

The Sentinel-3 Mission



**Susanne Mecklenburg (ESA Sentinel-3 Acting Mission Manager)
and ESA/EUMETSAT Teams**



The aim of Sentinel-3 is to provide CONTINUITY for Envisat data ...



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- Gap analysis/consultation process with GMES services, GSE, DUE and FP GMES projects, downstream services
- Consultation with particular user communities:
 - Numerical weather prediction
 - Maritime safety and security
 - Coastal zone monitoring
 - Open ocean and ice monitoring
 - Atmospheric services
 - Global land monitoring applications
 - Environmental policy and law
 - Climate change monitoring
 - European security, humanitarian and emergency services
- Measurement heritage: continuity of presently operating space infrastructures; synergy with external missions

☐ Led to the MRTD

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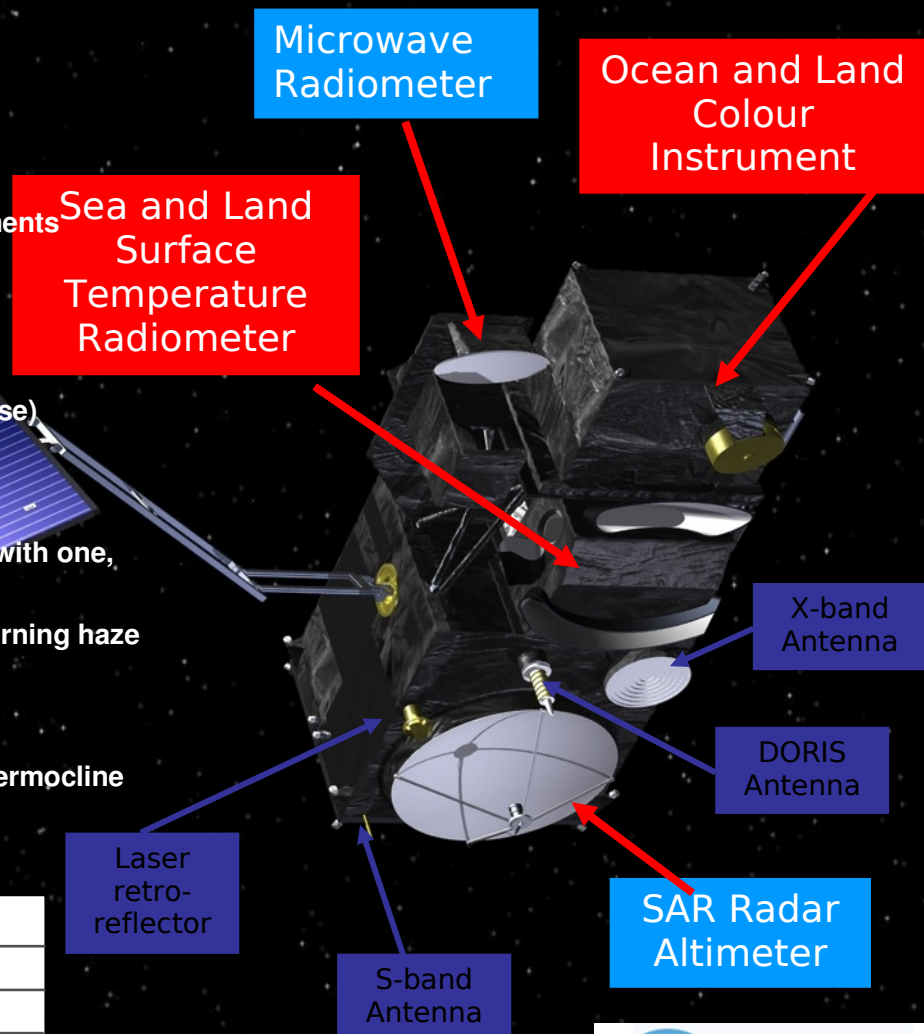


The satellite - orbit selection

ORBIT SELECTION

- **Sun-synchronous frozen orbit close to 800 km**
 - Required for continuity of heritage optical measurements
- **Topography mission requirements:**
 - Repeat cycle > 20 days,
 - Optimum Topography mission spatial sampling (dense)
- **Ocean Colour mission requirements**
 - Short 2-day global coverage with 2 satellites, 4 days with one, Implies a sub-cycle of 4 days
 - Local time of observation shall be > 10 h to avoid morning haze
- **Sea Surface Temperature mission requirements**
 - Local time at node shall be < 11 h to avoid diurnal thermocline
 - < 4 day coverage even with one satellite

Orbit type	Repeating frozen SSO
Repeat cycle	27 days (14 + 7/27 orbits/day)
LTDN	10:00
Average altitude	815 km
Inclination	98.65 deg



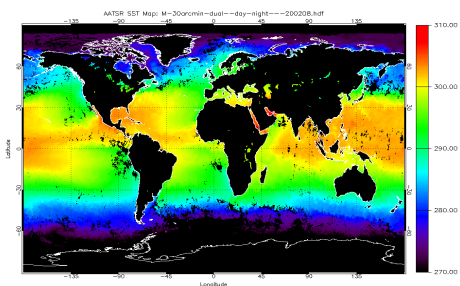
SLSTR Overview



Conical scanning imaging radiometer with dual view capability

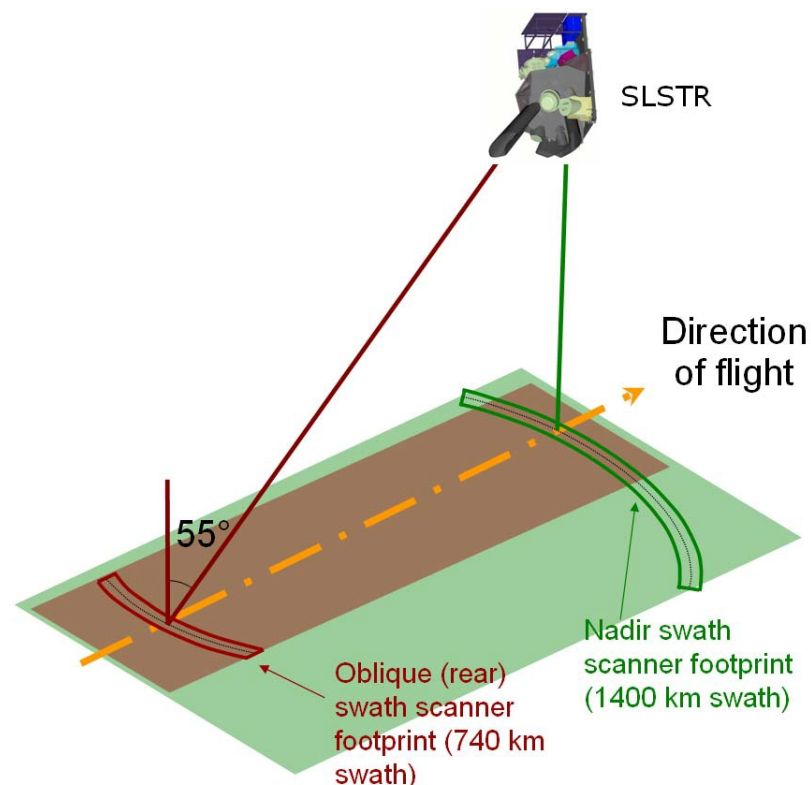
Heritage from (A)ATSR on ERS-1/2, ENVISAT

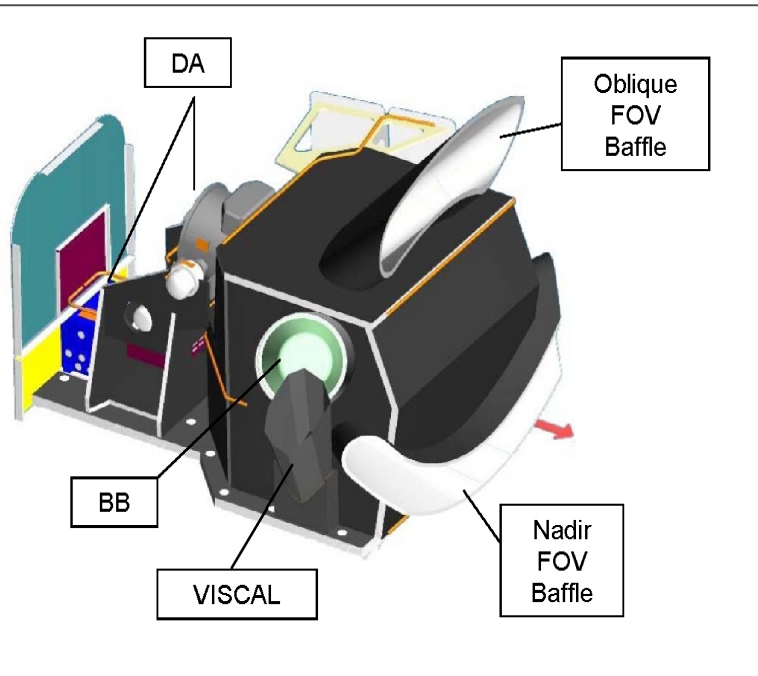
- Geom. Performance:
 - Nadir swath: 74° (1420 km typ)
 - Dual view swath: 49° (750 km typ)
 - Nadir swath covering OLCI swath
- Spectr. Performance: 9 spectral bands
 - Visible: 555 | 659 | 865 nm
 - SWIR: 1.38 | 1.61 | 2.25 μm
 - TIR : 3.74 | 10.85 | 12 μm
- One Vis channel used for co-registration with OLCI



Objective

Allow Sea & Land temperature retrieval with typical absolute (relative) accuracy of 0.2 (0.08) K





New features compared to AATSR

- Additional channels at 1.378 (cirrus detection over land) and 2.25 μm (vegetation and cloud clearing) to enhance cloud detection.
- New channels dedicated to active fire measurements (3.74, 10.95).
- Wider nadir swath due to improved scanning mechanism (3 instead of 1 mechanism, 2 scanners and one flip mechanism)
- As a consequence: more complex front-end and electronics and new detector technology (multiple pixels)
- Nadir swath is offset to cover OLCI swath; One VIS channel (865nm) is used for co-registration with OLCI swath
- Oblique view 55 deg inclination maintains a longer atmospheric path length compared to nadir for better atmospheric correction

SLSTR radiometric performance

- 7 AATSR & 2 additional bands: 1.375, 2.2 μm
- Noise equivalent differential temp < 0.08K (TIR)
- Signal to Noise Ratio > 20 (solar @ Lmin)
- Absolute accuracy < 2-5%, 0.2K
- Radiom. Stability < 0.1%, 0.08K
- Polarisation sensitivity < 0.07

Pushbroom Imaging Spectrometer (VIS-NIR)

MERIS ENVISAT heritage

- 5 fan-shaped cameras, 21 programmable spectral bands (incl. bands for MERIS & VGT legacy products)
- Abs. radiometric accuracy < 2%
- Relative accuracy 0.1%
- Minimisation of sun-glint by design: offset by 12.5 deg

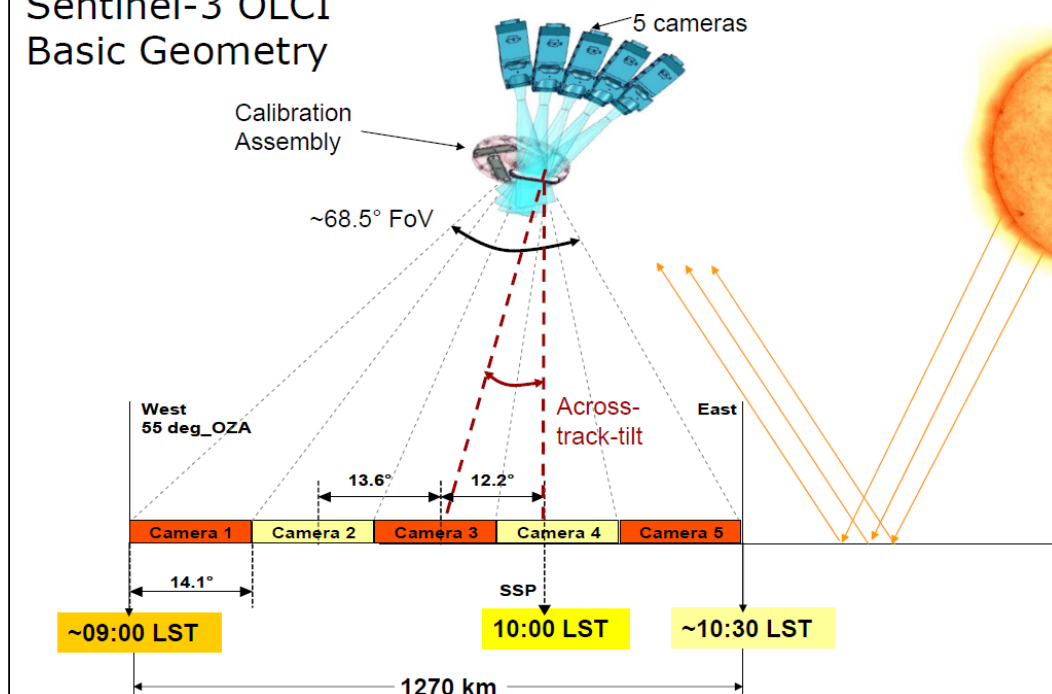
Spatial Resolution: 300m (at nadir)

- 1200m open Ocean, after L1 processing
- 300m over Land & Coastal Ocean

Objective

Allow Sea & Land Colour observation with high absolute (relative) accuracy of 2 (0.5) %

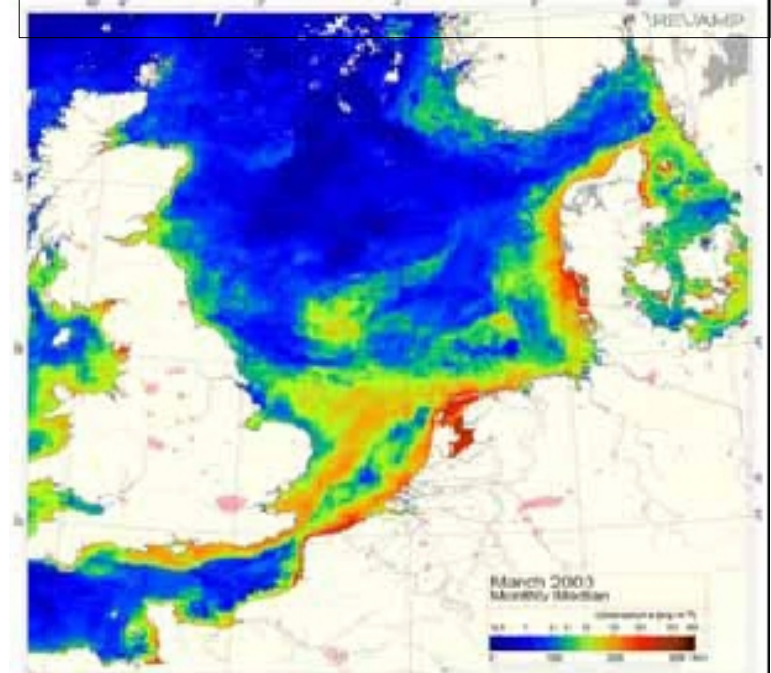
Sentinel-3 OLCI Basic Geometry



New features compared to MERIS

- An increase in the number of spectral bands (from 15 to 21)
- Improved long term radiometric stability
- Mitigation of sun glint contamination by tilting cameras in westerly direction
- Complete Full Resolution (FR, 300m) coverage over both land and ocean
- Reduced Resolution (RR, 1200m) over ocean binned on ground (L1B)
- Improved instrument characterization, e.g., stray light, camera overlap
- Improved coverage (Ocean < 4 days, Land < 3 days c.f. MERIS eff. 15 days)
- Improved data delivery timeliness: 3 hours NRT Level 2 product
- 100% overlap with SLSTR
- Improved L2 products (e.g., Chl-a, HAB, Transparency, Sediment loading, Turbidity, NDVI, MGVI, MTCI, faPAR, LAI).

Close MERIS heritage
(spectral bands and
Radiometric performances)

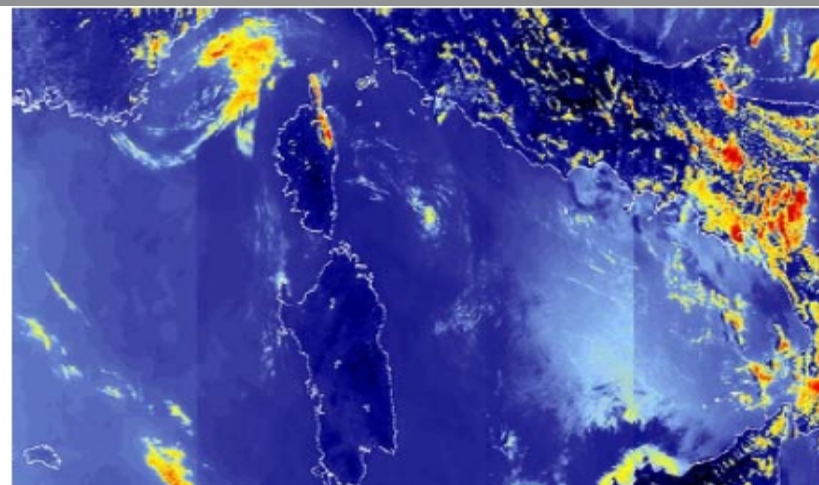


**Chlorophyll Atlas of the North Sea
(MERIS)**

OLCI Bands



Channel	Centre Wavelength (nm)	Approx. Band (nm)	Band-width (nm)	Signal to Noise Ratio*	Application
O1	400	392.5-407.5	15	2180	Aerosol correction, improved water constituent retrieval
O2	412.5	408-418	10	2050	Yellow substance and detrital pigments (Turbidity).
O3	442.5	437.5-447.5	10	1810	Chl absorption max., Biogeochemistry, Vegetation
O4	490	485-495	10	1540	High Chl, Other pigments
O5	510	505-515	10	1490	Chl, Sediment, Turbidity, Red tide.
O6	560	555-565	10	1280	Chlorophyll reference (Chl minimum)
O7	620	615-625	10	1000	Sediment Loading
O8	665	660-670	10	880	Chl (2 nd Chl abs. max.), Sediment, Yellow Substance / Vegetation
O9	673.75	670.5-678	7.5	705	For improved Fluorescence retrieval and to better account for Smile together with the bands 665 and 680nm
O10	681.25	677.5-685	7.5	750	Chl fluorescence peak, red edge
O11	708.75	703.75-713.75	10	790	Chl fluorescence baseline, red edge transition.
O12	753.75	750-757.5	7.5	600	O2 absorption / Clouds, vegetation
O13	761.25	760-762.5	2.5	230	O2 absorption band/Aerosol corr.
O14	764-375	762.5-766.25	3.75	300	Atmospheric correction
O15	767.5	766.25 - 768.75	2.5	330	O2A used for cloud top pressure, fluorescence over land.
O16	778.75	771.25-786.25	15	810	Atmos. Corr. / Aerosol corr.
O17	865	855-875	20	680	Atmos. Corr. / Aerosol corr., Clouds, Pixel co-registration.
O18	885	880-890	10	400	Water vapour absorption reference band. Common reference band with SLST instrument. Vegetation monitoring.
O19	900	895-905	10	300	Water vapour absorption / Vegetation monitoring (max. reflectance)
O20	940	930-950	20	205	Water vapour absorption, Atmos. / Aerosol corr.
O21	1020	1000-1040	40	150	Atmos. / Aerosol corr.



Radiance in the new OLCI band at 400 nm using re-programmed MERIS during the Sen3Exp campaign in 2009. Available from:

<http://earth.esa.int/campaigns/>

MERIS bands

OLCI new bands

Topography Mission



Observed surfaces

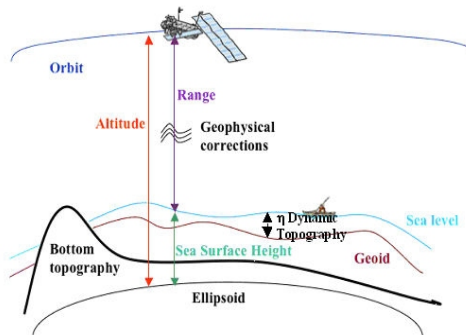
- Open ocean, coastal ocean
- Ice sheets (interiors and margins)
- Sea ice
- In-land water (rivers & lakes)

Topography package

- SRAL: Dual frequency Ku/C band SAR Radar Altimeter, with SAR mode and open loop tracking (CryoSat/Jason heritage)
- MWR: Dual channel microwave radiometer

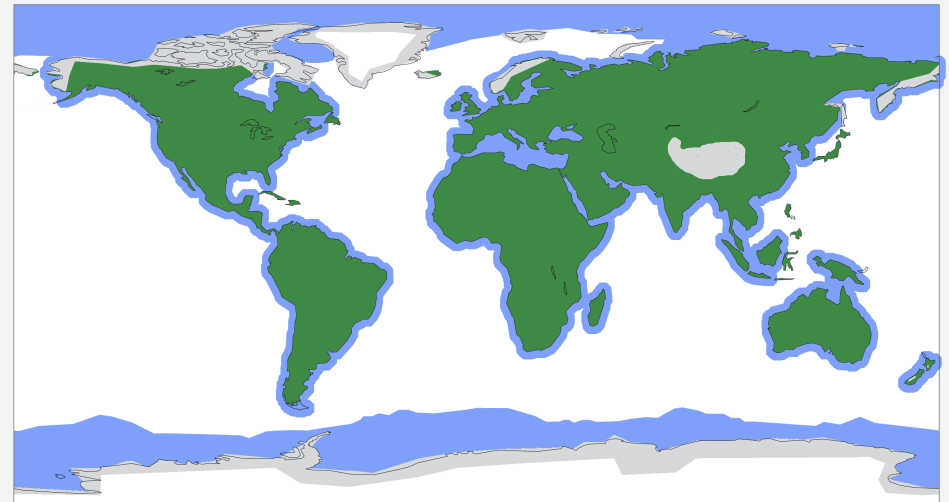
Precise Orbit determination

- GPS receiver
- Doris navigation receiver
- Li



Objective

Retrieve orbit altitude information with an end-to-end range accuracy of 3 cm (ocean) to determine SSH, wave spectra, sea ice thickness estimates, wind speed over the ocean, and other ocean/land parameters.



- SAR Open/Closed Loop: Land, Inland Waters
- SAR Open Loop: Ice Sheet Margins
- SAR Closed Loop: Sea Ice, Coastal Regions
- LRM Mode: Open Ocean, Ice Sheet Interiors

Dual frequency Ku/C band Radar Altimeter

CryoSat and Jason heritage

High horizontal resolution (SAR mode)

SRAL Radar features:

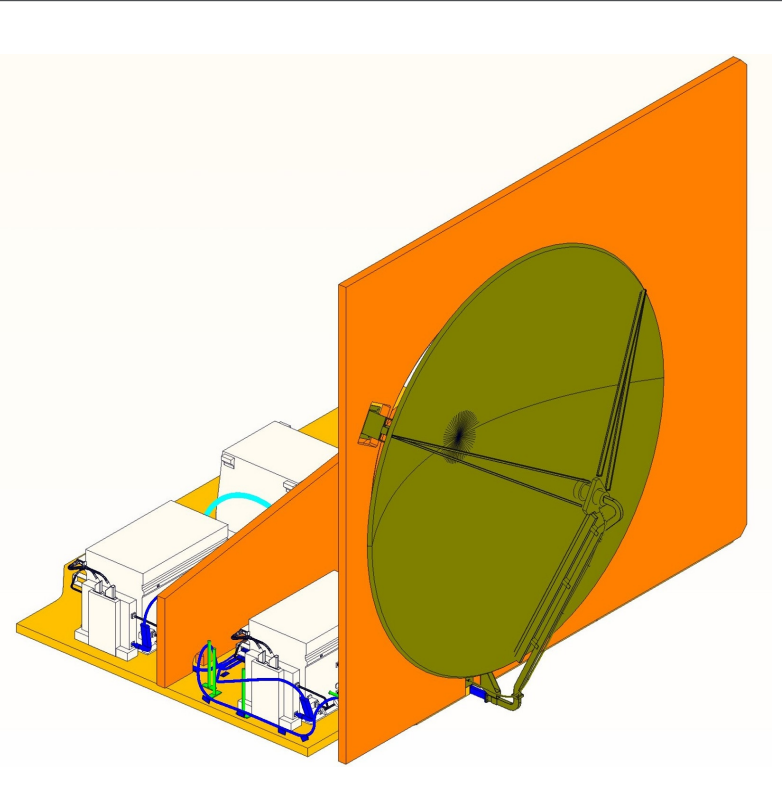
- Ku-Band (13.575 GHz) : main frequency
- C-Band (5.41 GHz) : ionosphere corrections
- Fully redundant

Measurement modes (depending on surface):

- 2 radar modes: Low Resolution Mode (LRM) and Nadir SAR mode
- 2 tracking modes: Closed-loop and open-loop tracking modes
- Any radar mode can be combined to any tracking mode

Objective

Retrieve orbit altitude information with an End-to-end range accuracy of 3 cm (ocean).



MWR Overview



Dual Frequency Noise Injection Radiometer, with cold sky calibration

CryoSat and Jason heritage

Technical:

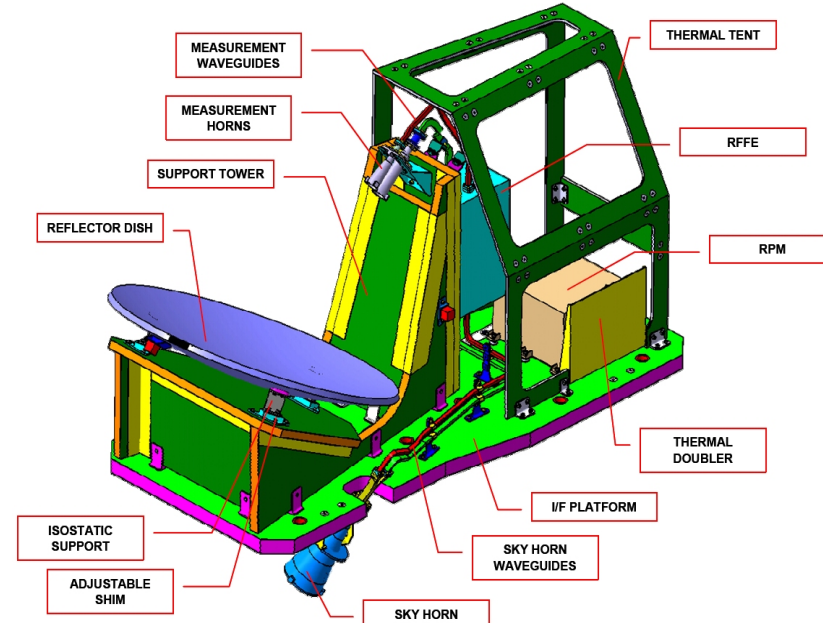
- 2 channels: 23.8 and 36.5 GHz
- Bandwidth: 200 MHz
- Integration time: 150 ms
- Footprint: 20km
- Co-located with SRAL
- Blanking of SRAL pulses

Radiometric performance (typ.):

- Sensitivity: <0.4 K
- Stability: <0.6 K
- Abs. accuracy: <3 K
- Br. Temp. range: 150 K–313 K

Objective

Allow wet troposphere correction with typical accuracy of 1.4 cm



3 channel GPS receiver (~3m NRT, 2-3cm on ground)

- Satellite Navigation - AOCS (on-board - permanent function)
- Datation of scientific telemetry (on-board - permanent function)
- Control of SRAL open-loop tracking (on-board - commanded function)
- POD (on ground)
- USO frequency monitoring (on-ground)



DORIS Navigation receiver (~1 cm)

- Provide USO frequency to SRAL (on-board - permanent function)
- Control of SRAL open-loop tracking (on-board - commanded function)
- POD (on ground)
- USO frequency monitoring (on-ground)



Laser Retro-Reflector (<2 cm)

- Contribution to POD, validation of POD solution



POD radial accuracy requirements (rms)

- Near Real Time (NRT < 3h): 10 cm (8 cm goal)
- Short Time Critical (STC < 48h): 4 cm (3 cm goal)
- Non Time Critical (NTC < 1 month): 3 cm (2 cm goal)

Revisit time and coverage



Topography Mission:

ground track repeatability, dense spatial sampling



Ground tracks after 1 complete cycle (27 days)

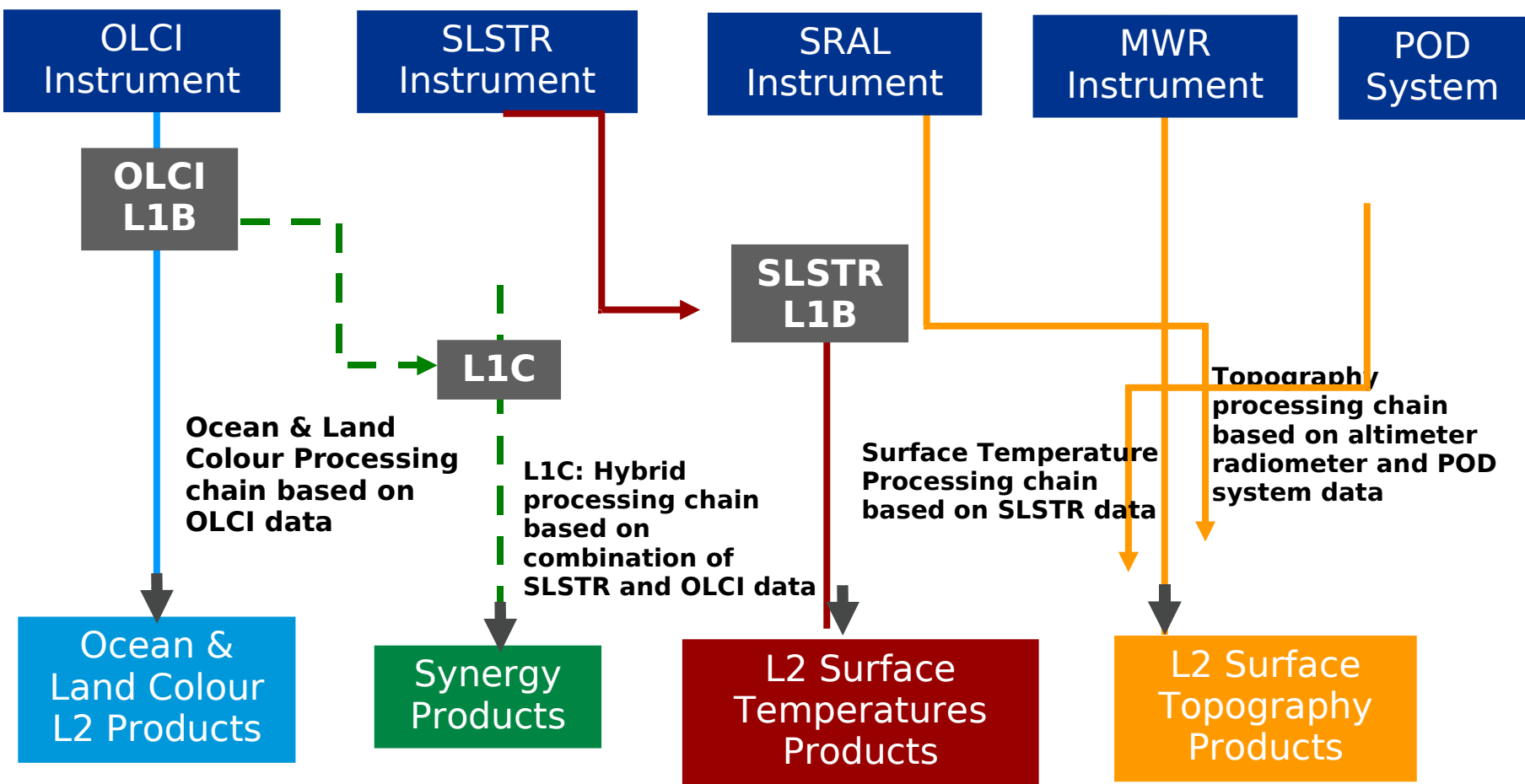
Optical missions: Short Revisit times for optical payload, even with 1 single satellite

		Revisit at Equator	Revisit for latitude > 30°	Spec.
Ocean Colour (Sun-glint free, day only)	1 Satellite	< 3.8 days	< 2.8 days	< 2 days
	2 Satellites	< 1.9 days	< 1.4 days	
Land Colour (day only)	1 Satellite	< 2.2 days	< 1.8 days	< 2 days
	2 Satellites	< 1.1 day	< 0.9 day	
SLSTR dual view (day and night)	1 Satellite	< 1.8 days	< 1.5 days	< 4 days
	2 Satellites	< 0.9 day	< 0.8 day	

- Near-Real Time (< 3 hr) availability of the L2 products
- Slow Time Critical (STC) (1 to 2 days) delivery of higher quality products for assimilation in models (e.g. SSH, SST)



Sentinel-3: Data processing chains



Product delivery timeliness:

- **Near-Real Time (< 3 hr) availability of L2 products (and L1b)**
- **1 to 2 days delivery of higher quality topography products for assimilation in models**

Sentinel-3 Core Products List



Level 1
ESA/EUMETSAT

- LEVEL 1
- OLCI L1B
 - SLSTR L1B

Marine products
EUMETSAT

- LEVEL 2
- OLCI ocean color
 - SLSTR sea
 - SRAL L2

Land products
ESA

- LEVEL 2
- OLCI Land
 - SLSTR Land
 - SYNERGY / VGT
 - SRAL L2

Sentinel-3 data delivery times



Annex of Draft GSC Operations Concept, PB-EO, May 2010

ESA/PB-EO(2010)56
Annex
Page 1

ANNEX: SENTINEL PRODUCTS

Product Level	Product Type	Processing concept	Data Access	Timeliness
				(availability after downlink)
L0	SAR L0	Systematic Local	On-line	< 10 min (for NRT areas defined through HLOP)
		Systematic Global		< 1 h (for NRT areas defined through HLOP)
				> 24 h (all acquired data)
L1	SAR L1 SLC	Systematic Regional (For regional areas of interest defined through HLOP)	On-line	< 1 h (for NRT areas defined through HLOP)
	SAR L1 GRD			> 24 h (all acquired data)
		MSI L1B, L1C		< 1 h (for NRT areas defined through HLOP)
				Systematic Global
	OLCI L1, SLSTR L1, SRAL L1			< 1.5 h (all acquired data)
		< 1 h for all acquired data < 1 month for consolidated production (e.g. updated orbit)		
L2	SAR L2 OCN			< 1 h For WV mode data acquired over ocean and HBR areas defined through HLOP
	SRAL L2 products	Systematic Global	On-line	< 1 h
				< 2 days
				< 1 month
OLCI L2 products SLSTR L2	< 1 h for all acquired data < 1 month for consolidated production (e.g. updated orbit)			
Vegetation L2		< 1 month for consolidated production		

Table 1 Sentinel-1, Sentinel-2 and Sentinel-3 Products list from the GSC Core Ground Segment

Sentinel-3 core ground segment: Data volume (uncompressed)



	Level 0 GB/ Orbit	Level 1 GB/ Orbit	Level 2 Marine GB/ Orbit	Level 2 Land GB/ Orbit
OLCI	9.5	29.6	35.5	7.8
SLSTR	4.8	45.6	5.8	2.8
SYN (OLCI+SLSTR)		55.8		31.2
SRAL + MWR	5.8	0.12	0.09	0.07
Total (GB/orbit)	20.1	131.12	41.39	41.87

	Level 0			Level 1			Level 2 Marine			Level 2 Land		
	GB/Orbit	GB/Day	TB/Year	GB/Orbit	GB/Day	TB/Year	GB/Orbit	GB/Day	TB/Year	GB/Orbit	GB/Day	TB/Year
OLCI	9.47	134.98	48.11	29.60	422.07	150.45	35.50	506.20	180.43	7.82	111.51	39.75
SLSTR	4.80	68.40	24.38	45.60	650.22	231.77	5.80	82.65	29.46	2.81	40.11	14.30
SYN (OLCI+SLSTR)	0	0	0	55.80	795.67	283.61	0	0	0	31.21	452.70	161.64
SRAL	5.82	82.98	29.58	0.12	1.65	0.59	0.09	1.31	0.47	0.07	1.00	0.36
MWR	0.003	0.039	0.014	0.003	0.039	0.014	0	0	0	0	0	0
GNSS/DORIS	0.03	0.39	0.14	0	0	0	0	0	0	0	0	0
NavAtt	0.001	0.010	0.004	0	0	0	0	0	0	0	0	0
HKTM	0.044	0.631	0.225	0	0	0	0	0	0	0	0	0
TOTAL	20.16	287.43	102.45	131.12	1,869.65	666.43	41.39	590.16	210.36	41.91	605.32	216.04
	GB/Orbit	GB/Day	TB/Year	GB/Orbit	GB/Day	TB/Year	GB/Orbit	GB/Day	TB/Year	GB/Orbit	GB/Day	TB/Year

Sentinel-3 operations are part of ...



... the GMES Space Component (GSC) Operations Concept will rely on a GSC Ground Segment consisting of a:

1. **GSC Core Ground Segment** (GSC-funded), providing:
 - the primary data access to Sentinel Missions, and
 - the coordinating access functions to Contributing Missions data,

NB: ESA and Eumetsat share certain aspects of operations for Sentinel-3.

2. **GSC Collaborative Ground Segment** (non GSC-funded) providing:
 - a supplementary access to Sentinel Missions data
i.e. either through specific data acquisition services (e.g. Quasi-Real-Time), or
specific data products ..
 - the frame for international cooperation

NB: For example for Sentinel-3: French project MCGS (CLS and Acri) to develop tailored Sentinel-3 products. is funded and ready to start



Main facilities for operations are ... (1/2)



1. **Flight Operations Segment:** Satellite commanding & control, up/downlink of telecommand and telemetry, satellite maintenance support

2. **Stations: Data Acquisition and Near Real Time Product Generation**
 - Observation and instrument planning: Data will be acquired systematically based on a pre-set nominal mission scenario, as defined in the HLOP:
 - Operations for OLCI and the visible channels of the SLSTR are based on specific solar illumination conditions.
 - SRAL acquires data over the whole orbit with a pre-defined, automatically performed split between Low Resolution Mode (LRM) and SAR mode.
 - MWR acquires data over the whole orbit.
 - Data processing is split into NRT and offline processing chain for both ESA and Eumetsat.
 - ESA and Eumetsat will produce same set of level 1 NRT data products.
 - ESA will process level 2 land NRT data products, EUMETSAT will process level 2 marine NRT data products.

Main facilities for operations are ... (2/2)



1. **Processing and Archiving Centres (PAC)**: perform the Sentinels' systematic non-time-critical data processing, the on-the-fly data processing for specific cases and the reprocessing in case of processing algorithms or calibration parameters upgrades.
 - ESA will establish a PAC dedicated to land application users, consisting of a layout of 3 PACs for the 3 instruments, namely:
 - DLR for OLCI processing and archiving
 - CLS for SRAL processing and archiving
 - ACRI for SLSTR and S-3 synergy products processing and archiving
 - Matching set-up in Eumetsat: TBD

1. **Missions Performance Centres (MPC)**: collaboratively run between ESA and Eumetsat
 - Operational Quality Control
 - Expert Support Laboratories (ESL)
 - Calibration and Validation

3. **Precise Orbit Determination (POD)**: possibly one central POD facility for all Sentinels in the operations phase

3. **Payload Data Management Centre**: user interaction, helpdesk, mission planning, user registration etc

EC excluded GMES funds from MFF *"For projects such as ... GMES, where the costs and/or the cost overruns are too large to be borne only by the EU budget, the Commission proposes to foresee their funding outside the MFF after 2013."* COM(2011) 500 final, 29/06/2011

"creates high uncertainty for GMES[...] It would be more than likely that this option would mean a discontinuation of GMES [...]. It would lead to sunken costs and past investments would be lost." SEC(2011)868 final, 29/06/2011

EC proposed to fund GMES with a separate budget *"proposed to set-up a specific GMES fund with financial contributions from all EU Member States based on their GNI."* COM(2011) 831 final, 30/11/2011

Several ESA Member States and the EU Parliament have raised concerns if GMES is outside from the MFF

 **GMES 2014-2020 still needs to be secured**

Users should be aware that GMES is AT RISK

Users should be aware that Sentinels launches are AT RISK

Users are invited to support GMES to their Ministries

Sentinel-3 Cal/Val Workshop



First Sentinel-3 Calibration and Validation Planning workshop

ESA/ESRIN 20-22nd March 2012

Aim:

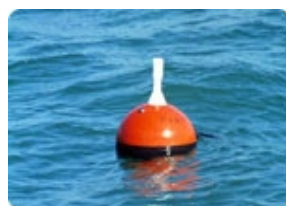
To review the plans and potential activities for Sentinel-3 Calibration and Validation activities in Phase E1 (LEOP) and E2 (Routine Operations)

Format:

Plenary presentations and discussion groups

Registration:

<http://www.s3cvt.org>



Backup slides

Sentinel-3 Core ground segment: Optical geophysical parameter list



Geophysical Product	Application Domain	Spatial Resolution	Continuity	Measurement Source
Normalised Water Surface Reflectances		300 m , 1.2 km	Envisat	OLCI
Chlorophyll Concentration for open ocean		300 m , 1.2 km	Envisat	OLCI
Chlorophyll Concentration for Coastal waters		300 m , 1.2 km	Envisat	OLCI
Total suspended Matter		300 m , 1.2 km	Envisat	OLCI
Diffuse attenuation coefficient		300 m , 1.2 km	GCM* (e.g. Modis)	OLCI
Coloured Detrital and Dissolved Material		300 m , 1.2 km	Envisat	OLCI
Photosynthetically active radiation		300 m , 1.2 km	Envisat	OLCI
Aerosol Optical Depth over water		300 m , 1.2 km	Envisat	OLCI
Aerosol Angstrom exponent over water		300 m , 1.2 km	Envisat	OLCI
Integrated Water Vapour Column		300 m , 1.2 km	Envisat	OLCI
Sea Surface Temperature		1 km	Envisat	SLSTR
Land Surface Temperature		1 km	Envisat	SLSTR
Sea Surface Chlorophyll Index		300 m , 1.2 km	Envisat	OLCI
Fraction of Absorbed PAR		300 m , 1.2 km	Envisat	OLCI
Surface Reflectances over Land		300 m	Envisat	OLCI+SLSTR
Aerosol Optical Depth over Land		300 m	Envisat	OLCI+SLSTR
Aerosol Angstrom exponent over Land		300 m	Envisat	OLCI+SLSTR
Vegetation-like Surface Reflectances 1 day Synthesis		1 km	Vegetation	OLCI+SLSTR
Vegetation-like Surface Reflectances 10 days Synthesis		1 km	Vegetation	OLCI+SLSTR
Vegetation Normalised Difference of Vegetation Index		1 km	Vegetation	OLCI+SLSTR

Sentinel -3 Core ground segment: Surface Topography Mission



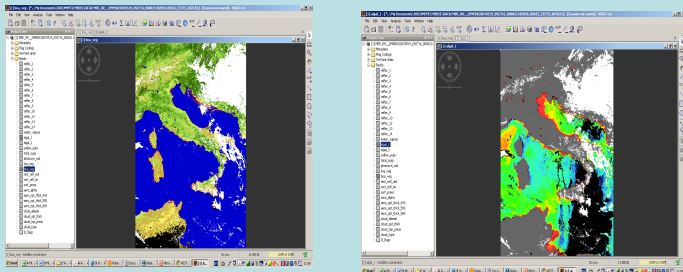
Geophysical Product	Spatial Resolution	Continuity	Measurement Source
Altimeter Range, Significant Waveheight, Backscatter, Sea Surface Height Anomaly, Altimeter Wind Speed, Freeboard (sea-ice), Brightness Temperatures, Wet Tropospheric correction, Ionospheric correction, Rain rate	SAR: 250 m LRM: > 2km	Envisat	SRAL+MWR
Altimeter Range (in-land water, ice-sheet margin), Surface Height	SAR: 250 m		SRAL

Sentinel-3 Core ground segment: Level 2 LAND / MARINE Production



L2 Optical production organisation

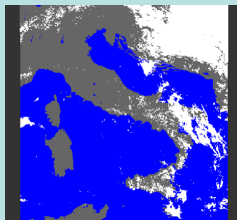
Example of geophysical product:
OLCI Terrestrial Chlorophyll Index (OTCI)
Chlorophyll Concentration for open ocean waters
(CHL_OC4ME)



Land products

Marine products

The Land and Water masks are perfectly complementary.



**The cloud mask is provided in white for a better interpretation of the information.*

L2 SRAL production organisation

Measurements included in the MARINE product

Measurements included in the LAND product

**The Land and Water masks are in overlap to ensure analysis of transition and meaningful continuity of segments*

Sentinel-3 in synthesis



• **European global land and ocean monitoring mission**

- Optical mission to cover sea and land colour and surface temperature
- Altimetry mission in support of sea-surface and land-ice topography
- Vegetation products through synergy between optical instruments

• **Optical payload 2 days global coverage with 2 Satellites in view of the increased swath**

• **Near-Real Time (< 3 hr) availability of the L2 products**

• **Increased number of bands compared to ENVISAT AATSR (7 -> 9) and MERIS (15 -> 21) allowing**

- Overlap and synergy between OLCI and SLSTR
- Enhanced fire monitoring capabilities

• **Improved altimetry mission with**

- Along-track SAR for coastal zones, in-land water and sea-ice topography
- Open-loop tracking for rough zones

• **Very accurate POD providing**

- A radial POD accuracy of 2.3 cm in ground processing.
- On-board navigation solution (3m) for real time range control of SRAL (Open Loop)

• **Highly autonomous onboard operations allowing for systematic measurement and data download with minimum ground intervention**

More information at <http://www.esa.int/gmes>