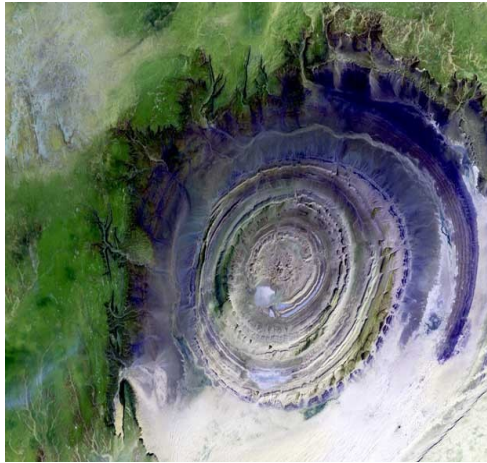
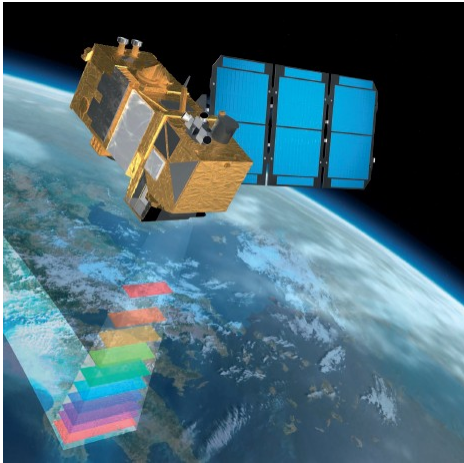


Sentinel-2 Algorithms and Cal/Val Plan



Ferran Gascon

ESRIN, Italy

28 January 2014



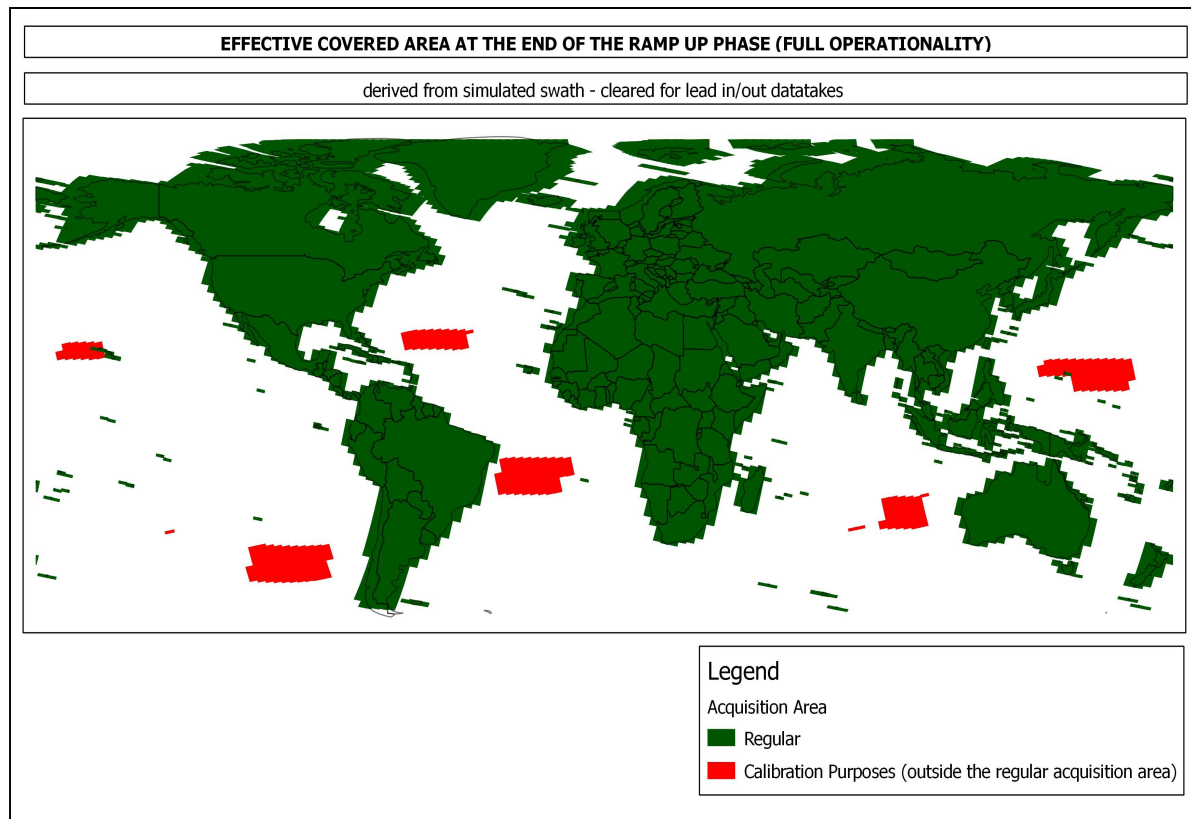
- Mission Overview
- Products
- Algorithms
- Cal/Val Plan



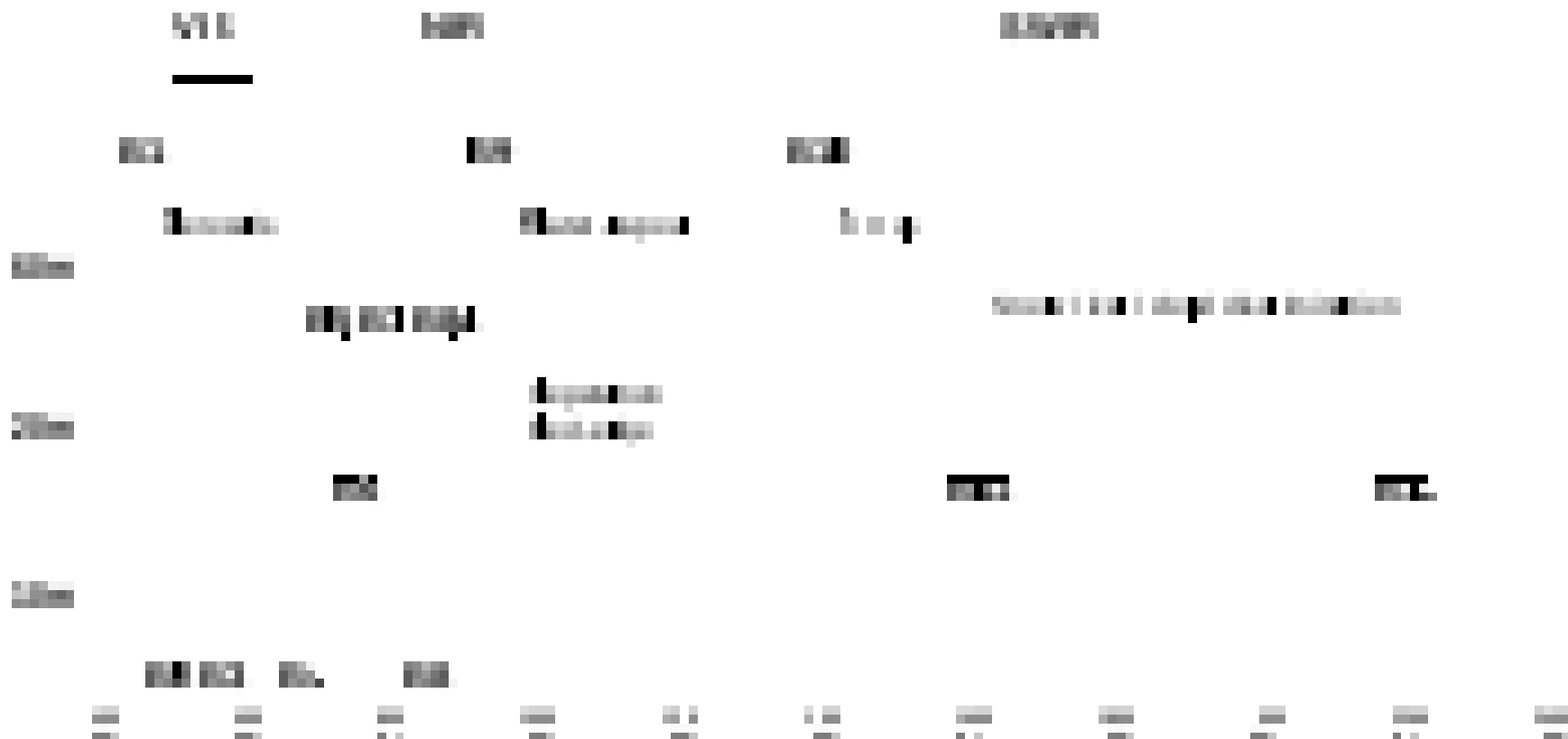
Feature	Description
Spacecrafts	2 operating in twin configuration
Instrument	MSI (Multi-Spectral Instrument) operating in pushbroom principle (filter based optical system)
Spectral bands	13 (VIS–NIR–SWIR)
Spatial Resolution	10m / 20m / 60m
Swath	290 km
Orbit	Sun-synchronous at 786 km (14+3/10 revs per day), with LTDN 10:30 AM
Revisit Periodicity	10-day with 1 satellite 5 day with 2 satellites
Lifetime	7.25 years, extendable to 12 years
Launch	Planned Spring 2015

Mission Overview / Coverage

- Systematic acquisition of:
 - ✓ All land surfaces (-56° and +84° latitude);
 - ✓ Major (greater than 100 km² size) and EU islands;
 - ✓ Coastal/inland waters, Mediterranean Sea and all closed seas;
 - ✓ Cal/Val sites.

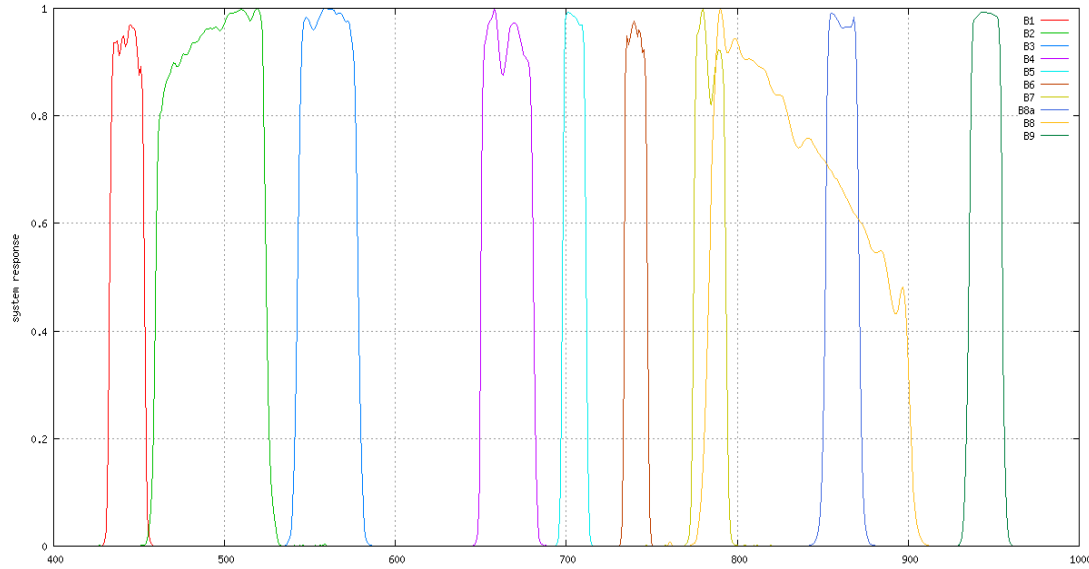


Mission Overview / Bands and Resolutions



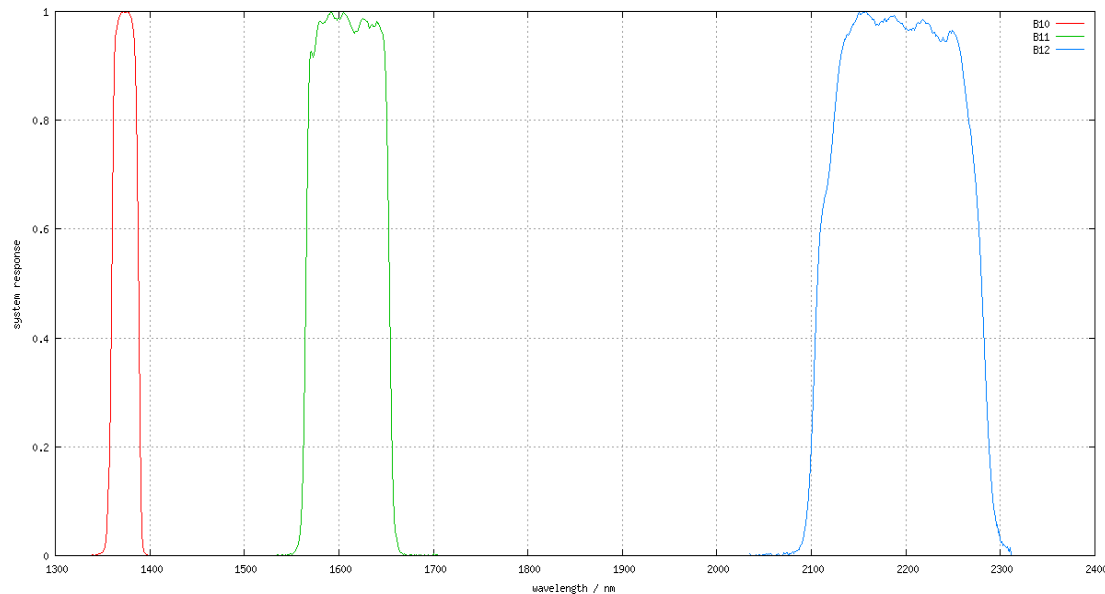
Mission Overview / Spectral Responses

Band #	Center λ nm	Spectral Width $\Delta\lambda$ nm
B1	443	20
B2	490	65
B3	560	35
B4	665	30
B5	705	15
B6	740	15
B7	783	20
B8	842	115
B8a	865	20
B9	945	20



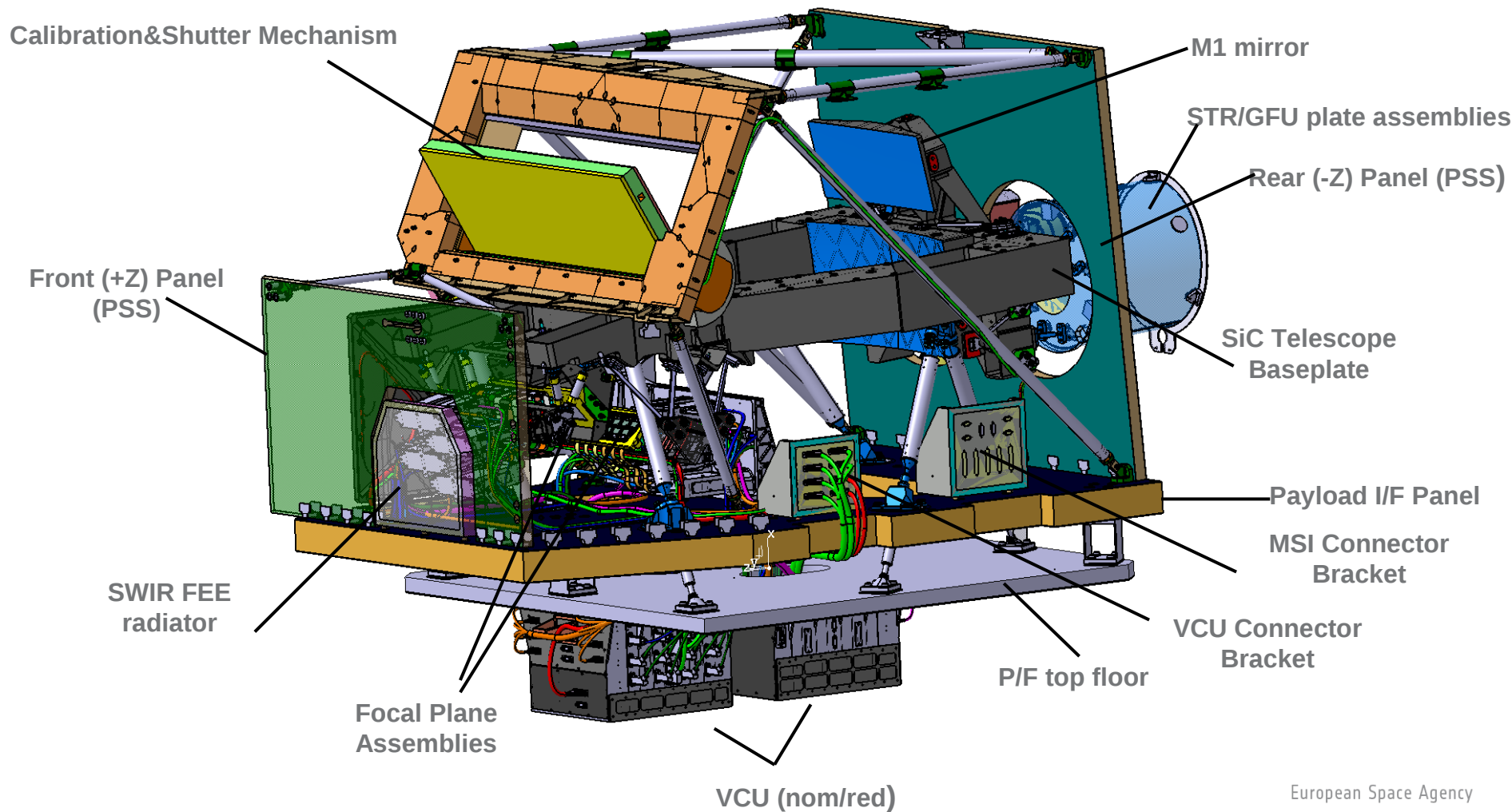
VNIR channels spectral response

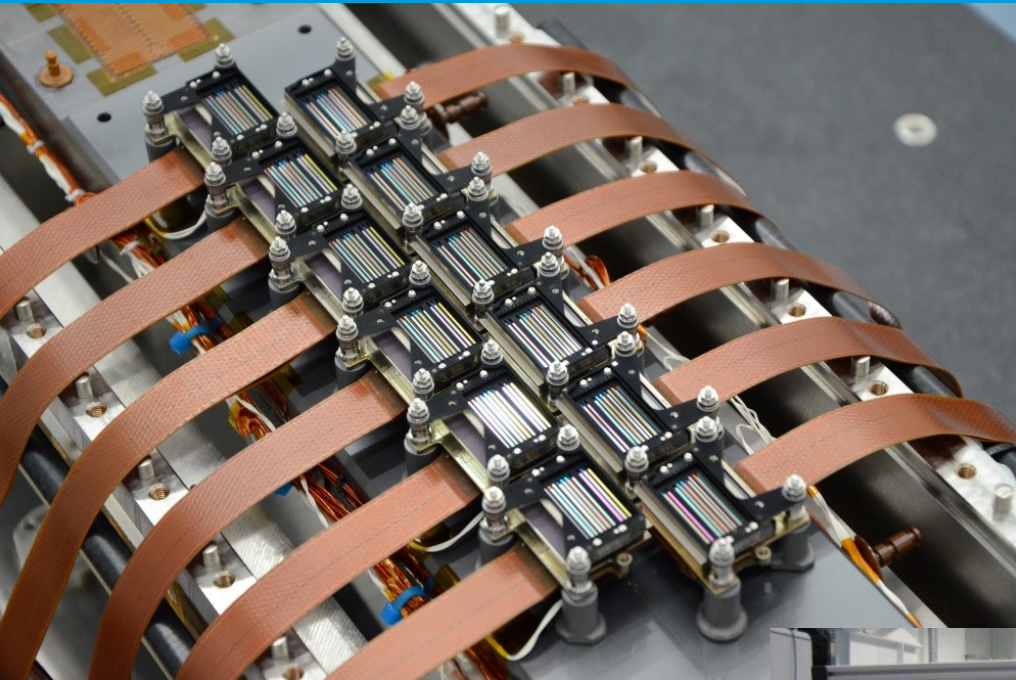
Band #	Center λ nm	Spectral Width $\Delta\lambda$ nm
B10	1375	30
B11	1610	90
B12	2190	180



SWIR channels spectral response

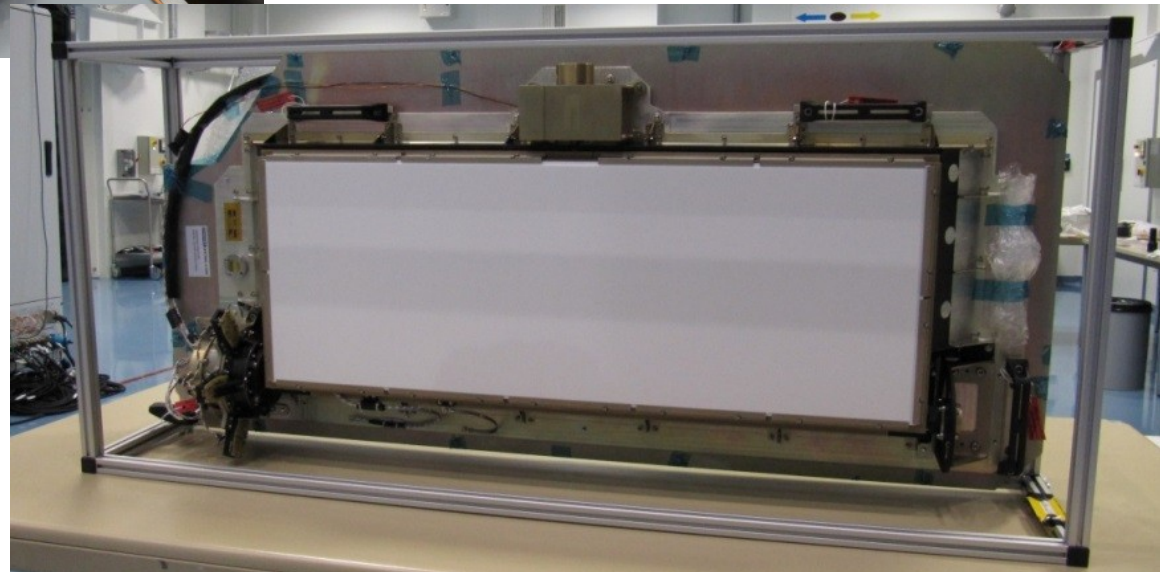
Mission Overview / MSI Internal View





VNIR flight focal plane including 12 staggered VNIR detectors / filters assemblies

A calibration and shutter mechanism (CSM) is implemented to calibrate over the full field/full pupil on-board using a PTFE diffuser



Name	High-level Description	Production	Preservation Strategy	Volume
Level-1B	Top-of-atmosphere radiances in sensor geometry	Systematic	Long-term	~27 MB (each 25x23km ²)
Level-1C	Top-of-atmosphere reflectances in cartographic geometry (UTM/WGS84)	Systematic	Long-term	~500 MB (each 100x100km ²)
Level-2A	Bottom-of-atmosphere reflectances in cartographic geometry	On user side (using Sentinel-2 Toolbox)	-	~600 MB (each 100x100km ²)

Radiometric Data Quality

Absolute radiometric uncertainty	3 % (goal) , 5 % (threshold)
Inter-band relative radiometric uncertainty	3%
Linearity knowledge accuracy	1%
Modulation Transfer Function (MTF)	0.15 to 0.3 (for 10m bands) <0.45 (for 20 & 60m bands)

Geometric Data Quality

Absolute geolocation uncertainty	20m 2σ (threshold) 12.5m 2σ (goal) with GCPs
Multi-temporal registration	0.3 pixel 2σ (goal) with GCPs
Multi-spectral registration (for any couple of spectral bands)	0.3 pixel 3σ

For further details see Mission Requirements Document (MRD) at:

http://esamultimedia.esa.int/docs/GMES/Sentinel-2_MRD.pdf

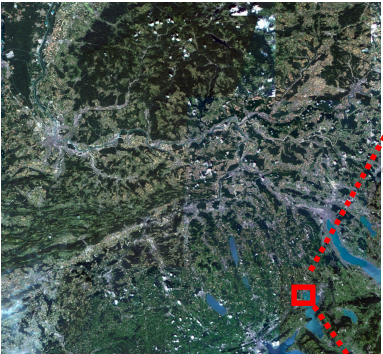
Algorithms / Level-1 Algorithm



Algorithms / L1C Product Example



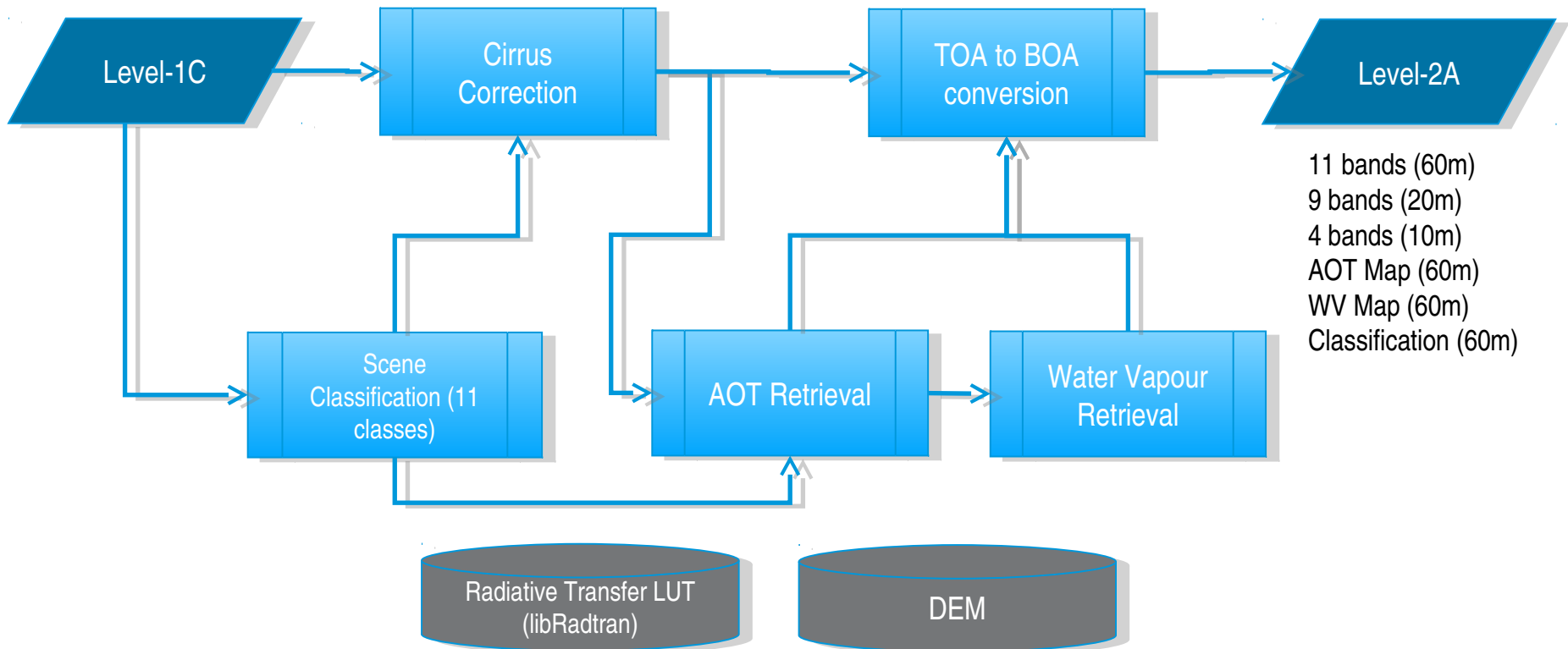
100 km



RGB composite of a Level-1C Tile



Algorithms / Level-2A Algorithm



Algorithms developed with

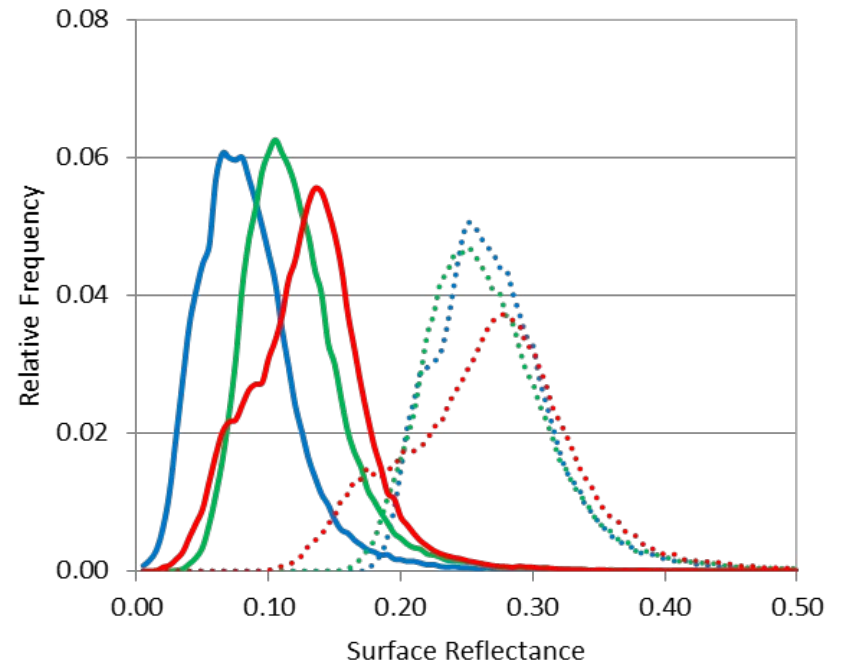




Level 1C



Level 2A



- TOA Ch1 (Blue)
- TOA Ch2 (Green)
- TOA Ch3 (Red)
- BOA Ch1 (Blue)
- BOA Ch2 (Green)
- BOA Ch3 (Red)

Algorithms / L2A Product Example



TOA reflectance
(RGB composite = bands at 665, 560 and
443 nm)



Cirrus band image (1375 nm)



BOA reflectance
(After cirrus detection and atmospheric correction)

- To meet the baseline products quality requirements, Cal/Val plans and procedures will be systematically applied during both in-orbit commissioning and operational phases.
- Operational phase is planned to start at Launch+3 months after completion of the in-orbit commissioning phase.
- Cal/Val activities during the operational phase will be performed by the Sentinel-2 Mission Performance Centre (MPC).



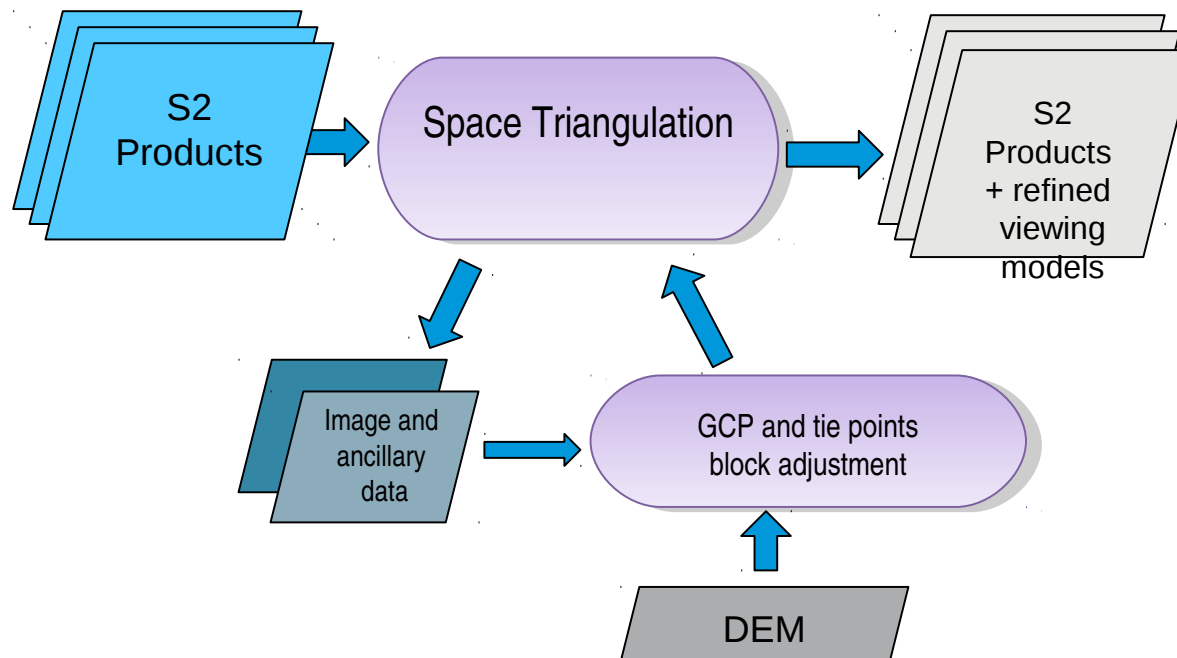
		Activity
Level-1	Radiometric Calibration	Dark Signal Calibration
		Relative Gains Calibration
		Absolute Radiometric Calibration
		SWIR Detectors Re-arrangement Parameters Generation
		Crosstalk Correction Calibration
	MSI Refocusing	
	Geometric Calibration	Global Reference Images Generation
		Absolute Calibration of the Viewing Frames for the Reference Band
		Relative Calibration of the Viewing Frames for Non-Reference Bands
		Absolute Calibration of the Focal Plane for the Reference Band
Relative Calibration of the Focal Plane for Non-Reference Bands		

		Activity
Level-1	Radiometric Validation	Equalization Validation
		Absolute Radiometry Vicarious Validation
		Absolute Radiometry Cross-Mission Validation
		Multi-temporal Relative Radiometry Vicarious Validation
		Inter-band Relative Radiometric Uncertainty Validation
		Signal-to-Noise Ratio (SNR) Validation
		Pixel Response Validation
		Modulation Transfer Function (MTF) Validation
	Geometric Validation	Geolocation Uncertainty Validation
		Multi-spectral Registration Uncertainty Validation
		Multi-temporal Registration Uncertainty Validation
		Global Reference Images Validation

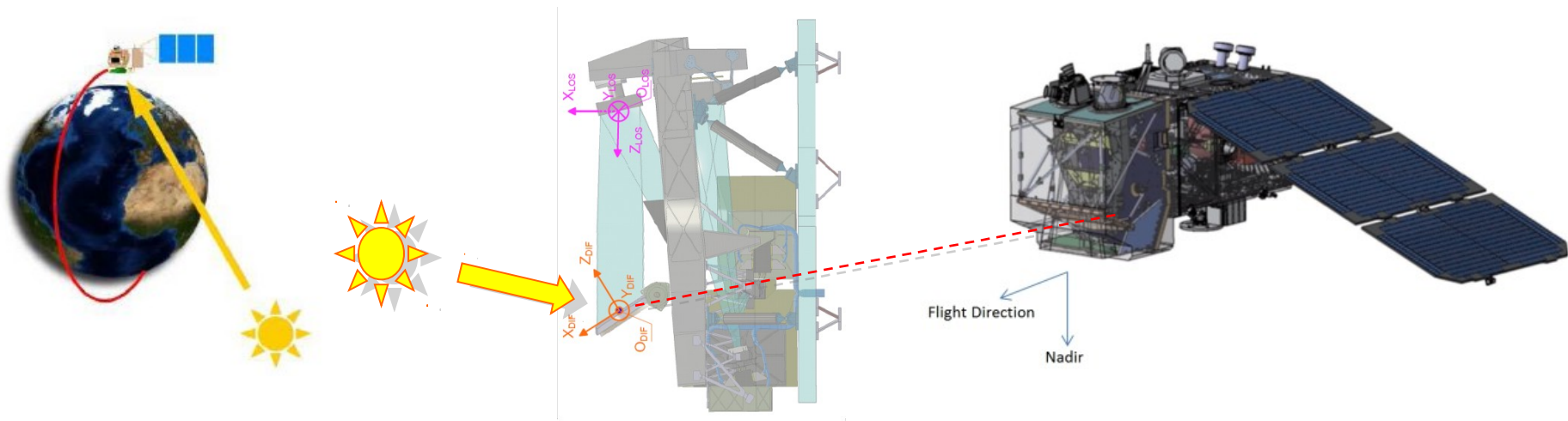
		Activity	Description
Level-2A	Radiometric Calibration	Cloud Screening Parameterisation	Algorithms calibration (e.g. threshold and parameters definition) based on an empirical approach using a reference dataset.
		Atmospheric Correction Param.	Calibration using a large set of test site representative of main surface-atmosphere types.
	Scene Classification Calibration	Classification Algorithm Param.	This activity includes the parameterization of the scene classification algorithm using in-situ data from a large set of reference test sites.

		Activity	Description
Level-2A	Radiometric Validation	Cloud Screening Validation	Visual inspection of images and on-ground observations of the atmosphere status.
		Atmospheric Correction Validation	On-Ground ad-hoc validation campaigns, using CEOS/LANDNET sites or other (e.g. AERONET) reference sites.
	Scene Classification Validation	Classification Algorithm Validation	This activity includes the validation of the classification results using in-situ data.

- **Objective:** To obtain a full repeat cycle dataset of well-localized mono-spectral Level-1B images (band 4, red) which will be used as reference images in the processing chain.
- **Methodology:** Massive spatio-triangulation on multi-continental blocks (starting with Europe-Asia-Africa block).
- **GRI available by Launch + 9 months.**



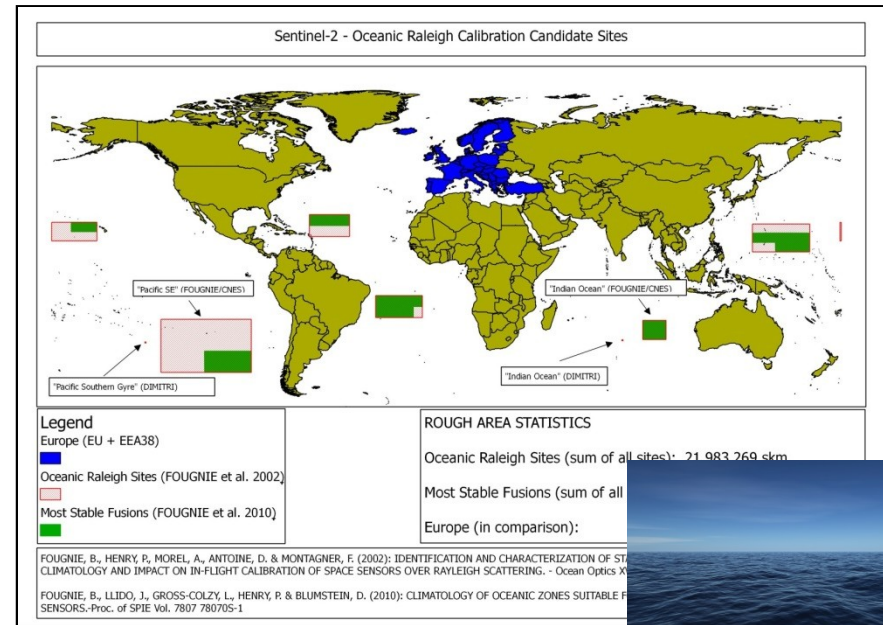
- **Objective:** Determining all parameters of the radiometric model linking the digital signal at the output of the MSI with the input radiance.
- **Methodology:** Relative and absolute radiometric calibration based on the use of the on-board sun diffuser.
- Diffuser stability monitored using vicarious calibration and cross-comparison with other missions.
- Dark Signal Calibration performed through acquisition during night over ocean.



Cal/Val Plan / Equalization and Absolute Radiometry Validation



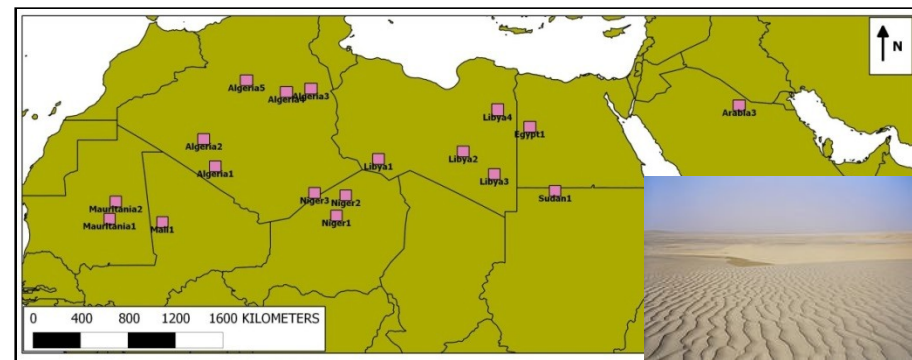
- **Objective:** Validating the equalization and absolute radiometric parameters.
- **Methodology:** Acquisition and processing of images over oceanic, desert and snow sites.



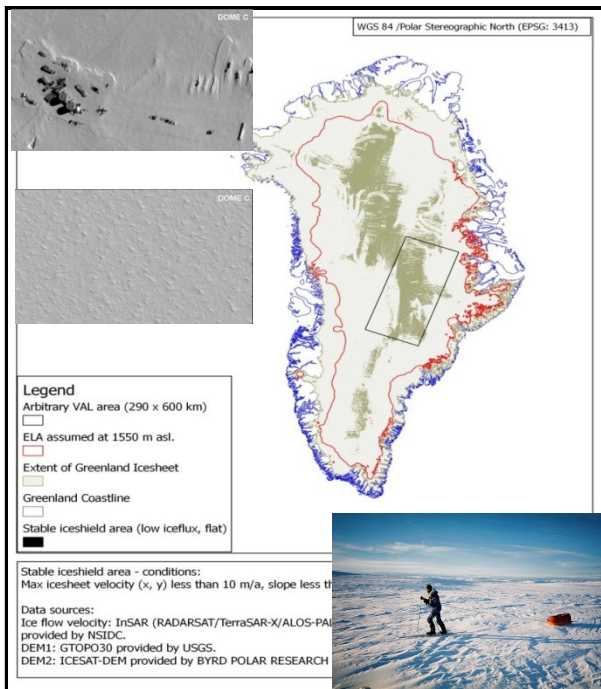
Land Equipped Sites



Oceanic sites



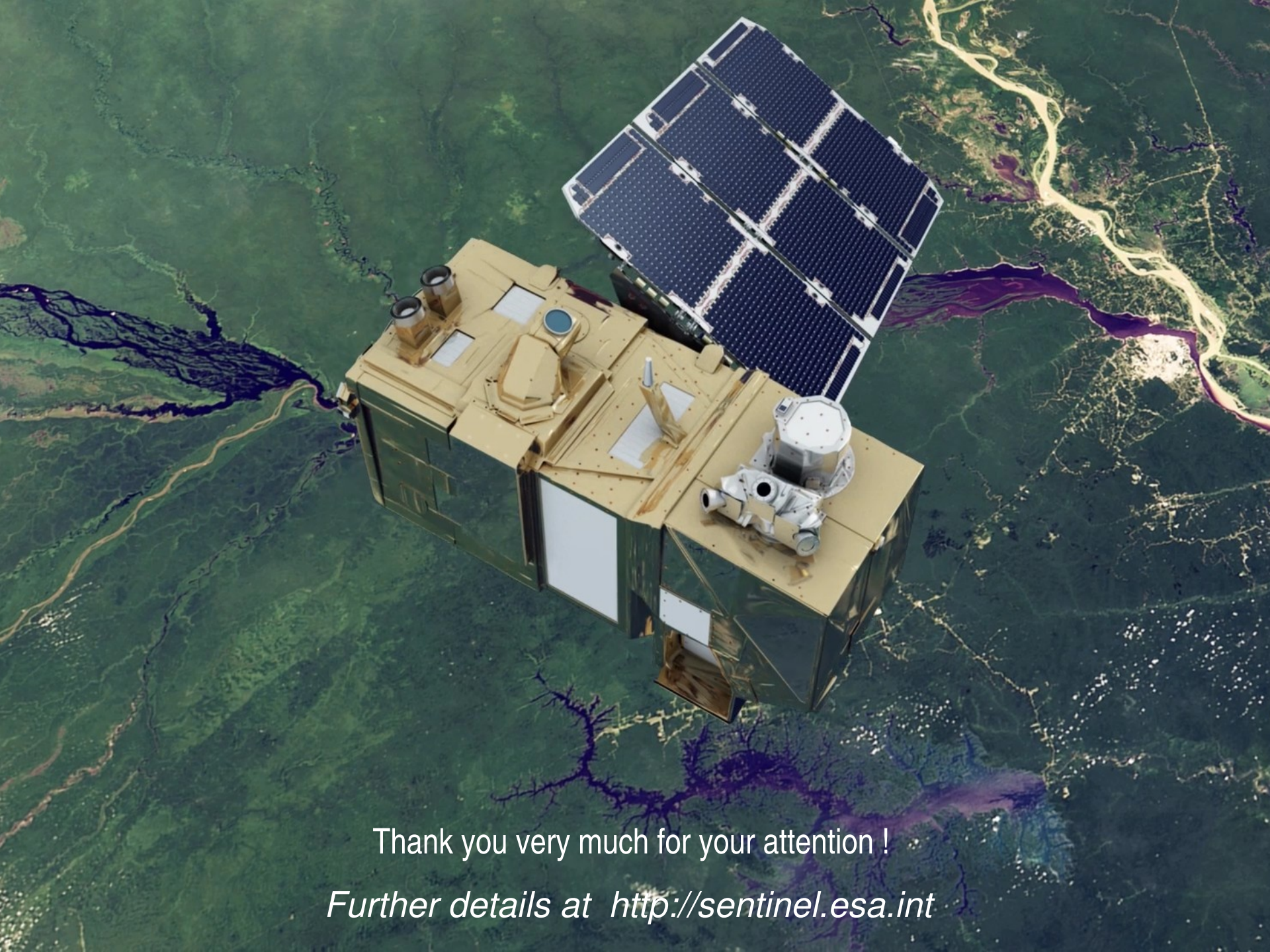
Desert sites



Equalization validation sites

(Courtesy ESA, CNES and CEOS)

- The **cooperation** with other missions/teams could be considered around the following **four axes**:
 1. Share test sites and exchange of methods/results.
 2. TOA radiances cross-mission comparison.
 3. Organization of shared field campaigns.
 4. Organization of joint workshops for exchanging information on results and methods.



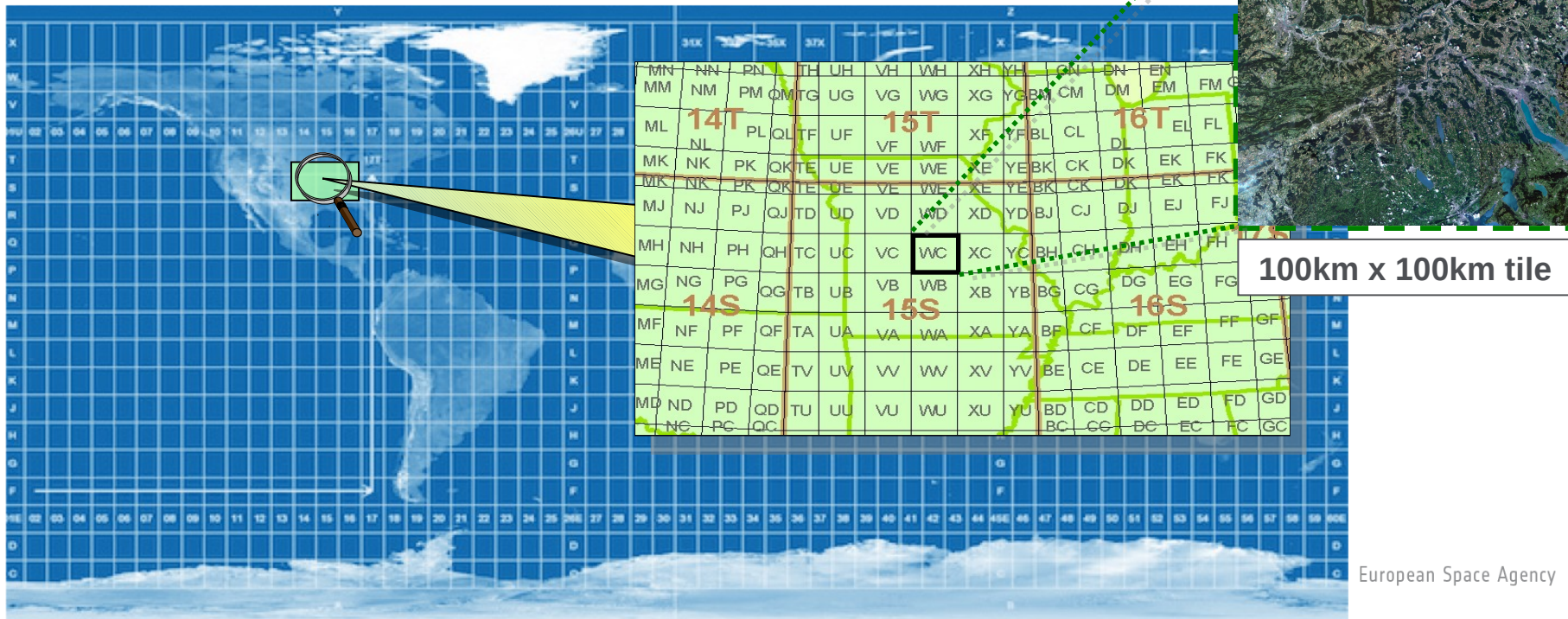
Thank you very much for your attention !

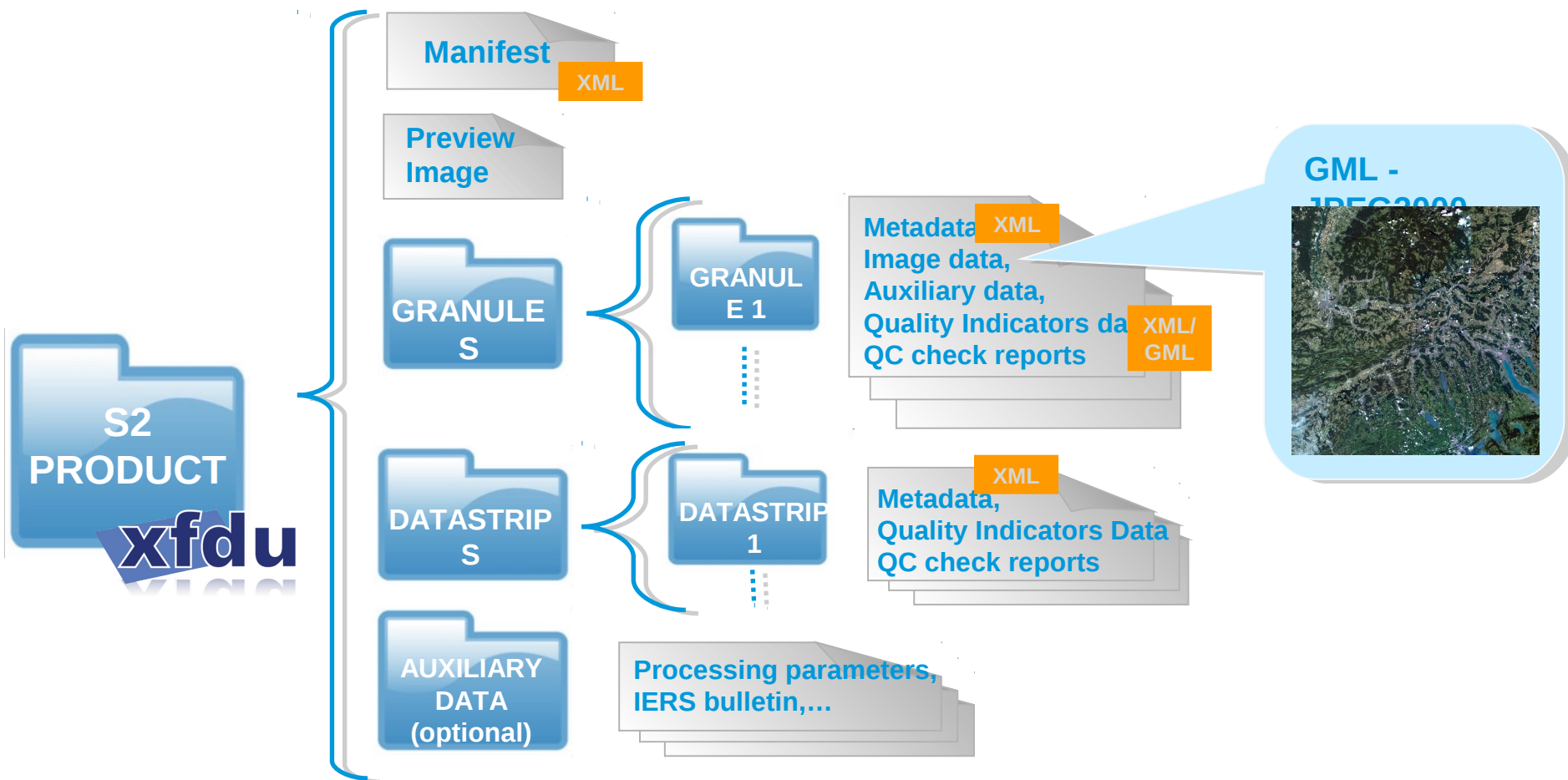
Further details at <http://sentinel.esa.int>

Back-up slides



- Global Reference System in UTM space ($6^{\circ} \times 8^{\circ}$ grid zones)
- Each grid zone is split into 100x100km (TBC) UTM “tiles”
 - An average orbit covers ~200 tiles, i.e. 106 /year/satellite.
- One tile weighs ~ 500MB with all bands





Cal/Val Plan / Mission Performance Centre

