PREPARATORY ACTIVITIES FOR THE GERMAN SPACEBORNE IMAGING SPECTROMETER MISSION ENMAP

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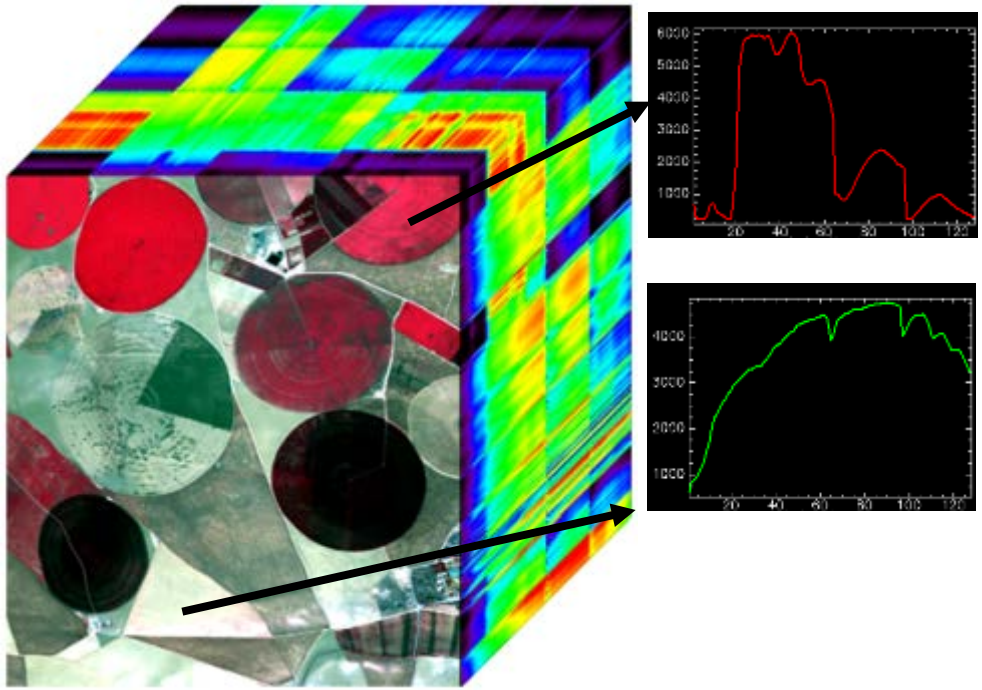
IGARSS 2017
Fort Worth, Texas

Mission Objectives

EnMAP - Environmental Mapping and Analysis Program

- Germany's first hyperspectral Earth observing satellite mission.
- Scientific path finder mission for later operational services
- Provide high-quality calibrated image products (ortho-rectification and atmo-spheric corrections) on a frequent basis.
- To observe a wide range of ecosystem parameters.
- To extend the scientific and technical know-how.
- Funded by



EnMAP
Hyperspectral Imager

Mission Organization

GFZ
Helmholtz-Zentrum
POTSDAM
Science Segment

DLR
Mission Management

OHB
SYSTEM
Space Segment

EOC
GSOC
DLR
Ground Segment

Platform

Instrument

Launcher

Mission Operations Segment

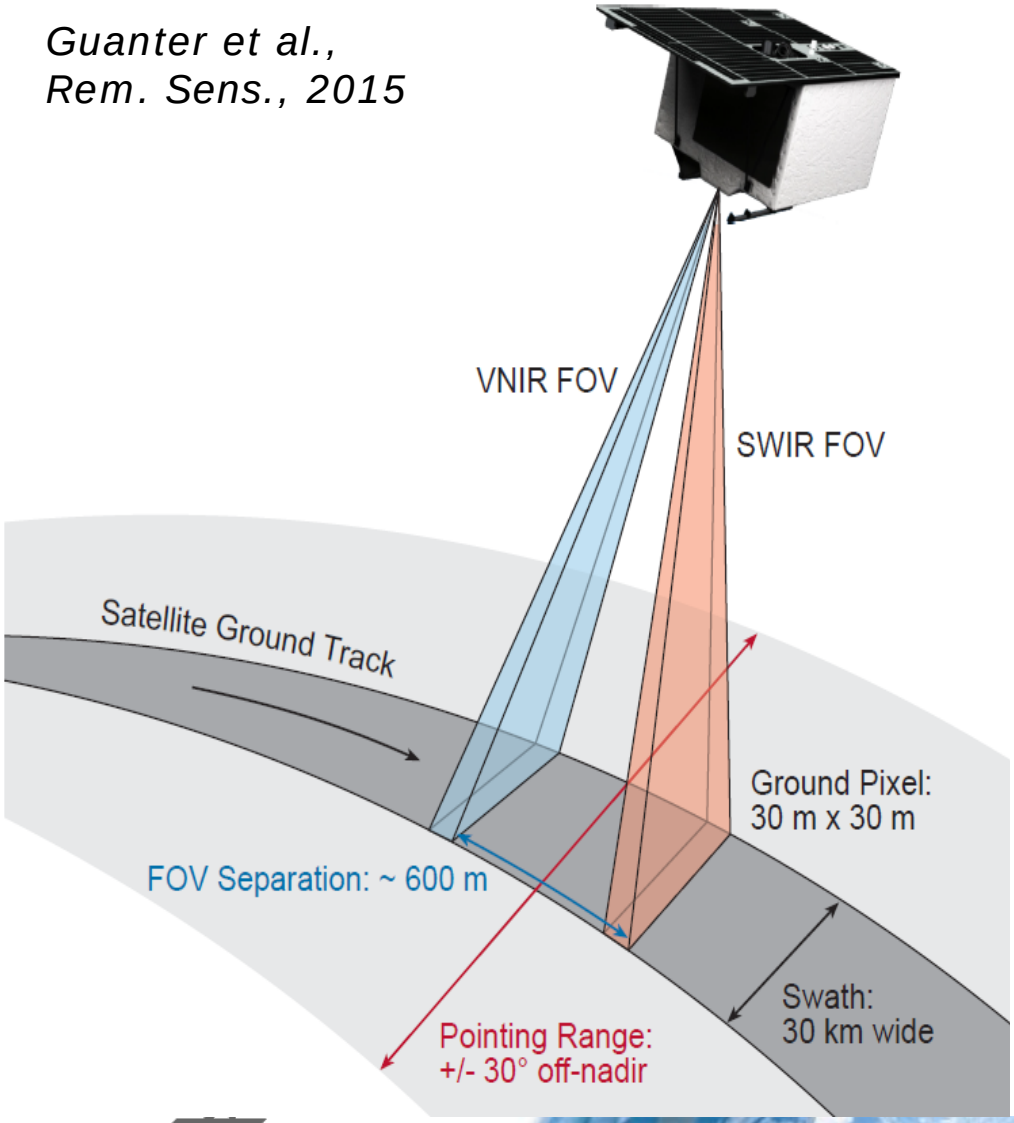
Payload Ground Segment

Prozessors Calibration Segment

DLR

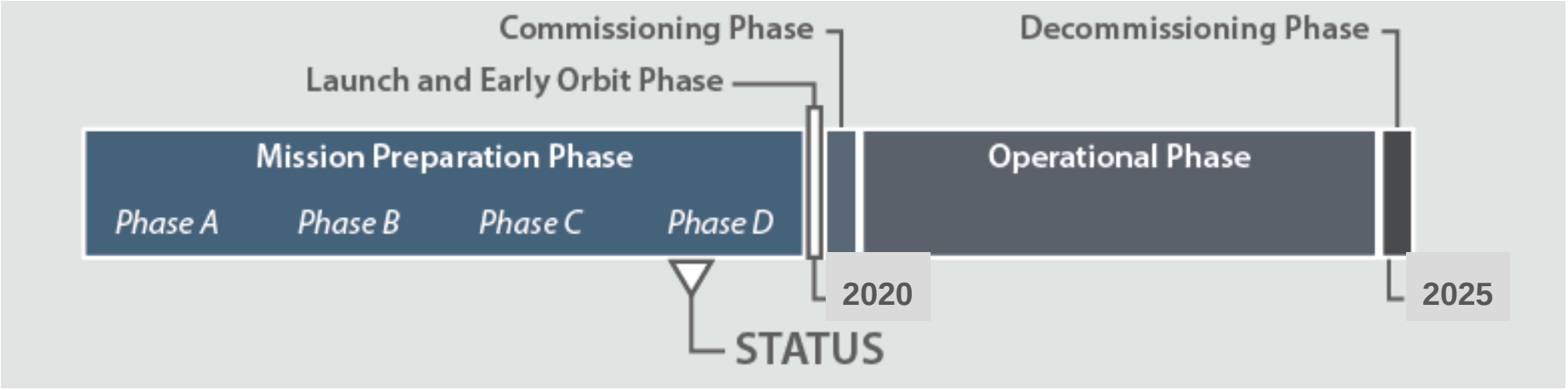
Main Mission Parameters

Guanter et al., Rem. Sens., 2015



- Push-broom imaging spectrometer
- Sun-synchronous orbit, 11h LTDN
- Spectral range
  - VNIR: 420 nm to 1000 nm
  - SWIR: 900 nm to 2450 nm
- Spectral sampling distance
  - VNIR ~6.5 nm
  - SWIR ~10 nm
- Data acquisition
  - ≤ 1000 km/orbit
  - ≤ 5000 km/day
- Swath width 30 km
- Ground sampling distance 30 m
- Revisit time
  - ≤ 27 d quasi-nadir (≤ 5º across-track pointing)
  - ≤ 4 d with 30º across-track pointing

Mission Status



Launcher:

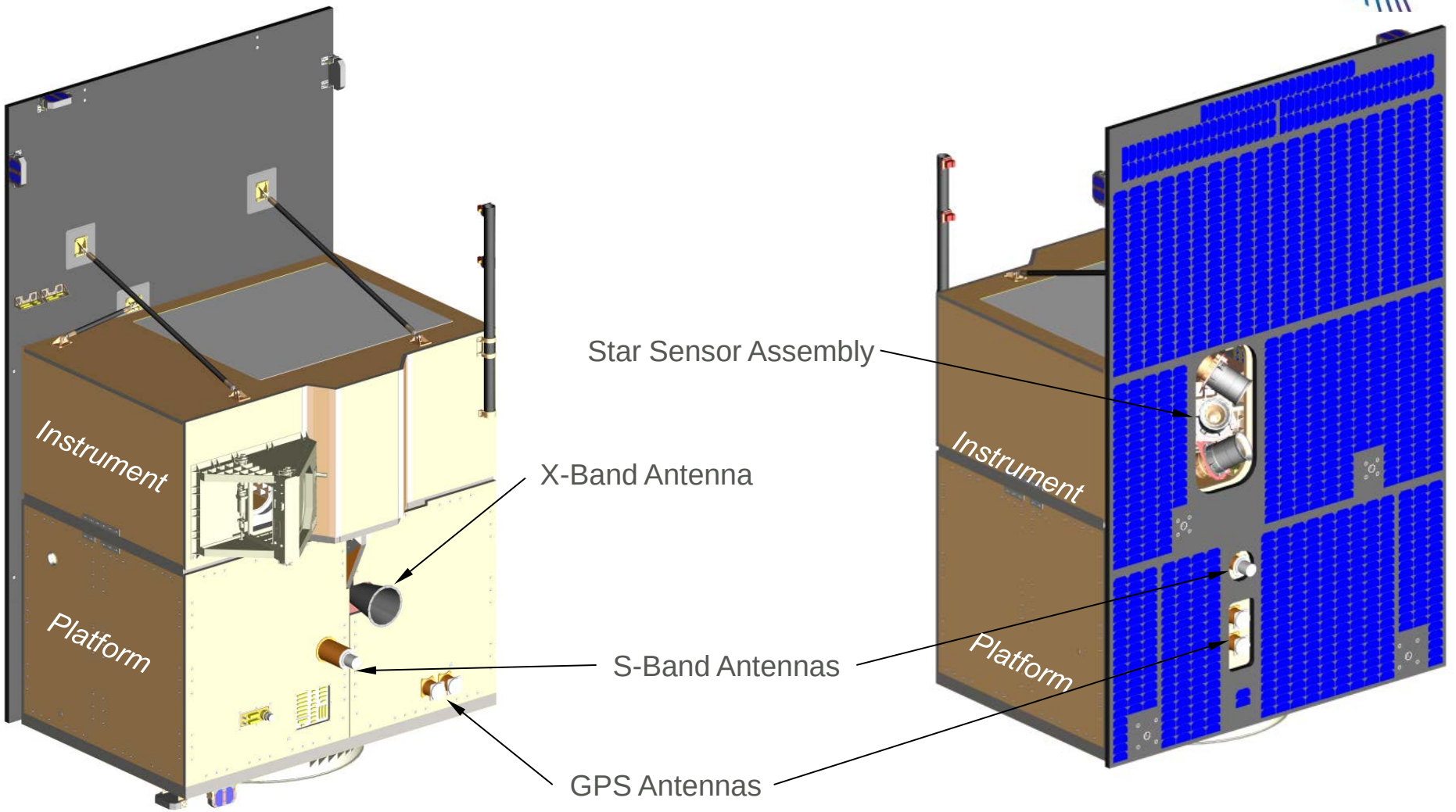
Indian PSLV (Polar Satellite Launch Vehicle)

Launch date:

27.02.2020

DLR

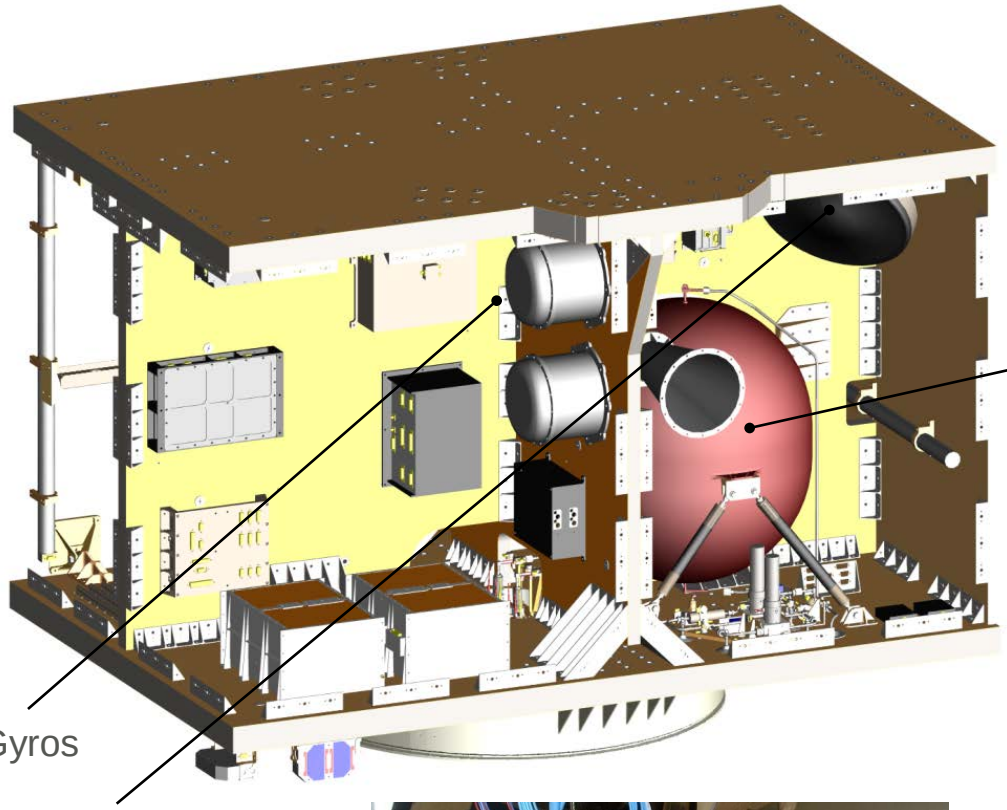
EnMAP Satellite



Source: OHB

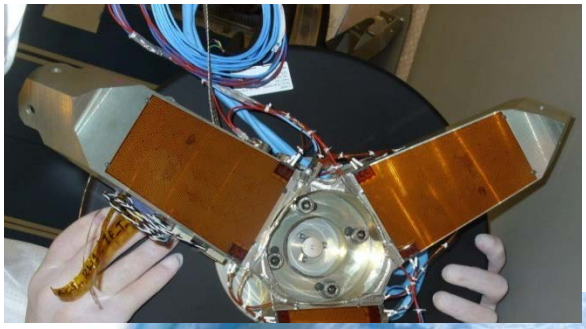
EnMAP Platform

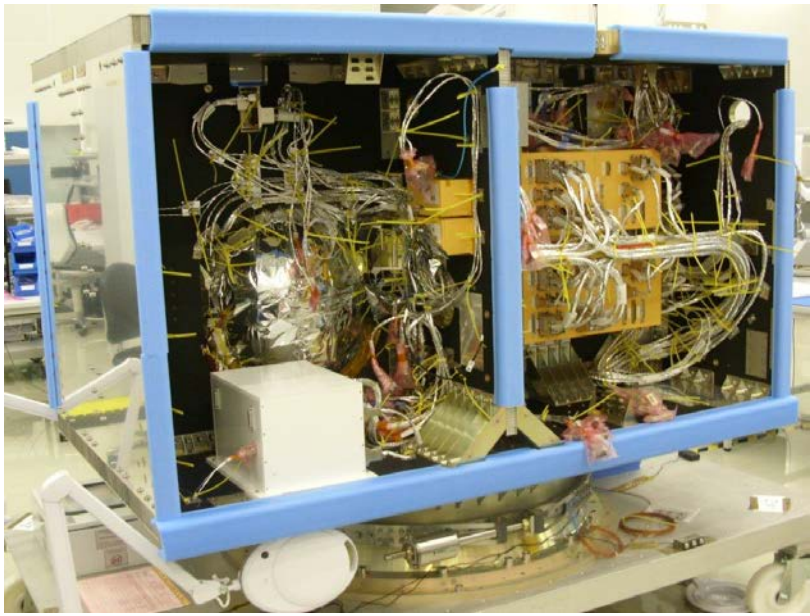
Hydrazine tank (50 kg)



Gyros

Reaction wheels (three axes stabilization)

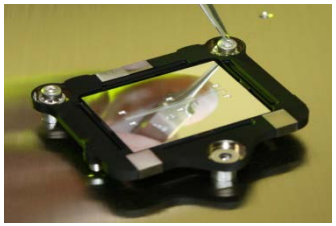


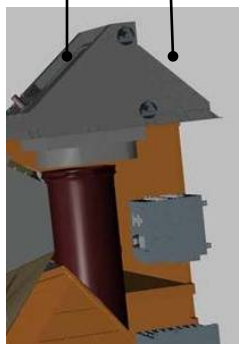


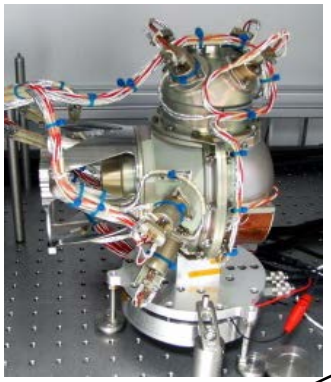
Source: OHB

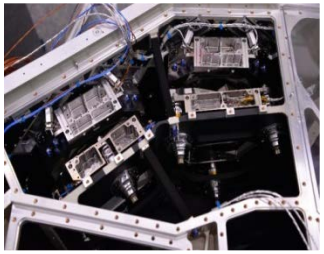
DLR

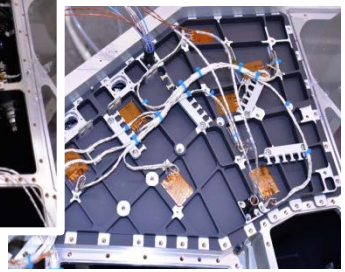
EnMAP Instrument







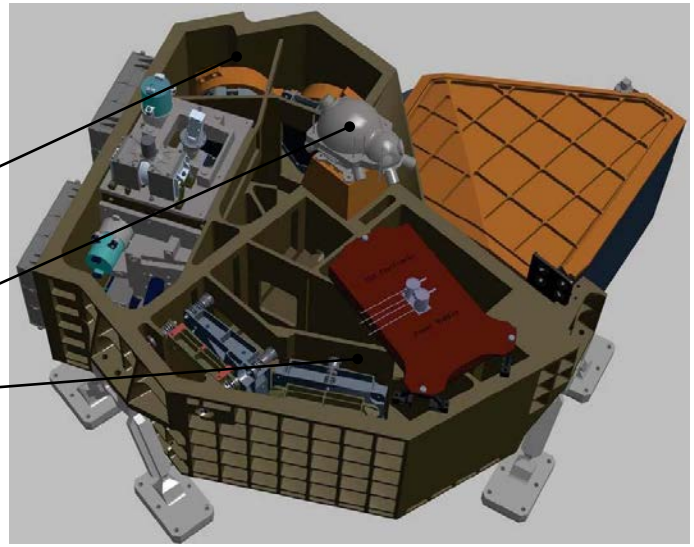


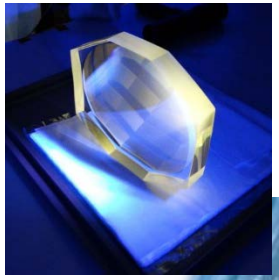


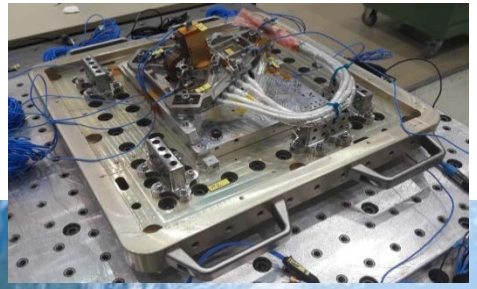
SWIR Spectrometer

Calibration Assembly

VNIR Spectrometer







Source: OHB

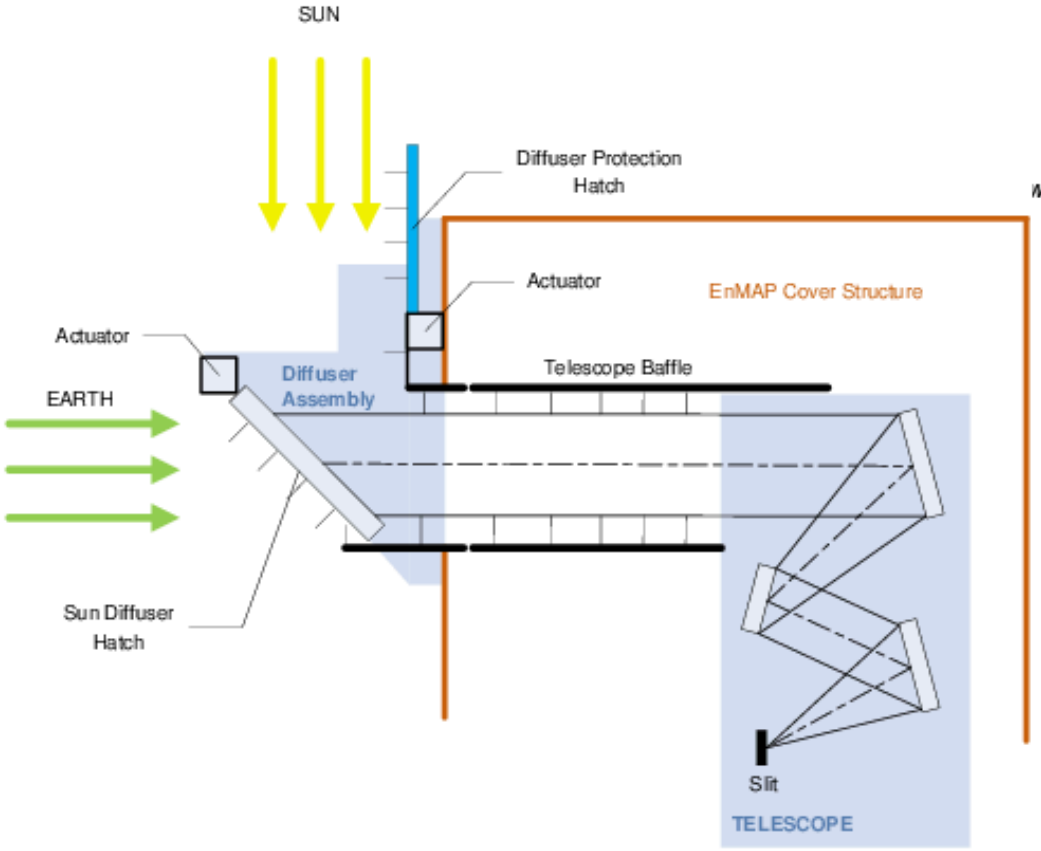
Onboard calibration units

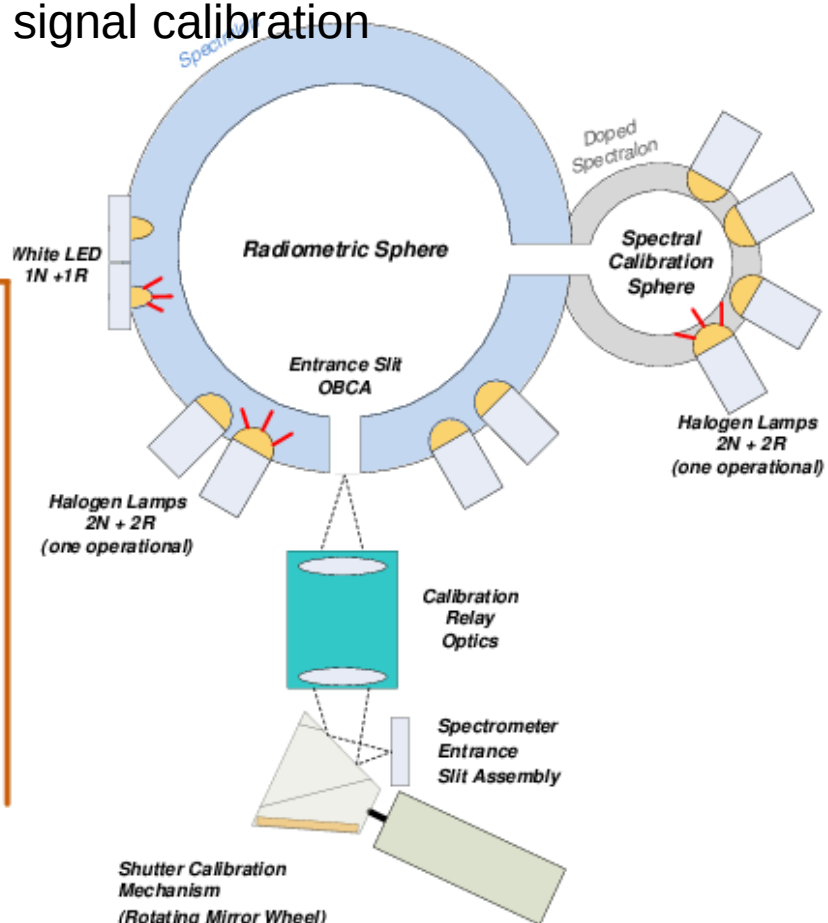
Radiometric sphere + LEDs: relative radiometry and detector linearity

Spectral sphere + doped spectralon: spectral calibration

Sun diffuser: absolute radiometric calibration

Shutter mechanism / deep space: dark signal calibration





Data Products & Acquisition

Product	Definition
Level 0	Time-tagged instrument raw data with auxiliary information (internal)
Level 1B	Radiometrically-corrected, spectrally- and geometrically-characterised radiance
Level 1C	Orthorectified level 1B
Level 2A	Atmospherically-corrected level 1C

Available for users

Acquisitions:

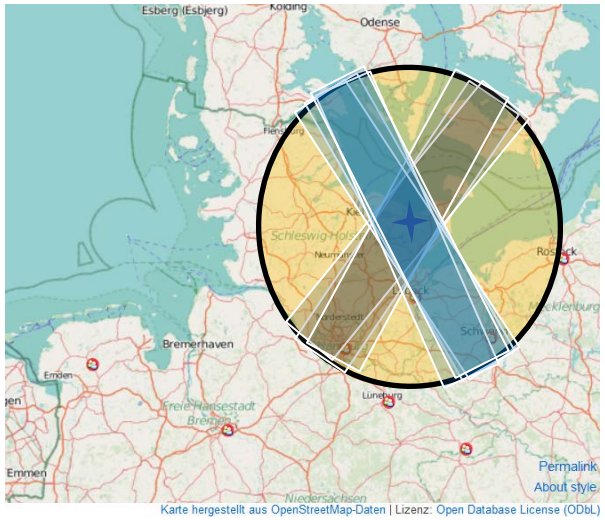
- Restricted to 1000 km/orbit and 5000 km/day
- Acquisitions based on user requests
- Daily acquisition plan driven by user priorities, cloud forecast, data storage capacity and instrument status

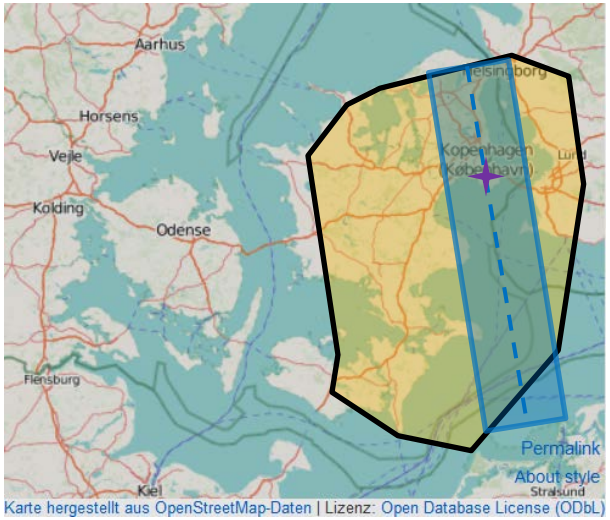
Observation request parameters

- Area coverage
- Acquisition window
- Allowed tilt angle
- Allowed cloud coverage
- Allowed sun-glint

Acquisition Planning

- **Circle** [list of datatakes and one selected by mission planning]
  - Center coordinate
  - Swath length
  - Time window
  - Off-nadir angle
  - Sun glint, Cloud coverage
- **Polygon** [one datatake]
  - Reference coordinate
  - Swath length
  - Time window
  - Cloud coverage





Acquisition Planning

- The objective of Mission Planning (MP) is to maximize the number of cloud-free data takes while taking priorities and quotas into account
- Continuous replanning, commanded acquisitions cannot be replanned
- Planning conflicts are solved by calculating the benefit (B):

$$B = \sum_i w_i b_i$$

b_i describe 3 parameter that are considered by MP

w_i allows for weighting b_i

b_1 = priority

b_2 = cloud forecast

b_3 = statistic cloud coverage

Acquisition Planning

b1 = priority

- Defined in data policy
- User categories ordered after priority

Priority	Name of category
9	Internal
8	Charter / Emergency
7	Cat-1 - Science User with proposal – high priority
6	Cat-1 - Science User with proposal
5	Cat-2 – Science User without proposal
4	Cat-1 – Science User
0	Background

Year of Operation	Quota CAT I	Quota CAT II
1	80%	20%
2	70%	30%
3	70%	30%
4	60%	40%
5	60%	40%

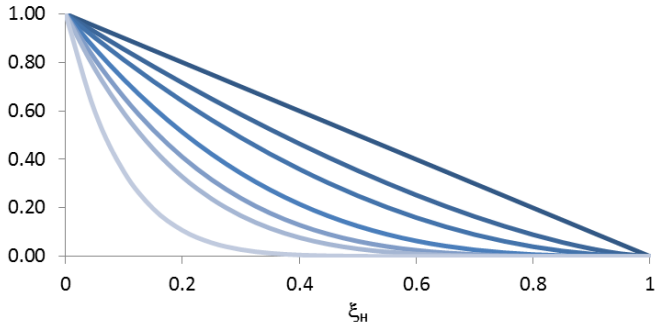
Acquisition Planning

b2 = cloud forecast

- 0 – if forecast cloud coverage C_A is above the user-defined could-coverage threshold C_{limit}
- 1 – in all other cases or if there is no predicted cloud coverage information available

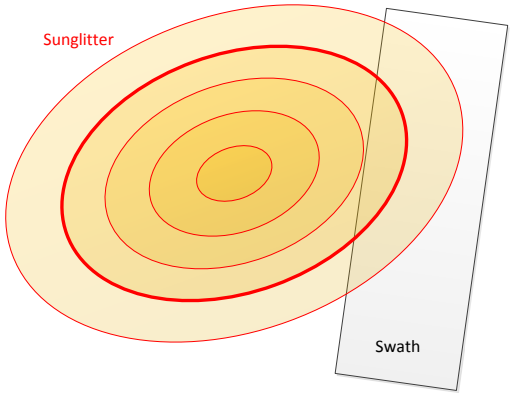
b3 = cloud cover statistics

- Areas frequently covered by clouds are prioritized („lucky shot“)
- Data from Germany's National Meteorological Service

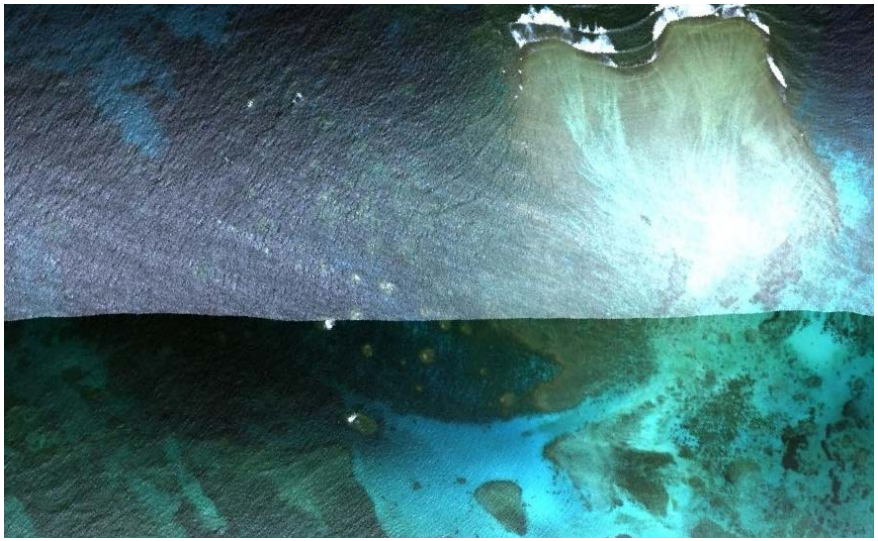


$$b_3 = |\xi_H(\lambda, \varphi, t) - 1|^{c_3}$$

Sunglint Avoidance - Principles

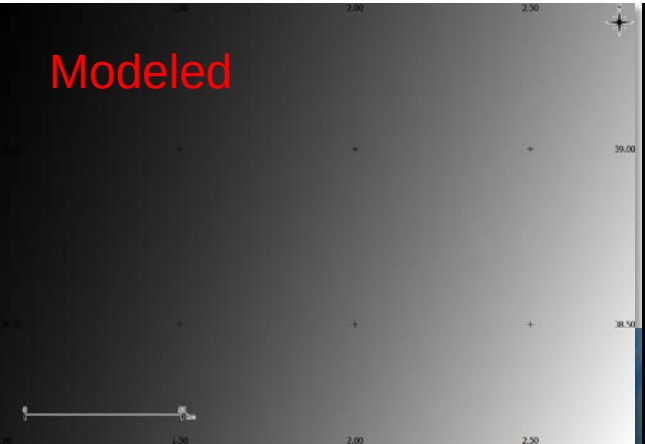


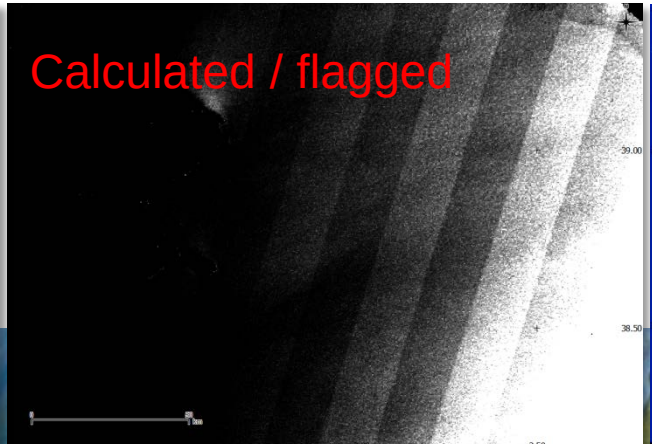
- Sunglint can be predicted as a function of:
  - Wind speed
  - Illumination geometry
  - Sensor/Viewing geometry
- Prediction using a variant of Cox and Munk formula
- Maximum coverage of areas affected by sunglint will be considered during acquisition planning by MOS
- Question: How do we predict sunglint affected areas?

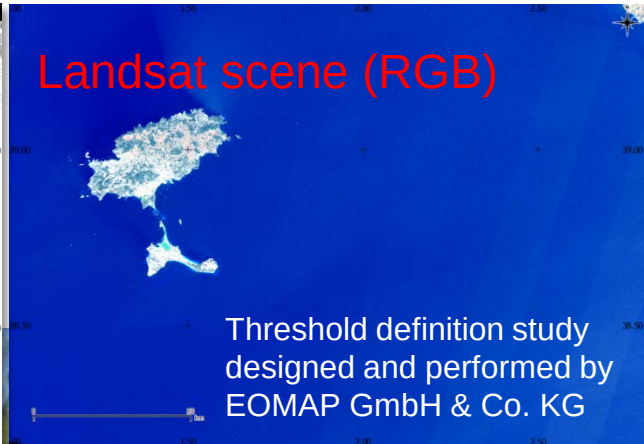


Sunglint Avoidance – Threshold definition

1. **Modelling of specular sunlight** reflectance with a variant of **Cox and Munk** (illumination geometry and observational geometry, wind speed (3/6/9 [m/s])) for 100 Landsat scenes per pixel
2. **Pixelwise detection** of significant sunglint perturbations using **noglint_detection** (EOMAP software) resulting in 3 classes:
   - 2 = affected by sunglint
   - 1 = not affected by sunglint
   - 0 = not water
3. **Threshold definition** and reliability assessment:
   - When flagging all pixels with a modelled specular sunlight reflectance of more than 0.0115 (~mean for all used Landsat scenes), only 5% of the detected noglint_detection sunglint class pixels remain unflagged
   - Confirmed by visual analysis







EnMAP Campaign Portal

Airborne hyperspectral images, simulated data and associated in-situ data

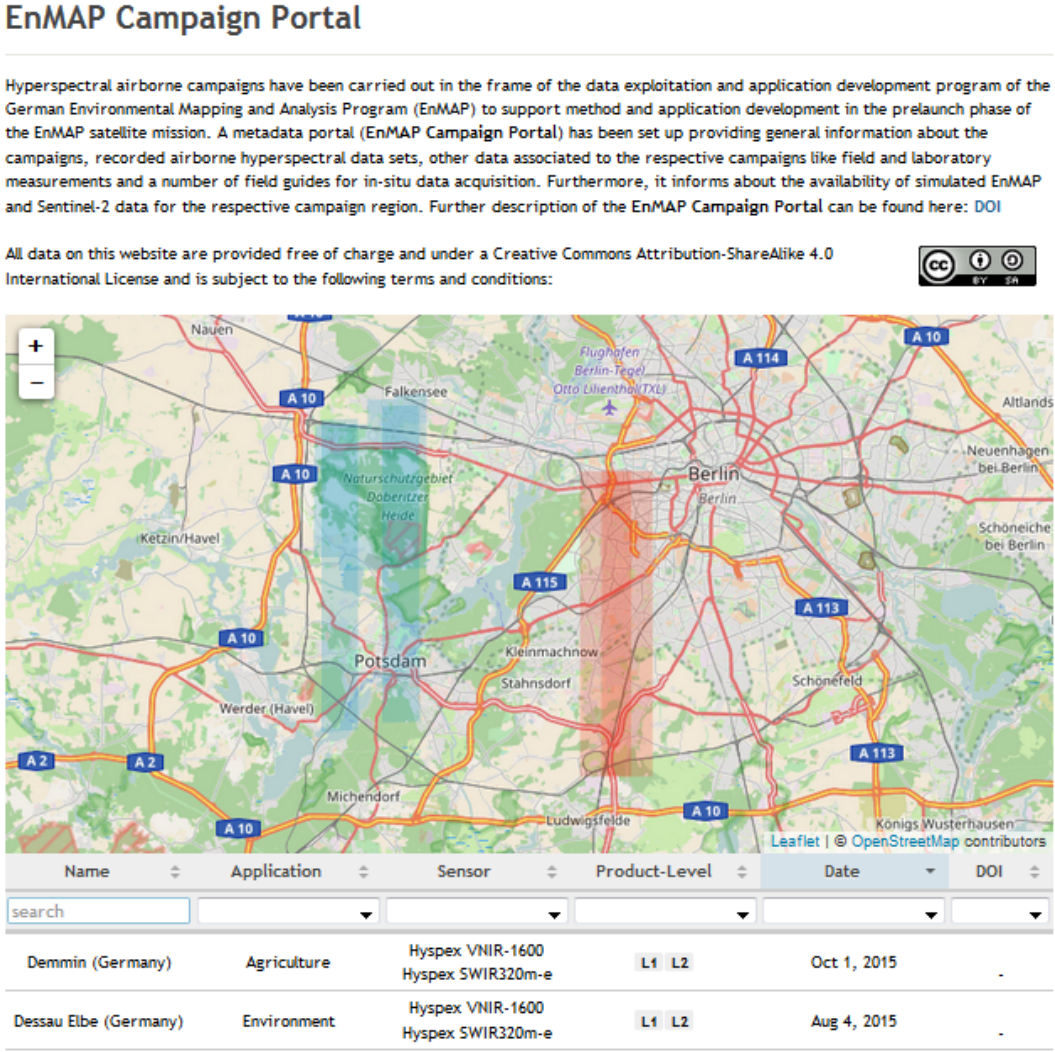
provided free of charge to science community under CC BY-SA Licence

Datasets published as **data publications** (with DOI)

Technical Report is provided with each dataset (documentation of data acquisition, processing, quality etc.)

Possible processing option: EnMAP-Box = Free, open source and platform independent

http://www.enmap.org/?q=flights

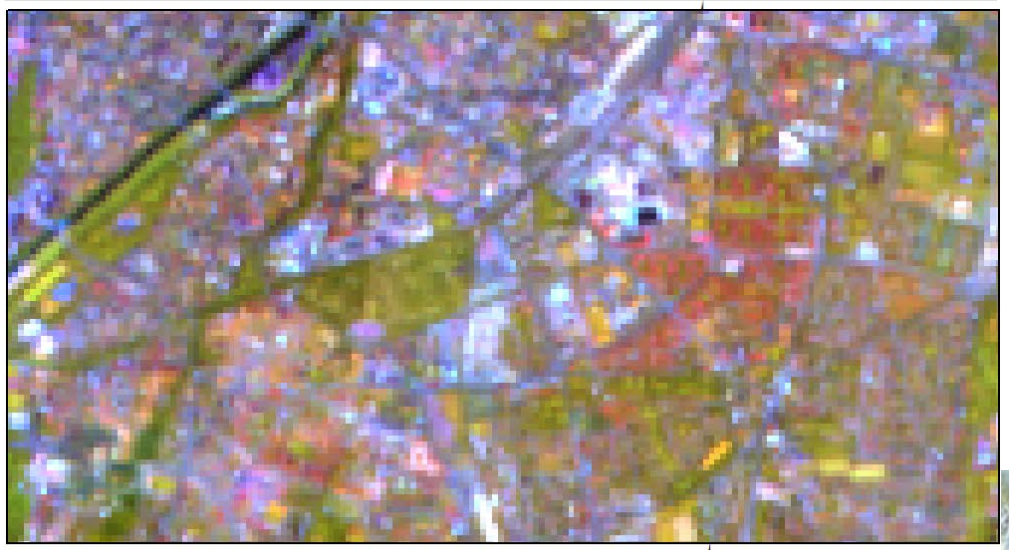


Thank you very much for your attention!

EnMAP Hyperspectral Imager

Airborne

Spaceborne (Simulated)



Federal Ministry of Economics and Technology

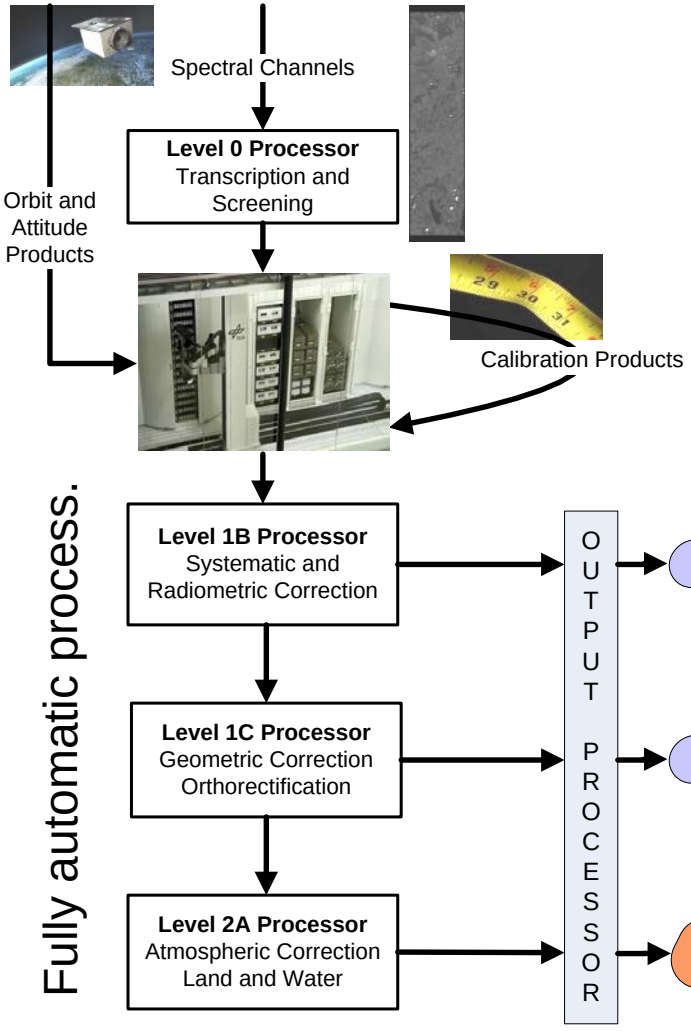
GFZ Helmholtz Centre Potsdam

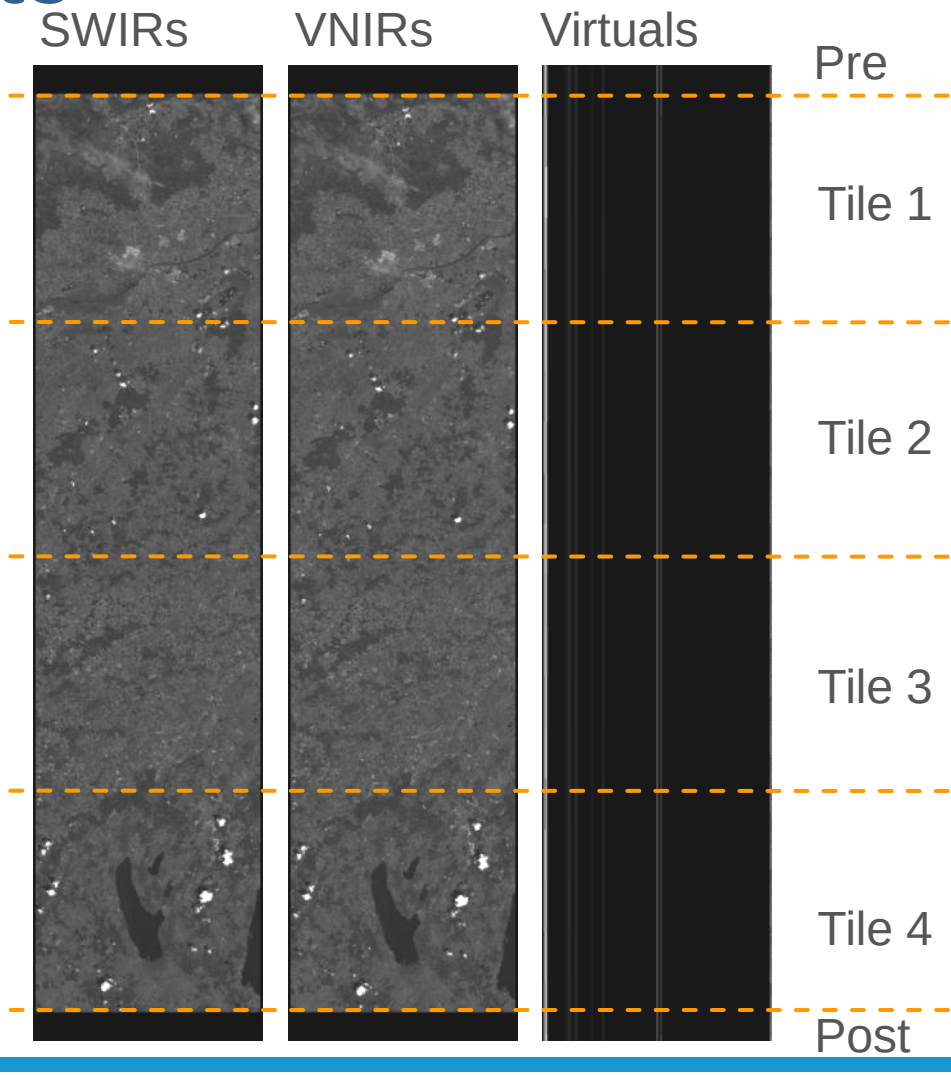
DLR

www.enmap.org

Backup Slides

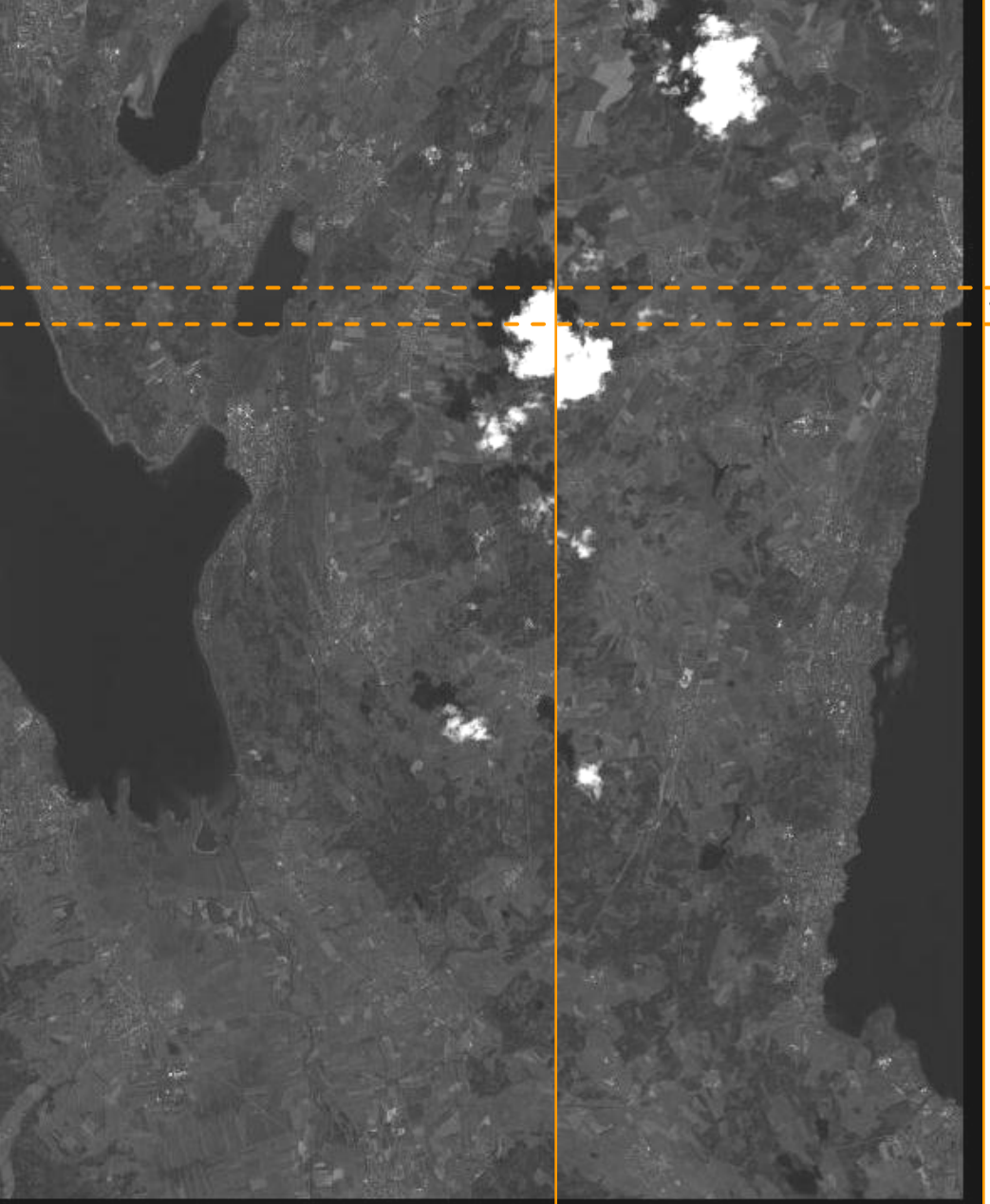
EnMAP Products





Source: DLR, ESA, JAXA

Simulated Scene



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IMAGE_TYPE 1
[standard Earth observation]
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[standard channels]
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[4.4 ms]
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HSI_FTIME 256
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Source: DLR, ESA, JAXA

Virtuals

EnMAP Level 1B Processor

Spectral Channels

Level 0 Processor
Transcription and Screening

Orbit and Attitude Products

Calibration Products

Level 1B Processor
Systematic and Radiometric Correction

Level 1C Processor
Geometric Correction Orthorectification

Level 2A Processor
Atmospheric Correction Land and Water

Fully automatic process.

Defective Pixels Flagging ← Dead Pixels Map

Non-Linearity Correction ← NL Look-Up Table

Dark Signal (and Digital Offset) Correction ← Dark Signal Calculation ← Closed Shutter, Look-Up Table

Gain Matching

Straylight Correction ← Straylight Correction Matrix

Radiometric/Spectral Referencing ← Radiometric Calibration Table, Spectral Calibration Table

Radiometric Calibration ← Calibration Equation

EnMAP Level 1C Processor

Spectral Channels

Level 0 Processor
Transcription and Screening

Orbit and Attitude Products

Calibration Products

Fully automatic process.

Level 1B Processor
Systematic and Radiometric Correction

Level 1C Processor
Geometric Correction Orthorectification

Level 2A Processor
Atmospheric Correction Land and Water

Direct Georeferencing

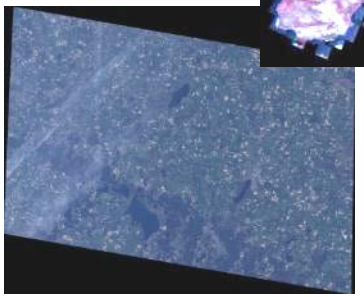
Digital Elevation Model Intersection

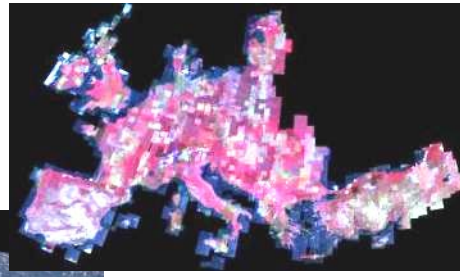
Map Projection

Resampling

Reference Image DB

Digital Elevation Model DB





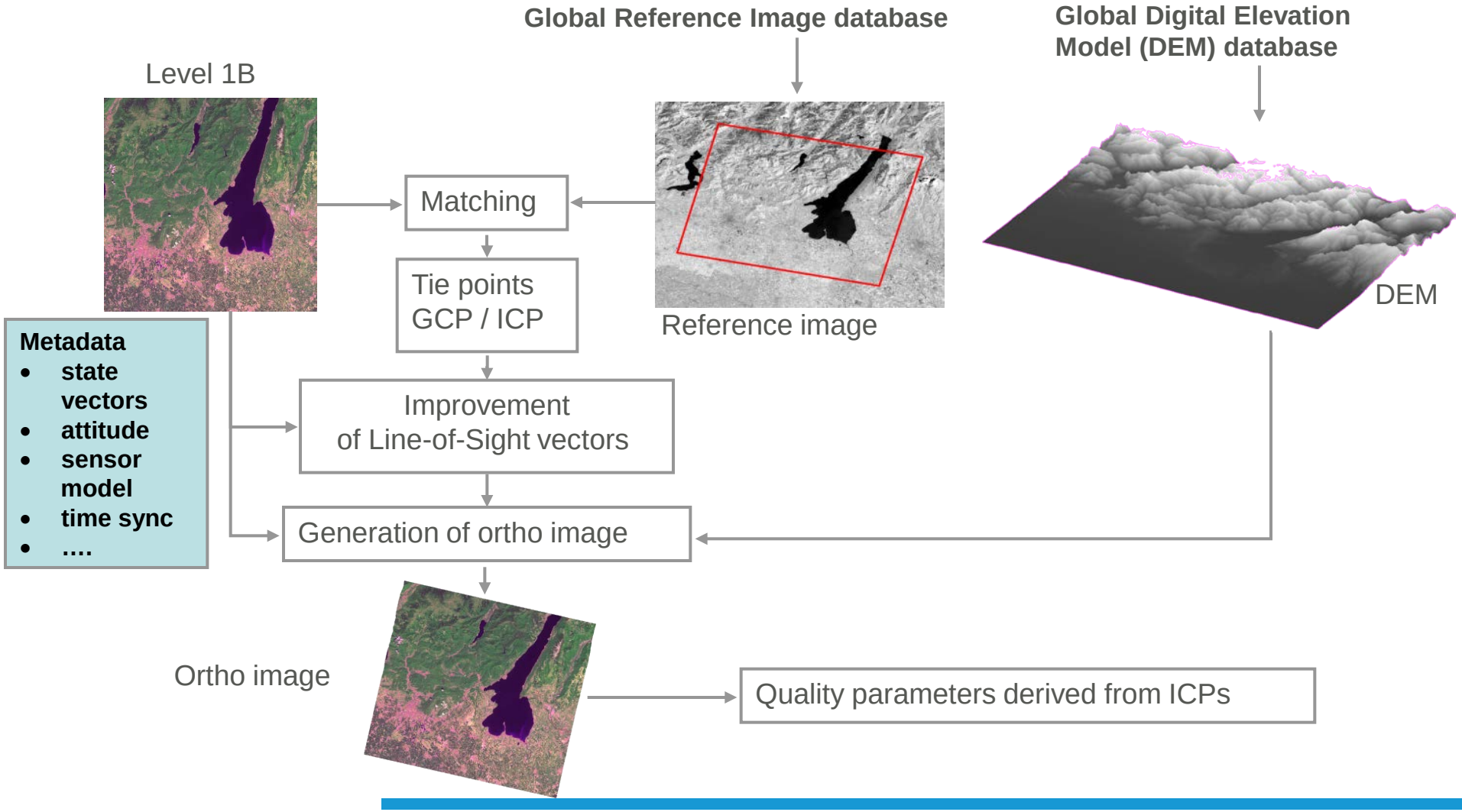
Based on:
ORTHO and MATCHING (MF-PBA)

Projection: UTM (Zone of center) (± 1 zone), Geographic
Resampling: Bi-cubic, Bi-linear, Nearest Neighbour

e.g., ALOS/AVNIR-2

Source: DLR, ESA, JAXA

EnMAP Level 1C Processor



EnMAP Level 2A Processor

Spectral Channels

Level 0 Processor
Transcription and Screening

Orbit and Attitude Products

Calibration Products

Level 1B Processor
Systematic and Radiometric Correction

Level 1C Processor
Geometric Correction Orthorectification

Level 2A Processor
Atmospheric Correction Land and Water

Fully automatic process.

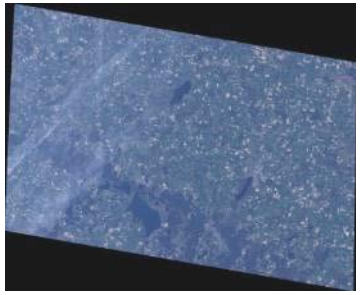
Classification (Land-Water, Cloud-Cirrus-None, Snow, Cloud Shadow)

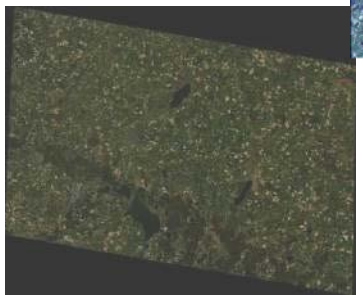
Look-Up Table

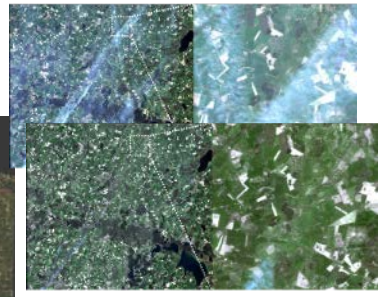
Over Land (with aerosol optical thickness and adjacency correction)

Over Water (with aerosol optical thickness and adjacency correction)

Haze and Cirrus Removal







Type: Land, Water, Land-Water combined
Haze and Cirrus Removal: Yes, No

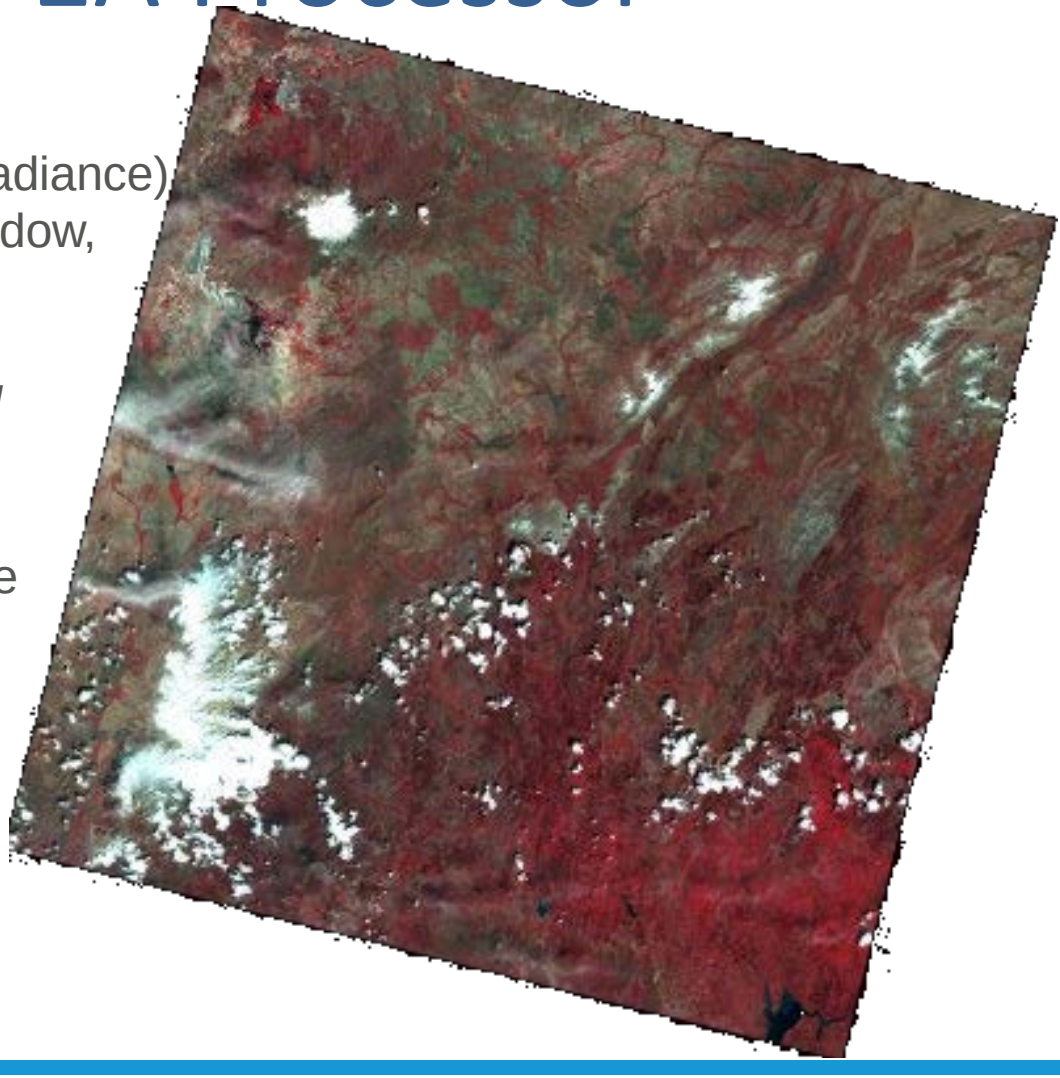
Based on:
ATCOR/MIP (EOC/EOMAP)

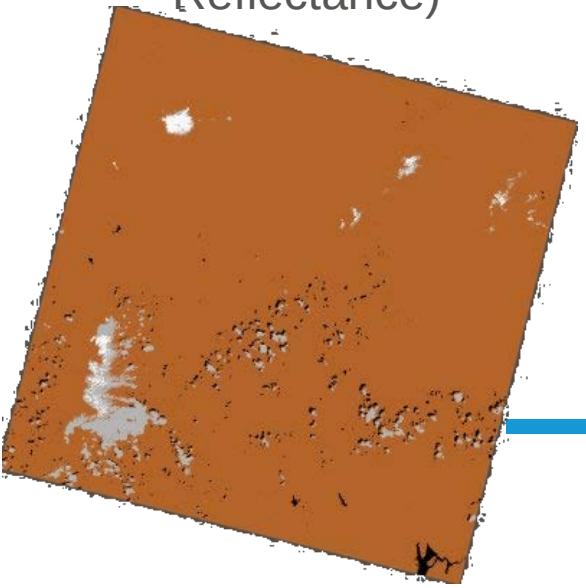
e.g., ALOS/AVNIR-2

Source: DLR, ESA, JAXA

EnMAP Level 2A Processor

- Level 1C (Top-of-Atmosphere Radiance)
- Classification (Cloud, Cloud Shadow, Land-Water, …)
- Aerosol Optical Depth Retrieval
- *Columnar Water Vapor Retrieval*
- Cirrus detection and removal
- Retrieval of surface reflectances
- Level 2 A (Bottom-of-Atmosphere Reflectance)



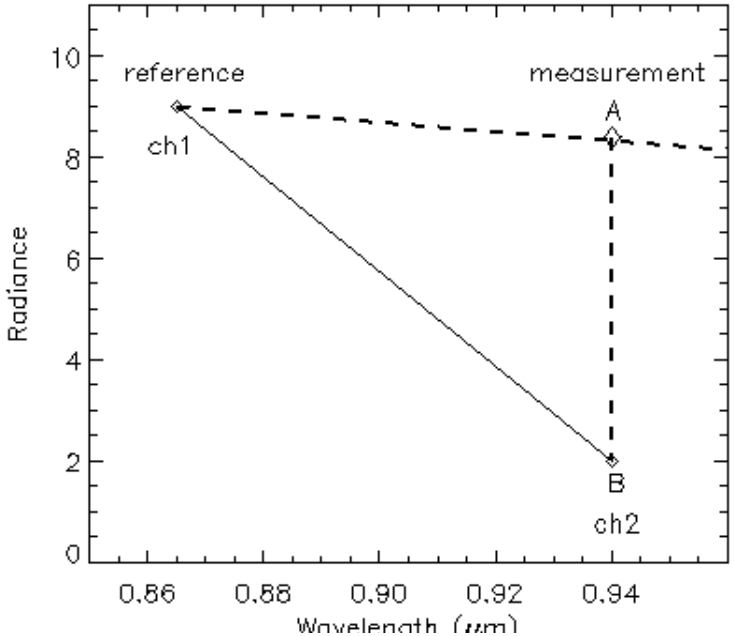


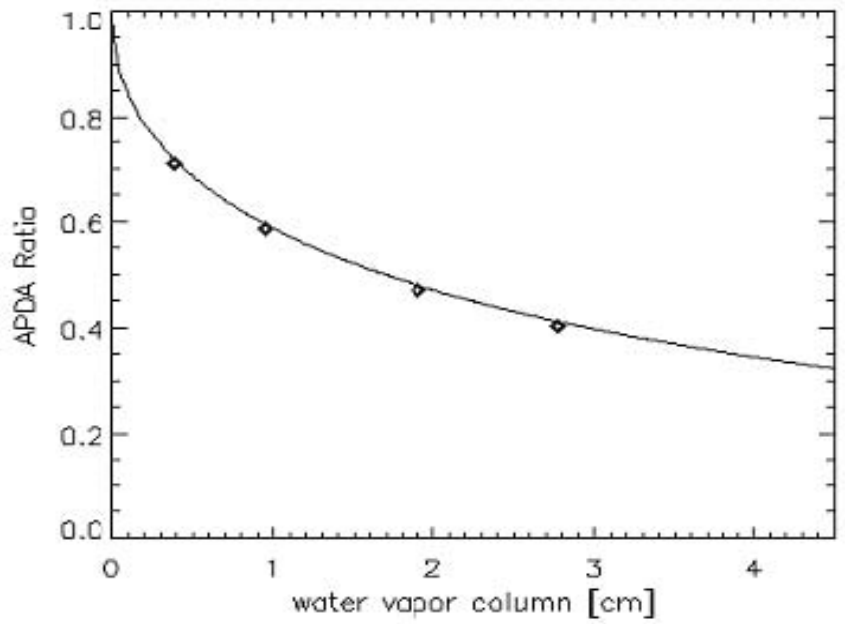
Source: DLR, Airbus DS

Columnar Water Vapor Retrieval

$$R = \frac{L_2(\rho_2, u) - L_{2,p}(u)}{L_1(\rho_1, u) - L_{1,p}(u)} = \exp\left(-\alpha + \beta\sqrt{u}\right)$$

$$u = \left(\frac{\alpha + \ln(R)}{\beta}\right)^2$$



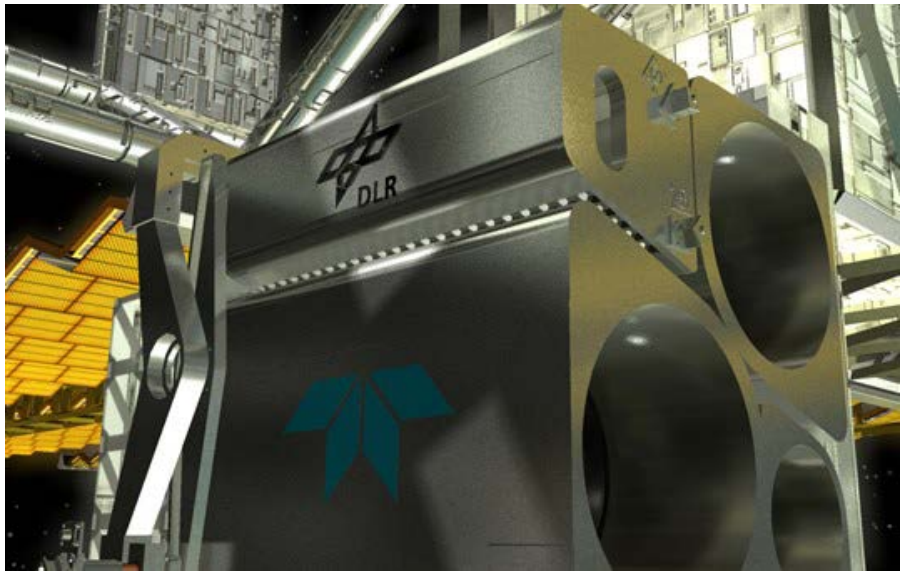


APDA (atmospheric pre-corrected differential absorption) algorithm
ch1 and ch2 indicate Sentinel-2 band 865 nm (20 nm) and 940 nm (20 nm), respectively
L and L_p indicate radiance and path radiance assuming no water vapor

Hyperspectral Missions

DESIS Mission on ISS

DESIS (DLR Earth Sensing Imaging Spectrometer) on ISS MUSES platform



Teledyne Brown Engineering:

- Owner of MUSES
- Operator

DLR:

- Sensor (DLR Berlin-Adlershof)
- Processing chain (IMF + DFD)

Schedule:

MUSES Launch: SpaceX Falcon 9 on June 3, 2017

Calibration of instrument finished in Dec 2017

Instrument delivered to NASA (Jan 2018)

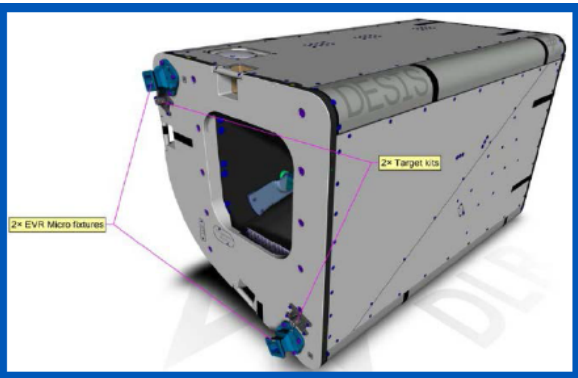
Launch planned for March/April 2018 (SpaceX)

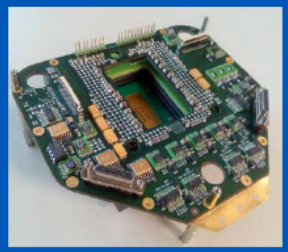
Presentation at ASPRS anual conference (Perkins et al., 2017)

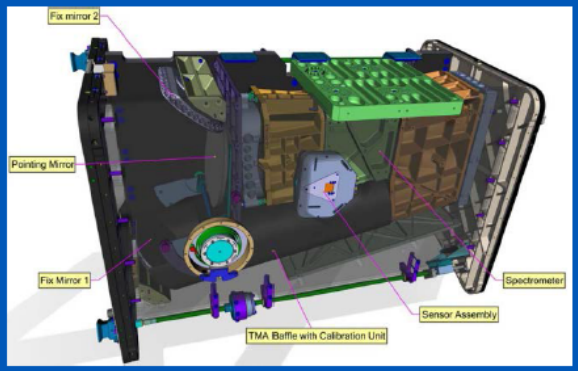
Hyperspectral Missions

DESIS Mission on ISS

Characteristic	DESIS Features
F# / Focal Length	3 / 320 mm, telecentric
FOV / IFOV	4.4° / 0.004°
Ground Sampling Distance	30 m @ 400 km altitude
Ground Swath	30 km @ 400 km altitude
Spectral Range	400 nm – 1000 nm
Spectral Sampling	Measured: 235 @ 2.55 nm Programmable binning factor (1 to 4)
Quantization	12 bits + 1 gain bit
Spatial Pixels	1024
Radiometric Linearity	95% (10% - 90% FWC)
MTF @ Nyquist (no smearing)	< 3 nm
On-board Calibration	Dark Field for DSNU LED Array for PRNU
Independent Pointing	Pointing Unit, ±15° Along Track
Independent Time and Position	On-board GPS







DLR