Sentinel-2

The Optical High-Resolution Mission for GMES Operational Services


Sentinel-2 will extend land-imaging missions such as Landsat and Spot. Shown is a Spot image of Berlin in 2004. (© CNES 2004 – Distribution Spot Image)

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The ESA Sentinels will be the first series of operational satellites to meet the Earth observation needs of the European Union-ESA Global Monitoring for Environment and Security (GMES) programme. The pair of Sentinel-2 satellites will routinely provide high-resolution (10–20 m) optical images globally with frequent revisits tailored to the needs of GMES land and emergency services. Sentinel-2 aims at ensuring continuity of Spot- and Landsat-type data, with improvements to allow service evolution. The first launch is expected in 2012.

What Users Need

The pair of Sentinel-2 satellites will routinely generate valuable information for the European Union (EU) and its Member States as part of the Global Monitoring for Environment and Security (GMES) programme, in the areas of global climate change (Kyoto Protocol and ensuing regulations), sustainable development, European environmental policies (such as spatial planning for the Soil Thematic Strategy, Natura 2000, and the Water Framework Directive), risk management, the

Common Agricultural Policy, development and humanitarian aid, and common foreign and security policy.

To meet these needs, Sentinel-2 data will underpin the routine generation of products such as: generic land-cover, land-use and change maps, and risk mapping and fast images for disaster relief. They will also evolve towards the generation of geophysical variables like leaf coverage, leaf chlorophyll content and leaf water content.

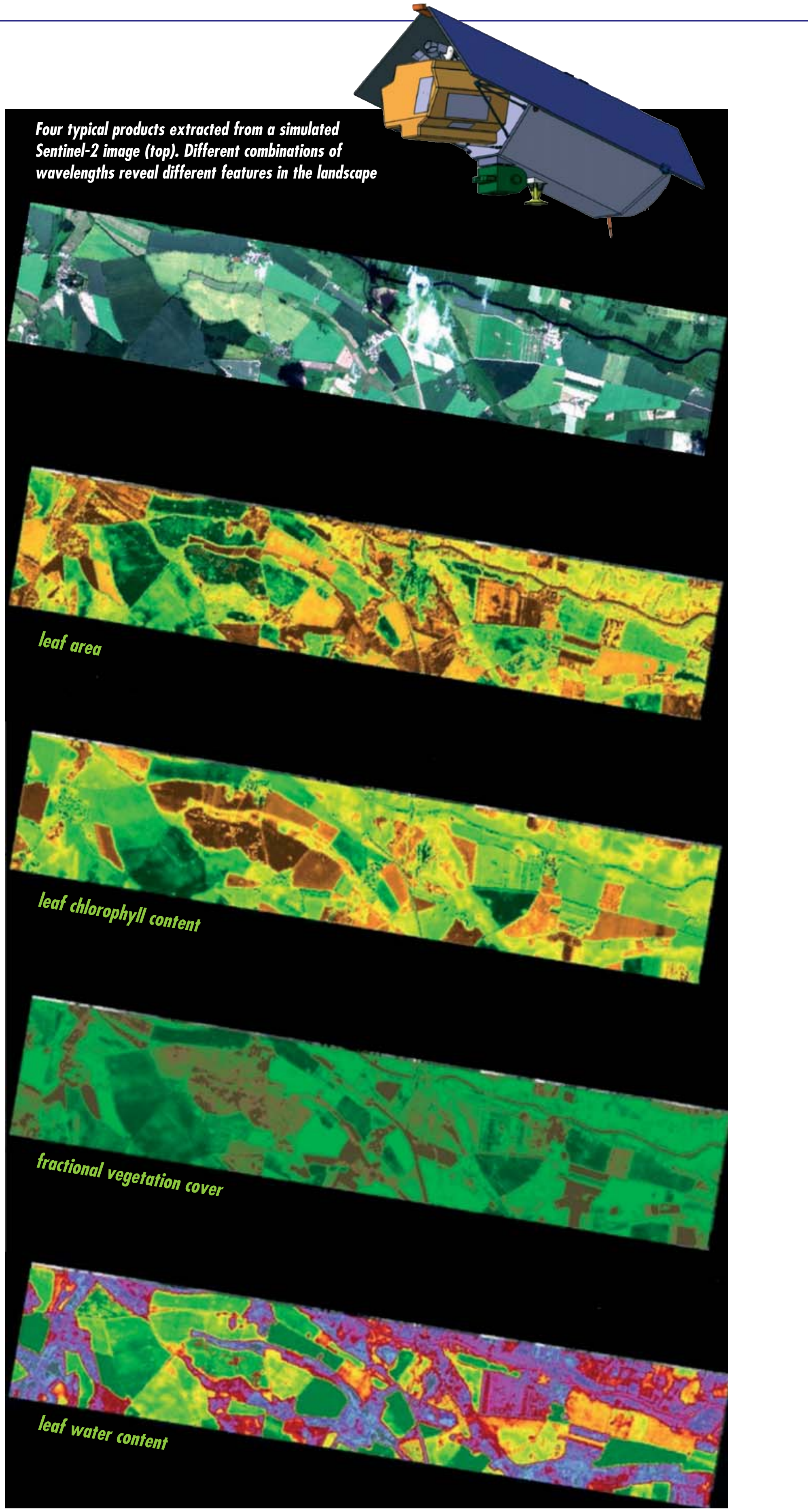
GMES will use Sentinel-2 along with with other optical satellites to provide complete observations. Conversely, Sentinel-2 will be a member of the land-surface imaging constellation of the international Committee on Earth Observation Satellites (CEOS), who will coordinate access to the missions of the same type (especially for Landsat data-continuity) to improve the final information for users. Sentinel-2 will ensure European independence while contributing to the global push for improved land imaging.

These goals have driven the design towards a dependable multispectral Earth-observation system that ensures continuity for Landsat and Spot observations and improves data availability for users. That, in turn, has identified priority improvements over past satellites.

Geographic coverage

The mission is dedicated to the full and systematic coverage of land surfaces (including major islands) from 56ºS (southern Americas) to +83ºN (northern Greenland), providing cloud-free products every 15–30 days. To achieve this and for reliability, a constellation of two operational satellites is required, yielding 5 days between revisits. At the beginning, with only one satellite, the gap is 10 days (although optical instruments on other GMES satellites will help to fill the gaps).

Additionally, some limited geographical areas will be reachable within 1–3 days in emergencies such as floods and earthquakes by rolling and tilting the satellite.



Four typical products extracted from a simulated Sentinel-2 image (top). Different combinations of wavelengths reveal different features in the landscape

By comparison, the US Landsat-7 has 16-day revisits and Spot 26-day revisits, and neither provides systematic coverage of land.

In order to support operational services for at least 15 years from the launch of the first satellites, a series of four satellites is planned, with two operating in orbit and a third in ground storage as backup.

Spectral coverage

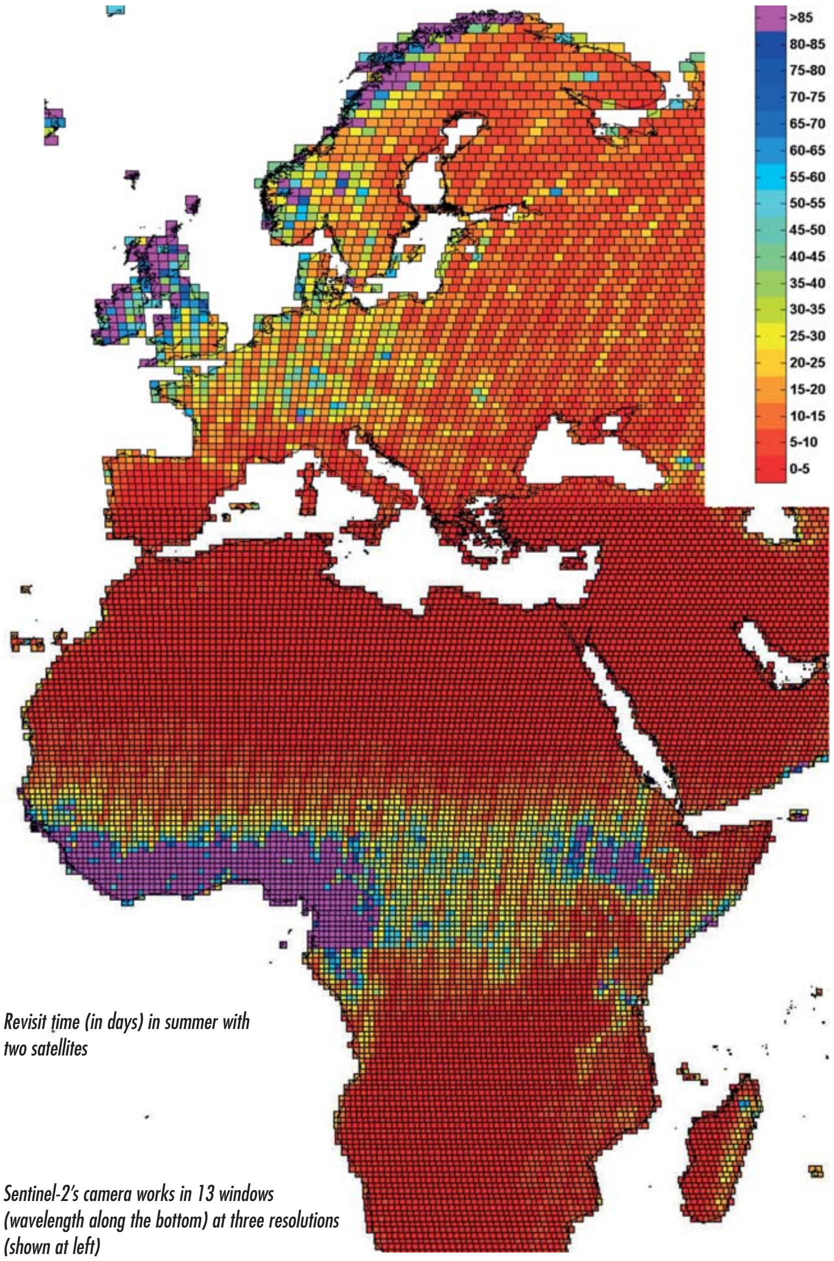
The Multi-Spectral Instrument (MSI) features 13 spectral bands from the visible and near-infrared (VNIR) to the short-wave infrared (SWIR), featuring four at 10 m, six at 20 m and three at 60 m resolution. The best compromise in terms of user requirements and mission performance, cost and schedule risk, it provides enhanced continuity for Spot and Landsat, with narrower bands for improving identification of features, additional red channels for assessing vegetation, and dedicated bands for improving atmospheric correction and detecting cirrus clouds.

Processing and distribution

After reception, the data will be processed systematically over predefined areas in predefined time windows, selected by user requests. The data will then be made available to users who have notified their interest in that particular set. Dissemination will be performed mostly online. This avoids individual ordering. It is made possible by the largely repetitive geographical coverage that can dispense with day-to-day mission planning. However, on-demand production and delivery will be provided for important specific cases like disaster management. Mission planning is required only for the roll-tilt manoeuvre in these unpredictable cases.

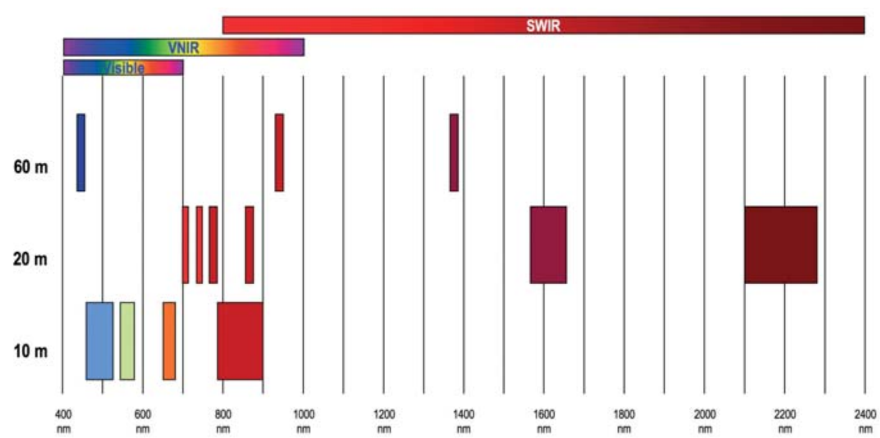
Mission Description

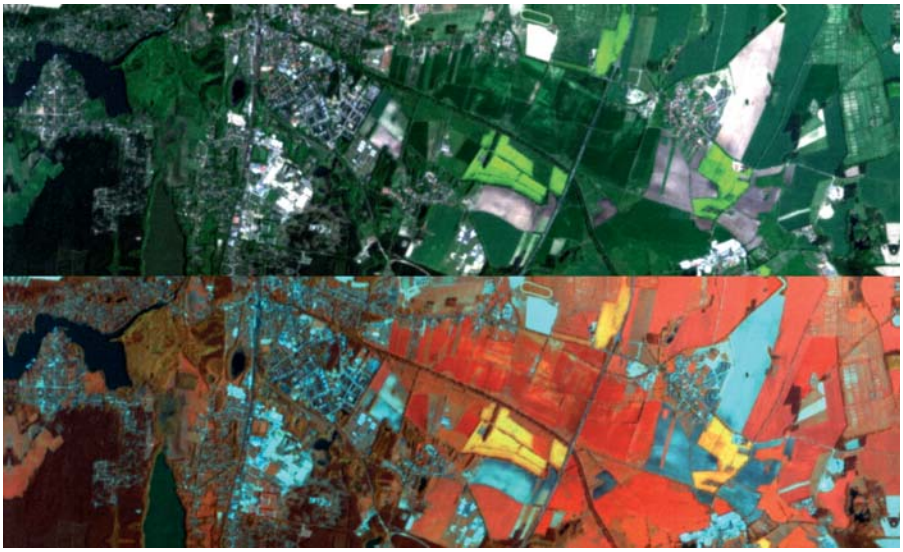
Frequent revisits and high mission availability require two Sentinels operating simultaneously, which dictates a small, cost-effective and low-risk satellite. The orbit is Sun-synchronous at 786 km altitude (14+3/10 revolutions



Revisit time (in days) in summer with two satellites

Sentinel-2's camera works in 13 windows (wavelength along the bottom) at three resolutions (shown at left)





Simulated Sentinel-2 colour composite images using the red/green/blue bands (above) and near-infrared/red/green (below)

per day) with a 10:30 a.m. descending node. This local time is the best compromise between minimising cloud cover and ensuring suitable Sun illumination. It is close to the Landsat local time and matches Spot's, allowing the seamless combination of Sentinel-2 data with historical images to build long-term time series. The two satellites will work on opposite sides of the orbit.

The ground station network must provide long contact times in order to downlink all the observations; at least four core stations are required. One polar station for telemetry, tracking and control is sufficient. To a limited extent, the system will also allow direct reception by local user stations for near-realtime applications.

The Satellites

A compact 1 t satellite will be launched on ESA's Vega (baseline, with Rockot as backup). The satellite is designed for a 7-year lifetime, with propellant for 12 years of operations, including de-orbiting at the end. The roof-shaped configuration with a fixed body-mounted solar array as defined in Phase-A/B1 leads to a simple mechanical design, without solar array deployment or drive mechanisms. The satellite is controlled in 3-axes via high-rate multi-head startrackers, mounted on the camera structure for better pointing accuracy and stability, and gyroscopes and a satnav receiver. Power comes from high-efficiency gallium arsenide triple-junction solar cells and a lithium-ion battery. The satellite is tilted at 22.5° to its roll axis to maximise the illumination of its solar array.

Images are stored in a 2 Tbit solid-state mass memory before down-linking at 450 Mbit/s in the X-band. Command and control is performed through an omni-directional S-band antenna.

Multispectral instrument

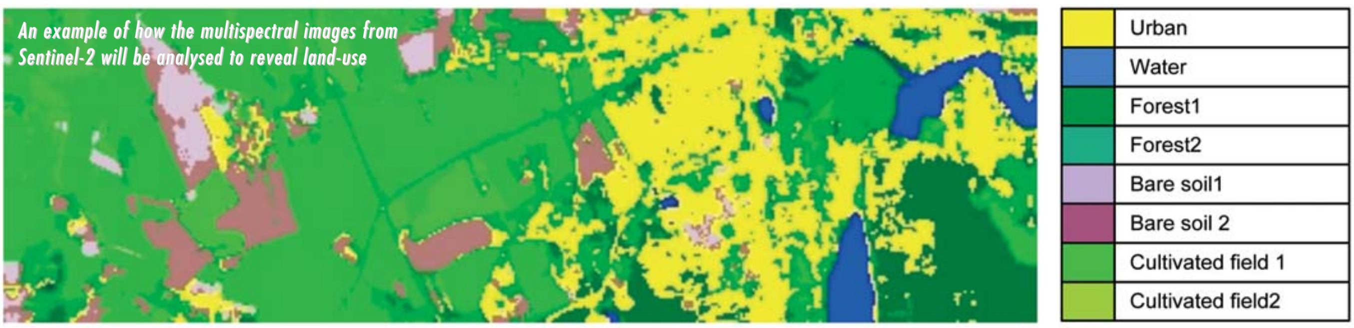
MSI features a three-mirror anastigmat telescope with a pupil diameter of about 150 mm; it is the key to the high image quality across the wide field of view of 290 km (Landsat 185 km, Spot 120 km). The telescope structure and mirrors are made of silicon carbide to minimise thermal deformation.

The VNIR focal plane employs monolithic CMOS (complementary metal oxide semiconductor) detectors, while the SWIR uses a mercury-cadmium-telluride detector hybridised on a CMOS read-out circuit. A dichroic beam-splitter separates the VNIR and SWIR channels. A combination of partial onboard calibration, using a Sun diffuser, and calibration with ground targets will guarantee high radiometric performance.

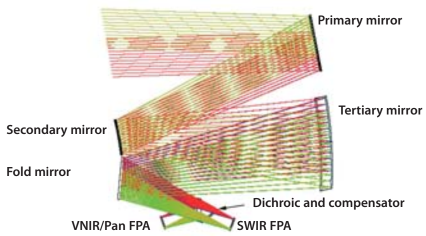
The detector signals are digitised at high resolution (12-bit), and state-of-the-art lossy data compression reduces the data volume. The compression ratio will be fine-tuned for each spectral band to ensure that there is no significant effect on image quality.

A shutter prevents direct viewing of the Sun in orbit and contamination during launch. The average observation time per orbit is 16.3 minutes, with a peak value of 31 minutes.

In order to mitigate the development risks and secure the development schedule, the technologies for building the critical VNIR and SWIR detectors and



An example of how the multispectral images from Sentinel-2 will be analysed to reveal land-use



The complex light path within the camera allows a more compact instrument. FPA is the Focal Plane Assembly.

filter assemblies are being developed before the main project begins. Each pre-development involves two manufacturers to reduce risks, foster competition and meet ESA's geographical return requirements for the main phase.

Ground segment

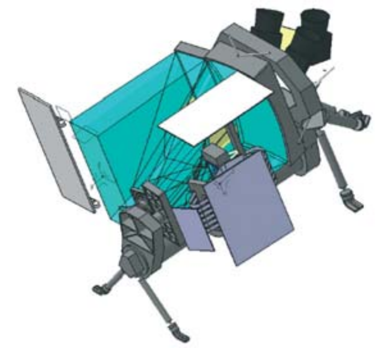
The ground segment includes a Flight Operations Segment for commanding the satellite, and a decentralised Payload Data Ground Segment, an evolving multi-mission infrastructure for mission planning, data reception, processing, archiving, quality control and dissemination.

The users in the dispersed Service Segment will take data from different satellites in combination with non-space data to deliver customised services to the final users.

Sentinel-2 will be a key European source of data for the GMES Land Fast-Track Monitoring Services and will contribute to the GMES Risk Fast-Track Services. It will provide continuity of data to ESA's GMES Service Element projects such as forestry (GSE Forest Monitoring), soil and water resources mapping, urban mapping and classification (SAGE, Urban Services, Coastwatch, GSE Land, RISK-EOS).

Conclusion

The Sentinel-2 wide-swath high-resolution multispectral system will provide improved continuity for Spot- and Landsat-type observations, with improved revisit time, coverage area, spectral bands, swath width, and radiometric and geometric image quality, meeting GMES needs for operational land and emergency services.



Sentinel-2's multispectral camera

The Sentinel-2 Definition Phase-A/B1 was performed by ESA in 2005 and 2006 with an industrial consortium led by Astrium GmbH (mission prime, platform, system engineering), with Astrium SAS as the major subcontractor (payload, system support). Following the completion of this phase in January 2007, the Invitation to Tender for the Implementation Phase was released in February 2007. This Phase-B2/C/D/E1 is expected to start in October 2007, with launch of the first satellite projected for 2012.