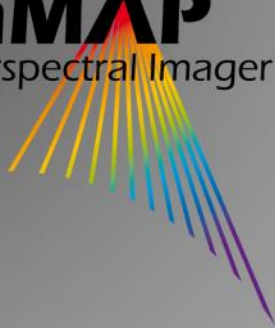


**EnMAP**  
Hyperspectral Imager



# EnMAP Mission Status

Emiliano Carmona for the EnMAP Ground  
Segment Team

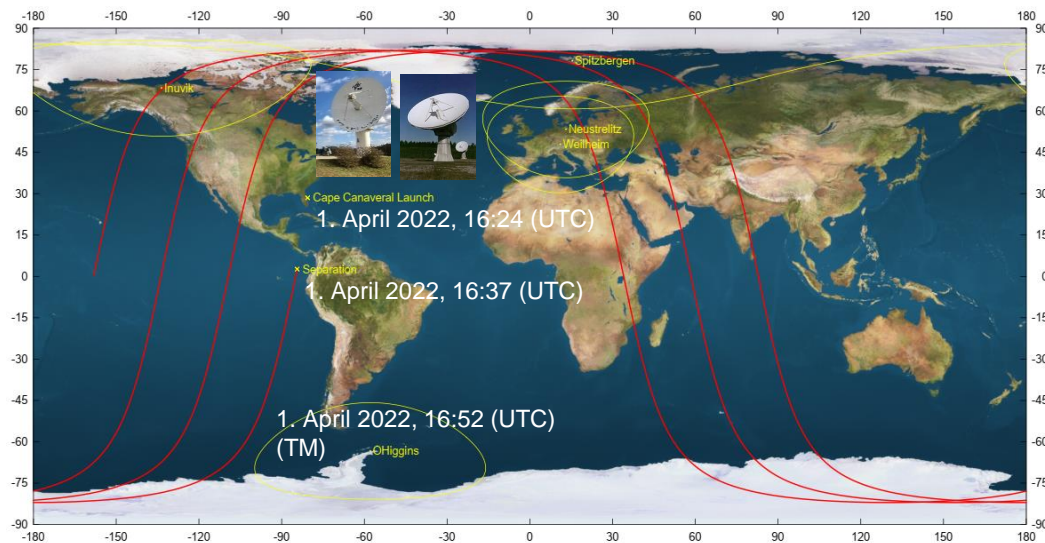
**GFZ**  
Helmholtz-Zentrum  
POTSDAM



**OHB**  
SYSTEM



- EnMAP launched on 1<sup>st</sup> April 2022 on a SpaceX Falcon 9 rocket from Cape Canaveral
- Precise launch and separation. First contact ~30 minutes later
- Commissioning Phase in progress

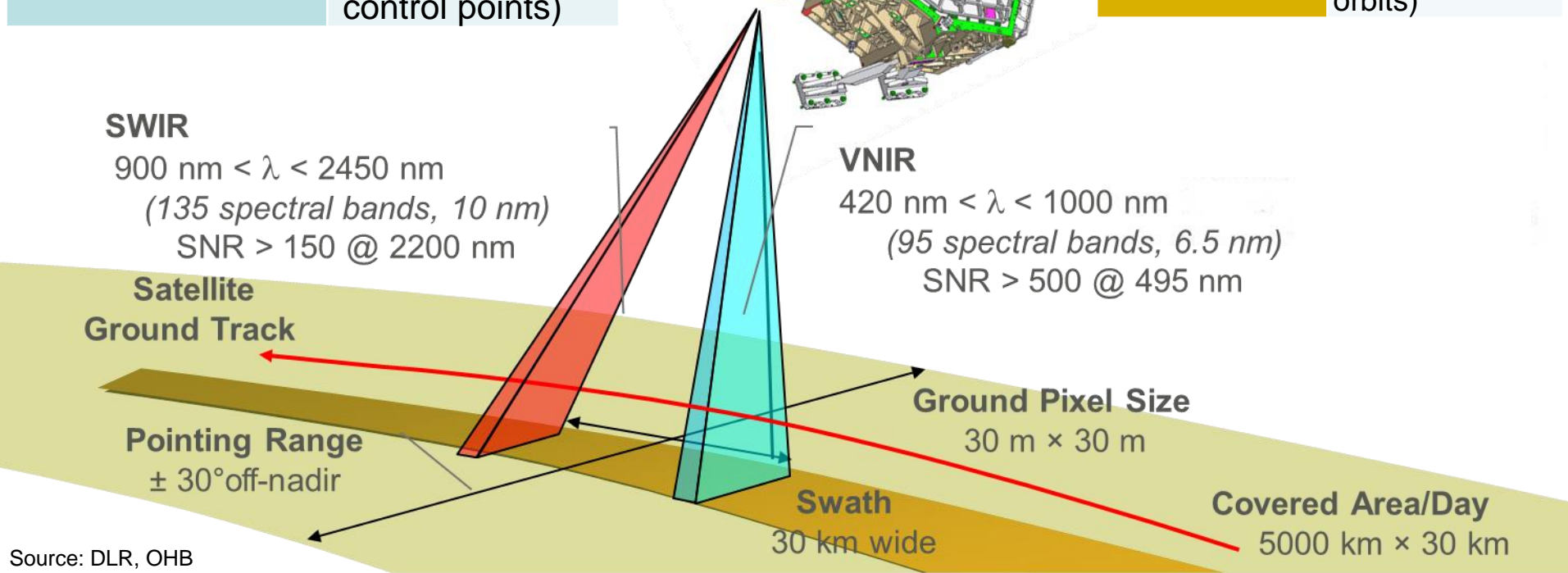


# EnMAP – Mission



Instruments Parameters	Value
Spectral Accuracy	0.5 nm (VNIR); 1.0 nm (SWIR)
Radiometric Accuracy	<b>5.0% (absolute); 2.5% (relative)</b>
Geometric Accuracy	100 m (30 m with control points)

Parameter	Value
Orbit type	Sun-synchronous
Orbit height	653 km
Orbit Period	97 minutes
Repeat Cycle	27 days (398 orbits)

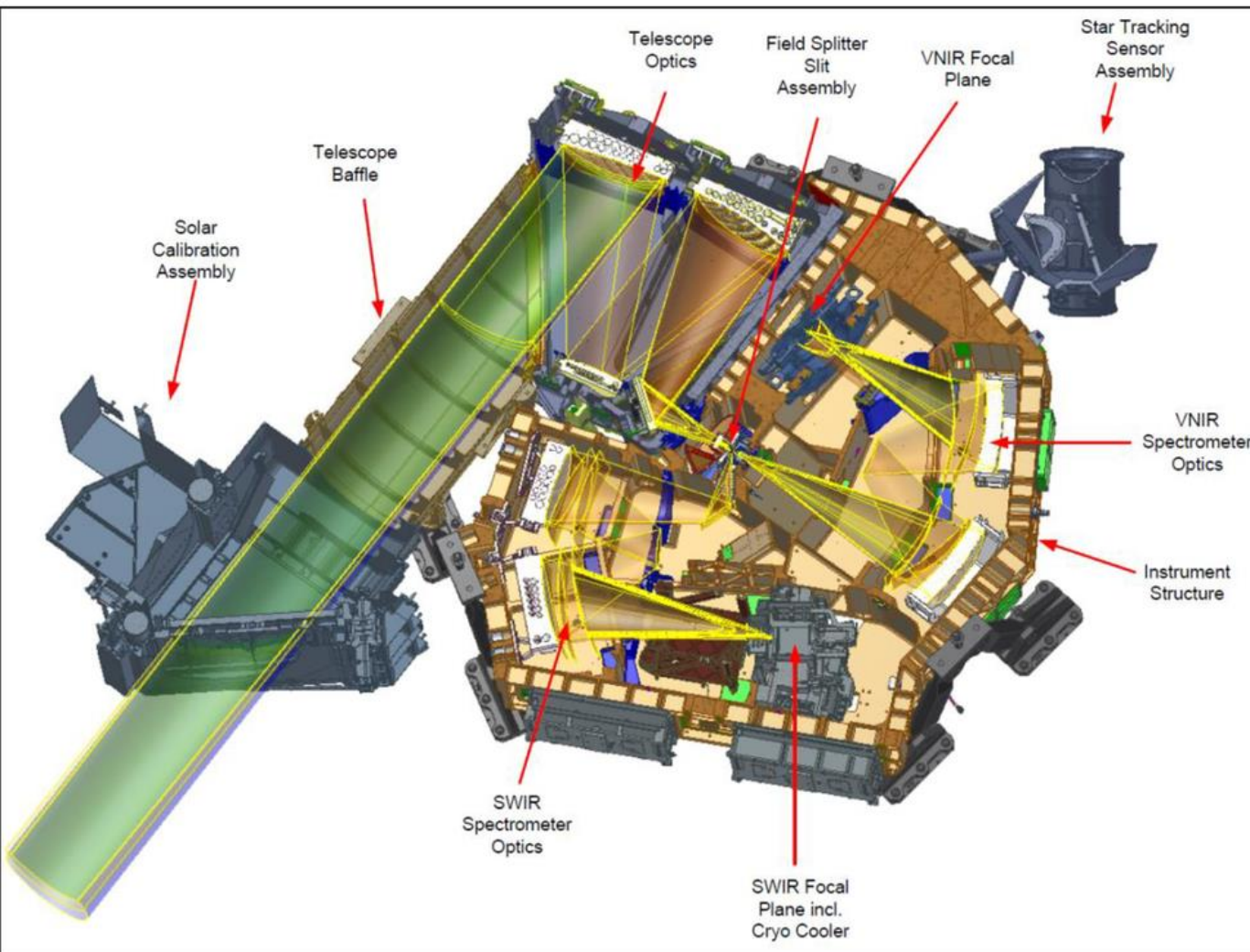


Source: DLR, OHB

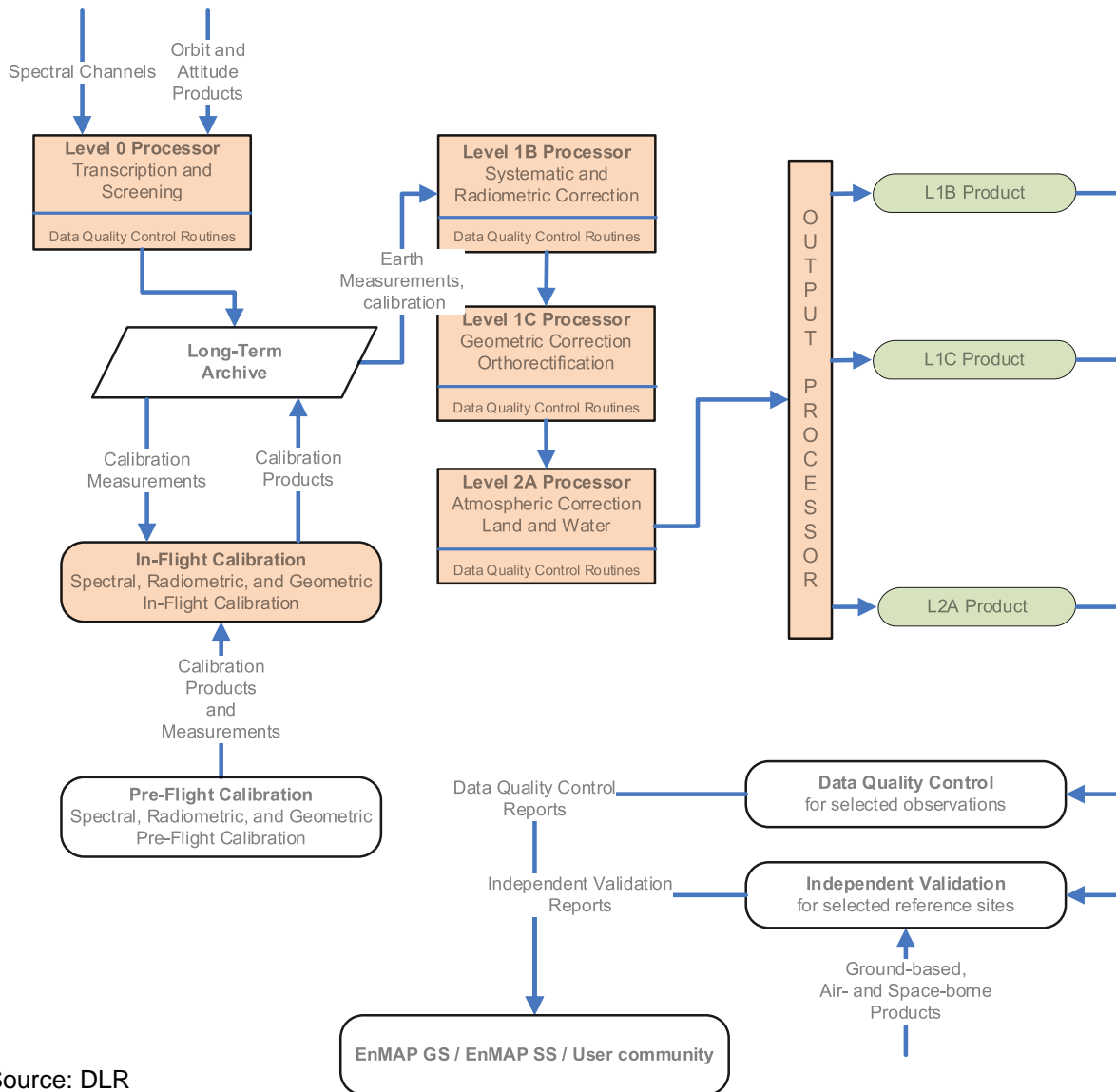
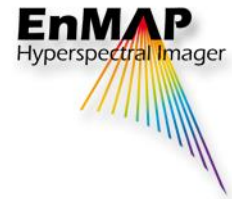


- Three mirror anastigmatic telescope  $\pm 1.3^\circ$  across track
- Independent VNIR and SWIR spectrometers
- Curved prism design
- 2D focal planes acquiring 14 bit resolution data at 230 Hz

Guanter et al. Rem. Sens. (2015)



# EnMAP – Processing Workflow and user products

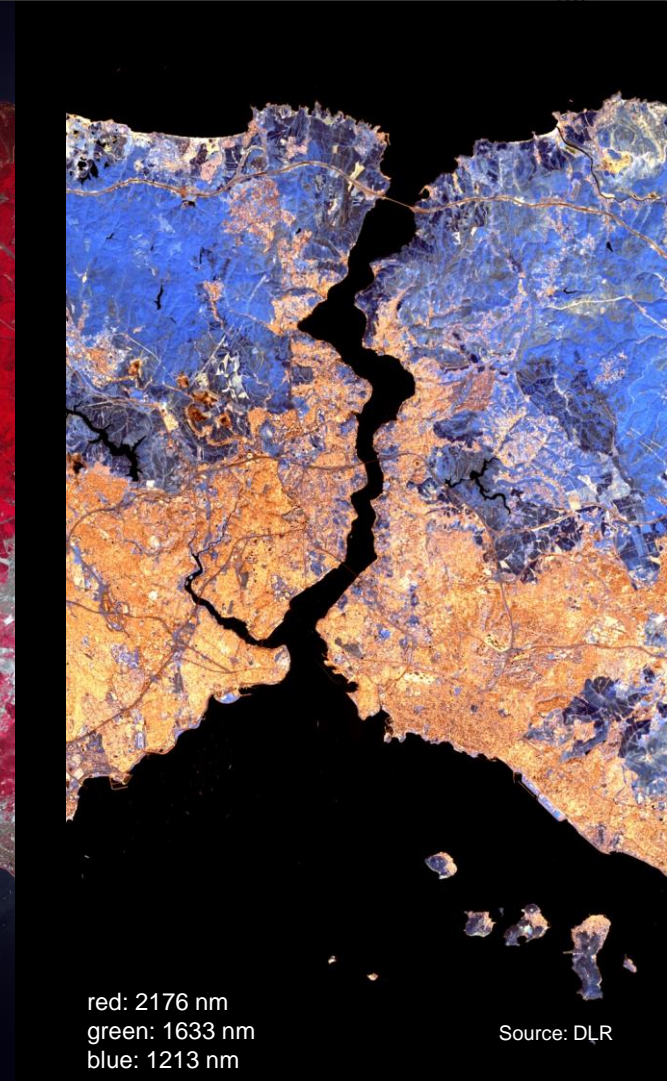


- In-flight calibration observations are processed to generate updated calibration tables
- Three level of users products can be ordered (L1B / L1C / L2A) from Earth observations
- User products annotated with quality information (metadata) plus periodic quality and validation reports
- Quality Control (GS) and Independent Validation (GFZ) performed on user products

Source: DLR

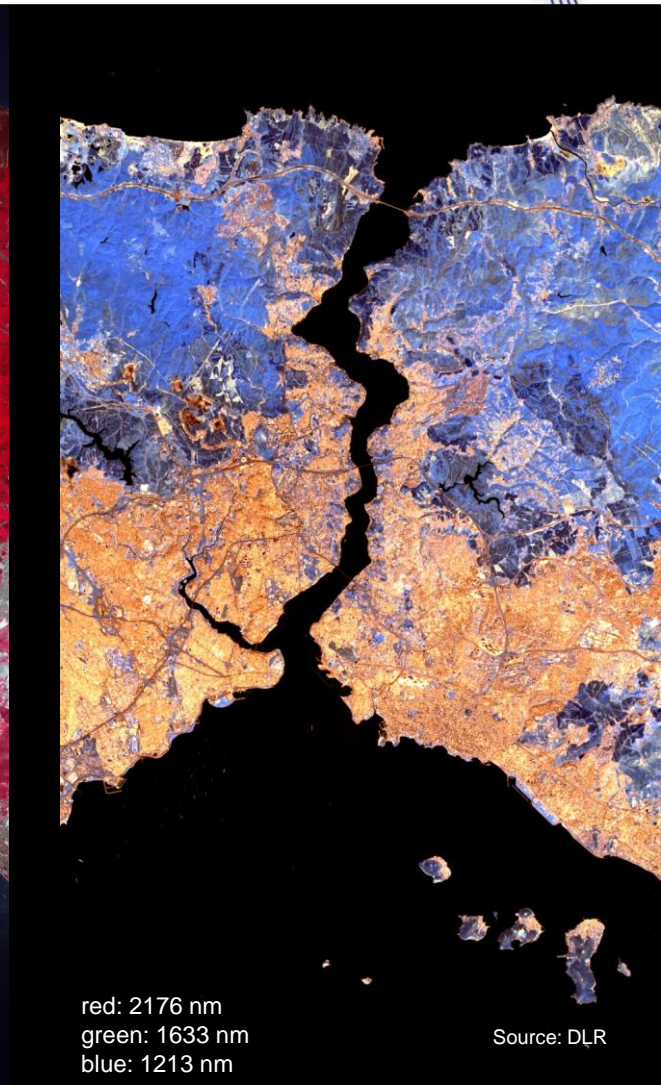
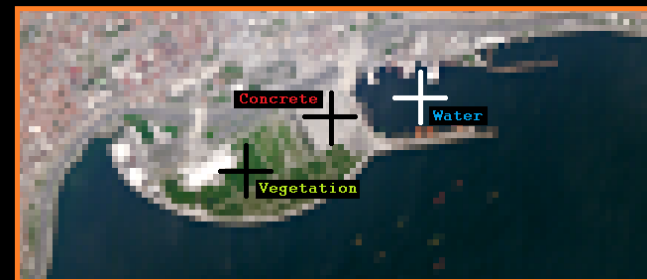
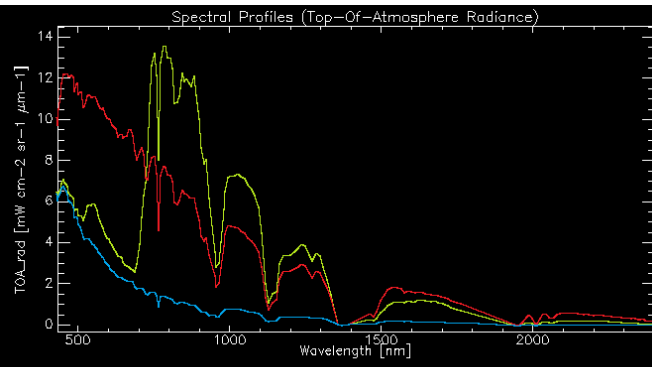


# EnMAP – First Image data



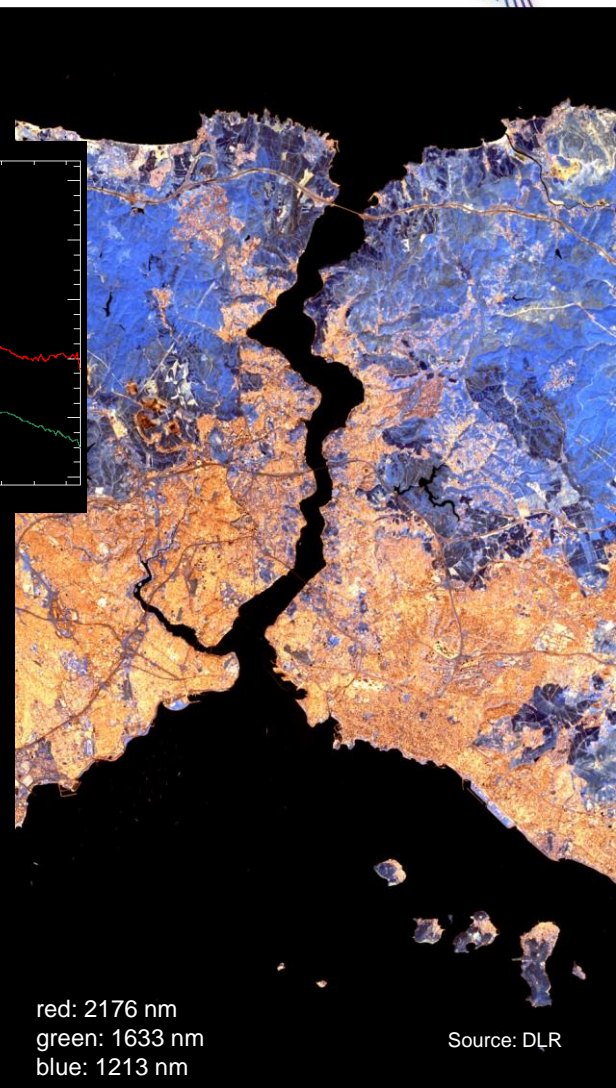
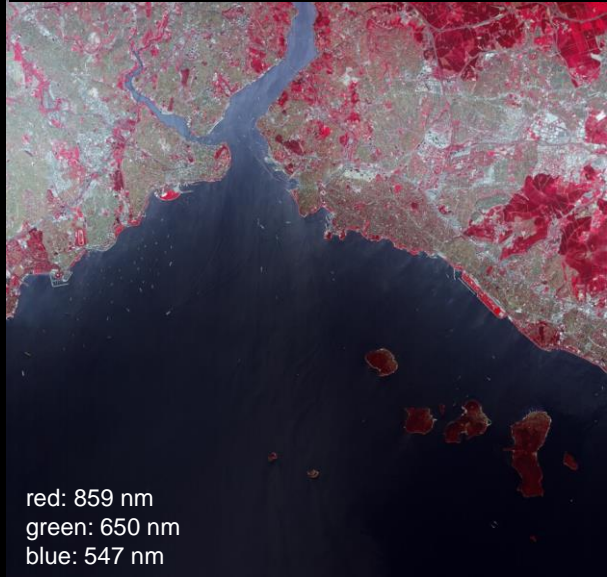
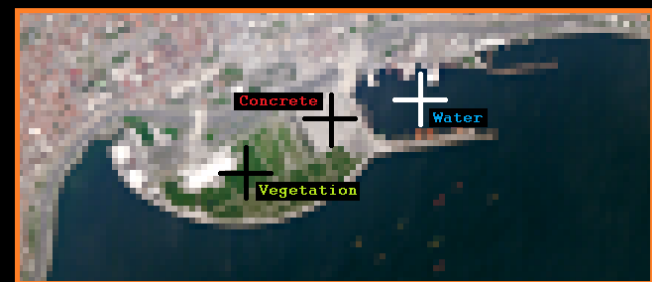
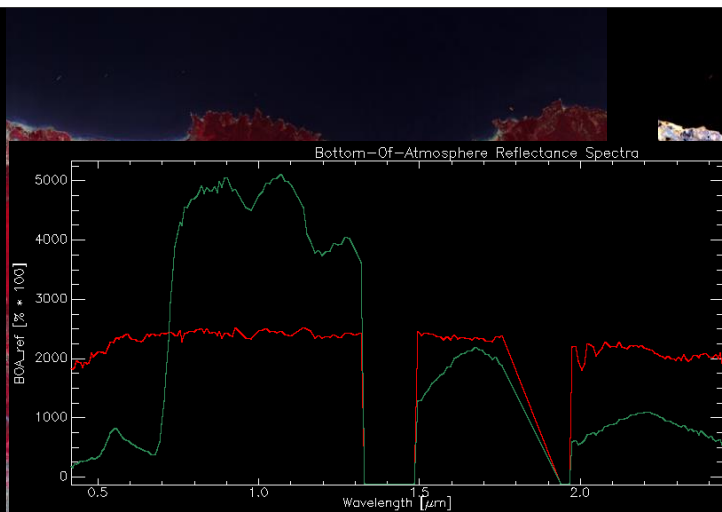
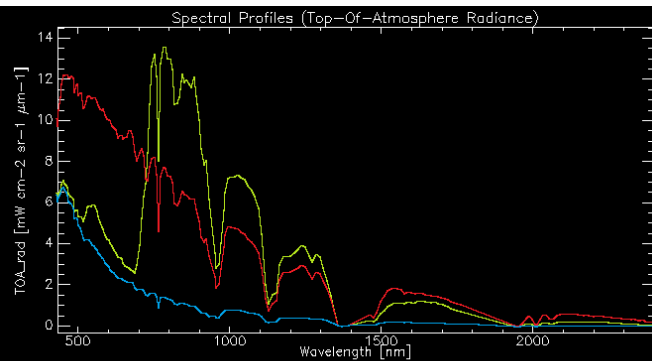


# EnMAP – First Image data



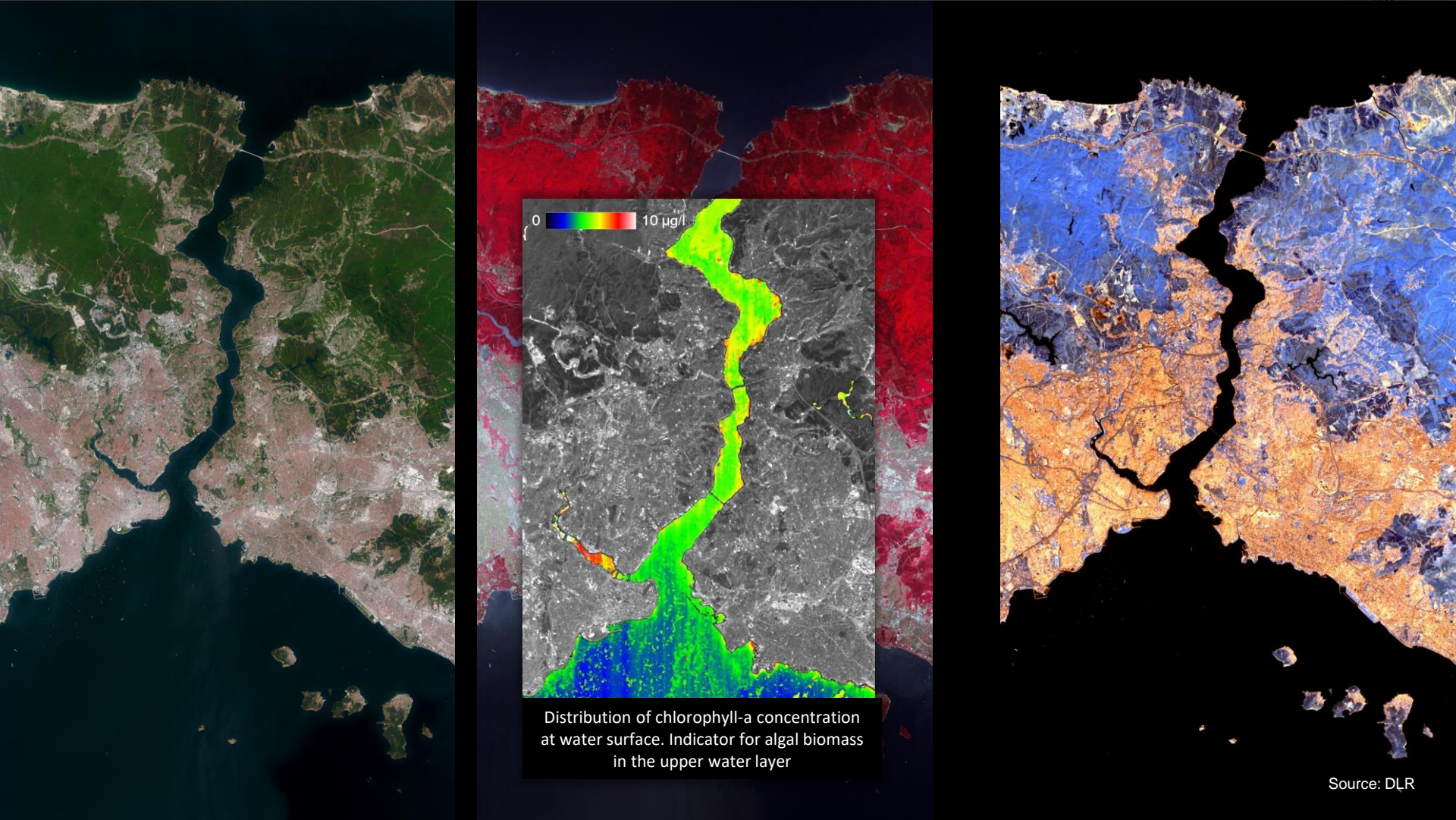
Source: DLR

# EnMAP – First Image data



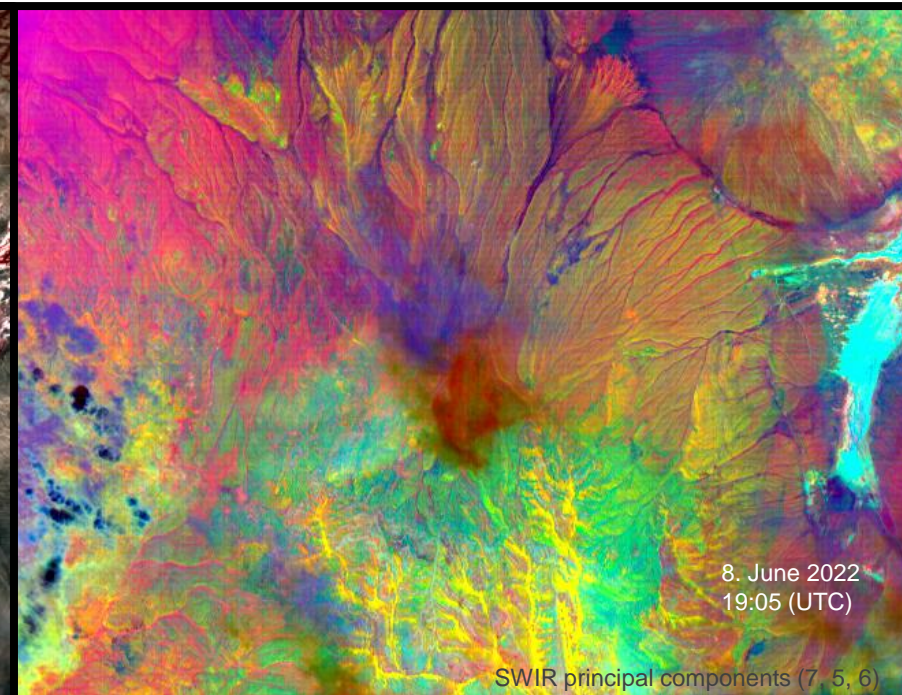
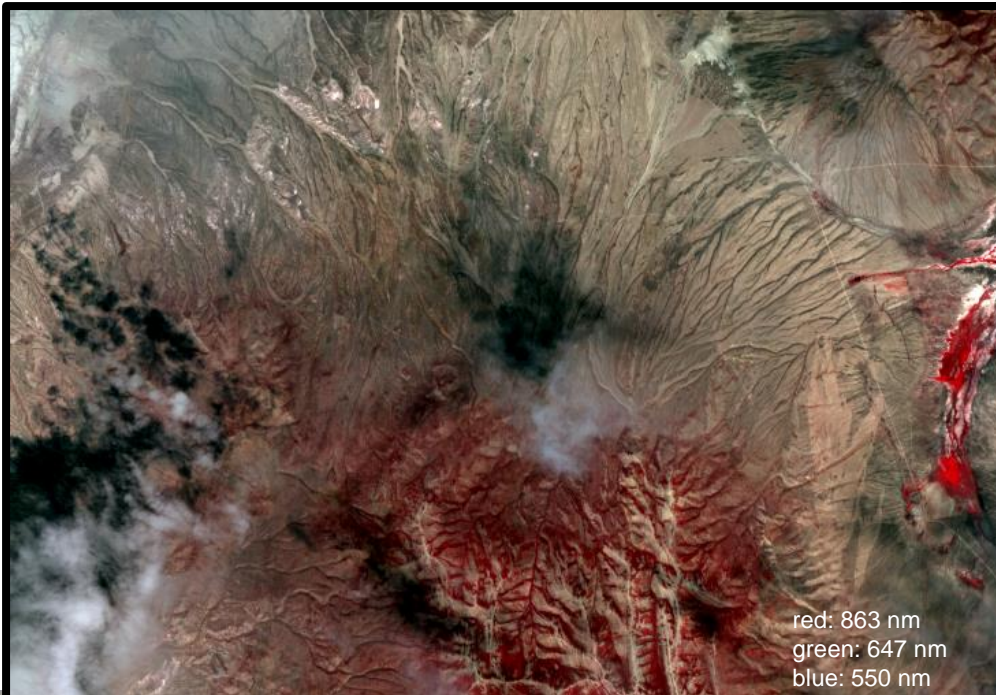
Source: DLR







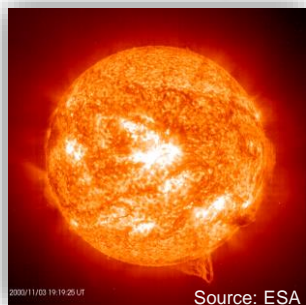
# EnMAP – More Images



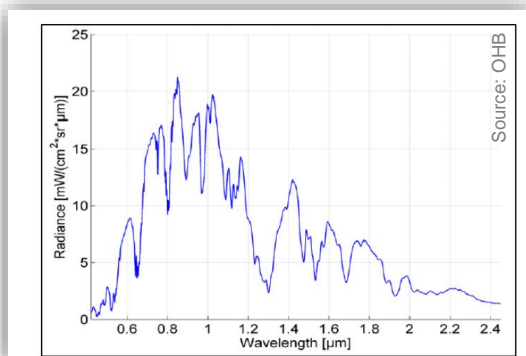
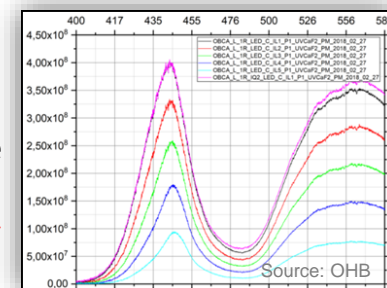




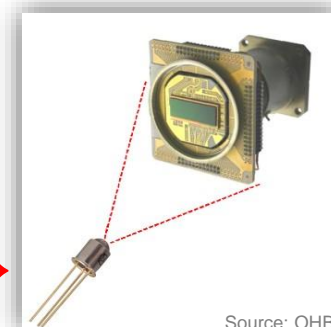
- ← • Closed Shutter [dark]
- Deep Space [dark] →



- ← • Sun Calibration [absolute radiometric]
- White Spectralon [relative radiometric] →

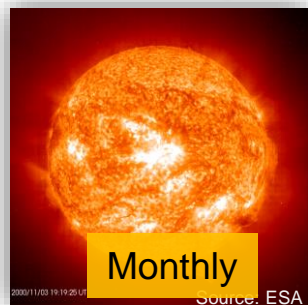
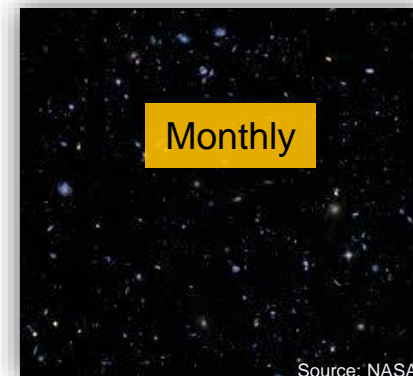


- ← • Doped Spectralon [absolute spectral]
- Focal Plane LED [linearity] →



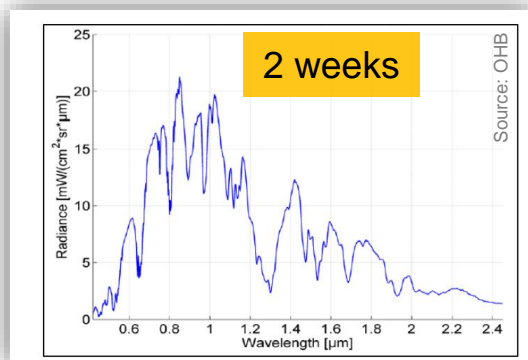
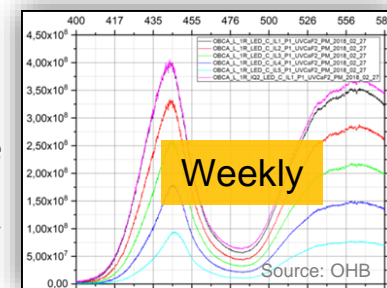


- Closed Shutter [dark] ←
- Deep Space [dark] →



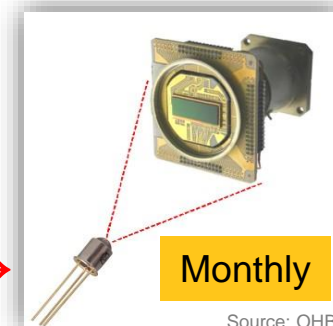
- Sun Calibration [absolute radiometric] ←

- White Spectralon [relative radiometric] →



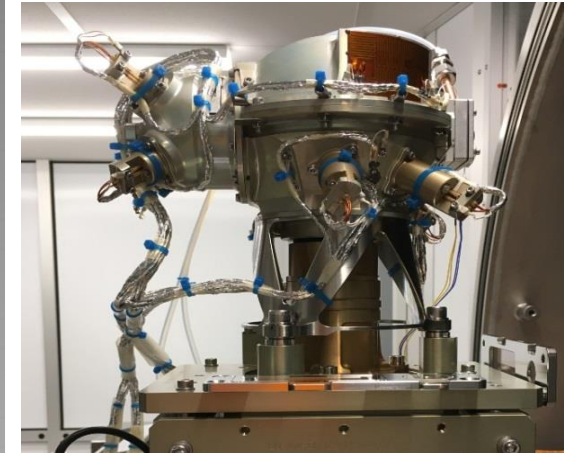
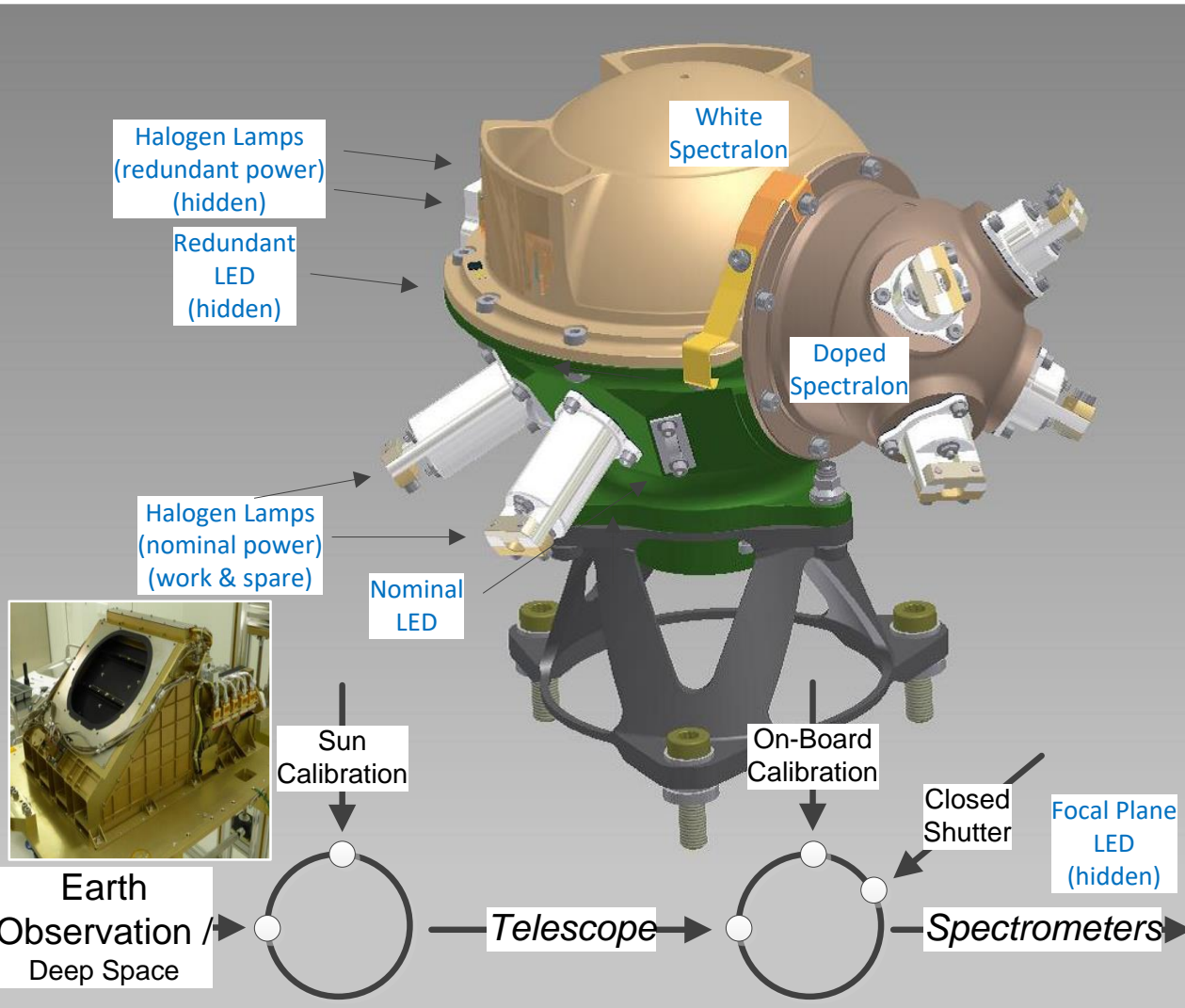
- Doped Spectralon [absolute spectral] ←

- Focal Plane LED [linearity] →





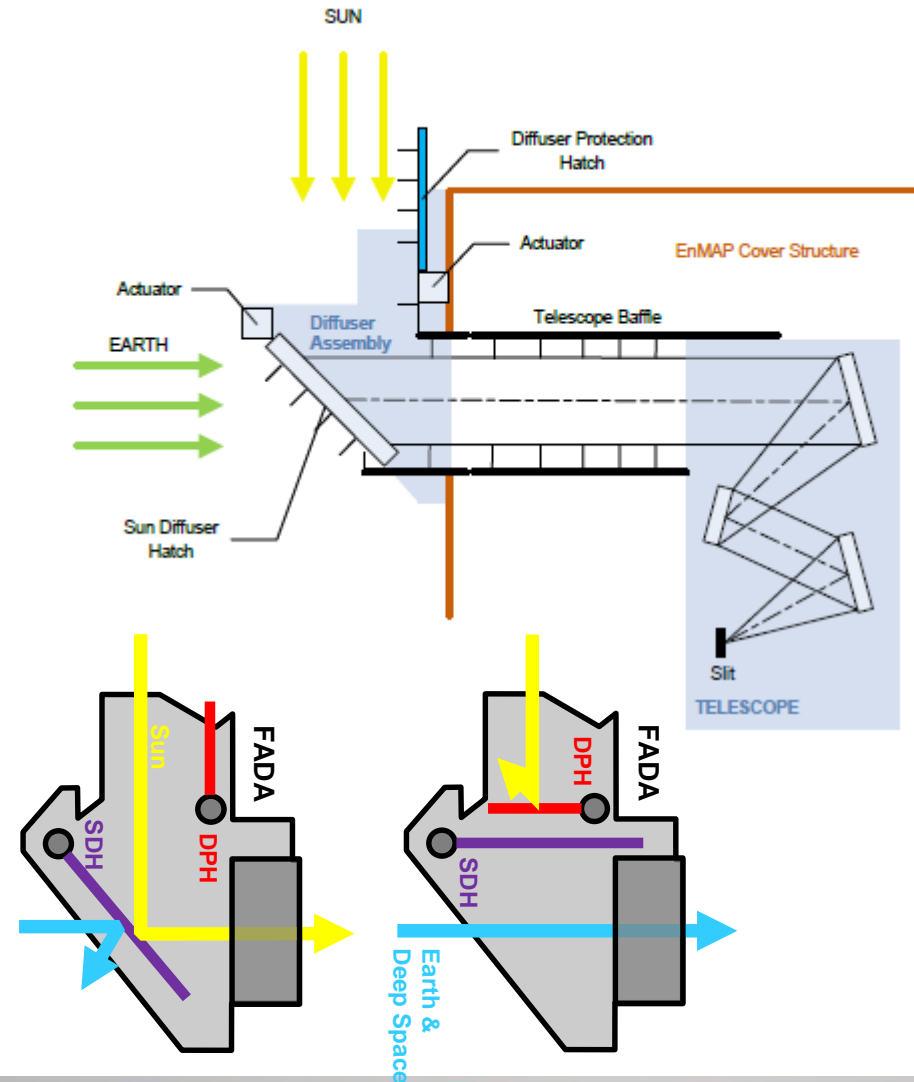
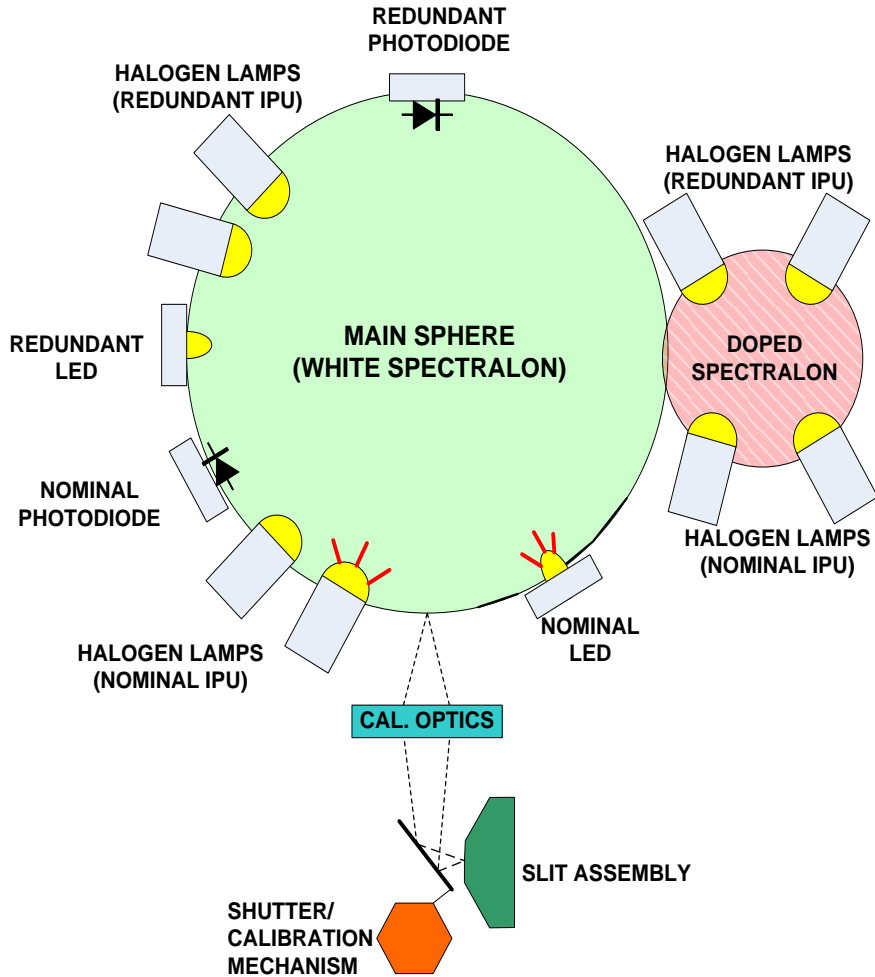
# EnMAP – On-Board Calibration Equipment



- White Spectralon [relative radiometric]
- Doped Spectralon [absolute spectral]
- Focal Plane LED [linearity]

Source: OHB

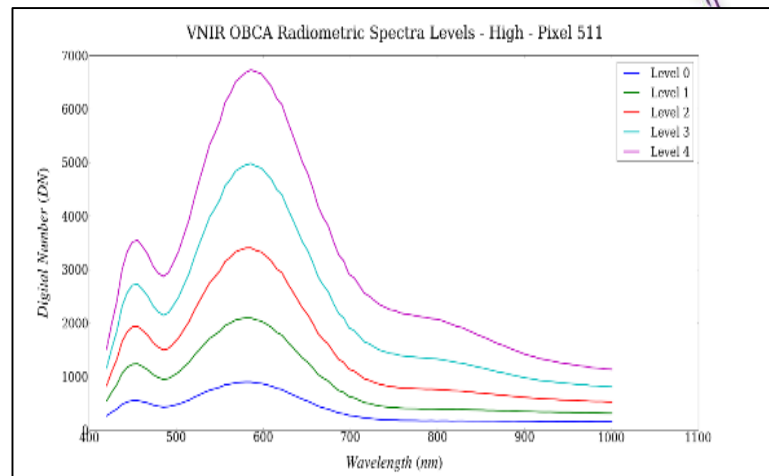
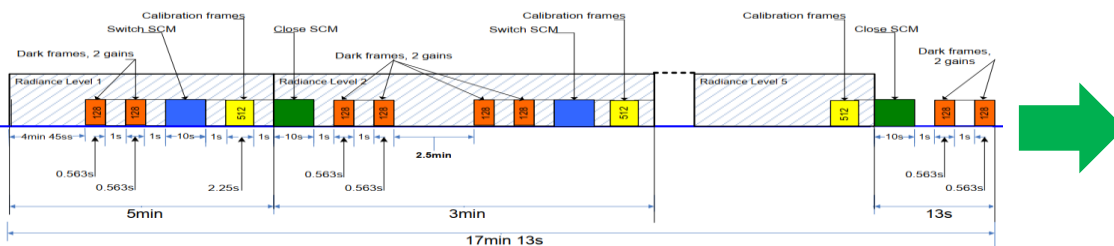
# EnMAP – On-Board Calibration Equipment



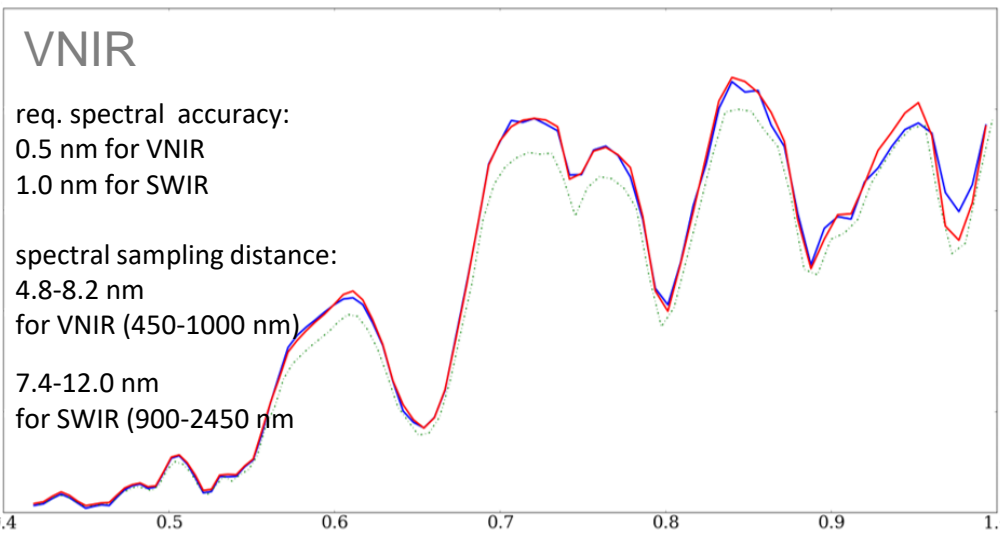
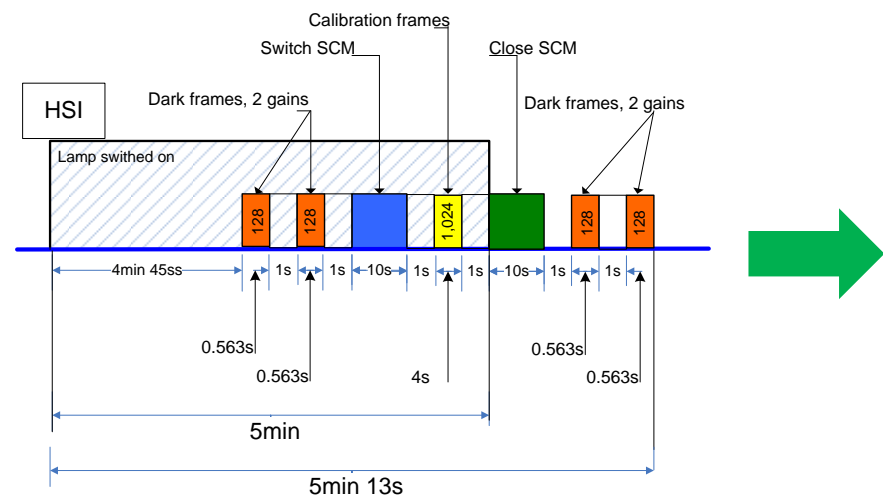
Source: OHB



## Lamp calibration: 5 intensity levels



## Spectral calibration:

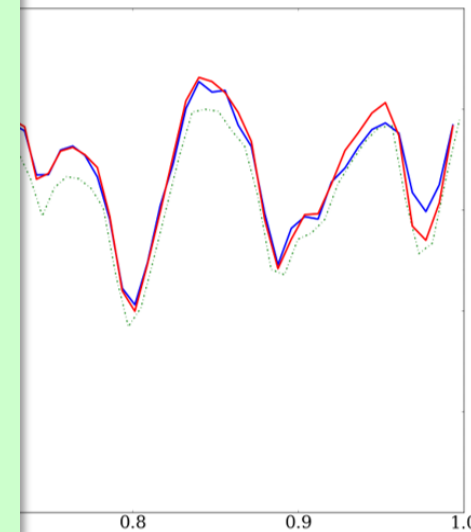
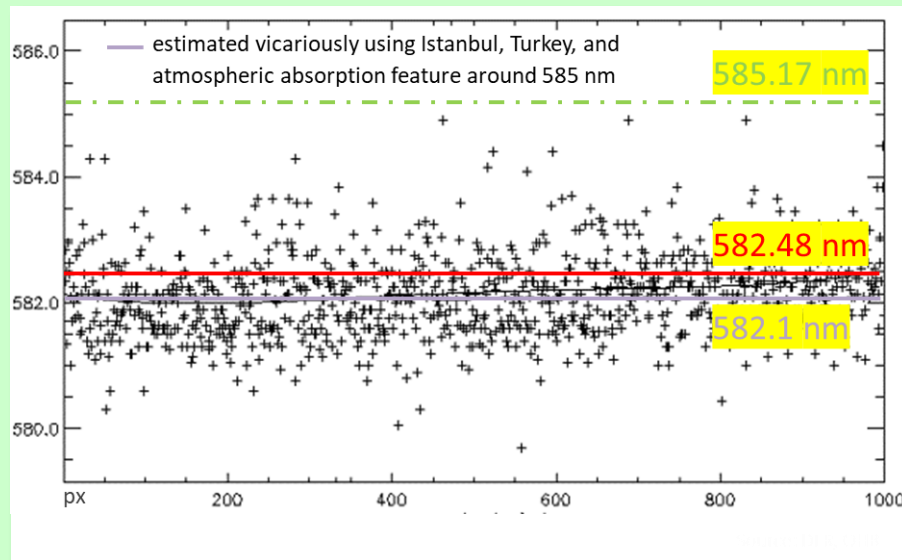
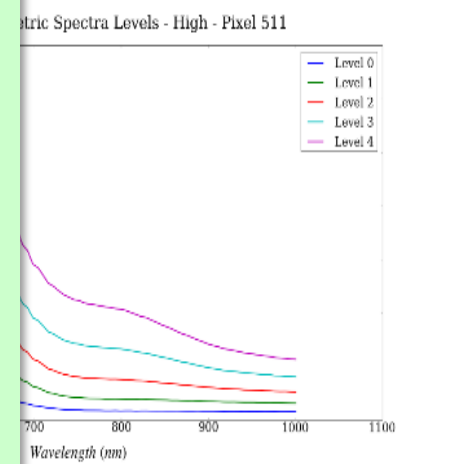
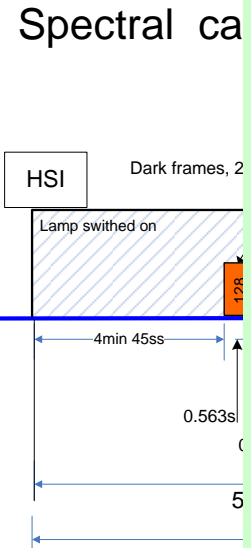
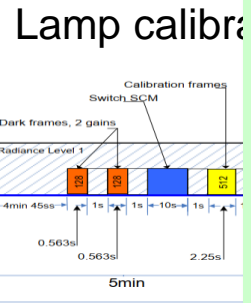


Source: OHB, DLR

Constant spectral shift for 1<sup>st</sup> spectral calibration of -0.47 spectral sampling distance\* (expected due to gravity release)

Spectral shift between 1<sup>st</sup> & 2<sup>nd</sup> spectral calibration of 0.002 SSD\* (expected stability)

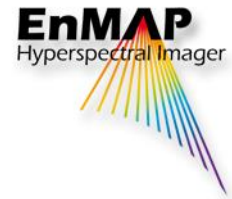
Confirmed vicariously:



Source: OHB, DLR

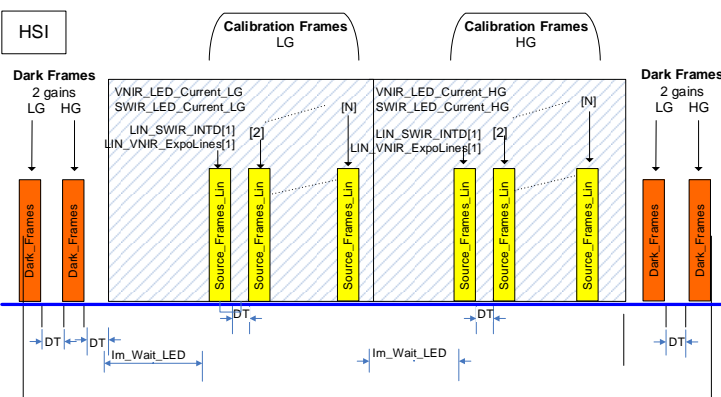
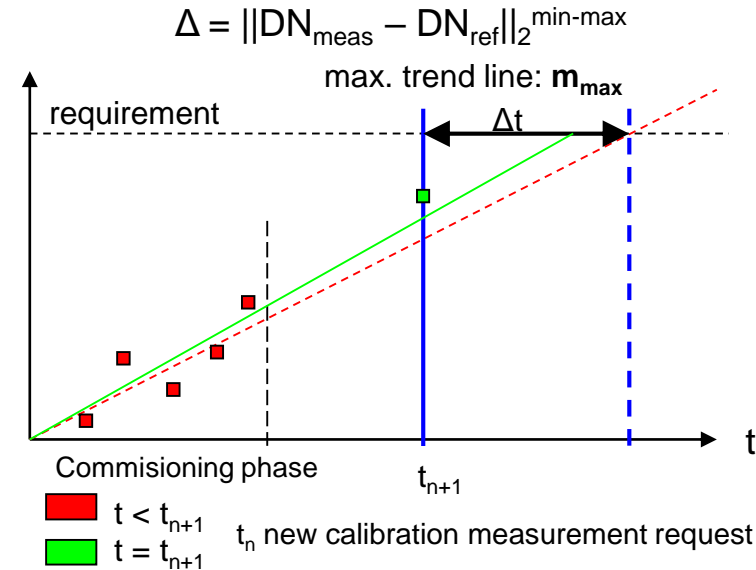
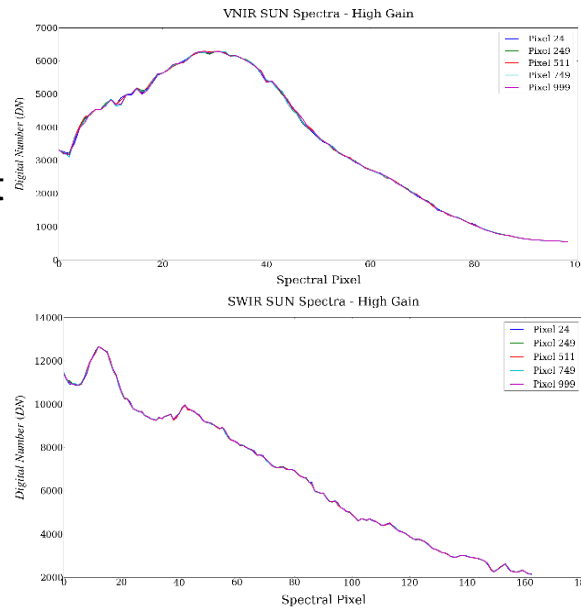


# EnMAP – Sun and Linearity Calibrations



Absolute calibration from Sun Measurement (also RNU correction and gain matching)

Requirement radiometric accuracy: 5%

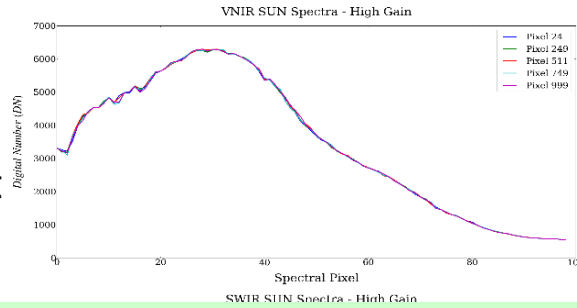


## • Linearity Calibration

- Monthly
- Only sensor
- Only for monitoring

Source: OHB, DLR

Absolute calibration from Sun Measurement (also RNU correction and gain matching)



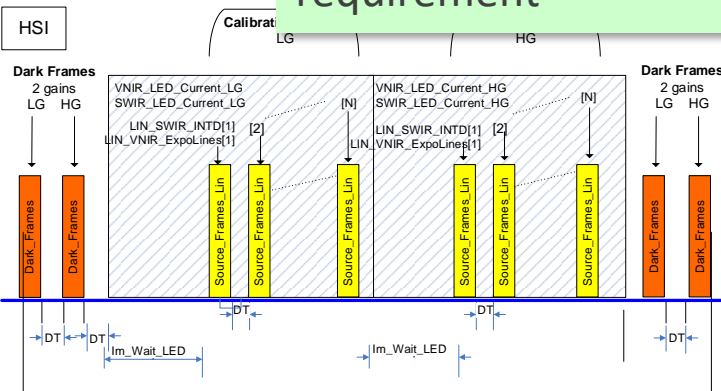
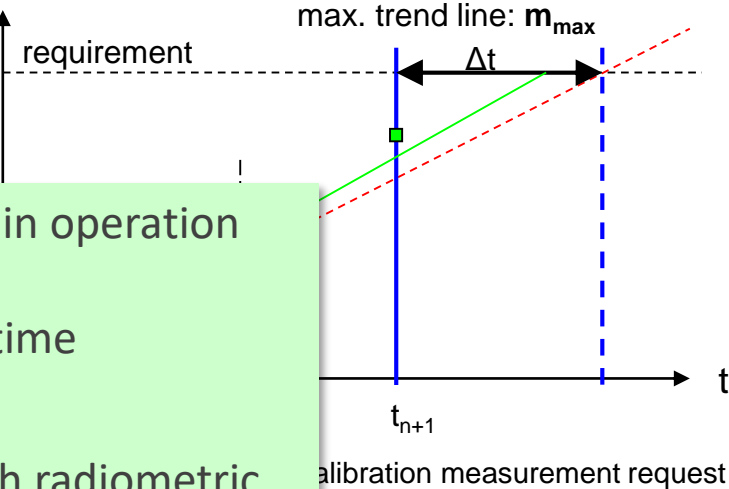
Requirement radiometric accuracy 5%

SWIR detector very stable after a few weeks in operation

VNIR detector shows higher variability with time

Preliminary results show no problem to reach radiometric requirement

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



## • Linearity Calibration

- Monthly
- Only sensor
- Only for monitoring

Source: OHB, DLR

# EnMAP – Radiometric Calibration (RNU)

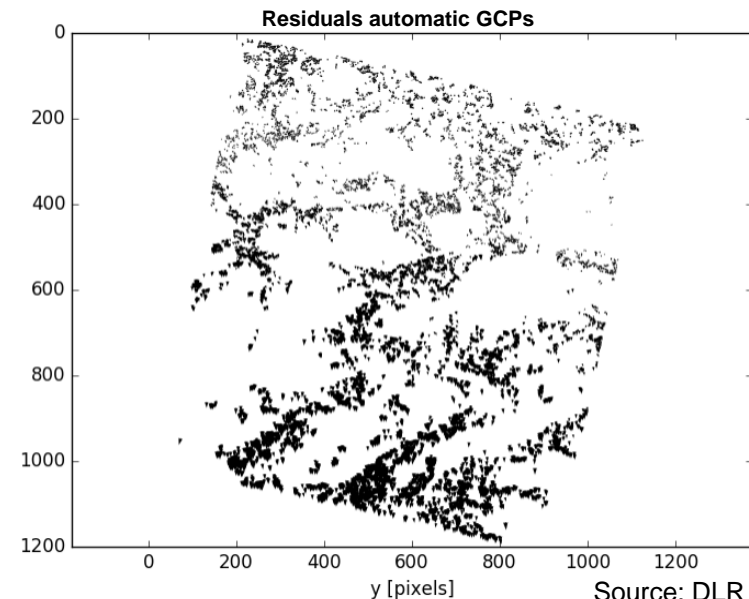
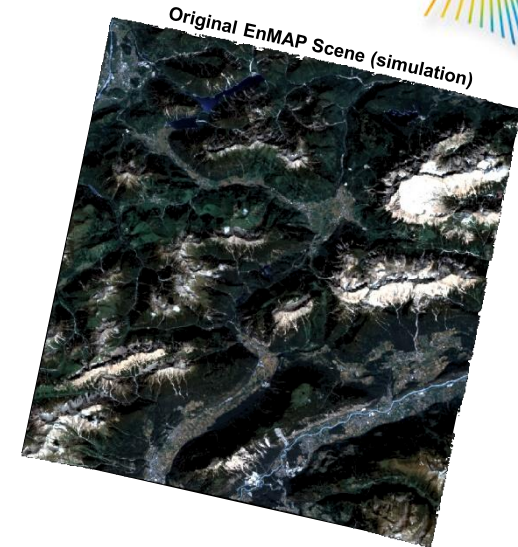
corrected using pre-flight

corrected using in-flight

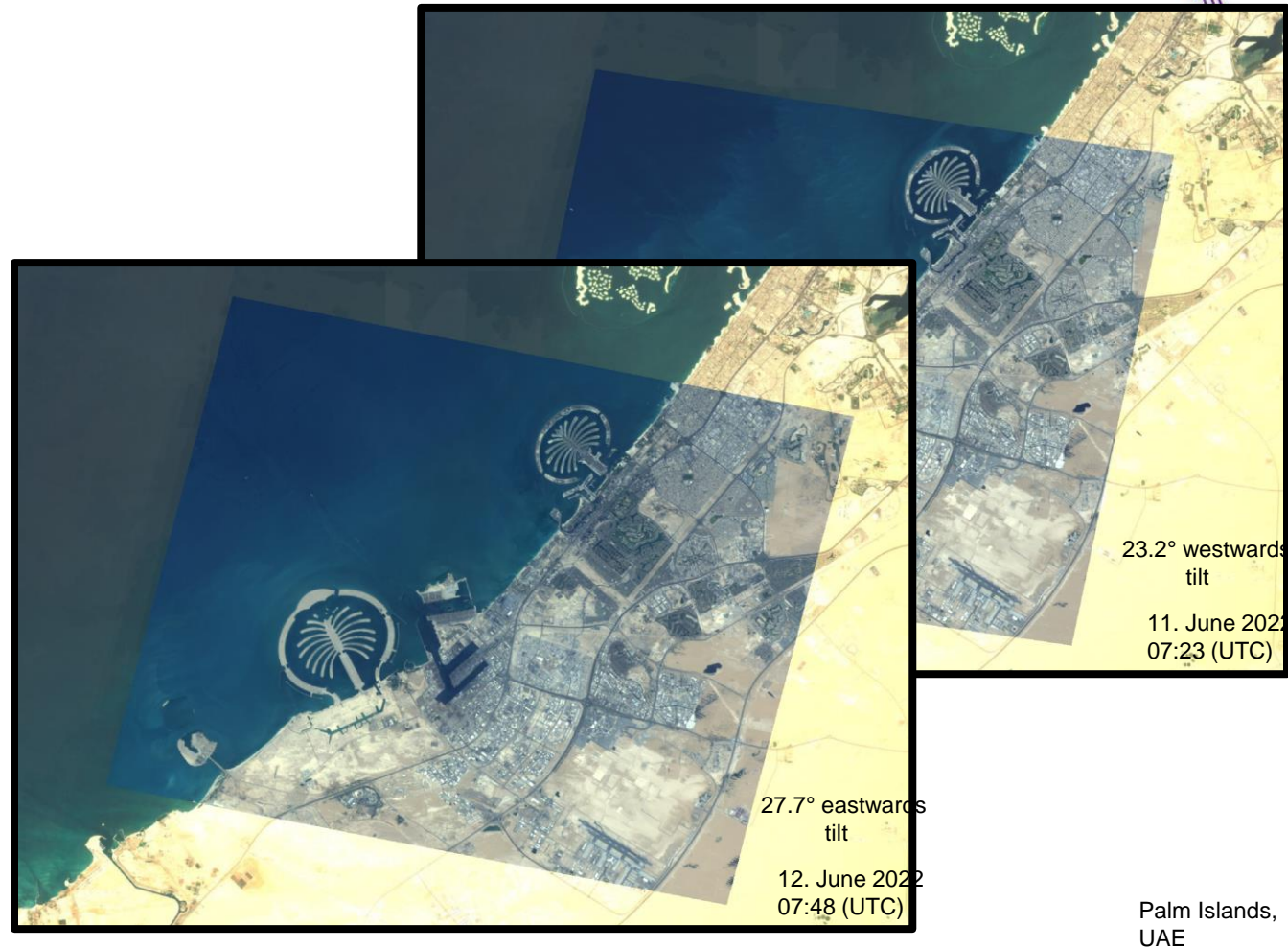
PICS Algeria 3  
red: 625 nm  
green: 508 nm  
blue: 456 nm



- Like spectral and radiometric characterization, extensive geometric pre-flight characterization in laboratory
- After launch, vibrations and gravitational release demand monitoring of geometric performance and the possibility of geometric calibration
- Boresight misalignment angles can be computed on Earth observations based on automatically extracted GCPs on EnMAP scenes and reference Sentinel-2 scenes
- Requirements:
  - Geolocation accuracy with GCPs at nadir look  $< 1$  pixel (30 m) w.r.t. reference images,  $< 100$  m without GCPs
  - VNIR / SWIR co-registration  $< 0.2$  pixel



# EnMAP – Geolocation Accuracy



- EnMAP (using matching) to Sentinel-2 reference (1 tile)

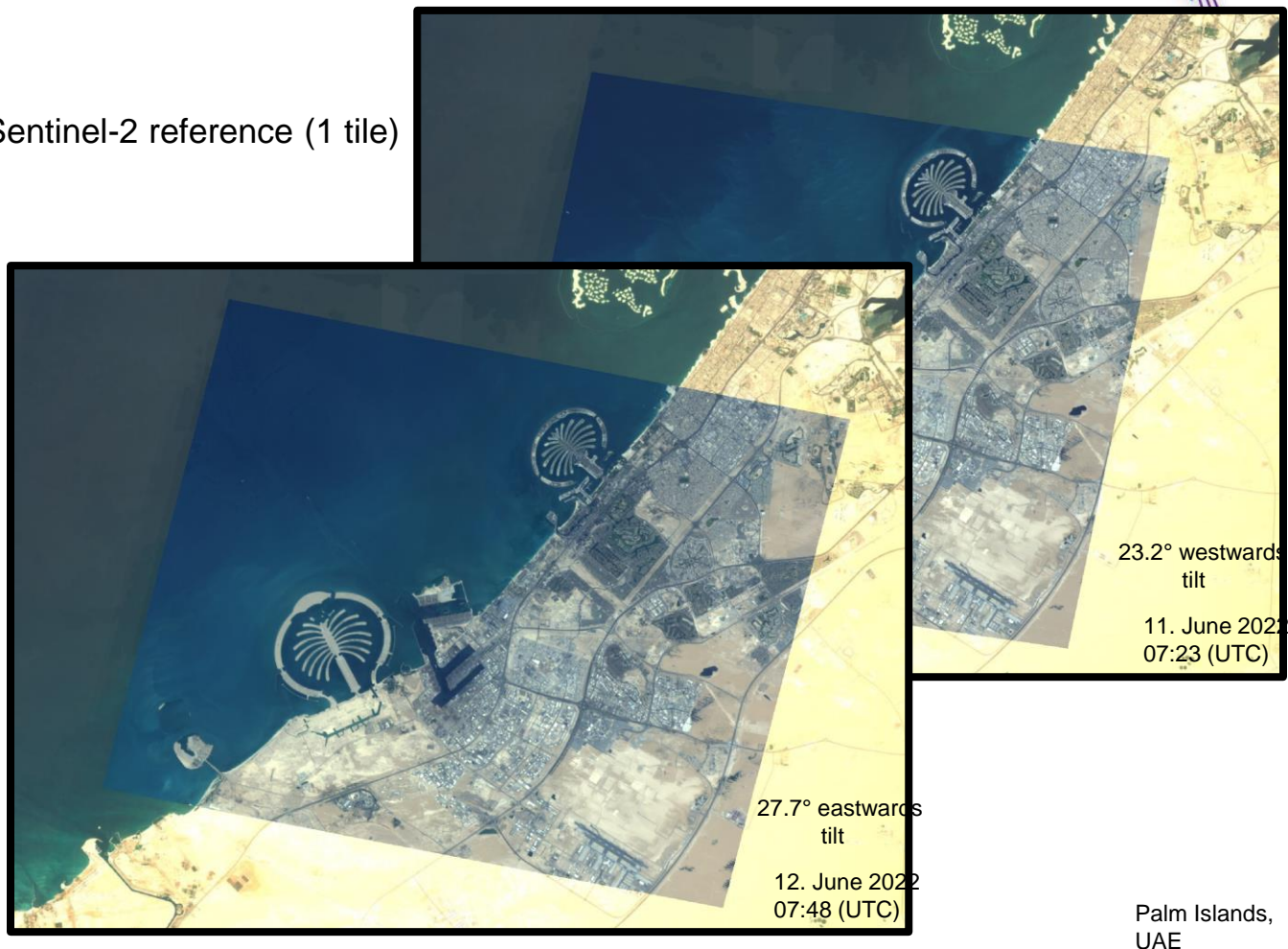
11.06.2022, 07:23	X [pixel]	Y [pixel]
Mean Deviation	0.10	-0.64
RMSE	0.24	0.70

12.06.2022, 07:48	X [pixel]	Y [pixel]
Mean Deviation	0.26	-0.43
RMSE	0.36	0.53

- EnMAP processing (3 tiles)

11.06.2022, 07:23	X [pixel]	Y [pixel]
RMSE	0.1	0.6

12.06.2022, 07:48	X [pixel]	Y [pixel]
RMSE	0.3	0.5





Currently assessed (by June '22):

Product	CEOS-ARD Type	PFS Version	Agency	Mission(s)	Threshold Specification	Target Specification
Landsat Collection 2	Surface Reflectance	v5.0	USGS	Landsat 4, 5, 7, 8, 9	100%	81%
Landsat Collection 2	Surface Temperature	v5.0	USGS	Landsat 4, 5, 7, 8, 9	100%	83%
Sentinel-2 Level-2A	Surface Reflectance	v5.0	ESA	Sentinel-2A, 2B	100%	Not assessed
EnMAP	Surface Reflectance	v5.0	DLR	EnMAP	100%	Not assessed
Sentinel-1 RTC	Normalised Radar Backscatter	v5.5	Sinergise & Digital Earth Africa	Sentinel-1 (A, B)	100%	Not assessed
Landsat Collection 2 U.S. ARD	Surface Reflectance	v5.0	USGS	Landsat 4, 5, 7, 8, 9	100%	Not assessed
Landsat Collection 2 U.S. ARD	Surface Temperature	v5.0	USGS	Landsat 4, 5, 7, 8, 9	100%	Not assessed



- EnMAP Products conformant with CEOS-ARD for LAND (CARD4L) at Threshold Specification
- *CEOS Analysis Ready Data (CEOS-ARD) are satellite data that have been processed to a minimum **set of requirements** and organized into a form that allows **immediate analysis** with minimum of additional user effort and **interoperability** both **through time** and **with other datasets**.*



# Thanks!

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