ENMAP RADIOMETRIC INFLIGHT CALIBRATION, POST-LAUNCH PRODUCT VALIDATION, AND INSTRUMENT CHARACTERIZATION ACTIVITIES

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GFZ
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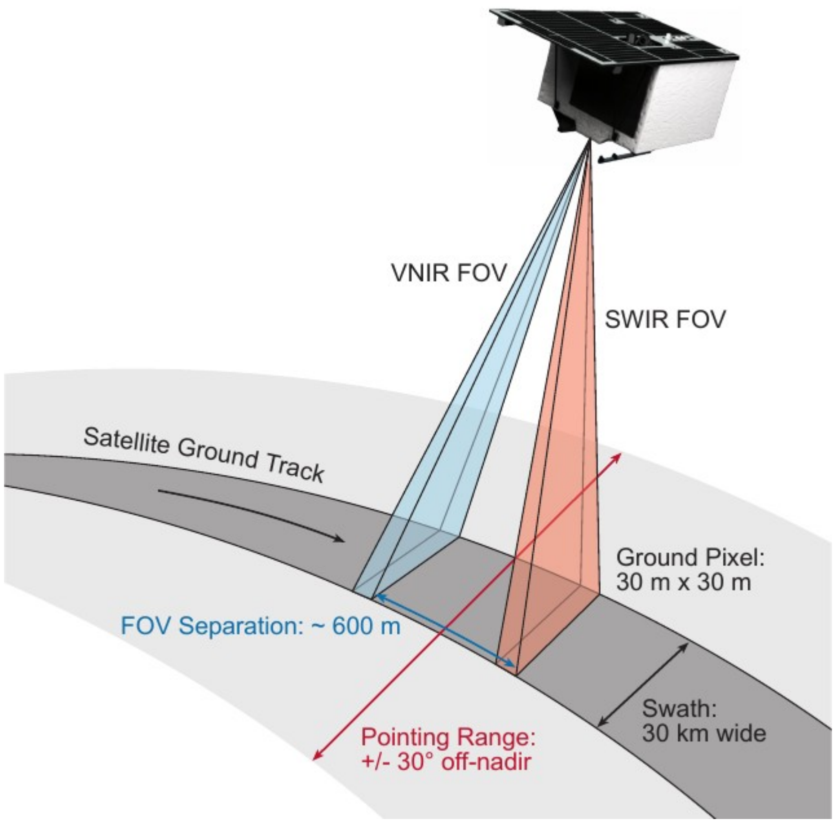
Outline

ENMAP RADIOMETRIC INFLIGHT CALIBRATION, POST-LAUNCH PRODUCT VALIDATION, AND INSTRUMENT CHARACTERIZATION ACTIVITIES

The Environmental Mapping and Analysis Program (EnMAP) – Key Facts

Orbit characteristics		
Orbit / Inclination	sun-synchronous / 97.96°	
Target revisit time	27 days (VZA ≤ 5°) / 4 days (VZA ≤ 30°)	
Equator crossing time	11:00 h ± 18 min (local time)	
Instrument characteristics	*VNIR*	*SWIR*
Spectral range	420 - 1000 nm	900 - 2450 nm
Number of bands	89	155
Spectral sampling interval	6.5 nm	10 nm
Spectral bandwidth (FWHM)	8.1 ± 1.0 nm	12.5 ± 1.5 nm
Signal-to-noise ratio (SNR)	› 400:1	› 150:1
Spectral calibration accuracy	0.5 nm	1 nm
Ground sampling distance	30 m (at nadir; sea level)	
Swath width	30 km (field-of-view = 2.63° across track)	
Swath length	1000 km/orbit - 5000 km/day	

to be launched in June 2018



1: http://www.enmap.org/sites/default/files/pdf/pub/EnMAP_komplett_web_eng.pdf

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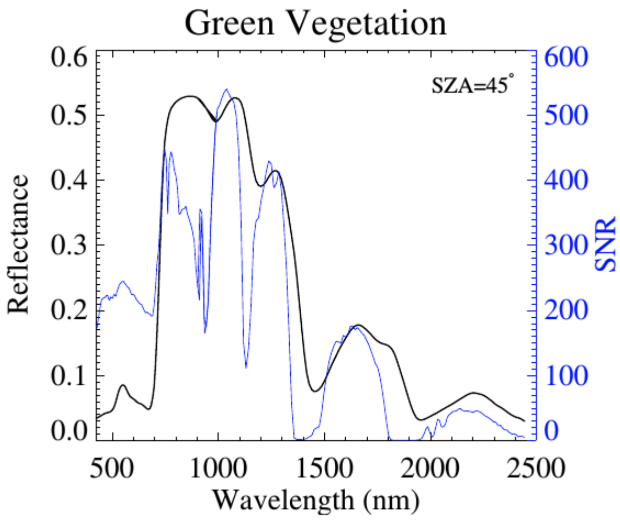

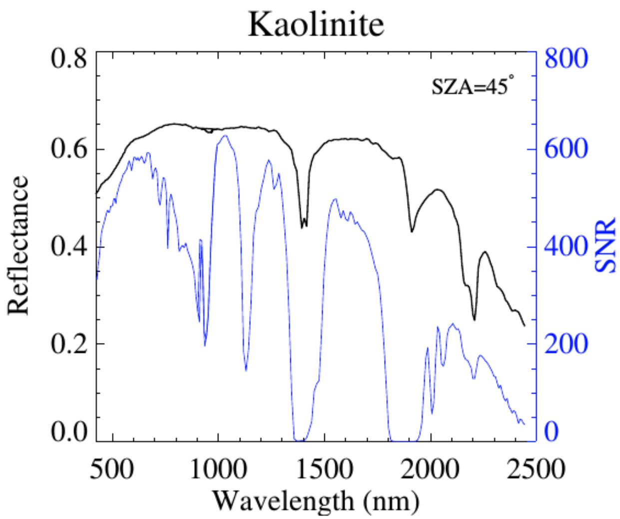

1: www.enmap.org/sites/default/files/pdf/pub/EnMAP_komplett_web_eng.pdf
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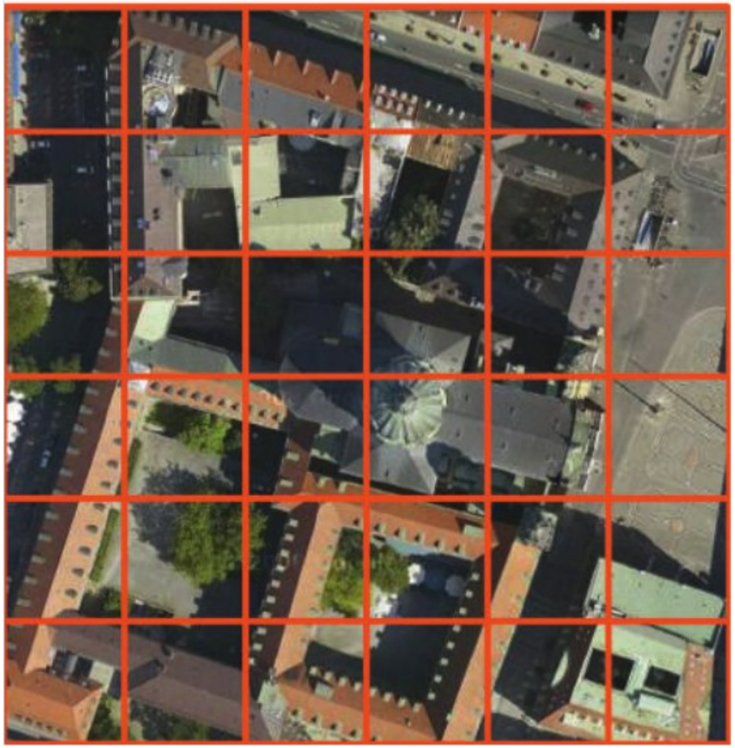
Pixel size 30 m x 30 m (e.g. EnMAP)



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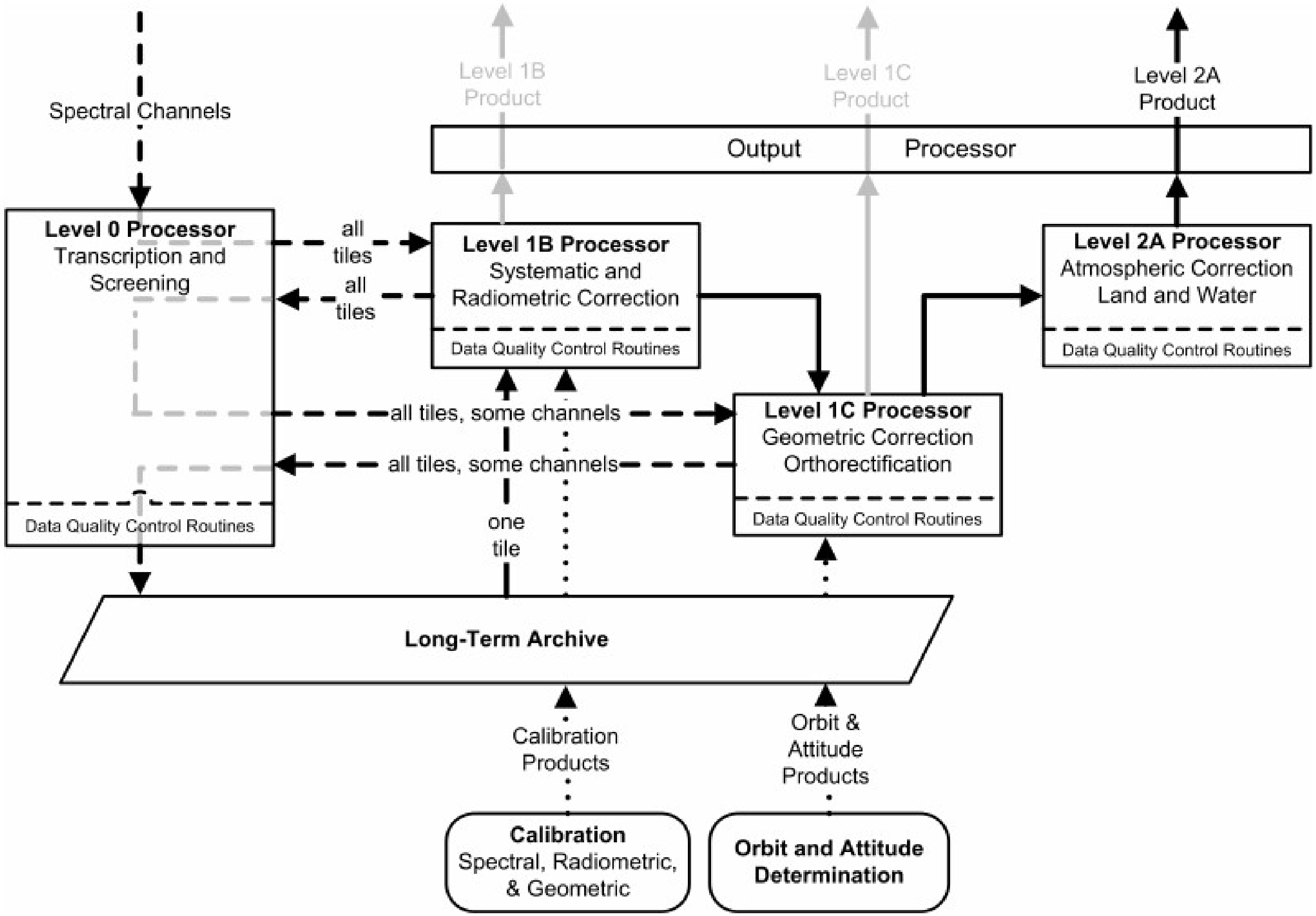
EnMAP Data Processing Scheme by DLR GS



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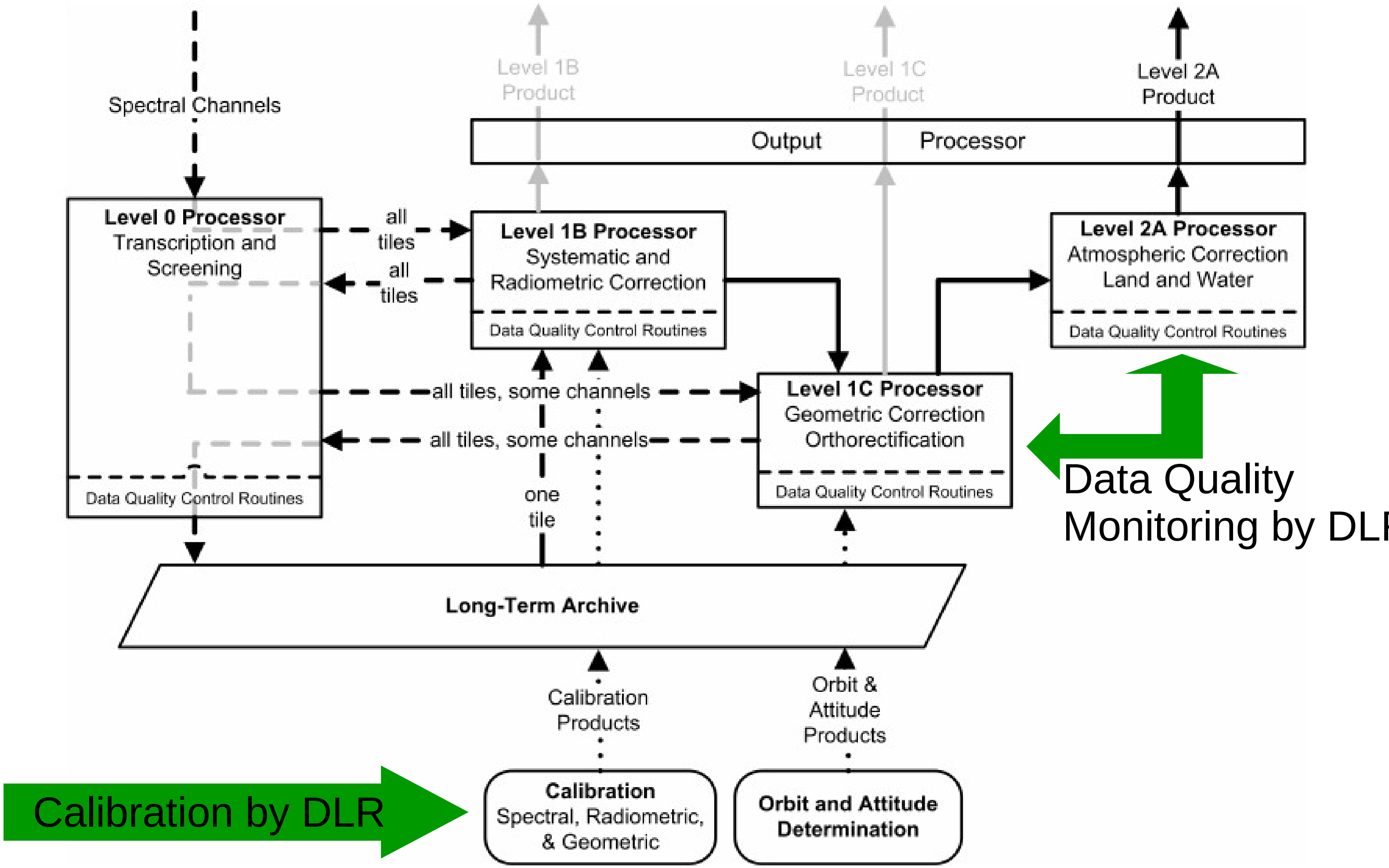

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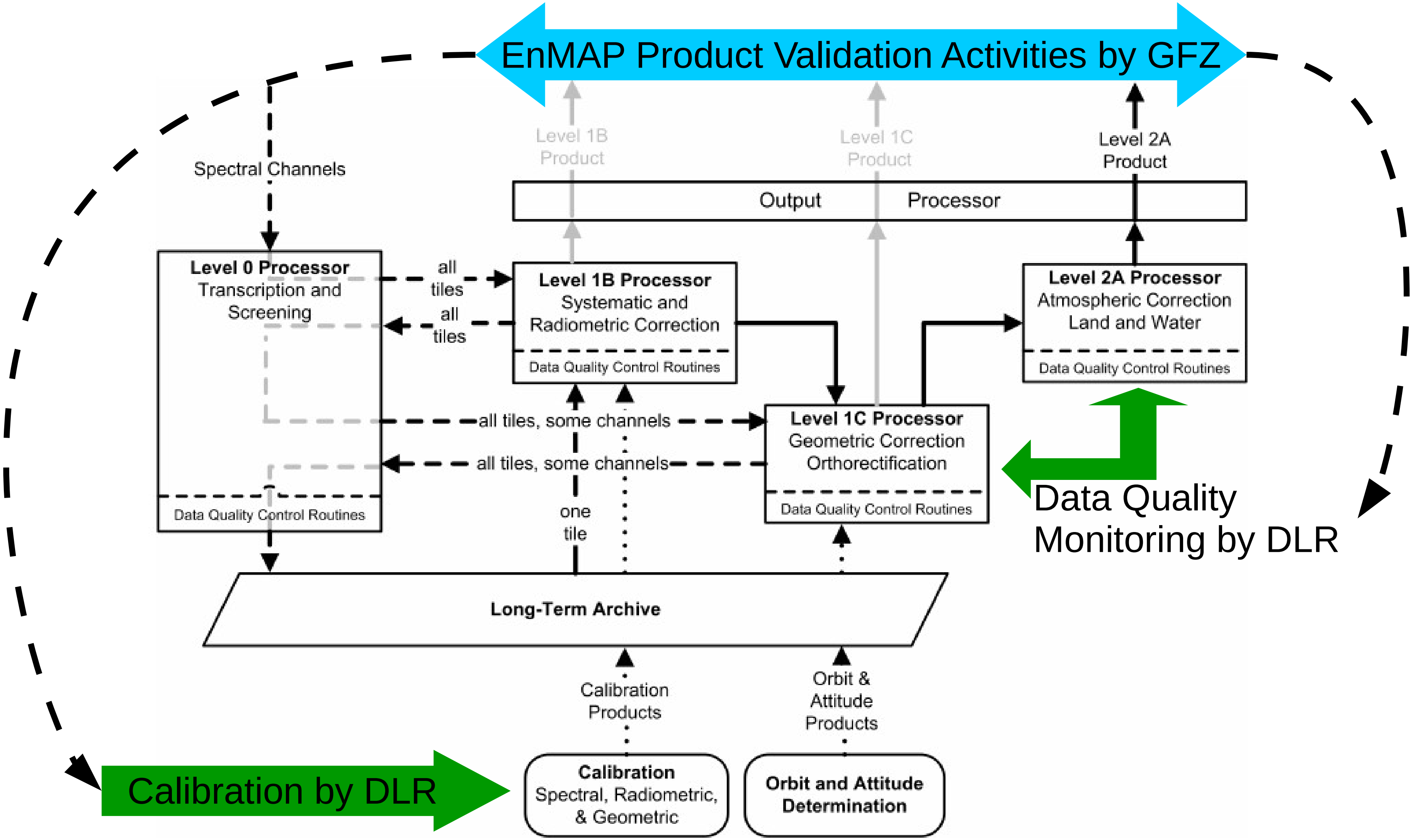

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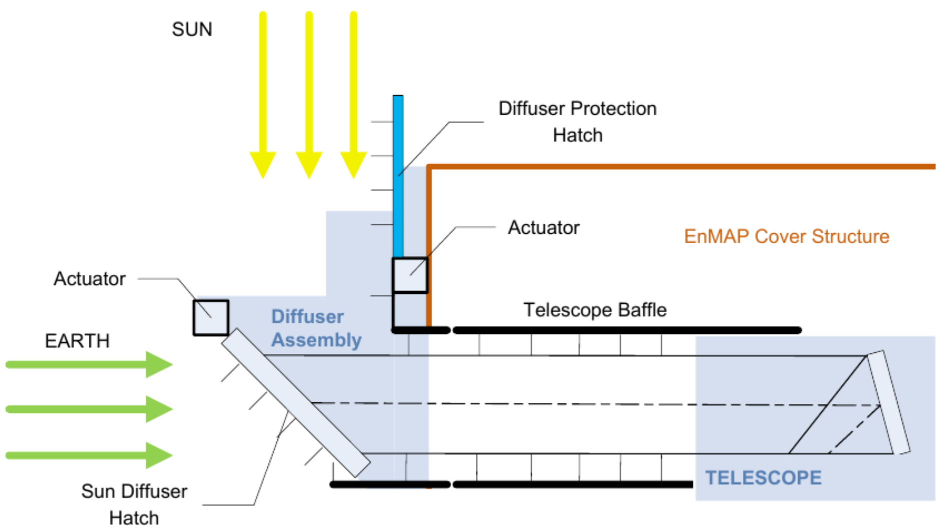
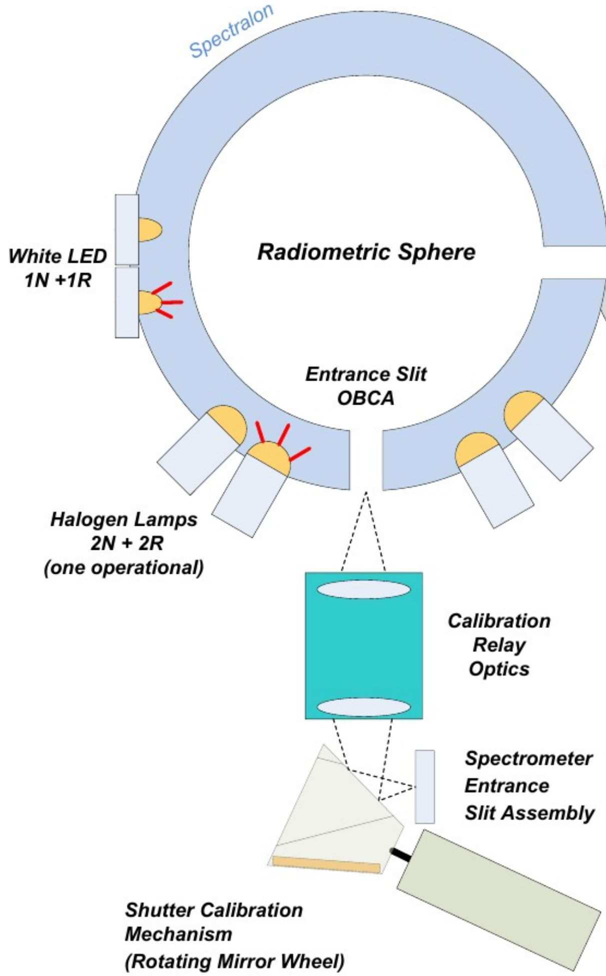
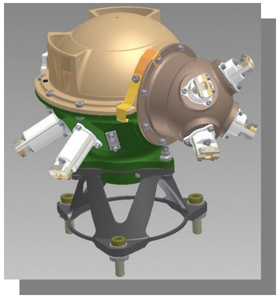
On Board Spectral and Radiometric Calibration

- <u>Dark values calibration</u>: using recordings while looking at the closed shutter or into deep space
- <u>Absolute Calibration:</u> Solar calibration using full aperture diffuser assembly, also used for <u>response non-uniformity</u> calibration
- <u>Relative radiometric calibration:</u> monitoring of temporal changes using the large integrating sphere
- <u>Spectral calibration</u>: small integrating sphere with doped Spectralon and dedicated lamps for spectral calibration
- <u>Response non-linearity:</u> focal plane assembly LED's







1:Guanter et al. The EnMAP Spaceborne Imaging Spectroscopy Mission for Earth Observation. Remote Sens. 2015

In-flight Calibration Frequencies

Calibration type	Time	Frames	Frequency (planned)
Dark (shutter)	23 sec	2*128 (2 gains)	each datatake
Dark (deep space)	30 sec	1*1024 (2 gains)	every 4 months
Relative radiance	17 min 13 sec	1*512 (5 steps)	weekly
Sun calibration	140 sec	2*1024	monthly
Spectral calibration	5 min13 sec	1*1024	every 2 weeks
Linearity measurement	< 5 min	2*128*40 (2 gains)	monthly

Objectives of GFZ Validation Activities and Characterization Plan

Quantitative validation of those EnMAP products to be delivered to end-users; by independent means as considered in the ground segment:

- Level-1B: top of atmosphere radiance
- Level-1C: top of atmosphere radiance with geometric correction
- Level-2A: surface reflectance including geometric correction

Objectives of GFZ Validation and Characterization Plan - Two-Fold Approach

Ground-based:

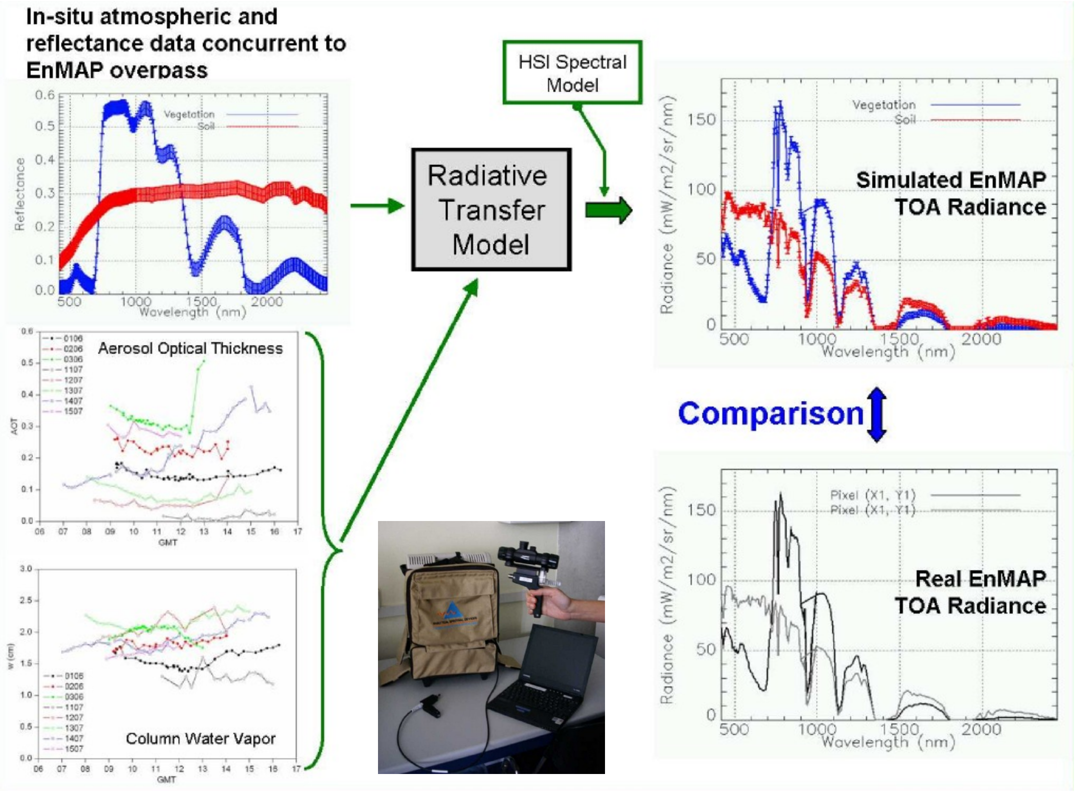
- Comparison of EnMAP user products to *absolute* references for Level-1B/C and Level-2A measurements at to be selected reference sites (e.g. CEOS sites)
- Validation of Atmospheric products from Level-2A processing, e.g. using AERONET sites: aerosol optical thickness, surface pressure, total columnar water vapor
- Using hyper spectral flight campaigns which are a benefit from other science related collaborative efforts ← in discussion, how exactly to do it?

Scene-based:

- Sophisticated models and image processing techniques involved
- Activities considered "scientific" rather than "operational"
- Sensor characteristics: spectral smile, spectral shifts, Keystone, modulation transfer function (MTF)
- Image quality: dead and bad pixels, co-registration, artifact detection such as striping

Approach for Ground-Based Validations – Vicarious Calibration

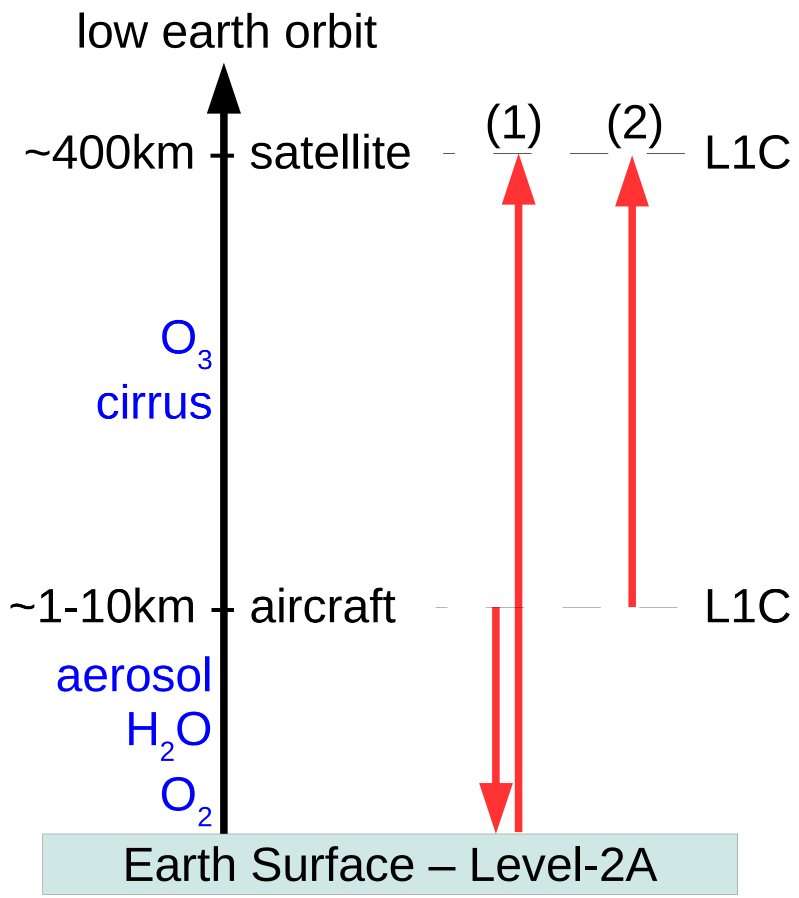
- Comparison of EnMAP Level-1B/C products with reference radiance spectra generated from in-situ surface reflectance measurements and radiative transfer simulations
- Needed are:
  - In-situ surface reflectance measurements for suitable reference site (homogeneous , …)
  - Known atmospheric composition (surface pressure, aerosol optical thickness, total columnar water vapor)
  - Accurate radiative transfer simulations
  - Spectral response functions
- Potential benefit from airborne sensors: “closer” to TOA radiance and able to extend validation area to cover EnMAP’s swath and to check across-track radiometric response → but need a way to convert airborne data to EnMAP measurement ← in discussion how exactly to do it



1: EnMAP Validation Plan, EN-GFZ-CalVal, Guanter et.al
2: http://aeronet.gsfc.nasa.gov/

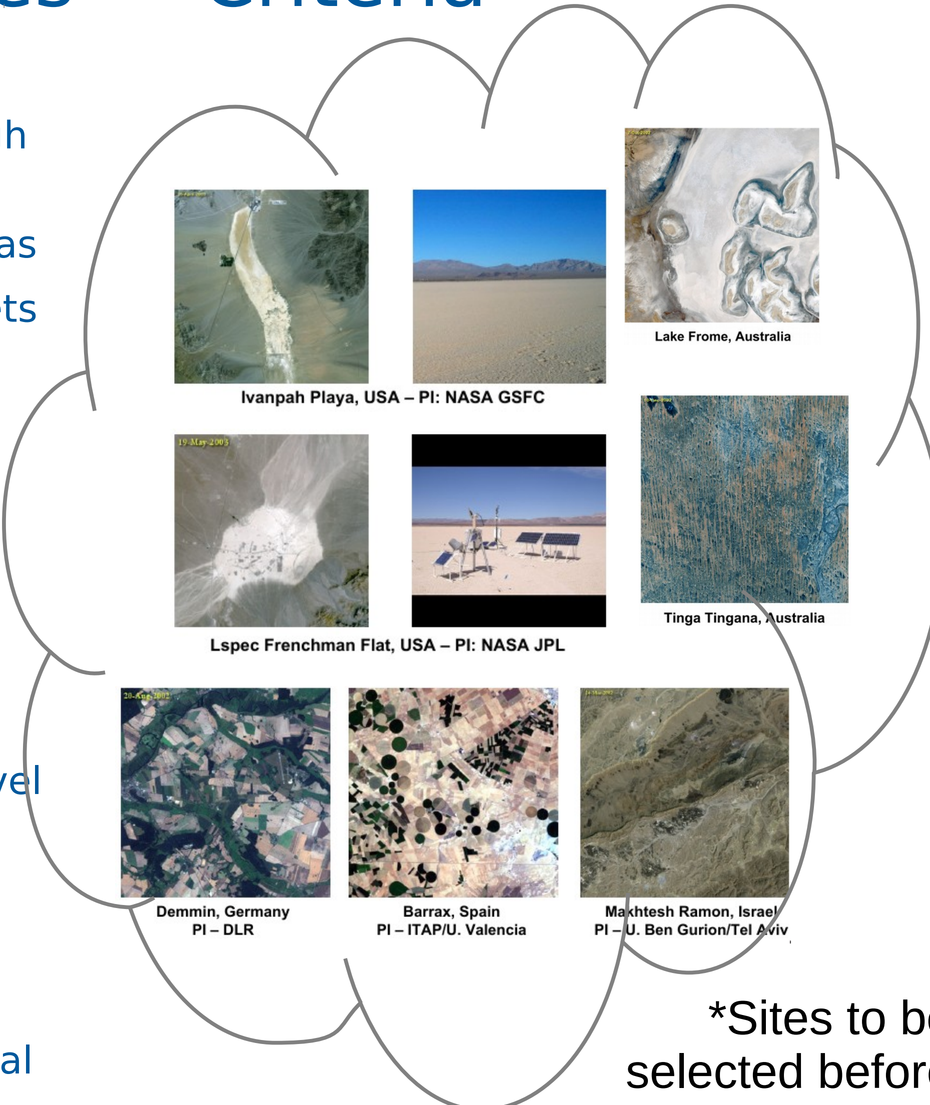
Vicarious Validation using Airborne Sensors

- two approaches:
  1) airborne Level-1C → Level-2A trough atmospheric correction → radiative transfer modeling + atmospheric parameters for total column → top of atmosphere radiance → Level-1C satellite products
  2) airborne Level-1C → radiative transfer modeling + atmospheric parameters for column above aircraft → top of atmosphere radiance → Level-1B/C satellite products
- geometric transfer to satellite instrument
- spectral re-sampling must be performed



Validation Sites* – Criteria

- Level-1B/C → **toa radiance**
  - Best conditions for instrument testing (high SNR, minimal atmospheric impact,…)
  - Far from ocean and urban & industrial areas
  - Vegetation-free, bright and elevated targets
  - Wide-spread over the globe
- Level-2A → **surface reflectance**
  - Under normal acquisition conditions
  - Typical EnMAP science sites (agricultural, coastal, geological…)
  - Included in extensive science-oriented campaigns
  - Validation sites across the world at sea level (short-term accessible)
- Level-2A → **geometry and sensor characteristics**
  - Flat and mountainous regions
  - spectrally heterogeneous with high spectral contrast, geologically stable

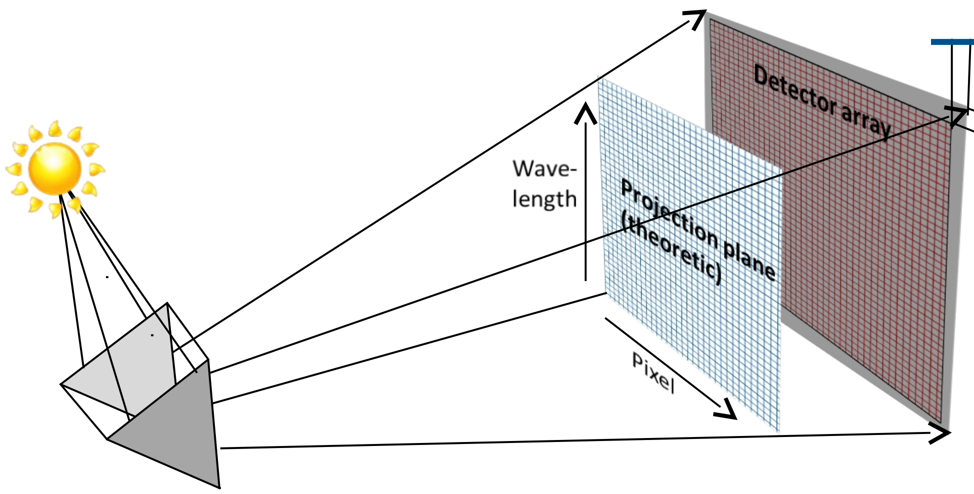


*Sites to be selected before launch.

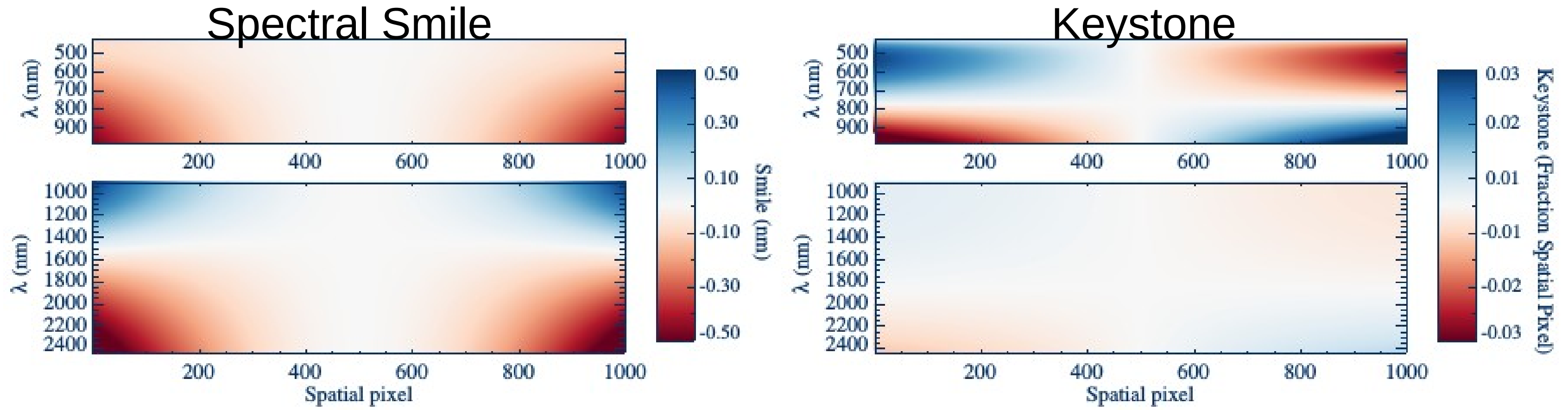
1: Guanter et al. EnMAP Validation Plan

Scene Based: Uniformity - Keystone and Smile

Keystone and **Smile/Frown** are spatial deviations from an optimal projection on the detector array and part of instrument characterization → line of sight and PSF for each detector pixel



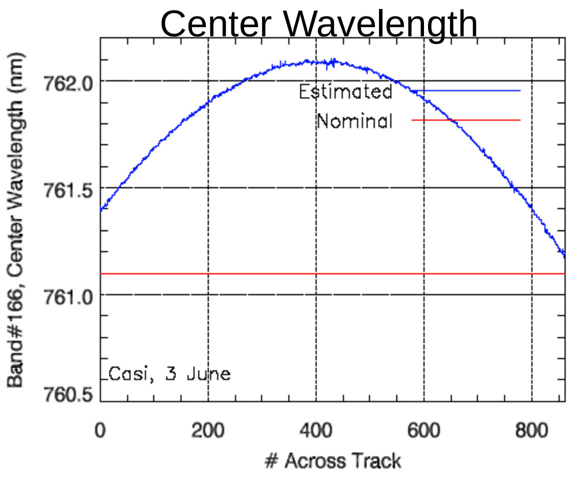
→ Smile and Keystone are expected to be very small.

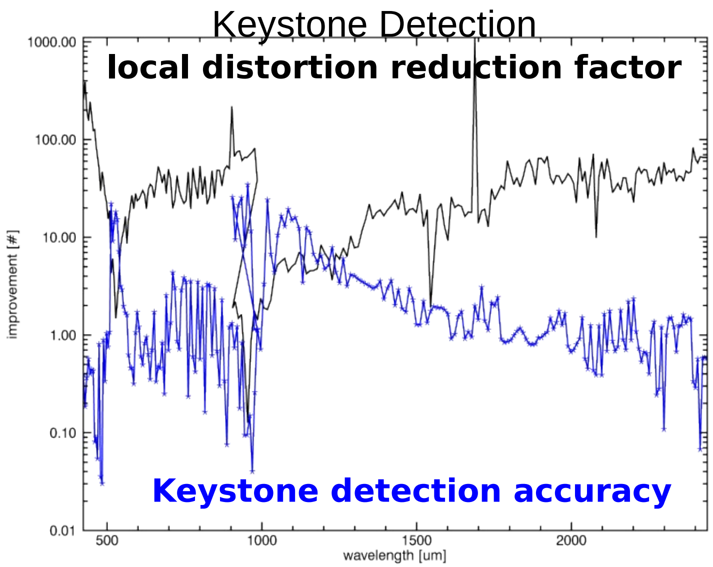


1:Guanter et al. The EnMAP Spaceborne Imaging Spectroscopy Mission for Earth Observation. Remote Sens. 2015

Scene Based Non Uniformity Assessment – If Needed -

- Smile detection
  - Characterization of spectral shift and smile from Level-1B/C scenes
  - Use of atmospheric absorption features (Oxygen-A 760nm & water vapor 1140nm) – only as a complement of on-orbit measurements
  - Use same atmospheric model as for the atmospheric correction algorithm → maximize smoothness of surface reflectance in the vicinity of atmospheric absorption bands
  - Assumed to be stable after launch → no need to apply correction to each individual image
- Keystone detection
  - Sophisticated detection algorithm
  - Mean keystone detection accuracy: >99% without outliers → accuracy < 1µPixel
  - Local distortion reduction factor ~ 1/keystone detection accuracy





1:Guanter, Luis, Karl Segl, Bernhard Sang, Luis Alonso, Hermann Kaufmann, and Jose Moreno. "Scene-based spectral calibration assessment of high spectral resolution imaging spectrometers." Optics express 17, no. 14 (2009): 11594-11606.
2: Rogass, Christian, Maximilian Brell, Karl Segl, Theres Kuester, and Hermann Kaufmann. "Automatic reduction of keystone, applications to EnMAP." In Proceedings of the 8th EARSeL SIG imaging spectroscopy workshop; EARSeL. 2013.

Conclusions

- DLR performs calibration of EnMAP products as part of Level-1A/B/C processing
  - Pre-flight characterization (not covered in this talk)
  - On-board dedicated calibration equipment for:
    - Spectral calibration
    - Detector linearity calibration
    - Absolute calibration
    - Uniformity
    - ...
- GFZ performs independent validation activities based on EnMap products
  - Vicarious validation using yet to be defined test sites, atmospheric products e.g. from AERONET, and accurate radiative transfer
  - Scene based assessment of modulation transfer function (MTF)
  - Although spectral smile, spectral shifts and keystone are expected to be small, scene based assessment can be performed using sophisticated algorithms

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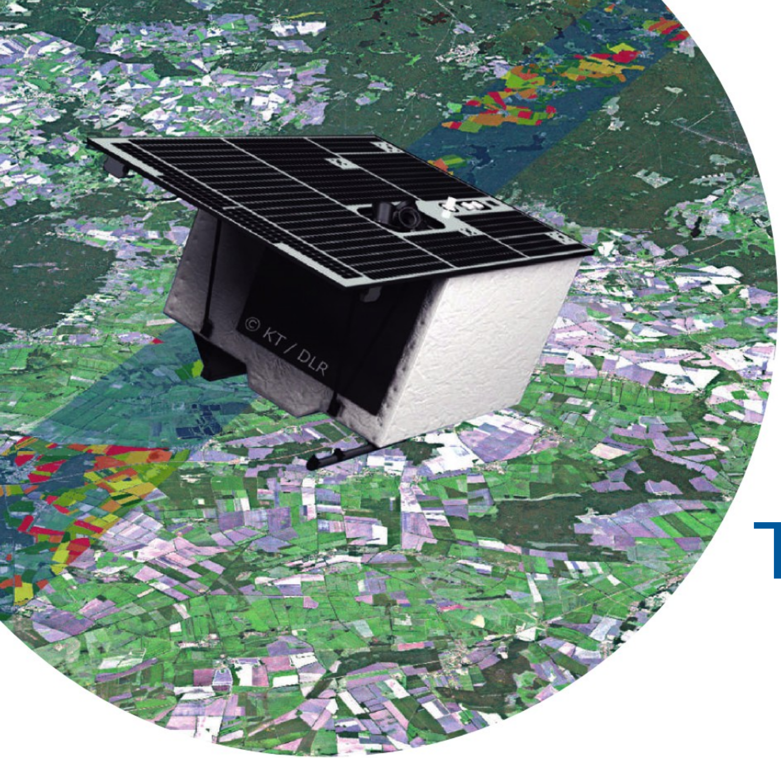

Thank You

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