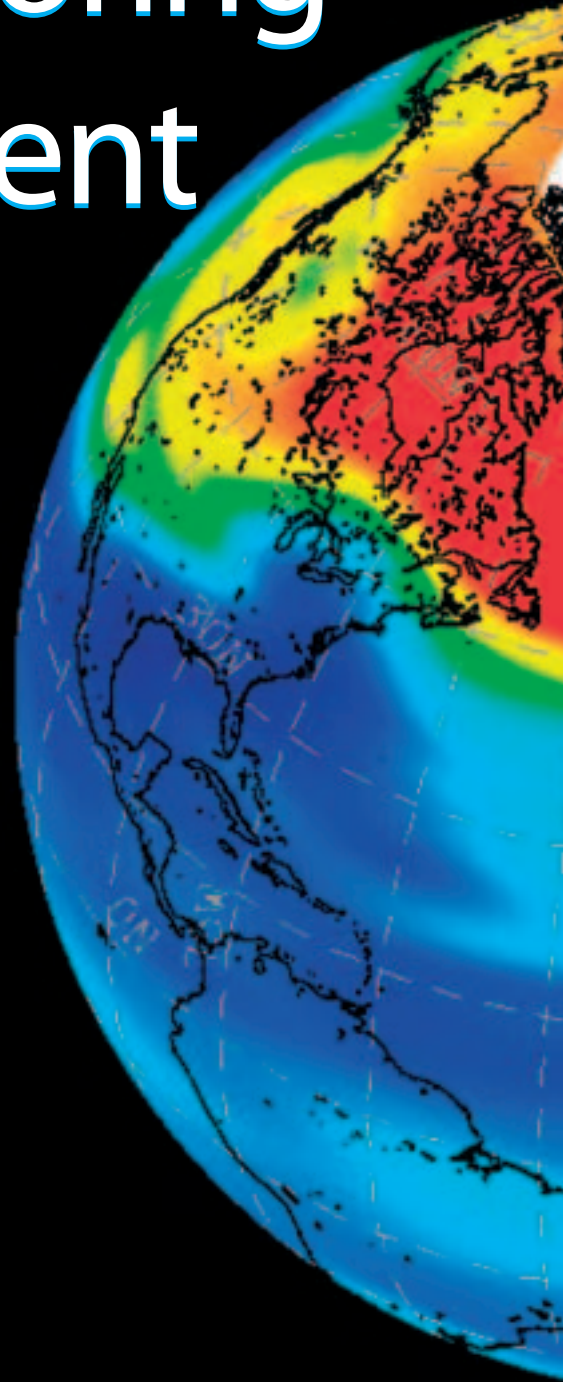
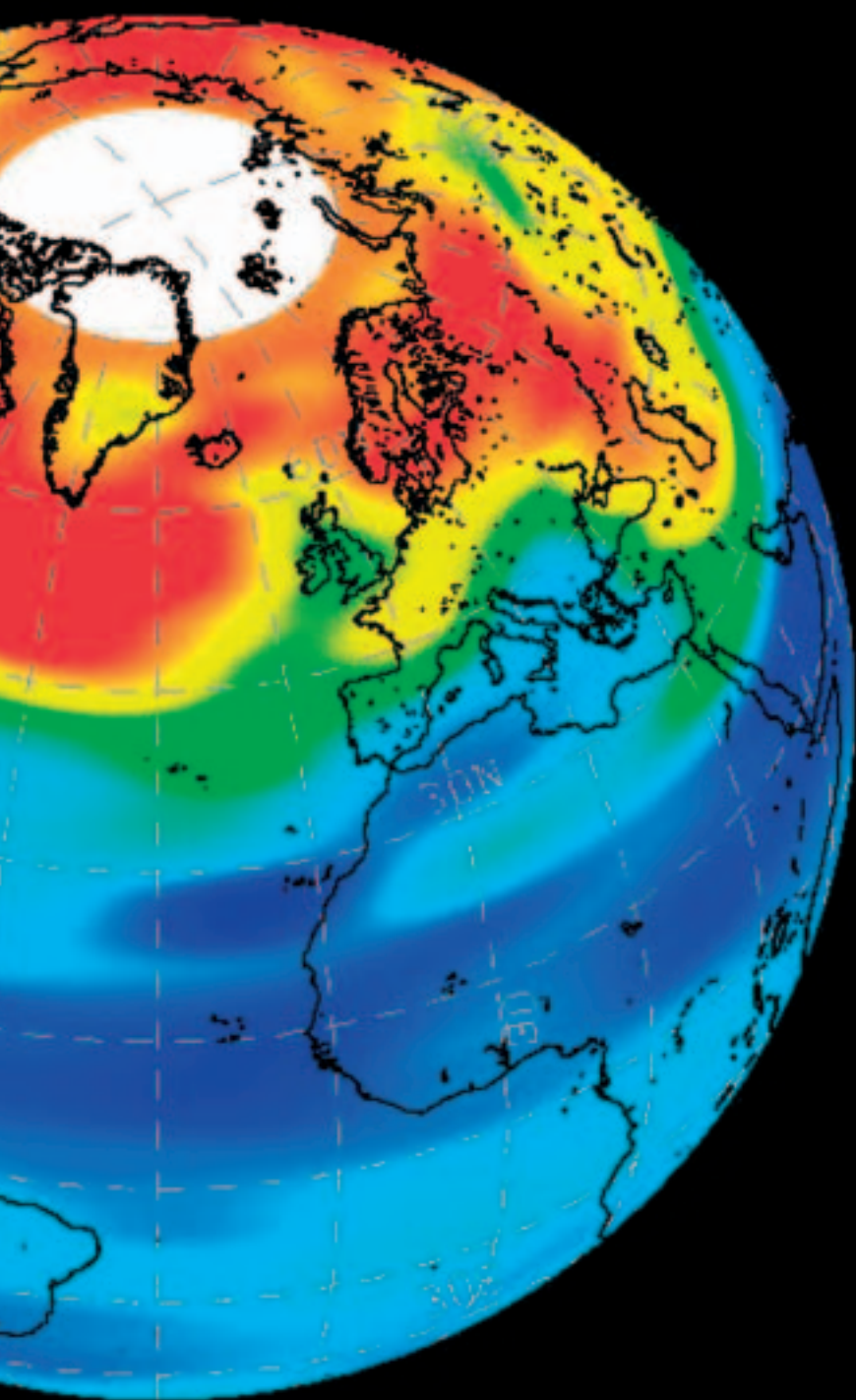


# Global Monitoring for Environment and Security

– Europe's next space  
initiative takes shape



*The ozone hole over the Earth's Northern Hemisphere in January 2002, based on measurements made by ESA's Envisat satellite (courtesy of DLR)*



*Volker Liebig*

ESA Directorate for Earth Observation  
Programmes, ESRIN, Frascati, Italy

*Josef Aschbacher*

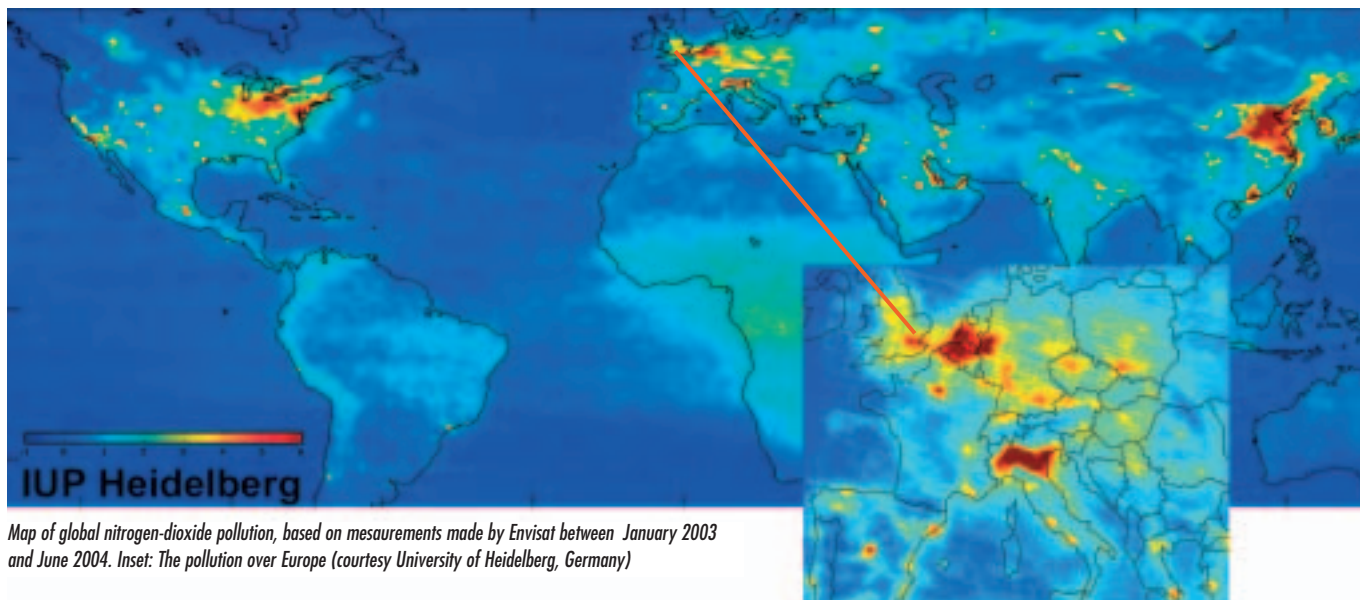
Programme Coordinator, Directorate for Earth  
Observation Programmes, ESA, Paris

**A**t the first Space Council in November 2004, Global Monitoring for Environment and Security (GMES) was proclaimed as the next flagship initiative for space in Europe, after Galileo. This underlines that GMES has come a long way since its beginnings in 1998. Initially conceived as a relatively loosely coordinated forum for cooperation among space agencies, GMES today stands on firm ground. The European Commission has assumed political leadership for GMES, and the European Union's policy priorities have been confirmed. A strong user base has been built up through numerous GMES projects funded since 2001 by ESA and the Commission. Currently ESA is preparing, with its Member States, a firm proposal for the 2005 Ministerial Council to start building up the space infrastructure necessary to sustain operational GMES services in the long term.

### Why GMES ?

At their 2001 Summit in Gothenburg, the EU Heads of State and Government requested that: “the Community contribute to establishing by 2008 a European capacity for global monitoring for environment and security (GMES)”.

GMES serves two main policy requirements for Europe in terms of the need for geo-spatial information services. Firstly, it provides independent access to information for policy and decision makers to advance European and national agendas related to environment and security. Secondly, it federates European contributions to the international Global Earth Observation System of Systems,



Map of global nitrogen-dioxide pollution, based on measurements made by Envisat between January 2003 and June 2004. Inset: The pollution over Europe (courtesy University of Heidelberg, Germany)

GEOSS, which was established at the Third Earth-Observation Summit in Brussels in February 2005.

**Europe's Independent Access to Global Information**

Access to information has strategic value for the development of nations and regions. GMES will contribute to Europe's ability to fulfil its role as a global player. This entails the capacity to have independent access to reliable and timely information on the status and evolution of the Earth's environment at all scales, from global to regional and local. GMES must also ensure long-term, continuous monitoring based on space and in-situ observations on a time-scale of at least decades.

Through GMES, Europe is now in the process of capitalising on its strengths by better coordinating its observation capacities, hence providing continuity of services to support the implementation of EU policies. These include policies in the domains of environment, agriculture, regional development, fisheries, transport, humanitarian aid and external relations, as well as the Common Foreign and Security Policy and the European Security and Defence Policy.

The Third Earth Observation Summit in Brussels in February 2005, at which the GEOSS 10-Year Implementation Plan was adopted

**GEOSS, the Global System of Systems**

The need for better-integrated observations has been recognised by different governments as a major pre-requisite to understanding global issues such as climate change and to tackling them appropriately at the political level. To advance the integration of these measurements, then US Secretary of State Colin Powell hosted the first Earth Observation Summit in Washington DC in July 2003. This was followed by intermediate and concluding Summits hosted by Japan's Prime Minister Junichiro Koizumi in Tokyo in April 2004 and EU Commissioners Verheugen and Potocnik in Brussels in February 2005. A 10-Year Implementation Plan for a Global

Earth Observation System of Systems, GEOSS, was adopted during the Brussels Summit, which asks for closer cooperation among the 60 governments and 40 international organisations that constitute GEO today. Nine 'Societal Benefit Areas' have been identified as the focus for the implementation of the 10-Year Plan: in short, disasters, health, energy, climate change, water, weather, coastal and marine ecosystems, desertification and biodiversity. The 10-Year Plan identifies 2-, 6- and 10-year targets in terms of observational capabilities for the nine areas and indicates their benefits to society.

Statements made by European governments and the European Commission have



*Variation in sea-surface temperature between March 2003 and March 2004, based on measurements made by Envisat*

repeatedly underlined the intention to provide the European contribution to GEOSS via GMES. This will not include the totality of GMES, but rather those elements that are deemed appropriate to be shared at international level. Likewise, GMES will also act as recipient of data and information from external sources for the benefit of European users.

*Through GMES, Europe has established intellectual leadership* in developing a holistic space and in-situ based observation system coupled with Earth system prediction models which is driven by policy needs identified by government authorities. Indeed, the GEOSS 10-Year Plan has taken advantage of GMES, translating some of Europe's challenges to the global scale. In addition, a number of countries are establishing national systems, which serve their policy priorities. Examples are the USA, Japan, India, China or Morocco.

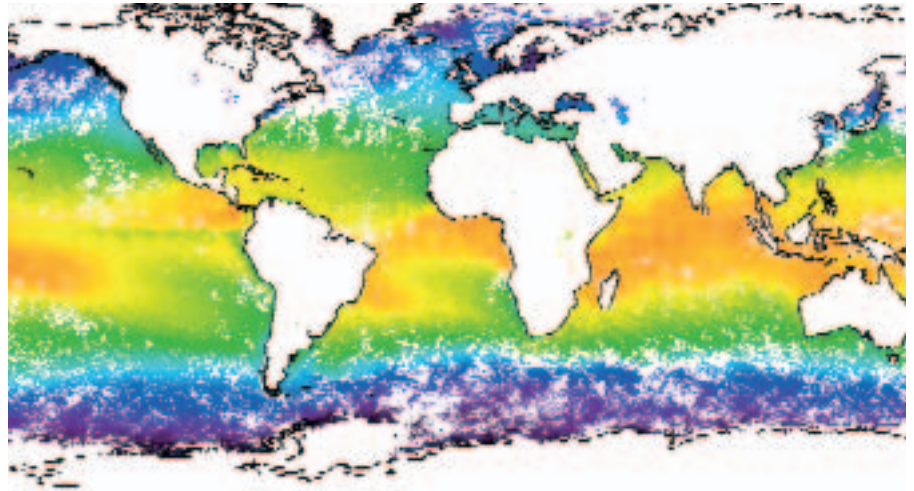
### **IEOS – The US Equivalent of GMES**

The United States is developing the Integrated Earth Observation System, IEOS. A Strategic Plan for IEOS has been established over the past two years, which addresses the same nine societal benefit areas as GEOSS, hence allowing coherence between both systems from the outset. The Strategic Plan identifies six priority areas from the nine GEOSS domains that are to be tackled in the near-term. These are: data management, disaster warning, global land observations, sea-level observations, national drought information, and air-quality forecasts.

The IEOS Strategic Plan was developed by 17 federal agencies that are part of the Interagency Working Group on Earth Observation, IWGEO. It reports to the National Science and Technology Council's Committee on Environment and Natural Resources, which advises the office of President George W. Bush on science and technology issues.

### **The Content of GMES**

The overall GMES architecture comprises



four major elements, as outlined in the EC Communication on GMES. These are services, space observations, in-situ observations, and data integration and information management. The establishment of a policy and regulatory framework, as well as the setting up of an institutional structure to govern, finance and operate GMES as a whole, are also required. They are dealt with in the GMES Programme Office at the working level, and by the GMES Advisory Committee at Member State level.

### **From EU Policy Priorities to the GMES Space Component**

The definition of the GMES Space Component is based on a number of steps, such as: (i) the identification of EU policy priorities and the respective users within the EC and the EU/ESA Member States; (ii) the implementation of GMES service projects responding to these policy needs, such as those funded by the EC and ESA over the past years; (iii) the retrieval of service requirements and space-observation requirements; and (iv) the identification of gaps in the continued provision of Earth Observation data for European policies, after analysing the current and planned EO missions of ESA, EU/ESA Member States, Eumetsat and third-party operators. The GMES 'Sentinel' missions are defined as an output of these steps.

Gathering requirements from these users has been a highly structured process conducted with their active participation.

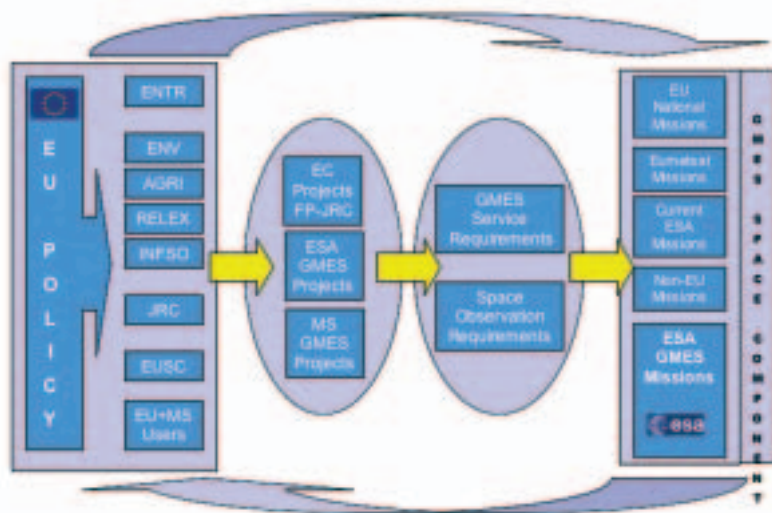
Within the framework of current GMES projects, the process has been based on policy review, traced down to the nature and scope of responsibilities of legally mandated organisations under the identified policies, followed by an assessment of their requirements for information as well as the nature of their working practices and applicable standards that place constraints to be met within such organisations.

Data gaps are expected to occur in the near future. ERS-2 and Spot-4 have already exceeded their nominal lifetimes in 2002, Envisat and Spot-5 have a nominal end-of-life in 2007, and the ETM imaging sensor on Landsat-7 has already failed a few years ago.

Observation requirements for satellite instruments have been derived and the satellite elements aggregated into the definition of the space component of GMES, which is made up of components from ESA, Eumetsat and ESA/EU Member States.

### **Who Are the GMES Users?**

GMES is user driven and responds directly to user requirements. In particular cases, requirements can come from users sufficiently expert in remote-sensing technologies. This is the case, for example, for the European Environment Agency requiring Landsat TM-class observations for operational updates to the Corine land-cover database, and for users involved in programmes such as Global Land Cover 2000 (GLC2000) where there is a direct, demonstrated and endorsed requirement



POLICIES → USERS → SERVICES → REQUIREMENTS → GAP ANALYSIS → SOLUTIONS

Analysis of the GMES space component based on EU policy priorities

- Air-pollution monitoring (local to regional scales)
- European water-quality monitoring
- European land-use / land-cover state and changes monitoring
- Forest monitoring
- Food security – early-warning systems
- Global-change monitoring
- Maritime security (marine transport, coastal-area surveillance, ice monitoring)
- Humanitarian-aid support.

All of these services are set to progressively enter the operational stage from 2010 onwards, provided that Earth-observation data are continuously available to users.

for continuity of MERIS/vegetation-type measurements.

In other cases, users have only recently been exposed to GMES services through dedicated GMES projects funded by ESA, the EC or Member States. The users comprise European, national and local-government level organisations, and include environmental agencies, civil protection and safety agencies, city councils, coastguards, geological surveys, meteorological offices, fishery-management authorities, transport authorities, development and aid agencies, river-basin authorities, port authorities and health departments.

A recent survey identified some 330 organisations as users of currently running GMES service projects. As these are organisations at European, national and regional level, they have a multiplier effect in terms of the numbers of citizens benefiting from this information. For example, the European Environment Agency is using and redistributing satellite-based Corine land-cover maps of the European territory at 1:50 000 scale to national environmental organisations for further use and distribution.

**GMES Initial Services**

The GMES Advisory Council has endorsed a number of GMES Initial Services, which require immediate attention in terms of data provision and service development. They have been derived from on-going GMES projects, and they satisfy EU policy priorities that are described in different documents. The identified GMES Initial Services cover:

- Marine and coastal environment monitoring (including pollution, oil spills)
- Risk management (floods and forest fires)
- Risk management (subsidence and landslides)

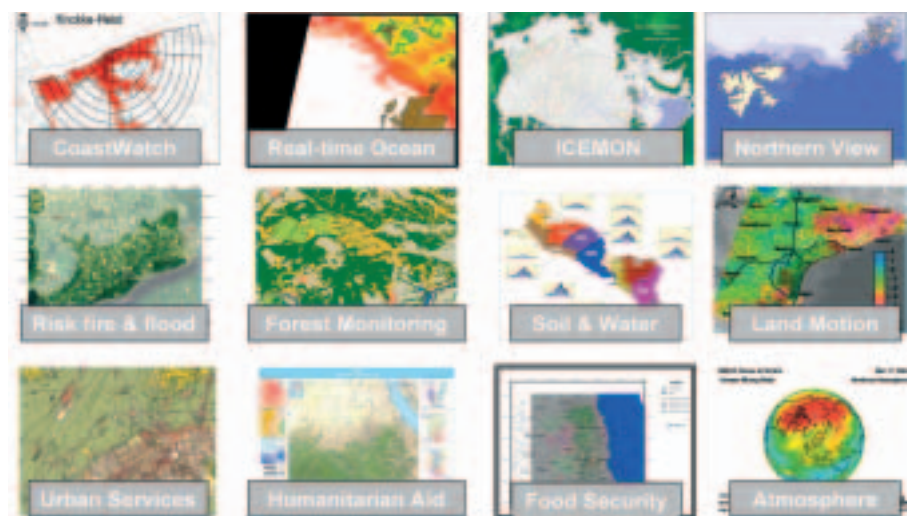
**GMES Pilot Services**

Among the Initial Services that the EC has identified are a limited number of early GMES pilot services to which it would give priority for operational implementation by 2008. These are:

- Emergency management
- Land monitoring
- Ocean monitoring.

It is planned to establish a fourth pilot service on atmospheric chemistry in a second stage.

The EC will engage in an intense user-consultation process through a series of three workshops at the end of 2005 in order



The 12 ESA GMES Service Element projects subscribed to at the ESA Ministerial Council in Edinburgh in 2001

to consolidate and update existing user requirements, develop an action plan for 2006-2008, and define criteria for the sustainability of the three GMES pilot services.

### The ESA GMES Space-Component Programme Proposal for the 2005 Ministerial Conference

The ESA programme currently being negotiated with Member States in preparation for the 2005 Ministerial Council concentrates on the *GMES space component*, which comprises the space segment and the associated ground segment, including access to national, Eumetsat and third-party missions.

In this context, it is worth recalling that ESA, several ESA Member States and Eumetsat are funding a number of Earth-observation satellite programmes, which should become an integrated part of the overall architecture of the GMES space component. ESA has duly taken account of these missions and has designed the proposed satellite missions – the ‘Sentinels’ – in a complementary manner.

The following missions are candidates for contributions to GMES:

#### National

- Spot-5 (operating)
- TerraSAR-X (1 satellite, launch 2006)
- Cosmo Skymed (3 satellites, launches 2007, 2008, 2009)
- Radarsat-2 (1 satellite, launch 2006); C-band constellation (tbc)
- Pleiades (2 satellites, launches 2008, 2009)
- Other national missions (tbc).

#### Eumetsat

- Jason-2 (with CNES, 1 satellite, launch 2006)
- MSG (4 satellites, launches from 2002); MTG (launch 2015, tbc)
- MetOp (3 satellites, launches from 2006); Post-EPS (launch 2019, tbc).

#### Privately funded or third-party missions

- DMC-UK (constellation of satellites, launches from 2003)
- RapidEye (5 satellites, launch 2007).

The architecture of the GMES Space Component is designed in such a way that



Flight models of MSG-2 and MSG-3 in the clean room at Alcatel Space in Cannes (F)

a certain degree of dual-use capability can be achieved. This involves investments in the space segment, ground segment and information and service dissemination element. Details of security-related aspects will be defined during 2006-2007 and proposed in a later phase (post-2008) of the GMES Space-Component Programme.

#### GMES Sentinels

The following five members of the Sentinel family have been identified as core elements of the GMES Space Component:

- Sentinel-1 a radar imaging mission with interferometric capability
- Sentinel-2 a multispectral optical imaging mission
- Sentinel-3 an ocean and global-land surface monitoring mission with altimeters and wide swath, low-to medium resolution radiometers
- Sentinel-4, -5 two families of atmospheric chemistry missions, on geostationary (Sentinel 4) and low Earth orbit (Sentinel-5) spacecraft.

#### GMES-1, the First GMES Mission

The core element of the ESA programme proposal for the 2005 Ministerial

Conference includes the development of a first GMES mission, GMES-1, planned for launch in 2010/11. This mission's definition is driven by three factors. Firstly, as mentioned above gaps in data will occur in the 2009-2011 time frame. Secondly, no definitive financial commitments are expected from the EC before 2007. And thirdly, the developments must be the basis for a robust and affordable operational system, incorporating sufficient flexibility and modularity to allow for the anticipated evolution that will occur throughout the extended lifetime of the system.

The GMES-1 mission will satisfy the most urgent data needs by combining selected instruments on one spacecraft, the design of which will allow for future payload growth. The envisaged instrument package forms a coherent set of instruments, sharing similar constraints in terms of orbit requirements. It is anticipated that the instruments developed for GMES-1 will also be used on the future operational series of GMES satellites.

Aimed at addressing the observational needs of Sentinel-1 and -3, as a starting point GMES-1 will include a C-band imaging radar capable of continuing the interferometric and ocean/ice/land measurements of ERS and Envisat, as well as an ocean-colour instrument providing continuity of MERIS-type measurements. An infrared instrument for fire monitoring

will also be included to demonstrate its capabilities. The option of embarking an infrared radiometer (AATSR-type SST instrument) or a radar altimeter will also be investigated early in the programme.

### **GMES Ground Segment**

The GMES ground segment related to space data comprises tasking, tele-command and tele-control, acquisition, archiving, processing up to appropriate product level and distribution of Earth-observation data according to GMES service needs. It includes the payload ground segment, flight-operations segment as well as access to historical data. The payload ground segment is based on existing national and commercial facilities in a fully distributed approach. In addition, access to and integration of Earth-observation data from Eumetsat, national and third-party missions are provided to users via the GMES ground segment.

### **GMES Service Portfolio Extension**

GMES services must serve many diverse user communities in Europe and worldwide, continuously integrate new techniques and research advances from many different fields, exploit spatial and non-spatial data from a multitude of different sources including newly available satellite data, and evolve to deliver new forecasting, prediction and early-warning capabilities. The service extension will contribute to bringing the current GMES services to full operational status and to developing new Earth-observation-based GMES services. It is understood that this element is to be funded through (future) European Commission budgets as part of the joint implementation of GMES by the Commission and ESA.

### **GMES Operations**

The operation of the GMES space component covers the space, ground and service segments. The different GMES missions (Sentinels, Eumetsat, national) and their related ground segments will be operated by different entities, with ESA ensuring the integrity and coordination of the GMES space component.

The operating entities for the GMES

Sentinel family will emerge over the next years in parallel with an agreement on the governance of GMES as a whole.

### **Cooperation with the European Commission**

GMES has, from the outset, been a cooperative effort involving all major stakeholders in Europe. Over the past years, the Commission and ESA have cooperated on GMES on behalf of their respective Member States. Investments so far have focused on the consolidation of the GMES user base and the provision of initial services. ESA and the Commission have each provided some 100 MEuro for the development of services based on EC and EU/ESA Member State priorities. In 2004, the ESA Member States have approved an additional 40 MEuro for preparatory studies of the GMES space component.

The GMES Advisory Council and GMES Programme Office lead the GMES process. The GMES Advisory Council is chaired by the European Commission (DG Environment, to underline the user-driven aspect of GMES). The GMES Programme Office is co-led by the Commission and ESA.

The model of shared responsibility has been a successful means to continuously move GMES forward. It has led to the consolidation of a significant user base across Europe and has raised the political awareness in the EC and the EU and ESA Member States. On the international scale, GMES has been portrayed as a model for establishing the Global Earth Observation System of Systems, GEOSS.

Taking these considerations into account, and making use of existing co-ordination and consultation mechanisms, ESA continues to closely coordinate the definition of the GMES space component with the EC and the EU/ESA Member States using existing mechanisms, such as the GMES Advisory Council for the definition of the GMES Space-Component Programme.

### **Implementation Approach**

The approach proposed has to be compatible with the fact that no definitive financial commitments will be available

from user entities, represented through the European Commission, before 2007. The second programme imperative is to anticipate potential data gaps that might occur in the period 2008-2012, particularly in:

- the C-band radar imaging and interferometric capability
- Landsat-Spot type data
- wide-swath radiometer data.

The implementation of the GMES Space-Component Programme is proposed to take place in two segments:

- Segment-1 covering the period 2006-2012, and
- Segment-2 covering the period 2008-2013.

Segment-1 will be funded through the ESA Optional Programme, while Segment-2 is expected to be co-financed with the European Commission according to a financing model to be agreed in 2007.

### **Outlook**

Data continuity over a period of decades is a key requirement for operational services. In order to prepare for the full implementation of GMES, the ESA Space-Component Programme assures data continuity for critical satellite observations from 2010/2011 onwards. The Ministerial Conference will be a decisive event, in particular for ESA, to ensure that GMES continues to move forward.

Only a well-funded and strongly implemented GMES can serve the ambitious goal of Europe becoming one of the most dynamic knowledge-based societies in the World. Furthermore, GMES has provided intellectual leadership in establishing the Global Earth Observation System of Systems, GEOSS. It is important that Europe continues to support this leadership through action, thus providing a favourable platform for Europe's industry, institutions, organisations and scientists to maintain a leading edge in preserving the global environment and ensuring security to Europe's citizens and people everywhere. r