

SENTINEL-1 ESA's NEW EUROPEAN RADAR OBSERVATORY

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ABSTRACT:

The ESA Sentinels constitute the first series of operational satellites responding to the Earth Observation needs of the EU-ESA Global Monitoring for Environment and Security (GMES) programme. The GMES space component relies on existing and planned space assets as well as on new complementary developments by ESA. This paper describes the Sentinel-1 mission, an imaging synthetic aperture radar (SAR) mission at C-band. It provides an overview of the mission requirements, how they were derived and some insight into the preliminary technical concept for the satellite. The information about Sentinel-1 is presented with a view to contribute to a discussion at the workshop about the suitability of spaceborne SAR to address future users needs in comparison with contributions to be expected from airborne sensors. The question is posed if airborne and spaceborne remote sensing systems are competitive or complementary to each other.

1. BACKGROUND

As part of the GMES space component, ESA is undertaking the development of a European Radar Observatory (Sentinel-1), a European polar orbiting satellite system for the continuation of SAR operational applications.

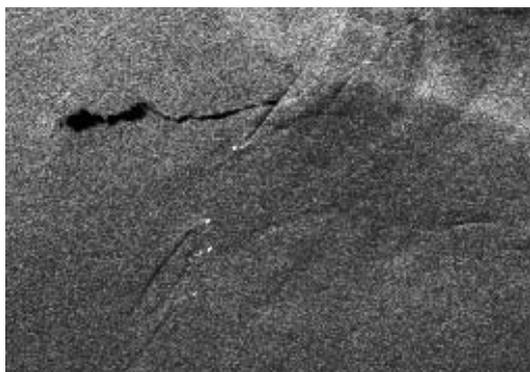


Fig. 1 Radar observation of ships and pollution

Sentinel-1 is an imaging radar mission at C-band aimed at providing continuity of data for user services. Special emphasis is placed on services identified in ESA's GMES service elements (GSE) program. Additional inputs come from on-going GMES projects funded by ESA, EU (FP5 and FP6) and ESA/EU member states. Three priorities (fast-track services) for the mission have been identified by user consultation working groups of the European Union: Marine Core Services, Land Monitoring and Emergency Services. These cover applications such as:

- Monitoring sea ice zones and the arctic environment.
- Surveillance of marine environment (Fig. 1)
- Monitoring land surface motion risks (Fig. 2)
- Mapping of land surfaces: forest, water and soil, agriculture (Fig. 3)
- Mapping in support of humanitarian aid in crisis situations

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2. DERIVATION OF MISSION REQUIREMENTS

SENTINEL-1 is user-driven and responds directly and demonstrably to user requirements. User requirements are typically formulated in terms of information needs covering areas such as:

- general description of service including a description of customers and the information products generated by the service
- description of radar information products upon which the service is based
- geographical coverage requirements
- timeliness requirements

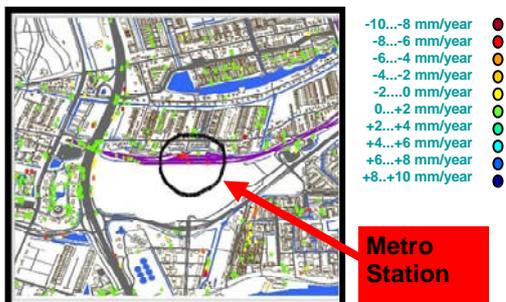


Fig. 2 Radar-based subsidence determination

Some services have a demonstrated track-record in operational SAR-image base services and have developed sufficient technical expertise to contribute directly to the technical specification of required space based observations. In other cases services have only recently been exposed to SAR through GMES programs so that firm information requirements are not yet available and interpretation is required.

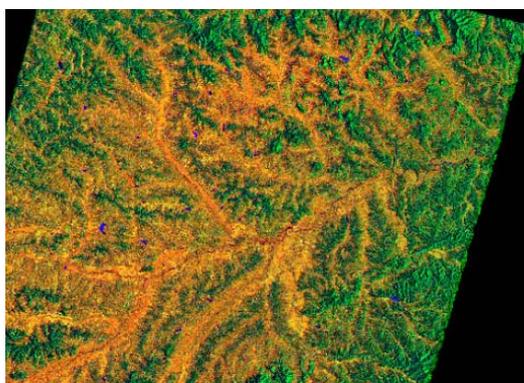


Fig. 3 Forest mapping by radar (ERS-1 & -2)

Following a preliminary review of the user requirements three mission design elements appear as keys to meeting user requirements.

Revisit

This is perhaps the most important mission parameter for operational services already exploiting SAR. These services encompass ship and oil spill detection, wind speed measurements, sea ice monitoring as well as services based on interferometric measurements. Daily revisit or better of maritime and the Arctic environment areas are a firm requirement. Exact revisits (i.e. same orbit) of 14 days or less are required for services based on interferometric measurements.



Fig. 4 Emergency service: radar-based flood mapping

Coverage

In addition to daily revisit, a minimum instantaneous swath coverage of 200-300km is required for the mapping of rapidly changing phenomena (e.g. sea ice, ship detection).

Timeliness

Quick and reliable access to SAR data is a third key requirement of many services. For ship detection, for instance, the near-real-time (NRT) delivery of data within 1 hours of acquisition is essential.

Additional mission requirements and a discussion on their derivation are summarised in the Mission Requirements Document (Attema, 2005).

3. SENTINEL-1 SYSTEM

Sentinel-1 is an imaging Synthetic Aperture Radar mission at C-band. The design of its

system has been driven by the need for continuity of ERS/Envisat class data provision with improved revisit, coverage, timeliness and reliability of service. Its main technical characteristics are listed below.

Orbit

Sentinel-1 will be in a near-polar sun-synchronous orbit with a 12-day repeat cycle and 175 orbits per cycle.

Operational Modes

Sentinel-1 has four nominal operational modes designed for inter-operability with other systems.

1. Stripmap Mode (SM) with 80 km swath and 5x5 metre spatial resolution
2. Interferometric Wideswath Mode (IW) with 250 km swath, 5x20 metre spatial resolution and burst synchronisation for interferometry
3. Extra-wide Swath Mode (EW) with 400 km swath and 25x100 metre spatial resolution (3-Looks)
4. Wave Mode (WV). Sampled image mode with low data rate and 5x20 metre spatial resolution.

Operations

Sentinel-1 is anticipated to work largely in a pre-programmed fashion imaging all global land masses, coastal zones, shipping routes in full resolution (IW mode) and covering the global ocean with imageries (WV mode). To satisfy revisit requirements a constellation of satellites is required with 2 satellites as a minimum. With both satellites operating for 20 minutes per orbit, ESA's Member States and Canada will be fully imaged every two days or better - dependent on latitude - in full imaging mode and the remainder of the world every six days or better.

Data Delivery

Due to consistent and conflict-free mission operations Sentinel-1 provides a high level of service reliability with near-real time delivery of data within one hour after reception by the ground station and with data delivery from archive within 24 hours.

Polarisation

Sentinel-1 has selectable single polarisation (VV or HH) for the Wave Mode and selectable dual polarisation (VV+VH or HH+HV) for all other modes.

Data Quality

The sensitivity of Sentinel-1 expressed by the noise equivalent sigma naught is specified to be -22 dB or better. The radiometric accuracy of its data products is within a statistical error (3-sigma value) of 1.0 dB. For distributed targets the ambiguity ratio is specified to be -22 dB or better.

Launch Date

Sentinel-1 is expected to be launched in 2011.

4. SPACEBORNE AND AIRBORNE REMOTE SENSING

The new space assets brought to the GMES programme by ESA's Sentinel missions do not necessarily satisfy all emerging requirements for global monitoring and security. In particular the requirements for very high spatial resolution regional radar observations during emergency situations may be better served by some of the national radar projects currently under development. For further reduction of revisit intervals collaboration with other international organisations is also pursued.

In-situ observation networks and airborne sensors may have a role to play as well. However, with the introduction of the Sentinel missions and the concept of reliable and frequent data supply - similar to the current daily satellite weather data - the need for airborne sensors to replace satellite data sources will become questionable. It is to be expected, however, that airborne and spaceborne remote sensing will continue to cover complementary requirements. For ESA's missions airborne remote sensing has been an invaluable tool for mission development, validation and algorithm development. Satellite data on the other hand are routinely used as background information for the efficient deployment of airborne remote sensing resources.

REFERENCE

Attema, E., 2005. Mission Requirements Document for the European Radar Observatory Sentinel-1, ESA, ES-RS-ESA-SY-0007, Noordwijk, The Netherlands, http://esamultimedia.esa.int/docs/GMES/GMES_SENT1_MRD_1-4_approved_version.pdf (accessed Friday, 01 September 2006).