Data Quality Assurance for hyperspectral L1 and L2 products

Cal/Val/Mon procedures within the EnMAP Ground Segment

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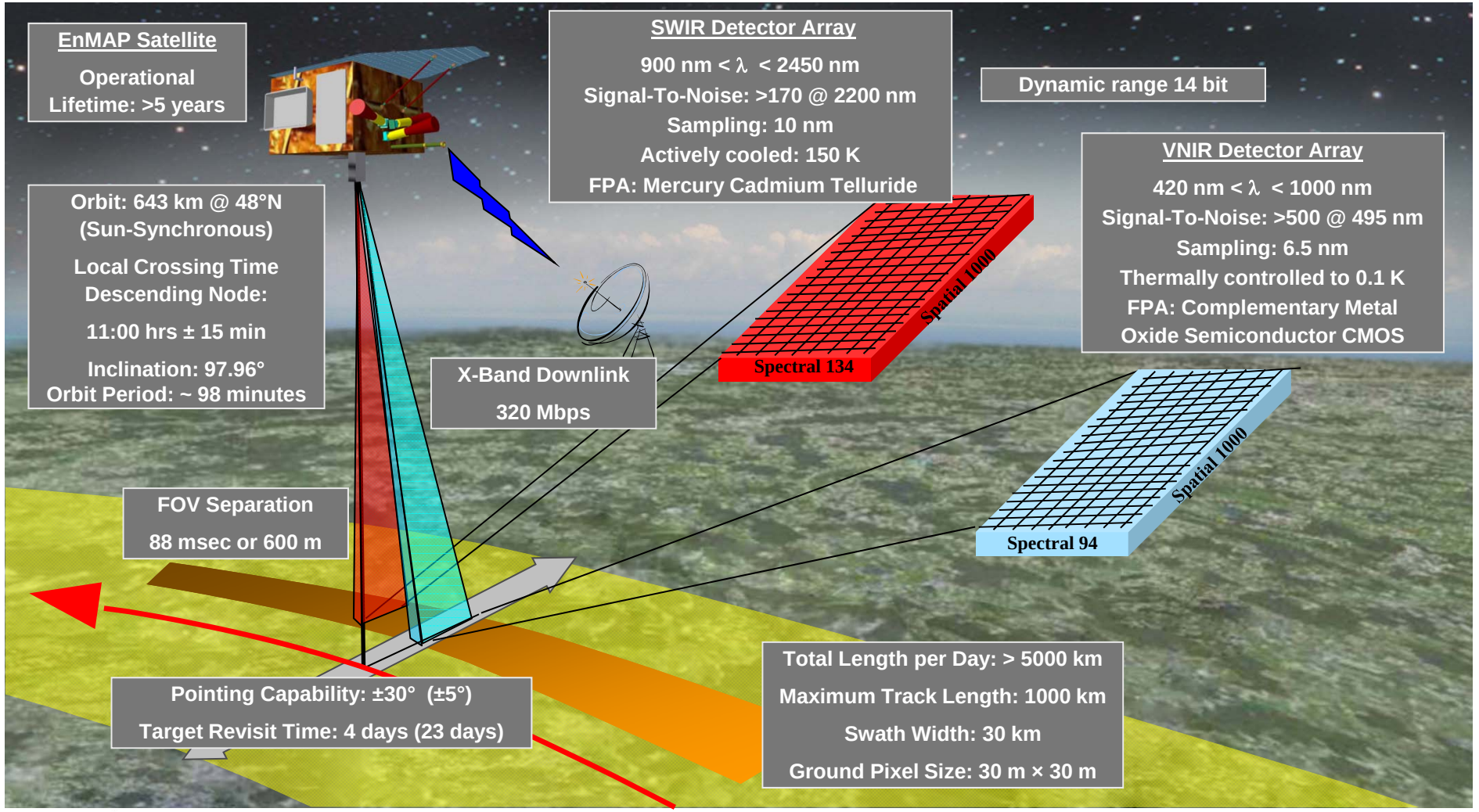
Background & Objectives

”All data and derived products must have associated with them a Quality Indicator based on documented quantitative assessment of its traceability to community agreed reference standards”
(CEOS QA4EO)

- Growing request for highly reliable & well-documented data
  - to fulfill data needs for COPERNICUS services
  - need also shown by initiatives like GEOSS / CEOS, EUFAR, VDI guidelines, ISO 19115, INSPIRE, …
  - existing data Quality Control approaches (e.g., MODIS, MERIS, …)

- Objectives of this talk:
  - overview of the EnMAP mission
  - present EnMAP DataQC / Cal / Val / Mon activities
  - focus: DataQC within processing chain

Mission and Instrument Characteristics



Project Partners

Scientific Principal Investigator
GFZ Potsdam

EnMAP Science Advisory Group

Project Management
DLR Space Administration

Space Segment

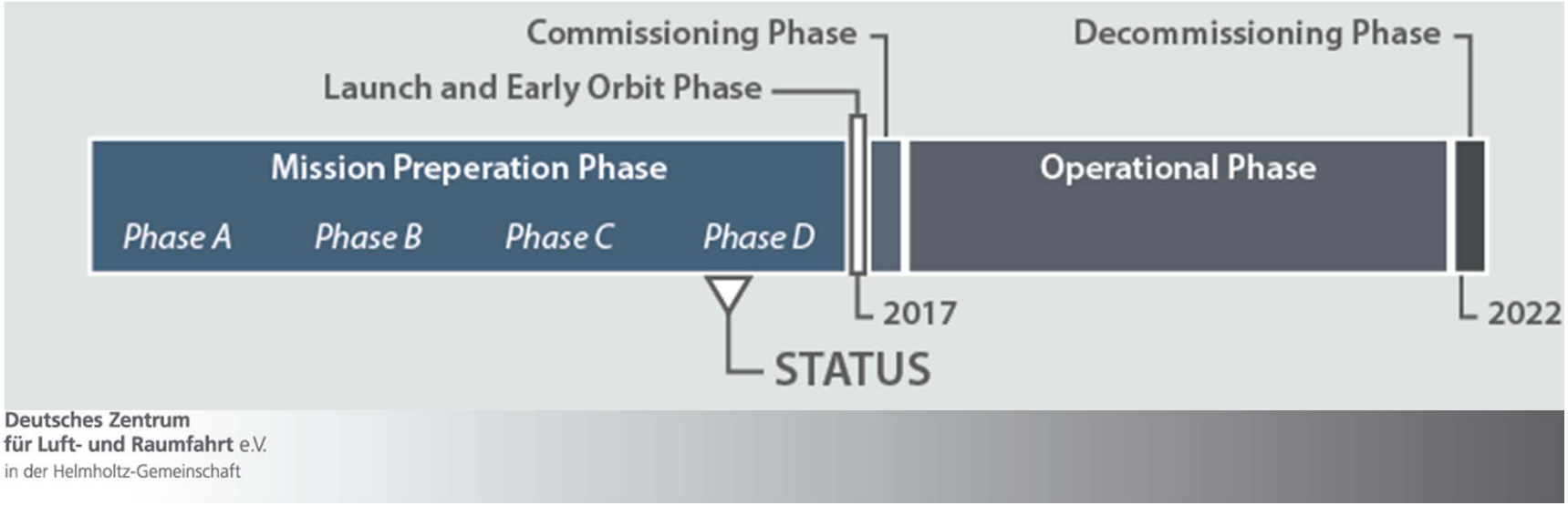
Sensor	Platform
Kayser-Threde	*OHB*

Ground Segment

Operations	Payload	Processing
DLR-GSOC	*DLR-DFD*	*DLR-IMF*

History and Current Status

- 2005 Phase A study accomplished
- 2006 Start of phase B
- 2007 End of phase B
- 2008 Start of phase C/D
- 2010 CDR Ground Segment
- 2012 System CDR
- **2013 Start Phase D**
- **2017 Launch date**

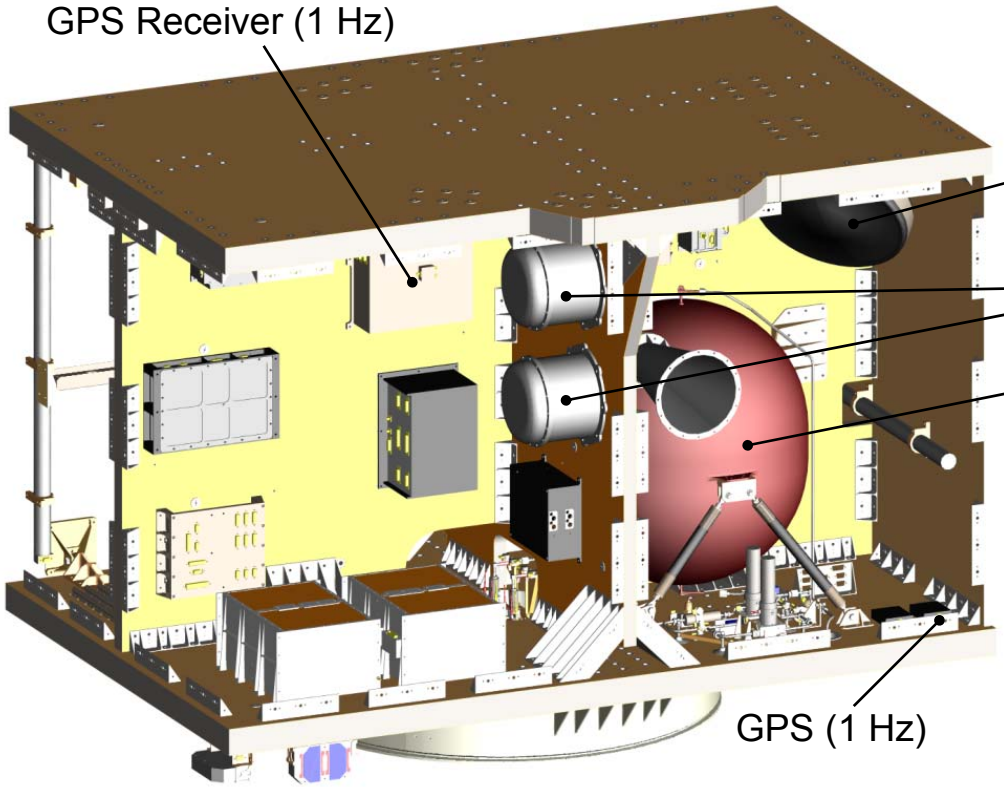


EnMAP
Hyperspectral Imager

Instrument Calibration & Monitoring

EnMAP
Hyperspectral Imager

GPS Receiver (1 Hz)



Reaction Wheels
(3 axis stabilized platform)

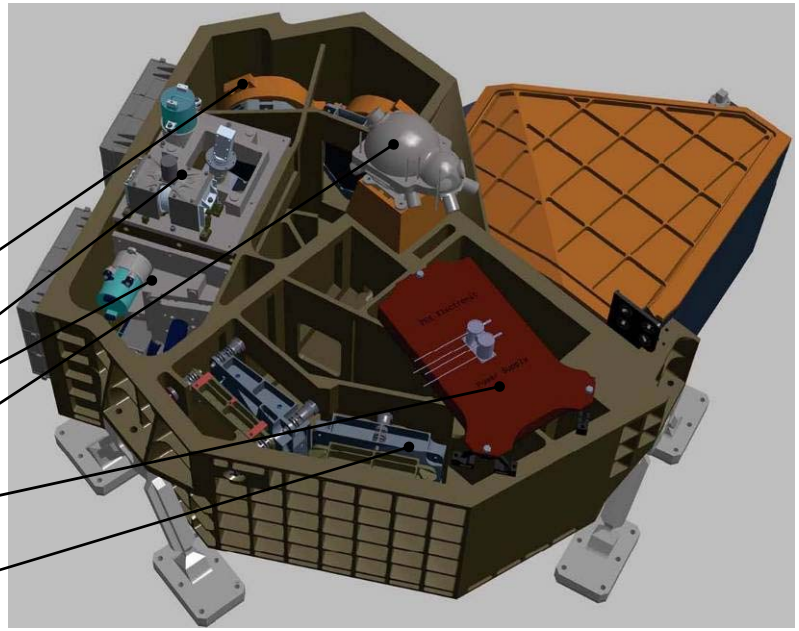
Gyros (10 Hz)

Propellant Tank (50 kg)
of hydrazine propulsion
system

GPS (1 Hz)

Earth

Sun



SWIR Spectrometer

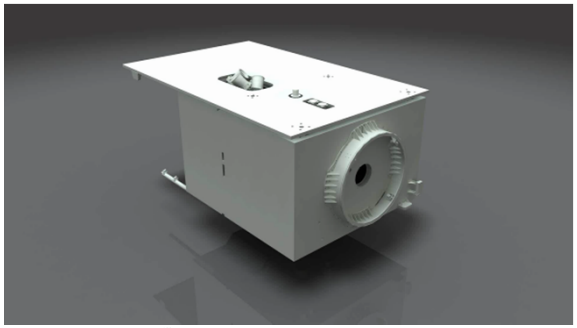
SWIR FPA redundant

SWIR FPA nominal

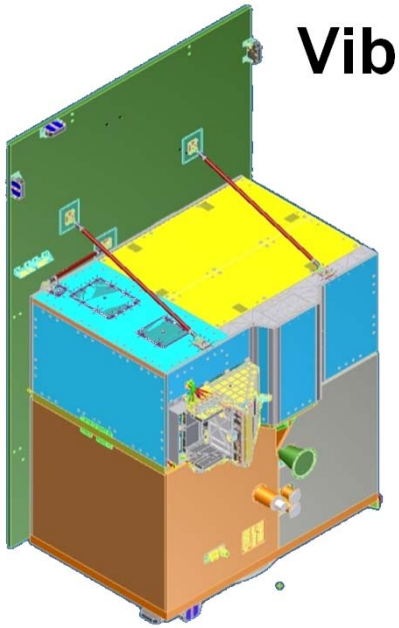
Calibration Assembly

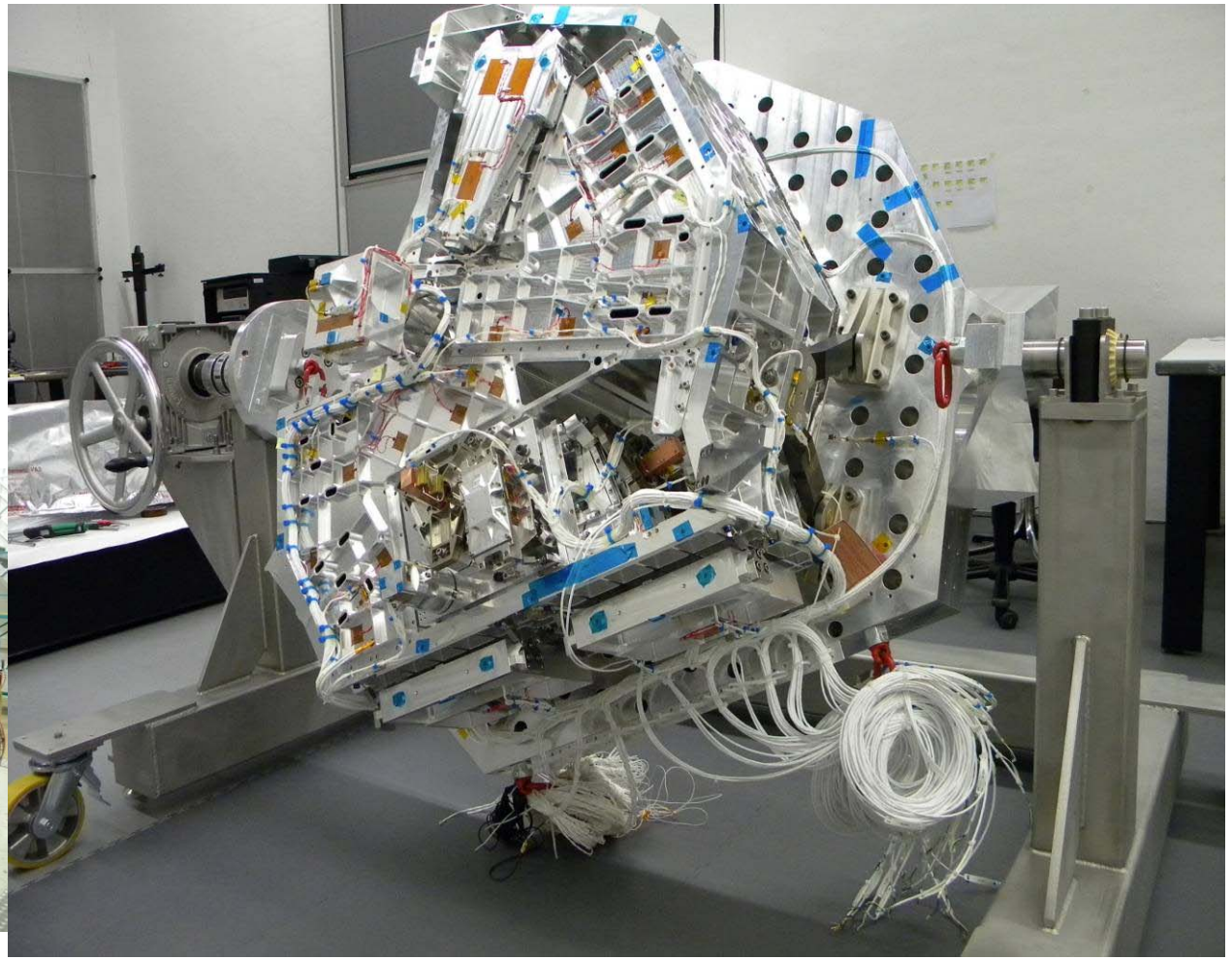
VNIR FPA

VNIR Spectrometer

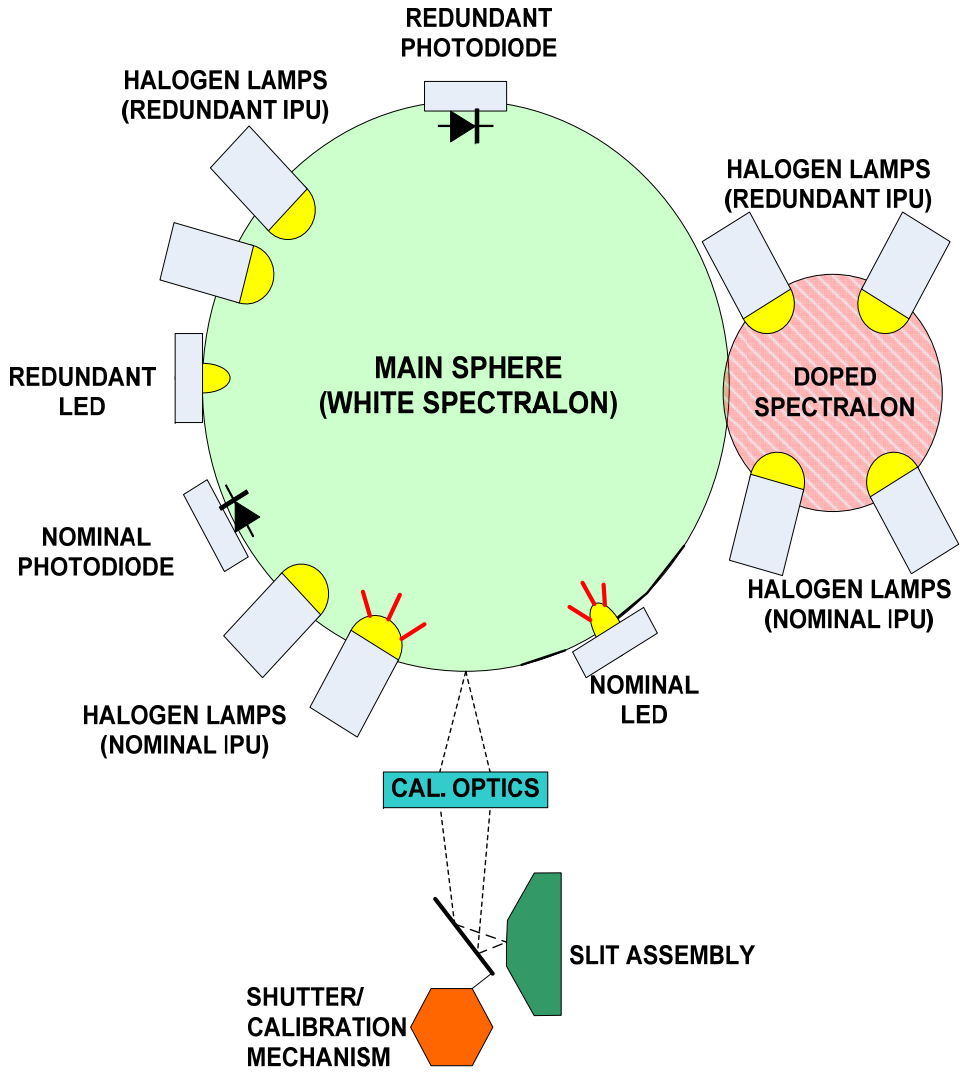


Vibration Test / Clean Room-Bench





Onboard Calibration Sources



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

In-flight Calibration Frequencies

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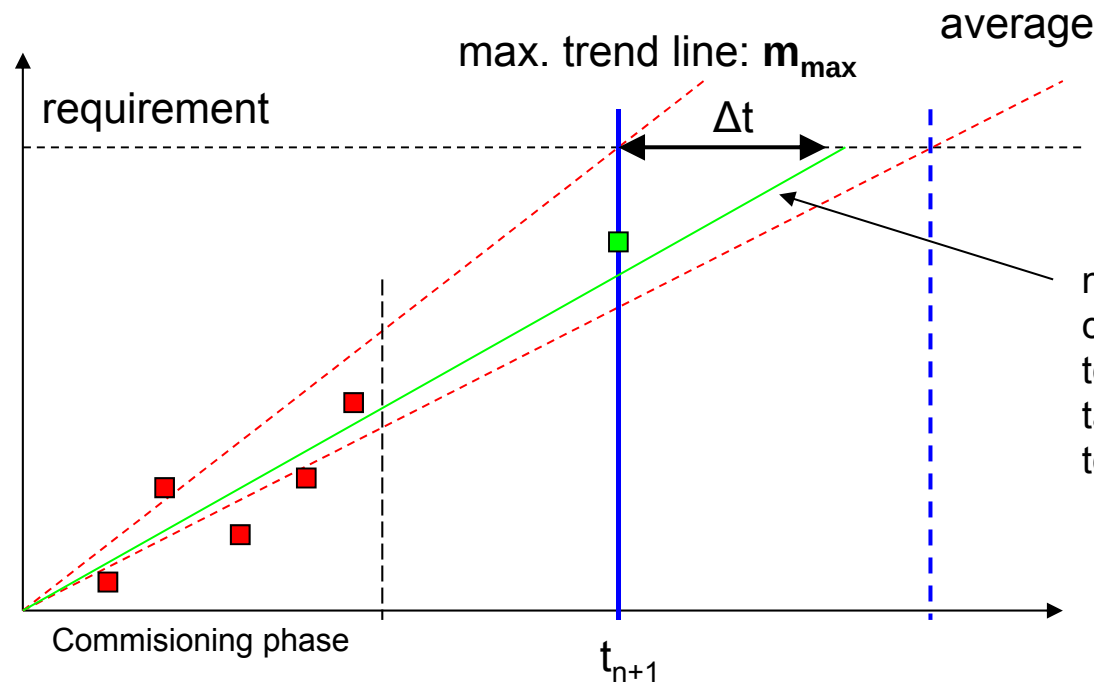
Sun Calibration using Shutter Mechanism
Life-Limited-Item: Measurement frequency optimized

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



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

$t < t_{n+1}$

$t = t_{n+1}$

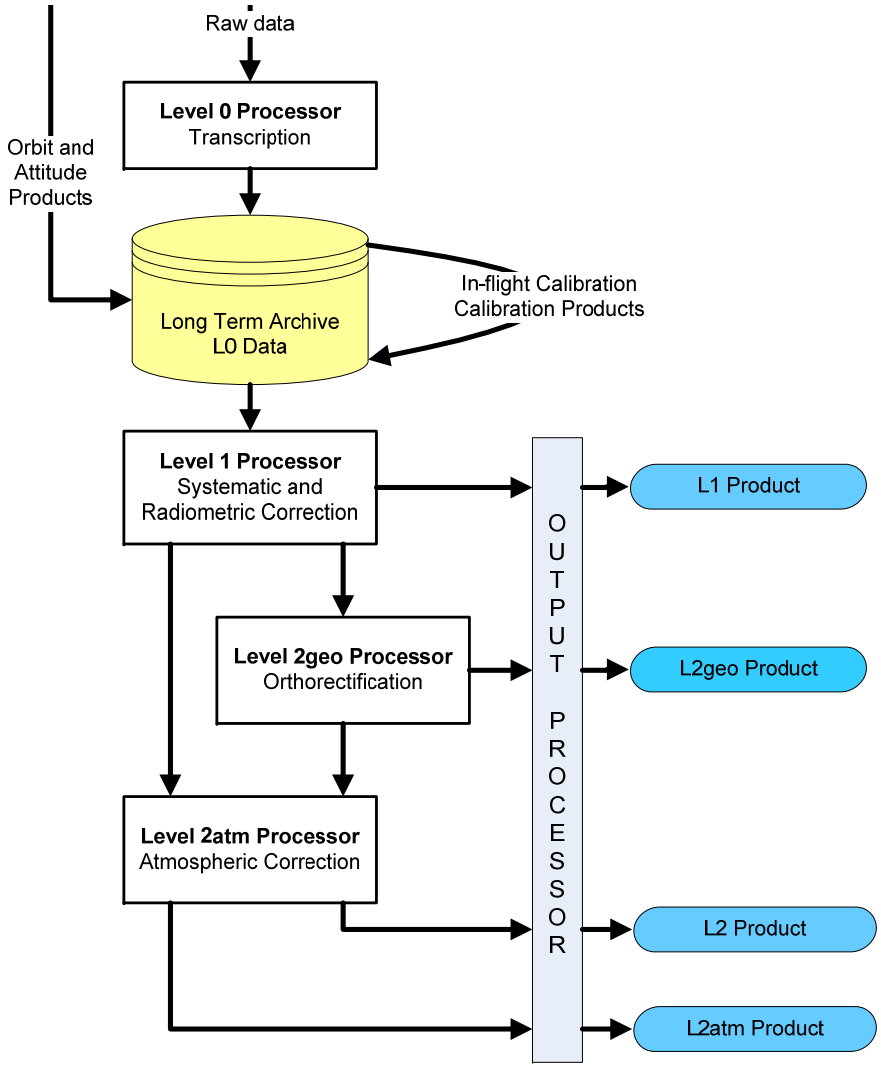
t_n new calibration measurement request

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

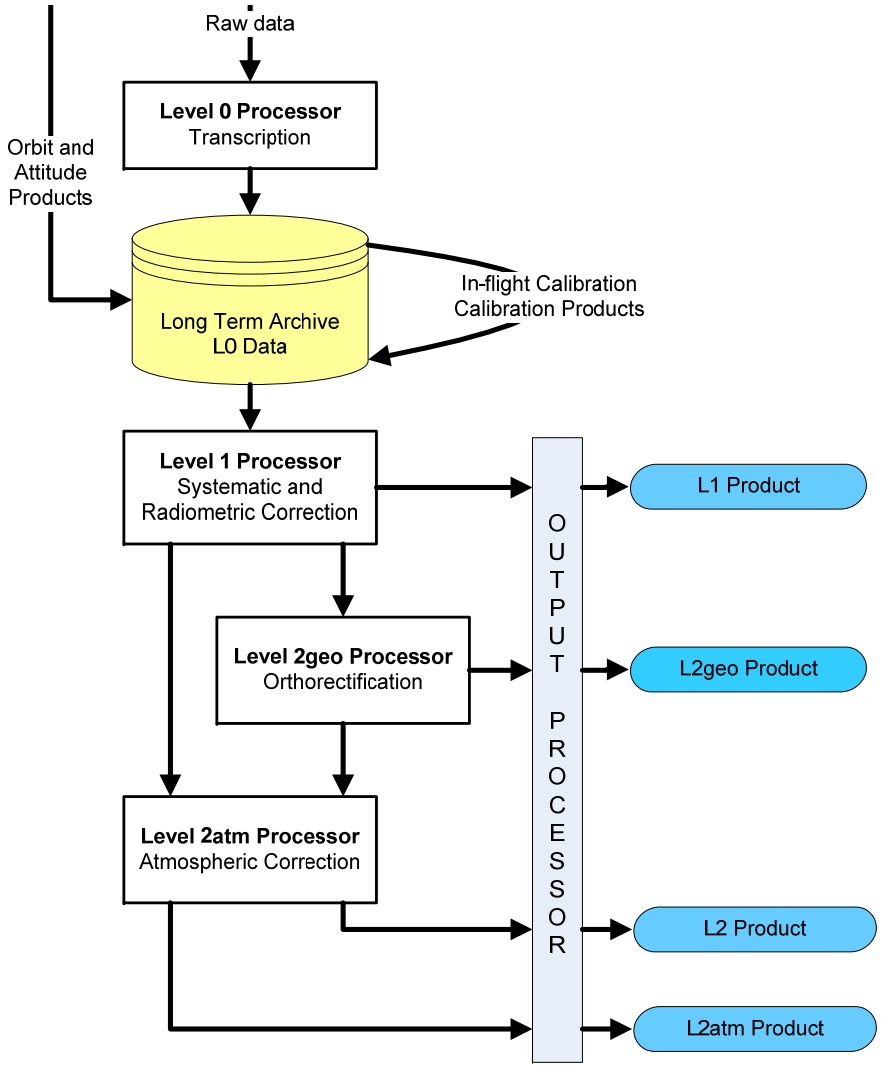
EnMAP
Hyperspectral Imager

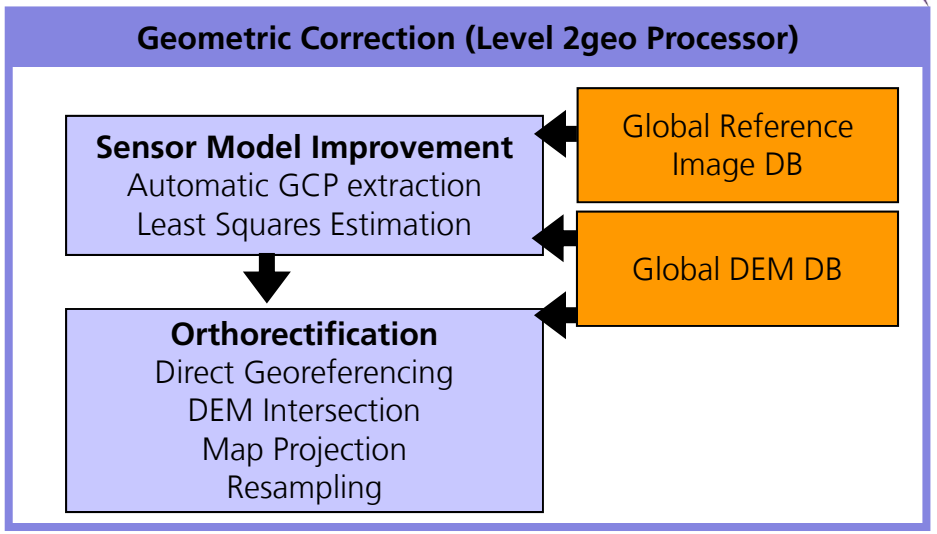
Data Quality Control within Pre-Processing Chain

Overview Processing Chain

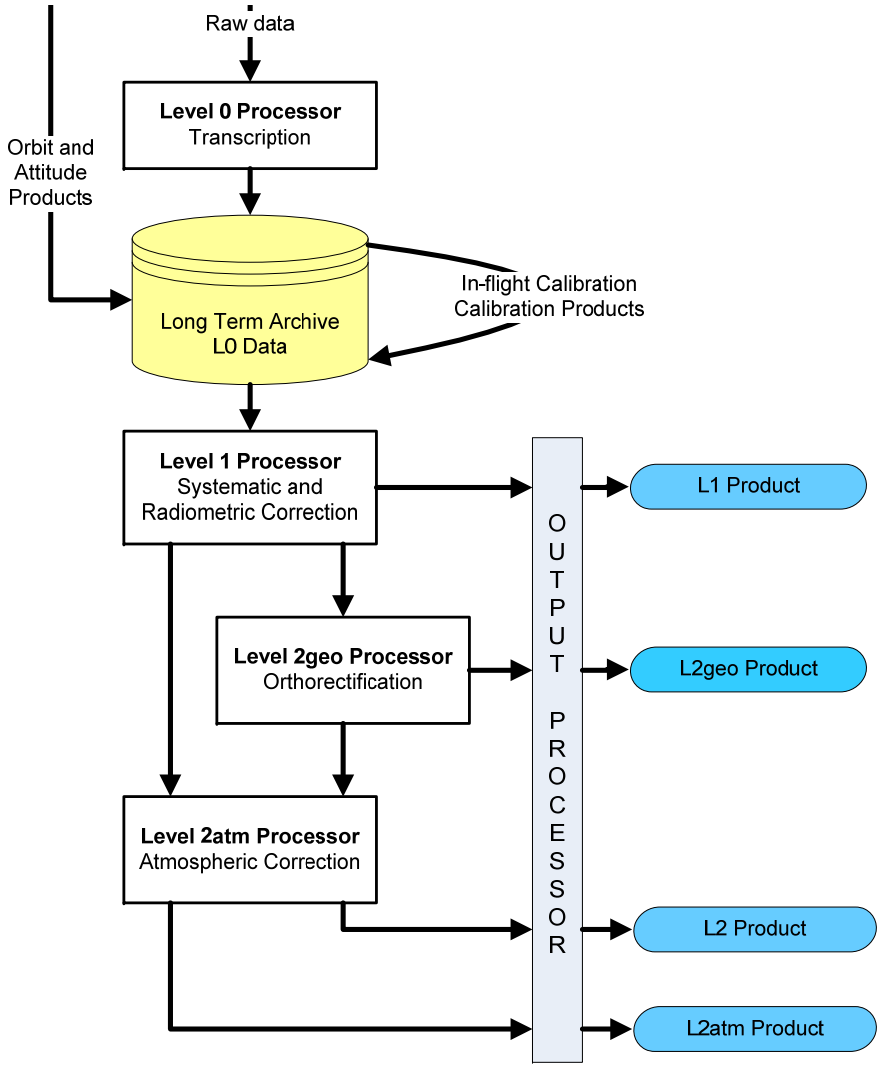


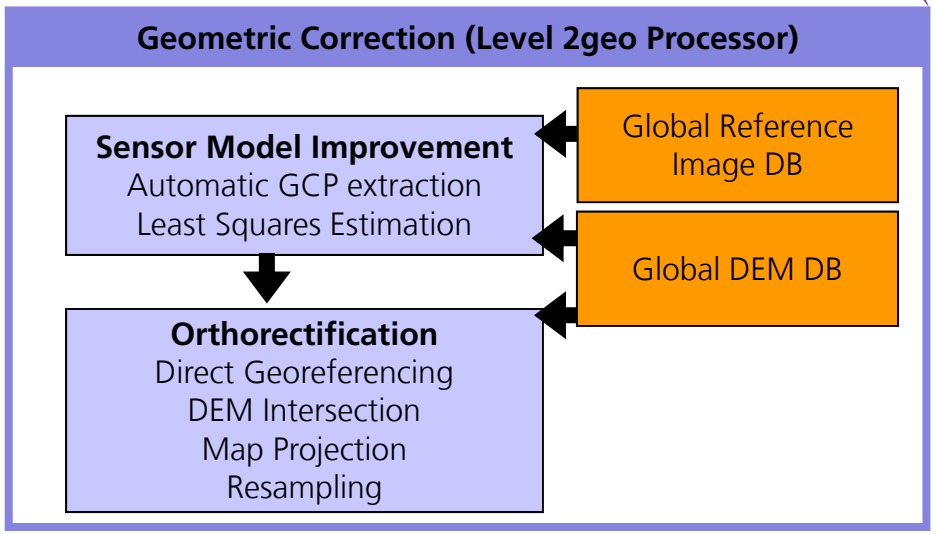
Overview Processing Chain

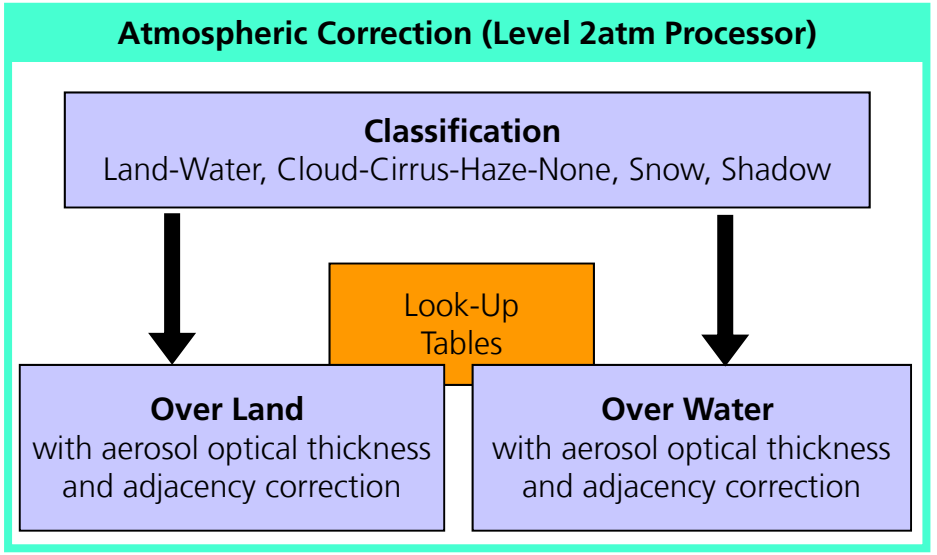




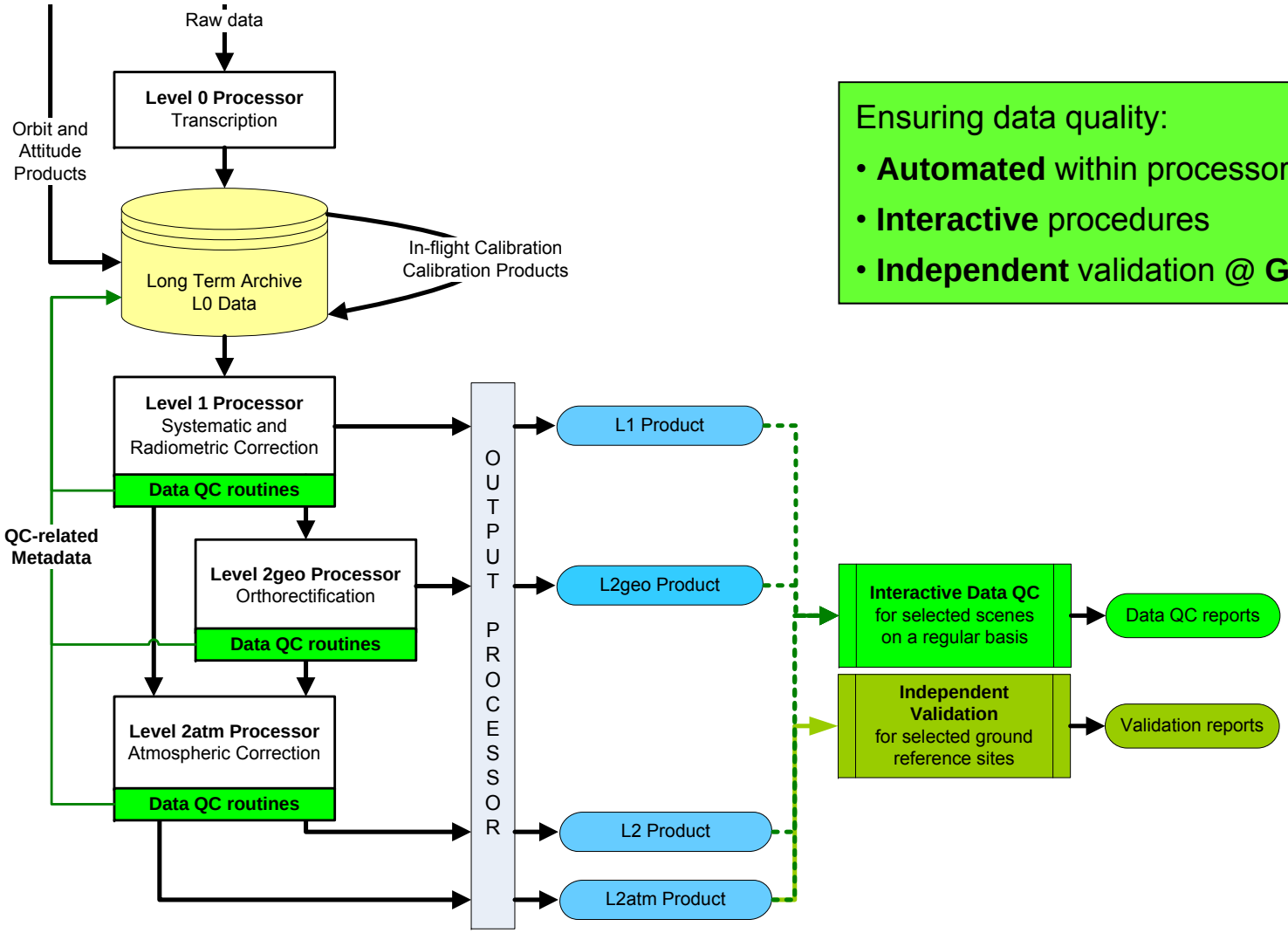
Overview Processing Chain







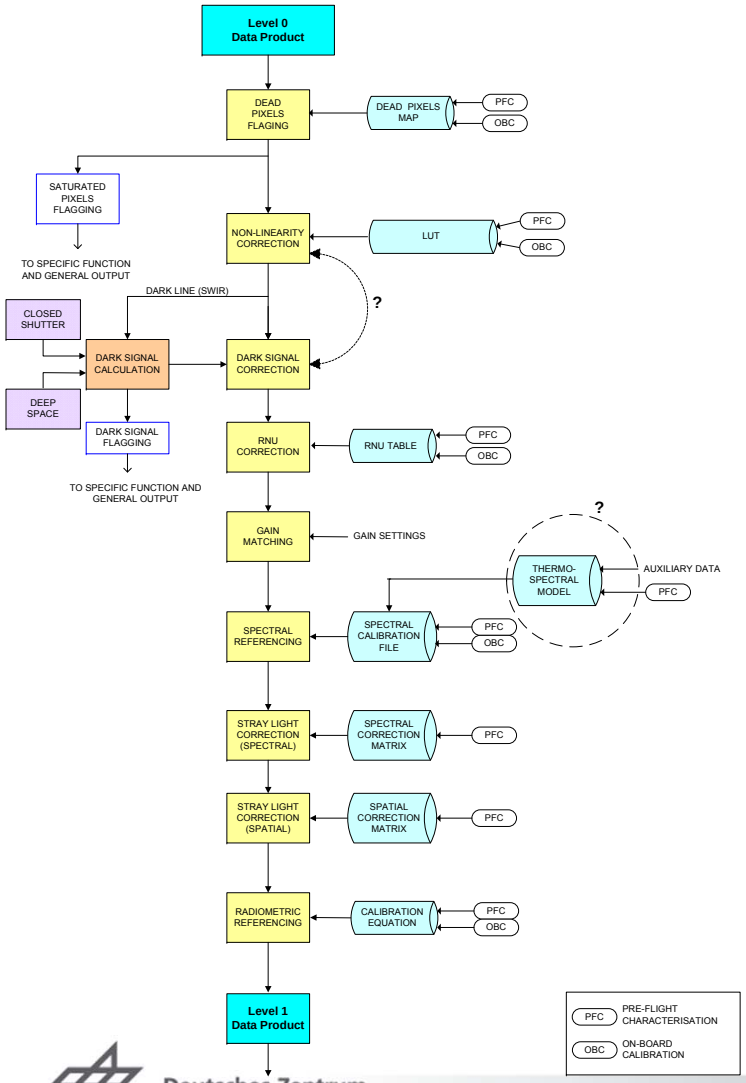
Overview Processing Chain



Ensuring data quality:

- **Automated** within processors
- **Interactive** procedures
- **Independent** validation @ **GFZ**

EnMAP Level 1 Processing – detailed steps



- **Bad (dead & suspicious) pixel flaging**
- **Saturated pixel flagging (incl. blooming)**
- Non-linearity correction
- Dark signal correction
- RNU correction
- Gain matching (VNIR)
- Spectral referencing
- Spectral / spatial straylight correction
- Radiometric referencing
- **QL generation**
- **Cloud-haze and land-water masks generation**

L2

- Geometric correction (incl. keystone correction)
- Atmospheric correction (incl. smile correction)

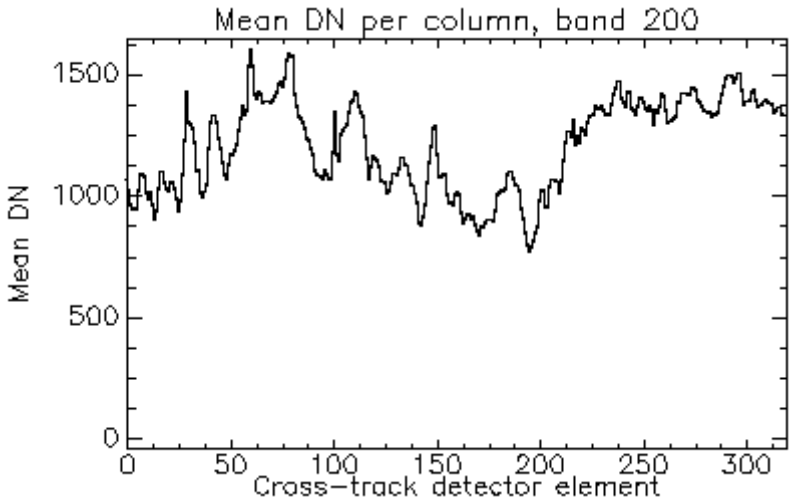
EnMAP – Data Qality Indicators

- **Radiometry**
  - Artifacts related to radiometric calibration (striping, banding)
  - Artifacts related to dual gain
- **Image properties**
  - Saturation (cross-talk, blooming)
  - Other artifacts / suspicious pixel / repetitive pattern
  - Error messages in virtual channel, sensor & processor log files
- **Environmental conditions** during acquisition
  - Sun elevation
  - Percentage of cloud, haze, cirrus and cloud shadow
  - Average scene visibility / AOT / WaterVapour
  - Problems in atm. correction (e.g., # DDV pixels, meaningful aerosol type, …)
  - Artifacts related to terrain correction / DEM
- **...**

Operational QC within pre-processing chains

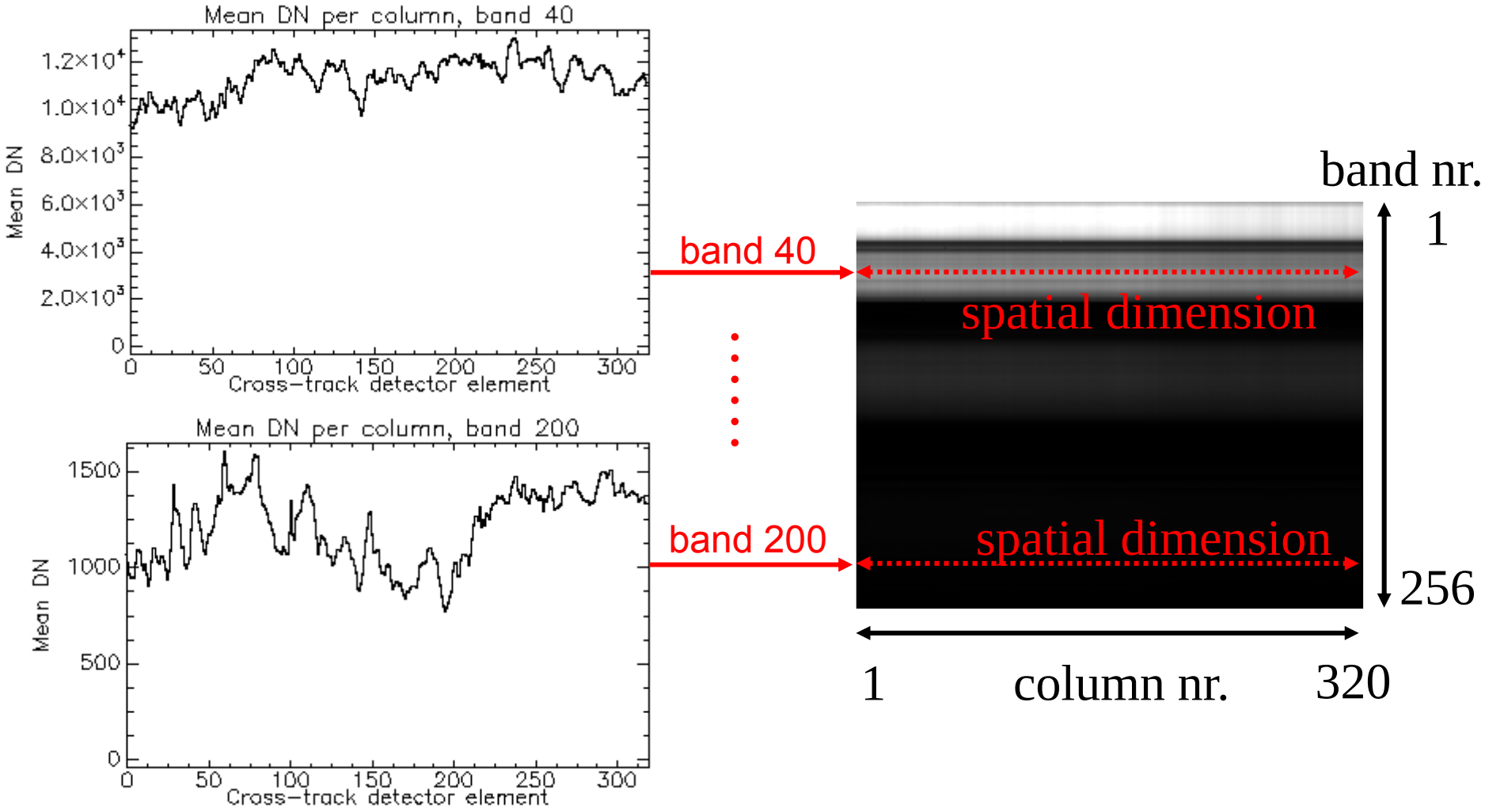
- **Radiometry**
  - Artifacts related to radiometric calibration (striping, banding)

Examples using the airborne HySpex scanner (SWIR camera depicted)



BACHMANN et al., 2013:
Extending DLR's operational data quality control (DataQC) to a new sensor - Results from the HySpex 2012 campaign
EARSeL SIG-IS, Nantes, 2013.

Radiometry - “Detector Map”



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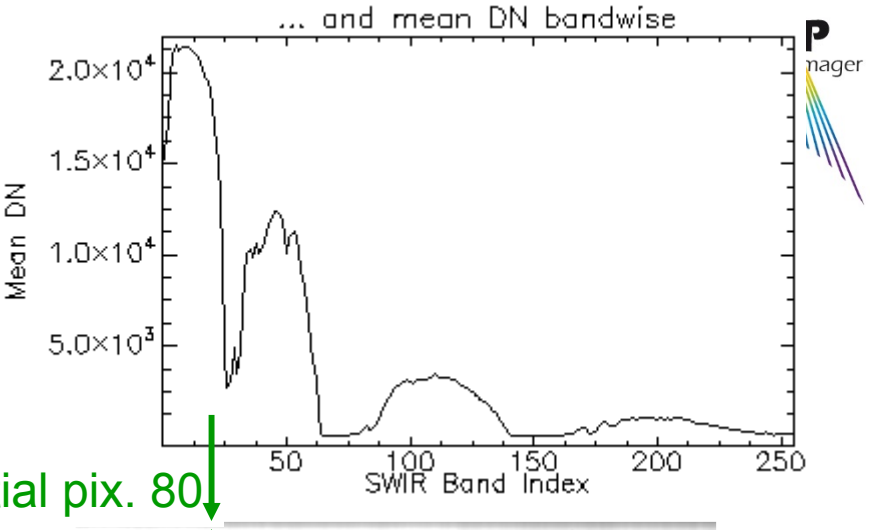
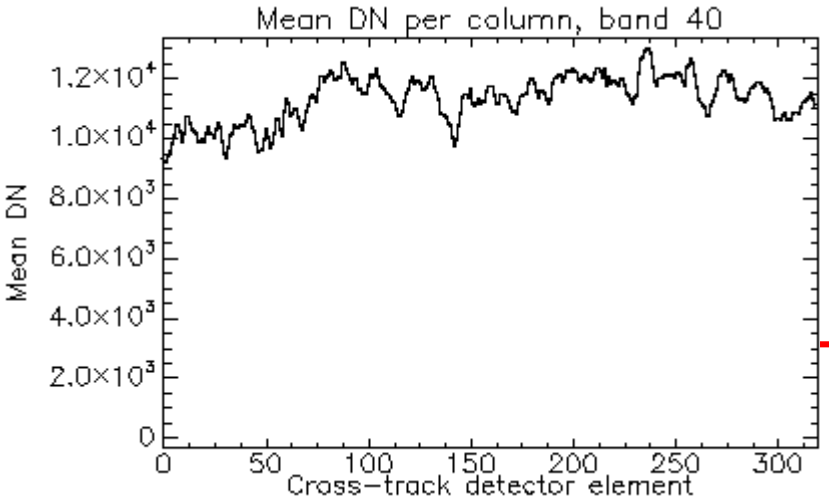
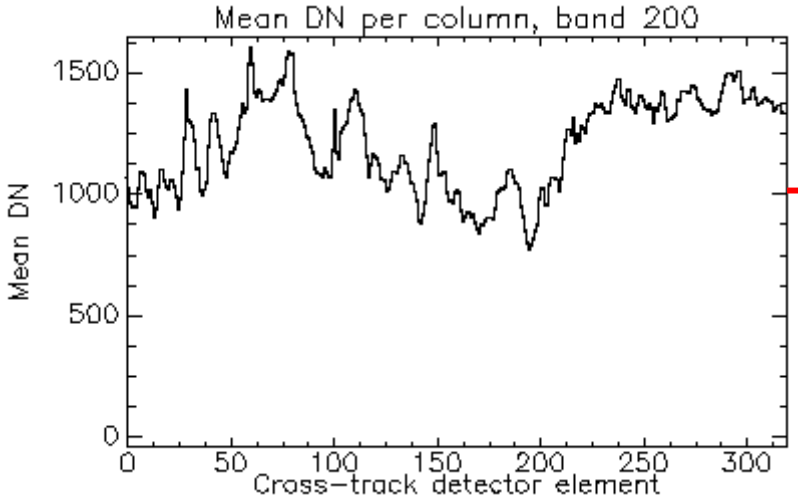


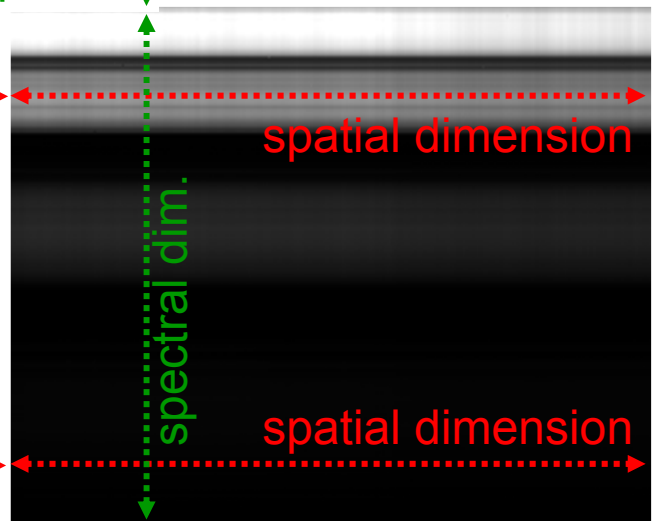




spatial pix. 80

band 40

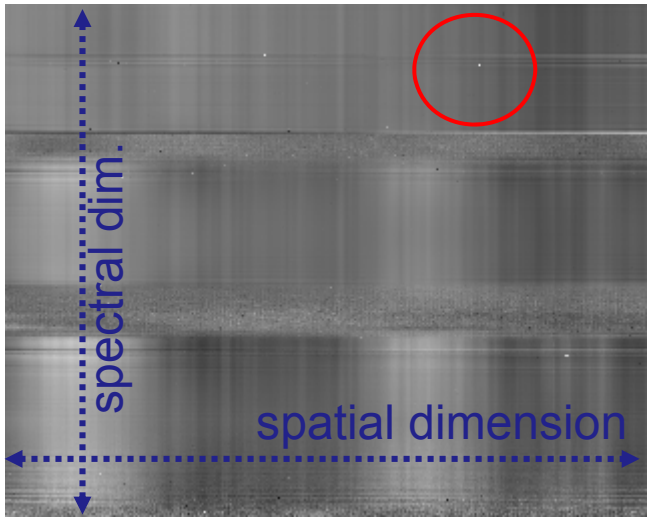
band 200



„Detector map“:
mean DN for every band and cross-track detector element

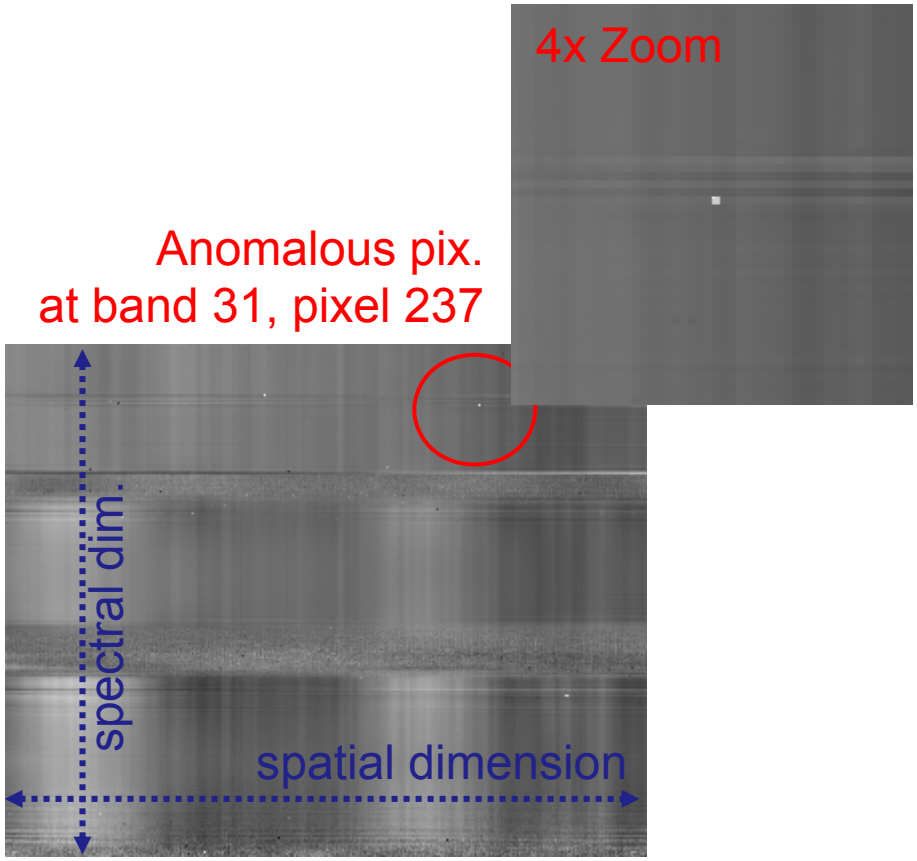
Detecting Striping Artefacts in L1 Data

Anomalous pix.
at band 31, pixel 237



Normalized detector map of scene “Lehrforst”

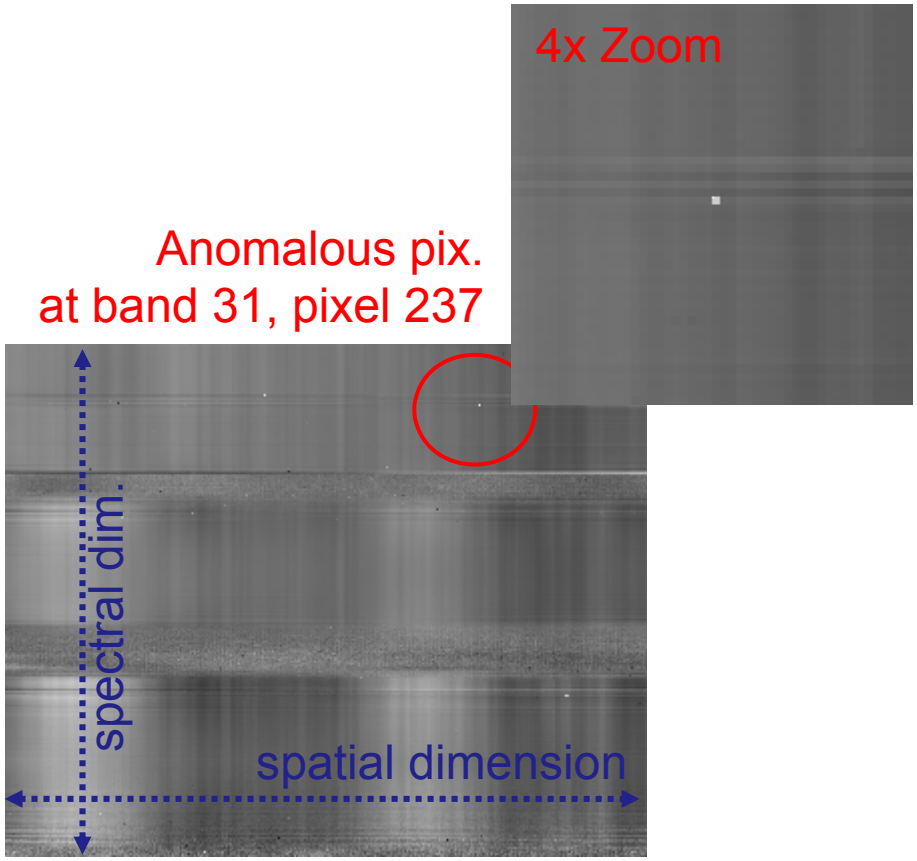
Detecting Striping Artefacts in L1 Data



Difference of ~30% (in radiance) to spatially & spectrally neighboring detector elements

Normalized detector map of scene “Lehrforst”

Detecting Striping Artefacts



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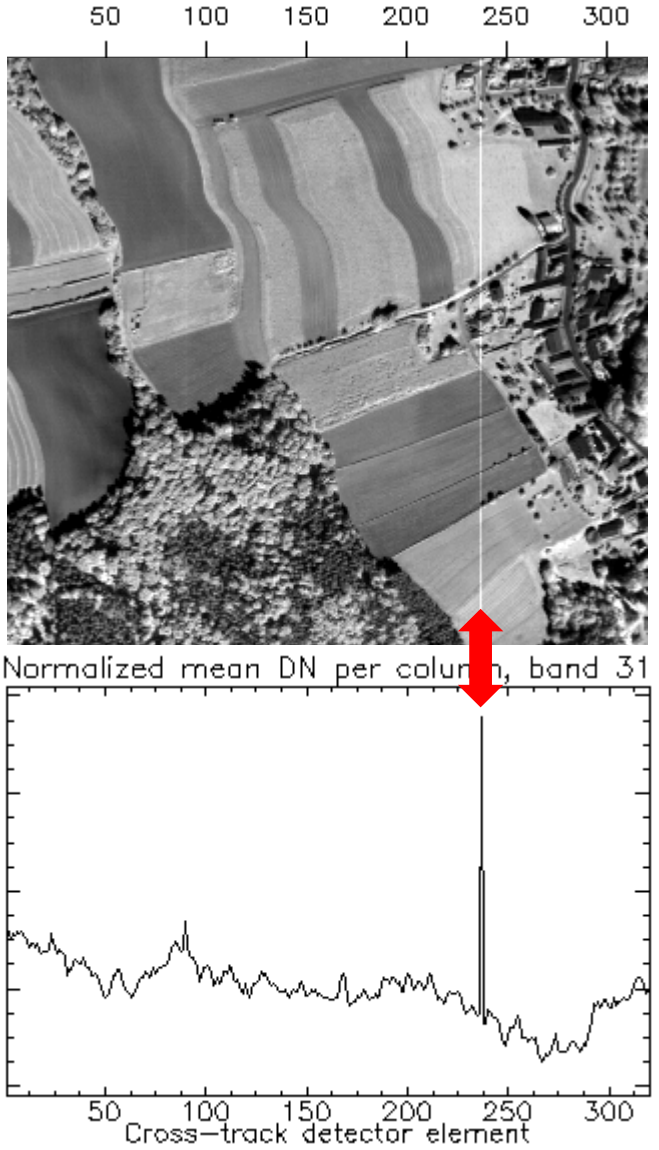
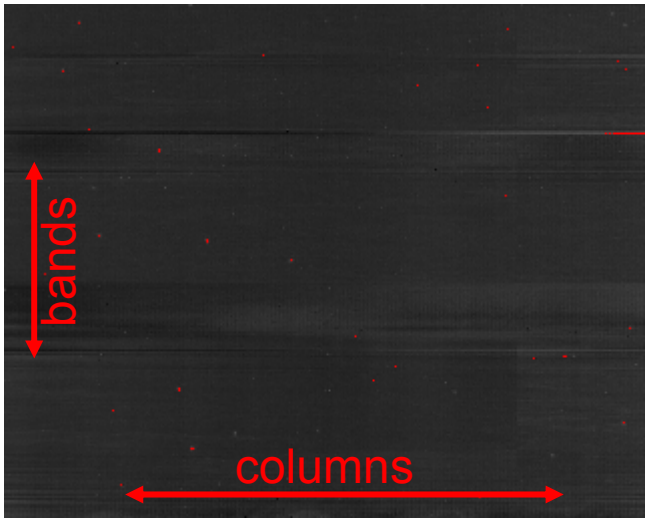
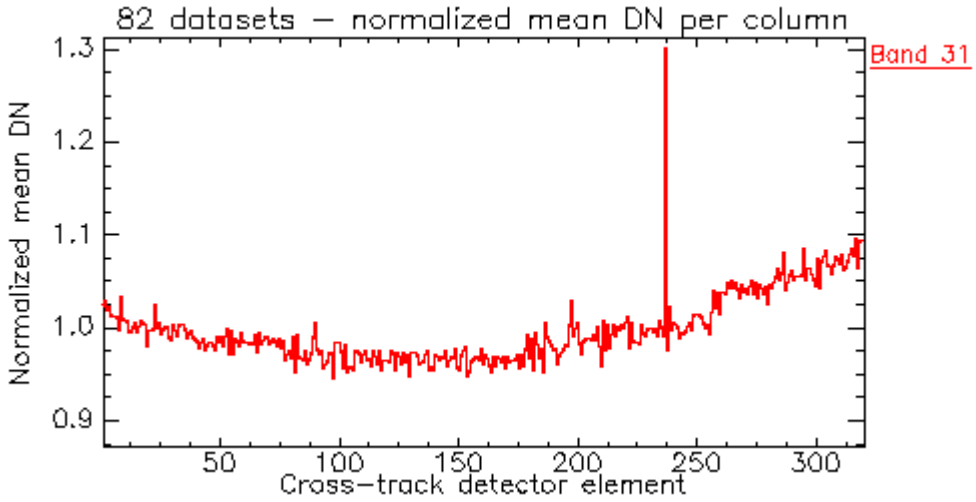


Analysis of 82 L1 Datasets: Consistency in Bad Pix

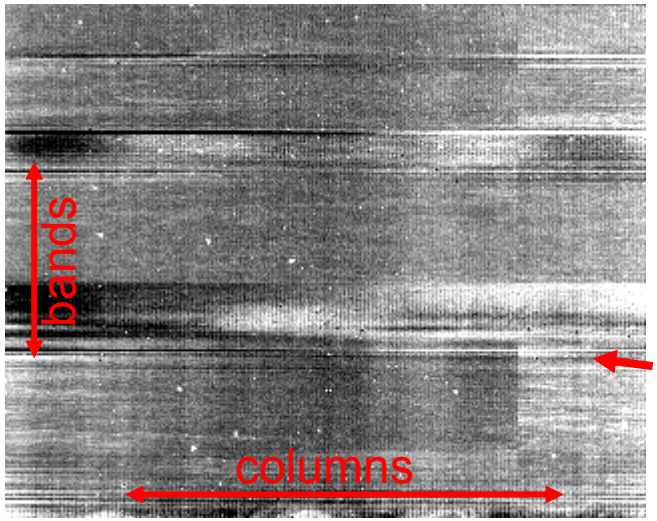


Mean normalized radiance over 82 datasets,
linear stretch,
all pix with >20% derivation from mean in red



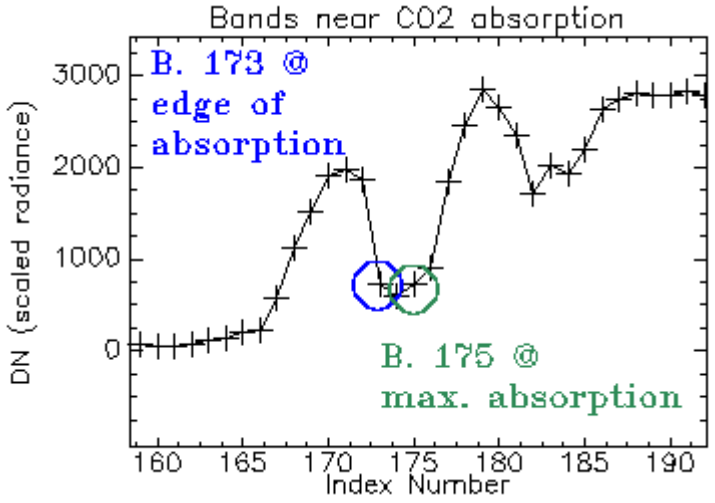
Anomalous detector element at band 31, pixel 237
is consistent over campaign
i.e., decalibrated

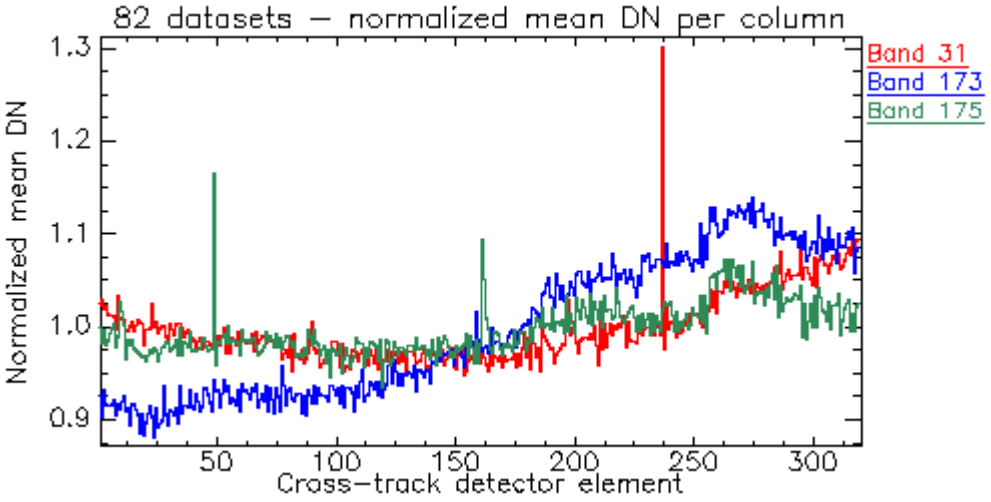
Analysis of 82 L1 Datasets: Spectral Smile



175 / 2.01 µm

Mean normalized radiance over
82 datasets,
non-linear stretch





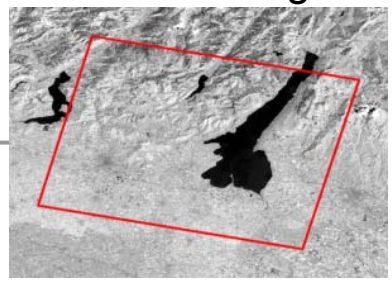
Geometric Processing using Reference Images

Original images

Original image

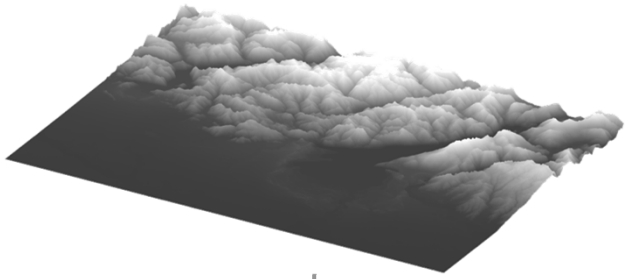
Reference image database (Image2006/Landsat)

Reference image



DEM database (w42)

DEM



Matching

Tie points
GCP / ICP

Metadata
- ephemeris
- attitude
- sensor
- time
- RPC
- ….

Improvements of model parameters

RMSE/CE90 check against Requirement (< 3 GSD)

Generation of ortho image

Ortho image

Data Delivery

EnMAP Data QC for L2_geo products

QC Entry	Parameter	Category	Report format	Metadata (DIMS IIF)	
				Internal	Public
			(**R**)eport (**L**)ayer		
orthoTerrain	DEM-related displacements	GEO	R	Y	
orthoRMSE	**Geometric accuracy** of the orthoimage (I)	GEO	R	Y	Y
orthoResidual	Geometric accuracy of the orthoimage (II)	GEO	R	Y	

Blue: implemented in L2_geo processor

EnMAP Data QC for L2_atm products

QC Entry	Parameter	Category	Report format	Metadata (DIMS IIF)	
				Internal	Public
			(R)eport (L)ayer		
overallQuality	**Overall data quality**	all	R	Y	Y
processorLog	Warning messages in processor log	IMG	R	Y	
sceneSZA	**Solar zenith angle**	IMG	R	Y	Y
sceneSunglint	Sun glint / sun glitter probability	IMG	R	Y	
cloudCover	**Percentage clouds**	ATM	R, L	Y	Y
hazeCover	Percentage haze	ATM	R, L	Y	Y
cirrusCover	Percentage cirrus	ATM	R, L	Y	Y
cloudShadow	Percentage cloud shadow	ATM	R, L	Y	Y
sceneWV	**Average scene WV**	ATM	R	Y	Y
sceneVIS	Average scene visibility / AOT	ATM	R	Y	Y
sceneAtmParam	**Validity of atm. correction**	ATM	R	Y	
sceneTerrain	DEM artifacts in terrain correction	ATM	R, L		
internalMasking	**Masks** generated during processing (cloud, shadow, haze, land / water)	ATM	R		
specCal	Artifacts related to spectral calibration / ATCOR LUTs	SPEC, ATM	R		

Blue: implemented in L2_atm land / L2_atm water processor

EnMAP Data QC for L1 products

QC Entry	Parameter	Category	Report format	Metadata (DIMS IIF)	
				Internal	Public
			(**R**)eport (**L**)ayer		
overallQuality	Overall data quality	all	R	Y	Y
stripingBanding	Artifacts related to **radiometric calibration**	RAD	R	Y	
dualGain	Artifacts related to dual gain	RAD	R, L		
saturationCrosstalk	Saturation, cross-talk, blooming	IMG	R, L	Y	Y
generalArtifacts	Other **artifacts** / suspicious pixel	IMG	R, L	Y	
sensorLog	Warning messages related to sensor	IMG	R	Y	
processorLog	Warning messages in processor log	IMG	R	Y	
internalMasking	**Masks** generated during processing (cloud, shadow, haze, land / water)	ATM	R		
specCal	Artifacts related to **spectral calibration**	SPEC	R		
signalToNoise	Signal-to-noise estimate	IMG	R		

Blue: implemented in L1 processor

EnMAP
Hyperspectral Imager

External Validation @ GFZ

External Validation @ GFZ

- Establishing **international partnerships for EnMAP Cal/Val activities** (e.g., CEOS)

- **Ground-based** comparison of EnMAP user products to **in-situ reference** measurements:
  - Field campaigns with in-situ measurements of atmospheric and surface parameters.
  - Benefit from joint effort with ground-based science activities.

- **Scene-based** further validation from scene-based data analysis:
  - User products and intermediate parameters to be analysed.
  - Sophisticated models and image processing techniques involved.
  - **Activities considered “scientific” rather than “operational”.**

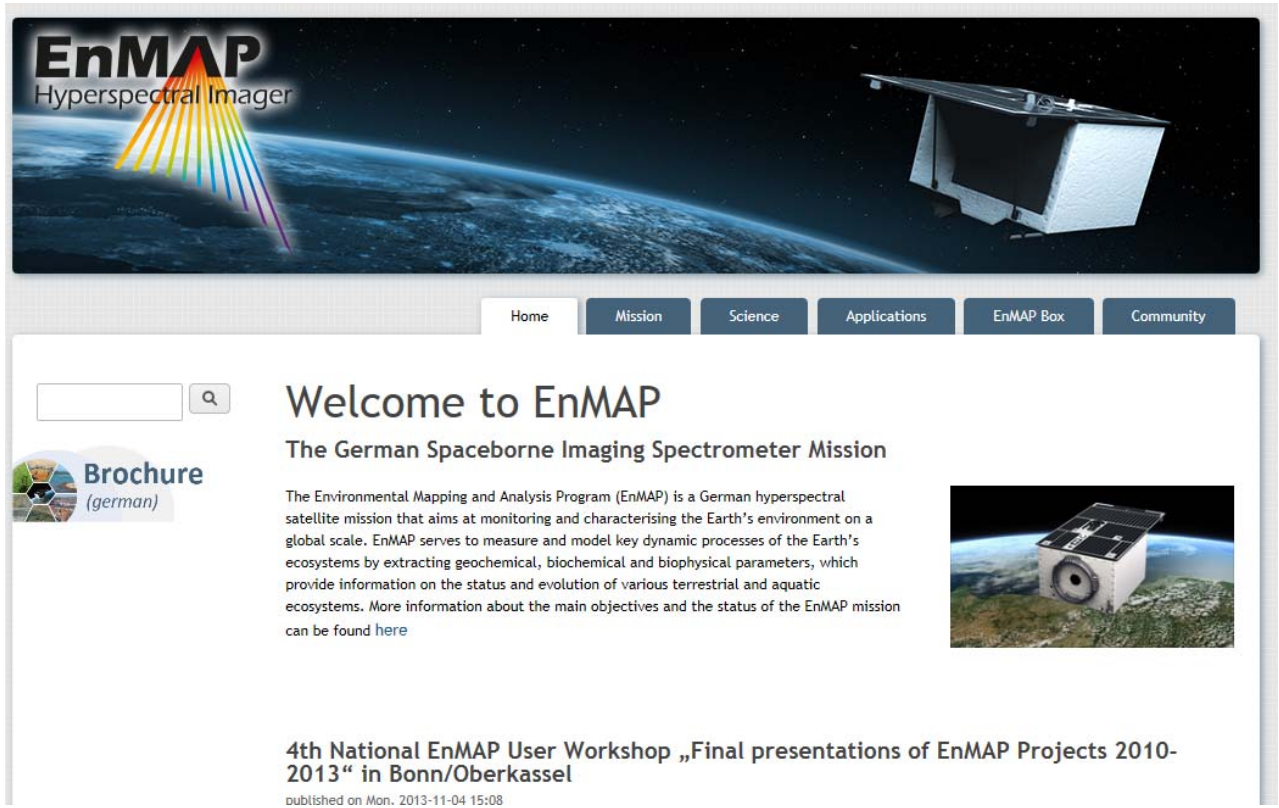
Summary – Cal/Val/Mon/DataQC for EnMAP

- **Calibration & monitoring**
  - On-board calibration sources & sun calibration
  - Procedures taking into account life-limited items

- **DataQC within pre-processing chain**
  - Integrated within L1 / L2geo / L2atm processors
  - Generation of QC-related metadata, QC flags + reports
  - Interactive procedures for additional parameters

- **Independent validation**
  - Incl. ground-based CalVal activities

Thank you very much for your attention!



enmap.org