CEOS WGCV IVOS 31, Perth

EnMAP Status Update

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EnMAP – mission status overview

Space Segment / Instruments

- VNIR FM: camera integrated, fine aligned and characterized
- SWIR FM:
  - 1st: environmental tested, integration started
  - 2nd: environmental testing started
- OBCA FM - 2 integrating spheres: integrated & characterized @ PTB
  - full aperture solar diffuser: BRDF to be characterized

Ground Segment

- Phase D1 (TVVRR) successfully completed in Dec. 2018,
  re-tests to be completed by this week
- D2 (ITVV) interface tests & system-wide tests done by July / Dec. 2019

Overall

- Launch foreseen Dec. 2020
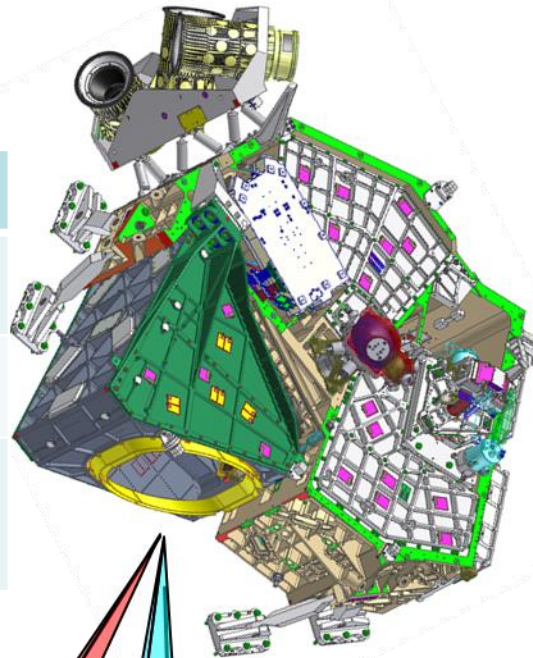
EnMAP – linkage to ARD / CARD4L

CARD4L for EnMAP L2A products
- Self assessment: „Threshold" will be achieved with foreseen metadata update
- Review for compliance ?

GENERAL METADATA

#	Item	Threshold (minimum requirements)	COMMENTS BY
1.1	Traceability	Not required	
1.2	Metadata		
1.3	Data colle		
1.4	Geograph		
1.5	Coordina		
1.6	Map proj		
1.7	Geometri		
1.8	Geometri		

RADIOMETRIC AND ATMOSPHERIC CORRECTIONS

	Item	Threshold (minimum) requirements	COMMENTS BY PCV
3.1	Measurement	Pixel values that are expressed as a measurement of	
3.2	Measurement unce		
3.3	Measurement Norn		
3.4	Aerosol corrections		
3.5	Water vapour corre		
3.6	Ozone corrections		

PER-PIXEL METADATA

	Item	Threshold (minimum) requirements	COMMENTS BY PCV	Target (desired) requirements	COMMENTS BY PCV
2.1	Metadata machine readability	Metadata is provided in a structure that enables a computer algorithm to be used to consistently and automatically identify and extract each component part for further use.	ok	As threshold, but metadata is formatted in accordance with ISO 19115-2.	ok, as ISO 19115 (plus ISO 19119) are INSPIRE, so conformity is given
2.2	No data	Pixels that do not correspond to an observation ('empty pixels') are flagged.	ok	As threshold.	ok
2.3	Incomplete testing	The metadata identifies pixels for which the per-pixel tests (below) have not all been successfully completed. *Note 1: this may be the result of missing ancillary data for a subset of the pixels.*	ok (=> flag overall quality, bits (0-1) as "11: not produced")	The metadata identifies which tests have, and have not, been successfully completed for each pixel.	could be added by extending the quality flags
2.4	Saturation	Metadata indicates where one or more spectral bands are saturated.	ok	Metadata indicates which pixels are saturated for each spectral band.	can be easily done. But this would imply that the quality quicklook will largely increase in size.
2.5	Cloud	Metadata indicates whether a pixel is assessed as being cloud	ok	As threshold, with referencing (DOI) to a peer-reviewed algorithm for cloud detection.	can be done - currently no publication available for "land"
2.6	Cloud shadow	Metadata indicates whether a pixel is assessed as being cloud shadow.	ok	As threshold, with referencing (DOI) to a peer-reviewed algorithm for cloud shadow detection.	can be done - currently no publication available for "land"
2.7	Land/water mask	Not required	ok	The metadata indicates whether a pixel is assessed as being land or water. The metadata references a citable peer-reviewed algorithm, expressed as a DOI.	can be done - currently no publication available for "land"
2.8	Snow/ice mask	Not required	ok	The metadata indicates whether a pixel is assessed as being snow/ice or not. The metadata references a citable peer-reviewed algorithm, as a DOI.	the mask is called "snow" but actually flags both snow and ice. Both are indistingible in the current software. Reference documentation the same as for the rest of masks.
2.9	Terrain shadow mask	Not required	-	The metadata indicates pixels that are not directly illuminated due to terrain shadowing	can be done - but only possible when DEM is provided and the accuracy will depend on the DEM itself.
2.10	Terrain occlusion	Not required	-	The metadata indicates pixels that are not visible to the sensor due to terrain occlusion during off-nadir viewing.	currently not possible.
2.11	Illumination and viewing geometry	Not required	-	The solar incidence and sensor viewing angles are identified for each pixel, including coefficients used for terrain illumination correction.	currently, we are providing these values for the corners and the center of the scene. Could be extended.

EnMAP Mission

Parameter	Value
Spectral Accuracy	0.5 nm (VNIR); 1.0 nm (SWIR)
Radiometric Accuracy	**5.0% (absolute); 2.5% (relative)**
Geometric Accuracy	100 m (30 m with control points)

SWIR

900 nm < λ < 2450 nm

(135 spectral bands, 10 nm)

SNR > 150 @ 2200 nm

VNIR

420 nm < λ < 1000 nm

(95 spectral bands, 6.5 nm)

SNR > 500 @ 495 nm
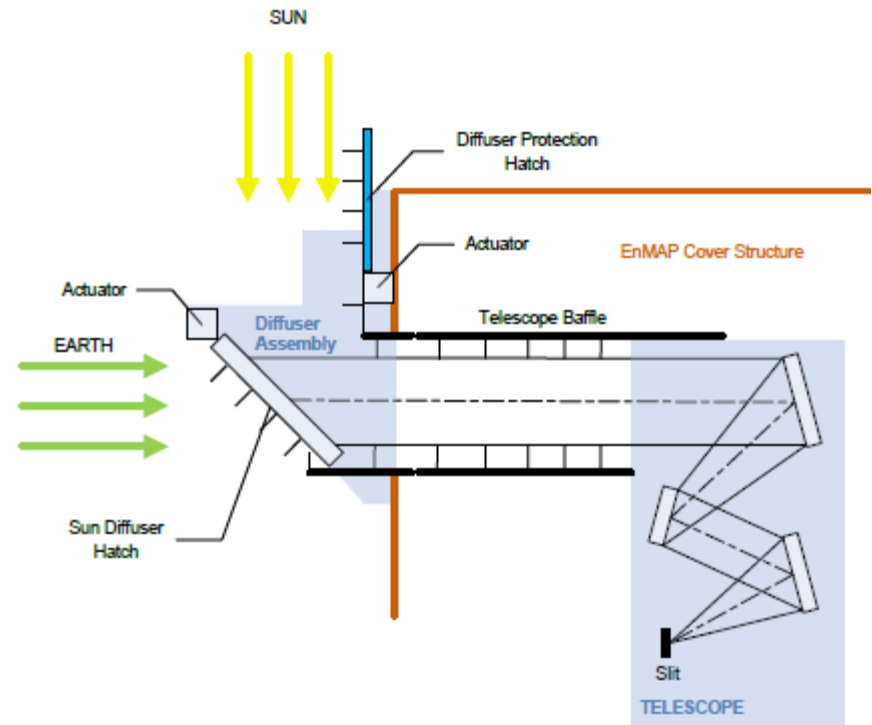
Satellite Ground Track

Pointing Range
± 30°off-nadir

Ground Pixel Size
30 m × 30 m

Swath
30 km wide

Covered Area/Day
5000 km × 30 km

- **On-Board Calibration Equipment**

- Orbit:
  - Sun-synchronous, 11:00, 398/27

- Launch:
  - 12/2020

Source: DLR, OHB

EnMAP On-Board Calibration Equipment

EnMAP On-Board Calibration Equipment

White Spectralon

Halogen Lamps (redundant power) (hidden)

Redundant LED (hidden)

Doped Spectralon

Halogen Lamps (nominal power) (work & spare)

Nominal LED

Sun Calibration

On-Board Calibration

Closed Shutter

Focal Plane LED (hidden)

Earth Observation / Deep Space

Telescope

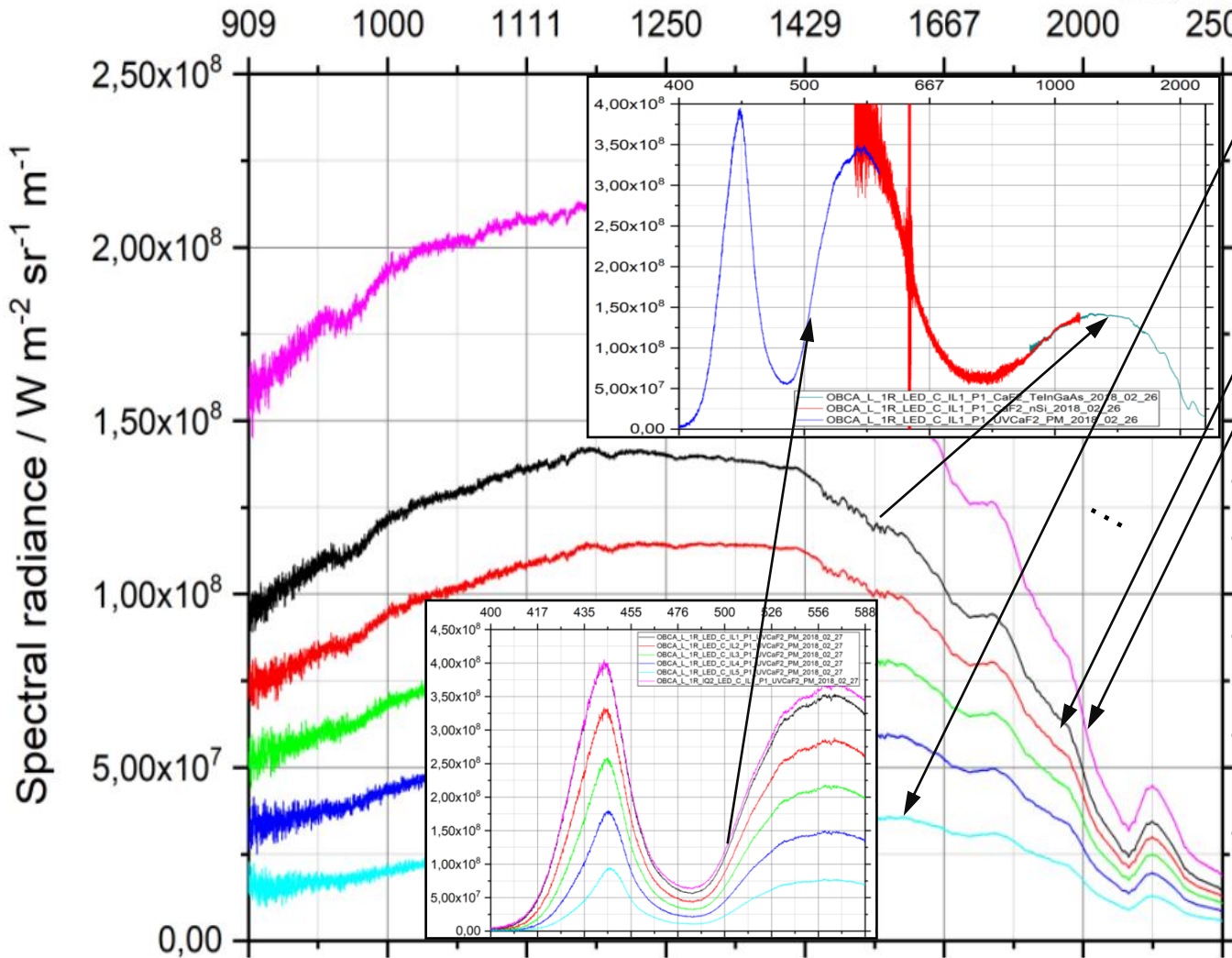Spectrometers
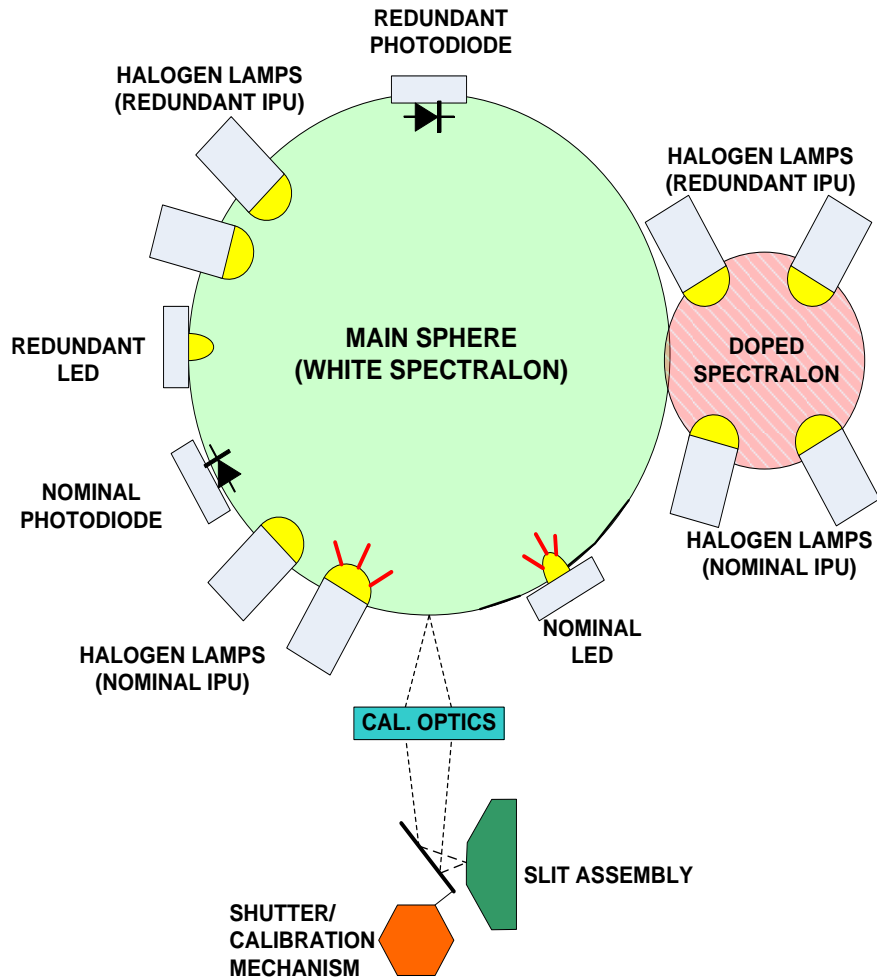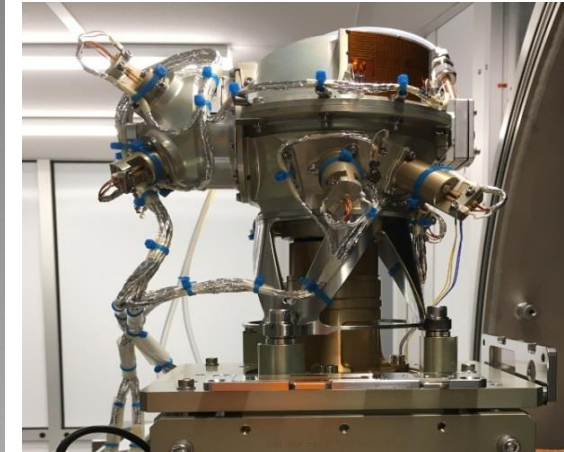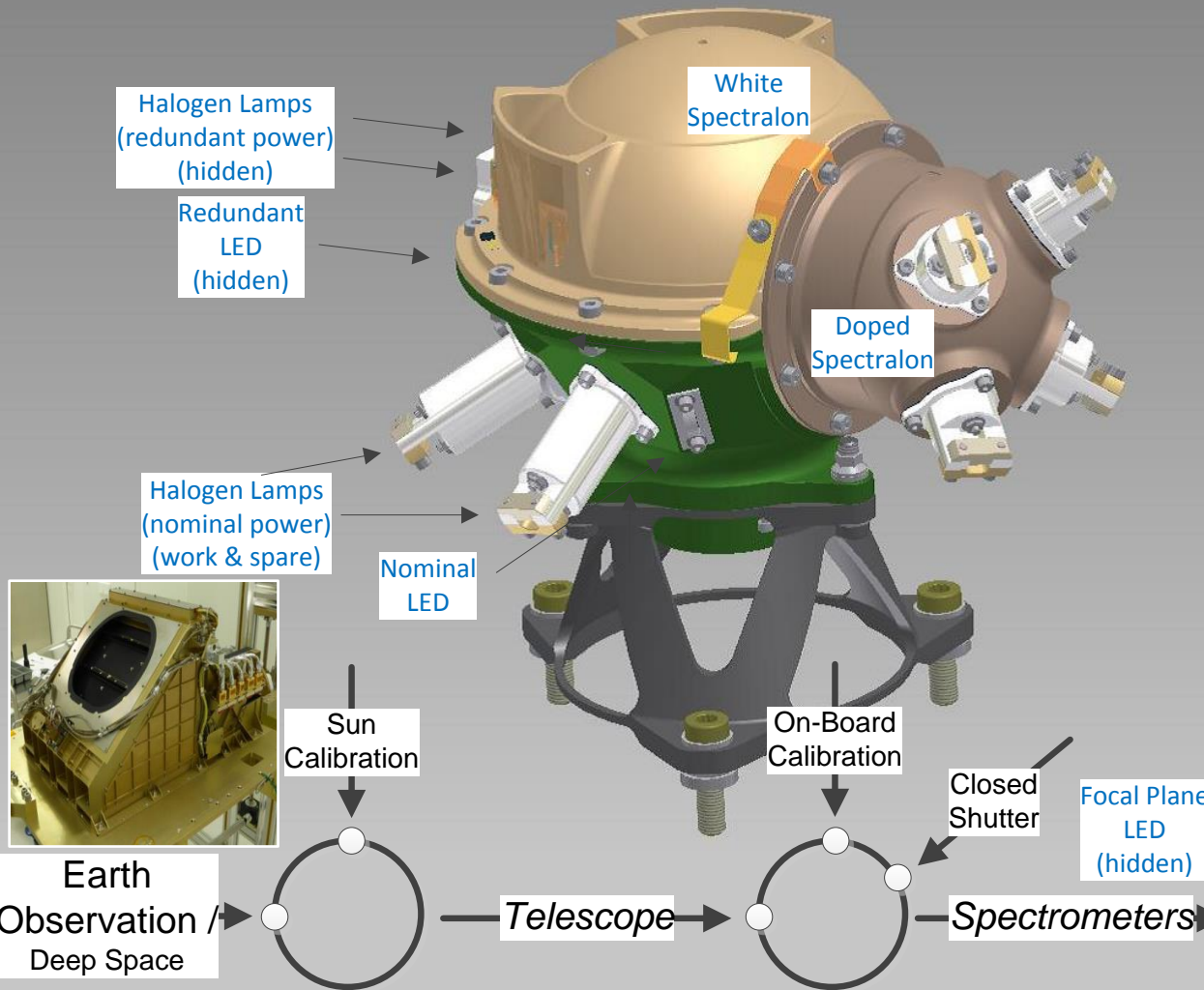
- Closed Shutter [dark]
- Deep Space [dark]
- Sun Calibration [absolute radiometric]
- **White Spectralon** [relative radiometric]
- Doped Spectralon [absolute spectral]
- Focal Plane LED [linearity]

Source: OHB

DLR

EnMAP White Spectralon [Pre-Flight]

Wavelength / nm

909 1000 1111 1250 1429 1667 2000 2500

Spectral radiance / W m^{-2} sr^{-1} m^{-1}

2,50x10^8
2,00x10^8
1,50x10^8
1,00x10^8
5,00x10^7
0,00

Illumination Level	Current halogen lamp	Current LED
IL1 (60%/90%)	716.7 mA	855.6 mA
IL2 (48%/72%)	674.5 mA	634.4 mA
IL3 (36%/54%)	626.9 mA	445.7 mA
IL4 (24%/36%)	569.3 mA	282.0 mA
IL5 (12%/18%)	491.6 mA	134.5 mA
IQ2/IL1 (90%/90%)	807.3 mA	855.6 mA

- 5 (+1) Illumination levels
- 5 Field positions (homog.)
  - 0 mm, ±6 mm, ±11.5 mm
- 4 Light sources
  - Nom. (work & spare) / Red.
- 3 Temperatures (stabil.)
  - 20° C, 21° C, 22° C (&air/vac.)
- Characterized using
  - Vac. Fourier-transf. spectrom.
  - 3 beam-splitter detectors
  - 2 radiative transfer standards

Source: PTB, OHB

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Source: OHB

dark between levels not considered
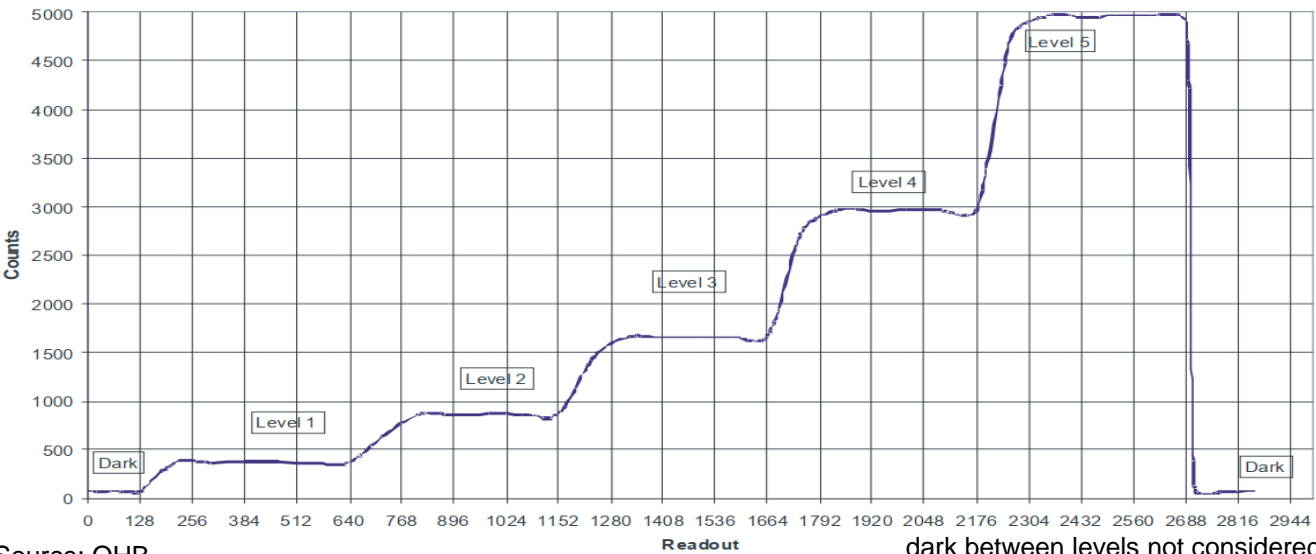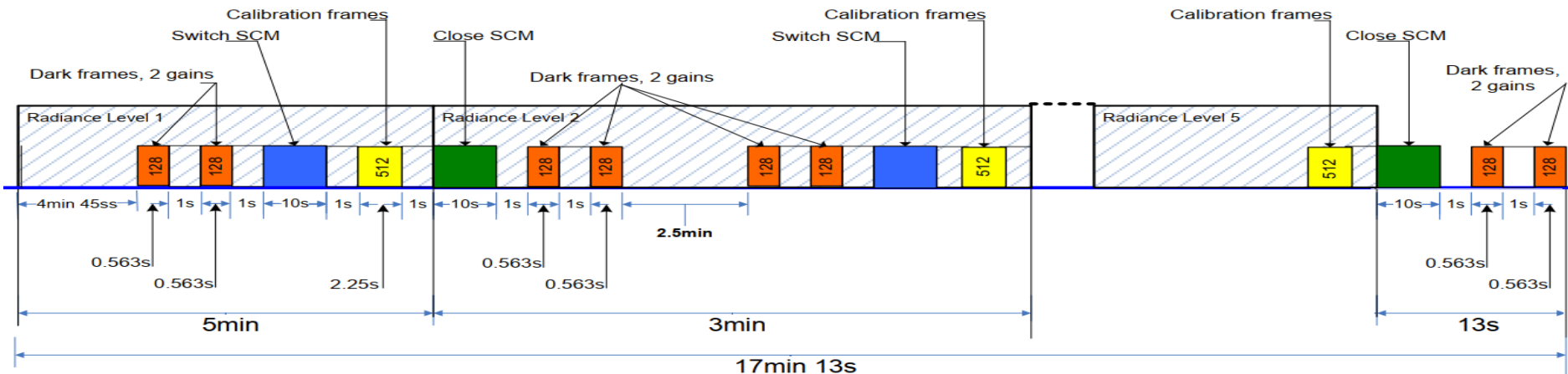
- White Spectralon [relative radiometric]
  - Weekly
  - Full optical system: Not telesc.
  - Aging known: Medium
  - For Calibration Coefficients: No
- Sun Calibration [absolute radiometric]
  - Monthly (or less)
  - Full optical system: Yes
  - Aging known: High
  - For Calibration Coefficients: Yes

EnMAP In-Flight Calibration Frequencies

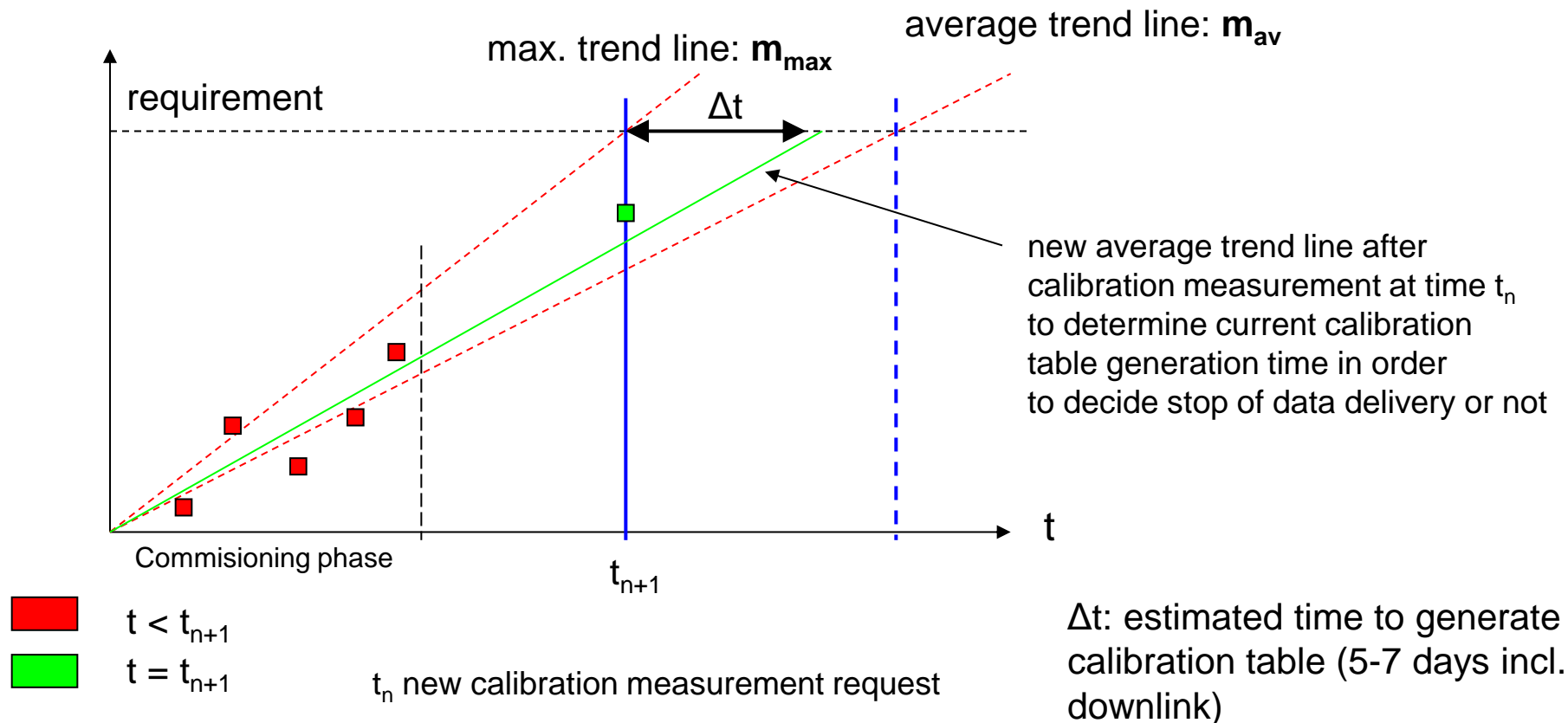| Calibration type	Time	Frames	Data Volume	Expected Amount of Measurements	Frequency
Dark (shutter)	23 sec	2 * 128 (2 gains)	0,27 GB	~ 36500	each datatake
Dark (deep space)	30 sec	1 * 1024 (2 gains)	1,38 GB	~ 20	every 4 months
Relative radiance calibration	17 min 13 sec	1 * 512 (5 steps)	1,66 GB	~ 260	weekly
Sun calibration	140 sec	2 * 1024	1,38 GB	~ 60	monthly
Spectral calibration	5 min13 sec	1 * 1024	0,83 GB	~ 120	every 2 weeks
Linearity measurement	< 5 min	2 * 128 * 40 (2 gains)	5.8 GB	~ 60	monthly

in total: ~ 11 TB

EnMAP In-Flight Calibration Frequencies

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$$\Delta = ||DN_{meas} - DN_{ref}||_2^{min\text{-}max}$$

max. trend line: m_{max}

average trend line: m_{av}

requirement

Δt

new average trend line after
calibration measurement at time t_n
to determine current calibration
table generation time in order
to decide stop of data delivery or not

Commisioning phase

t_{n+1}

t

🟥	$t < t_{n+1}$
🟩	$t = t_{n+1}$

t_n new calibration measurement request

Δt: estimated time to generate
calibration table (5-7 days incl.
downlink)

[White Spectralon]
[Calibration]

EnMAP Hyperspectral Imager

Dead Pixels Map → Saturated and Dead Pixels Flagging

Non-Linearity LUT → Non-Linearity Correction

Dark Signal Correction

Gain Matching

Stray-Light Matrix → Stray-Light Correction

used for: Dead Pixels Map, Signal-to-Noise Information ← Averaging for each Illumination Level

Relative Radiometric Reference → Comparison Ref. and Measurement

(1st: based on (radiometric) pre-flight calibration campaign)

OK ↓

not OK →

VNIR Calibration coefficient table	Calibration coefficients for: Low Gain VNIR (LV), High Gain VNIR (HV)	for (channel) for (pixel) GetGainMatchingCoeff(float) for (pixel) GetRNU(float) for (channel) ...CalCoeff(float)	(256 x 1056 x 2 + 256) x 4 Bytes Gain matching coefficients and RNU per pixel, Cal coefficients per channel Type SINGLE
SWIR Calibration coefficient table	Calibration coefficients for: Low Gain (L), High Gain (H) nominal SWIR (S), redundant SWIR (R)	for (channel) for (pixel) GetGainMatchingCoeff(float) for (pixel) GetRNU(float) for (channel) GetCalCoeff(float)	(256 x 1024 x 2 + 256) x 4 Bytes Gain matching coefficients and RNU per pixel, Cal coefficients per channel Type SINGLE

Calibration Coefficients based on Sun Calibration

Relative Radiometric Reference

Update Relative Radiometric Reference

Repeatable: Yes

Request for (repeated) White Spectralon or Sun Calibration

Repeatable: No

Closed Shutter Measurements

Source: DLR, OHB

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[Earth Observation] [Correction]

EnMAP Hyperspectral Imager

Dead Pixels Map → Saturated and Dead Pixels Flagging

Non-Linearity LUT → Non-Linearity Correction

Offset Value → Shutter Thermal Emission Correction for SWIR

Closed Shutter Measurements → Dark Signal Correction

Gain Matching

Stray-Light Matrix → Stray-Light Correction

Spectral Calibration File → Spectral Referencing

Calibration Coefficients → Conversion to At-Sensor Radiances

Data Quality

Digital Number [instrument]

$mW \cdot cm^{-2} \cdot sr^{-1} \cdot \mu m^{-1}$ [at-sensor radiance]

e.g., spaceborne ALOS/AVNIR-2

Source: DLR, ESA, JAXA, OHB

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EnMAP
Hyperspectral Imager

Band 31
Cross-track detector element
50 100 150 200 250 300

Normalized mean DN per column, band 31

Cross-track detector element
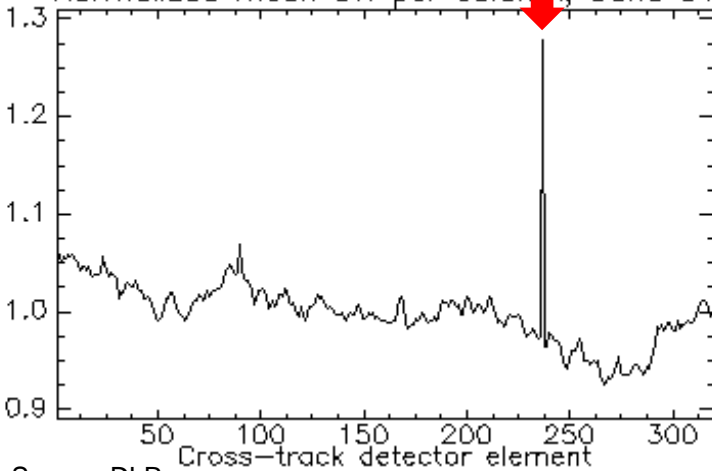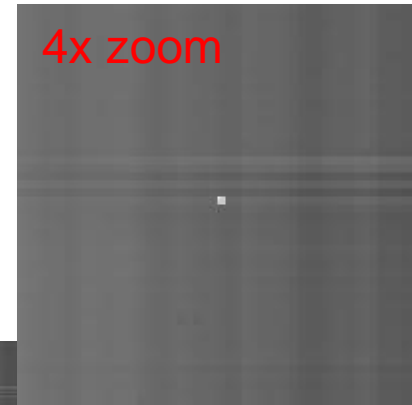
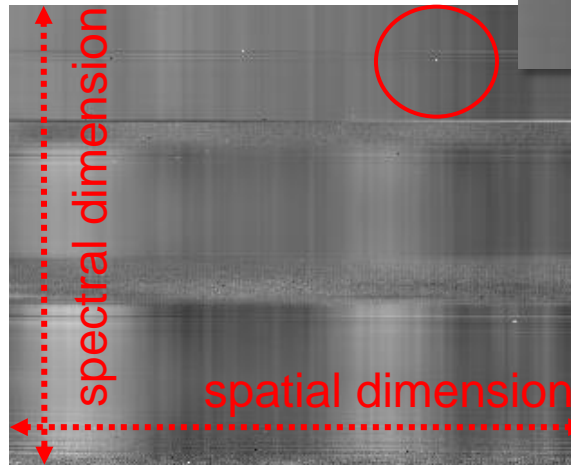Source: DLR

Difference of approx. 30% (in radiance) to spatially and spectrally neighboring detector elements

4x zoom

Suspicious pixel at band 31

spectral dimension

spatial dimension

Normalized detector map of one scene, mean DN for every band and every across-track detector element

- Automated processes for each product
  - e.g. striping artefacts
  - meta and image data
- Interactive procedures for selected products
  - e.g. cloud classification
  - reports
- Independent vicarious validation
  - e.g., airborne HySpex

DLR

EnMAP Summary on Radiometric…

Ground Segment   15
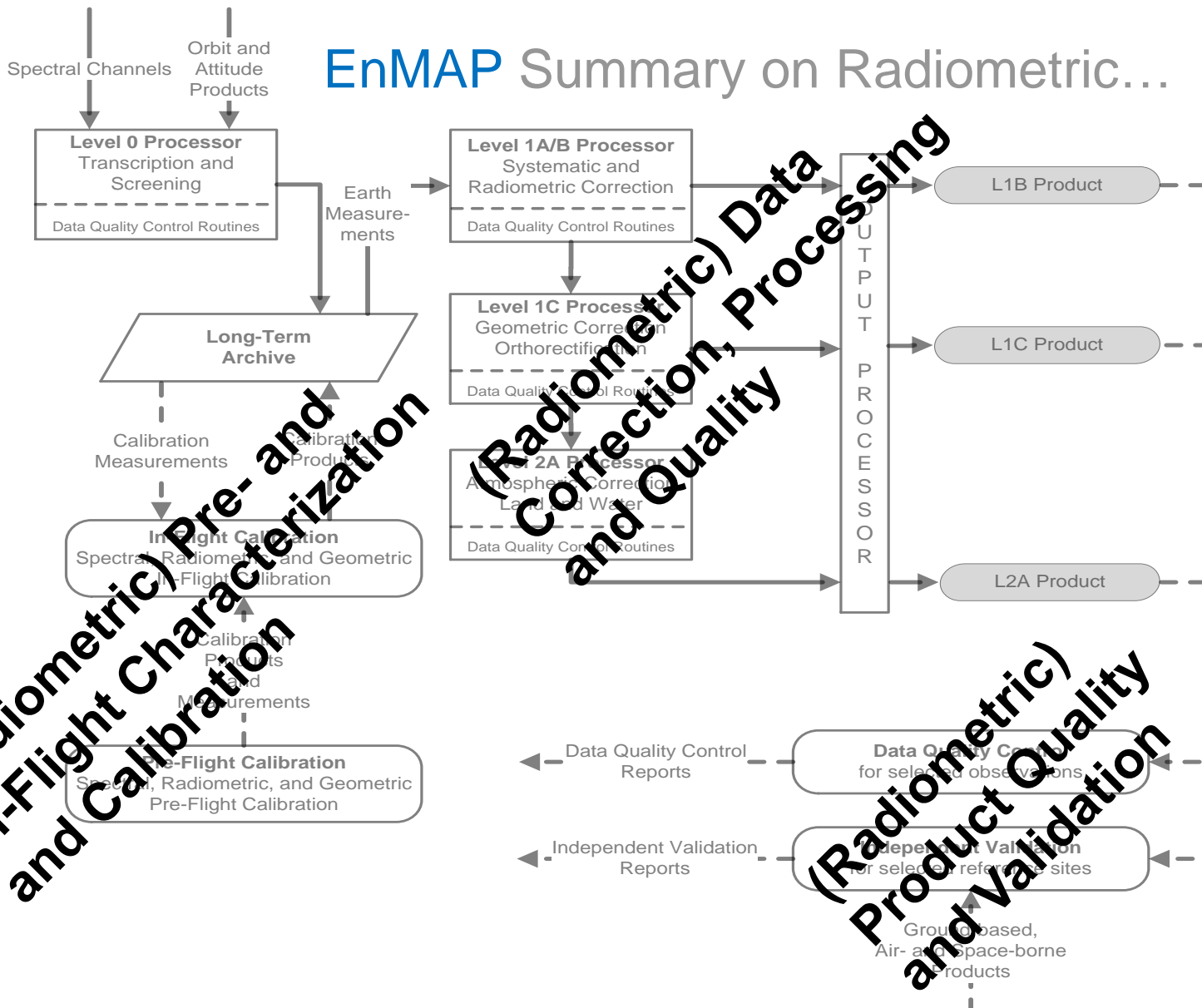
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Federal Ministry
for Economic Affairs
and Energy

Source: DLR, OHB