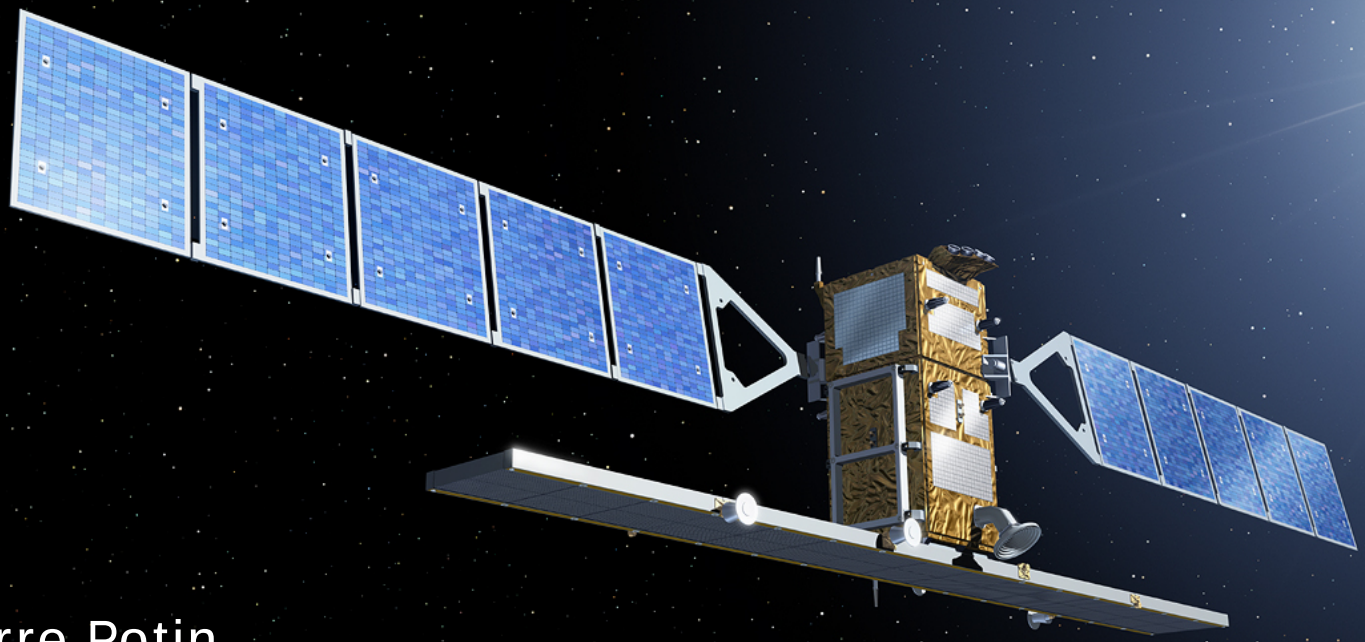
Sentinel-1 Mission Overview



Pierre Potin
Sentinel-1 Mission Manager, ESA

2nd Advanced Course on Radar Polarimetry
ESRIN, Frascati, 21-25 January 2013

Outline

1 - GMES context

2 - Sentinel-1 mission overview

3 - Sentinel overall operations concept, data policy

4 - Sentinel-1 observation concept

5 - Concluding remarks

Global Monitoring for Environment and Security - GMES

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

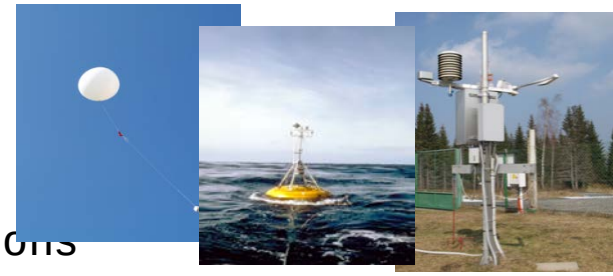
Global, timely and easily accessible information in Land, Marine, Emergency response, Atmosphere, Security and Climate Change domains

Global Monitoring for Environment and Security (GMES)

- EU/ESA co-funded program aiming at providing operational GMES services based on Earth observation and in-situ data
- Provides relevant information to policy-makers, institutional EU + MS authorities (Core service), and local/regional users (Downstream)

Space Component – developed & coordinated by ESA

- ✓ Sentinels
- ✓ Contributing (national) Missions – Data Access

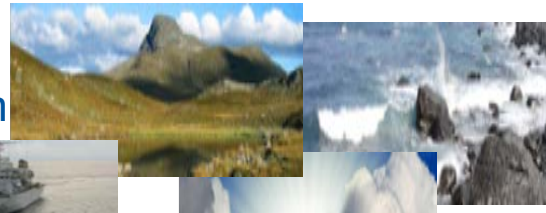


In-situ component – coordinated by EEA

- ✓ Observations mostly within national responsibility, with coordination at European level
- ✓ Air, sea- and ground-based systems and instrumentations

Service component – coordinated by EC

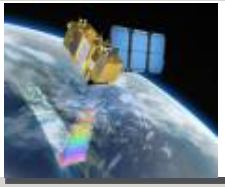
- ✓ Mapping and forecasting services: Land, Marine, Atmosph Emergency, Security and Climate Chan



GMES dedicated missions: Sentinels

Sentinel-1 (A/B) – SAR imaging
All weather, day/night applications, interferometry

2013 /2015



Sentinel-2 (A/B) – Multi-spectral imaging
Land applications: urban, forest, agriculture,…
Continuity of Landsat, SPOT

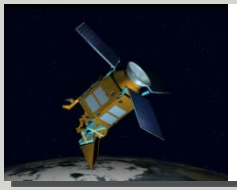
2014 /2016

Sentinel-3 (A/B) – Ocean and global land monitoring
Wide-swath ocean color, vegetation, sea/land surface temperature, altimetry

2014/2017

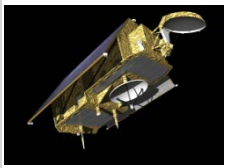
Sentinel-4 (A/B) – Geostationary atmospheric
Atmospheric composition monitoring, trans-boundary pollution

2019/2027



Sentinel-5 precursor/ Sentinel-5 (A/B) – Low-orbit atmospheric
Atmospheric composition monitoring

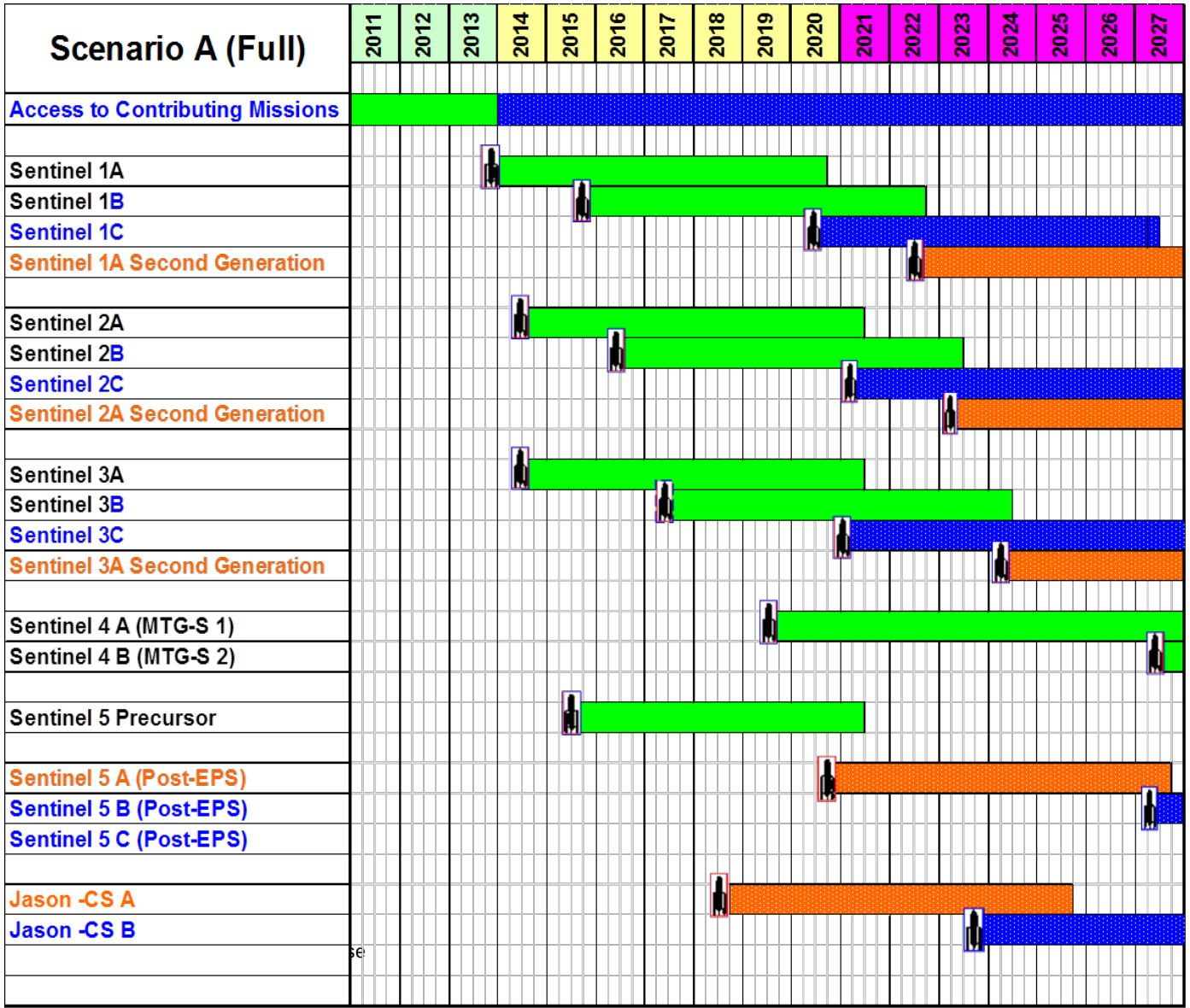
2015/2020/2027



Jason-CS (A/B) – Low inclination Altimetry
Sea-level, wave height and marine wind speed

2018/2023

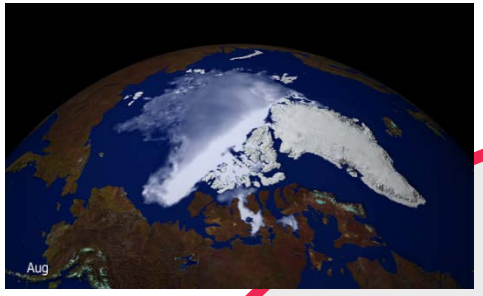
GMES Space Component: Long Term Scenario of the dedicated infrastructure



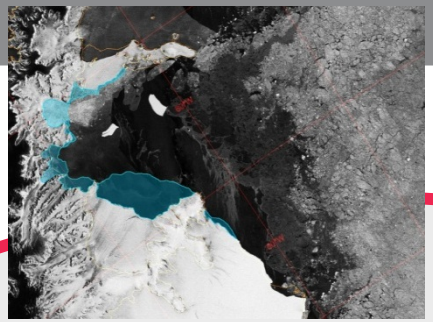
Sentinel–1: C-band SAR mission

- ✓ **Data continuity of ERS and ENVISAT missions**
- ✓ **GMES radar imaging mission for ocean, land and emergency services**
- ✓ **Applications:**
  - monitoring sea ice zones and the arctic environment
  - surveillance of marine environment (e.g. oil spill monitoring)
  - maritime security (e.g. ship detection)
  - wind, wave, current monitoring
  - monitoring of land surface motion (subsidence, landslide, tectonics, volcanoes, etc.)
  - support to emergency / risk management (e.g. flooding, etc.) and humanitarian aid in crisis situations
  - mapping of land surfaces: forest, water and soil, agriculture, etc.

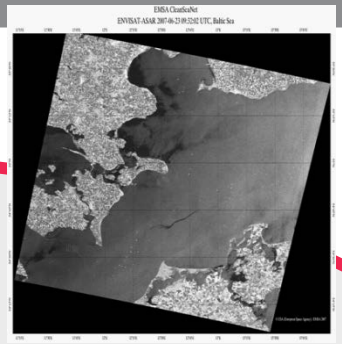
A wide range of applications



Arctic ice extent
August 2009
(Credit: MyOcean)

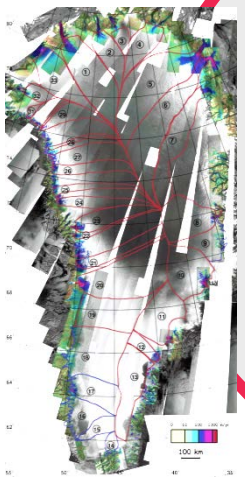


Larsen ice shelf loss between
2002 and 2009
(Credit: Polar View)



Oil spill detection
and Surveillance
(Credit: EMSA)

Ship detection
(Credit: ESA)



Acceleration of
Greenland glaciers flow
(Credit: Rignot et Al)

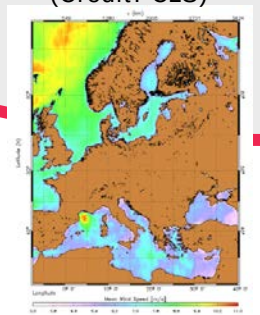
C-band SAR observations to support a wide range of applications

Land use
(Credit: ESA)

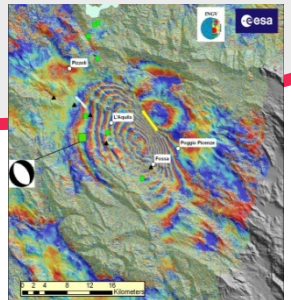
Subsidence map
1992-2006
(Credit: Terrafirma)

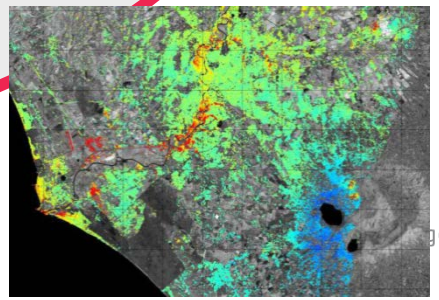
Emergency
management: flooding
(Credit: SAFER, DLR)

Mean wind speed
from 2005 to
2009
(Credit: CLS)



Earthquake
analysis
(Credit: INGV)

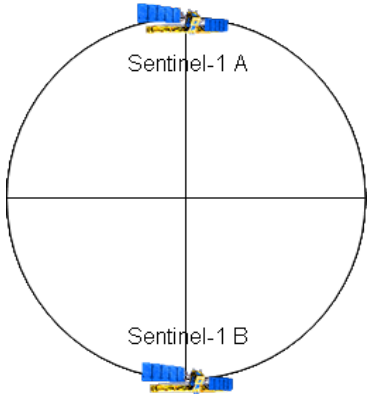


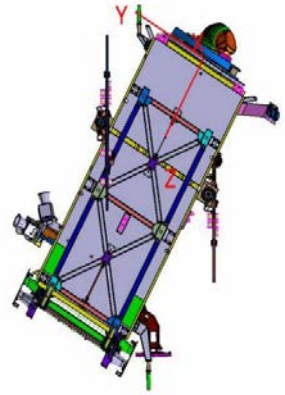


ESA UN

Sentinel-1 Mission Facts

- Constellation of two satellites (A & B units)
- C-Band Synthetic Aperture Radar Payload (at 5.405 GHz)
- 7 years design life time with consumables for 12 years
- Near-Polar sun-synchronous (dawn-dusk) orbit at 698 km
- 12 days repeat cycle (1 satellite), 6 days for the constellation
- Both Sentinel-1 satellites in the same orbital plane (180 deg phased in orbit)
- On-board data storage capacity (mass memory) of 1400 Gbit
- Two X-band RF channels for data downlink with 2 X 260 Mbps
- On-board data compression using Flexible Dynamic Block Adaptive Quantization (FDBAQ)
- Optical Communication Payload (OCP) for data transfer via laser link with the GEO European Data Relay Satellite (ERDS)
- Launch of Sentinel-1A scheduled for October 1st, 2013 (Sentinel-1B launch subject to EC funding)



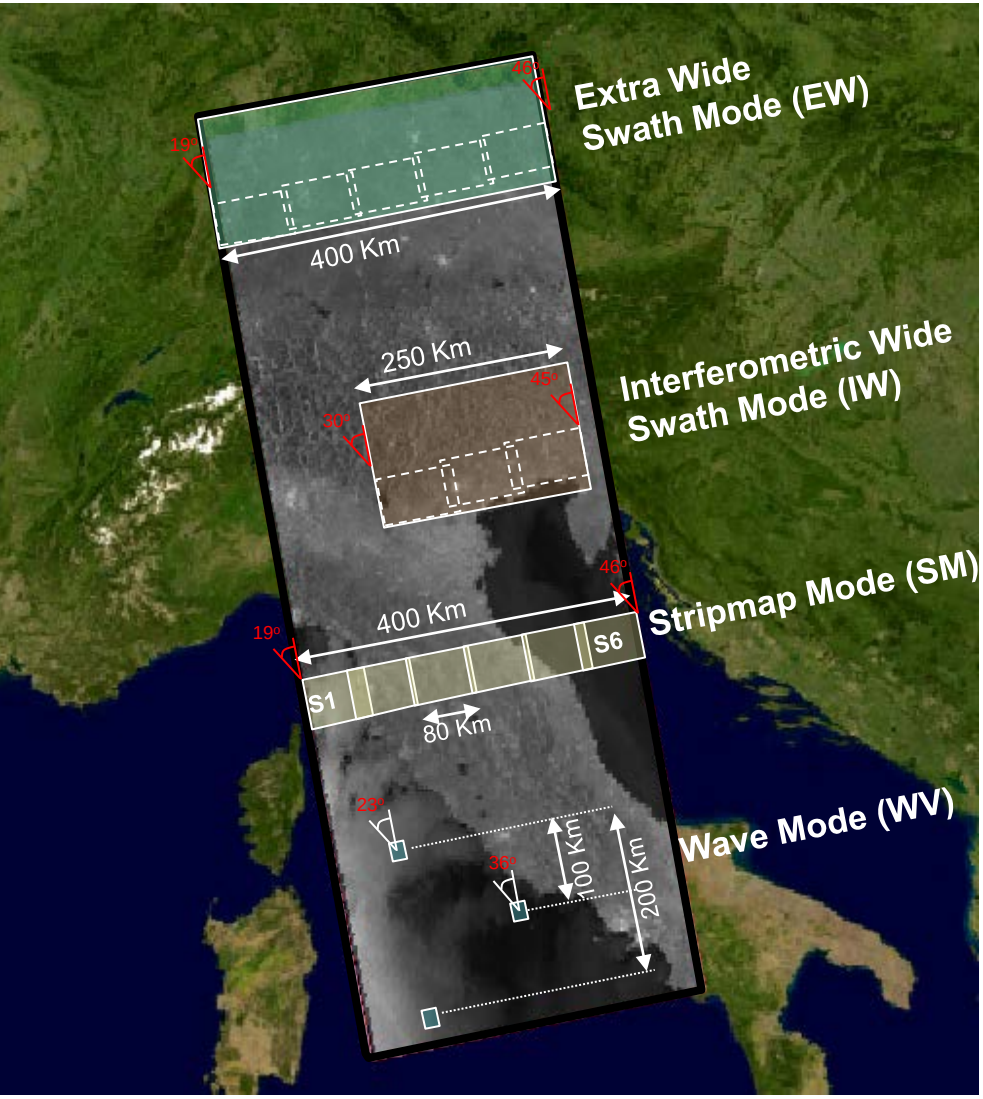


Mission Performance

Mode	Access Angle	GR Single Look Resolution	Swath Width	Polarisation
Strip Map	20-45 deg.	Range 5 m Azimuth 5 m	> 80 km	HH or VV or HH+HV or VV+VH
Interferometric Wide Swath	> 25 deg.	Range 5 m Azimuth 20 m	> 250 km	HH or VV or HH+HV or VV+VH
Extra Wide Swath	> 20 deg.	Range 20 m Azimuth 40 m	> 400 km	HH or VV or HH+HV or VV+VH
Wave mode	23 deg. & 36.5 deg.	Range 5 m (TBC) Azimuth 5 m (TBC)	> 20 x 20 km Vignettes at 100 km intervals	HH or VV

For All Modes	
Radiometric accuracy (3 σ)	**1 dB**
Noise Equivalent Sigma Zero	**-22 dB**
Point Target Ambiguity Ratio	**-25 dB**
Distributed Target Ambiguity Ratio	**-22 dB**

Sentinel-1 SAR Modes



Sentinel-1 SAR can be operated in 4 exclusive imaging modes with different resolution and coverage:

Mode Rate	SAR Mode
High Bit Rate (HBR)	IW
	EW
	SM (S1 → S6)
Low Bit Rate (LBR)	WV

Polarisation schemes for IW, EW and SM:

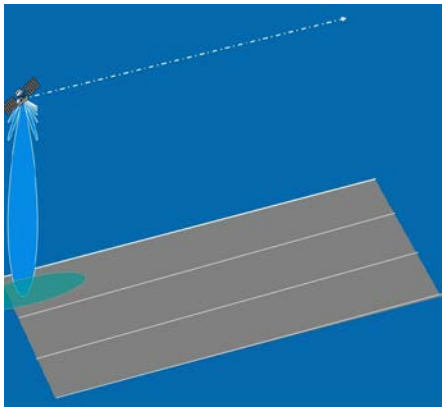
- single polarisation: HH or VV
- dual polarisation: HH+HV or VV+VH

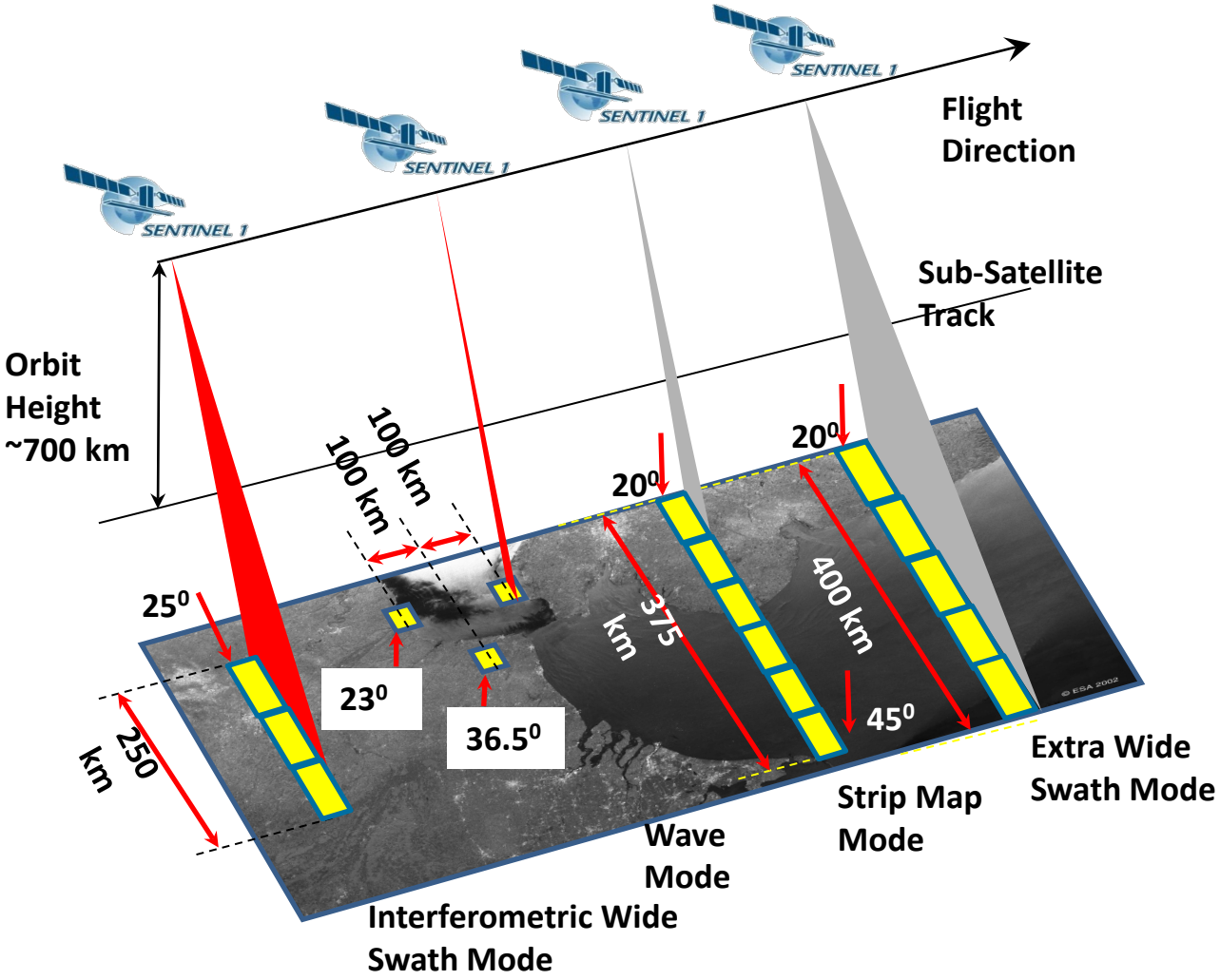
For Wave mode: HH or VV

For all of these operating modes, the same family of products is available to the users.

European Space Agency

Sentinel-1 SAR Modes: TOPS





Planned ESA Operational Products available to users

LEVEL-0 PRODUCTS

Compressed, unprocessed instrument source packets, with additional annotations and auxiliary information to support the processing.

LEVEL-1 PRODUCTS

Level-1 Slant-Range Single-Look Complex Products (SLC):

Focused data in slant-range geometry, single look, containing phase and amplitude information.

Level-1 Ground Range Detected Geo-referenced Products (GRD):

Focused data projected to ground range, detected and multi-looked.
Data is projected to ground range using an Earth ellipsoid model, maintaining the original satellite path direction and including complete geo-reference information.

LEVEL-2 PRODUCTS

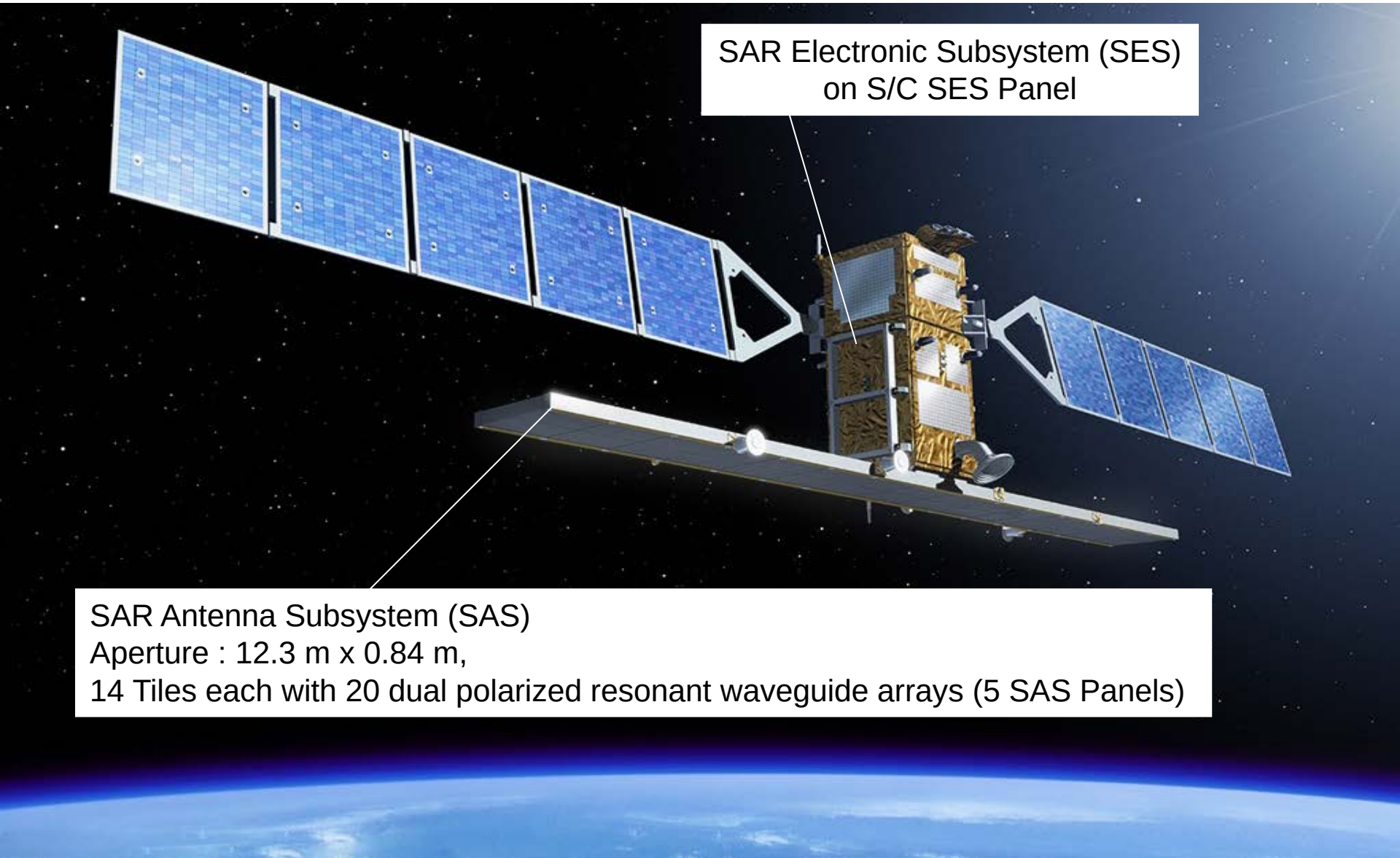
Level-2 Ocean products
Ocean wind field, swell wave spectra and surface radial velocity information as derived from SAR data.

Planned operational ESA Sentinel-1 products - L1 characteristics

Acq. Mode	Product Type	Resolution Class	Resolution [Rng x Azi] [m]	Pixel Spacing [Rng x Azi]	No. Looks [Rng x Azi]	ENL
SM	**SLC**	-	**1.7 x 4.3 to 3.6 x 4.9**	**1.5 x 3.6 to 3.1 x 4.1**	1 x 1	1
	GRD	FR	9 x 9	4 x 4	2 x 2	3.9
		HR	23 x 23	10 x10	6 x 6	34.4
		MR	84 x 84	40 x 40	22 x 22	464.7
IW	**SLC**	-	**2.7 x 22 to 3.5 x 22**	**2.3 x 17.4 to 3 x 17.4**	1	1
	GRD	HR	20 x 22	10 x 10	5 x 1	4.9
		MR	88 x 89	40 x 40	22 x 5	105.7
EW	**SLC**	-	**7.9 x 42 to 14.4 x 43**	**5.9 x 34.7 to 12.5 x 34.7**	1 x 1	1
	GRD	HR	50 x 50	25 x 25	3 x 1	3
		MR	93 x 87	40 x 40	6 x 2	12
WV	**SLC**	-	**2.0 x 4.8 and 3.1 x 4.8**	**1.7 x 4.1 and 2.7 x 4.1**	1 x 1	1
	GRD	MR	52 x 51	25 x 25	13 x 13	139.7

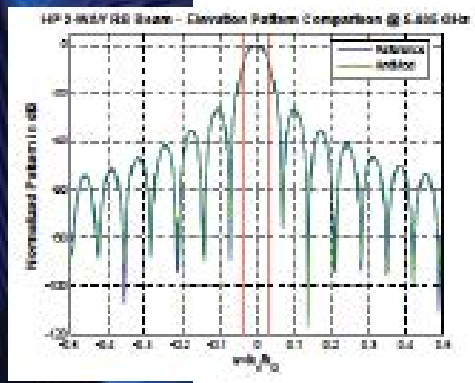
- **For Ground Range Products, the resolution corresponds to the mid range value at mid orbit altitude, averaged over all swaths.**
- **For SLC SM/IW/EW products, the resolution and pixel spacing are provided from lowest to highest incidence angle. For SLC WV products, the resolution and pixel spacing are provided for beams WV1and WV2.**
- **For SLC products, the range coordinate is in slant range. All the other products are in ground range.**

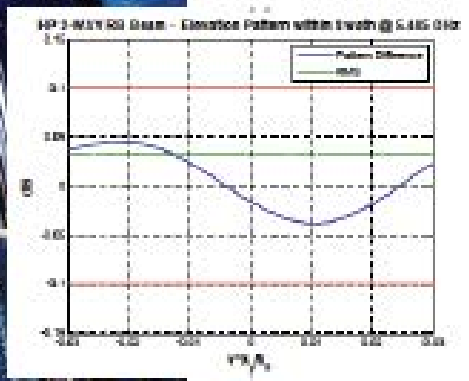
Sentinel-1 Spacecraft – SAR elements



Sentinel-1A platform

Sentinel-1A SAR Antenna





Main objectives of the Sentinel operations strategy

- Provide data to GMES services and for utilisation by ESA / EU Member States according to their specified requirements

- Ensure systematic and routine operational activities:
  - ✓ with a high level of automation
  - ✓ with pre-defined operations to the maximum extent possible

- Establish a conflict free operations profile, therefore anticipate conflict resolution, in particular with the elaboration of pre-defined mission observation scenarios
  - ✓ required in particular for Sentinel-1
  - ✓ the use of 2 spacecraft constellation allows:
    - o to solve the vast majority of potential conflicts
    - o to fulfil the necessary revisiting requirements

Sentinel Data Policy

Sentinel Data Policy
=
full and open access to Sentinel data to all users

- Aim for maximum availability of data & corresponding access services
- Support to increasing demand of EO data for
  - → implementation of environmental policies
  - → climate change initiatives

In practical terms:

- Anybody can (has the right to) access acquired Sentinel data
- Licenses for the Sentinel data are free of charge
- Online access with users registration including acceptation of generic Terms and Conditions, at no fees, within the technical and financial limits (available operations budget).

Sentinel-1 observation scenario objective

Implement a pre-defined and conflict-free observation plan, aiming at fulfilling, to the maximum feasible extent, the observation requirements from:

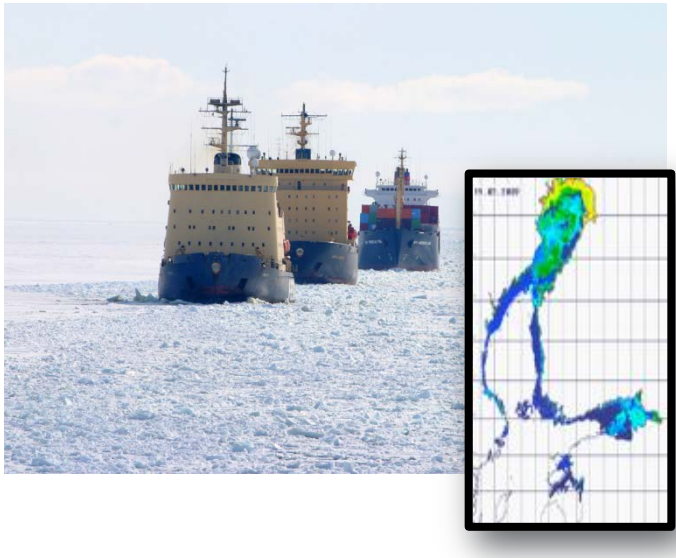
- the GMES services
- the use by ESA / EU Member States

In addition, on best effort basis and in order to ensure some continuity of ERS/ENVISAT, requirements from the science community are also considered, as well as contribution to international cooperation activities.

→ Need to find *a priori* the solutions on the potential conflict among users (e.g. different SAR operation modes / polarisation required over same geographical area)

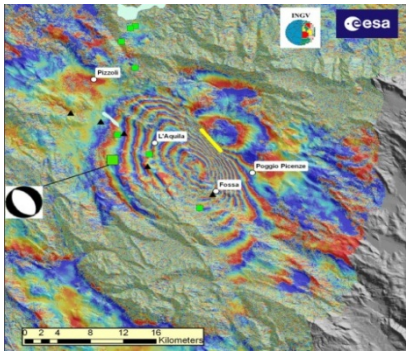
Sentinel-1 services over oceans, seas and sea-ice areas

- These services require quasi real time or near real time data, typically in less than 3 hours, and in some cases in less than 10 min.
- Quasi real time services or services requiring data within 1 hour from sensing rely on the support from collaborative ground stations
- These “monitoring” types of service require systematic or very frequent (e.g. daily) observations
- These services include, e.g.:
  - ✓ Sea-ice and iceberg monitoring
  - ✓ Oil spill monitoring
  - ✓ Maritime security information services (incl. ship detection)
  - ✓ Wind, wave, current monitoring



Sentinel-1 services and applications over land

- These services or applications cover a wide range of different thematic domains
- They do not generally require data in quasi real time, few of them require data in 3 hours NRT
- Related data are planned to be recorded on-board and downloaded to the core ground station network (direct transmission to collaborative stations may however be made in Europe)
- These services / applications include e.g.:
  - ✓ risk management in support to flooding
  - ✓ “security” services in the GMES framework
  - ✓ land motion / geo-hazard monitoring with InSAR (seismic hazards, volcanoes, landslides, subsidence / inactive mines, coastal lowland and flood defence)
  - ✓ glacier, snow monitoring
  - ✓ large ice sheet monitoring (Greenland, Antarctica, in particular to support climate change studies)
  - ✓ river and lake ice monitoring
  - ✓ global forest mapping (e.g. in support of REDD / GFOI)
  - ✓ global / regional land mapping (incl. for food security, crop monitoring, land cover and change monitoring, soil moisture, etc.).



Examples of Sentinel-1 operations constraints (list not exhaustive)

Instrument operations constraints:

- SAR modes exclusivity (incl. polarisation schemes)
- SAR mode transition time (2.4 sec.)
- SAR duty cycle (25 min/orbit for the 3 high rate modes)

Data transmission / acquisition constraints:

- Huge volume of data, potentially up to 2.4 TB/day with the two satellites
- Data rate versus X-band downlink capacity (use of on-board data compression – FDBAQ)
- Data downlink conflict between RT data transmission in dual-polarisation and download of on-board recorded data
- On-board memory sizing (1410 Gbits)
- X-band duty cycle (max. 30 min/orbit, max. 20 min consecutive)
- X-band downlink switches (X-Band system specified for a total of 150,000 operation cycles)

Process for collecting and implementing the Sentinel-1 observation requirements

Category	Source of Requirements	Status / Comments / Issues
GMES Services	- Extrapolation of Data Access Data Warehouse requirements - Direct discussions with GMES services and EMSA	- Requirements available from key current GMES services and EMSA - Issues: o GMES services which will be operational in 2014+ ? o "perimeter" of GMES services
National (public) services (in accordance with GSC Prog. Declaration)	- Discussions with Delegations - Reply to Collaborative GS questionnaire (GOCG)	- Requirements available from ~13 Member States (AT, CND, DE, DK, E, FIN, F, GR, I, NO, PT, RO, UK) - Some require clarification and/or consolidation - Reply to collaborative GS questionnaire
Scientific use, on-going ESA projects, continuity of ERS/ENVISAT	- Recommendations from scientists at key SAR workshops (FRINGE, SEASAR), Sentinel-2 workshops, SEN4SCI, etc. - ESA GSE Projects (e.g. Polar View, MARISS, Terrafirma, GMFS, etc.) - Glob-series projects, CCI, SEOM, etc. - Extrapolation of ERS/ENVISAT projects	Some requirements available. Continuous process. Requirements to be implemented in 2014.
International Initiatives, International cooperation	- GEO, CEOS, IGOS, FAO, FCT, GFOI, REDD, PSTG, IICWG, GCOS, CliC, TIGER, DRAGON, Geo-hazard Supersites, etc. - Requests from international partners (e.g. US (NOAA / NASA / USGS), Australia, China, etc.)	Some requirements available (e.g. NOAA). Requirements to be implemented in 2014
Other incl. use for commercial VA	- EARSC, etc.	

Sentinel-1 observation scenario

High level strategy during Full Operations Capacity

• Optimum use of SAR duty cycle (25 min/orbit for 1 satellite), taking into account the various constraints (e.g. limitation in number of X-band RF switches, mode transition times)

• Wave Mode continuously operated over open oceans, with lower priority w.r.t. the other high rate modes

• IW or EW modes operated over pre-defined geographical areas:

- ✓ Over land: pre-defined mode is IWS
- ✓ Over seas and polar areas, and ocean relevant areas: pre-defined mode is either IWS or EWS

• The Full Operations Capacity is reached with the 2-satellite constellation

High level strategy to fulfil observation requirements for services over LAND during Full Operations Capability

→ Baseline mode of operations: IW, if possible in dual-polarisation. Single polarisation however sufficient for INSAR operational applications

• Systematic (or very frequent) mapping of the whole Europe

• Systematic (or very frequent) mapping of tectonic / subsidence / landslides / volcano areas to support operational services based on INSAR
→Need to provide pairs in both ascending / descending passes

• Regular mapping of areas prone to risks to acquire strategic background data (e.g. for flood)

• Regular mapping of areas to support GMES security services

• Regular mapping or ice sheets (Greenland, Antarctica), polar coastal regions and of relevant areas for glacier and snow monitoring (based on season)

• Regular global/regional coverage of all land areas supporting among others forest mapping (e.g. REDD / GFOI), land cover change, crop monitoring, soil moisture, etc. based on seasonal requirements: frequency of coverage is TBD

Sentinel-1 observation scenario evolution during the operations phase

The Sentinel-1 observation plan will evolve based on:

- The inclusion of the 2nd Sentinel-1 satellite leading to the Full Operational Capacity of the missions with the 2-satellite constellation
- The gradual use of the EDRS system to complement the data downlink capacity
- The evolution of the requirements from the services (GMES, National, etc.)
- The constraints on the space and ground segment resources (e.g. core and collaborative ground station networks)
- The contribution of (and interoperability with) the Radarsat Constellation Mission from CSA

➔ A procedure will be set up to perform a regular update of the S-1 observation plan during routine operations

Synergy Sentinel-1 / RCM

- CSA-ESA discussions on-going to explore synergies between Sentinel-1 and Radarsat Constellation Mission and in view of a certain level of interoperability between the missions

- RCM – Sentinel-1 interoperability would bring strong benefits to users

- The following cooperation items are explored:
  - Joint / integrated pre-defined observation plans (complementarities in observations / modes, increased revisit, etc.)
  - Level 1 Product format
  - Harmonisation of catalogue interface
  - Development of common tools
  - Harmonised communication, joint publications etc.

- A joint calibration working group has been set up

Concluding remarks

- The Sentinel-1 mission will provide continuity to ERS and ENVISAT C-band SAR with improved performance and revisiting

- Sentinel-1 will be operated with a predefined routine observation plan currently under definition, fulfilling in priority the requirements from the GMES services and from ESA / EU Member States

- Towards a free and open access to Sentinel data for all users, within technical and budget constraints / restrictions.