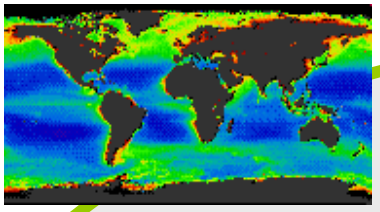
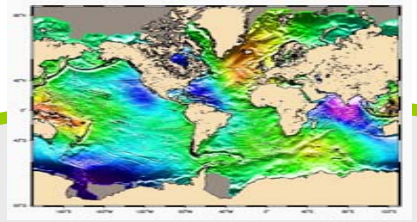
Sentinel-3

Jérôme Benveniste
esa

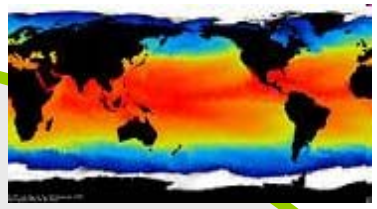
S3 Background: Primary Objectives



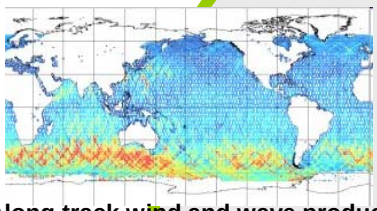
Ocean colour products
(Credit: MyOcean)



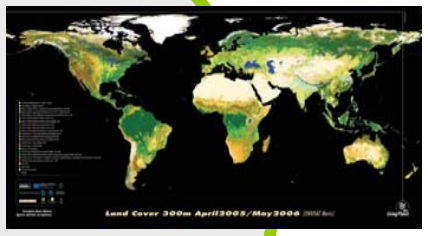
Sea Surface Height products
(Credit: CLS)



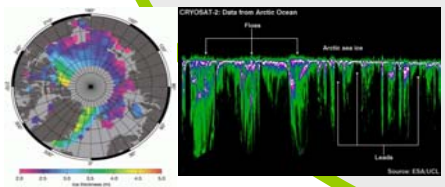
Sea Surface Temperature products
(Credit: Met Office)



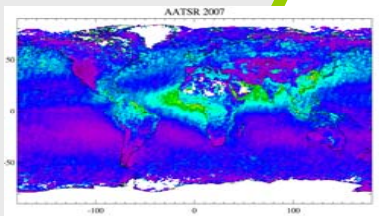
Along track wind and wave products
(Credit: AVISO)



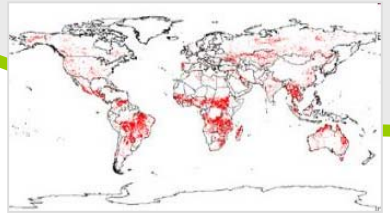
Land cover products
(Credit: ESA)



Sea Ice products
(Credit: UCL)



Atmospheric aerosol products
(Credit: GlobAerosol)



Fire products
(Credit: ESA World Fire atlas)

User parameters derived from L1b products
(Credit: GEO)

S3 Background: Objectives

Primary **Secondary**

- ***Sentinel-3 shall provide continuity of an ENVISAT type ocean measurement capability for GMES Services, including:***

Continuity of ocean colour as good as ENVISAT MERIS or better

Continuity of SST as good as ENVISAT AATSR or better

Continuity of SSH as good as ENVISAT RA-2 or better with SAR capability derived from CryoSat-2 over coastal zones and sea ice

coastal zones and over sea ice.

- **Continuity of land products (reflectance's, temperature) as good as ENVISAT MERIS and AATSR or better**

temperature and land-surface colour (reflectance)

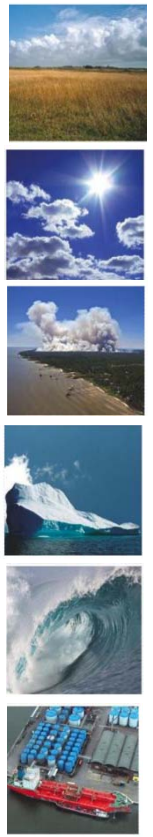
- **Provide consistent quality L1b and L2 optical and topography products in a timely manner for GMES services**

GMES Services

- **Continuity of SPOT VGT-P like products**

tion SPOT Vegetation P-like global products

- **Fire, “River and Lake” height, atmospheric products…for GMES services**



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S3: Mission Heritage…

1992: TOPEX / Poseidon-1

Poseidon-1

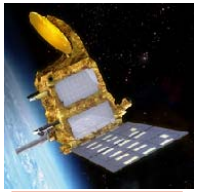
2001: JASON-1

Poseidon-2

2008: JASON-2

Poseidon-3

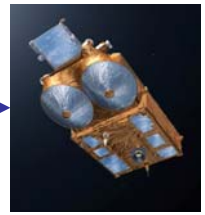
2011:AltiKa



SARAL

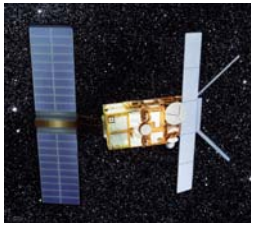
2005: CryoSat-1

SIRAL



2010: CryoSat-2

SIRAL



1992: ERS-1
1995: ERS-2

RA-1

ATSR

2002: ENVISAT

RA-2

AATSR

MERIS

2013: Sentinel-3

SRAL

SLSTR

OLCI

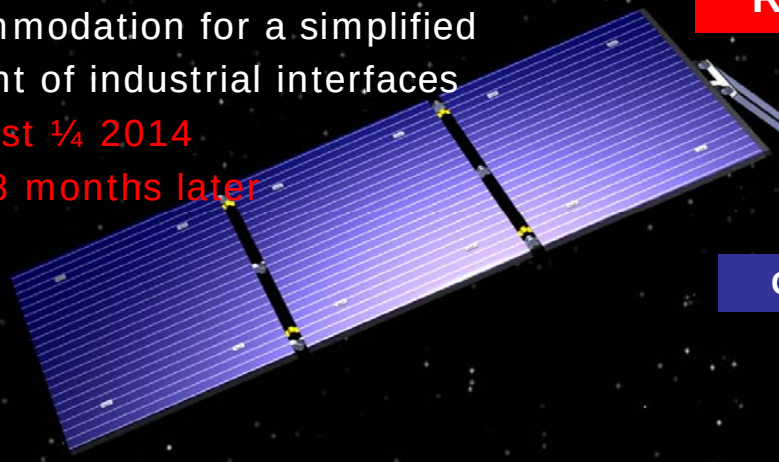
Vegetation

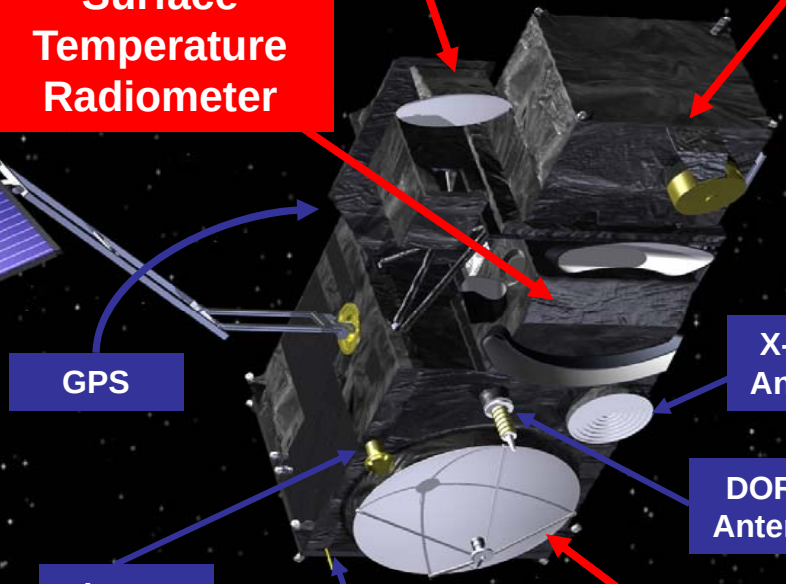
1998: SPOT-4

S3 Configuration: Satellite description

Main satellite characteristics

- 1250 kg maximal mass
- Volume in 3.89 m x 2.202 m x 2.207 m
- Average power consumption of 1100 W
- 7.5 years lifetime (fuel for 5 add. years)
- Large cold face for optical instruments thermal control
- Modular accommodation for a simplified management of industrial interfaces
- Launch S3A first ¼ 2014
- Launch S3B 18 months later





Observation Data Management

- 21.25 Gb (170 Gbit) of observation data per orbit
- Space to ground data rate 2 x 280 Mbps X-Band
- 1 ground contact per orbit
- 3h delivery timeliness (from satellite sensing)

S3: Key requirements for 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

S3: Instrument payload swath / footprints

SLSTR nadir: 1420km

Offset westward from nadir

SLSTR oblique: 750 km

Centred at nadir

OLCI: 1270 km

Westward inclination to avoid sunglint

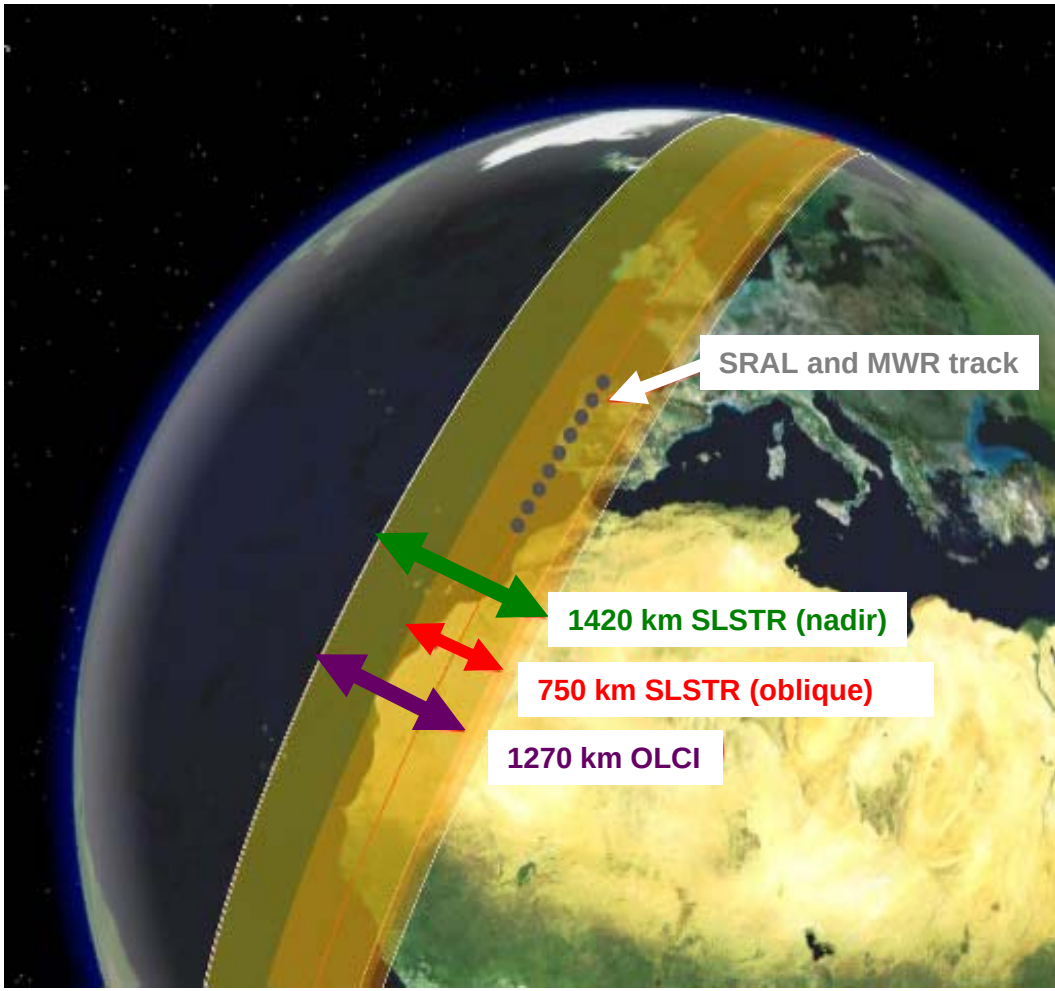
Fully within SLSTR nadir and oblique swath

SRAL: > 2km

Centred at nadir and fully within SLSTR and OLCI swath

MWR: 20 km

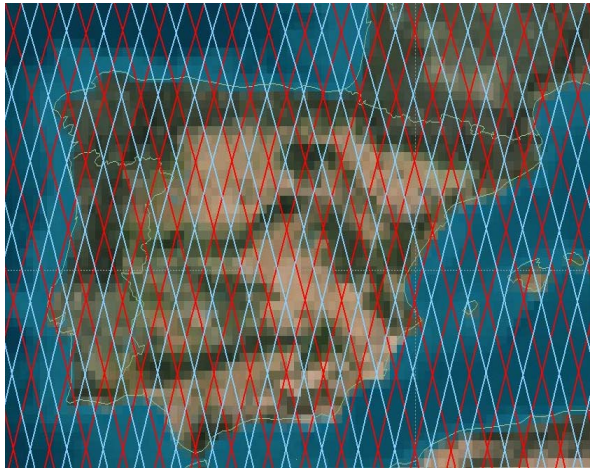
Centred at nadir and fully co-located with SRAL



Revisit time and coverage

Key elements of the Sentinel-3 mission are:

Topography Mission: ground track repeatability, dense spatial sampling



Ground tracks after 1 complete cycle (27 days) S3A & S3B

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	< 1.9 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)**

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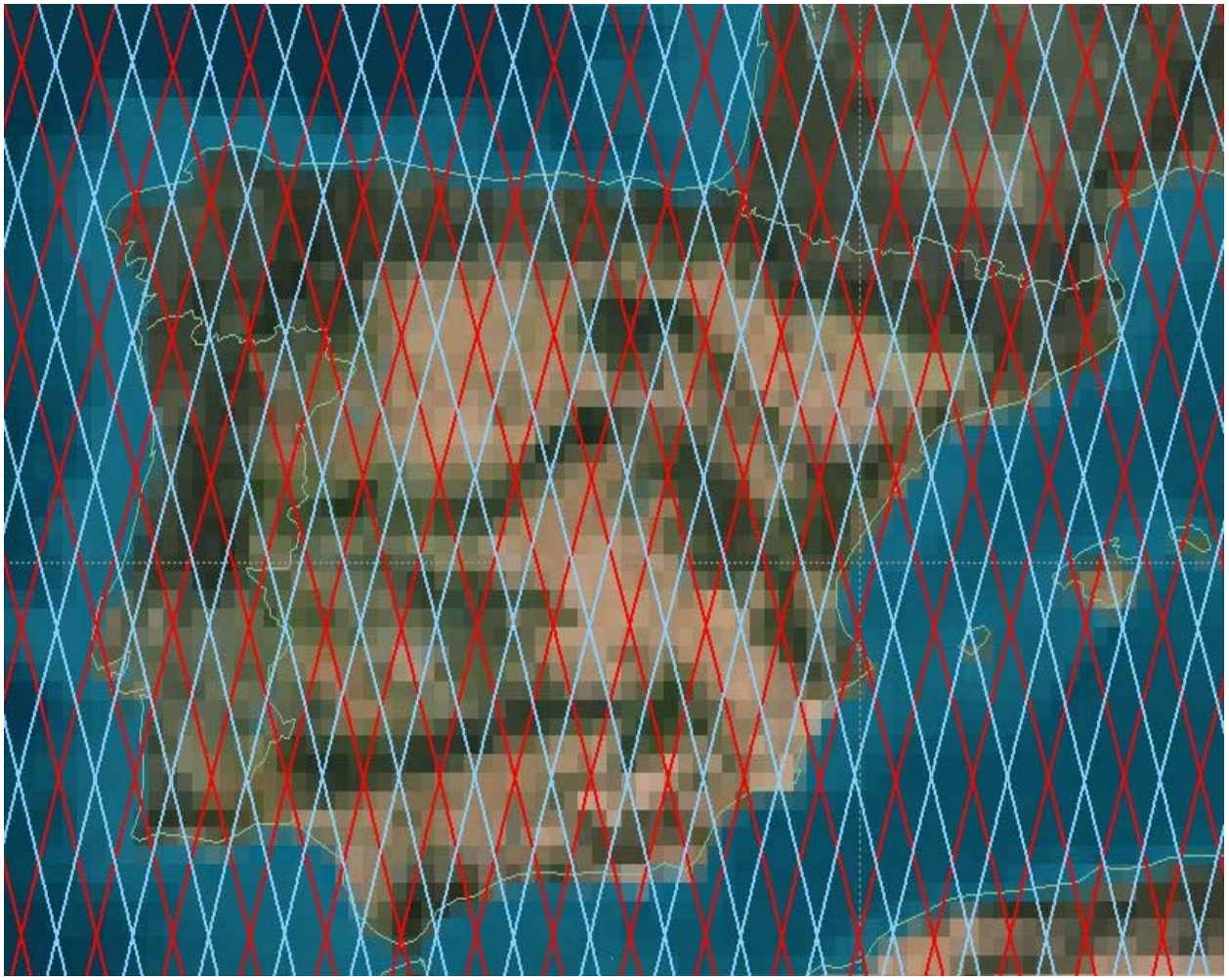
Revisit time and coverage

Topography Mission: ground track repeatability, dense spatial sampling



Ground tracks after 1 complete cycle (27 days) S3A & S3B

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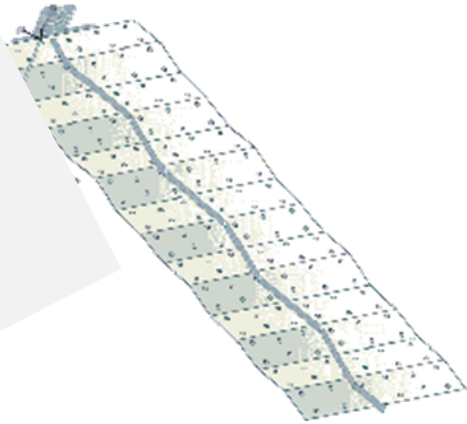
S3: ENVISAT Heritage Accuracy

- **MERIS**
  - Accuracy: 2-5% fu
  - Surface reflectance (ocean) <2
  - Surface reflectance (Land)
  - Chlorophyll retrieval
  - Yellow substance
  - Suspended matter
  - Water vapour
  - Cloud al
  - Clo
  -
- .5 deg
  urface
  - <1K
- **RA-**
  - A < 4.5cm,
  - Wa t: < 5% or 0.25m

Current ENVISAT Mission ends in mid 2014

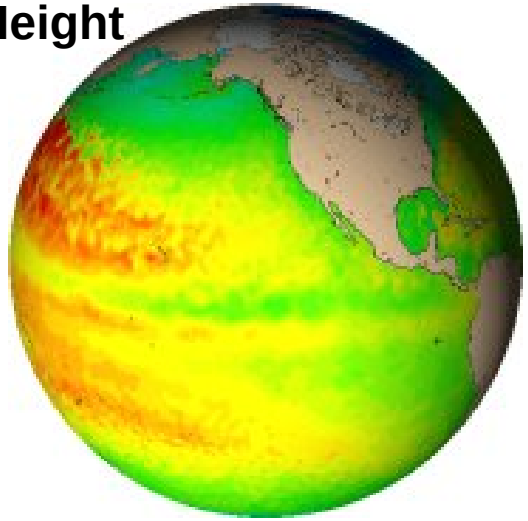
S3 launch planned for late 2013

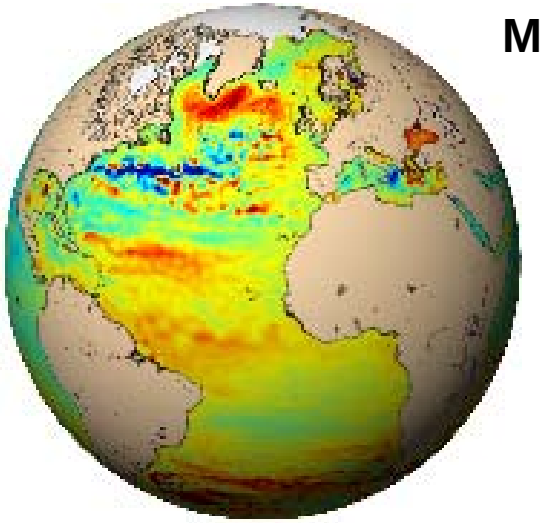
Overlap ~6-8 months



S3 Topography Mission

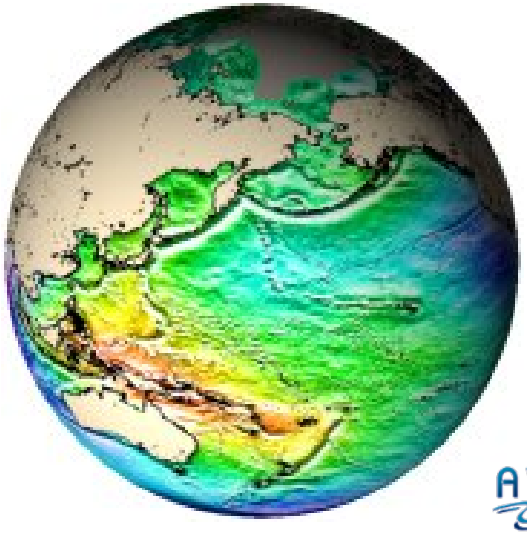
Sea Surface Height

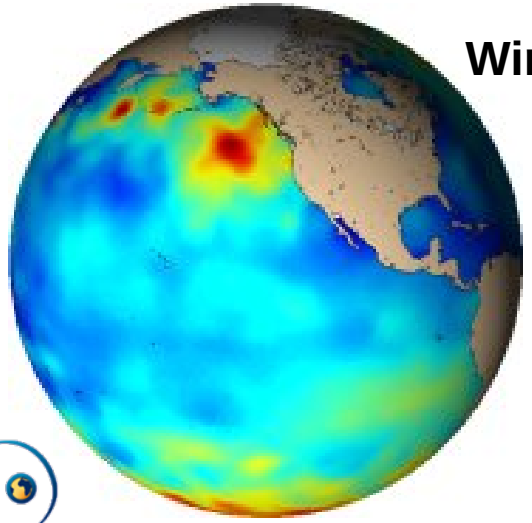




Mean Sea level

DEM, Tides, River and lake Heights, MSS …





Wind and Waves

AVISO

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S3: Topography Mission

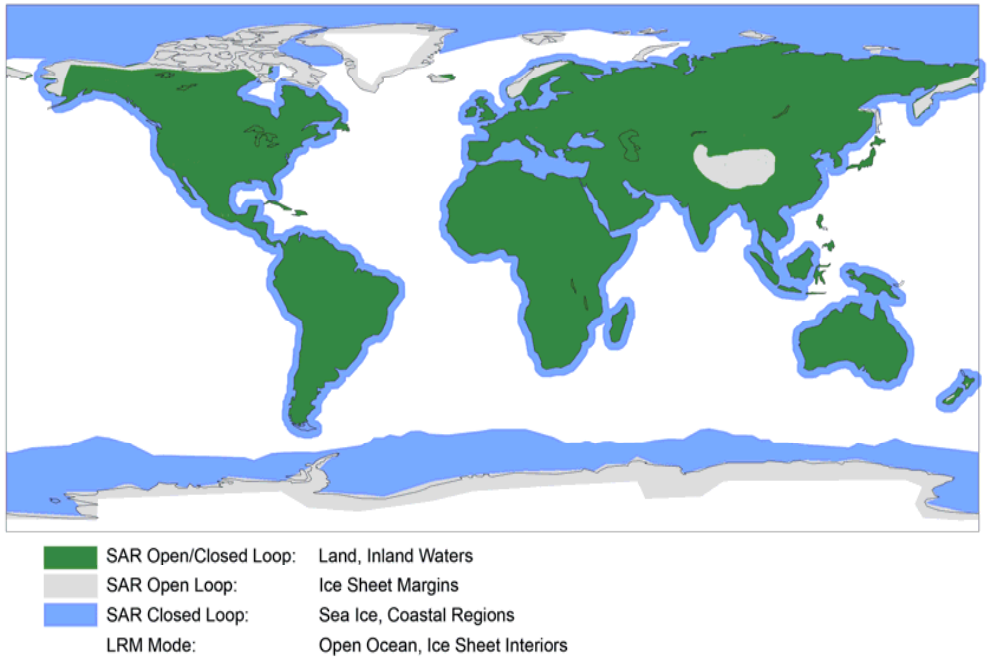
Topography package:

1. **Synthetic Aperture Radar Altimeter (SRAL)**
2. **Microwave Radiometer (MWR)**
3. **Precise Orbit Determination (POD)**

Key Improvements:

- SAR & LRM mode
- Better POD
- Better tracking
- Polar Oceans

S3 Topography mission Mode mask



Observed surfaces

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

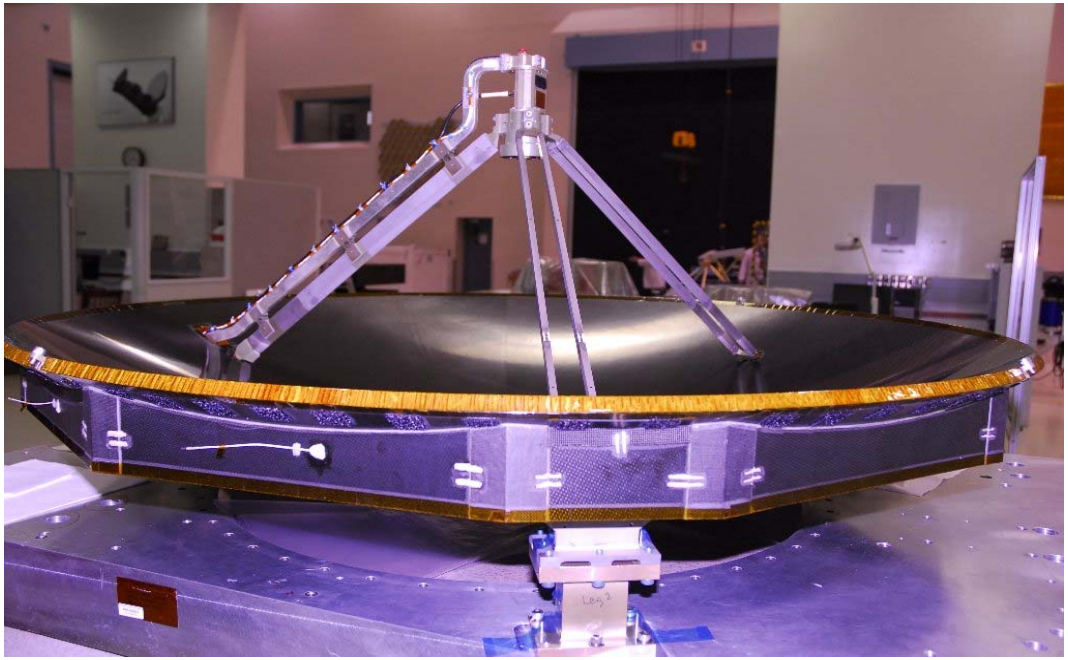
S3 SRAL: Technical

Dual frequency Ku/C band Radar Altimeter
CryoSat and Jason heritage

- **High horizontal resolution (~300m in SAR mode)**
- **SRAL Radar features:**
  - Ku-Band (13.575 GHz) : main frequency
  - C-Band (5.41 GHz) : ionosphere corrections
- **Fully redundant electronics**
- **Measurement modes:**
  - 2 radar modes: Low Resolution Mode (LRM) and Nadir SAR mode
  - **2 tracking modes: Closed-loop and open-loop tracking modes over rough terrain**
  - **Any radar mode can be combined to any tracking mode**

Objective: To retrieve orbit altitude information with an End-to-end range accuracy of 3 cm (ocean).

Supported by MWR, GPS, LRR and DORIS



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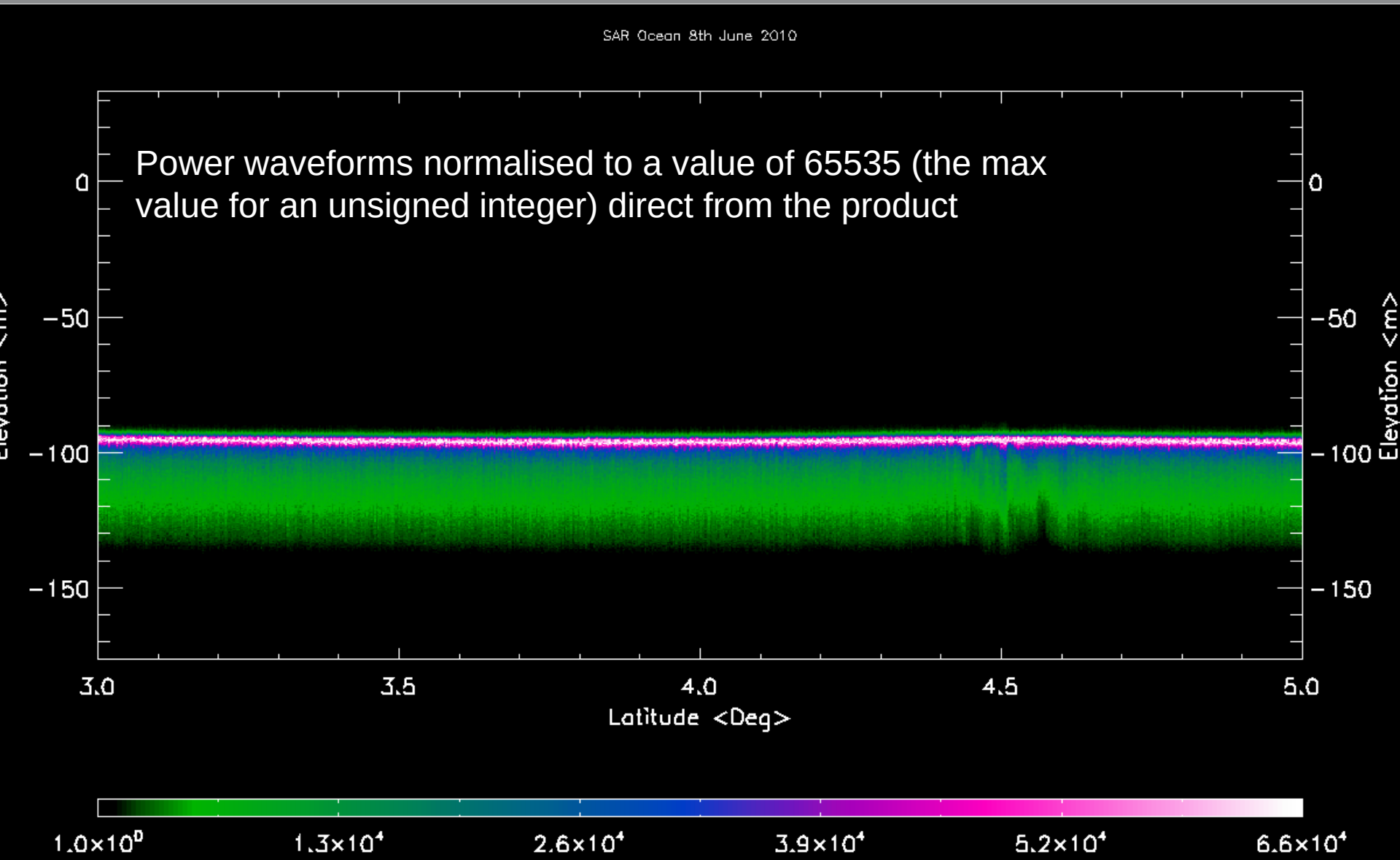
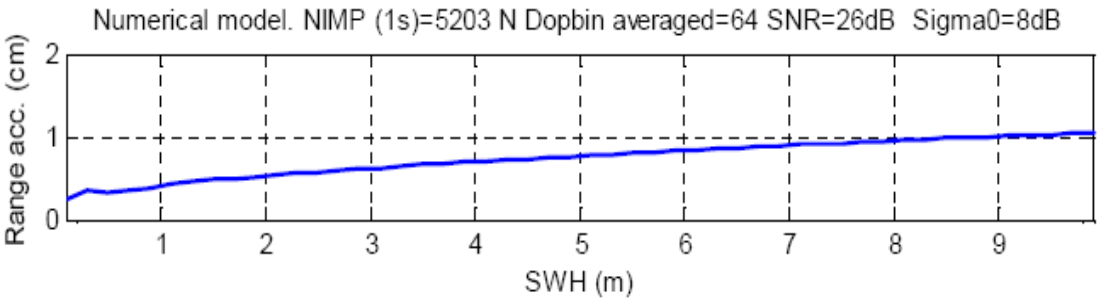
S3: SRAL SAR Mode

(with help from CryoSat in Equatorial Indian Ocean)

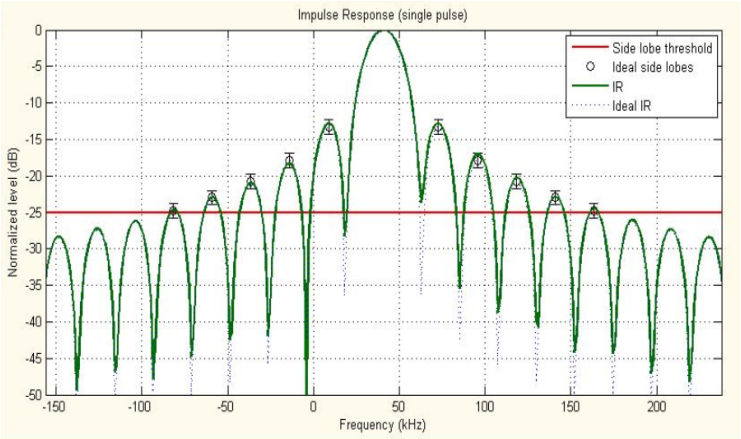


SRAL calibration and characterisation

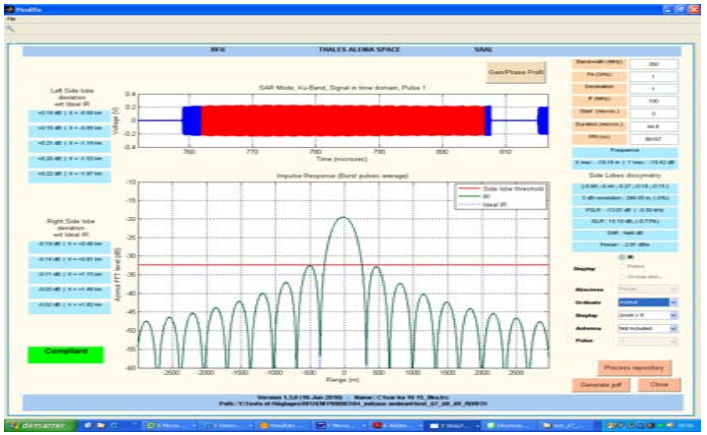
- Key parameters to **characterize the SRAL** altimeter instrument performances are:
  - Range Impulse response:
  - Low Pass Filter:
  - Range noise
- Some other parameters will require in-flight validation, this will be done during commissioning:
  - Antenna pointing accuracy, antenna pattern
  - Range Absolute bias



At SWH = 2m, the altimeter range noise is estimated to 0.7 cm rms. Better than LRM mode since the number of averaged pulses is greater in SAR mode (256 instead of 84 within a tracking cycle)



C-band Range Impulse Response



Ku Azimuth Impulse Response

S3 MWR: Overview

Dual Frequency Noise Injection Radiometer, with cold sky calibration

- ENVISAT and Jason heritage

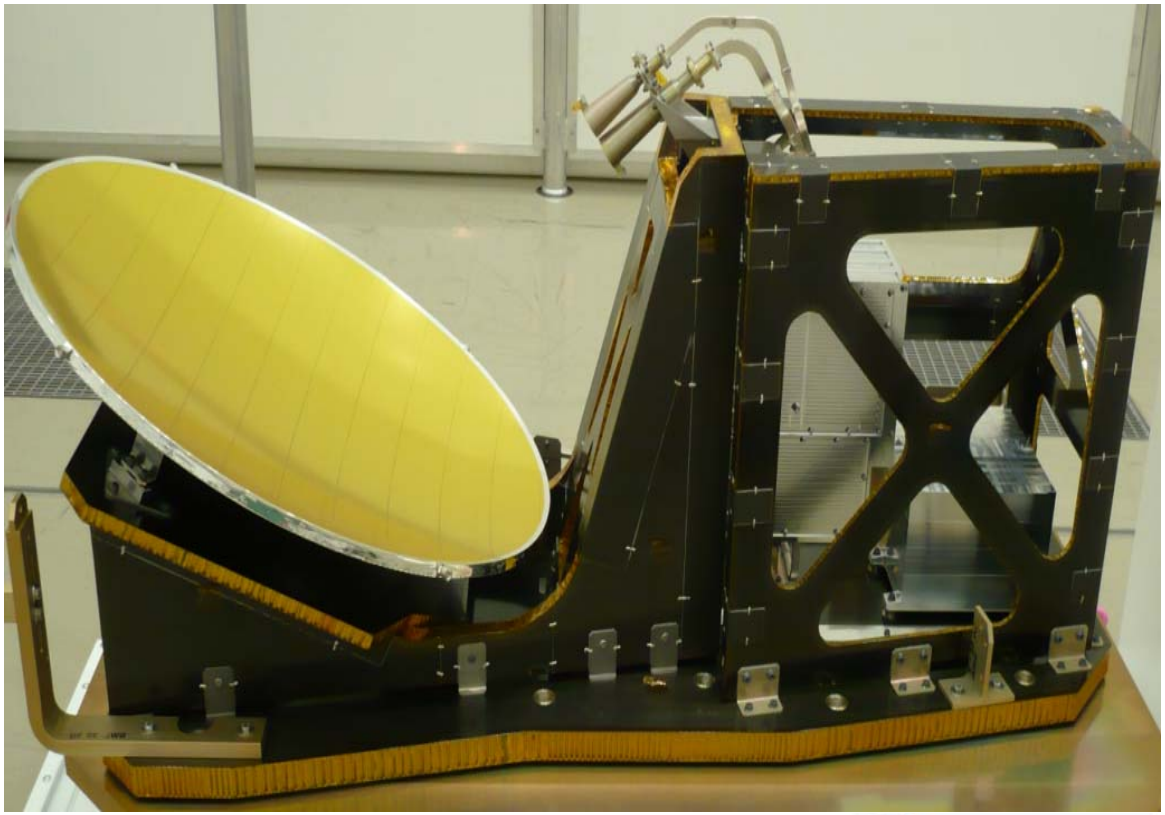
Technical:

- 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: Provide the altimeter wet troposphere correction with typical accuracy of ~1.4 cm



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S3: Precise Orbit Determination (POD)

8 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

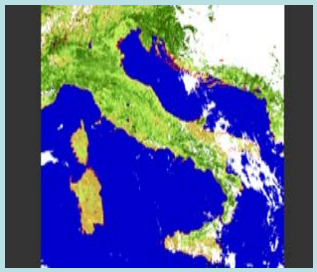
POD radial accuracy requirements (rms)

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

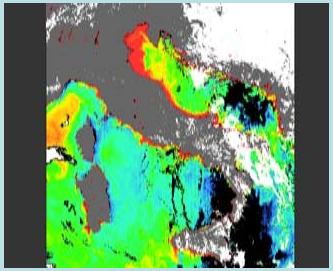
Sentinel-3 Core PDGS
L2 LAND / MARINE Production

L2 Optical production organisation

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

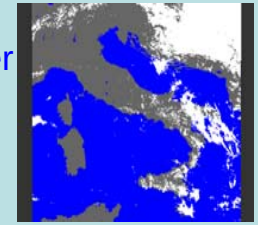


Land products



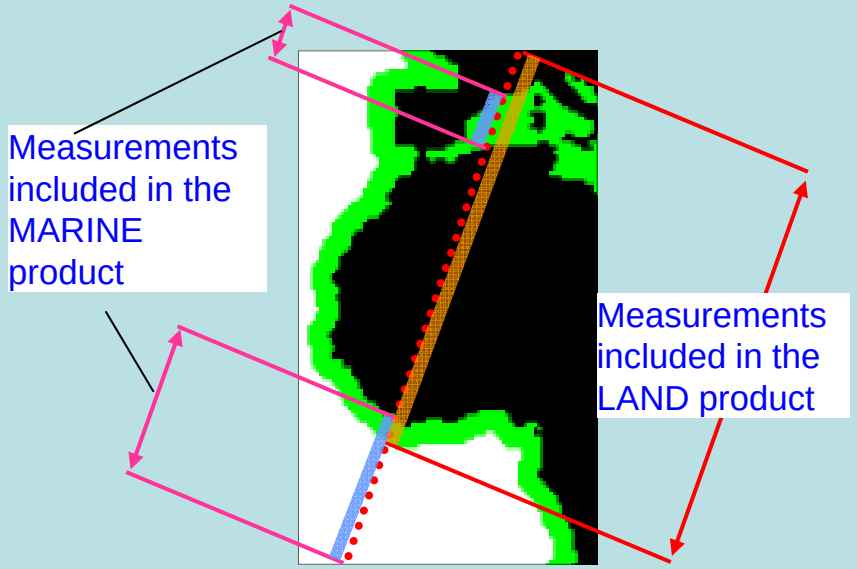
Marine products

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



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

Sentinel – 3 Core GS User 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

NB: Validated Level 2 products are swiftly available through commissioning and GIO Phase

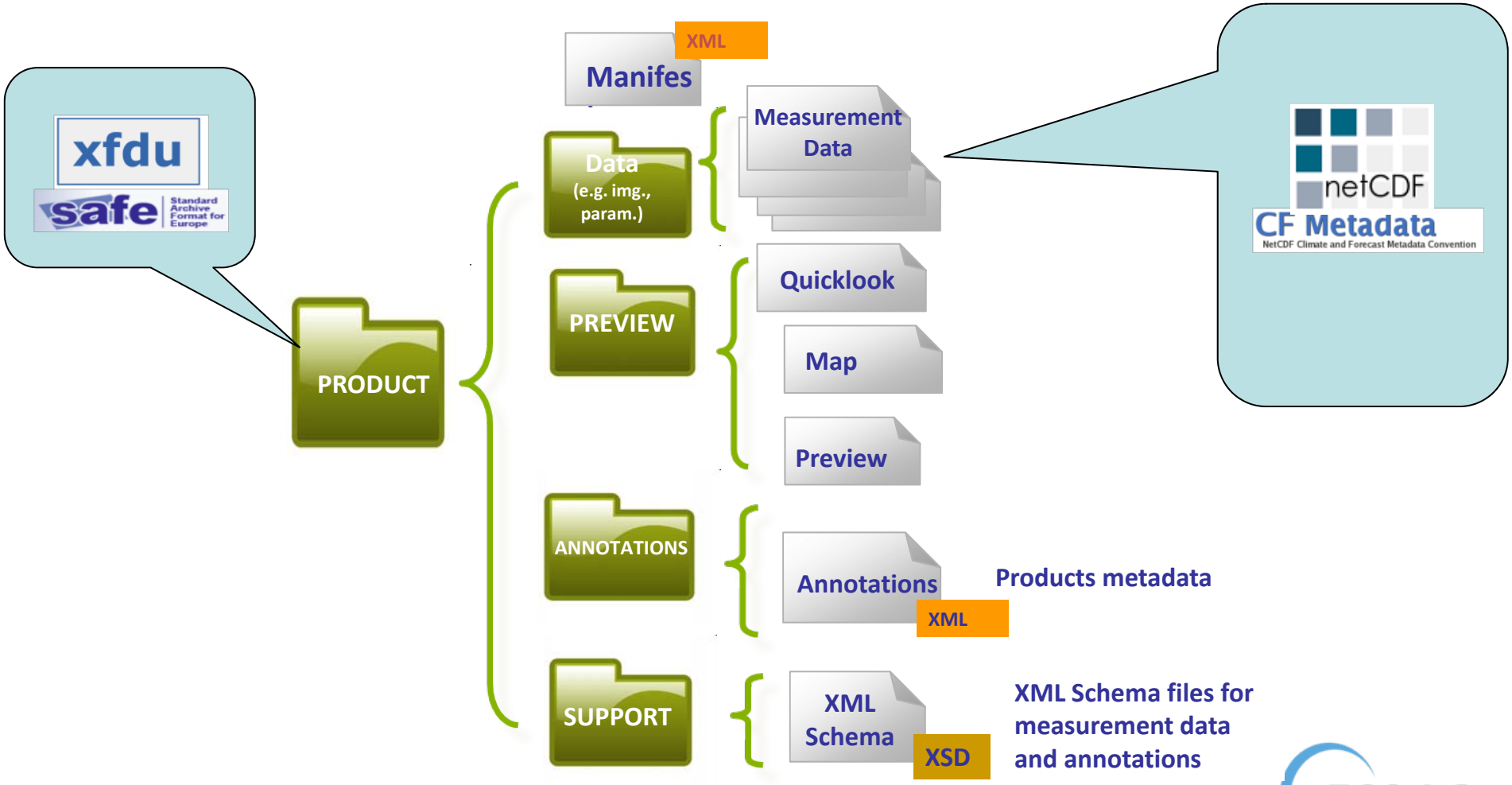
Sentinel -3 Core products
Surface Topography Mission

Geophysical Product	Observed Surfaces	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 …	Ocean	SAR: ~300 m LRM: > 5km	Cryosat ERS, Envisat	SRAL + MWR + POD
In-land water Ice-sheet margin Land surface height …	Non-Ocean	SAR: ~300m	Cryosat	SRAL + POD

S-3 STM L2 Geophysical content

Sentinels Core Products Products Format

A unique packaging concept adapted to different missions user communities



S3 PDGS 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+SLTSR)		**55.8**		31.2
SRAL + MWR	5.8	**0.12**	0.09	0.07
Total				

	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

S3: Altimetry Product Validation

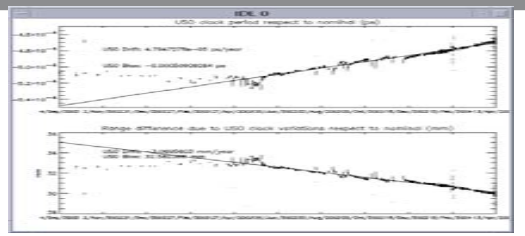
The Validation is the assessment of the altimetry measurements data quality via:

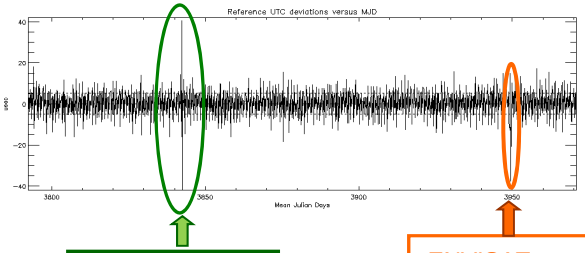
- Data coverage analysis
- Detection and investigation of spurious data
- Measurement of the altimetry system perfor
- Consistency/continuity check with oth

Three main categories of diagr

- **Global internal analyses**
  - → Ensure consist
  - → Diagnost ack and crossovers
  - al corrections
- **Cr Altimetry missions**
  - → A y between different altimetry missions
  - → As ty of the altimetry system
- **Global al metry and in-situ /model data comparison**
  - → Use independent data for system stability and consistency estimation

    e.g. Tide Gauges, Temperature/Salinity profilers, Meteo Models, Radiosondes, etc

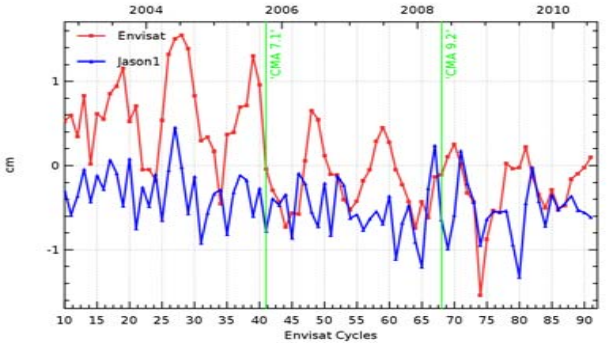




9 Jul 2010
00:04

Anomalous AUX_TIM file at 00:24

ENVISAT orbit lowering (24 Nov 2010)



In Development
Please get involved!

Sentinel-3: Summary

- **European global land and ocean monitoring mission**
  - **Optical mission to cover see 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 both AATSR and MERIS allowing**
  - **Overlap and synergy between OLCI and SLSTR**
  - **Enhanced fire monitoring capabilities**

Sentinel-3: Summary

- **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 on-board operations**
  - **allowing for systematic measurement and data download with minimum ground intervention**
- **Both L1b and L2 core products from Optical and topography mission at high-resolution**
- **Calibration and Validation planning now in progress**
- **Launch planned for last ¼ 2013**

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

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Sentinel-3 Altimetry

NOW is the time to get prepared!

GMES
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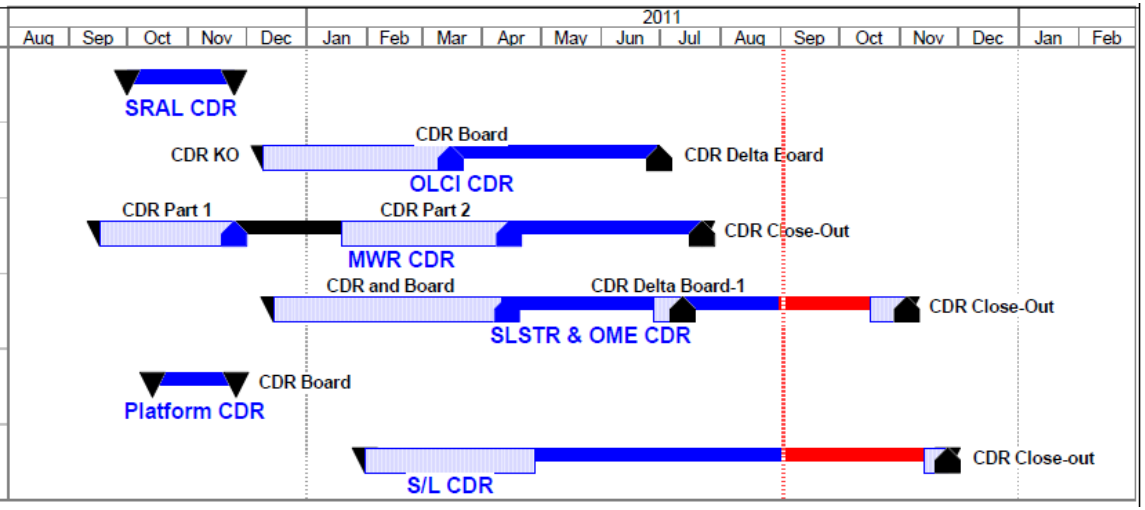
S3 Satellite General Status: Contractual

- **Sentinel-3 Satellite industrial consortium completed**
- **2nd Amendment to ESA/EC cooperation agreement to release EC funding to cover the GIO (GMES Initial Operations) until 2014 approved and signed by ESA/EC mid June 2011. It includes, among the others**
  a. Securing the Sentinel-B launch services (only requested min. down-payment)
  b. Early operations of "A" Sentinels until June 2014
- **Launch Services selection process unblocked**
  a. IPC on 29 June approved contract proposal for placement of S3A (and S2A) Launch Service Contract with Eurockot
  b. Sentinel-3B (and 2B) Launch Services selection also completed
     – **Phased approach to account for the only "partial" budget available**
     – **TEB recommendation for the selection of two VEGA's**
     – **Further recommendation to use these two VEGA's as backup for the A launchers**
  c. Negotiation of contracts for both the A and B Launch Services to be finalised by the end of 2011
     – **Consequences on Sentinel-3: two scenario's to be maintained, consisting in one launch with Rockot and one with Vega**

Sentinel-3 General Status

- **Satellite CDR review process completed with Board which took place at ESTEC on 27th of April**
  a. The Board concluded that, except for the SLSTR instrument, the Sentinel-3 design maturity is commensurate with a status as expected at a CDR.
  b. A Sentinel-3 CDR Close-out, in form of written report, expected by November 2011
- **Synthesis of Main CDR's Status:**

ID	Task Name
1	SRAL CDR
9	OLCI CDR
12	MWR CDR
17	SLSTR & OME CDR
22	Platform CDR
29	S/L CDR



Sentinel-3 CDR's Status (1/4)

- **SRAL CDR completed successfully**
  a. SRAL Design considered fully mature
  b. Only 3 Board recommendations issued, only related to documentation (VCD's completion and approval) and securisation of manufacturing processes qualification (schedule affected)
  c. No technical risks identified, PFM manufacturing on-going, flight Antenna's already delivered
- **Platform CDR completed successfully**
  a. Only 4 technical recommendations out of the 14 total (mainly documentation)
  b. No show stopper, critical recommendations closed by S/L CDR collocation
- **MWR CDR (in two parts) completed successfully**
  a. 10 recommendations in total most of which already closed
  b. Succesfull CDR close-out occurred in 2nd half of July, based on REU CDR outcome

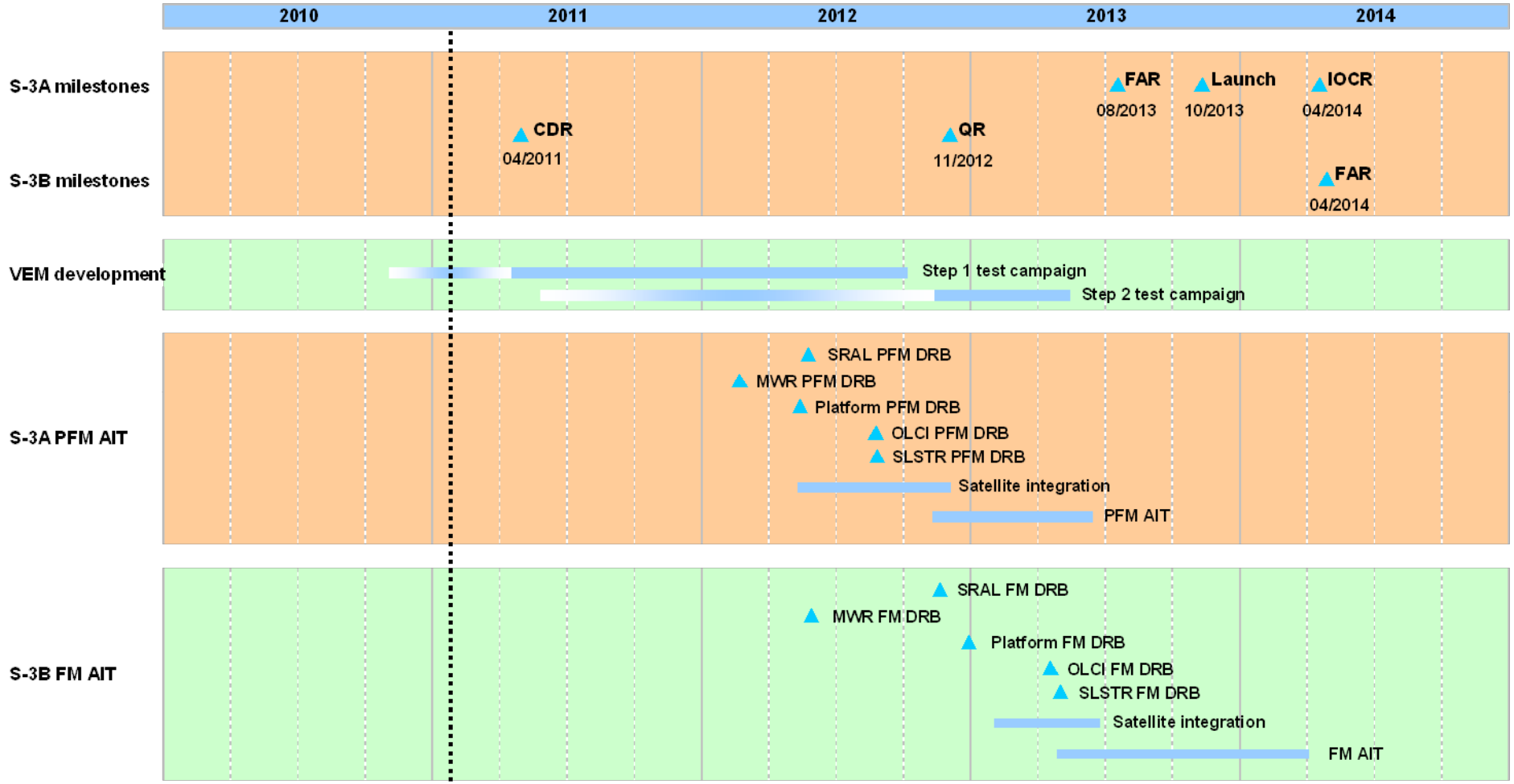
Sentinel-3 CDR's Status (2/4)

- **OLCI CDR also successfully completed (final delta Board held on 30th of June)**
  a. 7 recommendations issued, mostly closed
  b. OEU CDR close-out by TAS-E still not achieved
     – **Impacts assessment for increased power consumption and further consolidation of values blocking OEU CDR closure, now planned in October**
- **SLSTR CDR only partially achieved**
  a. Numerous open lower level CDR's in particular in the OME areas (late design consolidation)
  b. Major Delays in the availability of the instrument STM and EM models
     – **STM campaign (thermal + mechanical) on-going, TRB expected end of October '11**
     – **EM testing TRB expected later this year**
  c. Delta CDR completed on the 12th of July
     – **Still design uncertainties in the field of Structure, Cryocooler and VISCAL**
  d. CDR Close-out by end October '11 expected to confirm CDR conclusions based on STM test results and further design consolidation

S3A & S3B schedule

- **The SLSTR and the Platform are the most critical items on the satellite development schedule**
  a. Platform schedule mainly driven from Structure availability, with PCDU, PDHU and SMU immediately sub-critical
  b. SLSTR schedule driven by several elements: OME (Flip mirror and Structure in particular), Cryocooler, Detectors
- **Implementation of several mitigation actions allowed announcing a launch date of 30 October 2013**
- **As mitigation for further schedule delays, S3B activities at equipment/instrument level need to proceed rapidly**
  a. This will allow taking full benefit of eventual exchange of S3A and S3B elements
     – **Both in case of failure of one unit**
     – **Or in case of late availability, where a "partially" tested A unit integrated at S/L level may be replaced at a later stage by a fully tested B unit,**
- **Recently, in the updated GMES LTS, a tentative Launch Date for S3B of end October 2014 has been indicated, which would be compatible with the current planning**

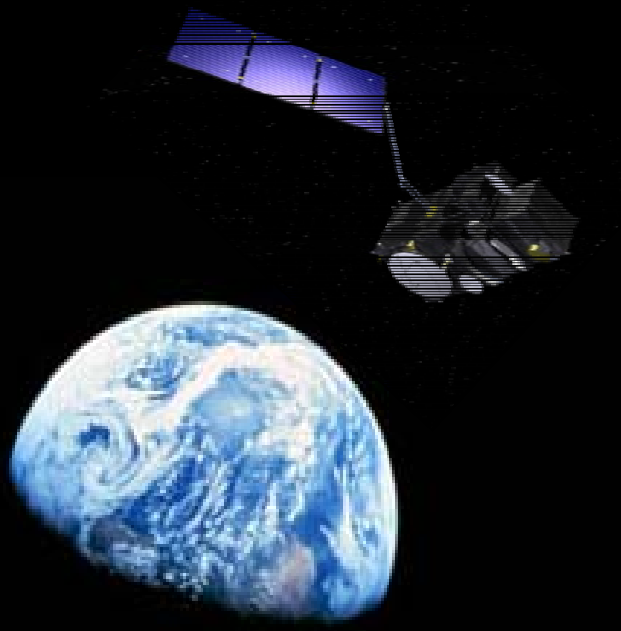
S3A & S3B schedule



Sentinel-3: Future months main activities

- **Satellite / Instrument CDR's completion**
  a. Full completion of the CDR process by Nov. 2011 is fundamental to
     - **Maintain credibility on the maturity status of the programme**
     - **Confirm credibility of current Launch Date**
- **Start of PFM MAIT activities**
  a. Instrument/Platform AIT and Satellite V-EM activities starting now at beginning of September 2011
- **Launcher Contracts placement and K.O.**
- **Phase E1 (Launch preparation and Commissioning Phase) consolidation**
  a. Through the review of the requested Launch Campaign activities
  b. …..and the consolidation of the requested CalVal activities and of the Commissioning Plan

Thank you - any questions?



For more information http://www.esa.int

See Donlon et al (2011) The GMES Sentinel-3 Mission, *Remote Sensing of Environment, In press*

and the Mission Requirements Traceability Document (MRTD) at http://download.esa.int/docs/EarthObservation/GMES_Sentinel-3_MRTD_Iss-1_Rev-0-issued-signed.pdf

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