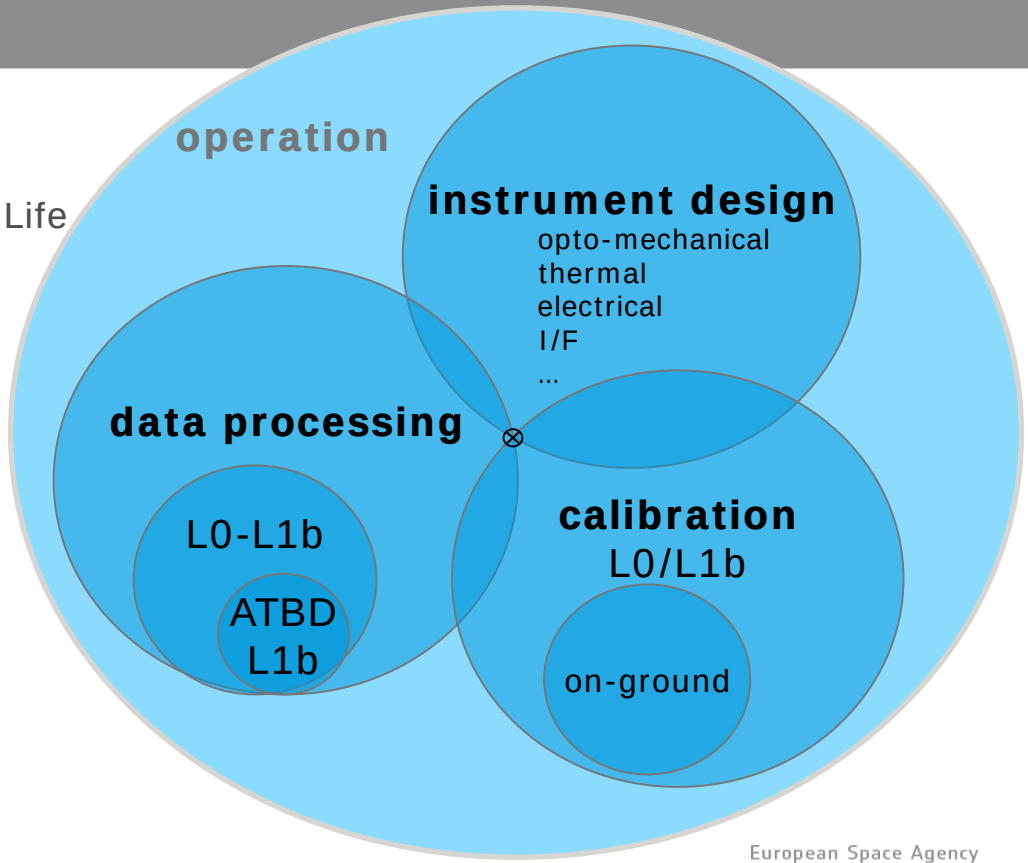
Apportionment – delicate balance

space segment

compliance with instrument Level 1b
requirements at Begin Of Life and End Of Life

optimisation considering

- instrument performance at L1b
- accuracy budgets and
- programmatic aspects



ATBD – algorithm theoretical basis document

Radiometric measurements

	OGSE	Radiance	Irradiance
1	FEL	1R	1I
2	SBS	2R	2I
3	Integrating Sphere	3R	3I

Using different radiometric sources is absolutely essential to obtain required radiometric accuracy and to quantify measurement uncertainties.

Measurement sequence include:

- Absolute radiance/ irradiance/ reflectance
- Irradiance goniometry
- Radiance angular dependency

Product	Msm	Comment
Refl	2I/2R	Best (calibration keydata)
Refl_FEL	1I/1R	Analysis result from measurement expected to be less good
Abs_Rad	1R	Calibration keydata (expected to be the most accurate key parameter to be used for L0 to L1b processing)
Abs_Irrad	Abs_Rad x Refl	Best (expected to be the most accurate key parameter to be used for L0 to L1b processing)
Abs_Irrad_FEL	1I	Analysis result from measurement expected to be less good
Ang_dept _sphere	3R	Radiance angular dependence
Refl_sphere	3I/3R	Instrument BSDF
Abs_Rad´	3R	Radiance angular dependency & calibration keydata (to be used in L0 to 1 processing in case more accurate than Abs_Rad)
Abs_Irrad'	Abs_Rad' x Refl	Calibration keydata (to be used in L0 to 1 processing in case more accurate than Abs_Irrad)