

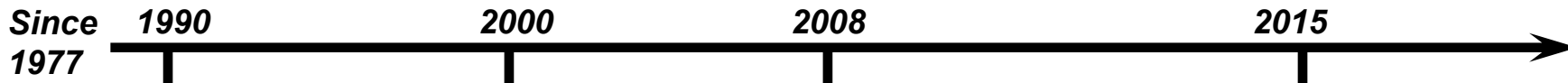
DRAGONESS

WP 2:

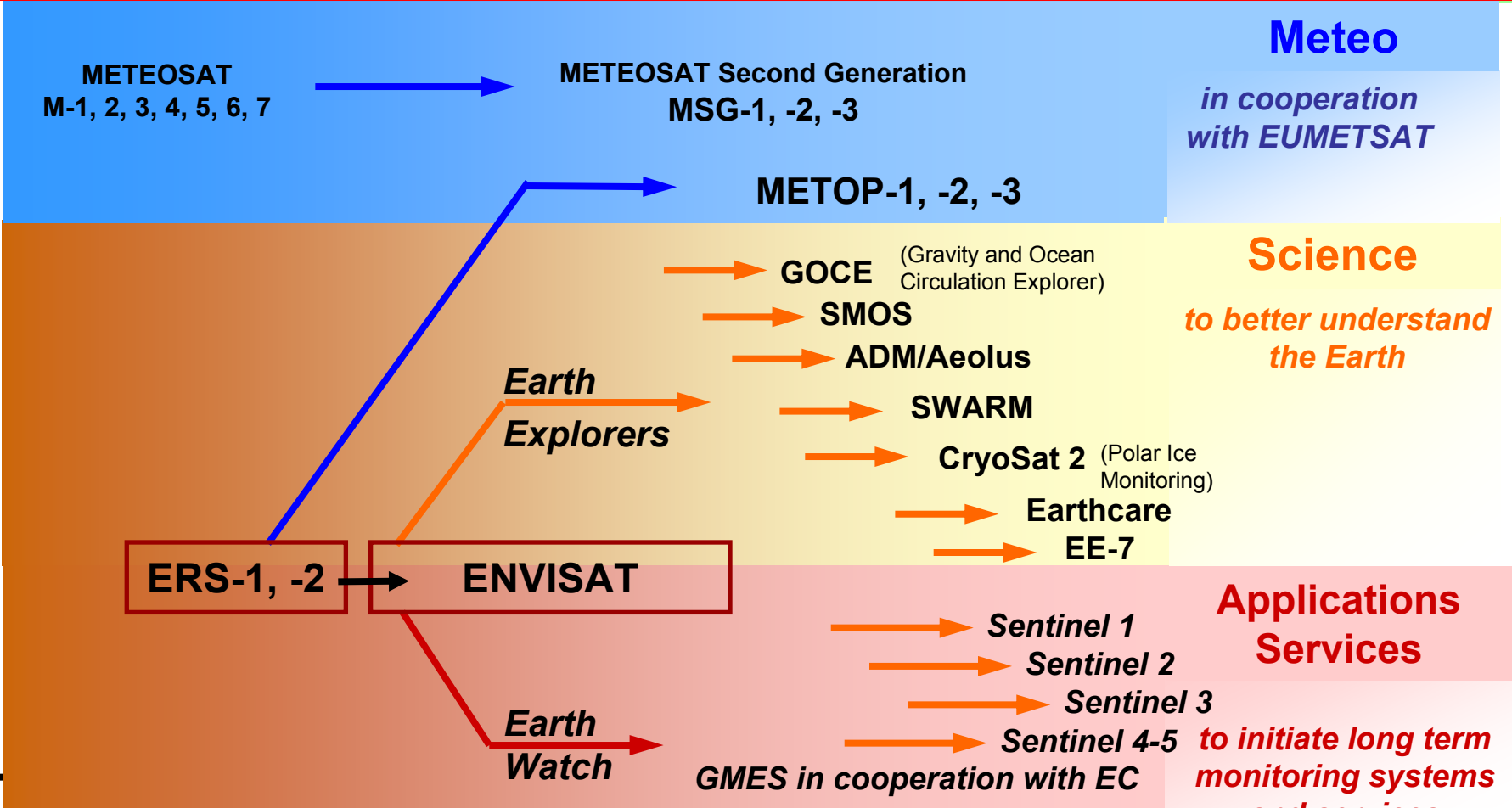
Review and utilization of spaceborne systems (for marine monitoring)

**European future earth observing satellites for marine
monitoring: Sentinel 1 and Sentinel 3**

European Earth Observation Missions handled by ESA



Earthnet: European access to non-ESA missions:
Landsat, SeaWifs, NOAA, JERS, MODIS, ALOS, Proba, Bird, Scisat... **European users**



European contributions to Global Monitoring for Environment and Security (GMES) and Sentinel satellites

Global Monitoring for Environment and Security (GMES)

**European autonomy in data sources for environment
and security monitoring**

and

**The European contribution to the Global Earth
Observation System of Systems (GEOSS)**



Global Monitoring for Environment and Security

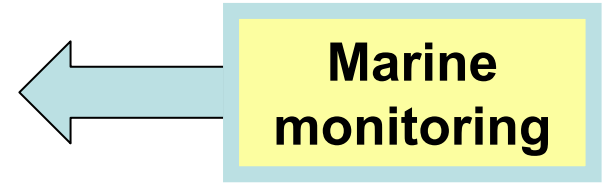
A joint initiative of ESA and the European Union

“to respond to the need to establish a European Capacity for Global Monitoring of Environment and Security to support the public policy maker’s need for global access to reliable, accurate and up-to-date information on issues of environment and security”

EC Communication COM(2001)264, 15 April 2001

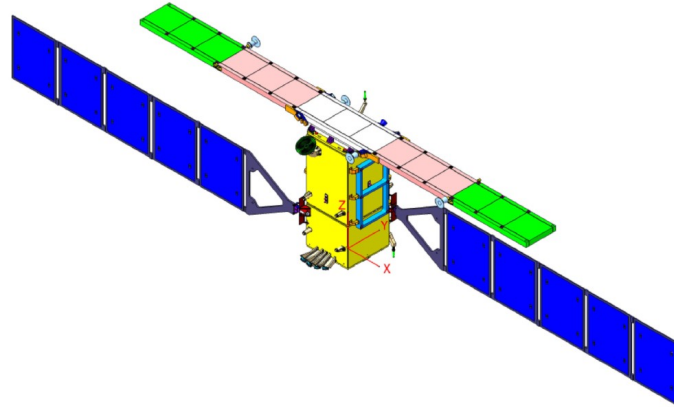
Sentinel Missions

- **Sentinel 1 – SAR imaging**
 - All weather, day/night applications, interferometry, ocean/ice/land
- **Sentinel 2 – Superspectral imaging**
 - Continuity of Landsat, SPOT - type of data for land mapping
- **Sentinel 3 – Ocean monitoring**
 - Wide-swath ocean color, surface temperature and land mission & radar altimeter
- **Sentinel 4 – Geostationary atmospheric**
 - Atmospheric composition monitoring, trans-boundary pollution
- **Sentinel 5 – Low-orbit atmospheric**
 - Atmospheric composition monitoring



Sentinels provide continuity of ERS, ENVISAT, SPOT missions

Sentinel-1



- European Radar Observatory: C-band Synthetic Aperture Radar (same frequency as Radarsat 2)
- Main operational mode: SAR imaging (Interferometric Wide Swath)
- Prime task: Continuity of operational SAR applications including interferometry

Sentinel-1 Services

GMES Consolidated Service	Sentinel-1 Contribution	
Polar Environment Services	<ul style="list-style-type: none"> •Iceberg Monitoring •Glacier and Snow Monitoring •Sea Ice Monitoring 	<ul style="list-style-type: none"> •Near Shore Ice Complex •Lake Ice Monitoring •River Ice Monitoring
Marine & Coastal Environment	<ul style="list-style-type: none"> •Sea surface winds, currents & waves •Oil spill information services (surveillance, drift forecasting) •Ship detection services for fisheries and security 	
Land Information Services	<ul style="list-style-type: none"> •Basic Land Cover •Soil Sealing Map 	
Forest Monitoring Services	<ul style="list-style-type: none"> •Green house gas reporting •Sub-National Forest Information Updates •Mapping and Monitoring of Disturbances (Clearing, Fires) •Land Cover & Forest Indicators 	

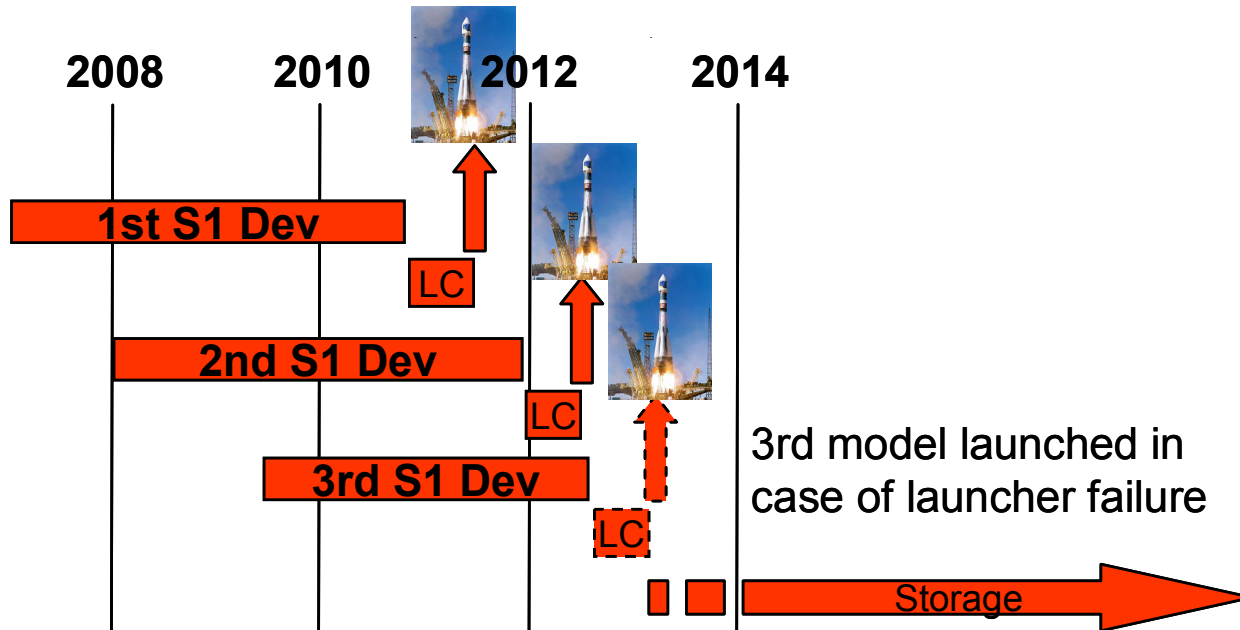
Sentinel-1 Mission requirements for marine monitoring

Provide C-band Synthetic Aperture Radar coverage and repeat observation to completely cover

- coastal zones and shipping routes on a daily basis;
- open ocean continuously by imagerettes.

Sentinel-1 Programme Status

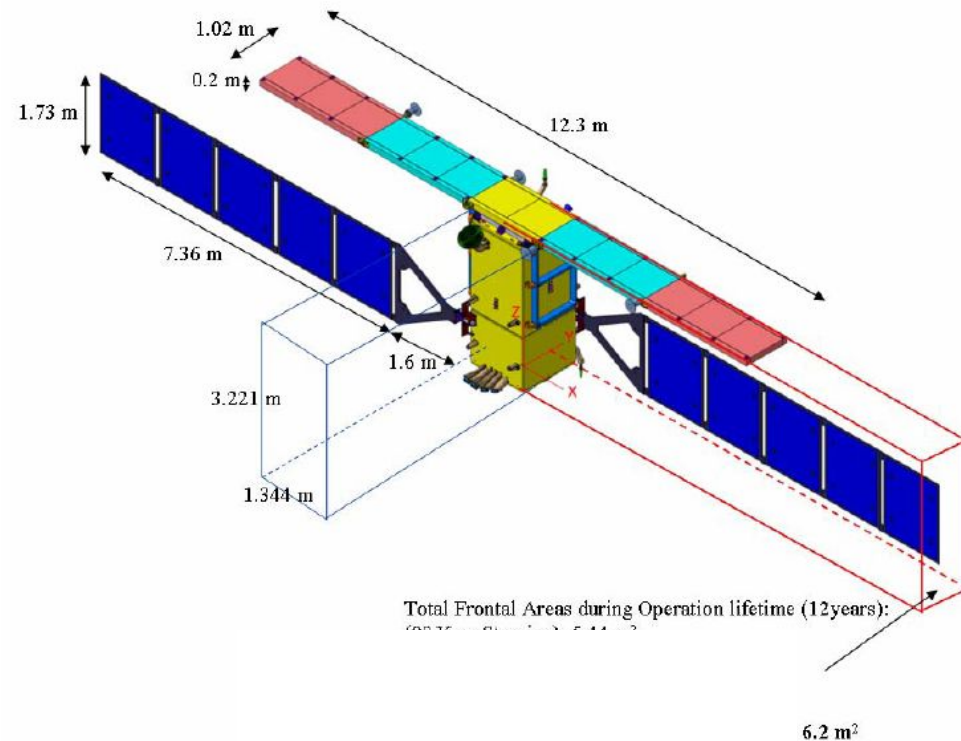
- Contract signed for development, launch and commissioning
- First satellite launch Q4 2011
- Services provided for 20 years



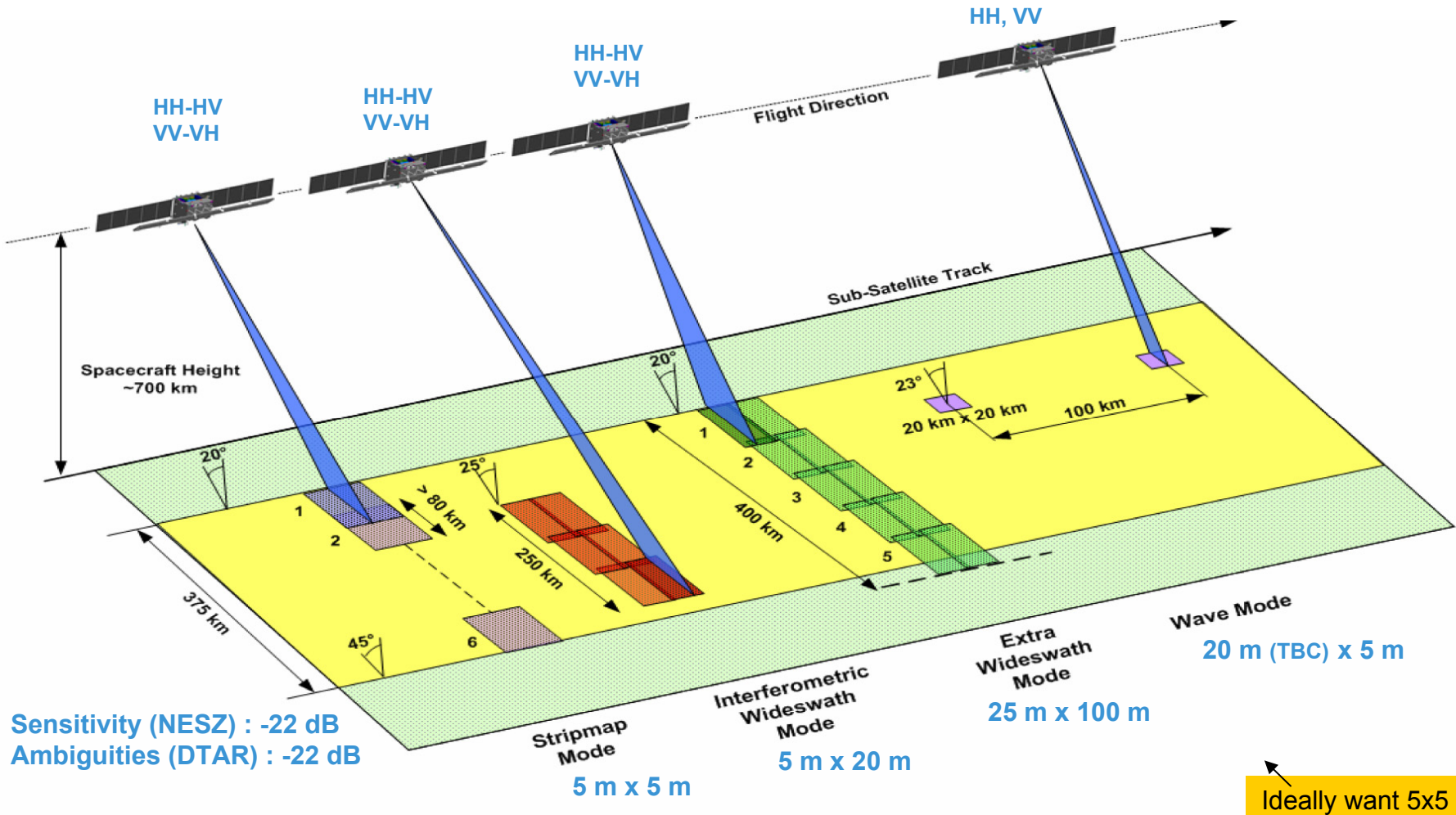
Sentinel-1 System

- Space Segment

- A constellation of two satellites with a nominal lifetime in orbit of 7 years (consumables for 12), ensuring global coverage by flying on a Near-Polar Sun-Synchronous dusk-dawn Low Earth Orbit of 693 km.
- The second satellite in the same orbit.
- The satellites carry a C-band Synthetic Aperture Radar (SAR) payload.



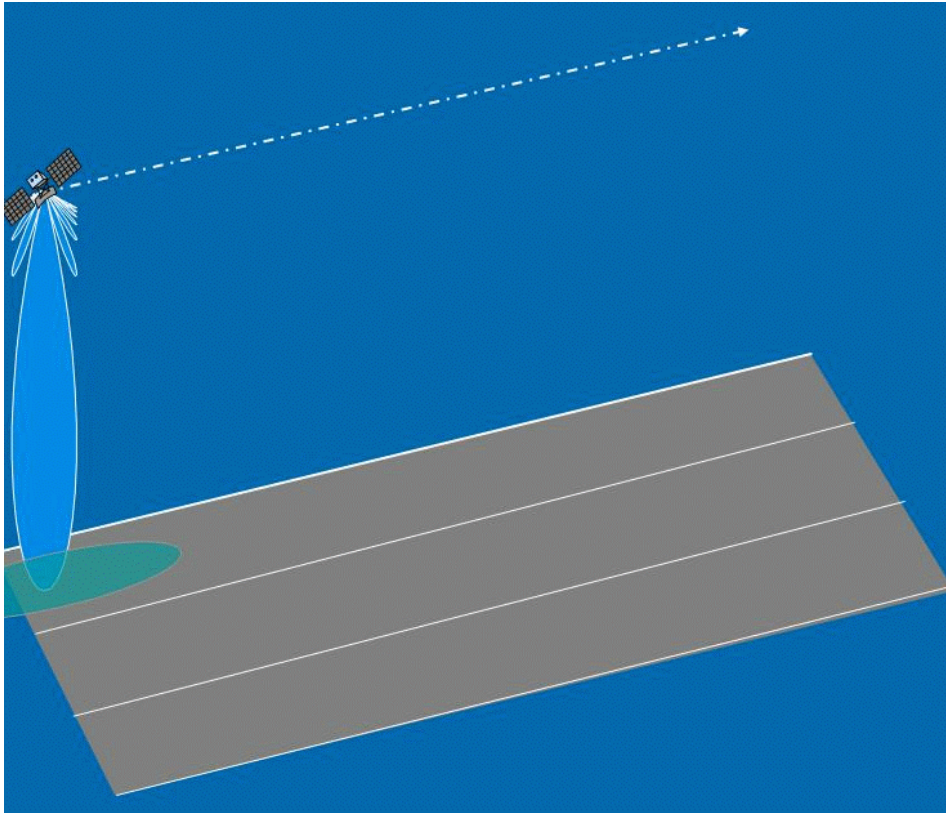
Sentinel-1 Observation Geometry



Real dual polarization functionality is implemented, with dual receiver and dual polarization performance not impacting the performance of the single polarization

TOPSAR acquisition mode

TOPS replaces conventional ScanSAR for wide swath modes



- **Evolution of classic ScanSAR**
- **Progressive scanning in azimuth direction**
- **Uniform illumination of the imaged area eliminates performance variation typical of ScanSAR mode**
- **Optimal performance along the swath**

Sentinel-1 is designed to operate in TOPSAR mode to be used in:

- **Interferometric WideSwath (IWS): 3 beams**
- **Extra WideSwath (EWS): 5 beams**

Courtesy of
POLIMI and
TAS-I

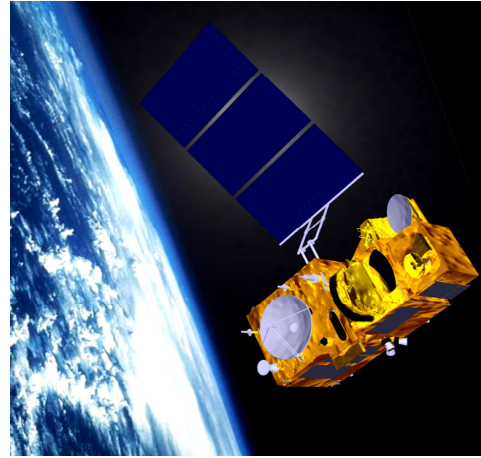
Sentinel-1 image quality

Parameter	Strip-Map Mode (SM)	Interf. Wide-Swath Mode (IW)	Extra Wide Swath Mode (EW)	Wave Mode (WV)
<i>Polarization (Dual not Quad)</i>	Dual (HH-HV, VV-VH)	Dual (HH-HV, VV-VH)	Dual (HH-HV, VV-VH)	Single (HH, VV)
<i>Access (Incidence angles)</i>	20° - 45°	25° (min. angle)	20° (min. incidence angle)	23° (mid incidence angle)
<i>Azimuth Resolution</i>	< 5 m	< 20 m	< 100 m	< 5 m
<i>Azimuth Looks</i>	single	single	3 minimum	Single
<i>Ground Range Resolution</i>	< 5 m	< 5 m	< 25 m	< 20 m
<i>Range Looks</i>	single	single	Single	Single
<i>Swath</i>	> 80 km	> 250 km	> 400 km	Vignette 20 x 20 km
<i>Minimum swath overlap</i>	2%	2%		
<i>Pixel localization</i>	2.5 m (3 σ)	10 m (3 σ)		
<i>PTAR / DTAR</i>	-25 dB / -22 dB	-25 dB / -22 dB	-25 dB / -22 dB	-25 dB / -22 dB
<i>NESZ</i>	-22 dB	-22 dB	-22 dB	-22 dB
<i>Radiometric Stability</i>	0.5 dB (3 σ)	0.5 dB (3 σ)	0.5 dB (3 σ)	0.5 dB (3 σ)
<i>Radiometric Accuracy</i>	1 dB (3 σ)	1 dB (3 σ)	1 dB (3 σ)	1 dB (3 σ)

S1 Payload

Orbit: 12 d (06:00 LTDN)	ASAR : 35 d (10:00 LTDN)
<u>Stripmap Mode (SM)</u>	
Swath: 80 km	comparable to ASAR
Resolution: 5x5 m (1L)	better than ASAR capability
<u>Extra-wide Swath Mode (EW)</u>	
Swath: 400 km	same as ASAR
Resolution: 25x100 m (3L)	better than ASAR capability
<u>Wave (WV)</u>	
Swath: 20x20 km	better than ASAR
Resolution: 20x5 m	better than ASAR
<u>Interferometric Wideswath Mode (IW)</u>	NEW MODE (BASELINE)
Swath: 240 km	
Resolution: cell area	comparable to ERS
Sensitivity, Ambiguity, Radiometric performance	comparable to ASAR
No separate AP mode but dual-pol capability in all modes without performance reduction	

Sentinel-3



- Consistent, long-term collection of remotely sensed marine and land data
- Operational ocean state analysis, forecasting and service provision
- Advanced Radar Altimeter concept
- Multi-channel optical imager (VIS, IR)

Key Drivers for marine monitoring

- **Operational continuity of core operational ocean services** based on:
 - Jason-1 (Jason-2 in the future), ERS-2 RA, GFO and Envisat RA2
 - MERIS, MODIS, SeaWIFS Ocean Colour
 - (A)ATSR, MODIS, and AVHRR Surface Temperature
- Routine, continuous operation with consistent product quality and high level of availability

Sentinel-3 Marine Services

GMES Initial Service	S-3 Features
Marine and Coastal Environment	sea-surface topography mesoscale circulation water quality sea-surface temperature wave height and wind sediment load and transport eutrophication
Polar Environment monitoring	sea-ice thickness ice surface temperature
Marine Security	ocean-current forecasting water transparency wind and wave height
Global Change - Ocean	global sea-level rise global ocean warming ocean CO₂ flux

Ocean Products

- **Surface Topography:**
 - SSH, SWH, Wind, Geostrophic currents
 - Sea-ice thickness
- **Ocean surface colour**
 - Cla, PFTs, HAB, Transparency, Sediment loading, Turbidity
- **Sea Surface Temperature**

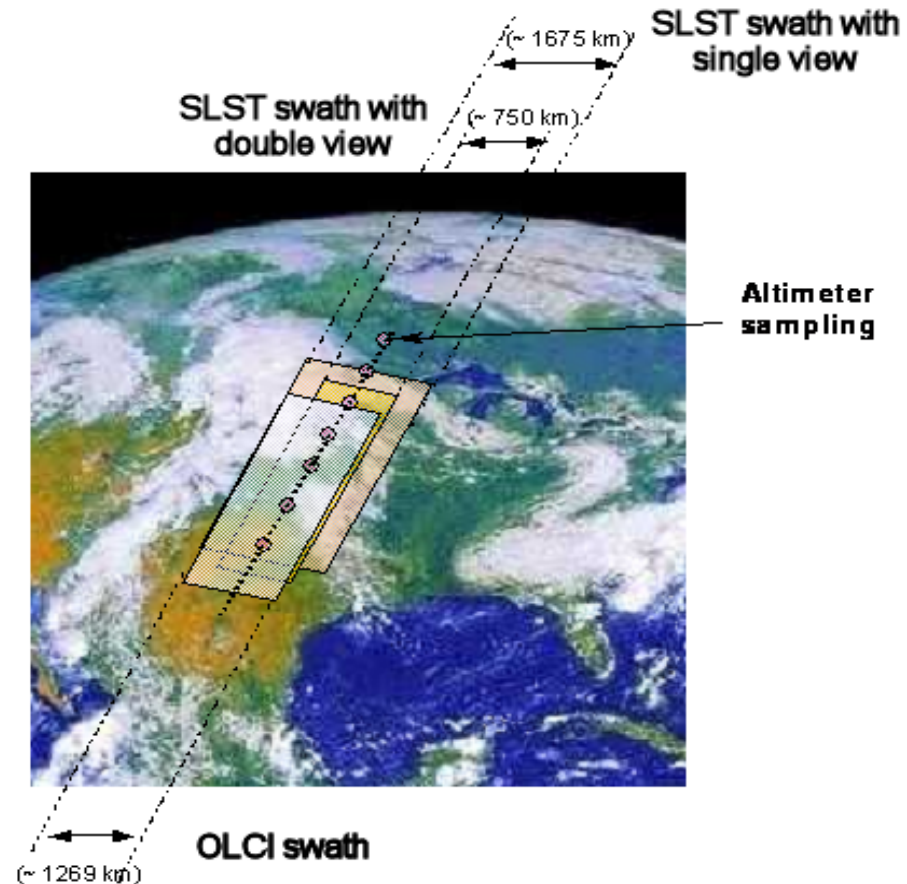
Cla = Chlorophyll - a

PTF = Phytoplankton functional type

HAB = Harmful algal blooms

Sentinel-3 Payload Complement

- **Topography Mission**
 - **Bi-frequency Synthetic Aperture Radar Altimeter**
 - **Microwave Radiometer (Bi- or Tri- frequency)**
 - **Precise Orbit Determination (POD) including**
 - **GNSS Receiver**
 - **Laser Retro-Reflector**
- **Optical Payload**
 - **Ocean and Land Colour Instrument (OLCI)**
 - **Sea and Land Surface Temperature (SLST)**



Topography instruments overview

- **Radar Altimeter**
 - Heritage from CryoSat & Jason
 - Ku & C-band (for ionospheric corrections)
 - New features: SAR mode and open-loop tracking
 - ⇒ Improved monitoring of coastal ocean, ice surfaces and inland water
- **Microwave radiometer**
 - 23.8 / 36.5 (/ 18.7) GHz
 - Path correction accuracy: 1.4 cm
- **Precise Orbit Determination**
 - High accuracy GPS (+Galileo) receiver
 - 2 cm accuracy (radial)

Ocean and Land Colour Instrument (OLCI) Overview

- Heritage from MERIS
- Pushbroom type imaging spectrometer
- 5 cameras, 16 programmable spectral bands (incl. channels for MERIS & VGT legacy products)
- Low polarisation < 1%
- Sun Glint free configuration by design
- Swath covered by SLST for atmospheric correction
- Resolution optimized for observation with full resolution over Coastal/Land
 - Land 300 m
 - Coastal Ocean 300 m
 - Open Ocean 1.2 km

Sea and Land Surface Temperature (SLST) Overview

- Heritage from AATSR, dual-view (nadir and backward) required for aerosol corrections:
 - Nadir swath $>74^\circ$ (1300 km min up to 1800 km)
 - Dual view swath 49° (750 km)
 - Nadir swath covering OLCI
- 9 spectral bands:
 - Visible : 555 – 659 - 859 nm
 - SWIR : 1.38 – 1.61 – 2.25 μm
 - TIR : 3.74 – 10.85 – 12 μm
- One IR channel used for co-registration with OLCI

Mission Performance

- Revisit time (optical observations):
 - Full performance is met with 2 satellites. Significant improvement wrt to Envisat achieved with 1 satellite: wider instrument swath and optimised orbit.

		Revisit at Equator	Revisit for latitude > 30°	Requirement
Ocean Colour (sun-glint free)	1 Satellite	< 3.8 days	< 2.8 days	< 2 days
	2 Satellite	< 1.9 days	< 1.4 days	
Land Colour (and vegetation)	1 Satellite	< 2.2 days	< 1.8 days	< 2 days (goal 1 day)
	2 Satellite	< 1.1 day	< 0.9 day	
SLST dual view	1 Satellite	< 1.8 days	< 1.5 days	< 4 days
	2 Satellite	< 0.9 day	< 0.8 day	

Mission Performance (cont'd)

- **Ocean Topography:**

Error type	Value (error budget)
<i>Altimeter random</i>	<i>1.3 cm</i>
<i>Sea model</i>	<i>2.0 cm</i>
<i>Ionosphere</i>	<i>0.7 cm</i>
<i>Dry troposphere</i>	<i>0.7 cm</i>
<i>Wet troposphere</i>	<i>1.4 cm</i>
Total range error (rms)	3.0 cm
POD (rms)	2.0 cm
Sea Surface Height (rms)	3.6 cm

- **Products**

- Near Real Time L2 optical and topography products, available within 3 hours following acquisition.
- Highest quality, Non-time critical L2 products, available within 1 month.

Status of Sentinels 1-3

- Sentinel-1
 - Phase B2 start: 2007
 - Critical Design Review: 2009
 - Launch: 2011

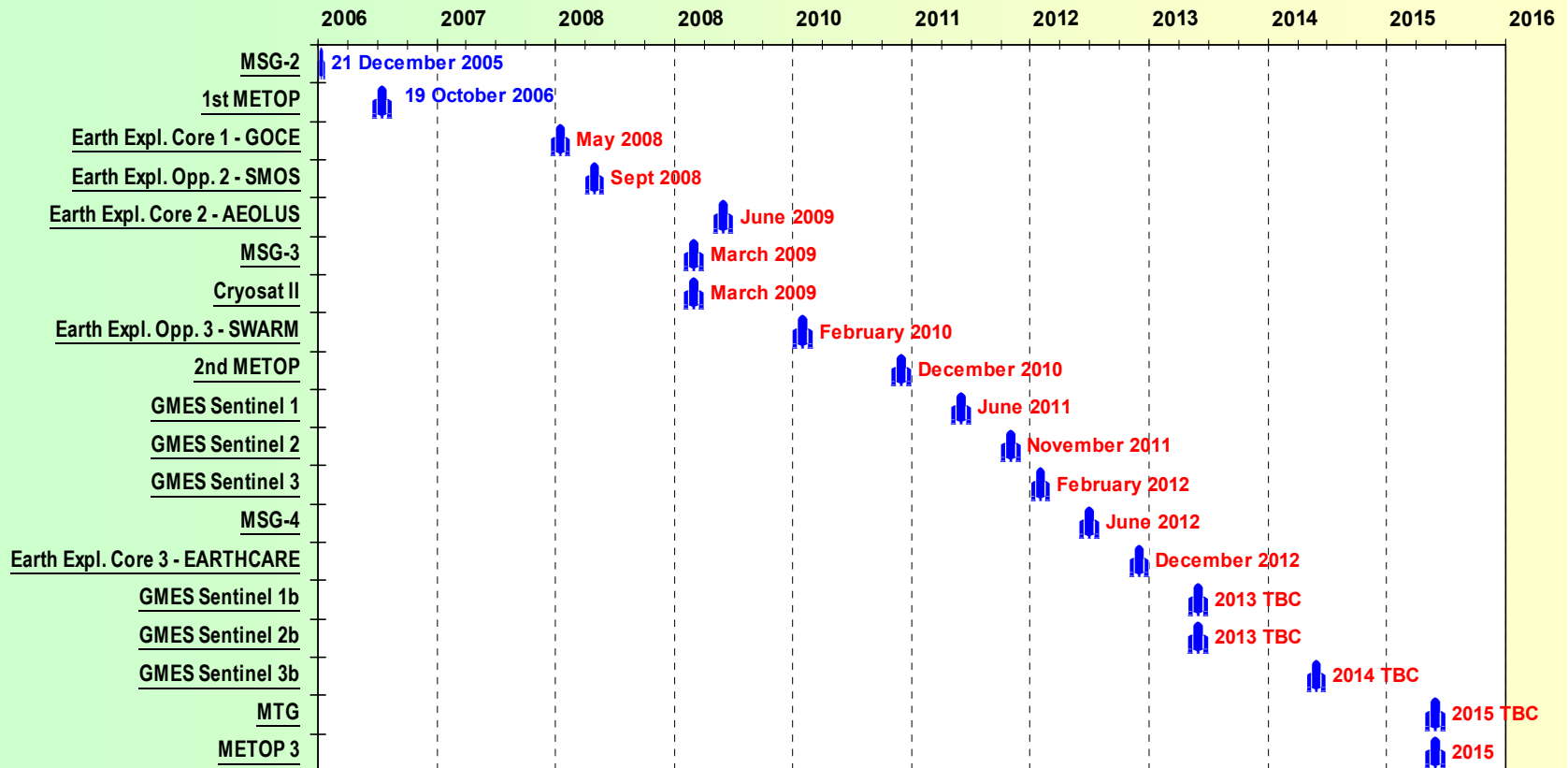
- Sentinel-2
 - Phase B2 start: 2007
 - Critical Design Review: 2010
 - Launch: 2012

- Sentinel-3
 - Phase B2 start: 2007
 - Critical Design Review: 2010
 - Launch: 2012

EOP overall launch schedule

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D / E O P Overall Launch Schedule



More missions are in the planning, yet not included due to not yet defined launch dates: Sentinel-4, Sentinel-5 and the 7th Earth Explorer