New Operational Radar Remote Sensing Satellites for GMES

How to Vote for the Satellite You Ne

The ESA (European Space Agency) Sentinels constitute the first series of operational satellites responding to the Earth Observation needs of the EU (European Union) - ESA GMES (Global Monitoring for Environment and Security) program. 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 SAR (Synthetic Aperture Radar) mission at C-band. It provides an overview of the mission requirements and shows how the needs of future users are taken into account.

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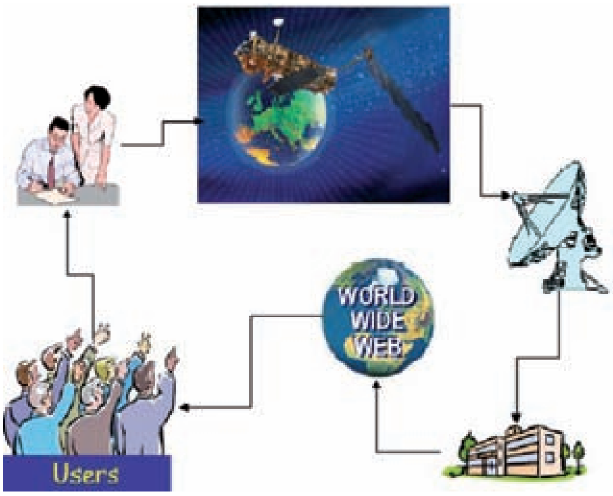


Fig. 1: The Birth of a new Earth Observation Satellite.

It has been suggested that the history of remote sensing and earth observation began with the invention of photography in 1839 and with the use of balloon photography for topographic surveying proposed one year later. Satellite Earth Observation programs were initiated during the 1960s and 70s and currently we depend on spaceborne sensors to assist in tasks ranging from weather prediction, crop forecasting and mineral exploration to applications as diverse as pollution detection, rangeland monitoring, and commercial fishing. Earth observation is still developing quickly, with many new sensors and improved spacecraft put into orbit each year (Ref. 1, Ref. 2).

Earth observation technology no longer relies solely on cameras taking pictures of the Earth using visible reflected sunlight. It also includes sensors for emitted radiation not visible to the human eye and active systems such as Lidar and SAR for weather-independent observation day and night. After more than a decade of experience with scientific radar sensors, the ESA is currently developing the new Radar Observatory (Sentinel-1), a European polar orbiting satellite system for operational services.

In this paper, the example of the Sentinel mission is used to explain who drives these developments in Europe, how priorities are defined and how user requirements are taken into account.

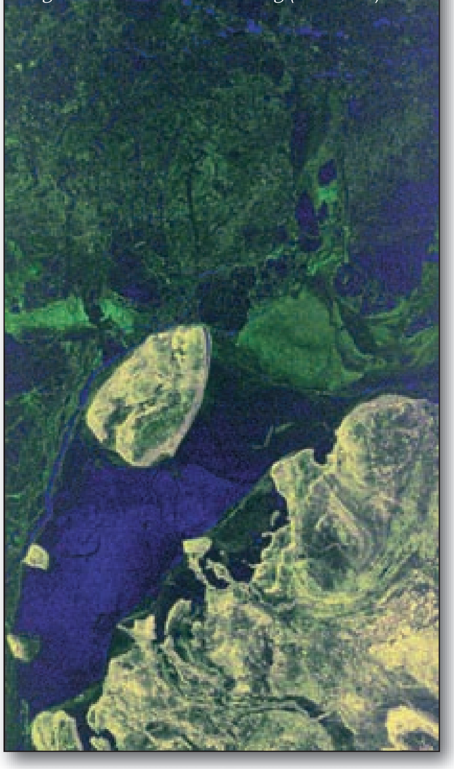
Conception of a Program

Most large Earth observation satellite programs were conceived following the general procedure depicted in Fig. 1. Initially, a proposal is made to a sponsor organization for funding. The contents of such a proposal depend very much on the programmatic framework. For a purely commercial undertaking, the proposal would be a business plan stressing the market opportunities for the satellite data products and the prospect of profit. In the framework of research and development programs, the proposal would emphasize the degree of technological innovation of the system, the value of the data products for Earth sciences and the potential for remote sensing application development. After agreements have been reached and contracts are signed the systems are built, satellites are launched and the data products are delivered to the end user. Satellite data (images) can be free from open sources or may need to be ordered and paid for. In many cases the satellite images themselves are not the final product delivered to the end user but rather the information extracted from the satellite data by specialized interpretation centers or value-adding companies.

In the above cases the end users of the data products are not actively involved in the early project phases. This makes some people feel that satellites come and go in an unpredictable and uncontrollable fashion. It is interesting to note that this situation does not really apply to meteorological end users. Meteorological remote sensing satellites are used operationally on a daily basis, and new satellites are designed to satisfy user requirements for weather forecasting and climate monitoring.

In Europe, the development of space technology is being coordinated by the ESA under the tight control of its Member States and their normal democratic procedures. Although parliamentary debate on the space technology bud-

Fig. 2: Radar sea ice monitoring (Photo ESA).



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get does not make it to the headlines, in principle every interested taxpayer could - indirectly - vote in favor of or against a new Earth observation program. For mature Earth observation applications other than meteorology, a new European program framework for operational satellites is emerging, based on the explicit requirements of services provided to the end user. The GMES program is a joint initiative of the EU and the ESA and is currently aimed at satisfying the requirements of three high priority services identified by user consultation groups on Marine Core Services, Land Monitoring, and Emergency Services.

Sentinel-1 Mission Requirements

As part of the GMES space component, ESA is developing the Sentinels, a series of new satellite systems. Sentinel-1 is an imaging radar mission at C-band aimed at providing continuity of data for user services. They cover applications such as monitoring sea ice zones (Fig. 2) and surveillance of marine environment; mapping land surfaces: forest, water and soil, agriculture; monitoring land surface motion and construction damage risks (Fig. 3); and mapping in support of humanitarian aid in crisis situations.
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 the general description of the service, a description of customers and the information products generated by the service. Some services have a well-established track record in operational SAR image-based services and have developed sufficient expertise to contribute directly to the technical specification of required space-based observations. In other cases services have only recently been exposed to SAR, resulting in difficulty defining the information requirements for new satellites, and interpretation is required.
Following a review of the user requirements it appears that many users hesitate to fully integrate satellite data from experimental satellites into their services because there are doubts about reliability. Can we rely on the data supply for an extended period? In addition to this important emphasis on continuity, three other mission design elements appear key 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 measure-

Sentinel-1 Technical Characteristics

Sensor type	Synthetic Aperture Radar			
Wave Band	C-band (5.405 Ghz)			
Orbit	Near-Polar Sun-synchronous			
Repeat Cycle	12-day, 175 orbits per cycle			
Operational Mode	Strip Map Mode	Interferometric Wide-swath Mode	Extra-wide Swath Mode	Wave Mode
Swath	80 km	250 km	400 km	Sampled Image
Spatial Resolution	5x5 meter	5x20 meter	25x100 meter (3-looks)	5x20 meter
Polarization	Single (VV or HH) for the Wave Mode and Selectable Dual Polarization (VV+VH for HH+HV) for all other Modes			

ment, sea ice monitoring as well as services based on interferometric measurements. Daily revisit or better of maritime and Arctic environment areas are a firm requirement for several services. Exact revisits (i.e. same orbit) of 14 days or less are required for services based on interferometric measurements.

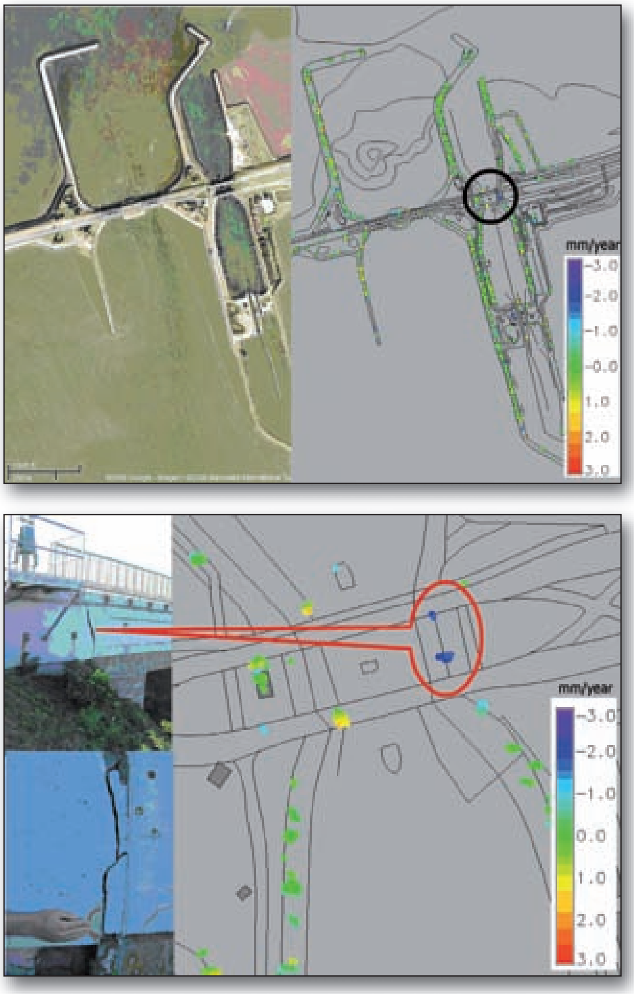

Fig. 3: Radar detection of structural instability. For the sluice complex Kornwerderzand in the Netherlands, satellite radar reflections identify potentially unstable locations.

Coverage and Timeliness

In addition to daily revisits, a minimum instantaneous swath coverage of 200 to 300 kilometers is required for mapping rapidly changing phenomena such as sea ice and ship detection. 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 one hour of acquisition is essential.

Additional mission requirements and a discussion of their derivation are summarized in the Mission Requirements Document (Ref. 3). Some technical characteristics of the current design are listed in the table. The interested reader is encouraged to contact the authors for more involvement in current applications and suggestions for the system of the future.

Sentinel-1 is anticipated to work largely in a pre-programmed fashion, imaging all global landmasses, coastal zones, and shipping routes in full resolution and covering the global ocean with sampled images (Wave Mode). To satisfy revisit requirements, a constellation of satellites is required with two 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 - depending on latitude - in full imaging mode and the remainder of the world every six days or better.

Due to consistent and conflict-free mission operations, Sentinel-1 will provide a high level of service reliability with near real-time delivery of data within one hour of reception by the ground station and data delivery from archive within 24 hours. The launch of Sentinel-1 is planned for 2011.

Spaceborne and Airborne

The new space assets brought to the GMES program 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 observations may be better served by airborne remote sensing. However, with the introduction of the Sentinel missions and the concept of reliable and frequent data supply - similar to current daily satellite weather data - the need for airborne sensors to provide data with fast turn-around delivery times will disappear.

Moving Ahead

The example of the Sentinel-1 mission shows that European Earth observation is moving ahead towards operational services, comparable to the level of meteorological services, for other sensors such as radar. At the current stage of satellite system development, potential end users have opportunities to influence the design of such systems, to fine-tune the services they propose.

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