Calibration of Earth observation hyperspectral instruments - some examples

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Outline

apportionment

instrument design – **calibration** – L0 to L1b processing

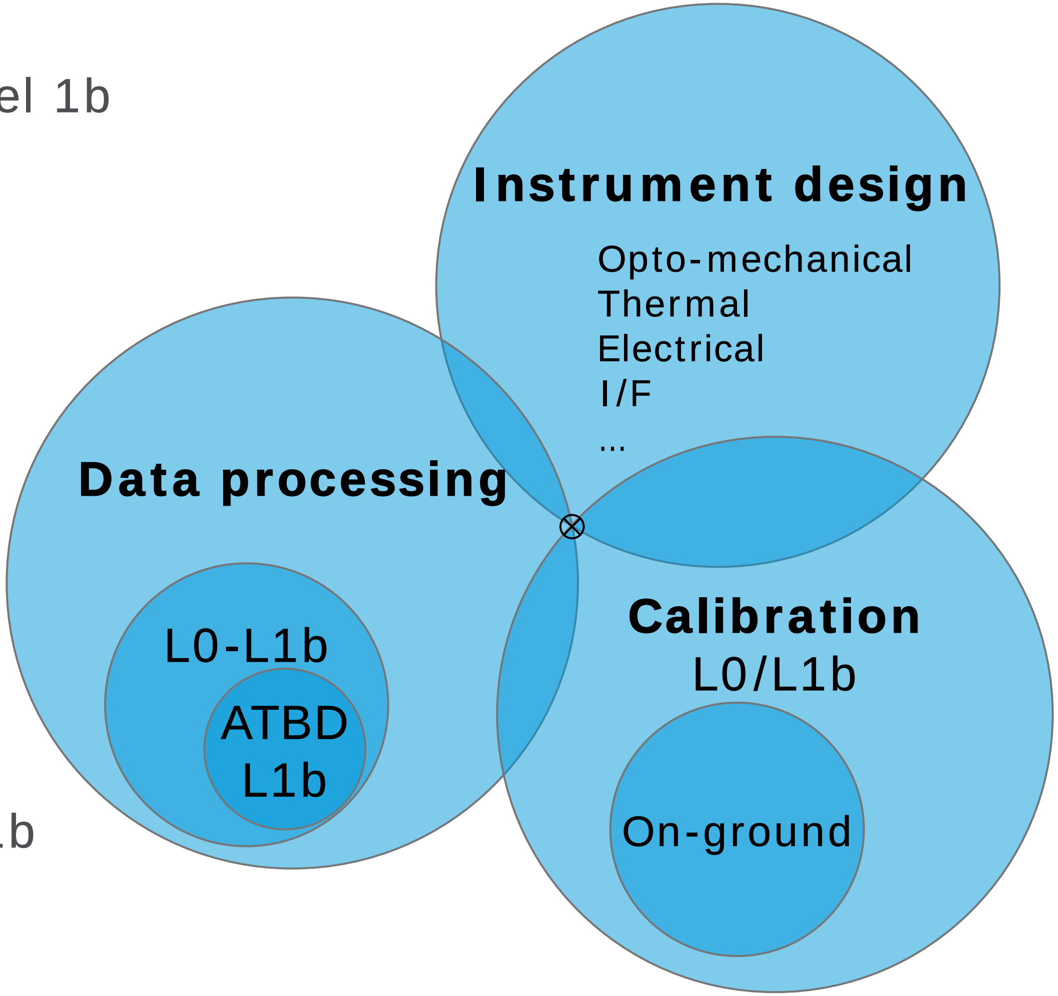
L0 performance verification and calibration

- calibration sources
- calibration parameters
- lessons learnt

Apportionment - delicate balance

space segment

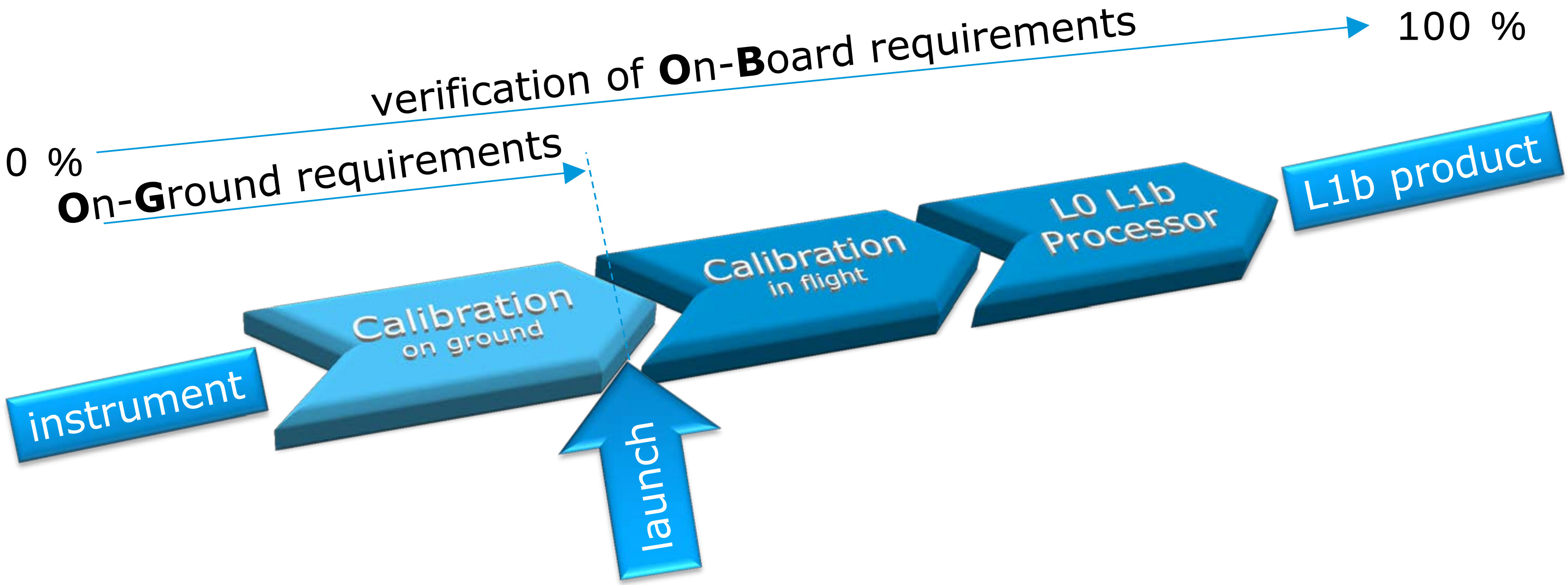
compliance with instrument Level 1b requirements at BOL and EOL



optimisation considering

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

On ground and in flight requirements



Calibration sources

EXTERNAL

Fraunhofer lines

atmospheric emission lines

Sun

moon

stars

OGSE’s

vicarious

...

INTERNAL

WLS PRNU, radiometric stability, degradation

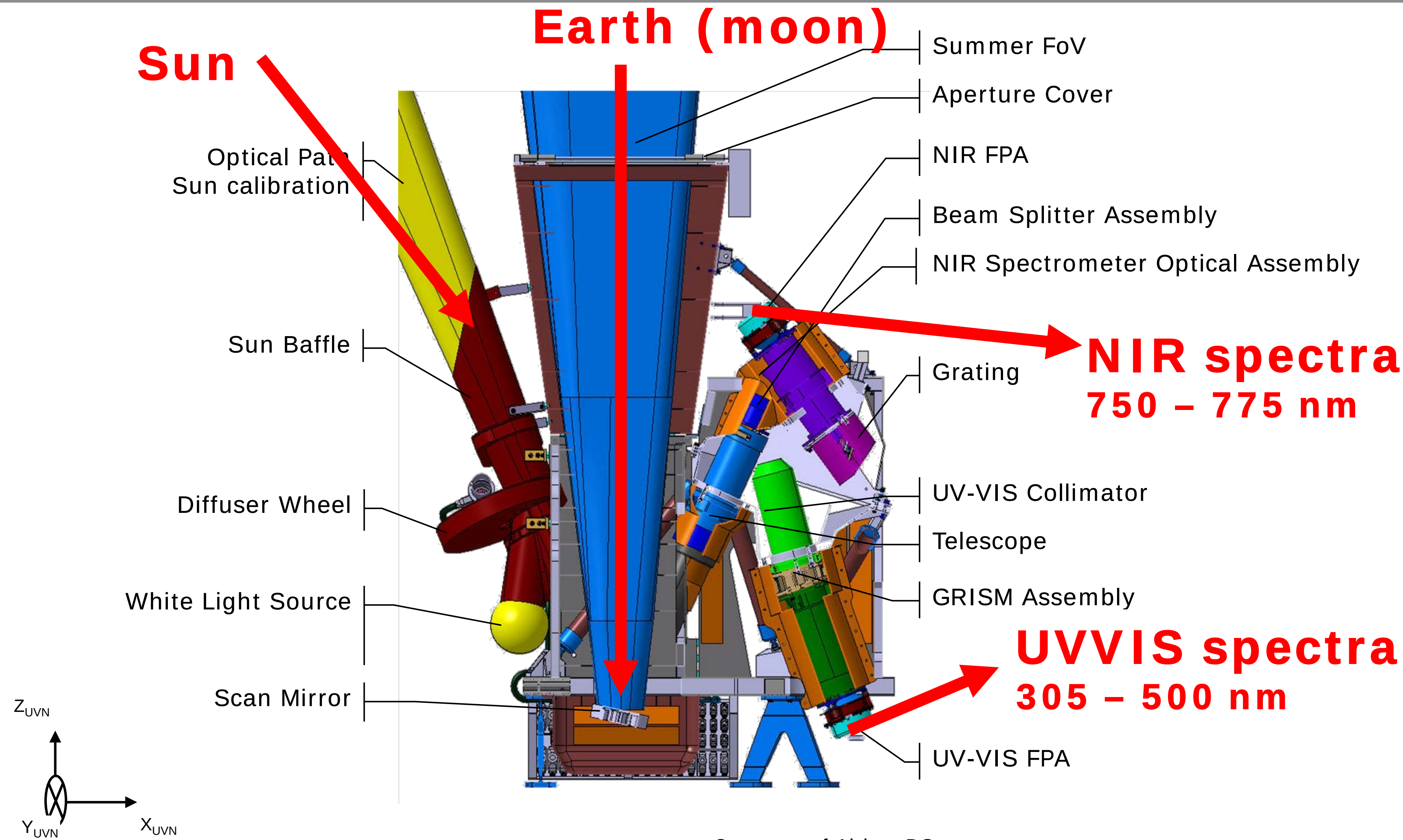
LED dead/bad pixel, pixel gain, pixel linearity

diffuser nominal/ redundant

spectral line source lamp/ laser

...

S4/UVN instrument



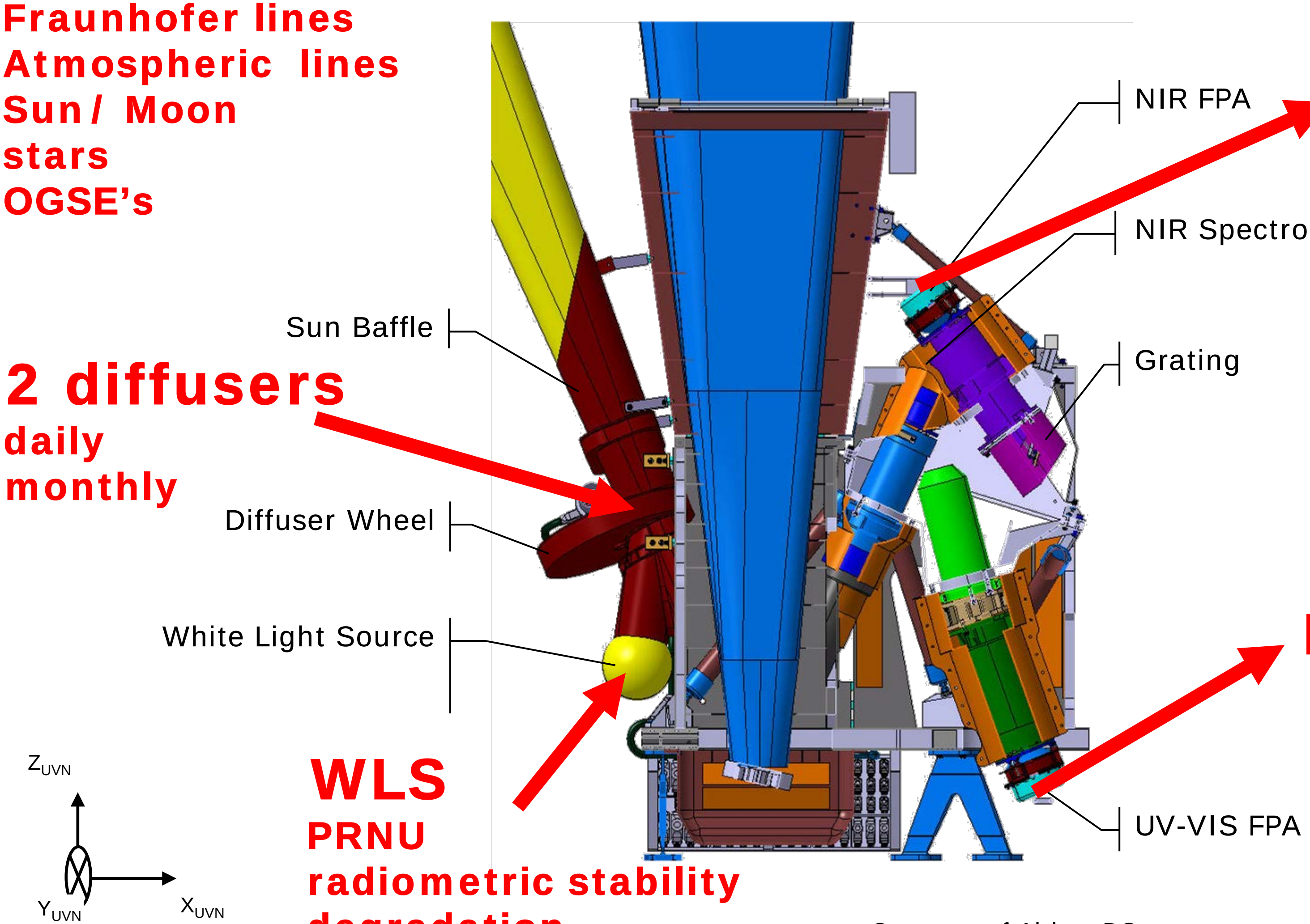
Courtesy of Airbus DS

S4/UVN calibration sources

external
Fraunhofer lines
Atmospheric lines
Sun / Moon
stars
OGSE's

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

2 diffusers
daily
monthly



LED (blue)

WLS
PRNU
radiometric stability
degradation

Courtesy of Airbus DS

Calibration parameters

- → **radiometric calibration** Earth spectral radiance, Sun spectral irradiance and Earth reflectance (radiance/irradiance)
- → **spectral calibration**
  - wavelength scale for uniform and non-uniform ground scenes
  - Instrument Spectral Response Function (ISRF)
  - optical bench temperature (gradient) dependencies
- → spectral/ spatial **straylight**
- → **electronic** and **detector** calibration parameters
- → **geometric** parameters, co-registration, Image Navigation and Registration (INR), geolocation
- → **polarisation** correction, verification at level 0 that instrument is sufficiently insensitive to incident polarisation or polarisation calibration
- → at level 0: no **spectral features** in instrument response that interfere with atmospheric gas absorptions

Radiometric calibration parameters

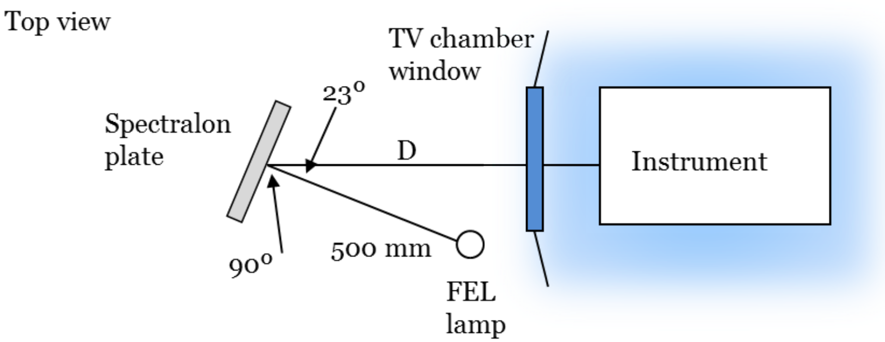
1. absolute Earth spectral **radiance**
2. absolute Sun spectral **irradiance**
3. **Earth** viewing **angle dependency**

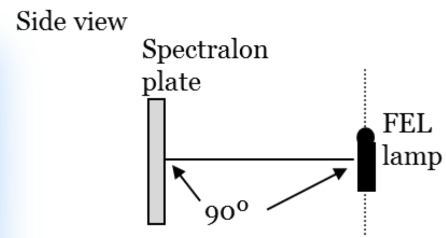
   North-South on detectors and scan mirror (OMI and OMPS have no scan mirror)
4. **Sun** viewing **angle dependency**
5. absolute Earth **reflectance**: Earth radiance/ solar irradiance, using dedicated sources optimised for this parameter

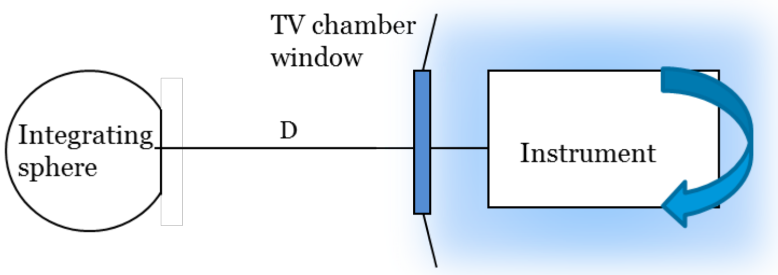
In orbit, relative radiometric **degradation** monitoring and quantification primarily with **Sun irradiance** measurements, but also with **WLS** and **LED,** Earth **radiance** and **moon** measurements.

Absolute radiometric radiance calibration - on ground

Absolute radiometric radiance calibration measurements using calibrated sources (FEL lamp, integrating sphere) and **radiance angle dependency calibration** measurements under flight-representative thermal-vacuum conditions



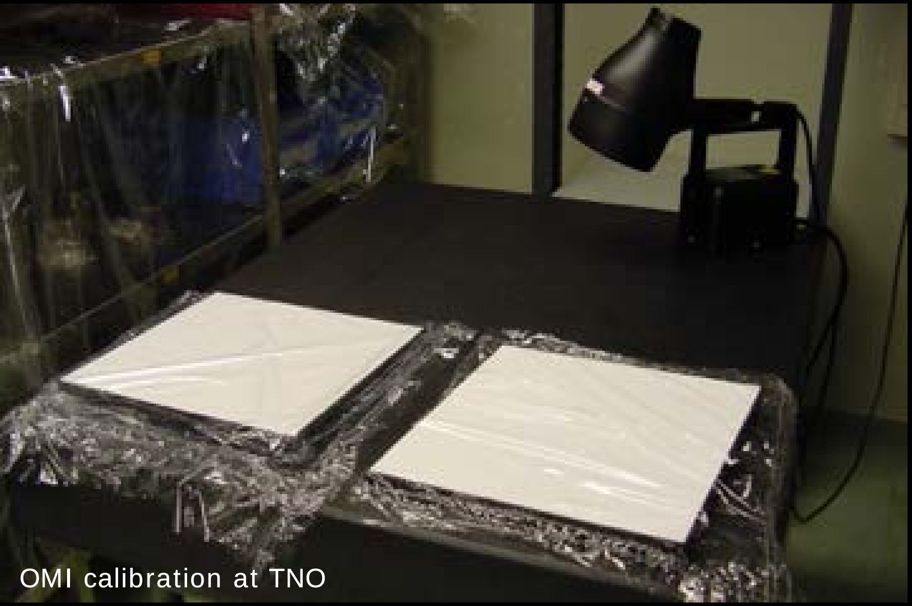




FEL lamp as part of OGSE

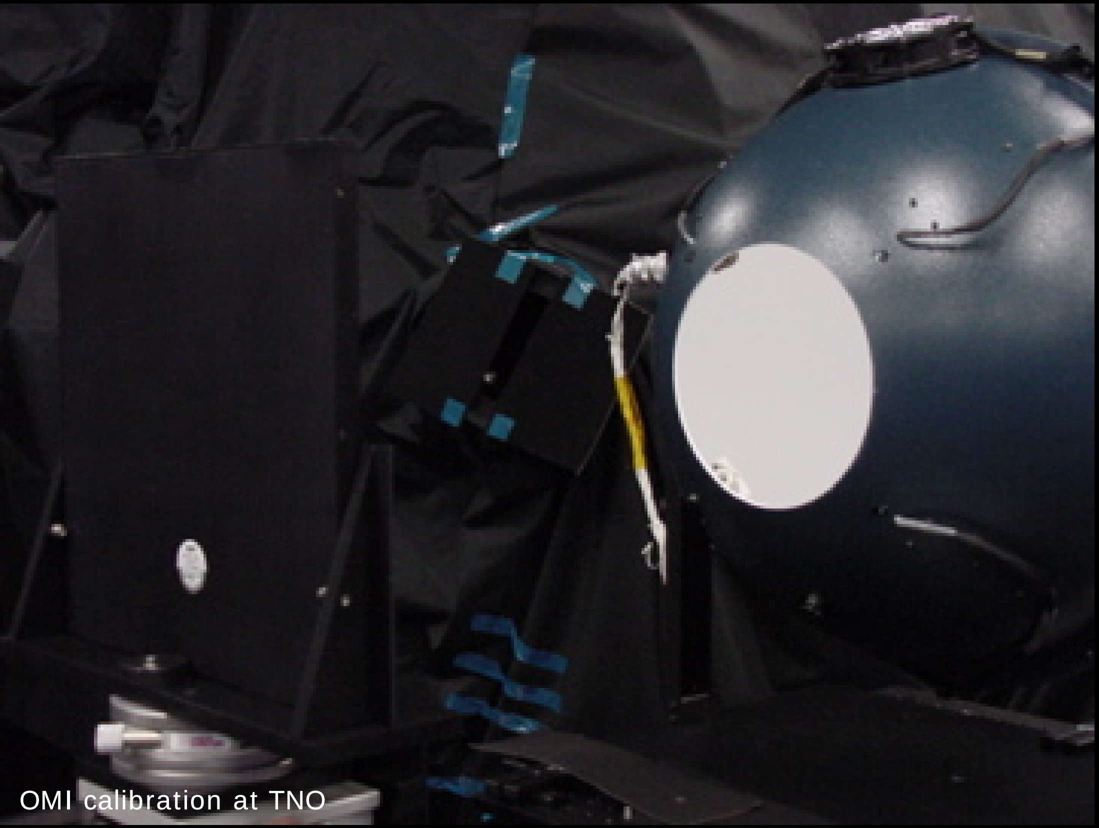
OMI calibration at TNO

Diffuser as part of OGSE



OMI calibration at TNO

Integrating sphere as part of OGSE



OMI calibration at TNO

... and do not forget Theo(dolite)!

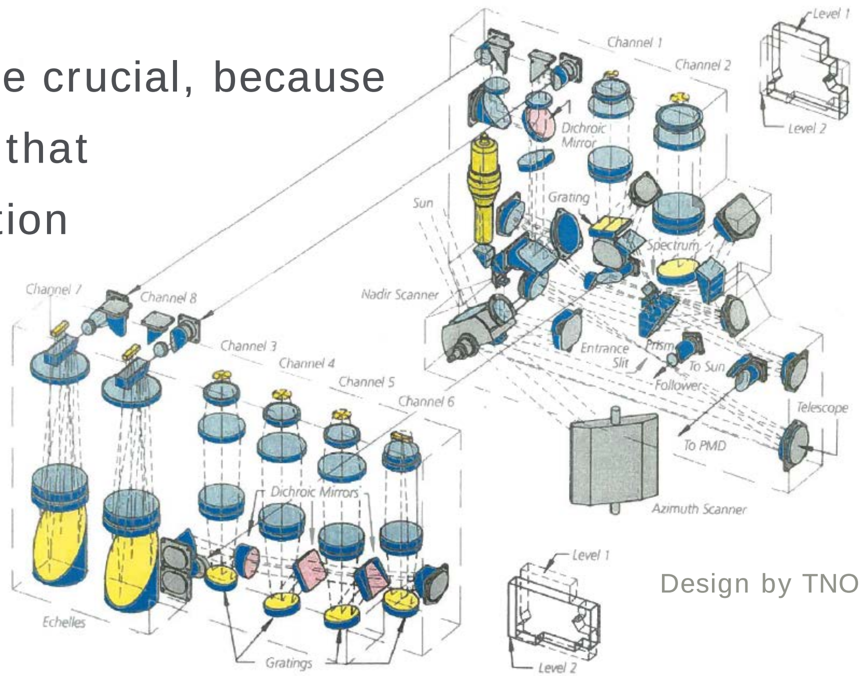
Predecessor atmospheric (hyperspectral) instruments

1. TOMS (NASA)
2. GOME
3. Sciamachy (ENVISAT)
4. GOME-2 (Metop)
5. OMI (Aura)
6. OMPS (NPP, NASA)
7. ...and many more...

SCIAMACHY (Envisat)

- → channel 2/8 breadboard calibrated in 2-3 months
- → 5 tests in TV chamber (OPTEC) were necessary on the PFM lasting between 6/9 months
- → SCIAMACHY not possible to rotate in vacuum
- → many new effects, as e.g. “spectral features” effect has been discovered on SCIAMACHY instrument level, resulting in late change of solar diffuser (additional diffuser)

<u>Note</u>: L0, Cal phase separation revealed to be crucial, because performance measurements revealed issues that had to be solved on hardware before calibration could start (e.g. channel out of focus, PMD electronic defect) and could have potentially invalidated some of the calibration measurements if discovered too late

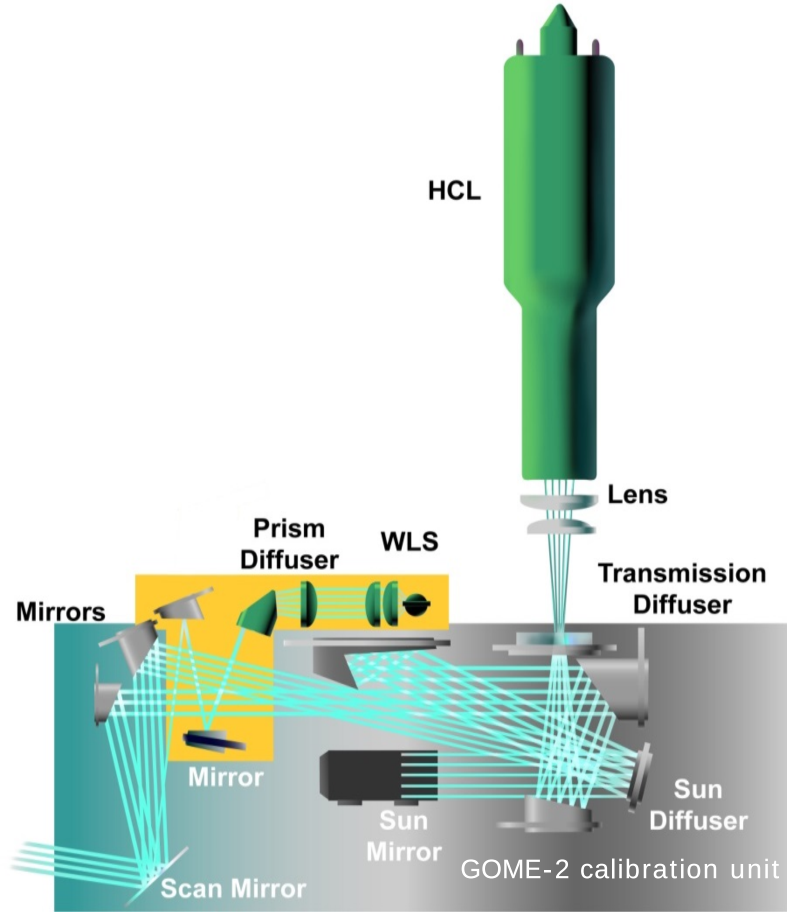


Design by TNO

SCIAMACHY OGSE example

GOME-2 (Metop)

- redo of GOME (first instrument of its class in Europe)
- using an EQM, calibrated in dry-run campaign
- still issues arisen during flight model calibration leading to a re-ship of the instrument back to the calibration facility (radiometric calibration deficiencies not understood for a long time)

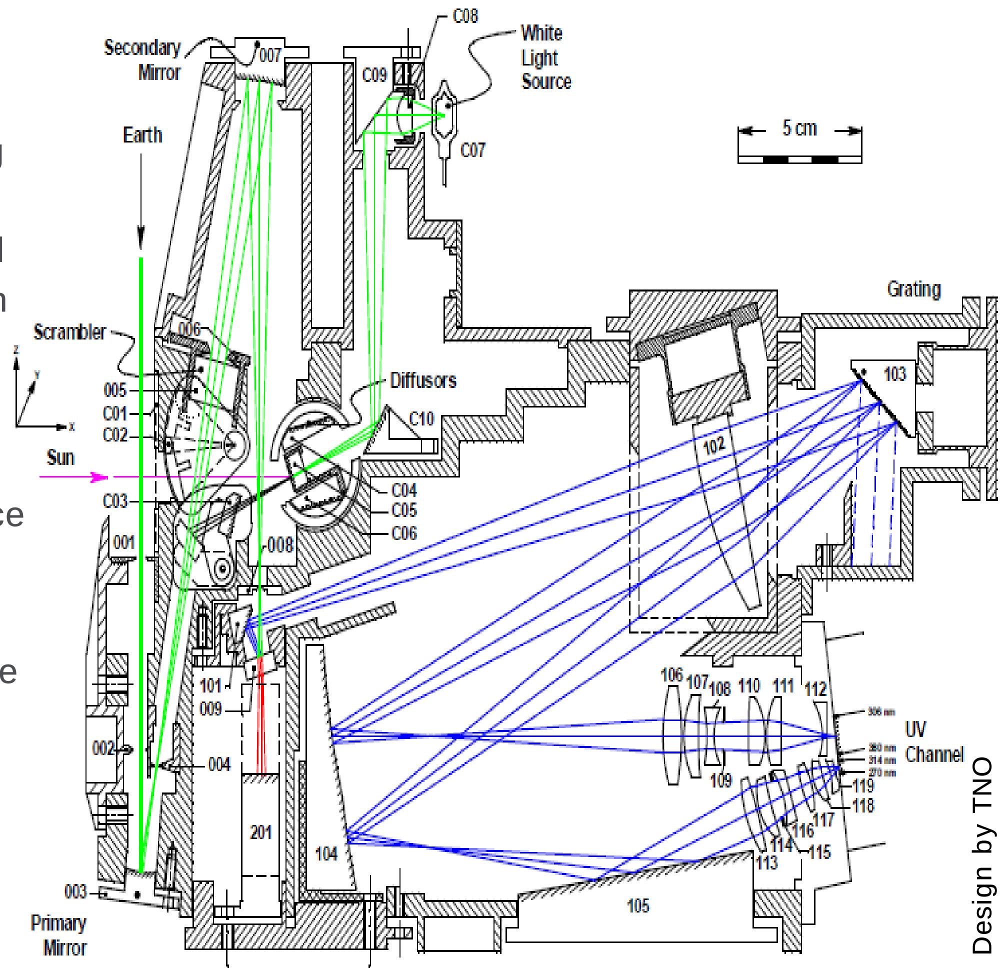


GOME-2 calibration unit

OMI (AURA)

- first instrument of this kind with a 2-dimensional detector
- using an OMI BB model (BBM), resembling OMI PFM as much as possible and performing the full performance verification & calibration campaign, using all OGSE and performing full analysis of the measurements data. Duration of about 3 months (measurement time).
- it was not possible to rotate OMI in vacuum
- PFM on-ground campaign was about 8 months, including a separation of performance verification and calibration phase (TV).

<u>Note:</u> separation revealed to be crucial because some of the calibration measurements would have been invalidated by some of the performance results.



Design by TNO

Lessons learnt from instruments

On ground 'Test as you fly'

→ i.e. thermal vacuum environment with flight representative conditions for pressure, temperatures for detectors and 'optical bench'

Consider EQM prior to flight model

→ calibrated in dry-run campaign, elimination of non-conformances

On ground and in flight

→ several parameters can only be measured with sufficient accuracy on ground, e.g. polarisation, straylight and ISRF

→ clear split between L0 performance verification and calibration

Instrument built as designed?

→ L0 performance verification

Calibration

→ retrieve calibration key parameters for L0 to L1b processing

Lessons learnt

Of paramount importance is that at the start of a programme,

- scientists,
- calibration staff,
- instrument operations staff and
- system and software developers

closely work together to identify the

- measurement types,
- the frequency of scheduling,
- the required corrections steps that are applied and
- data products

Thank you for your attention!