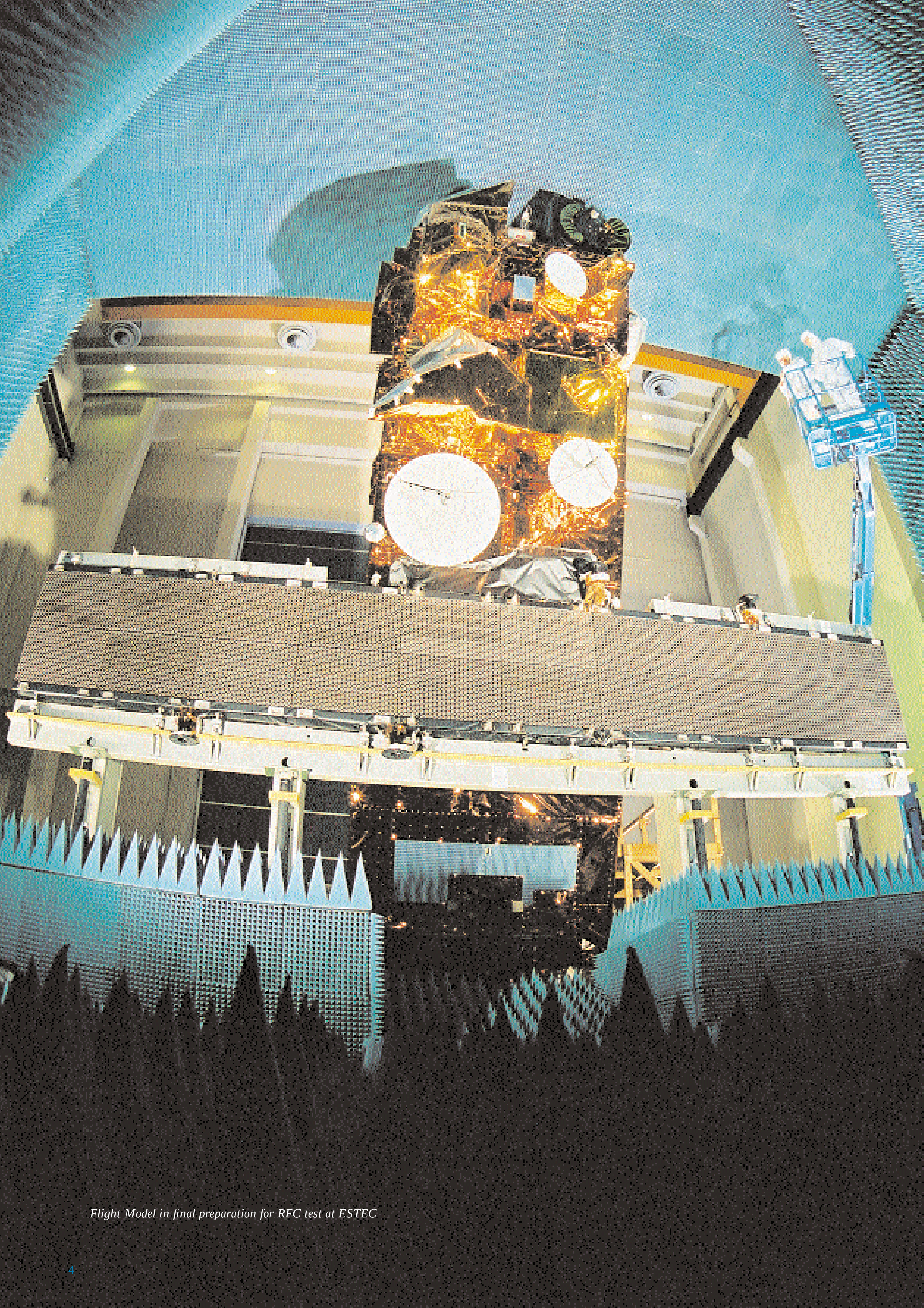
# Contents



*Flight Model in final preparation for RFC test at ESTEC*

# Introduction

Throughout history, our planet Earth has undergone changes to its physical characteristics caused by natural evolutionary activities.

Recently, however, it has been recognised that the changes in our environment may also be affected adversely by human activities. Growing population and economic development are placing heavier and expanding demands and stresses upon the finite resources of the Earth's system. There is also an increased awareness of the human and economic significance of the natural variability of the environment, particularly with regard to the effects of extreme events – manifested through natural disasters such as floods and earthquakes.

This growing concern has resulted in international agreements that future human activities and developments must minimise any type of environmental damage.

In order to monitor environmental changes and to support studies of the effects and interrelations of the various natural and man-made contributors to the global climate change, systematic observations of the Earth have to be performed. These observations need to be made both on a global scale for world-wide environmental needs, and on a regional scale to support local environmental issues and developments. They have to be performed over time periods long enough to allow seasonal variations to be considered, and have to comprise a number of different geophysical, biophysical and chemical measurements.

Modern technological developments have provided remote sensing satellites as a primary means of performing such global research. The European contribution to the Earth observation programme is the ENVISAT system, an advanced environmental satellite designed to provide measurements of the atmosphere, oceans, land and the polar regions.

After an overall development period in the order of ten years, the ENVISAT system has now successfully finished its final testing and is ready to be launched.

Once spaceborne, the ENVISAT mission will provide, in a continuation and extension of the ERS programme, information from a unique combination of ten multi-disciplinary sensors, resulting in unprecedented opportunities in environmental monitoring and operational Earth observation.

By the development of the ENVISAT system, the European space community has successfully managed the challenges of a highly demanding programme, confirming its leading role in Earth observation.

**Ocean**

- *Ocean colour*
- *Sea surface temperatures*
- *Surface topography*
- *Turbidity*
- *Wave characteristics*
- *Marine geoid*

**Atmosphere**

- *Clouds*
- *Humidity*
- *Radiative Fluxes*
- *Temperature*
- *Trace Gases*
- *Aerosols*

**Ice**

- *Extent and type*
- *Snow cover*
- *Topography*
- *Temperature*

**Land**

- *Surface temperatures*
- *Vegetation characteristics*
- *Surface elevation*
- *Earth crust and interior*

# Mission and System

To monitor and study our environment on a global scale, polar orbiting remote sensing satellites offer unique features:

- complete Earth coverage,
- high revisiting rate,
- continuity of measurements over seasons and years,
- stable and highly repeatable measurements.

With this background the ENVISAT mission has been defined to endow Europe with enhanced capability to:

- monitor and study the Earth's environment and climate changes,
- manage and monitor the Earth's resources,
- develop a better understanding of the structure and dynamics of the Earth's crust and interior.

The system will provide:

- continuity of the observations started with the ERS satellites,
- enhancement of the ERS missions, notably its ice and ocean missions,
- extension of the contributions to environmental studies in particular in the area of atmosphere chemistry and marine biology.

The mission will serve both global as well as regional monitoring objectives.
Continuous and coherent global data sets will be made available, for example, for:

- scientific and application communities to understand more fully the climatic processes and to improve climate models,
- medium and long term weather forecasts,
- studying of tectonic motions and seismic phenomena (in conjunction with SAR interferometry).

The regional data sets will support the science and application user communities with a variety of objectives, such as:

- coastal process and pollution monitoring,
- ship traffic routing,
- agriculture and large scale vegetation monitoring,
- hazard monitoring.

Depending on their application the data will be available in nearly real-time, or as off-line products in the order of days to weeks after sensing.

To meet the mission objectives the orbit for ENVISAT will be a high inclination, sun synchronous, near circular orbit in the altitude range between 780 km and 820 km. The local mean solar time at the descending node will be 10:00 a.m.

The orbit maintenance strategy ensures that the deviation of the actual ground track from the nominal one is kept below 1 km and that the mean local nodal crossing time matches the nominal one to better than 1 minute.

The ENVISAT operational design facilitates the acquisition of measurement data from any point on the Earth's surface and atmosphere within the coverage of its sensors.

Although the repeat cycle of the ENVISAT Reference Orbit is 35 days, it provides for most sensors a complete coverage of the globe within one to three days. The regions of higher latitude will be covered even more frequently. Because of their measurement principle, in particular their narrow field of view, the instruments DORIS, MWR and RA-2 do not provide real global coverage, but span a tight matrix of measurements over the globe.

The ENVISAT reference scenario for satellite-to-ground communication employs various ground stations (Kiruna, Fucino, Svalbard) and the ESA Data Relay Satellite ARTEMIS.
In addition, further national stations will be involved.

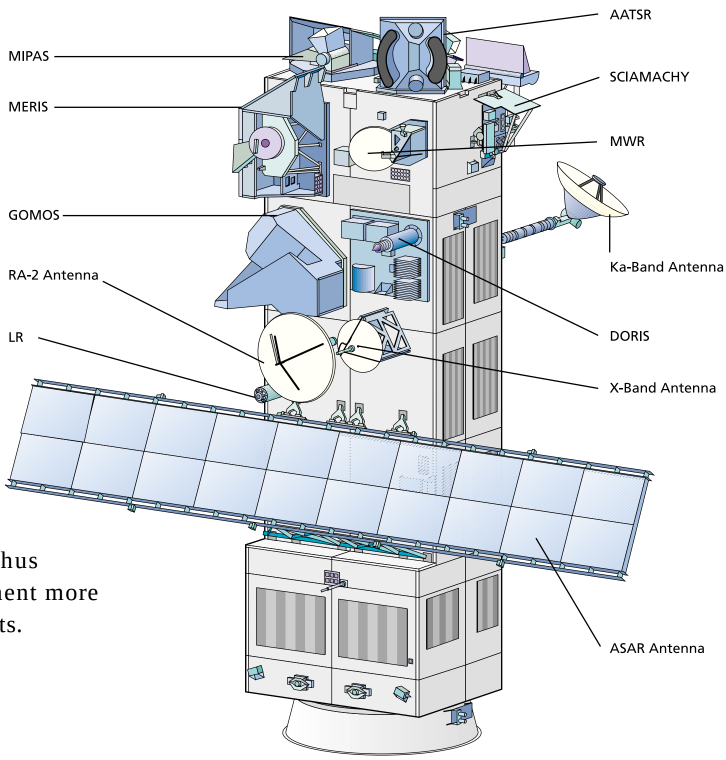
The satellite will be launched from the Kourou Space Centre in French Guyana by an Ariane 5 launch vehicle.

The system needed to achieve the mission objectives requires two major components:

- the Satellite and
- the Ground Segment.

Additionally, the ARTEMIS Data Relay Satellite system will be used for communication to ground.

To meet the mission requirements a coherent, multidisciplinary set of sensors has been selected, each contributing with its distinct measurement performance in various ways to the mission, as well as providing synergy between the scientific disciplines, thus making the total payload complement more than just the sum of the instruments.




*ENVISAT satellite configuration*

| Disciplines / Instruments | ASAR | GOMOS | RA-2 | MERIS | MIPAS | MWR | LR | SCIAMACHY | DORIS | AATSR |
|---|---|---|---|---|---|---|---|---|---|---|
| **Atmosphere** | | | | | | | | | | |
| Clouds | | | | ■ | | | | ■ | | ■ |
| Humidity | | | | | | ■ | | | | |
| Radiative Fluxes | | | | ■ | | | | | | ■ |
| Temperature | | | | | ■ | | | ■ | | |
| Trace Gases | | ■ | | | ■ | | | ■ | | |
| Aerosols | | ■ | | ■ | ■ | | | ■ | | ■ |
| **Land** | | | | | | | | | | |
| Surface Temperature | | | | | | | | | | ■ |
| Vegetation Characteristics | ■ | | | ■ | | | | | | ■ |
| Surface Elevation | ■ | | ■ | | | | ■ | | ■ | |
| **Ocean** | | | | | | | | | | |
| Ocean Colour | | | | ■ | | | | | | |
| Sea Surface Temperature | | | | | | | | | | ■ |
| Surface Topography | | | ■ | | | | ■ | | | |
| Turbidity | | | | ■ | | | | | | |
| Wave Characteristics | ■ | | ■ | | | | | | | |
| Marine Geoid | | | ■ | | | | | | | |
| **Ice** | | | | | | | | | | |
| Extent | ■ | | | ■ | | | | | | ■ |
| Snow Cover | ■ | | | ■ | | | | | | ■ |
| Topography | ■ | | ■ | | | | ■ | | | |
| Temperature | | | | | | | | | | ■ |

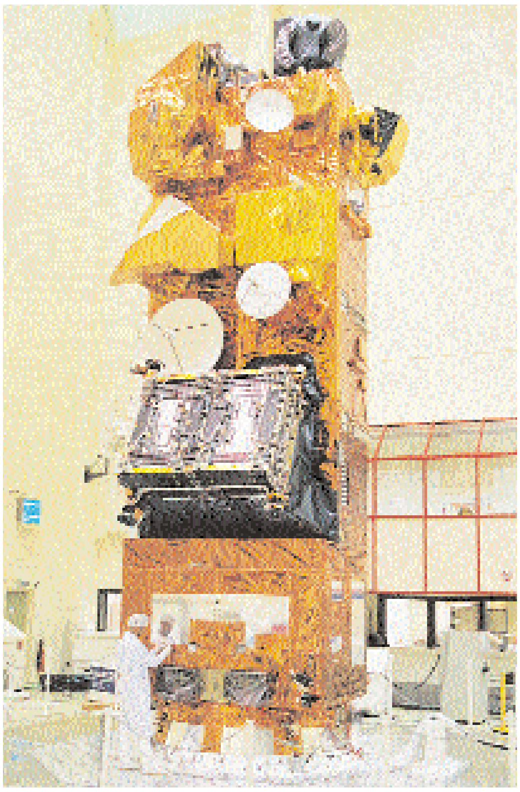
*Instrument contribution to ENVISAT measurement objectives*

The ENVISAT Satellite comprises a set of seven ESA Developed Instruments:

- Advanced Synthetic Aperture Radar (ASAR),
- Medium Resolution Imaging Spectrometer (MERIS),
- Radar Altimeter 2 (RA-2),
- Microwave Radiometer (MWR),
- Laser Retro-Reflector (LR),
- Global Ozone Monitoring by Occultation of Stars (GOMOS),
- Michelson Interferometer for Passive Atmospheric Sounding (MIPAS).

They are supported by three complementary Announcement of Opportunity Instruments:

- Advanced Along Track Scanning Radiometer (AATSR),
- Doppler Orbitography and Radiopositioning Integrated by Satellite (DORIS),



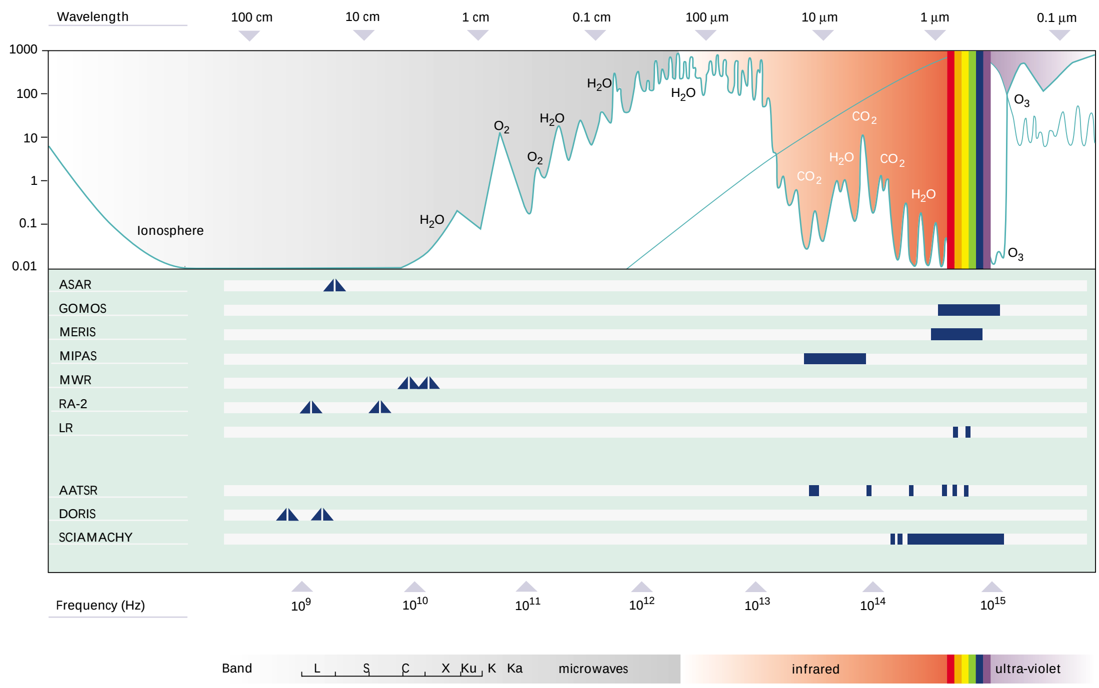
*ENVISAT in ESTEC Hydra Facility*

- Scanning Imaging Absorption Spectrometer for Atmospheric Cartography (SCIAMACHY).

These instruments operate over a wide band of the electromagnetic spectrum, ranging from centimetre waves to the ultraviolet.

The Polar Platform is made up of two major assemblies:

- the Service Module (SM) which accommodates most of the satellite support subsystems such as:
  - power generation, storage and distribution,
  - Attitude and Orbit Control System (AOCS),
  - communication on S-Band,
  - support structure and launcher interface,
- the Payload Module (PLM) on which the instruments and the payload dedicated support subsystems are mounted:
  - instrument control,
  - payload data storage,
  - communication on X- and Ka-Band,
  - power distribution,
  - support structure.



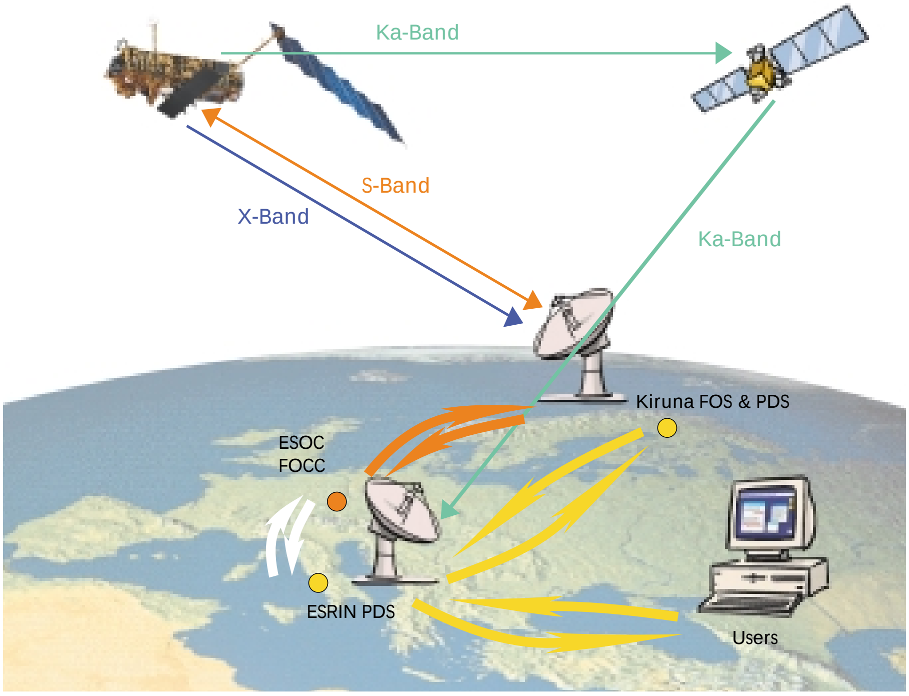

*Measurement spectrum of the ENVISAT instruments*

For the transmission of measurement data to ground, two alternative scenarios are defined:

- the baseline scenario with acquisition via X-and Ka-Band links,
- a back-up X-Band scenario where transmission will be performed on X-Band only.

Within both scenarios the global as well as regional mission objectives will be served.

The requirement for global coverage implies the use of onboard data storage in both scenarios. ENVISAT is equipped with two Solid State Recorders, each with a capacity of 70 Gbit, and a 30 Gbit tape recorder as a back up. They allow recording of the 4.5 Mbps composite data stream of the low data rate instruments over a complete orbit, as well as recording MERIS full resolution data or ASAR image mode data for dedicated regional observations. The data will also be downlinked via ARTEMIS or directly to the ground stations depending on the scenario.




*Data flow between Satellite and Ground Segment*

To downlink the stored data within the minimum ground contact time, playback rates of 50 Mbps and 100 Mbps are provided. For the downlink of the different categories of measurement data, the following channels transmitting 100 Mbps each, are available:

- one X-Band channel used for recorder dumps and real-time transmission,
- one X-Band channel for ASAR high rate measurement data,
- in case of transmission via ARTEMIS two Ka-Band channels with the same allocation as for the X-Band.

The Ground Segment provides the means and resources to manage and control the mission, to receive and process the data produced by the instruments, and to disseminate and archive the generated products. Furthermore, it will provide a single interface to the users to allow optimum utilisation of system resources in line with user needs.

The Ground Segment can be split into two major elements:

- the Flight Operation Segment (FOS),
- the Payload Data Segment (PDS).

The FOS is composed of the Flight Operations Control Centre (FOCC), located at ESOC Darmstadt (Germany), and the associated command and control stations. It provides control of the satellite through all mission phases:

- satellite operation planning based upon the observation plans prepared at the Payload Data Control Centre (PDCC),
- mission planning interface with ARTEMIS,
- command and control of the satellite, up-loading of operation schedules on a daily basis via the TT&C station at Kiruna-Salmijärvi (north Sweden).

Furthermore, the FOCC will support:

- satellite configuration and performance monitoring,
- software maintenance for PPF and payload elements,
- orbit prediction, restitution and maintenance.

Satellite command and control will nominally be performed using the S-Band via the Kiruna Ground Station. During Launch and Early Orbit Phase (LEOP), the Kiruna Station will be complemented by a LEOP TT&C station network providing coverage of critical events.

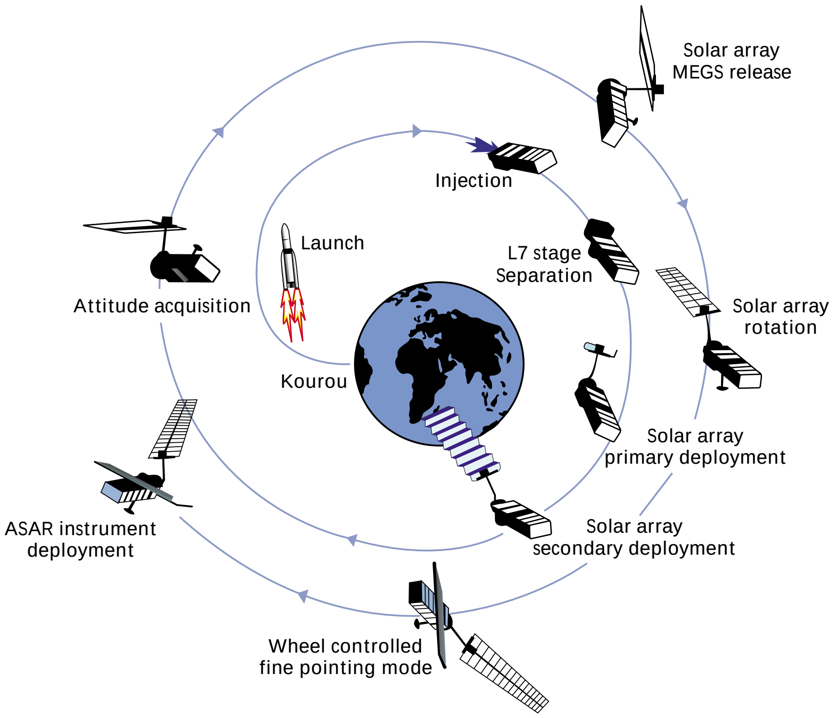
*Main Control Room at the FOCC*

The PDS comprises all those elements which are related to payload data acquisition, processing and archiving, and those concerning the user interfaces and services. The PDS will thus provide:

- all payload data acquisition for the global mission,
- regional data acquisition performed by ESA stations,
- processing and delivery of ESA Fast Delivery Products,
- data archiving, processing and delivery of ESA off line products with support of Processing and Archiving Centres (PACs),
- interfaces with national and foreign stations acquiring regional data,
- interfaces to the user from order handling to product delivery.

The PDS centres and stations will be co-ordinated by the PDCC located at ESRIN, Frascati, Italy. The PDCC will interface with the FOCC for all mission planning activities.

The PDS ESA stations include: a Payload Data Handling Station (PDHS-K), located at Kiruna-Salmijärvi, providing X-Band data reception; the PDHS-E located at ESRIN, receiving via a User Earth Terminal (UET) data relayed by ARTEMIS; and a Payload Data Acquisition Station (PDAS), located at Fucino (Italy), receiving X-Band data. For those orbits which are out of the visibility of the Kiruna PDHS and when ARTEMIS is not available, a high latitude receiving station at Svalbard will be used to acquire payload data dumps.




*ENVISAT Launch & Early Orbit Phase (LEOP) sequence*


*Flight Model after Service and Payload Module integration at ESTEC*

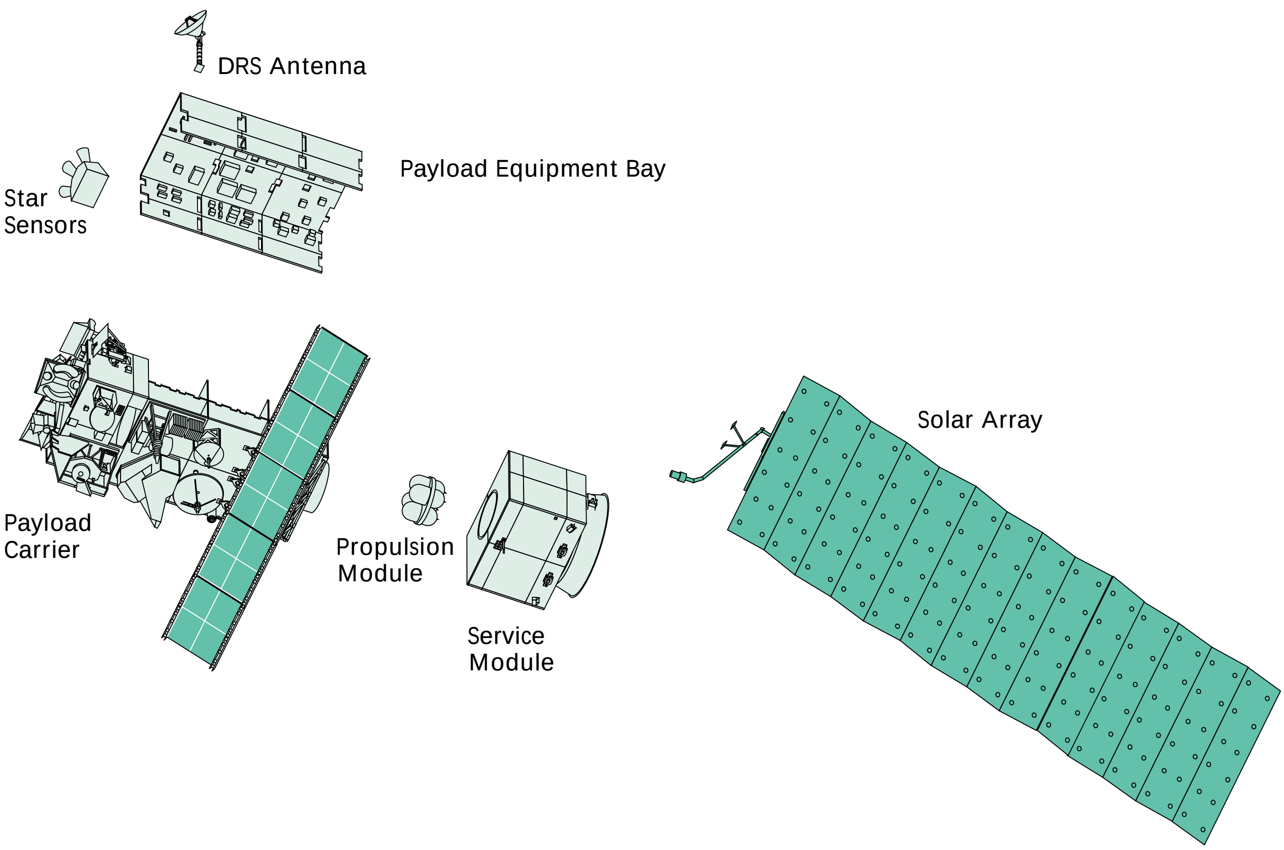
# Satellite

The ENVISAT satellite is composed of two major elements: the Polar Platform and the instruments constituting the Earth observation payload.

A major driver for the overall satellite configuration has been the need to maximise the payload instrument mounting area and to meet their viewing requirements, whilst staying within the constraints of the Ariane 5 fairing and interfaces.

The Polar Platform configuration concept provides a large modular construction comprising two major assemblies, the Service Module and the Payload Module. The Service Module provides the basic satellite functions of power generation, storage and distribution, Attitude and Orbit Control, S-Band Telemetry and Telecommand Communication, and data handling for the overall satellite control functions.

The Payload Module (PLM) consists of the Payload Carrier (PLC) and the Payload Equipment Bay (PEB). The PLC provides mounting surfaces measuring 6.4 m x 2.75 m for the payload instruments and associated electronics. The payload dedicated support systems are mounted in the PEB. The payload support functions include instrument control and data handling, X-Band and Ka-Band communications sub-systems, power distribution, support structure and thermal control.

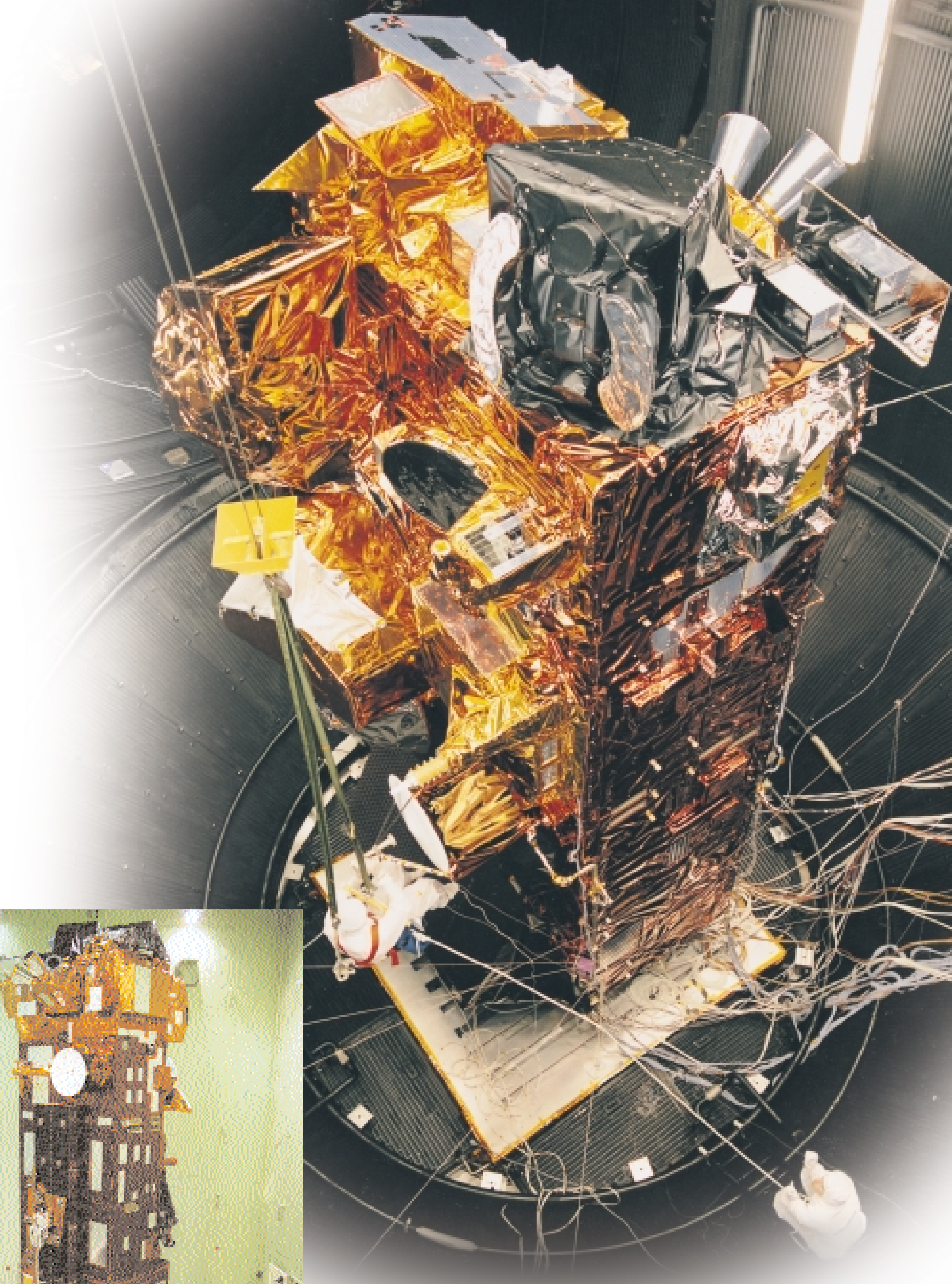



*Satellite – major components*

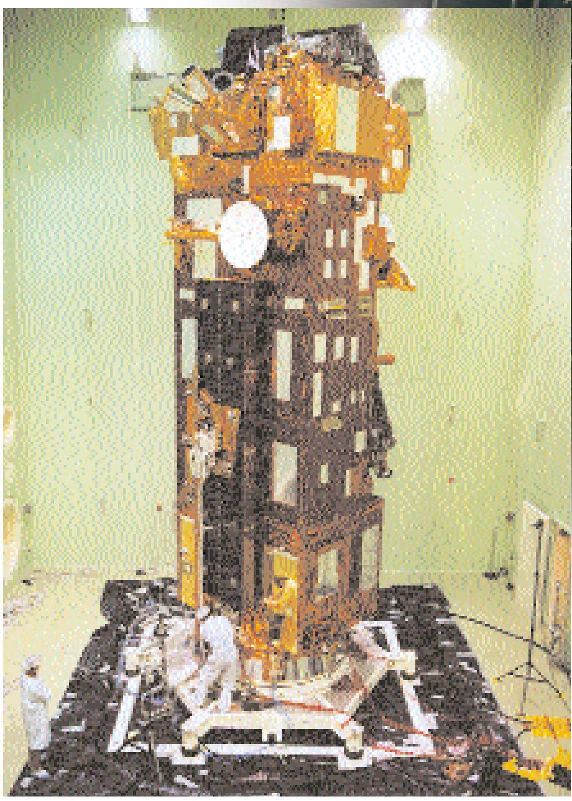
## Satellite Characteristics

| **Spacecraft** | | |
|---|---|---|
| **Spacecraft Dimensions** | **Appendages Stowed** | **Appendages Fully Deployed** |
| Height: | 10.0 m | 25.0 m |
| Depth: | 4.0 m | 7.0 m |
| Width: | 4.0 m | 10.0 m |
| Solar Array: | | 14.0 m x 5.0 m |
| Satellite Mass: | 8050 kg (at launch) | |
| Solar Array Output Power: | 6600 W (end of life) | |
| Design Lifetime: | 5 years | |
| Orbit: | Near-polar sun-synchronous | |
| Mean Altitude: | 800 km | |
| Local Solar Time: | 10:00 hr (descending node) | |
| Repeat cycle: | 35 days | |

| **Payload** | |
|---|---|
| Instrument Mass: | 2050 kg |
| Instrument Power: | 1930 W average, 3000 W peak |
| Recording Capabilities: | 2 solid state recorders with 70 Gbits storage capacity each, plus 1 tape recorder with 30 Gbits storage capacity |
| Downlink Interfaces: | 2 Ka-Band links to European Data Relay Satellite, and 2 X-Band links direct to ground, both at 50 Mbps or 100 Mbps |



Flight Model PLM in ESA Thermal Vacuum Chamber



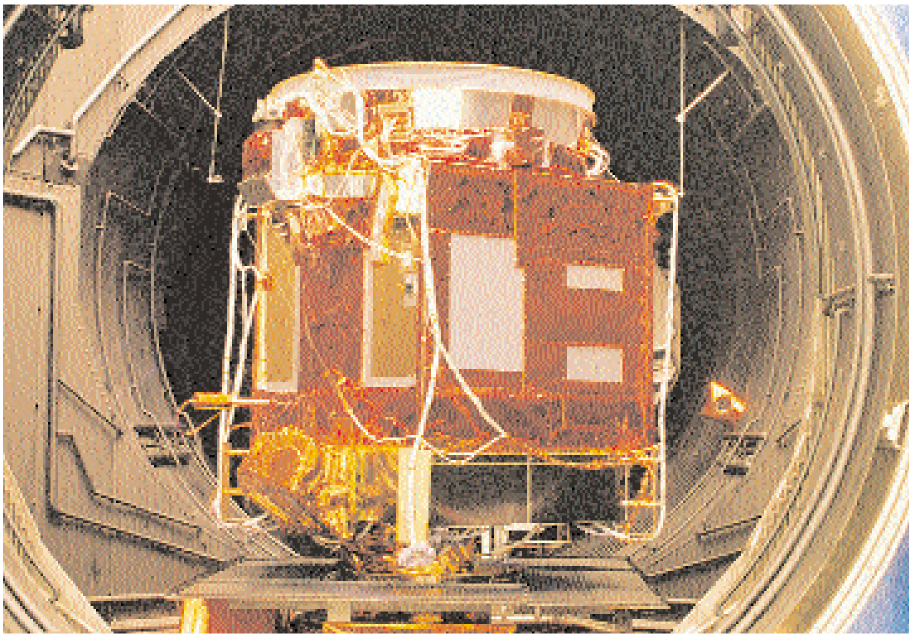
*Flight Model in preparation for acoustic test in LEAF, ESTEC*

## Service Module

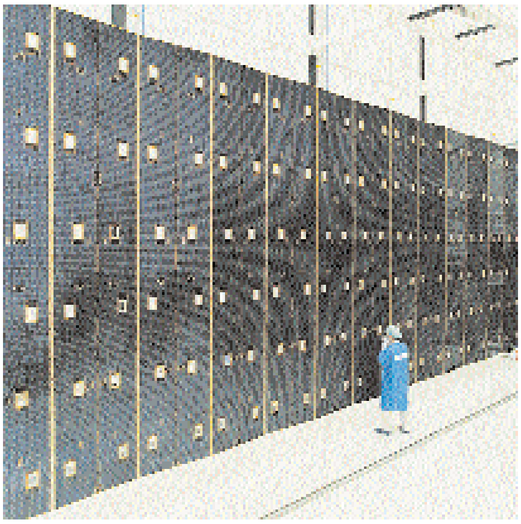
The Service Module (SM), developed by Astrium SAS (F), is based on the concept and design of the SPOT-4 Service Module with a number of important new developments, particularly in the area of mechanical design.

These include:

- an enlarged equipment module consisting of a box shaped structure made of aluminium honeycomb panels fabricated around a central carbon fibre composite cone, which constitutes the primary structure. The majority of the subsystem equipment, including additional Attitude and Orbit Control System actuators to cope with the increased size of ENVISAT compared to SPOT, are located inside this module. At the lower end of the module, the cone provides a means for interfacing with the ARIANE 5 launch vehicle adaptor. The upper end of the cone provides the interface to the propulsion module and in turn the Payload Module central cylinder,
- an enlarged battery compartment allowing installation of the required eight 40 Ah Nickel-Cadmium batteries,
- the propulsion module comprising four propellant tanks which provide ENVISAT with a fuel capacity of 300 kg of hydrazine.



*Flight Model SM installed in the ESTEC TB/TV test facility*



*Flight Model Solar Array (Photography by courtesy of Fokker Space)*

The single wing Solar Array is a particularly important new development. The array comprises a primary deployment mechanism and arm, plus a set of 14 deployable rigid panels capable of providing 6.6 kW at end of life. This array is based on the rigid panel technology already flown on EURECA.

The digital Dual Mode Transponder is another new development. It provides a 2000 bps forward and 4096 bps return S-Band link capability. Ranging and range rate measurements are performed by ground stations on the range signals transmitted by the transponders in either coherent or non-coherent modes.

The Attitude and Orbit Control System consists of Star Trackers and Gyros providing the primary measurement system, together with Sun Sensors and Earth Sensors. The actuators are reaction wheels for nominal operation, and thrusters for coarse pointing and orbit manoeuvering / correction.

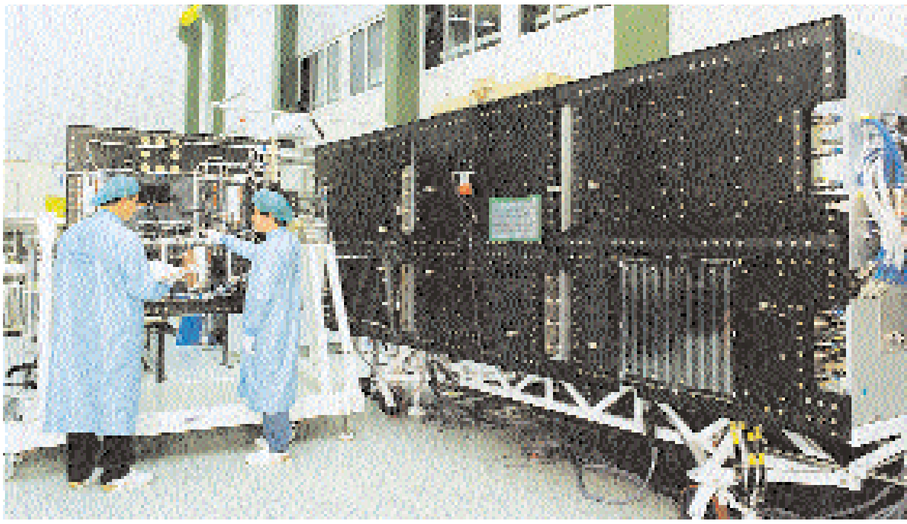
The attitude and orbit control, reaction control, power distribution, and data storage and handling systems extensively re-use SPOT developed hardware, either unmodified or with minor modification. In addition, the SM on-board and ground check-out softwares are re-used with only limited modification.

## Payload Module

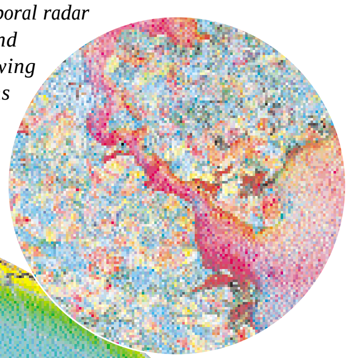
The Payload Module (PLM) comprises the Payload Carrier (PLC) and the Payload Equipment Bay (PEB). The PLC provides the main structural support for the PEB and the externally mounted instruments and antennae. In addition, the PLC provides accommodation for certain equipments which are functionally part of the Service Module but need to be located within the Payload Module.

The PEB, developed by Astrium GmbH (D), provides all the necessary functions to support and control the payload instruments as well as to handle scientific data. The PEB accommodates the following sub-systems:

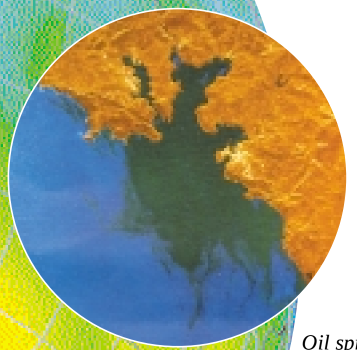
- the Payload Management Assembly, comprising the Payload Management Computer with its mission specific application software and three Remote Terminal Units constituting the interface for the monitoring and control of the PEB functions and the Payload Instruments,
- the Data Handling subsystem, including:
  - the High Speed Mutliplexer (HSM), which can select and assemble the instrument data into a continuous data stream of up to 50 Mbps for transmission to ground or 4.5 Mbps for data recording,
  - two 70 Gbit solid state recorders, backed up by a 30 Gbit tape recorder, allowing for intermediate storage of HSM output data during periods without direct ground station coverage,
  - the Encoding and Switching Unit, to encode and to switch HSM, recorder playback, or payload high rate data to the different RF downlink channels,
- the X-Band transmission subsystem, providing three 100 Mbps or 50 Mbps channels (including one redundant) for data transmission to ground. It comprises the modulators, the Travelling Wave Tubes and their power conditioners for signal amplification, the Output Multiplexer, which combines the three links prior to transmission, and the fixed X-Band antenna located on the Payload Module Earth face,
- the Ka-Band transmission subsystem, providing three 100 Mbps or 50 Mbps channels (including one redundant) for data transmission to ground via the ESA's ARTEMIS satellite. It uses similar modulation and amplification hardware as the X-Band subsystem, but requires on the zenith face an outboard assembly consisting of a deployable mast and antenna.
  An Antenna Pointing Mechanism ensures that the antenna tracks the Data Relay Satellite,
- the power subsystem, comprising two Power Distribution Units, one for the PEB equipments and the other for the instruments and the Heater Switching Unit, providing power to the Payload Module Heaters under the control of the Payload Management Computer.



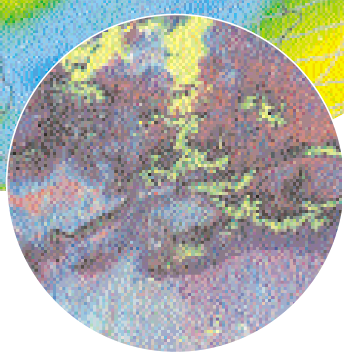
*Flight Model PEB undergoing final integration*



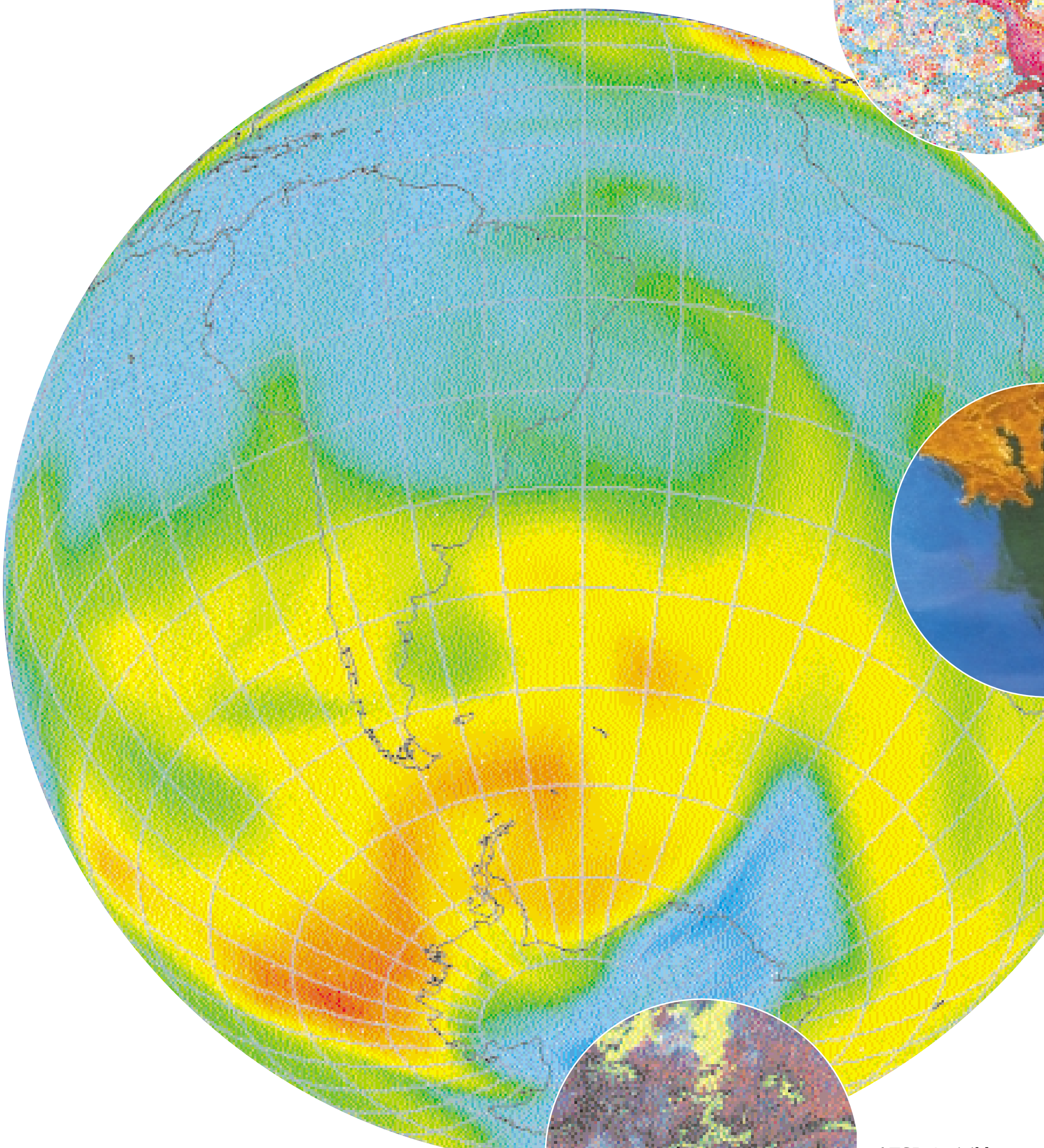
*ERS-1 multi-temporal radar image of Rügen and Vorpommern showing vegetation patterns*



*Oil spillage off Spanish coast*



*ATSR-2 visible composite image of the state of Colorado*



*Total ozone observed by ERS-2*

# Payload and Applications

Monitoring a complex system like the Earth's environment demands a specific set of multi-disciplinary payload instruments which complement each other. The translation of the mission objectives into physical and engineering parameters, which finally have to be measured, results in a payload comprising 10 individual instruments, even when using strong selection criteria governed by available financial budget and physical system constraints. The comprehensive measurement requirements with respect to the:

- atmosphere,
- biosphere,
- hydrosphere,
- geosphere,
- cryosphere,

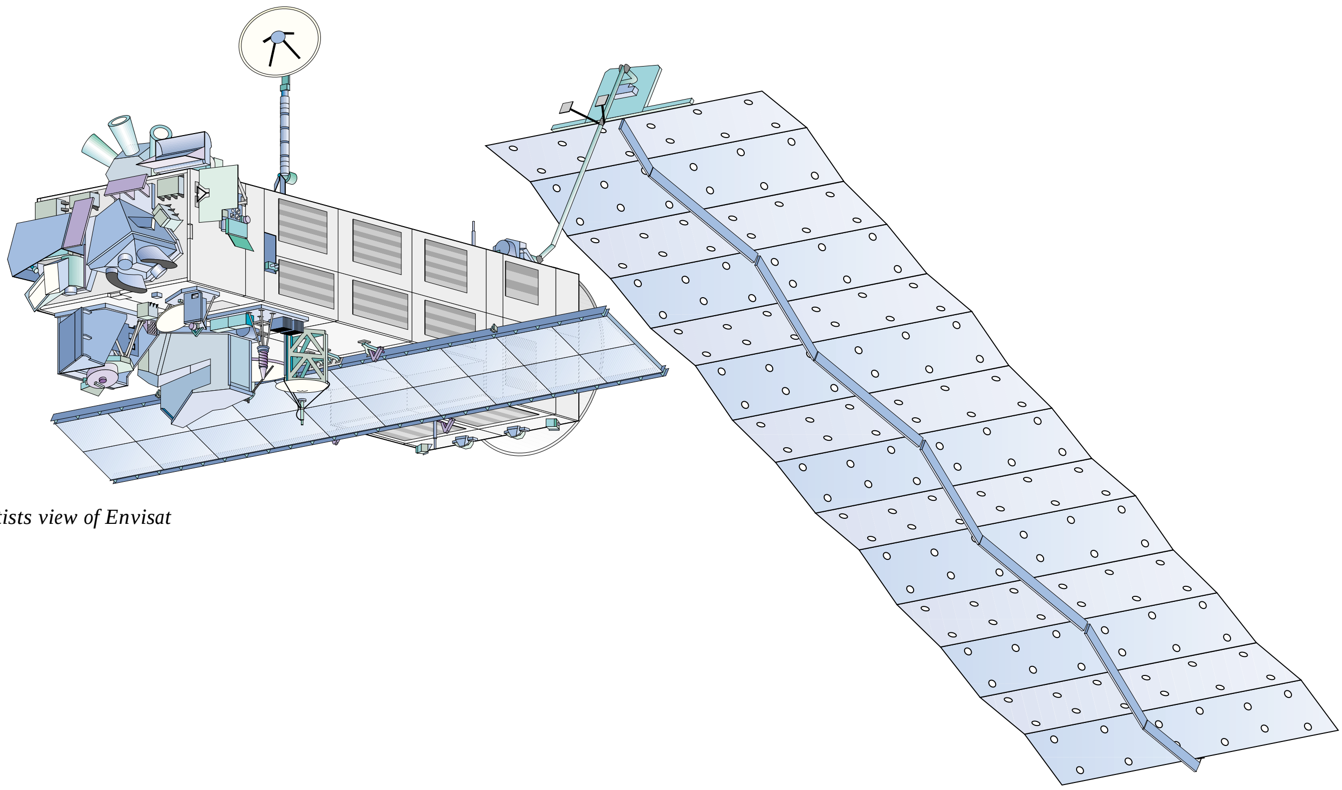
and corresponding distinct physical quantities:

- spatial resolution (global and regional data),
- spectral range and resolution,
- radiometric resolution

will be met by the unique set of two radar instruments, three spectrometers of different types and measurement characteristics, two different radiometers, broad and narrow band, and the first high-resolution spaceborne interferometer for long term observation, complemented by two instruments for range measurements.

In accordance with their primary field of application, the ENVISAT payload instruments can be categorised into four areas:

- radar imagery performed by ASAR,
- Ocean, Coastal Zone and Land observation supported by MERIS and AATSR,
- atmospheric measurements performed by GOMOS, MIPAS and SCIAMACHY,
- altimetric mission of RA-2 supported by MWR, LR and DORIS.



*Artists view of Envisat*

# Radar Imagery

## Advanced Synthetic Aperture Radar (ASAR)

The ASAR is a high-resolution, wide-swath imaging radar instrument that can be used both for site specific research and for global land and ocean monitoring and surveillance. Its main objective is to monitor the Earth's environment and to collect information on:

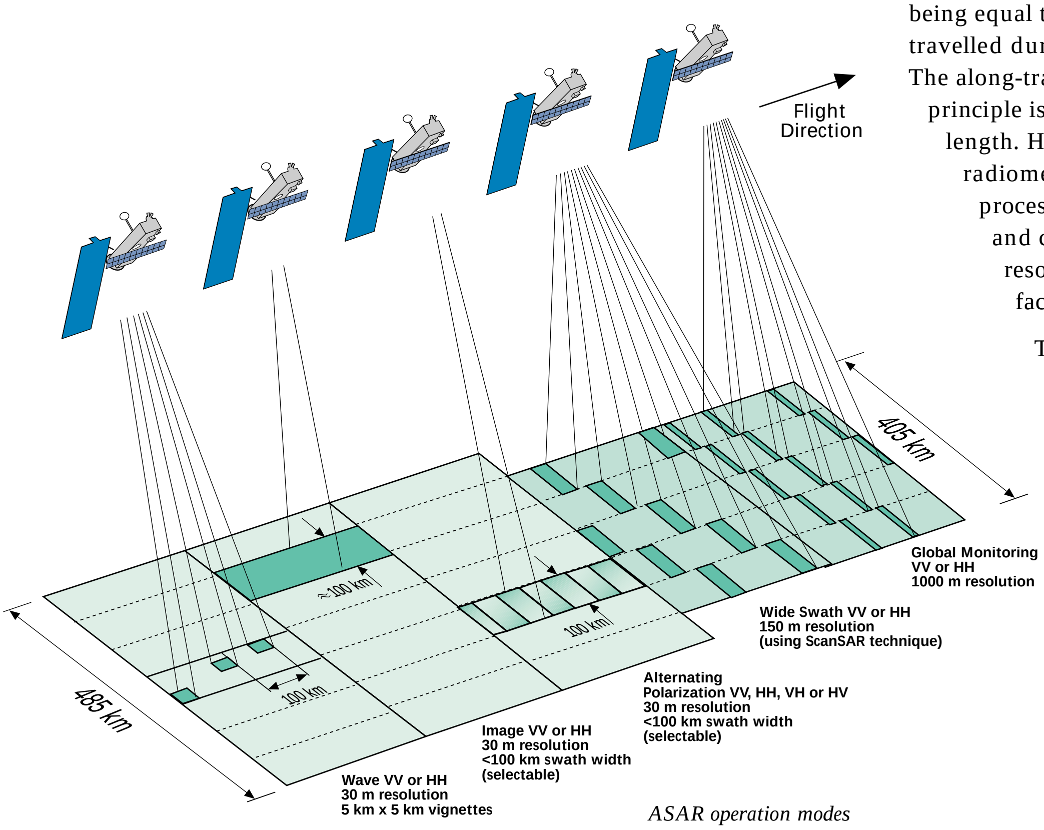
- ocean wave characteristics,
- sea ice extent and motion,
- snow and ice extent,
- surface topography,
- land surface properties,
- surface soil moisture and wetland extent,
- deforestation and extent of desert areas,
- disaster monitoring (flooding, earthquake, etc).

The major advantage of using a SAR instrument for these Earth observation tasks is its capability to take images independent of weather conditions, cloud coverage and solar illumination. Considering in particular observations of disasters like floods or hurricanes, which usually happen in adverse weather conditions, this weather independence is of vital importance.

Compared to the ERS-1 & 2 Active Microwave Instrument (AMI), the ASAR is a significantly advanced instrument employing a number of new technological developments, where the replacement of the passive radiator array of the AMI by an active phased array antenna system using distributed elements was the most challenging one. The resulting improvements are the capability to provide more than 400 km wide swath coverage using ScanSAR techniques, and the alternating polarisation feature allowing scenes to be imaged simultaneously in vertical (V) and horizontal (H) polarisation.

In nominal operation a radar antenna beam illuminates the ground to one side of the satellite. Due to the satellite motion and the along-track (azimuth) beamwidth of the antenna, each target element stays inside the illumination beam for a while. As part of the on-ground signal processing, the complex echo signals received during that time will be added coherently. In this way a long antenna is synthesised with the Synthetic Aperture length being equal to the distance the satellite travelled during the integration time. The along-track resolution obtainable with this principle is about half the real antenna length. However, to enhance the radiometric resolution, multilook azimuth processing will be applied on ground, and consequently the along-track resolution will be degraded by a factor equal to the look number.

The across-track or range resolution is a function of the transmitted radar pulse length. Pulse compression techniques are used to improve ASAR performance, taking into account the instrument peak power capability.




*ASAR operation modes*

The instrument is designed to operate in the following principal operating modes:

- image,
- wide swath,
- wave,
- alternating polarisation,
- global monitoring.

In image mode the ASAR gathers data from relatively narrow swaths (100 km within a viewing area of appr. 485 km) with high spatial resolution (30 m), whereas in wide swath mode using ScanSAR techniques a much wider stripe (400 km) is imaged with lower spatial resolution (150 m). In wave mode, ASAR measures the change in radar backscatter from the sea surface due to ocean surface waves.
In this mode images of 5 km x 5 km are taken over the ocean at a distance of 100 km.
The alternating polarisation mode provides imaging of a scene with alternating polarisation during transmission and reception. The spatial resolution is equal to that of image mode. In global monitoring mode a wide swath (400 km) is imaged with 1000 m spatial resolution.

The low data rates in wave and global monitoring mode can be recorded continuously up to the full orbit. The high rate data modes are operated upon user request. With the capability of on board recording, the operation of the instrument is independent of the availability of ground station contact. The radar images obtained by on-ground processing of the ASAR data will allow the generation of enhanced products suited to applications over land surfaces, ocean and coastal regions, and ice zones.

ASAR is developed under leadership of Astrium Ltd.. (UK).

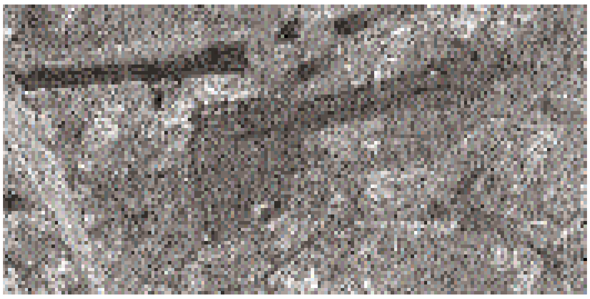
**Instrument Parameters**

| | Image | Wide Swath | Alternating Polarization | Wave | Global Monitoring |
|---|---|---|---|---|---|
| Spatial Resolution<br>along-track<br>across-track | ≤ 30 m<br>≤ 30 m | ≤ 150 m<br>≤ 150 m | ≤ 30 m<br>≤ 30 m* | ≤ 30 m<br>≤ 30 m* | ≤ 1000 m<br>≤ 1000 m |
| Radiometric Resolution | ≤ 1.54 dB | ≤ 1.54 dB | ≤ 3.5 dB | ≤ 2 dB | ≤ 1.5 dB |
| Swath Width | up to 100 km | ≥ 400 km | up to 100 km | 5 km vignette | ≥ 400 km |
| Ambiguity Ratio (Point)<br>along-track<br>across-track | ≥ 25 dB<br>≥ 30 dB | ≥ 25 dB<br>≥ 20.3 dB | ≥ 26 dB<br>≥ 18 dB | ≥ 30 dB<br>≥ 22.6 dB | ≥ 25 dB<br>≥ 24 dB |
| Ambiguity Ratio (Dist.)<br>along-track<br>across-track | ≥ 26.6 dB<br>≥ 17 dB | ≥ 20.3 dB<br>≥ 17 dB | ≥ 18 dB<br>≥ 17 dB | ≥ 22.6 dB<br>≥ 21.5 dB | ≥ 24 dB<br>≥ 17 dB |
| Radiometric Accuracy | ≤ 1.5 dB | ≤ 1.56 dB | ≤ 1.9 dB | ≤ 2.1 dB | ≤ 1.82 dB |
| Centre Frequency | | | 5.331 GHz | | |
| Pulse Repet. Frequ. | | | 1650 to 2100 Hz | | |
| Chirp Bandwidth | | | up to 16 MHz | | |
| Antenna Size | | | 10 m x 1.3 m | | |
| Operation | | Up to 30 min/orbit | | Rest of orbit | |
| Data Rate | ≤ 100 Mbit/s | ≤ 100 Mbit/s | ≤ 100 Mbit/s | 0.9 Mbit/s | 0.9 Mbit/s |
| Mass | | | 817 kg | | |
| Power | 1386 W | 1161 W | 1322 W | 400 W | 601 W |

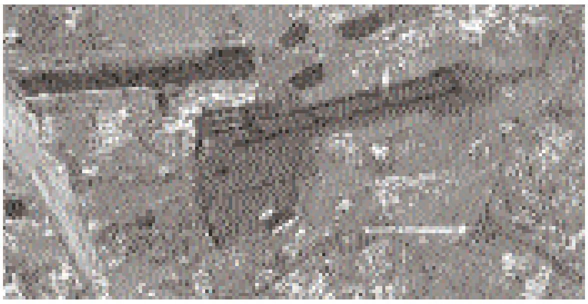
* slightly worse for near swath

*ASAR performance and budget data*

*ASAR antenna*



*SAR single look image*

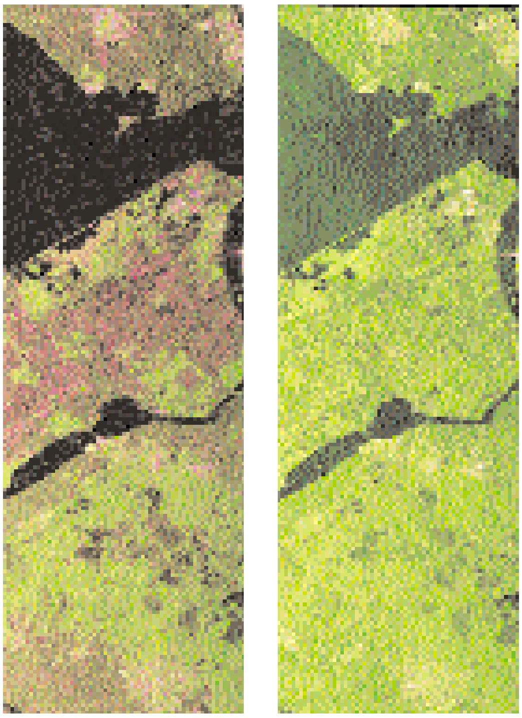


*SAR multi look image*

## Radar Image Principle

The signal from the synthetic aperture radar can be exploited to produce an image.
The radar image differs substantially from an optical image: it is, in reality, a map of apparent radar backscattering (coded as different grey levels) which not only depends on the target reflectivity at microwave wavelengths, but also on the viewing geometry.

One additional salient feature of a microwave image – which makes it different from optical images we are used to – is that the incoming 'light' (in this case, the 'received echo' of the radar signal) is a monochromatic coherent light. As a consequence, the image appears 'speckled' (see SAR single look image).
To reduce this effect, several images are incoherently combined as if they corresponded to different 'looks' of the same scene.
The resulting improvement in image interpretability is shown in the SAR multi look image.



*SAR alternating polarisation images*
*Left: SAR transmit H, receive H and V*
*Right: transmit H, receive V*
*(Images by courtesy of SARMAP S.A. (CH))*

## New ASAR Features

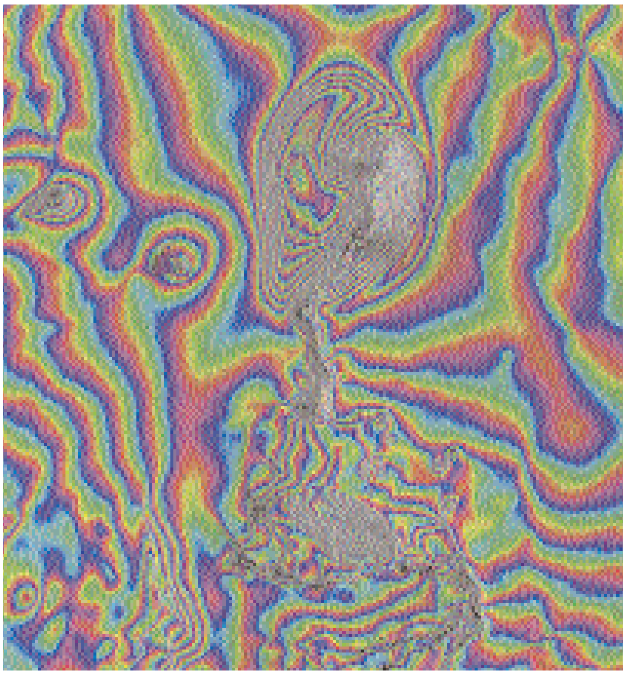
Among the many new features that ASAR presents, compared not only to ERS-1 & 2 but to any other spaceborne flying SAR, is the capability to transmit and receive signals with different polarisation (either vertical or horizontal). Because any given target responds in a specific way when illuminated with a different polarisation (see example in the figure), this technique greatly increases the capability of applications like classification, agriculture and forestry.

ASAR will also be characterised by the capability to image large areas (up to 400 km swath width), thus significantly improving the revisiting time compared to ERS-1 & 2.

## Interferometry

A powerful technique for application of the Synthetic Aperture Radar is that of SAR Interferometry, or INSAR. The INSAR technique exploits the phase information of the radar signal backscattered from the Earth's surface. By comparing the phase difference between two images of the same scene, taken by the same sensor in two subsequent passes, a phase difference image known as 'interferogram' is built.

The interferogram (right) shows, in the upper central part, a major depression caused by a sub-glacial volcanic eruption (see photographs below).

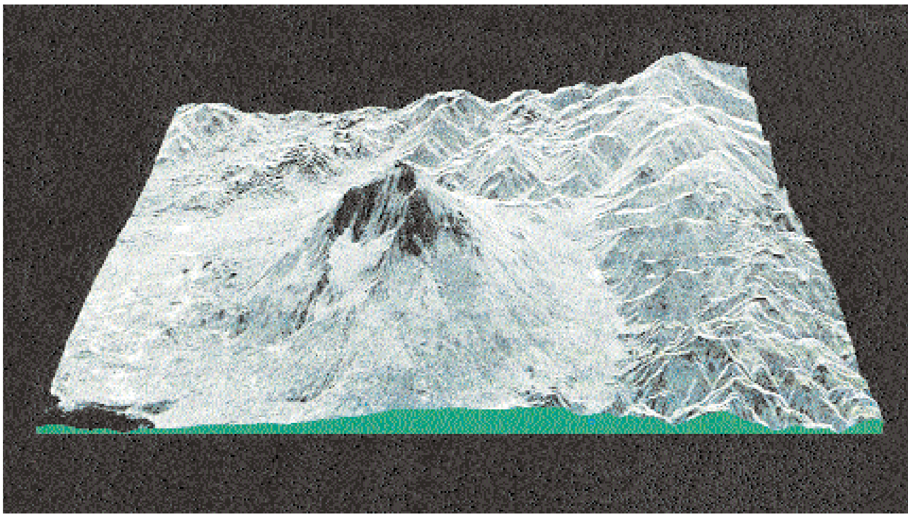


Interferogram from ERS Tandem Mission of part of the Vatnajokull Glacier, Iceland, May 1997
(Image by courtesy of H. Rott, Institut für Meteorologie und Geophysik, Innsbruck, Austria)

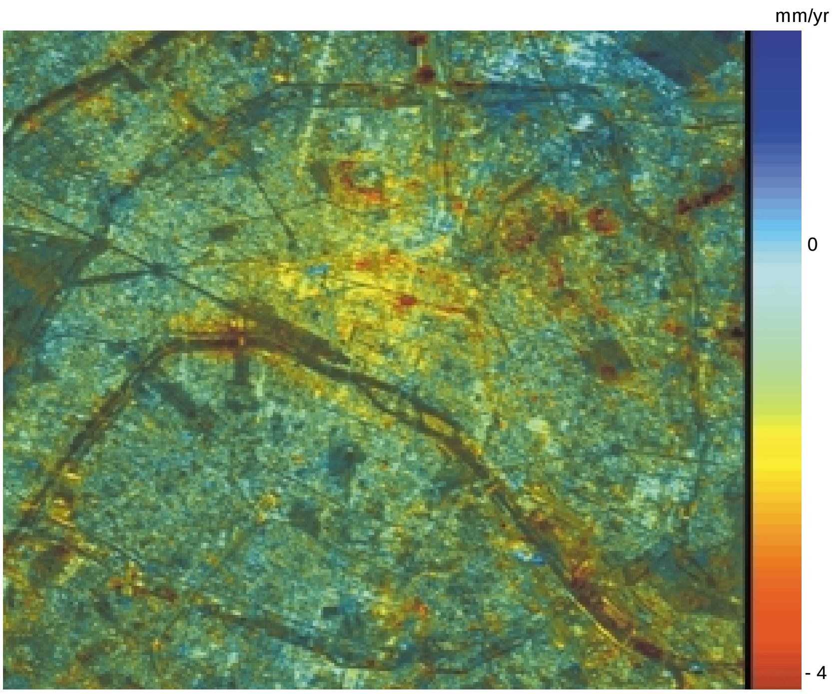
## Digital Elevation Models

Digital Elevation Models (DEM) are three dimensional maps of a terrain surface. The INSAR technique provides an excellent tool to derive large scale DEMs.

Digital Elevation Models (such as the one of Etna volcano shown here) can be constructed from interferometry data, with a maximum error in the order of 5 to 20 m, depending on the terrain topography.



*Digital Elevation Model of the Etna volcano built from ERS SAR data*




*Subsidence measured over Paris*
*(Image by courtesy of Politecnico di Milano–T.R.E.(I))*

## Subsidence by Differential Interferometry

By comparing interferograms taken at different times, the displacement of points on the ground can be estimated. This technique is extremely sensitive and displacements in the order of millimeters can be measured from space.

The image shows the mean velocity field of Paris from 1992 to 1999. The map has been derived from 64 ERS images and the subsidence rate is shown from zero (blue to light green) up to - 4 mm / year (red). More than 100 permanent scatterers per square kilometers have been identified and used to separate motion, elevation and to correct for atmospheric phase contributions.

*Earthquake between Istanbul and the lake of Sapanca*

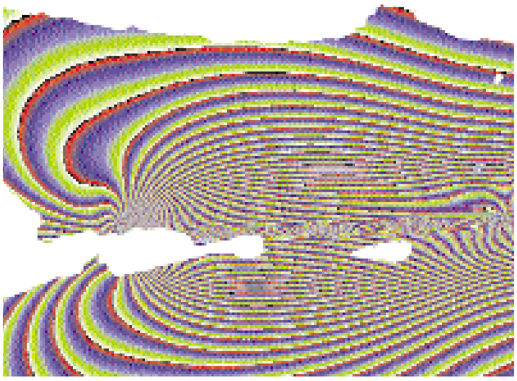


*Image A: Theoretical deformation model*

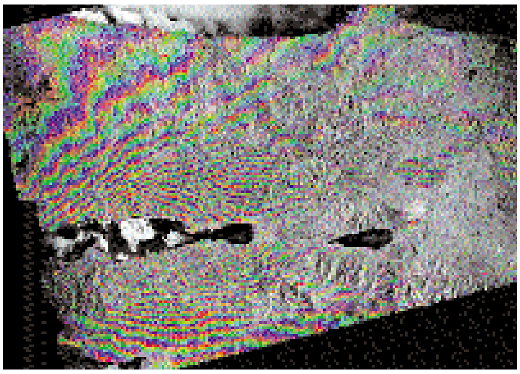


*Image B: SAR differential interferogram obtained from ERS SAR*

## Earthquake

SAR interferometry can be used to quantify the dislocation produced by an earthquake. Basically, two interferograms have to be compared, therefore three measurements are needed to derive the spatial displacements.

In the case of an earthquake which occurred in Turkey, a theoretical deformation model, derived from geophysical data, was used to recompute the terrain movement and display it as fringes, Image A.

The ERS SAR-derived phase interferogram, Image B, compares very closely with the model.

The geophysical interpretation of the model is that the rupture occurred along an east-west fault, causing a predominantly horizontal movement (right-lateral strike).

In the interferogram (Image B), each fringe corresponds to a ground displacement of 28 mm. By counting the number of fringes, one can calculate the co-seismic deformation of about 80 cm.

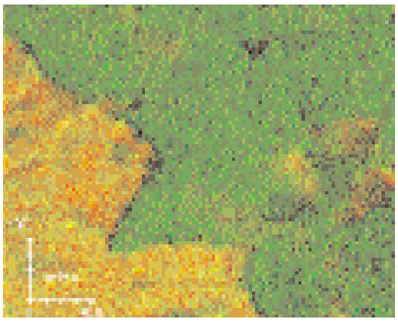
## Damage Assessment

Besides SAR intensity images and interferograms so called coherence products can be generated from SAR data. These coherence products show the interferometric correlation which is a measure of the variance of the phase coherence between two interferograms.

In terms of coherence imagery, different ground cover types manifest different degrees of coherence. Bare or sparsely vegetated soil has a high degree of coherence as there is little or no change in the scatterer properties between the two acquisitions. Forested areas, on the other hand, show a low degree of coherence, as the elementary scatterer (i.e. leaves) in each pixel move between the two acquisitions, mainly due to wind and, hence, lead to de-correlation in the imagery. This fact can be exploited to discriminate between forest and non-forest vegetation.

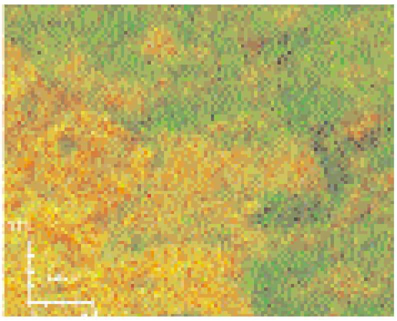
Results of the exploitation of the coherence product over the forest of Haguenau, 30 km north of Strasbourg, are illustrated in the images alongside. These were derived from the processing of two coherence products derived from two ERS-1 & 2 tandem pairs acquired before the storm, on 31 October and 1 November 1999 (a), and after the storm, on 9 and 10 January 2000 (b). In these products areas with high coherence are shown in orange-red, areas with less coherence (e.g. forests) in green. Thus, the coherence product allows one to separate forest / non-forest areas. The coherence product realised after the storm shows a strong increase of the coherence level within forested areas (b). A 'damage' image was produced based on the ratio of the two coherences, and averaged SAR intensity (c). In the 'damage' image composite, pink tones provide an estimate of the level of the damage. In this case, a level of damage of 50% had been reported by the forestry service which corresponds statistically to the increase of coherence over the area.

*Devastated forest*



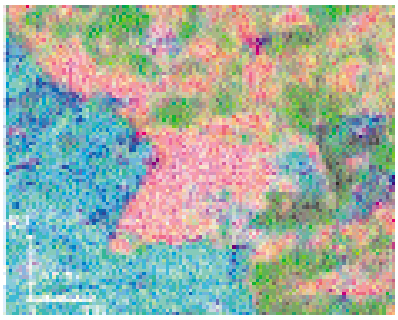
*(a)*

*SAR image of Haguenau forest before storm*



*(b)*

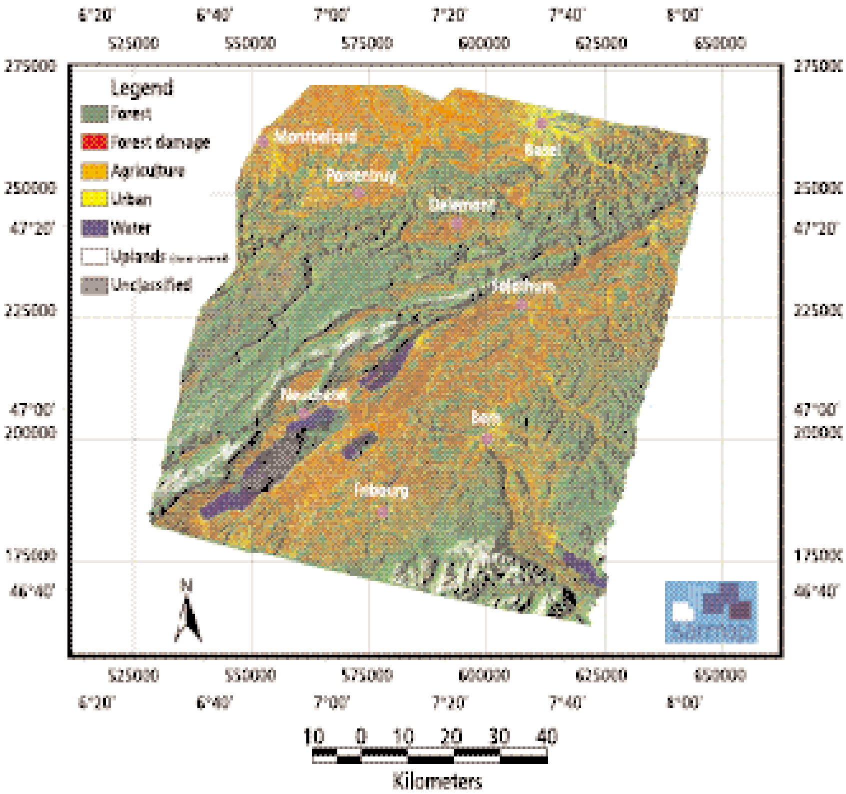
*SAR image of Haguenau forest after storm*



*(c)*

*'Damage' image of Haguenau forest*

*(Images by courtesy of Service Régional de Traitement d'Image et de Télédétection (F))*

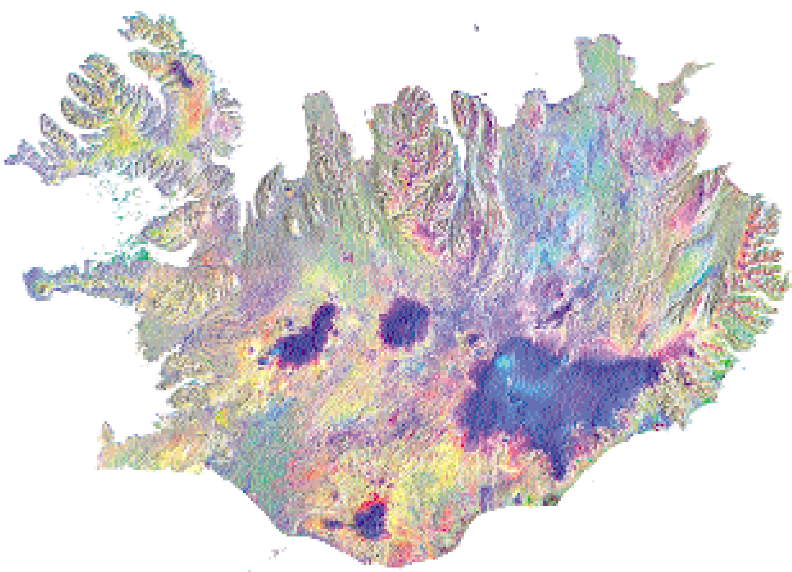



*Land classification in the vicinity of Bern using SAR data*
*(Image by courtesy of SARMAP S.A. (CH))*

## Classification

A combination of multi-temporal intensity images with coherence images allows a further discrimination of different type of land use.

In the illustrated example, using two coherence image pairs – one pair prior to the storm (4/5 April 1999) and one pair after the storm (9/10 January 2000) – a change within forested areas from low coherence to high coherence is indicative of forest damage. Using the coherence combined with the backscatter data, a supervised classification was carried out to identify forest areas damaged, as well as the other cover types in the scene. The classified image overlaid on a DEM, generated using InSAR techniques, is shown in the figure.



*Iceland multi-temporal composite ERS SAR image*
*(Image by courtesy of H. Rott, Univerität of Innsbruck (A))*

## Ice Classification

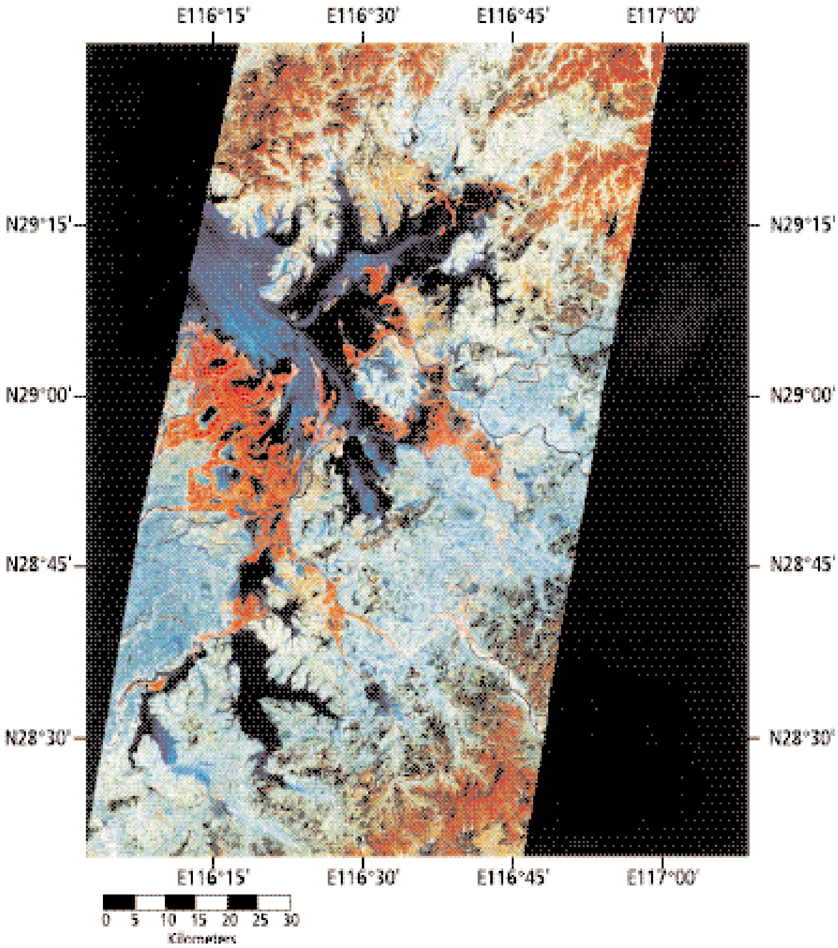
Combining and comparing SAR images acquired over the same area at different times allows surface characterisations ( type and variation). The multi-temporal image, figure of Iceland left, was obtained by combining three images acquired over different passes.
This image was produced with the following colour assignment: the blue colour for late winter 1996, green for mid summer 1997, and red for late summer 1997.

In these mosaics, the glaciers are the dominant features in terms of temporal variability.
The largest ice cap is Vatnajoekull, covering 8300 sq. km in area. This plateau, dark blue in the image, feeds ice in about 40 outlet glaciers. During summer, this plateau is covered with wet snow of low radar reflectivity. The purple colour identifies snow retreat, during late summer, in the mountains of northern Iceland.

## Floods

Floods are among the most severe risks to human lives and properties. The forecast and simulation of floods is essential for planning and operation of civil protection measures (e.g. dams, reservoirs) and for early flood warning (evacuation management). Considering that 85% of civil protection measures taken by EC Member States are concerned with floods (EC Report Task Force Water, 1996), the economic importance of flood forecasting becomes clear.

The SAR can monitor floods in real time as illustrated in the example image. The red area around the lake represents flooded land and agricultural fields.




*Flooding in Poyand Lake, central China, imaged by fusion of ERS SAR and Landsat-5 TM data*

## Sea Ice Navigation

Radar extracted sea-ice information can satisfy operational needs for navigation, offshore operations and weather forecasting.

The use of the wide swath mode (400 km wide) provided by ASAR as stripe products up to 4000 km long, will offer the possibility of monitoring large areas with frequent revisits.

Radar images will be provided to users in near real time to support, for example, icebreaker operations and to assist in optimising vessel routes.

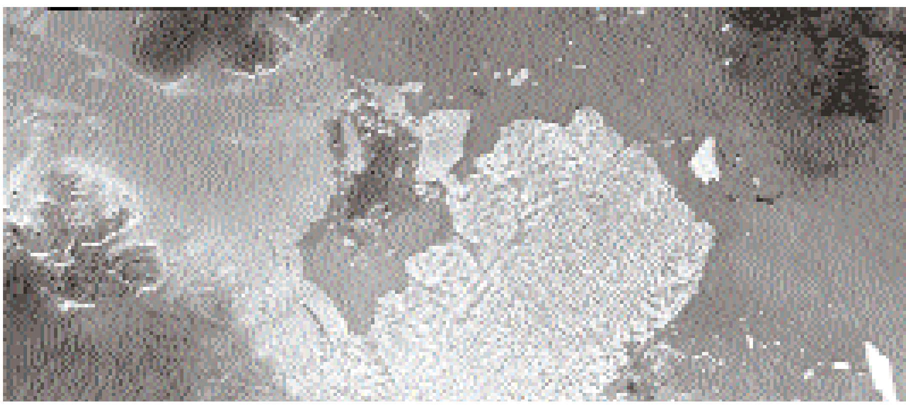
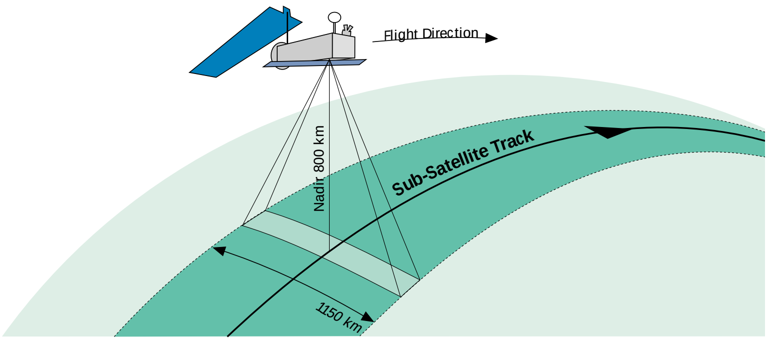


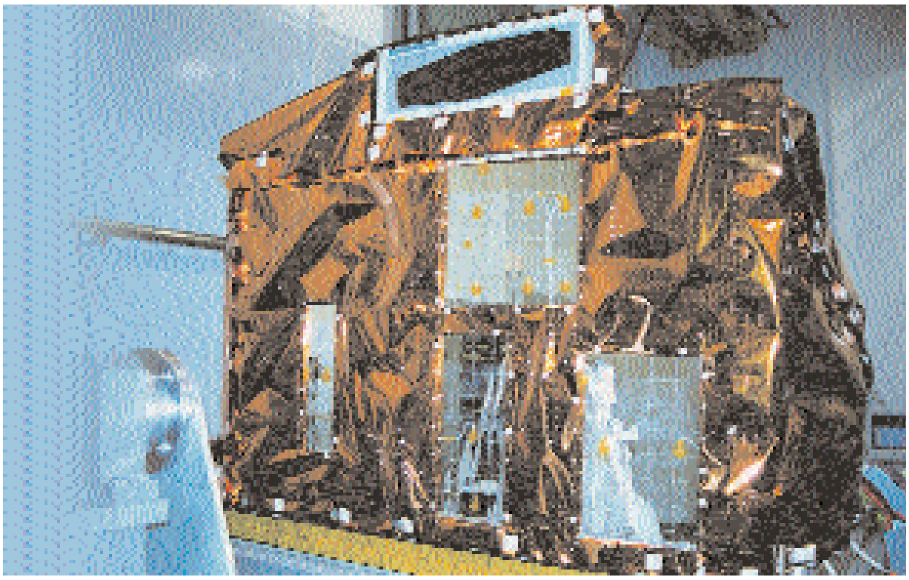
*Image of the Walgreen coast of Antarctica, acquired by ERS SAR and processed by the ASAR processor to simulate 150 metres resolution*

# Oceans, Coastal Zones and Land

## Medium Resolution Imaging Spectrometer (MERIS)




The Medium Resolution Imaging Spectrometer addresses the needs of three disciplines, primarily oceanographic and secondarily atmospheric and land observations. MERIS, complemented by the RA-2 and AATSR, provides a unique synergistic mission for bio / geophysical characterisation of the oceans and coastal zones, and thus for climate and global environment study and monitoring.

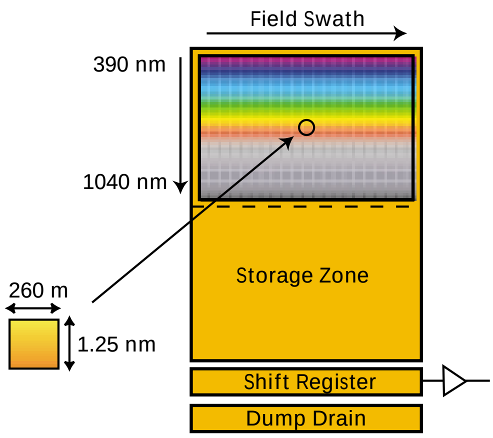


*MERIS Flight Model (Photograph courtesy of Alcatel SI (F))*

MERIS is a push-broom instrument measuring the solar radiation reflected from the Earth's surface and from clouds in the visible and near infrared range (390 nm to 1040 nm).
The 1150 km wide swath is divided into five segments covered by five identical cameras having corresponding fields of view with a slight overlap between adjacent cameras.
Each camera images an across-track stripe of the Earth's surface onto the entrance slit of an imaging optical grating spectrometer.
This entrance slit is imaged through the spectrometer onto a two-dimensional CCD array, thus providing spatial and spectral information simultaneously.

MERIS features a high degree of flexibility. Fully programmable on-board processing allows the selection of up to 15 different spectral bands with a bandwidth in the range between 1.25 nm and 30 nm.

The spatial information along-track is determined by the push-broom principle via successive read-outs of the CCD-array.
Full spatial resolution data, i.e. 250 m at nadir, will be transmitted over coastal zones and land surfaces. Reduced spatial resolution data, achieved by on-board combination of 4 x 4 adjacent pixels across-track and along-track resulting in a resolution of approximately 1000 m at nadir, will be generated continuously.




*CCD-array schematic*

The instrument is optimised for absolute and relative radiometric performances, featuring regular updating of calibration parameters applied on-board via dedicated calibration hardware to achieve long-term stability.

The instrument data will be pre-processed in flight and on ground to provide spectral images of the Earth, corrected for atmospheric influence. The data will be used for the generation of large scale maps, e.g. for:

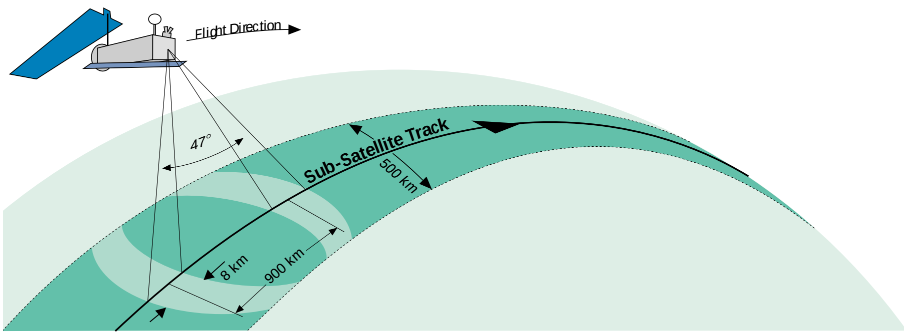
- ocean pigment concentrations,
- coastal water monitoring,
- clouds and water vapour,
- vegetation status and distribution.

MERIS is developed under leadership of Alcatel Space Industries (F).

| **Instrument Parameters** | |
|---|---|
| Spectral Range | 390...1040 nm |
| Spectral Sampling Interval | 1.25 nm |
| Spectral Bands | 15, centre frequencies programmable |
| Spectral Bandwidth | 1.25...30 nm, programmable |
| Instrument Field of View | 68.5°, equivalent 1150 km swath |
| Absolute Localisation Accuracy | < 2000 m |
| Solar Reflectance abs. Accuracy | < 2% |
| Measurement Modes | full resolution: 0.26 km x 0.29 km at nadir<br>reduced resolution: 1 km x 1 km at nadir |
| Polarization Sensitivity | < 0.5% |
| Error of Spectral Position | < 1 nm |
| Radiometric Resolution | 15 $\mu$W/ ($m^2 \cdot sr \cdot nm$) at 865 nm<br>(10 nm bandwith, reduced resolution) |
| Dynamic Range | ~ 40 dB |
| Operation | during day time |
| Data Rate | 24 Mb/s full resolution,<br>1.6 Mb/s reduced resolution |
| Mass | 209 kg |
| Power | 146 W |

*MERIS performance and budget data*

## Advanced Along Track Scanning Radiometer (AATSR)




The primary scientific objective of the AATSR is to establish continuity of the ATSR-1 and 2 data sets of precise Sea Surface Temperature (SST), thereby ensuring the production of a unique 15 year near-continuous data set at the levels of accuracy required (0.3 K or better) for climate research and for the community of operational as well as scientific users who will have been established through the ERS-1 & 2 missions.

The second objective is to develop and exploit the science of quantitative remote-sensing of land surfaces, particularly vegetation, through use of the improved visible-wavelength atmospheric correction that will be achievable with AATSR's two angle view. The land and cloud measurement objectives will be met through the use of a visible focal plane assembly, which will lead to indications of:

- vegetation biomass,
- vegetation moisture,
- vegetation health and growth stage.

The above parameters will be used to derive Global Vegetation Indices. The visible channels will also be used to measure cloud parameters like water/ice discrimination and particle size distribution.

| Instrument Parameters | |
|---|---|
| Spectral Channels | |
| Infrared | 1.6 µm, 3.7 µm, 10.8 µm, 12 µm |
| Visible | 0.55 µm, 0.66 µm, 0.87 µm |
| Spatial Resolution | 1 km x 1 km |
| Radiometric Resolution | 0.1 K |
| SST Accuracy | better 0.5 K |
| Swath Width | 500 km |
| Operation | continuously over full orbit |
| Data Rate | 625 kb/s |
| Mass | 108 kg |
| Power | 86 W |

*AATSR performance and budget data*

The field of view of the AATSR comprises two 500 km-wide curved swaths, with a pixel size of 1 km x 1 km at the centre of the nadir swath and 1.5 km x 2 km at the centre of the forward swath. The two views result from the instrument's conical scanning mechanism. Each scan takes a reading from the nadir position and then sweeps round to a point around 900 km along the satellite's track. Shortly after acquiring the forward view, the satellite passes over the same spot and takes a reading for the nadir view. As the two views of the same scene are taken through different atmospheric path lengths, it is possible to calculate a correction for the effect of atmospheric absorption.

*AATSR Engineering Model*

This principle of removing atmospheric effects in Sea Surface Temperature measurements by viewing the sea surface from two angles is the basis of the family of (A)ATSR instruments.

The SST objectives will be met through the use of thermal infrared channels (centred on 1.6 µm, 3.7 µm, 10.7 µm and 12 µm), identical to those on ATSR-1 & 2, plus the (A)ATSR's unique two-angle view of the Earth's surface.

As with the AATSR thermal infrared channels, the measurement philosophy with respect to the visible channels will be to develop and exploit a capability for making accurate quantitative measurements of radiation from the Earth's surface, using an on-board calibration system for basic radiometric accuracy, and using a two-angle viewing technique to obtain accurate atmospheric corrections.

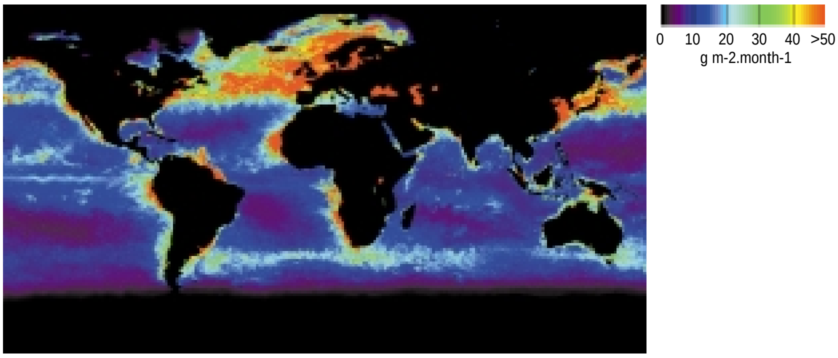
The most important two visible channels at 0.67 µm and 0.87 µm provide measurements of Vegetation Index, the additional channel at 0.55 µm supports the determination of the vegetation state (chlorophyll content).

The AATSR, developed under the leadership of Astrium Ltd. (UK), is a British / Australian contribution to the ENVISAT Mission.

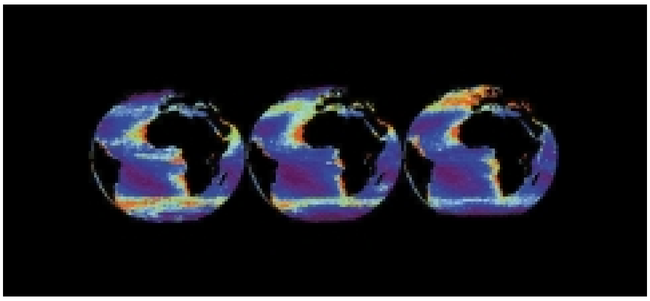
## The Carbon Cycle and Ocean Phytoplankton

MERIS will measure the bio-physical properties and chemical composition of the oceans and coastal waters. There remain major uncertainties about the amount of carbon stored in the ocean and in the biosphere, and about the fluxes between these reservoirs and the atmosphere. The ocean phytoplankton biomass accounts for about 50% of the biosphere's fixing of $CO_2$ through photosynthesis. This biological reaction produces oxygen. It also 'traps' atmospheric carbon dioxide into organic matter, resulting in primary biomass production. Increase of carbon dioxide concentration in the atmosphere results in global warming: it is the 'greenhouse effect'.

In the upper level of open oceans, chlorophyll concentration is the best index of phytoplankton abundance. Observing the oceans using specifically selected colour bands of MERIS will allow precise estimation of the chlorophyll concentration and derivation of phytoplankton abundance. It will aid analysis of the contribution of phytoplankton in the carbon-cycle.




*Ocean phytoplankton biomass primary production in May 1999, derived from SeaWifs (Image by courtesy of JRC Ispra (I))*

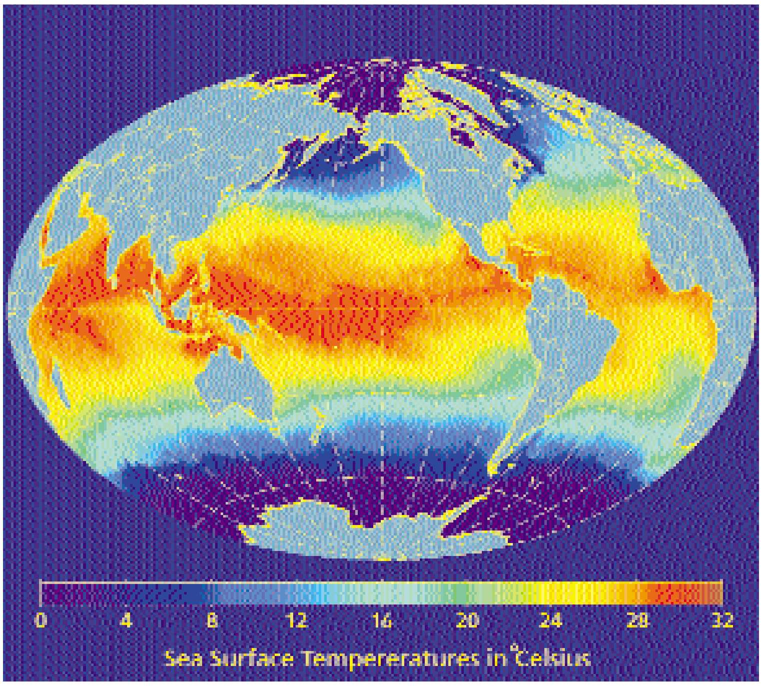


*Variation of the global primary production in January, March and May 1999, derived from SeaWifs (Image by courtesy of JRC Ispra (I))*

## Sea Surface Temperature (SST)

The SST is one of the most stable of several key geophysical variables which, when determined globally, characterise the state of the Earth's atmosphere system. The precise measurement of small changes in SST will provide an indication of quite significant changes in ocean / atmosphere heat transfer rates, especially in the tropics. Temperature anomalies of small amplitude occurring in specific areas are sometimes associated with massive atmospheric perturbations, leading to widespread and damaging changes in the global weather system.

The ocean is the largest heat reservoir of the globe. The heat exchange between the ocean and the atmosphere can be derived by the measurement of the SST. An event such as 'El Niño' can evolve from a SST anomaly of 2-3 K, and therefore the ability to detect early a 10% change of this anomaly field requires measurement accuracy which can only be provided by the (A)ATSR instruments.




*Global SST map produced from the ERS ATSR*

## Coastal Water Monitoring

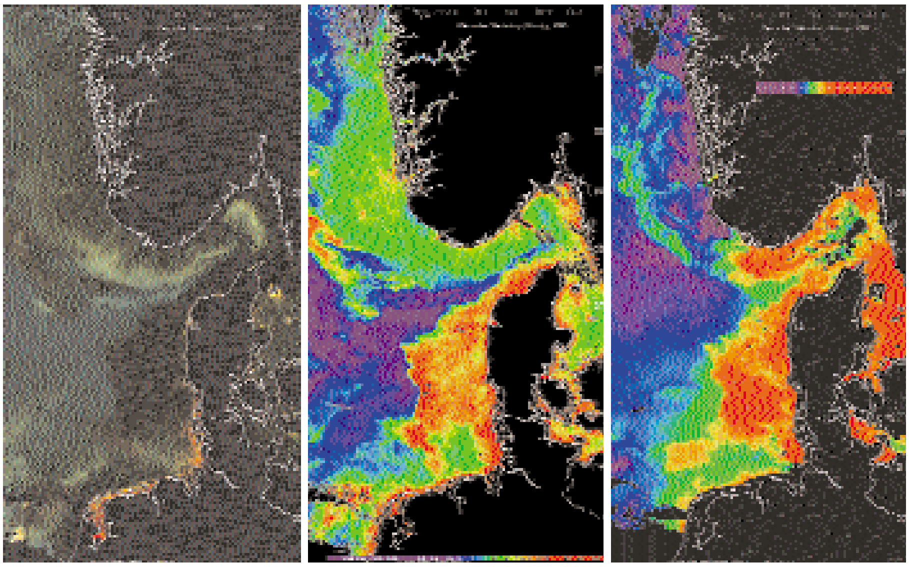
Like their terrestrial peers, fish in the oceans can be poisoned by their food, in particular toxic algae.

MERIS will provide near real time data on the composition of coastal water. No in situ measurement could provide such valuable information for fishery management. Furthermore, its high resolution and the adaptability of its spectral bands will be of unequalled value for scientists involved in coastal water studies.

Coastal water concentrations and sea surface temperatures, which will be provided respectively by the MERIS and AATSR instruments, are very complementary observations; in particular, it is well known that fish populations concentrate nearby thermal water fronts.

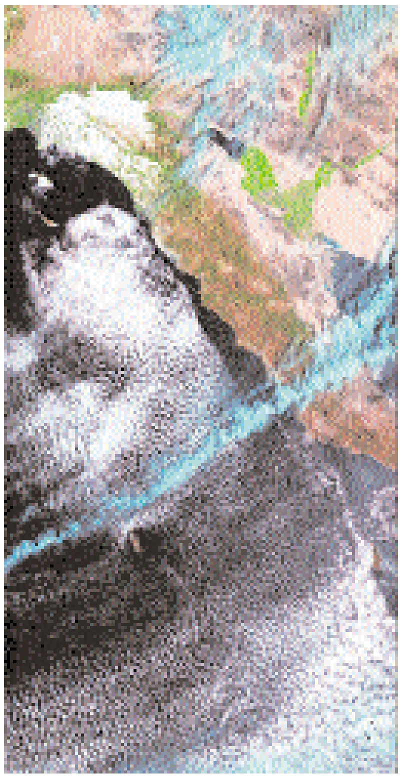
## Water Vapour and Clouds

The amount of water vapour in the atmosphere is an important component of the Earth's climate system. It varies considerably in response to variations in temperature and humidity, and acts as a carrier for redistributing energy around the planet. Water vapour has a large radiative effect and is the most important greenhouse gas. Water, in the form of clouds, liquid or ice, modifies the radiation reaching the surface and thereby strongly influences surface energy flux. The role of clouds in the climate system is still poorly understood. MERIS will routinely measure a number of cloud parameters, like cloud type, cloud albedo and cloud top height. This data will be provided to meteorological centres (in near real-time) thus improving our climate modelling and weather forecasting capabilities.



*From left to right: True colour composite image, chlorophyll concentration and sea surface temperature image in the Skagerrak region (Denmark)*

*(Images by courtesy of Plymouth Marine Laboratory (UK))*



*ATSR instrument image (Courtesy of RAL (UK))*

## Vegetation and Biomass

In 1997, most of the world's countries gathered in Kyoto agreed on the need to reduce greenhouse gas emissions. Because plants and trees are both sinks and sources of carbon dioxide, the monitoring of our biological resources remains crucial.

MERIS, with its large field of view combined with the proper selection of spectral bands, will allow regular observation of the world's landmasses.

This global view of our forest and vegetation will be complemented with high-resolution examination of particular areas, using the MERIS full resolution mode. This will help us to control and regulate deforestation, to monitor fire damage and more generally, to help protect the Earth.

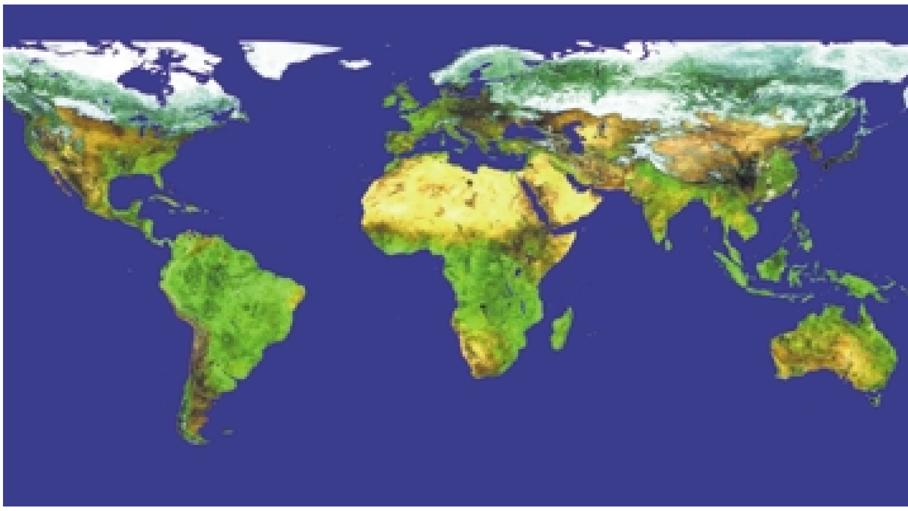
Biomass will be estimated from vegetation indices provided by both MERIS and AATSR.

Vegetation indices are estimated by taking the ratio of radiance measured on several specific spectral channels.

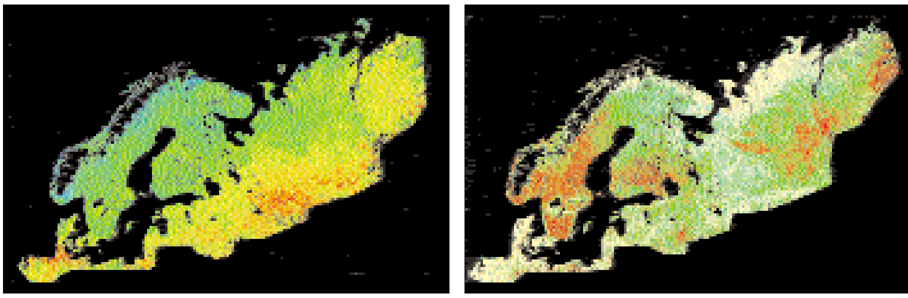
In the image example, a model is used to derive the biomass from the NDVI (Normalised Differential Vegetation Indices).

The biomass image uses the following colour code:

- light yellow: zero biomass,
- turquoise: 1-25 m3/ha,
- brownish green: 51-100 m3/ha,
- brownish red: 101-150 m3/ha,
- bright red: 150 m3/ha,
- black: water, mountains and clouds.



*World land vegetation map derived from Vegetation Data (Image by courtesey of CNES)*



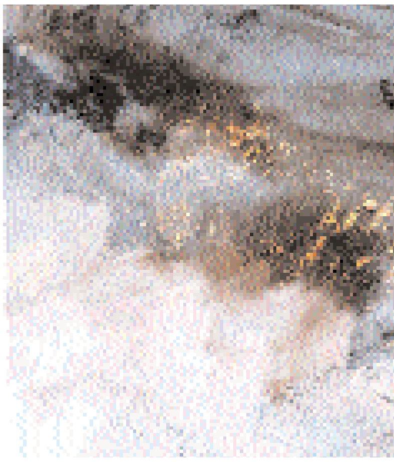
*NDVI estimation (left) and Biomass estimation (right) obtained from AVHRR (Images by courtesy of JRC (I))*

## Forest Fires

Fire detection and mapping using remote sensing measurements have demonstrated that a valuable amount of information can be derived in a systematic way by combining IR channel information with a time series of image data.

During the night, in the absence of reflected solar energy, the irradiance at 3.7 µm due to a fire burning is much greater than the background Earth surface. Ready-to-use fire products (hot spot images and localisation files) from the ERS ATSR are already processed and made available to users through a dedicated WWW server.

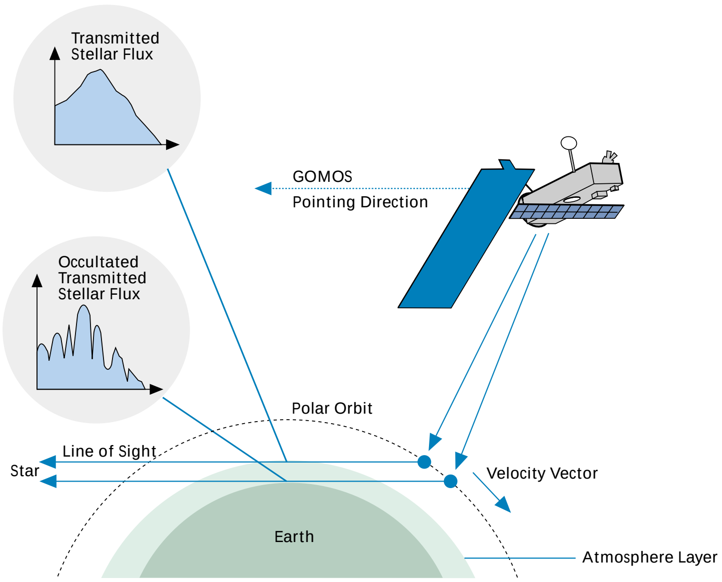
This service will be continued and fed with near real time products on the ENVISAT mission.



*Borneo forest fires imaged by the ATSR, October 1997 (Image processed by ESA)*

# Atmosphere

## Global Ozone Monitoring by Occultation of Stars (GOMOS)




The GOMOS instrument has been designed to enable simultaneous monitoring of ozone and other trace gases, as well as aerosol and temperature distributions in the stratosphere. Furthermore, it supports the analysis of atmospheric turbulences. Trace gas concentrations and other atmospheric parameters will be measured in the altitude range between 20 and 100 km with a vertical resolution of appr. 1.7 km.

The instrument accommodates a UV-visible and a near-infrared spectrometer fed by a telescope which has its line of sight orientated towards the target star by means of a steerable mirror. The instrument then tracks the star and observes its setting behind the atmosphere. Additional measurements provided by two fast photometers allow correction of the spectral data from the high frequency component introduced by atmospheric scintillations.

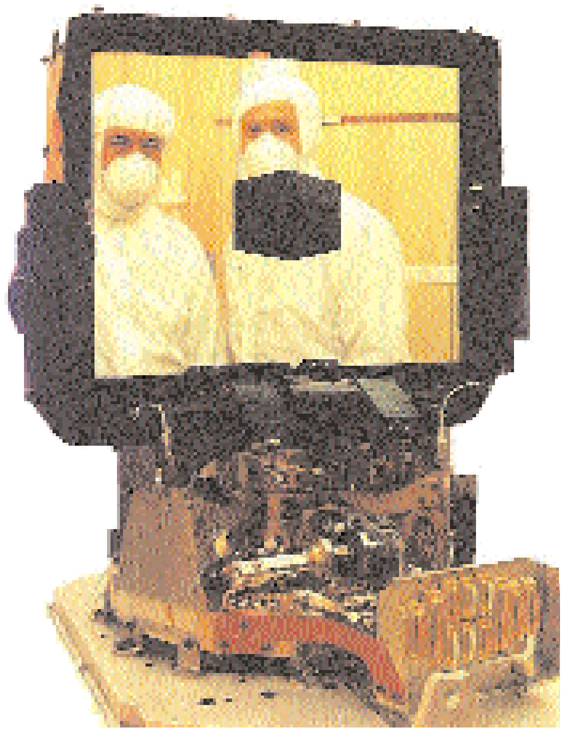
The 930 nm band of the near-infrared spectrometer permits derivation of vertical profiles of water vapour, which is a major contributor in the ozone destruction process. From the 760 nm band of this spectrometer, the vertical temperature profile can be retrieved which provides data for the extraction of the ozone concentration profile and for its long term trend monitoring.

GOMOS will be operated continuously over the full orbit. About 25 stars brighter than MV = 2 can be observed routinely at different longitudes from each orbit. With 14.3 orbits / day, the GOMOS instrument will produce as much data as a global network of 360 ground stations. The instrument is typically commanded to observe a sequence of up to 50 stars which are repeatedly observed on sequential orbits.

From the spectral analysis, spatial as well as short, seasonal and long-term temporal information can be derived. As a result, detailed maps, profiles and trends for various atmospheric constituents and parameters under investigation can be obtained.

The excellent performance of the GOMOS instrument stems from:

- the self-calibrating measuring scheme by detecting a star's spectrum outside and through the atmosphere,
- the drift and background compensating measurement algorithms introduced by the use of two-dimensional array detectors, which allow stellar and background spectra to be recorded simultaneously.



*GOMOS Steering Front Mechanism*

As a result, the spectra are easily corrected for background or stray light and detector dark current contributions. Successive recordings of stellar spectra outside and through the atmosphere allow any long-term changes in spectral emission characteristics, as well as drifts in sensor spectral sensitivity, to be compensated.

From simple relative measurements high stability is thus obtained. Over a five year mission period, ozone level changes as low as 0.05 % / year can be detected, far below the depletion rate expected from model calculations.

GOMOS is developed under leadership of Astrium SAS (F).

**Instrument Parameters**

| | Channel | Spectral Range | Spectral Resolution |
|---|---|---|---|
| Optical Performance Parameters | UV-VIS | 250 - 675 nm | 1.2 nm |
| | IR 1 | 756 - 773 nm | 0.2 nm |
| | IR 2 | 926 - 952 nm | 0.2 nm |
| | PHOT 1 | 650 - 700 nm | broadband |
| | PHOT 2 | 470 - 520 nm | broadband |
| Altitude Range | 20 km - 100 km | | |
| Vertical Resolution | 1.7 km | | |
| Operation | continuously over full orbit | | |
| Data Rate | 222 kb/s | | |
| Mass | 164 kg | | |
| Power | 187 W | | |

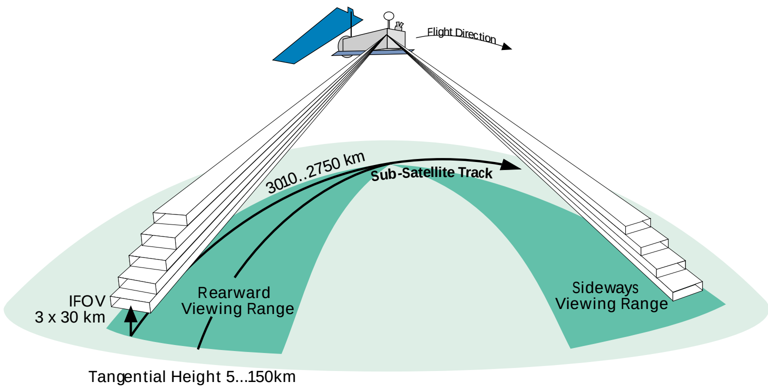
*GOMOS performance and budget data*

## Michelson Interferometer for Passive Atmospheric Sounding (MIPAS)

MIPAS is a high-resolution Fourier Transform Infrared spectrometer which is designed to measure concentration profiles of various atmospheric constituents on a global scale. It will observe atmospheric emissions from the Earth horizon (limb) in the mid infrared region (4.15 µm - 14.6 µm) providing global observations of photochemically interrelated trace gases in the middle atmosphere and the upper troposphere.

These data will contribute to the development of a better understanding in the following research areas:

- Stratospheric Chemistry: global ozone problem, polar stratospheric chemistry,
- Global Climatology: global distribution of climate relevant constituents,
- Atmospheric Dynamics: stratospheric transport exchange between troposphere and stratosphere,
- Upper Tropospheric Chemistry: correlation of gas distribution with human activities.



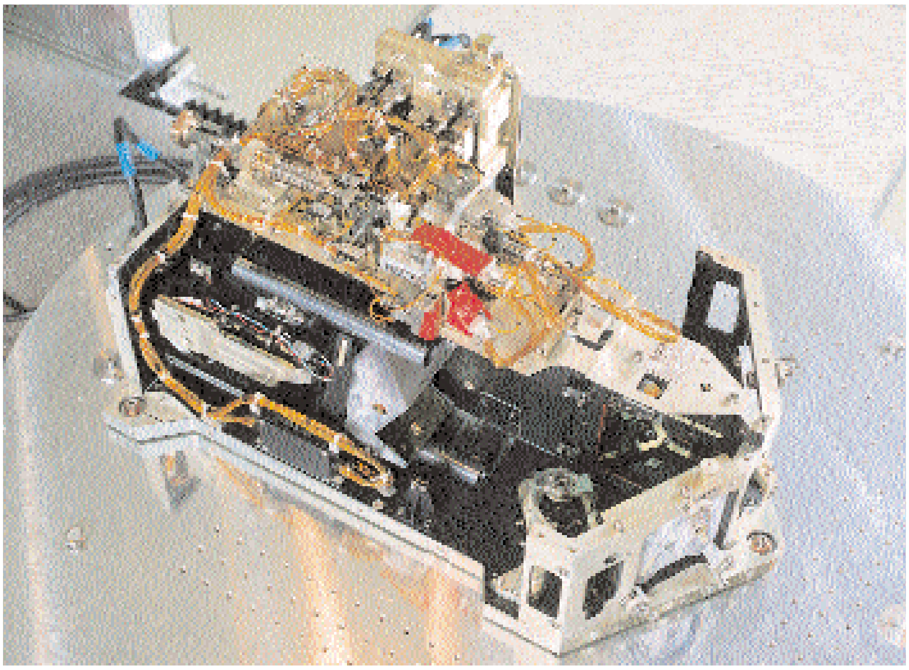

The instrument is designed to allow simultaneous measurement of more than 20 relevant trace gases, including the complete NOy-family and several CFCs. Atmospheric temperature as well as the distribution of aerosol particles, tropospheric cirrus clouds and stratospheric ice clouds (including Polar Stratospheric Clouds) are further important parameters which can be derived from MIPAS observations.

| **Instrument Parameters** | |
|---|---|
| Instrument $NESR_0$ | between 50 nW $cm^{-2}$ $sr^{-1}$/$cm^{-1}$ at 685 cm and 4.2 nW $cm^{2}sr^{-1}$/$cm^{-1}$ at 2410 $cm^{-1}$ |
| Radiometric Accuracy | 2 · $NESR_0$ + 2% to 5% of source radiance depending on wavelength |
| Spectral Coverage | 685 $cm^{-1}$ to 2410 $cm^{-1}$ |
| Spectral Resolution | < 0.035 $cm^{-1}$ |
| Spectral Stability Goal | < 0.001 $cm^{-1}$ over 1 day |
| Elevation Scan Range | between 5 km to 150 km tangential height |
| Azimuth Scan Range | 80° - 110° (sideways) and 160° - 195° w.r.t. flight direction |
| Line of Sight Pointing Knowledge | < 1.8 km in tangential height |
| Line of Sight Stability | < 500 m/4 s in tangential height |
| Detectors Oper. Temperature | 65 K - 75 K |
| Operation | continuously over full orbit |
| Data Rate | 533 kb/s; Raw Data Mode 8 Mb/s |
| Mass | 327 kg |
| Power | 196 W |

*MIPAS performance and budget data*

The data are obtained with complete global coverage, for all seasons and independent of illumination conditions, allowing measurement of the diurnal variation of trace species.

Atmospheric emissions will be measured at the horizon of the Earth (limb) over a height range of 5 km to 150 km. This observation geometry allows maximum measurement sensitivity and a good profiling capability to be achieved.



*MIPAS Interferometer (EM)*

MIPAS will perform measurements in either of two pointing regimes: rearwards within a 35° wide viewing range in the anti-flight direction, and sideways within a 30° wide range on the anti-sun side. The rearward viewing range will be used for most measurements, since it provides good Earth coverage including the polar regions. The sideways range is important for observations of special events, like volcanic eruptions, trace gas concentrations above major traffic routes, or concentration gradients across the dawn / dusk border.

MIPAS data products are calibrated high-resolution spectra which are derived on the ground from the transmitted interferograms. From these spectra the geophysical parameters are retrieved, such as trace gas concentrations, temperature profiles, mixing ratios, and global maps of atmospheric constituents.

MIPAS is developed under leadership of Astrium GmbH (D).

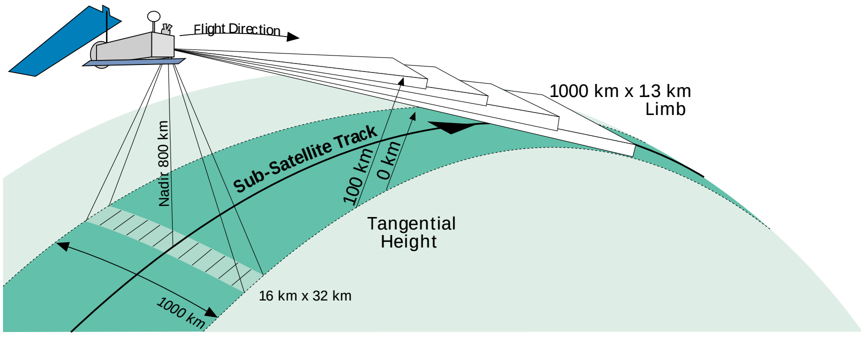
## Scanning Imaging Absorption Spectrometer for Atmospheric Cartography (SCIAMACHY)

The primary scientific objective of SCIAMACHY is the global measurement of various trace gases in the troposphere and stratosphere, which are retrieved from the instrument by observation of transmitted back scattered and reflected radiation from the atmosphere in the wavelength range between 240 nm and 2400 nm. The large wavelength range is also ideally suited for the determination of aerosols and clouds.
The nadir and limb viewing strategy of SCIAMACHY yields total column values as well as profiles for trace gases and aerosols in the stratosphere. This enables, in addition, estimates of global trace gas and aerosol content and distribution in the lower stratosphere and troposphere.

The measurements obtained from SCIAMACHY will enable the investigation of a wide range of phenomena which influence atmospheric chemistry, i.e.:

- in the troposphere: biomass burning, pollution, arctic haze, dust storms and industrial plumes,
- in the stratosphere: ozone chemistry, volcanic events and solar proton events.

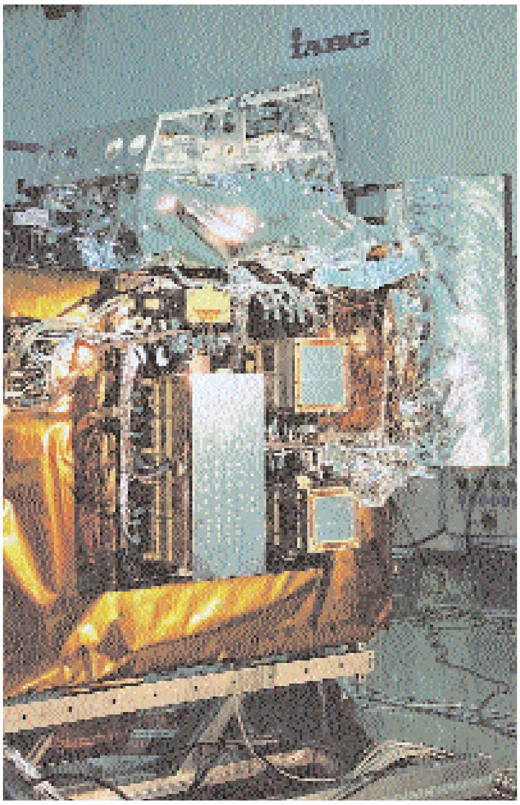
In order to achieve the scientific objectives, measurements are performed by observing the atmosphere under different viewing angles.
In Nadir Mode, the global distribution (total column values) of atmospheric trace gases and aerosols will be observed. Additionally, cloud measurements are obtained. In this mode, the instrument is scanning across-track, with a swath width of ± 500 km with respect to the subsatellite track. To obtain the altitude distribution of trace gases, SCIAMACHY performs observations in limb over an altitude range of 100 km, with a vertical resolution of 3 km. Starting at Earth horizon, the atmosphere is scanned tangentially over a 1000 km wide swath. After each azimuth scan, the elevation is increased until the maximum altitude of 100 km is reached.




Differential Optical Absorption Spectroscopy is applied in sun and moon occultation measurements, where either sun or moon are tracked or a vertical scan over the complete sun / moon surface is performed. The obtained spectra can then be compared with suitable calibration spectra to yield the differential absorption of the atmosphere.

| Instrument Parameters | | | |
|---|---|---|---|
| | Channel | Spectral Range | Spectral Resolution |
| High Resolution Channels | 1 | 240 - 314 nm | 0.24 nm |
| | 2 | 309 - 405 nm | 0.26 nm |
| | 3 | 394 - 620 nm | 0.44 nm |
| | 4 | 604 - 805 nm | 0.48 nm |
| | 5 | 785 - 1050 nm | 0.54 nm |
| | 6 | 1000 - 1750 nm | 1.48 nm |
| | 7 | 1940 - 2040 nm | 0.22 nm |
| | 8 | 2265 - 2380 nm | 0.26 nm |
| Polarisation Measurement Devices (broadband) | PMD 1 to 7 | 310 - 2380 nm | 67 to 137 nm (channel dependent) |
| Altitude Range | 10 km - 100 km depending on measurement mode | | |
| Vertical Resolution | 2.4 km - 3 km depending on measurement mode | | |
| Operation | continuously over full orbit | | |
| Data Rate | 400 kb/s; 1867 kb/s real time mode | | |
| Mass | 201 kg | | |
| Power | 119 W | | |

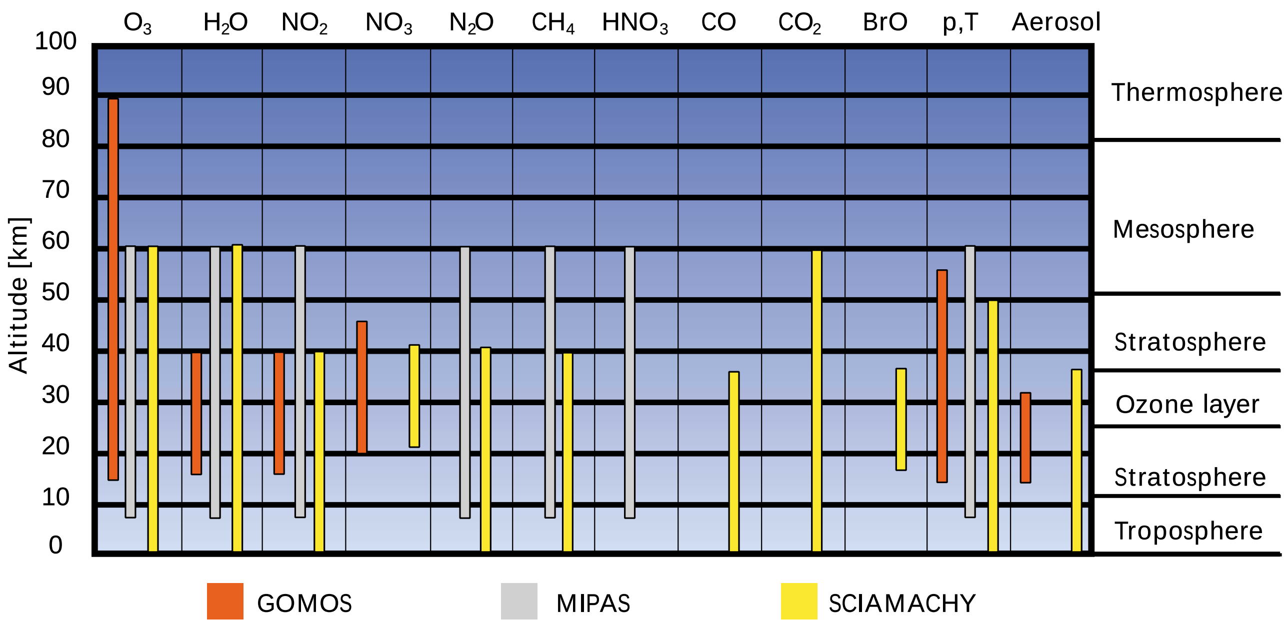
*SCIAMACHY performance and budget data*



*SCIAMACHY Flight Model*

SCIAMACHY is developed by a German / Dutch / Belgian programme under DLR, NIVR and OSTC contract with Astrium GmbH (D) and Fokker Space (NL) as the leading companies.

The figure below shows the altitude ranges over which GOMOS, MIPAS and SCIAMACHY will measure the different atmospheric constituents. The complementary observation among the three instruments – in terms of altitude coverage, trace gas retrieved, spectral and spatial resolution – is what gives a unique potential to the ENVISAT atmospheric payload.



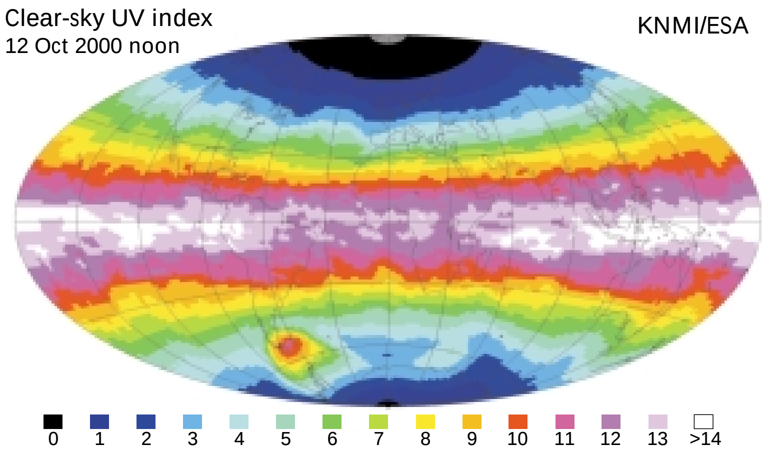

*Primary atmospheric species observed by GOMOS, MIPAS and SCIAMACHY*

## Ozone and UV Radiation

Many of the factors affecting the global environment are related to changes in the chemical composition of the atmosphere.

ENVISAT will make available global measurements of the many chemical species affecting the climate and will greatly contribute to improving forecasts of the Earth's climate.

It will, in particular, improve our present capabilities to retrieve the global distribution of ozone in the atmosphere. Among many other applications, the ozone products, provided by ENVISAT, will be assimilated into global ozone models. These models are used as the basis for reliable ultraviolet (UV) sunlight forecasts made available to the public, since it is an important hazard to be monitored for human health protection.

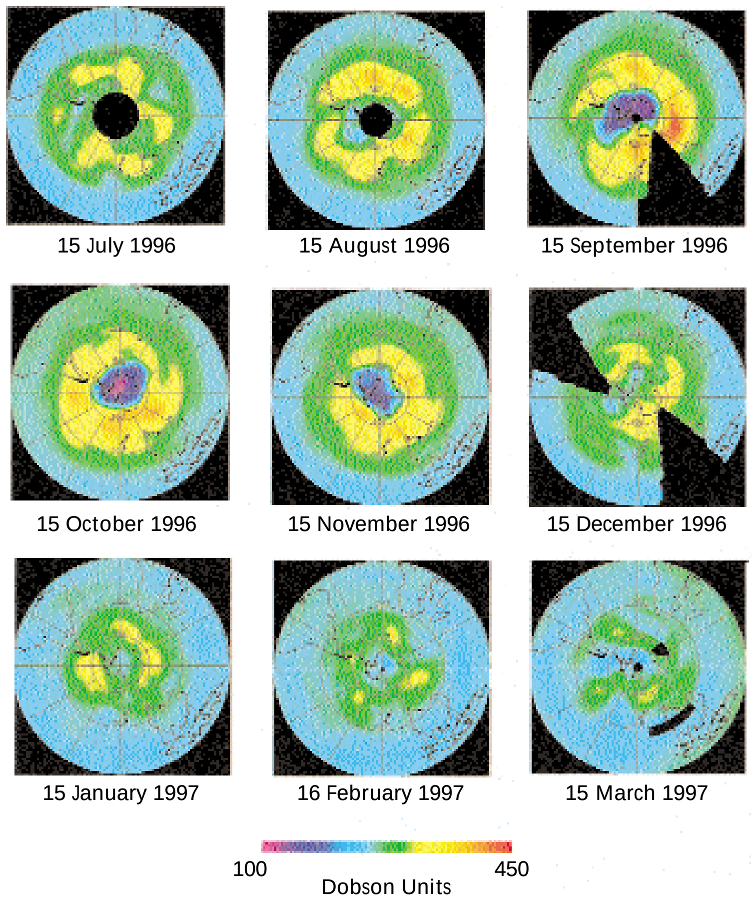



*Global UV Index forecasting for 15 November 2000, derived from GOME data (Image by courtesy of KNMI)*

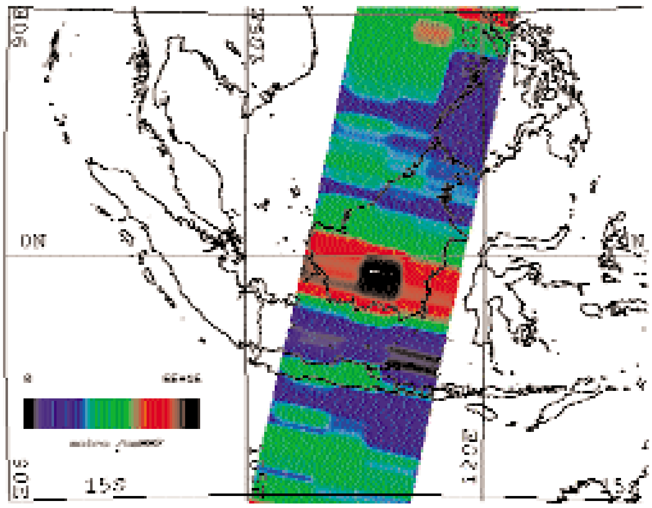
## Ozone Depletion

The reduction in stratospheric ozone concentrations since 1960 is the direct result of the use of ozone depleting chemicals. Conversely, pollution at the Earth's surface has led to increased levels of tropospheric ozone, particularly over industrial areas, with consequent threats to human health.

The figure alongside shows the time sequence of the global distribution of total column ozone in the Southern Hemisphere, measured by the GOME instrument on board the ERS-2 satellite. The sequence starts in mid-July 1996 (upper left) and ends in mid-March 1997 (lower right). Ozone depletion peaks in October, reaching record low values around 100 Dobson units. About 20 years ago the total column ozone was about 300 DU in this region. (The overhead vertical column of ozone is expressed in terms of the thickness of a sample of pure ozone at standard temperature and standard pressure: 1 DU = 0.01 mm)




*Southern Hemisphere ozone hole time sequence*



*Vertical column of $NO_2$ over Indonesia captured by GOME, indicating biomass burning events causing the $NO_2$ generation*

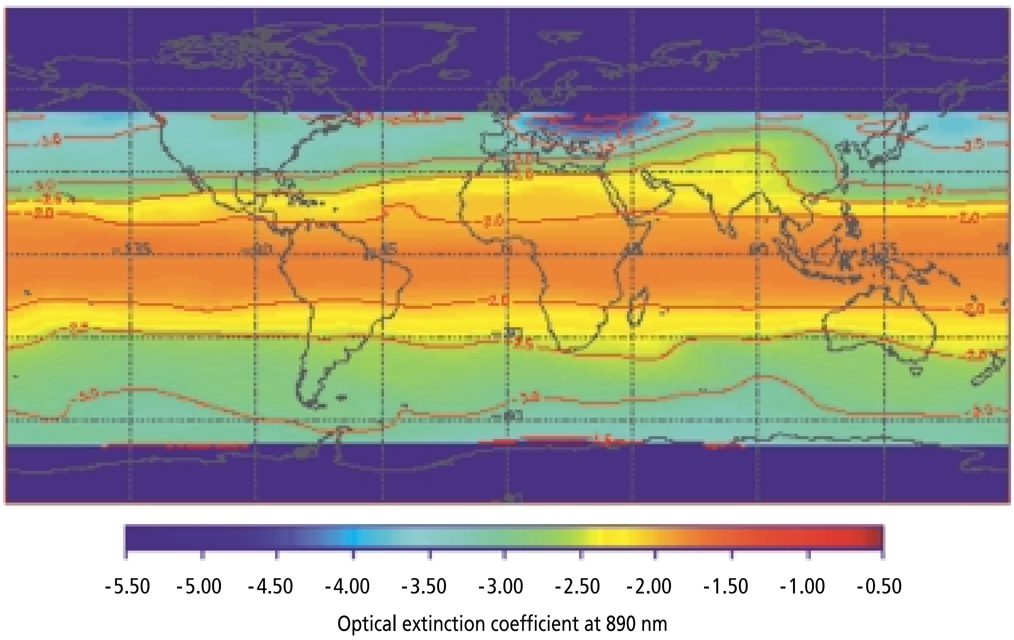
## Greenhouse Effect

The greenhouse effect relates to the warming of the troposphere by increasing concentrations of the so-called greenhouse gases (carbon dioxide, methane, nitrous oxide, ozone and others). The warming occurs because the greenhouse gases are transparent to incoming solar radiation, but absorb infrared radiation from the Earth that would otherwise escape from the atmosphere into space. The greenhouse gases then re-radiate some of this heat back towards the surface of the Earth. The rise in carbon dioxide as a result of industrialisation is primarily responsible for the enhanced greenhouse gas effect. Current carbon dioxide levels are more than double pre-industrial levels, and are the focus of international efforts to reduce emissions and offset the consequences of changed climate patterns, sea level rise, effects on hydrology, threats to ecosystems and land degradation.

## Aerosol Map

Global aerosol maps, generated by satellite measurements, give information about the radiative equilibrium of the Earth's atmosphere system. Increased levels of stratospheric aerosols can reduce the amount of sunlight entering the Earth's atmosphere. Large volcanic eruptions (e.g. Pinatubo during June 1991) may even globally affect power / fuel consumption and agriculture.

The attached aerosol map shows high aerosol extinction values, in January 1992, following the Pinatubo eruption.




*Aerosol map (optical extinction coefficient colour scale) based on SAGE II data, January 1992 after Pinatubo eruption (image by courtesy of BISA)*

## Trace Gases and Pollution

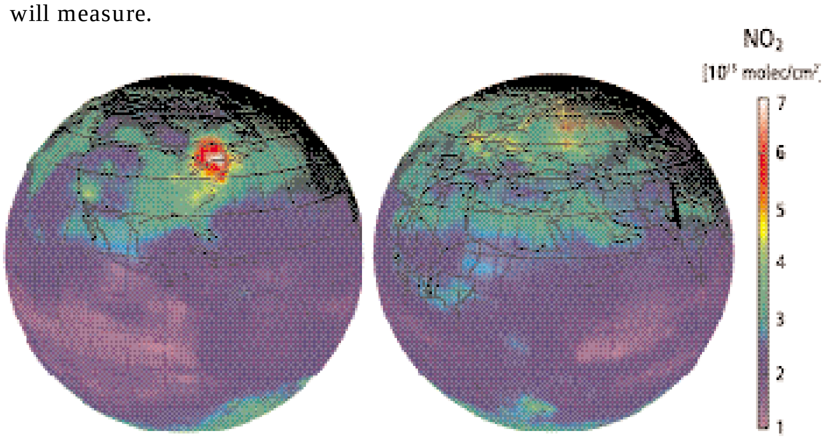
Lightning converts a tiny amount of inert nitrogen gas, which makes up 78% of air, into soluble compounds that plants can take up in their roots and metabolise. But the combustion of fossil fuels has unleashed a torrent of such nitrogen compounds into the atmosphere. When oil, gas and coal burn at high temperatures in engines and electric-power generators, they produce nitrogen oxides. Rain and wind carry these soluble compounds to the earth, further enriching coastal waters already replete with sewage and agricultural runoff. In all, fossil-fuel combustion accounts for about 15% of the biologically available nitrogen that human activities add to the world every year.

The rising concentration of methane ($CH_4$) in the atmosphere since the beginning of the 19th century is mainly due to changing agricultural practice, waste disposal, deforestation and mining. About 80% of the gas is produced by decomposition in rice paddies, swamps, the intestines of grazing animals and by tropical termites. The levels of methane have risen by 11% since 1978. The oxidation processes, which remove methane from the atmosphere, can be impaired by other emissions, principally those of man-made carbon monoxide, but also by natural hydrocarbons from plants. Up to 40% of the rise in methane concentration is ascribed to this reduction in the natural rate of its chemical decay.

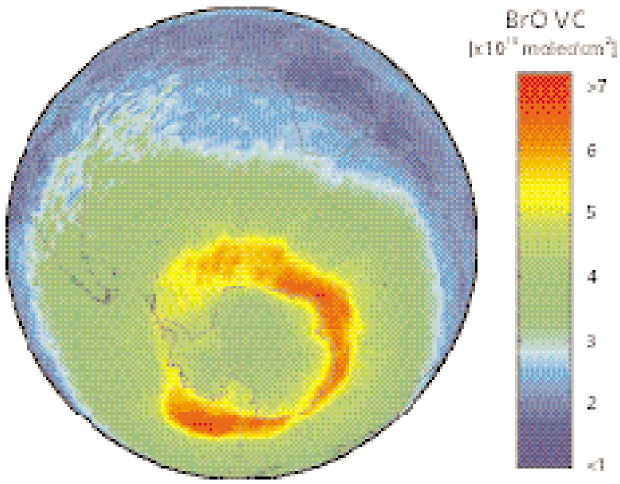
Also the CFC content of the atmosphere will remain a matter of concern for humanity for the next 50 years, the time it is estimated for these chemicals to disappear from the upper reaches of the atmosphere. The chemistry of the stratosphere is very complex, and the global measurement of these species or related reactive fragments leads to a better understanding of atmospheric physics and chemistry.

Bromine species play a significant role in the process that control's the amount of ozone in the lower atmosphere. Since the launch of GOME in 1995 the global monitoring of bromine monoxide has become possible, and these observations will be enhanced by the coming ENVISAT atmospheric observations.

In addition, to $CH_4$ and BrO, atmospheric constituents such as $SO_2$, $NO_2$, $NO_3$, $N_2O$, and $HNO_3$ are among the many other trace gases that MIPAS, GOMOS and SCIAMACHY will measure.

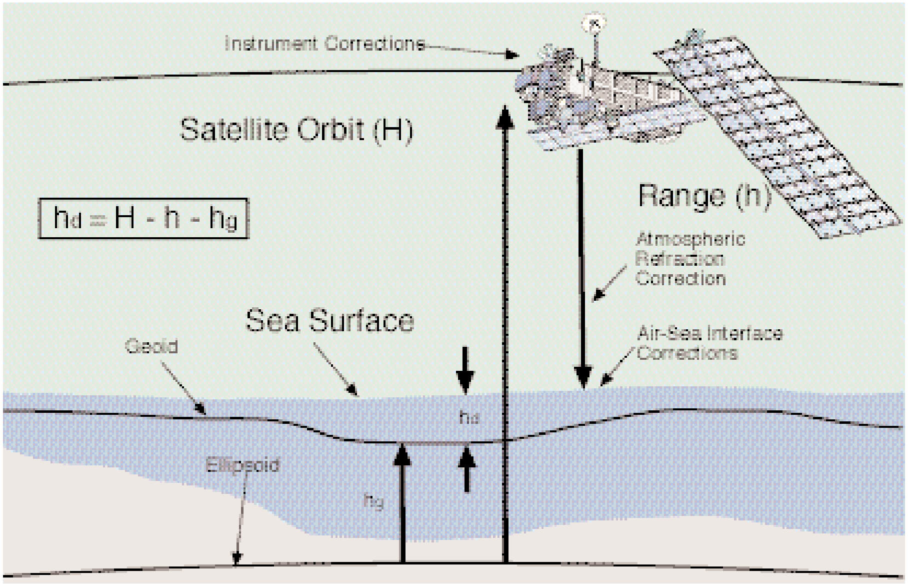



*Global $NO_2$ map measured by GOME*




*Global GOME bromine monoxide map over the South Pole for October 1999, showing tropospheric BrO plumes (Image by courtesy BISA)*

# Altimetry




## Radar Altimeter 2 (RA-2)

The Radar Altimeter 2 is derived from the ERS-1 & 2 Radar Altimeters, providing improved measurement performance and new capabilities.

The main objectives of the RA-2 are the high-precision measurements of the time delay, the power and the shape of the reflected radar pulses for the determination of the satellite height and Earth surface characteristics.

Operating over oceans, these measurements are used to determine the ocean topography, thus supporting the research of ocean circulation, sea floor and marine geoid characteristics.

The processing of the radar echo power and shape on ground enables the determination of wind speed and significant wave height in the observed sea area, thus supporting, in addition, the weather and sea state forecasting.

Furthermore, the RA-2 is able to map and monitor sea ice and polar ice sheets.

The new features of RA-2 enable it to extend to land the measurements of altitude and reflectivity.

The measurements will be used for the determination of Earth surface elevation, geological structure and surface characteristics.

RA-2 transmits radio frequency pulses which propagate at approximately the speed of light. The time elapsed from the transmission of a pulse to the reception of its echo reflected from the Earth's surface is proportional to the satellite's altitude. The magnitude and shape of the echoes contain information on the characteristics of the surface which caused the reflection.

On board the satellite, RA-2 measures with respect to transmission, power level and time position of the samples of the earliest part of the echoes from ocean, ice and land surfaces. This result is achieved by one of the new features on RA-2: a model-free tracker in the on-board signal processor that keeps the radar echoes within the sampling window. Window position and resolution are controlled by algorithms developed to suit the tracking conditions. Adaptive height resolution operation is implemented by selecting the bandwidth of the transmitted pulses.

*RA-2 Antenna (Photograph by courtesy of Alenia Spazio (I))*

As a result, measurements over ocean are carried out with improved accuracy at the highest resolution. Over land, ice or during transitions from one kind of surface to another, the tracking is maintained, accepting sometimes a certain degradation of the height resolution. Accurate altitude measurements over the ocean carried out by RA-2 at the main frequency of 13.575 GHz are affected by fluctuations in ionospheric characteristics. Measurements at a second frequency channel of 3.2 GHz enable the error to be corrected.

The RA-2 is developed under leadership of Alenia Spazio (I).

| Instrument Parameters | Range | Accuracy |
|---|---|---|
| Altitude | 764 km to 825 km | < 4.5 cm (highest res.) |
| Backscatter Coefficient | -10 dB to +50 dB | < 0.4 dB (bias)<br>< 0.2 dB (residual) |
| Waveheight | 0.5 m to 20 m | < 5 % or 0.25 m |
| Measurement Datation | +/- 100 µs wrt. UTC | |
| Operating Frequency | 13.575 GHz (Ku-Band)<br>3.2 GHz (S-Band) | |
| Bandwidth | 320 & 80 & 20 MHz & CW (Ku-Band)<br>160 MHz (S-Band) | |
| Pulse Repetition Frequency | 1795.33 Hz (for Ku-Band)<br>448.83 Hz (for S-Band)<br>interleaved operation | |
| Pulse Width | 20 µs | |
| IF Bandwidth | 6.4 MHz | |
| Operation | continuously over full orbit | |
| Data Rate | 68 kb/s nom.; 91 kb/s individual echoes | |
| Mass | 111 kg | |
| Power | 130 W | |

*RA-2 performance and budget data*

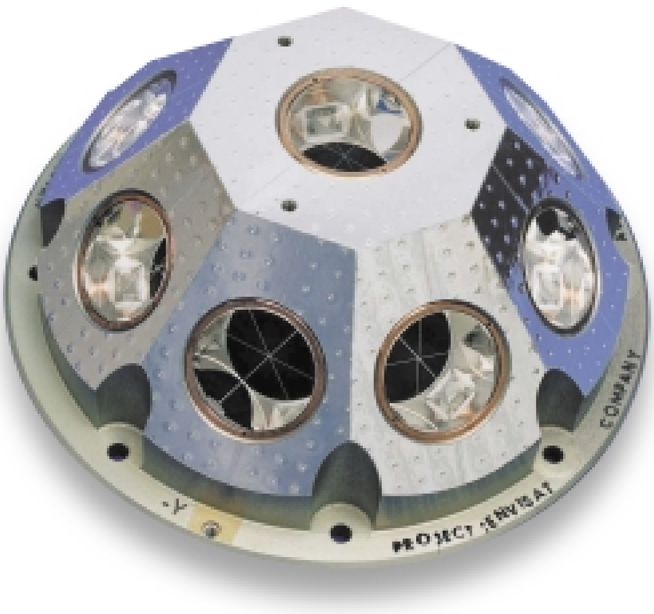
## Laser Retro-Reflector (LR)

The Laser Retro-Reflector is mounted on the nadir face of the satellite close to the RA-2 antenna to support satellite ranging and RA-2 altitude measurement calibration. The LR is a passive device which will be used as a reflector by groundbased laser-ranging stations using high power pulsed lasers.

The operating principle is to measure on ground the time of a round trip of laser pulses reflected from an array of corner-cubes mounted on the Earth-facing side of the satellite. The corner-cubes are designed to reflect the incident laser beam back directly, making the reflected beam parallel to the incident beam within a few arcseconds.

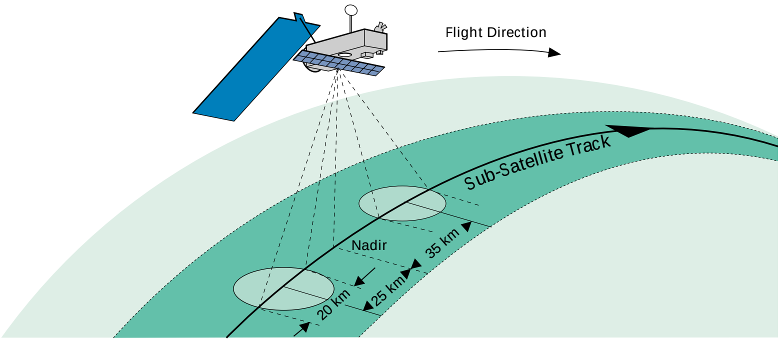
The corner cubes are made of the highest quality fused silica optimised for maximum reflectivity at 532 nm and 694 nm. They are symmetrically mounted on a hemispherical housing with one nadir-looking corner-cube in the centre, surrounded by an angled ring of eight corner-cubes. This will allow laser ranging in the field of view angles of 360° in azimuth and 60° elevation around the nadir.

The LR is developed under leadership of Alcatel Space Industries (F).




*Laser Retro-Reflector FM (Image by courtesy of Alcatel SI (F))*

## Microwave Radiometer (MWR)




The main objective of the Microwave Radiometer is the measurement of atmospheric humidity as supplementary information for tropospheric path correction of the Radar Altimeter signal, which is influenced both by the integrated atmospheric water vapour content and by liquid water. In addition, MWR measurement data are useful for the determination of surface emissivity and soil moisture over land, for the surface energy budget, investigations to support atmospheric studies and for ice characterisation.

*DORIS FM with MWR in the background (Photograph by courtesy of Sextant (F))*

The MWR instrument is a derivative of the radiometers used on the ERS-1 & 2 satellites. It is a dual channel, nadir-pointing Dicke type radiometer, operating at frequencies of 23.8 GHz and 36.5 GHz. Differential measurements at two frequencies have to be performed in order to eliminate Earth's irradiation.

With one feed horn for each frequency the MWR points via an offset reflector at an angle close to nadir. The instrument configuration is chosen such that the 23.8 GHz channel is pointing in the forward direction, the 36.5 GHz channel in the backward direction, with a footprint of about 20 km diameter for each beam.

| **Instrument Parameters** | |
|---|---|
| Operating Frequencies | 23.8 GHz (K-Band)<br>36.5 GHz (Ka-Band) |
| Dynamic Range | 3 K ... 335 K |
| Absolute Radiometric Accuracy | 1 K at $T_{ANT}$300 K, better 3 K at $T_{ANT}$85 K ... 330 K |
| Operation | Continuously over full orbit |
| Data Rate | 427 bit/s |
| Mass | 24 kg |
| Power | 10 W |

*MWR performance and budget data*

In nominal Dicke operation, the measured antenna temperatures are continuously compared with an internal reference load at a known temperature. The measurement range thus covered is 3 K to 335 K, with a reference temperature accuracy of better than 100 mK and an absolute radiometric accuracy of better than 3 K over the full measurement range.

The MWR is developed under leadership of Alenia Spazio (I).

## Doppler Orbitography and Radiopositioning Integrated by Satellite (DORIS)

DORIS is an orbit determination system, providing data of the satellite orbit with an accuracy in the order of centimetres.
In conjunction with the Radar Altimeter, DORIS contributes to climatology by measuring spatial and temporal ocean surface topography changes and variations in ice coverage. In addition, data are provided to:

- help in the understanding of the dynamics of the solid Earth,
- monitor glaciers, landslides and volcanoes,
- improve the modelling of the Earth's gravity field and of the ionosphere.

DORIS is based upon the accurate measurement of the Doppler shift of radio frequency signals transmitted from ground beacons and received on board the satellite. Measurements are made at two frequencies: 2.03625 GHz for precise Doppler measurements, and at 401.25 MHz for ionospheric correction of the propagation delay.

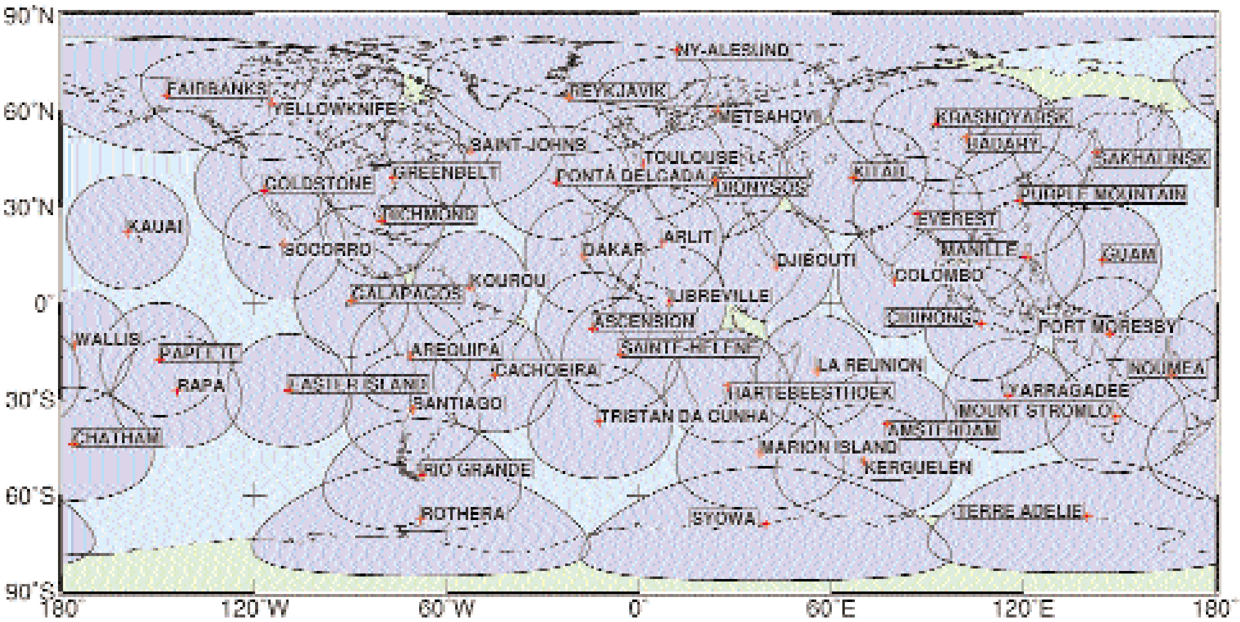
| Instrument Parameters | |
|---|---|
| Measurement Frequency<br>for Doppler Measurement<br>for Ionospheric Correction | <br>2.03625 GHz<br>401.25 MHz |
| Position Accuracy<br>Real-Time<br>Restituted | <br>< 1 m<br>0.05 m radial |
| Velocity Accuracy<br>Real-Time<br>Restituted | <br>< 2.5 mm/s<br>0.4 mm/s |
| Operation<br>Data Rate<br>Mass<br>Power | continuously over full orbit<br>16.7 kb/s<br>85 kg (incl. ICU)<br>51 W (incl. ICU) |

*DORIS performance and budget data*

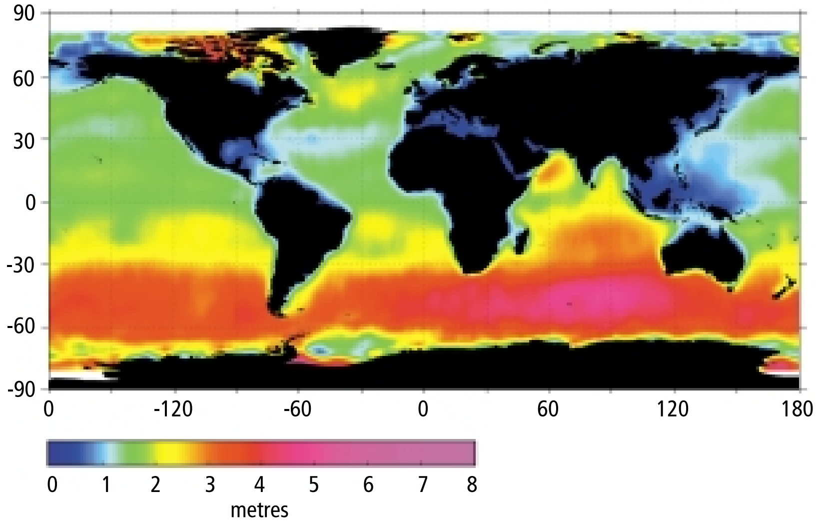
DORIS will allow determination of the satellite position with an accuracy of better than 0.05 m radial, and its velocity with an accuracy of better than 0.4 mm / s.

The DORIS system comprises the on-board instrument, a beacon network and the DORIS Control and Data Processing Centre.
The DORIS Control Centre performs instrument and beacon control on the basis of monitoring and telemetry data, and the operational orbit determination.

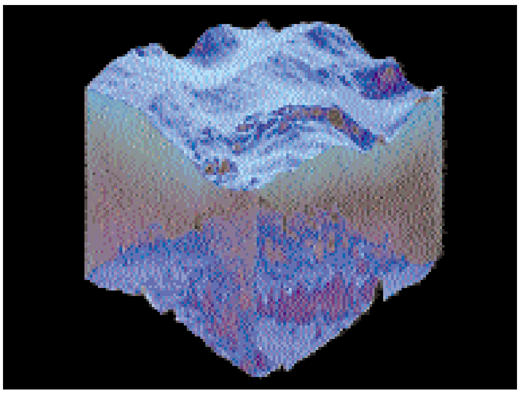
DORIS is provided to the ENVISAT programme by CNES (F).



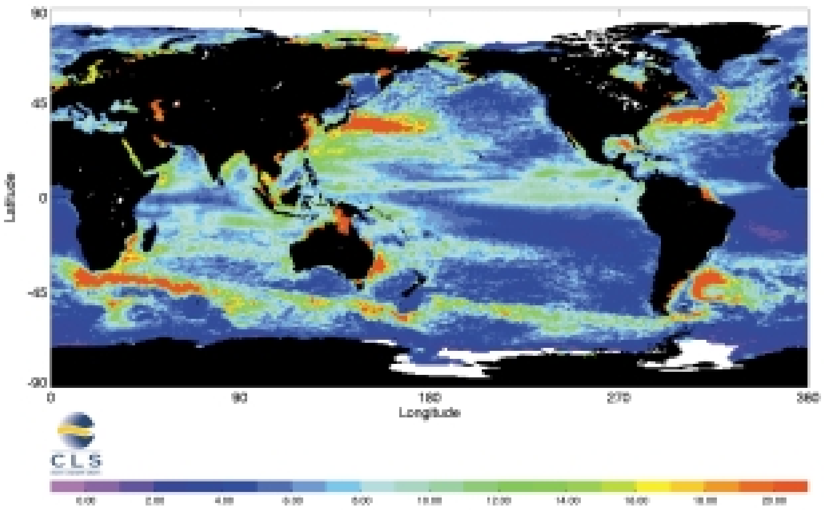

*DORIS Network, ENVISAT elevation: 12 deg, altitude: 800 km*




*Wave heights as measured by ERS-2 Radar Altimeter in the summer of 1995 (Processed by ESA 1996)*



*Relation between sea floor and sea surface elevation*




*Root mean square of sea level anomaly (in cm) obtained from merged ERS and T/P data from October 1992 to October 1997. Note the high resolution of the map brought by the denser ground track mesh of ERS. (Courtesy of PY LeTraon, CLS, F)*

## Wave and Wind

The Radar Altimeter is able to measure routinely wave heights (from the shape of the radar return echo) and wind speed at the ocean surface (from the strength of the returned power). Its measurements (together with those provided by the Wave Mode of the Synthetic Aperture radar) are commonly assimilated by the meteorological forecasting centres around the world.

This allows improvements of the wind and wave models which contributes to safer off-shore activities and more accurate routing of ships.

## Ocean Topography and Ocean Circulation

Earth observation satellites, such as ERS-1 & 2, have revolutionised the study of the ocean. They now provide accurate repetitive measurements over remote areas of the world, where previously there were only sparse observations from ships and buoys.

The ocean surface is not flat. The ocean surface carries signature of the shape of the sea floor, a bumpy surface called geoid. A better knowledge of the geoid carries information about the Earth's history.

The Radar Altimeter is able to measure ocean topography to a formidable degree of accuracy, in the order of centimetres.

Ocean circulation is generated by the combined effect of the attraction of the Moon and the Sun, by the heating of the water by the Sun, by the Earth's rotation, and by the winds.
The water circulation carries heat from the Equator and the mid-latitudes towards the polar regions. This giant heat transport process has a powerful influence on the Earth's climate.

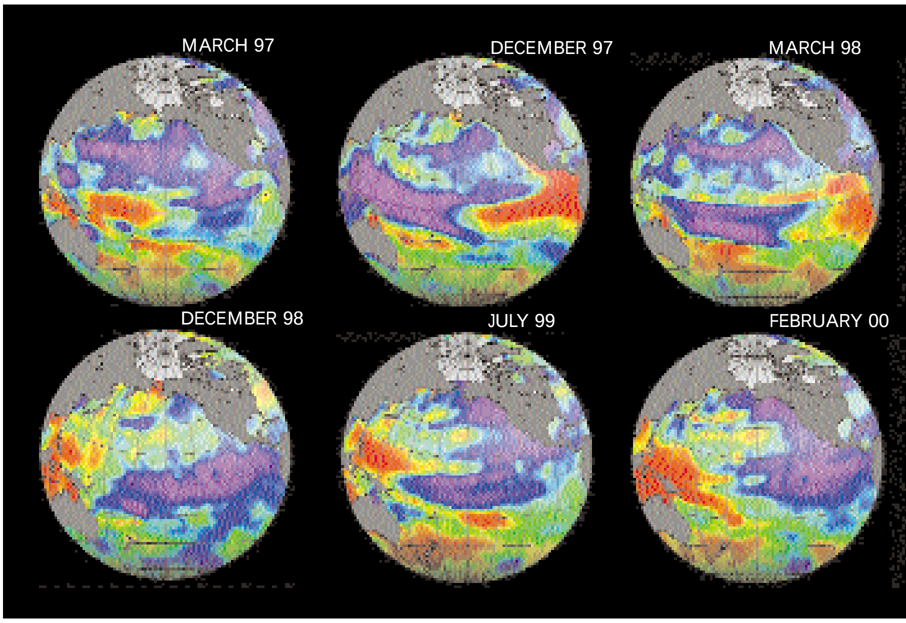
Typical ocean currents translate into ocean surface elevations of several tens of centimetres, easily observable by the Radar Altimeter. Variation of a few centimetres over a width of several hundreds of kilometres correspond to water flow variations of several millions of cubic meters per second, and therefore huge changes in the ocean current heat transport. To quantify the variations of the heat transport, these tiny variations of the surface elevation need to be observed with the centimetre accuracy achieved by the Radar Altimeter.

## El Niño

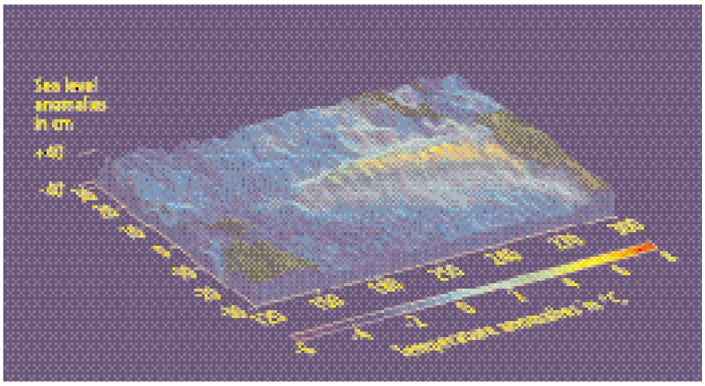
The El Niño phenomenon occurs when the nominal equilibrium is broken by the weakening of the trade winds. During an El Niño event, the trade winds weaken, there is an eastwards flow of warm surface water, a rise of the sea level by up to 30 cm on the eastern side, and an interruption in the up-welling of nutrient rich waters. Fish die or migrate to higher latitudes, and rainfall patterns change dramatically, causing heavy rain and floods on the western coast of South America and drought in Australia and south-east Asia.

During the last El Niño event, the Radar Altimeter and the ATSR, on board ERS-2, demonstrated very well their complementary capabilities to measure and track the evolution of the phenomenon.

The Radar Altimeter is able to measure the rise of the ocean surface due to the anomalous warming of the water, monitoring the development and evolution of the El Niño phenomenon. The time series from March 1997 to February 2000 illustrates the changes in the ocean surface elevation as seen from the Radar Altimeter. The second figure illustrates the combined use of measurements from the Radar Altimeter and ATSR instruments on board ERS. The Radar Altimeter measurements are shown as an increase of the ocean surface elevation, while the ATSR sea surface temperature measurements are shown in colour code. The high correlation between the two measurements is clearly visible.




*El Niño and La Nina 1997-2000 events as seen by altimetry*



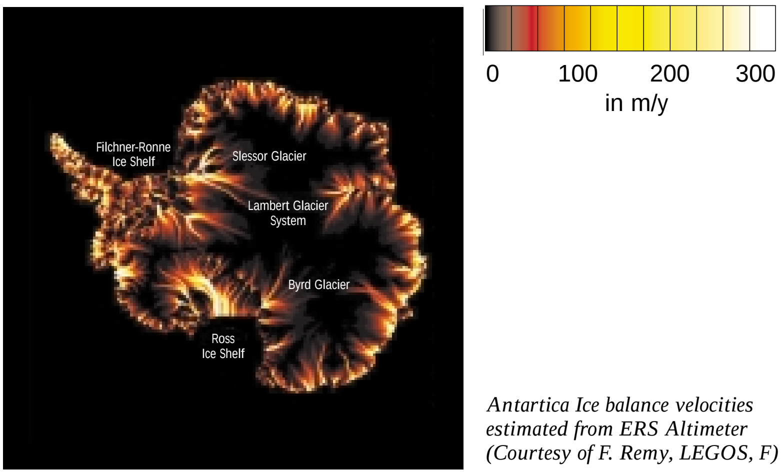

*Combined sea surface elevation and sea surface temperature anomalies provided by the ERS RA and ATSR during the El Niño event (image processed by ESA)*

## Ice Topography

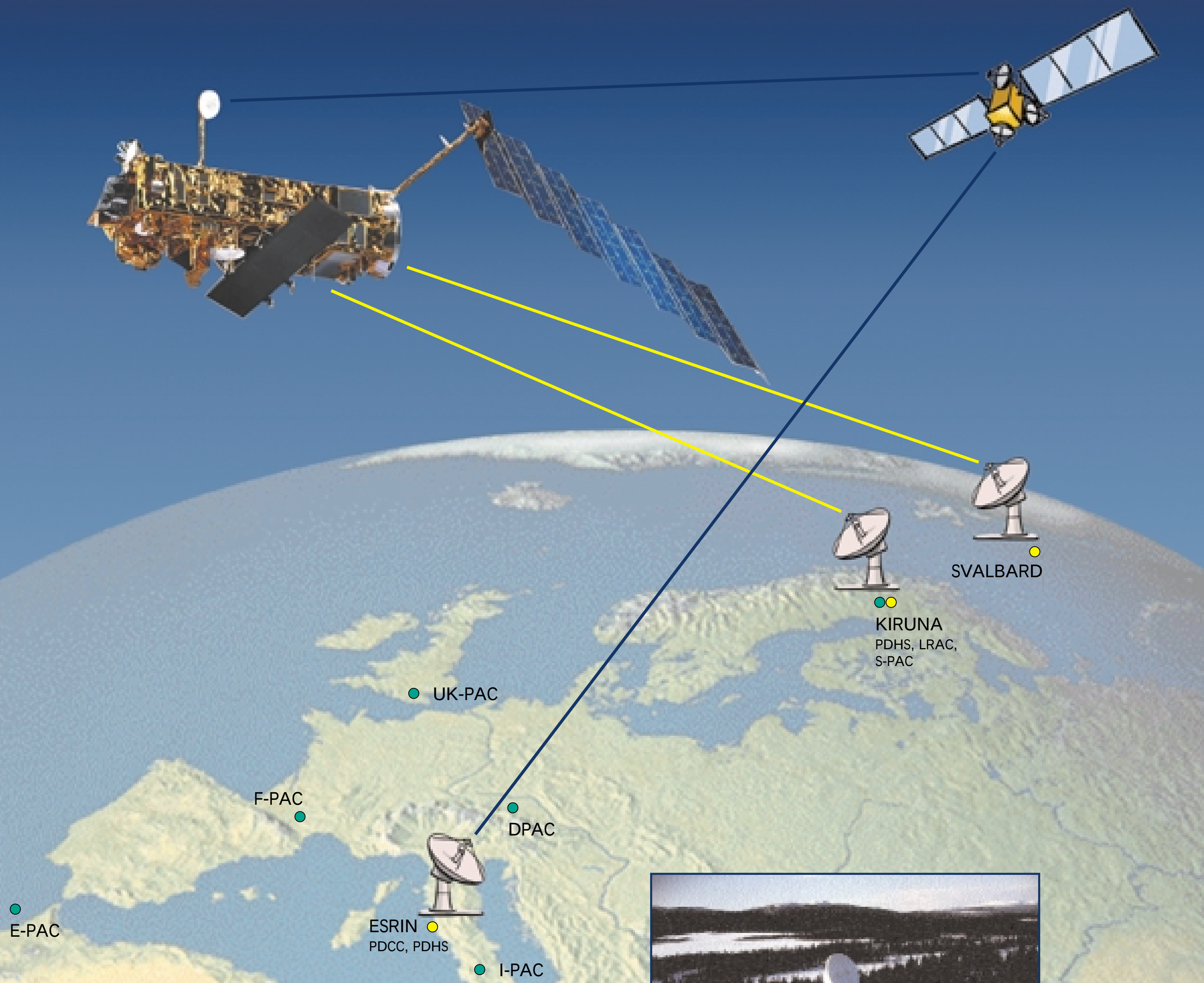
Topography of large ice sheets is measured by the Radar Altimeter, as illustrated by this map of Greenland derived from the ERS Radar Altimeter.

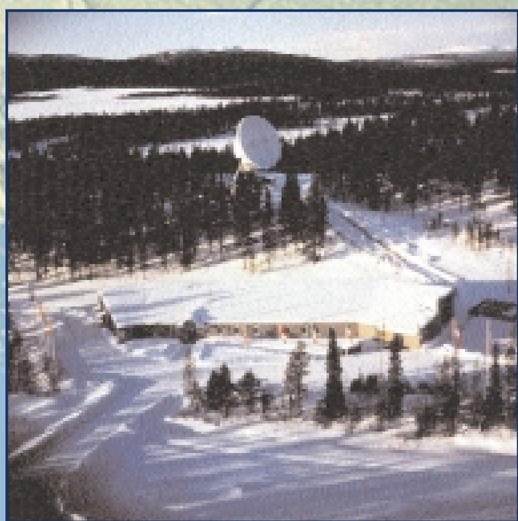
The ESA altimetry missions (ERS-1 & 2 and now ENVISAT), contrary to most altimetry missions, have the unique capability, thanks to the polar orbit, to map Antarctica, where most of the world ice is stored. This is of paramount importance in establishing if the ocean level is rising or not.

The Radar Altimeter on board ENVISAT (RA-2) has a specially designed tracking mode, with automatic adjustment of its tracking bandwidth to the underlying surface, maximising its capability to measure the ice shelf topography.

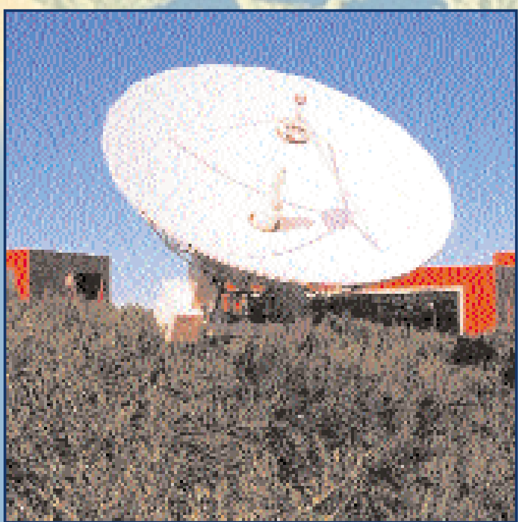



*Antartica Ice balance velocities estimated from ERS Altimeter (Courtesy of F. Remy, LEGOS, F)*



*Kiruna Salmijärvi Station*



*ARTEMIS receive antenna at ESRIN*

# Ground Segment

The Ground Segment provides the means and resources to efficiently manage and control the mission, satellite operation and the provision of services to the users.

The Ground Segment includes two major elements:

- the Flight Operation Segment (FOS),
- the Payload Data Segment (PDS).

## Flight Operation Segment (FOS)

With its Flight Operations Control Centre (FOCC), located at ESOC Darmstadt (Germany), and its two command and control stations of Kiruna-Salmijärvi and Svalbard, the FOS provides control of the satellite through all mission phases.

The Kiruna-Salmijärvi station is the primary control station for 9 to 10 consecutive orbits per day, the remaining 4 to 5 orbits per day are accessed via the Svalbard station. For the LEOP, 7 extra stations will complete the station network to obtain good coverage of the critical events.

The FOCC prepares the satellite operation plans based upon a fixed strategy defined for the Global Mission, and operation requests received from the PDCC for the Regional Mission, composed of ASAR High Rate and MERIS Full Resolution. It also plans the ARTEMIS related operations and interfaces with the ARTEMIS mission planning facilities.

The Flight Operation Control facilities are based on an upgrade of the well-proven SCOS-1B system used for the two ERS missions. This upgrade has been performed with successive deliveries allowing a stepwise acceptance and validation process. A satellite simulator, emulating the satellite on-board software, supports the operational procedures validation and the FOCC operators' training.

The Flight Dynamics software, derived from the ORATOS system already in use for ERS, was upgraded to support star tracker control and monitoring. The orbit prediction, orbit restitution activities and orbit control / manoeuvre planning will be performed as for ERS, with the same software and in-orbit control strategy.

## Payload Data Segment (PDS)

The PDS, coordinated by the Payload Data Control Centre (PDCC) located at ESRIN (I), comprises all those elements which are related to payload data acquisition, processing and archiving, as well as those concerning user interfaces and services. The PDCC builds up satellite observation scheduling based upon user requests, and provides it to the FOCC for satellite operation planning.

With its four stations, the PDS acquires directly, or in deferred mode via on-board recorder data dump, all payload data. They are processed in Near Real Time (NRT), providing to the users a complete suite of products within three hours from observation. For this purpose, all operation strategies, with or without ARTEMIS, ensure that the data stored on board are dumped every orbit in visibility of one of the ESA PDS stations.

| | | |
|---|---|---|
| **PDCC ( Payload Data Control Centre)** | | at ESRIN (I) |
| **NRT Services (Global & Regional level 1b and 2 products)** | | |
| - Two PDHS (Payload Data Handling Station) | | at Kiruna-Salmijärvi (S) and at ESRIN (I) |
| - Two PDAS (Payload Data Acquisition Station) | | at Fucino (I) and Svalbard (N) |
| **Offline Services (Global & Regional level 1b and 2 products)** | | |
| - LRAC | Low Rate Archiving Centre for all level 1b global mission products | at Kiruna-Salmijärvi (S) |
| - D-PAC | for all atmospheric products (with FMI for GOMOS) and ASAR* | at DLR Oberpfaffenhofen (D) |
| - F-PAC | for RA-2, MWR and Doris Orbit products | at CNES Toulouse (F) |
| - I-PAC | for ASAR and MERIS FR products* | at ASI Matera (I) |
| - E-PAC | for MERIS FR products* | at Maspalomas (E) |
| - S-PAC | for MERIS RR products, co-located with the LRAC | at Kiruna-Salmijärvi (S) |
| - UK-PAC | for AATSR and ASAR * | at NRSC Farnborough (UK) |

Note: *For ASAR and MERIS FR, archive and offline services are shared between several PACs

*The PDS centres and stations*

For providing off-line products, the PDS relies on the Processing & Archiving Centres (PACs), implemented by national funding by participating states.

The ESA PDS centres and stations are provided via a single ENVISAT PDS procurement, led by Alcatel. The ESA PDS design is based upon a modular architecture with building blocks (facilities). The various stations and centres are built by assembly of these facilities.

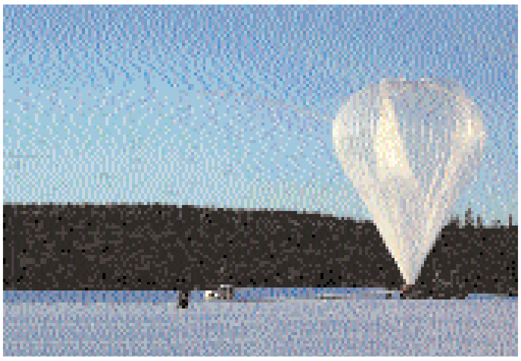
Since the PACs are providing offline ESA products based upon the same processing algorithms as the NRT products, the PACs are requested to use the facilities developed for the PDS. These facilities are made available to them as Generic Elements: each PAC procures its computer hardware set up, on which the generic elements are installed, to build up the specific configuration required to fulfil its assigned tasks. With this approach, the users get, for each instrument, a single suite of coherent products in NRT and Offline. ESA is committed to guarantee, with the support of Expert Support Laboratories (ESLs) and throughout the mission lifetime, continuous calibration and validation of the PDS products, as well as processing algorithm upgrades as required. Consequently, only one set of processors will be maintained and upgraded, ensuring coherency of all the user PDS services while minimising the corresponding overall maintenance cost.

## PDS Products and Validation Activities

ESA is committed to provide, with the PDS, a complete suite of Level 1b products and a comprehensive set of Level 2 products.

Level 1b products are geolocated data products providing engineering quantities directly derived from the instruments: radiance, reflectance, transmittance, polarisation, radar backscattering values, radar echo time delay. These products are presented as images for ASAR, MERIS and AATSR.
All Level 1b products will be calibrated during the in-orbit Commissioning Phase. Various techniques will be involved using on-board calibration devices and / or specific modes of the instruments to observe targets in the sky (sun, moon, stars) or on the Earth (natural stable targets, like deserts or tropical forests, as well as specially developed targets, like transponders or radar corner reflectors).

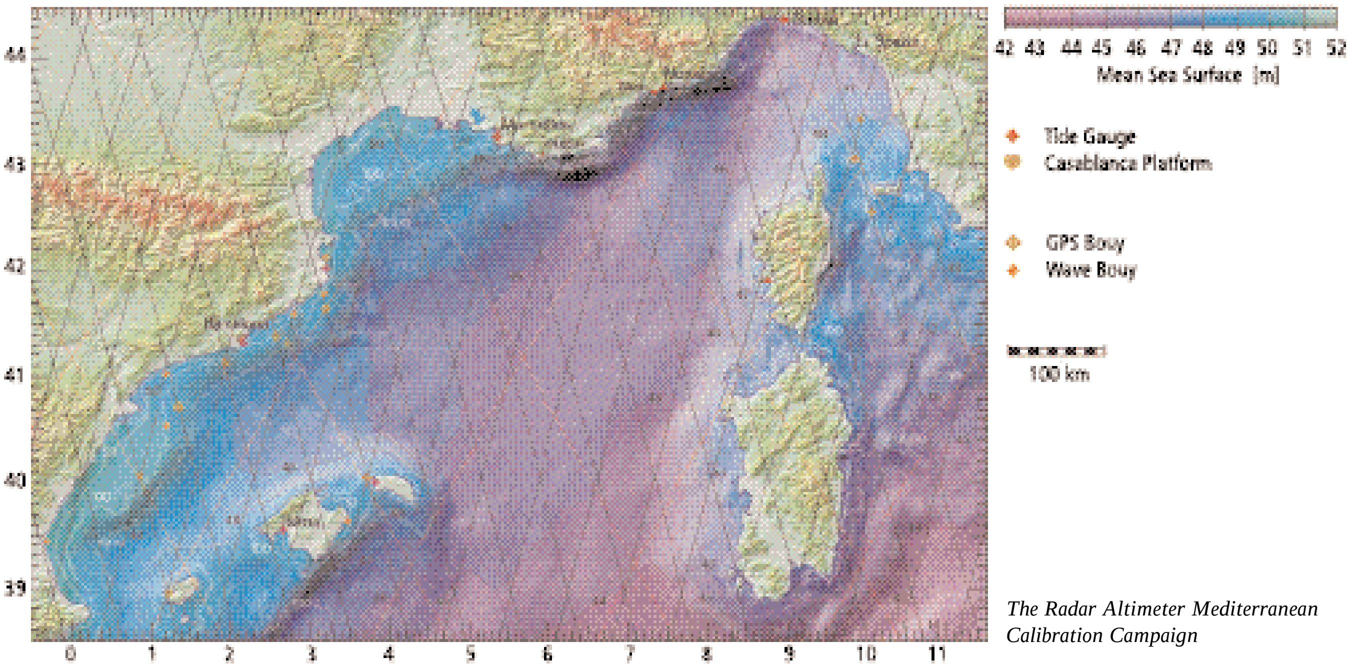
Level 2 products provide geophysical variables obtained by processing further the Level 1b products using validated geophysical algorithms. Level 2 products provide quantitative values for atmospheric variables (temperature, pressure, atmospheric constituents, aerosol and cloud parameters), as well as marine variables (ocean surface wind and waves, ocean and coastal zone water constituents, sea surface temperature), and land variables (vegetation indices, temperature, pressure and reflectances).



*Launch of a stratrospheric balloon to perform atmospheric in situ measurements*

For each geophysical data product, specific validation is required. It will be performed by correlation of the obtained data products with different in situ measurements using ground-based, airborne and balloon-borne instruments. In addition, comparisons will be performed with other satellite data as well as analyses based on the use of data assimilation models (meteorology, climatology, etc.).

Before the end of the Commissioning Phase, all the Level 1b products will be released as calibrated products. Most of the Level 2 products will be released with notification to the user of the corresponding confidences and error bars. For products obtained from ENVISAT instruments having an ERS heritage, the validation will be performed within 6 months. For novelties such as MERIS and the three atmospheric instruments, it is recognised that the validation will not be completed 6 months after launch.

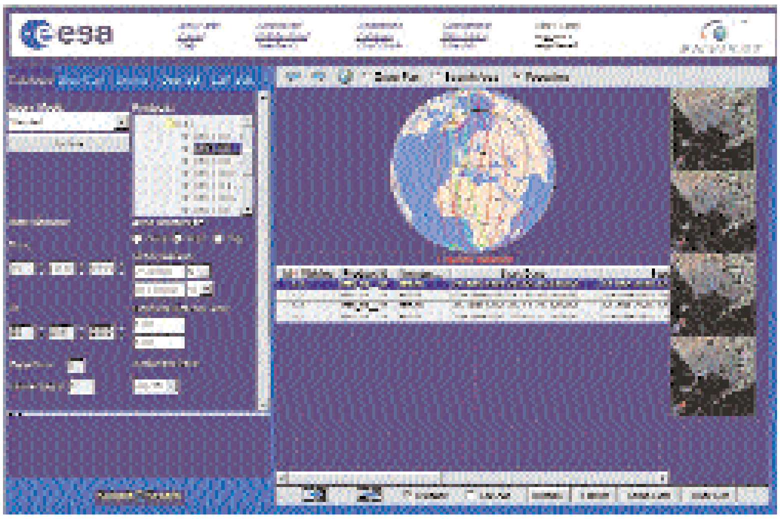



*The Radar Altimeter Mediterranean Calibration Campaign*

## User Services

The user services, via Internet, offer:

- a unified user interface, search mechanism and ordering interface, without the need to know where the data are physically stored since all stations and centres are linked by a PDS internal network, (ordering of products requiring specific data acquisition will be routed to the PDCC),
- on-line browsing, for all imaging instruments and the possibility of obtaining direct on-line delivery of small products,
- ordering on a subscription basis for systematic delivery of selected product type(s) in NRT or Offline.



*User Service Screen*

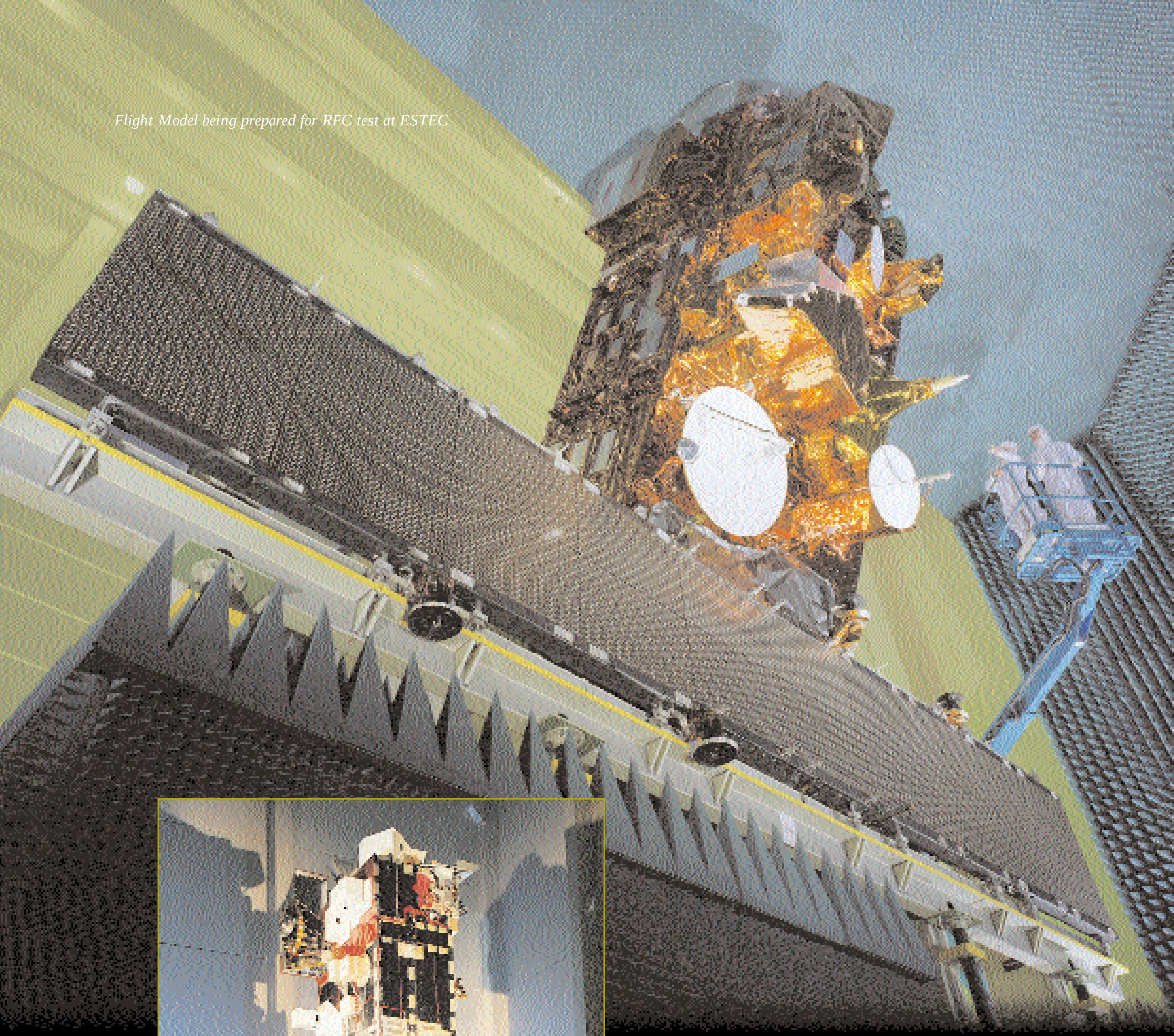
## Data Policy

The Data Policy defines two categories of use:

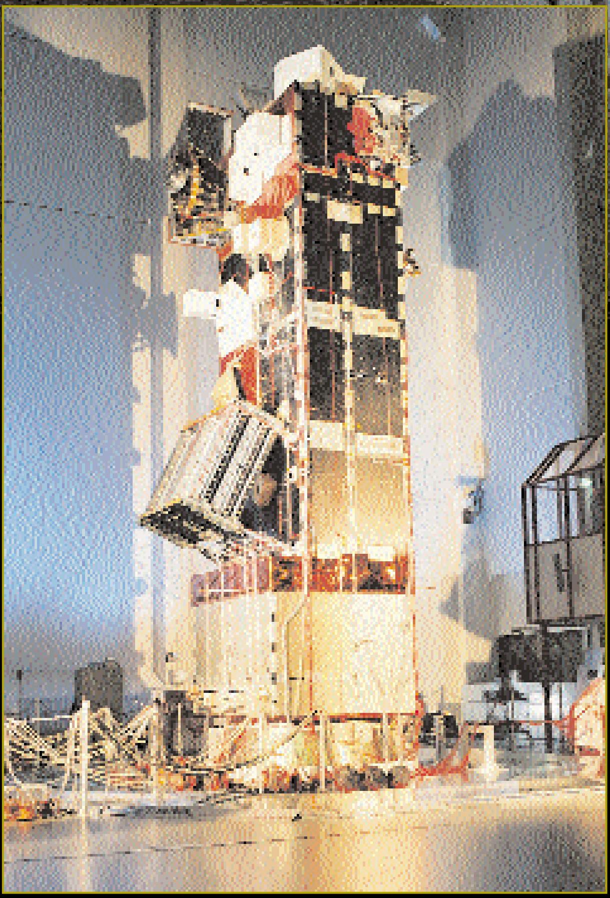
- Category 1 use: for research and applications development,
- Category 2 use: for operational and commercial use.

For Category 1 use, 700 proposals, including 130 proposals to support product validation, have been selected in response to an Announcement of Opportunity issued by ESA in 1998. Category 1 use will be served directly by the ESA PDS.

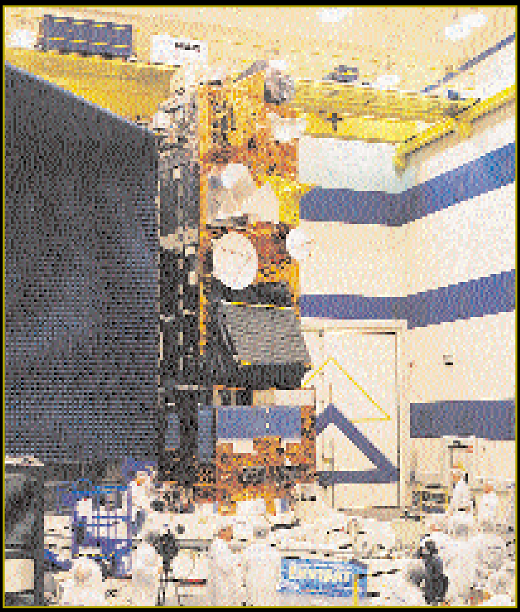
For Category 2 use, two world wide distributors have been selected, viz., SARCOM, led by Spotimage, and EMMA, led by Eurimage. Some niche distributors have also applied for specific licences, in accordance with the provisions laid down in the approved ENVISAT Data Policy. The PDS services and data products are provided to the distributors.



*Flight Model being prepared for RFC test at ESTEC*



*Structure Model in Hydra at ESTEC*



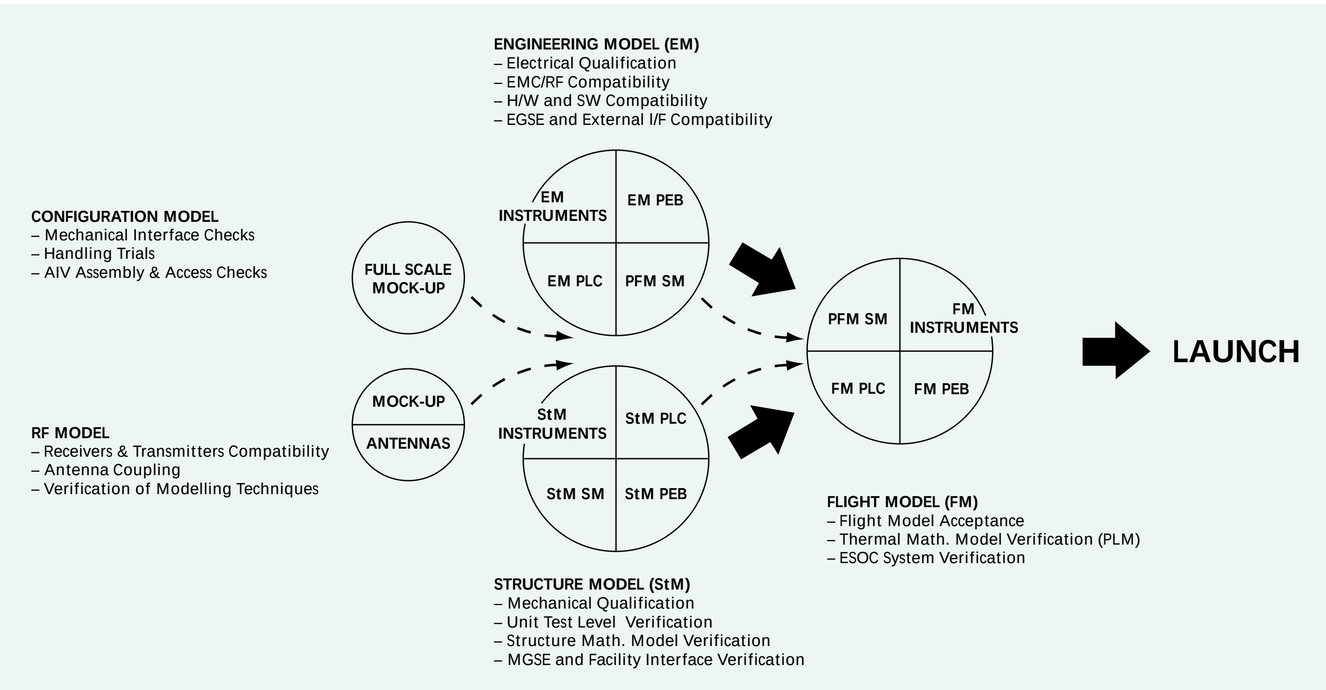
*Engineering Model being prepared for RFC test at Bristol*

# Overall Development and Verification

The ENVISAT programme has followed a conventional design and development approach, with units, instruments and sub-assemblies being tested to Qualification and Acceptance levels prior to delivery and their subsequent participation in the overall system level development activities.

The development approach used for the ENVISAT programme included a number of measures implemented to reduce development, risks and costs:

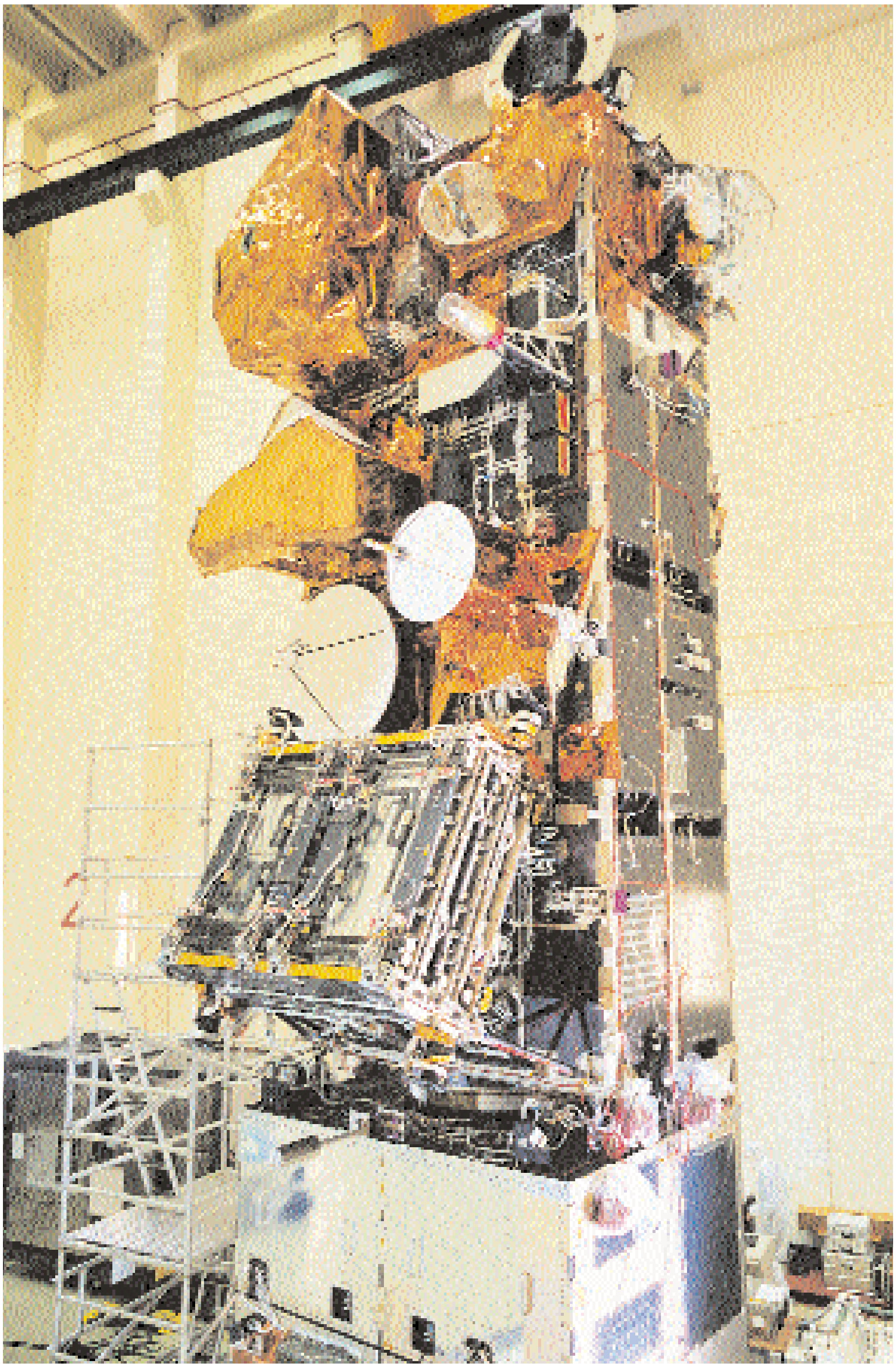
- the physical and functional autonomy of the Service and Payload Modules (SM and PLM) allowed them to be developed in parallel,
- the re-use of SPOT-4 equipment in the Service Module meant a number of its electrical units' designs had already been qualified. This allowed the development of the SM to be based on a Protoflight approach,
- the ENVISAT payload instruments have maximum functional autonomy from the Polar Platform (PPF). Their development, qualification and acceptance is performed on a stand alone basis against instrument level requirements. This allowed them to be integrated with the PPF relatively late in the schedule for satellite level mechanical, electrical and functional tests,
- satellite qualification and acceptance is achieved by using three basic major satellite modules depicted in the figure: the Structural Model (StM), Engineering Model (EM) and the Flight Model (FM),
- also, during the early development phase, two additional models were used: the Configuration Model used to study accommodation and access, and the RF Mock-up Model used in support of the overall satellite RF analyses including RF interference.




*System Models: Objectives and build standard*

# Instruments

Since the ENVISAT instruments range from completely new instruments to rebuilds of existing instruments with minimum adaptation for accommodation on PPF, they had to be treated, from a development and verification point of view, quite individually.



*Flight Model following final instrument integration*

For newly developed instruments, performance representative Engineering Models (EM) have been developed to get confidence as early as possible that the instruments can fulfil their mission objectives. Instrument EMs were built flight representative in form, fit and function, and equipped with commercial components suitable for thermal vacuum testing. Redundancies were not required for the EM instrument units.

Design qualification has been performed to the maximum extent possible for the given programmatic constraints on the EM. On selected equipment, Protoflight Model approaches were accepted.

Verification has been completely performed at instrument level against ENVISAT instrument requirements prior to their delivery to the PPF programme, i.e., as a general rule no satellite level tests were needed for instrument design qualification purposes. However, the satellite level tests were used to prove that the environment under which the instrument design was qualified was compatible with the actual PPF environment.

After the instruments had been integrated on the satellite, they participated in the corresponding system level tests as outlined below.

The following instrument hardware models were delivered to the spacecraft AIV programme:

- RF Mock-ups,
- Structure Models,
- Engineering Models,
- Flight Models.

# Satellite

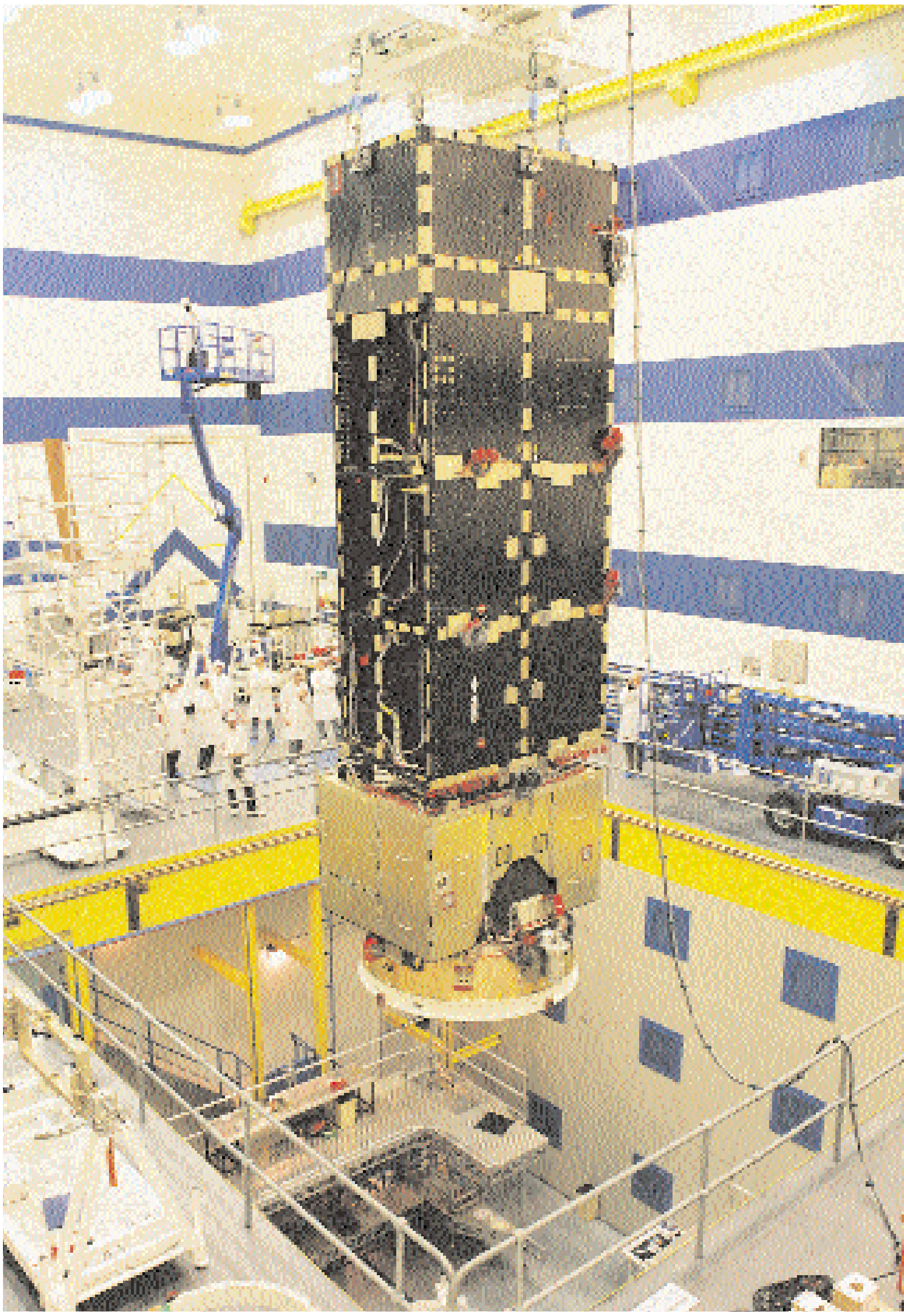
## The Structure Model

The Structure Model satellite comprised a fully representative structural model of the PPF, structural models for those instruments or assemblies with a first eigenfrequency below 100 Hz, and mass dummies for others.
The programme was successfully completed in 1996, and achieved mechanical qualification of the structure, verification of mechanical ground support equipment and facility interfaces, and verification of handling procedures.

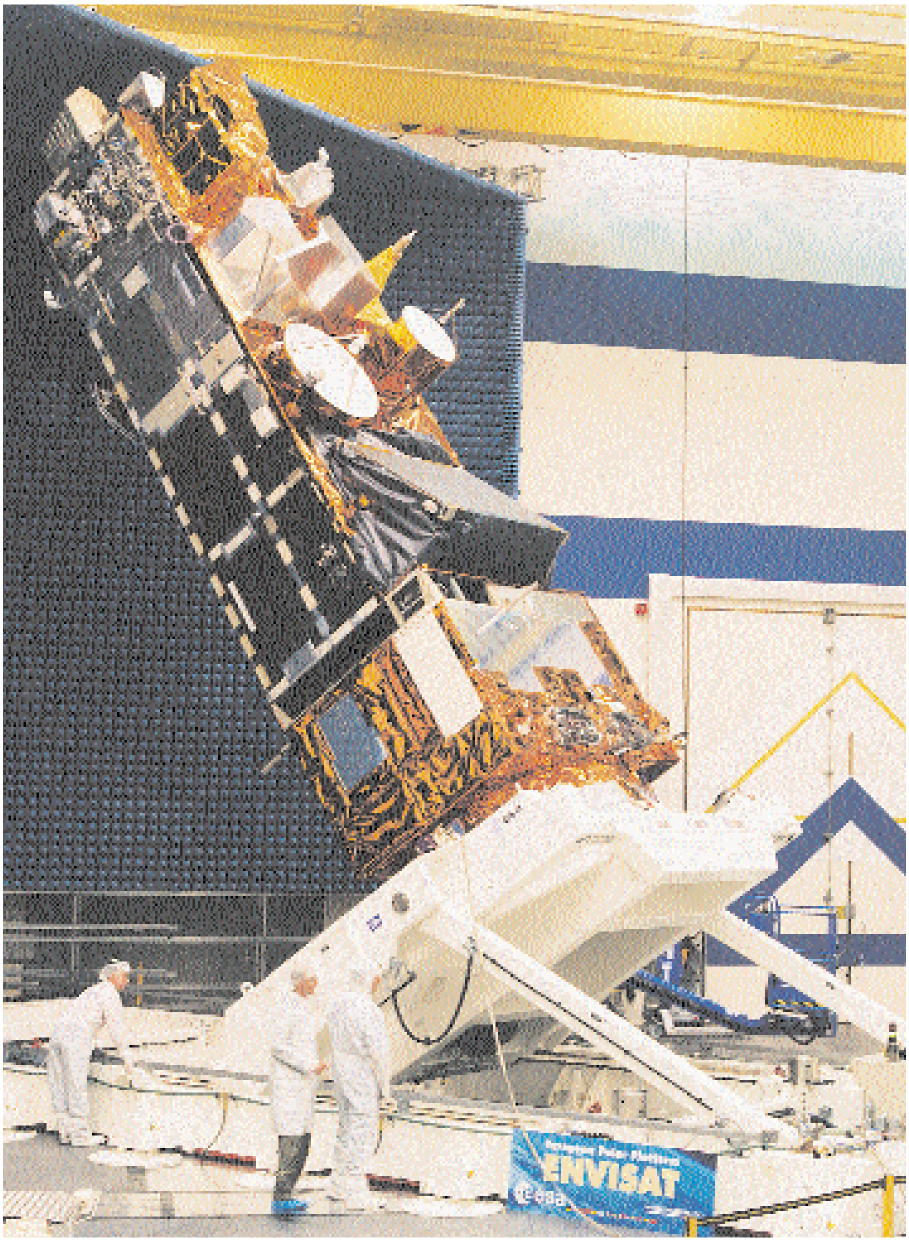
A dedicated follow-on programme of qualification against ARIANE 5 separation shocks was successfully completed in early 2000 by adopting a Protoflight approach on the Flight Model Service Module.

The achievements of the StM test programme were:

- confirmation of SM & PLM Static Load Capability,
- confirmation of SM StM Clamp-band and PLM StM Appendage Release shocks,
- establish SM StM Mass Properties,
- confirmation of PPF StM Mass Modal behaviour,
- qualification of structure at ARIANE 5 Acoustic noise and Vibration levels,
- confirmation of PPF StM Alignment,
- fit check of StM PLM in the Large Solar Simulation facility at ESTEC.



*Structure Model integration at Astrium Ltd., Bristol*




*Engineering Model during integration at Bristol*

## The Engineering Model

The Engineering Model satellite comprised the Protoflight Service Module, assembled with the Engineering Model Payload Module integrated with electrically representative models of the instruments. The Engineering Model satellite programme was successfully completed in April 1999, and achieved all its objectives to verify the electrical design, to validate assembly, integration and test procedures, and aspects related to the satellite's operation.

The achievements of the test programme included:

- confirmation of the electrical interfaces between the SM and the PLM and the successful integration of all the EM instruments,
- confirmation of the satellite functionality including Bit Error Rate and Datation tests,
- confirmation of EMC performance,
- confirmation of RFC performance,
- system Validation Tests with ESOC,
- instrument special performance tests for some instruments,
- development of user test software,
- update software and test procedures in readiness for the FM programme.

## The Flight Model

The Flight Model satellite comprises the Protoflight Service Module and the Flight Model Payload Module equipped with the ENVISAT payload complement. The Flight Model PLM structure is assembled from the refurbished StM primary structure fitted with new secondary structure panels.

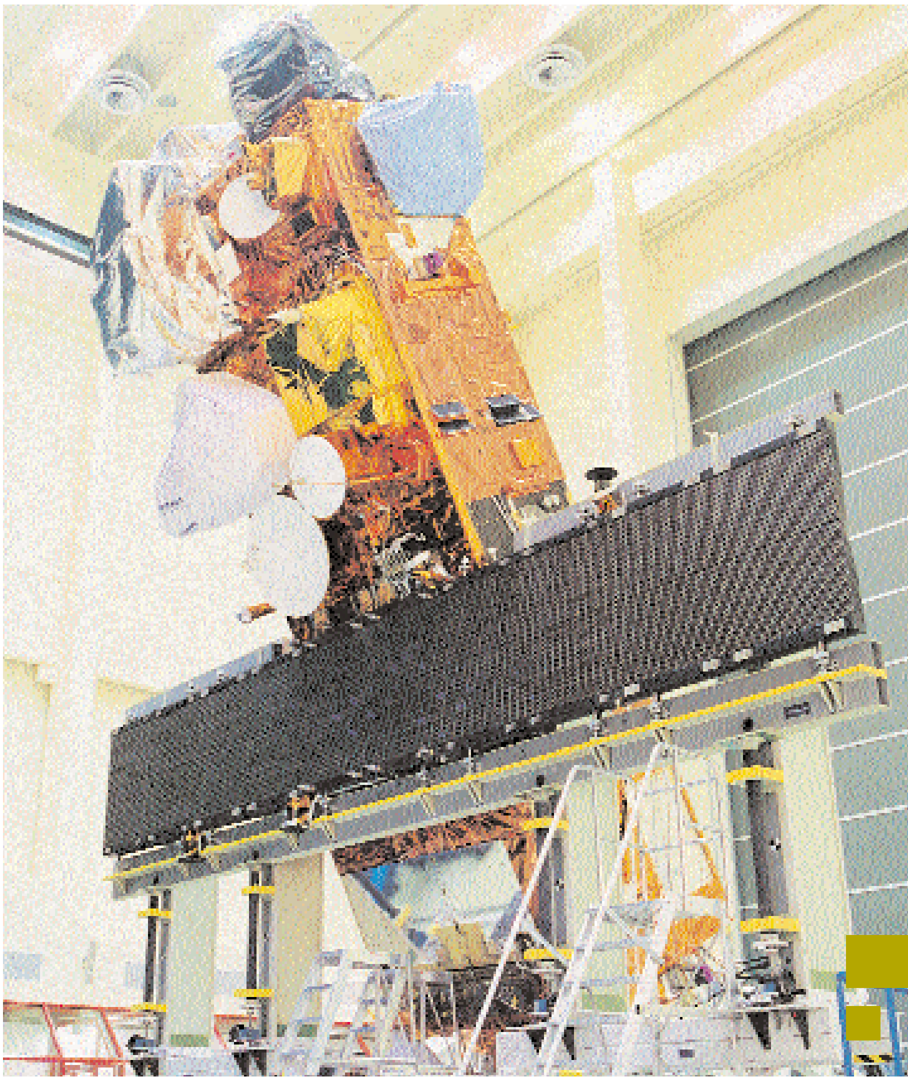
Following completion of the EM PPF programme, the Service Module underwent a planned retrofit activity, including upgrading of software and some units.

Following their own design and development programmes, the Payload Instruments successfully completed their individual qualification programmes, thus permitting the final build of the Flight Models.

Once the Flight Model Instruments and PEB had successfully completed their verification test programmes, they were integrated onto the PLM.

The achievements of the Flight Model programme include:

- integration of the Flight Model Payload Module (Instruments and PEB),
- thermal Balance and Vacuum testing at PLM level (SM already completed),
- Protoflight qualification for shock,
- integration of the FM PLM to the SM,
- Acceptance level acoustic noise testing,
- end to end release tests of Solar Array, Ka-Band mast and ASAR antenna,
- Acceptance level vibration testing,
- completion of RFC / EMC verification (partially performed already during the EM programme),
- overall system performance testing,
- verification of interfaces with Mission Control Centre, and flight operations procedure check-out,
- verification of full functionality of instruments and complete satellite by a number of overall system tests.



*Flight Model in preparation for RFC test at ESTEC (instruments protected by covers)*

# Ground Segment

For the Flight Operation Segment (FOS), the following approach was followed:

- incremental delivery and integration of the Flight Operation Control Centre (FOCC),
- four System Validation Tests (SVTs) using satellite databases delivered according to the SVT needs,
- production of the Flight Operation Procedures (FOPs) based upon the satellite contractor deliveries of the Flight Operation Manuals (FOMs) and the TM / TC databases,
- simulation campaigns at the FOCC, to train operators and to verify correctness and completeness of the procedures starting 6 months before launch.

For the Payload Data Segment (PDS), a similar incremental integration / validation approach was followed:

- Factory Acceptance Testing of the facilities, building blocks of the PDS, prior to their integration on the PDS reference platform located in Rome,
- incremental integration and acceptance testing on the reference platform of the complete centre and station configurations prior to deployment on their final sites,
- on-site deployment and acceptance of PDS version V1, and later on V2 versions, including their operational communication network. The PDS V2 version was accepted in March 2000.

Upgrading to PDS version V3 was initiated to provide:

- capability for the PDS to run on new and more powerful computers, reducing the procurement and operation cost of the PACs,
- implementation of updated instrument processing algorithms.

The PDS V3 version was accepted in April 2001. This version will support the in-orbit commissioning.

The Ground Segment Overall Validation (GSOV) completes the pre-launch testing activities. It comprises:

- all interfaces tested before launch in realistic operation scenarios. This is particularly relevant for the mission planning interfaces between FOS and PDS,
- propagation of test scenarios within the FOS and PDS towards execution of the corresponding operation plans for end to end validation and operation rehearsals with the operators,
- verification of the external interfaces with the Announcement of Opportunity Instrument Providers and the Institutes supporting the instrument calibration and validation activities,
- integration testing of the PACs with the ESA PDS, leading to PAC acceptance by ESA.

The last months before launch will be used at FOS and PDS to execute operation simulation campaigns to validate the procedures and to train the respective operators for the early in-orbit operations and the Commissioning Phase.

The Calibration and Validation participants have already participated in rehearsal test campaigns with access to the User Service Facilities and to the ENVISAT campaign data base. Simulated ENVISAT PDS products (a set of 10 CDs) have already been widely distributed to the user community. These CDs are available upon request to the ENVISAT Helpdesk: eohelp@esrin.esa.it.

The Ground Segment preparation activities are on schedule:

- to control the satellite throughout the launch and early in-orbit operations,
- to support the Commissioning Phase activities, leading to availability of calibrated Level 1b and validated Level 2 products,
- to respond to user needs with timely delivery of NRT and Offline ESA calibrated / validated products.


*Simulated PDS products on CD*

Further information regarding the ENVISAT mission, can be obtained from the ENVISAT website: http: / / envisat.esa.int

The ENVISAT Earth Observation Satellite has completed its design and development programme, achieving the objectives established at the time of its approval. Exhaustive testing over the last two years has demonstrated compliance with all satellite design and performance requirements for a five year multi-disciplinary polar orbiting mission. The Launch Campaign will lead to ENVISAT in space by the late summer of 2001.

## Acknowledgement

The ENVISAT programme is carried out on behalf of the European Space Agency by a consortium of over 120 companies from Europe, Canada and Australia.

ESA and Astrium acknowledge the work of all parties involved in contributing to the successful development of ENVISAT. The spirit of common interest on customer and industry sides is very much appreciated.

## Design and Print

Harley – The Communications Agency  Bristol  UK

May 2001