Envisat

Europe's Newest Scientific Satellite

At the beginning of March, the European Space Agency (ESA) is scheduled to have its new polar-orbiting satellite, Envisat, launched from the Kourou Space Centre in French Guyana using the powerful Ariane-5 rocket. Given the satellite's huge size (10m in height). weight (8.5 tons) and cost ($2.3 billion) and the large battery of imagers and other sensors that have been mounted on it, this is probably the single most important Earth observation project that has ever been undertaken by ESA. Indeed one can hardly contemplate the consequences for the Agency should there be a launch failure or a situation where the satellite cannot be operated fully. Not only have many of the current hopes of ESA been invested in Envisat, but so are the hopes of the large numbers of scientists who have signed up to use the data that will be generated by the satellite's imagers and other instruments. Indeed its importance within the scientific segment of the European space remote sensing community can hardly be over-emphasized - especially for those involved in various different aspects concerning the monitoring of the environment on a global scale.

By Prof. Gordon Petrie

To a certain extent, Envisat can be regarded as a follow-on to the ERS-1 and-2 satellites that ESA has operated successfully during the 1990s. Thus the inclusion of very similar instruments to those mounted on the ERS satellites is intended to ensure the continuity of the data that has been collected by these two older satellites. However Envisat also has a number of new instruments that are designed to provide additional information about the Earth's land and sea surfaces and about its atmosphere. On the political front, the original approvals for the development of an Earth observation programme comprising two polar-orbiting satellites - Envisat and Metop - were given by the ESA ministerial council in 1991 and 1992. Both satellites will use the same Polar Platform bus. However, whereas Envisat is designed specifically to provide scientific information about the Earth's environment, Metop is intended to be an operational meteorological satellite equipped with a different array of sensors. Present plans are that it will be launched into a polar orbit in 2005. It will then be operated by EUMETSAT, the European intergovernmental organisation that currently operates the well known Meteosat series of geostationary weather satellites. The plan is that Metop-1 will operate in tandem with NOAA's polar-orbiting weather satellites, taking over the morning (local time) pass, while NOAA will continue to provide the satellite for the afternoon pass.

Operational Aspects

Envisat will be placed in a near-polar Sun-synchronous orbit (with i = 98.7°) at a mean altitude of 800km. Thus the satellite will execute just over 14 orbits per day and will enter a repeat orbit over a particular area every 35 days. The satellite's operations will be controlled from the European Space Operations Centre (ESOC) located in Darmstadt, Germany. The data collected by the instruments on-board Envisat will be downloaded to the ESA ground receiving station located at Kiruna in northern Sweden. Alternatively, one of the ground stations located in Svalbard (Spitsbergen) in the Norwegian Arctic archipelago can be used if the Kiruna station is out of commission. A further alternative will be to use Artemis, ESA's new geostationary telecommunications satellite, which can transmit the data down to another suitable ground station located within Europe. From there, the received data will be passed on to ESA's main data processing centre (ESRIN) located at Frascati, near Rome in Italy. The processed data will then be sent out from ESRIN to six national processing and archival centres (PACs) located in France, Germany, Italy, Spain, Sweden and the U.K.

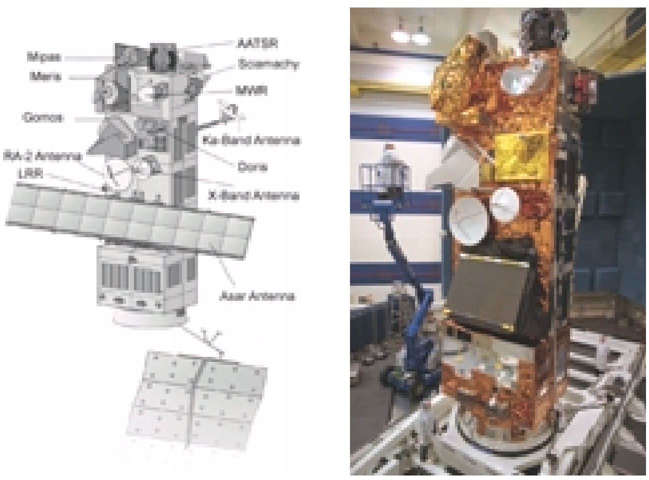

Figure 1: (a) A diagram showing the overall construction of Envisat and the positions of the antennae of the various imagers and other instruments that are mounted on the satellite. (b) The corresponding photograph of Envisat taken while under test at ESA-ESTEC. (Source: ESA-ESTEC)

Imagers & Non-Imaging Sensors

Although Envisat has ten different instruments mounted on-board the satellite, only three of them will be outlined here. These are the three imaging devices - ASAR, AATSR and MERIS - that are most likely to be of interest to readers of GeoInformatics. The other instruments are generating non-image data. They include measurements of certain specific atmospheric parameters (temperature, pressure, etc.) and many of the actual constituents of the atmosphere (trace gases, aerosols, liquid water, ice clouds, etc.) that are chiefly of interest to scientific researchers. As was the case with

ERS-1 & -2, a dual-frequency radar altimeter (RA-2) has also been included in the instrument package to help with the determination of the surface topography of the oceans. Envisat is also fitted with the DORIS microwave doppler tracking system to provide precise orbital data, together with a small array of laser reflectors to allow precise laser ranging measurements to be made from suitably equipped ground stations to the satellite.

• ASAR

The Advanced Synthetic Aperture Radar (ASAR) is a more advanced version of the AMI (Active Microwave Instrument) SAR imager that was operated on both of the earlier ERS satellites. Like the AMI imager, ASAR operates in the C-Band (with λ = 5.5cm) in the microwave part of the electro-magnetic spectrum. Furthermore, ASAR has been designed specifically to ensure continuity with both the image (SAR) mode and the wave mode of operation that were used with the earlier AMI imagers. However it also incorporates a number of technical advances that will result both in an improved performance and in an extension to the modes in which it can be operated. Instead of using a centralized high-powered amplifier in combination with a passive waveguide antenna (as used in the AMI SAR), ASAR makes use of a fully active array antenna employing distributed transmit/receive elements. This arrangement allows a wide range of swath widths and beam elevations to be used, together with two different (horizontal or vertical) polarization patterns.

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Thus the ASAR imager can be operated either in the image or wave modes (like with AMI) as a Stripmap SAR to image a swath of a pre-determined and relatively narrow width of up to 100km, having a ground pixel size of 30m. Alternatively it can be operated as a ScanSAR by which a much wider swath (405km) of the Earth's surface can be imaged - either in wide-swath mode or in global monitoring mode.

Figure 2: Envisat in its protective container being loaded on to the Antonov 124 heavy-lift freight aircraft at Schipol Airport, Amsterdam prior to its flight to Cayenne in French Guyana. (Source: ESA-ESTEC)

If either of the two ScanSAR modes is used, then the ground resolution of the resulting image data will of course be reduced to 150m (in wide swath mode) and 1,000m (in global monitoring mode) respectively while the swath width and coverage is being increased to 405km. As with all microwave radars, ASAR will allow all-weather, day/night observation of the Earth's surface, irrespective of cloud cover or time of day.

• AATSR

In much the same way, the Advanced Along Track Scanning Radiometer (AATSR) is a more highly developed version of the ATSR-1 and -2 imagers operated on the ERS-1 and -2 satellites respectively. Thus, on the one hand, the continuity of the images gathered at various wavelengths - λ = 1.6μm (SWIR), 3.7μm (MWIR), 10.7μm and 12μm (LWIR) - in the infra-red part of the spectrum is assured. Using these channels, the main objective of the AATSR will be to measure sea-surface temperatures globally with a high degree of resolution (0.1°C) and accuracy (±0.5°C) over the huge areas of the World's oceans. It will do this using a 500km swath width at the quite moderate spatial resolution of a 1km x 1km ground pixel size, as required for the purposes of global climate research.

These IR images will be supplemented by others recorded at three much shorter wavelengths - at λ = 0.55μm (green), 0.67μm (red) and 0.865μm (NIR) - in the visible and near infra-red parts of the spectrum. These will mainly be used to fulfil a secondary objective of the AATSR imager to carry out measurements of certain characteristics (biomass, moisture, etc.) of the vegetation of the Earth's land surfaces. In this particular respect, the red and NIR images will provide the main data - which will be similar to that provided by the

Figure 3: The Ariane-5 launcher awaiting the arrival and fitting of Envisat. (Source: Astrium)

Figure 4: Envisat being checked out at the Kourou Space Centre in French Guyana. (Source: Astrium)

Figure 5: An artist's impression of Envisat operating in space with the ASAR antenna and the satellite's solar panels fully deployed. (Source: Astrium)

AVHRR imagers on the NOAA satellites. The remaining (green) channel will provide further information on the chlorophyll content and health of the vegetation appearing on the imagery. The AATSR imager makes use of an unusual conical scanning system, which has its rotation axis pointing ahead of the satellite in the along-track direction. This allows a double scan to be across the Earth's surface - the one at an angle of 53° to the nadir ahead of the satellite, the other in the nadir direction. This allows the atmospheric effects (absorption, refraction, etc.) to be removed to improve the accuracy of the temperature measurements made by the scanner.

• MERIS

Unlike the two previous imagers discussed above, the Medium Resolution Imaging Spectrometer (MERIS) does not provide a continuity from the previous ERS missions. It is a new type of programmable imaging spectrometer providing images over a limited number (15) of spectral bands in the visible and NIR parts of the spectrum. However the MERIS imager will be operated mainly with a fixed set of spectral bands that will be decided upon before launch - although experiments with alternative sets of spectral bands can be undertaken for short periods. MERIS uses a CCD areal (2D) array to generate the required spatial and spectral components of its image data simultaneously. It will be operated as a pushbroom scanner giving a 300m ground pixel size over a 1,150km wide swath to satisfy specific user requests. However it will also be operated continuously at a much reduced spatial resolution to provide images with a 1km x 1km ground pixel size for global monitoring purposes. It is intended to be used primarily for oceanographic research purposes to assess the surface optical properties and chemical constituents of large areas of water. A secondary objective of the imager will be to make observations of atmospheric cloud patterns and land vegetation.

Launch

The final testing of Envisat was carried out at ESA's ESTEC centre at Noordwijk in the Netherlands in April 2001. After which, the satellite was then shipped from Schipol Airport in Amsterdam to Cayenne in French Guyana using an Antonov 124 heavy-lift freight aircraft, arriving there on May 15th, 2001. In addition, a further 400 tons of ground support equipment and satellite spare parts were sent by ship and by air in two Boeing 747 freight aircraft. Originally, the launch of the satellite was scheduled to take place in mid-summer 2001. This was then postponed by Arianespace until September 2001. However, in the meantime, the preceding launch of the Ariane-5 rocket on 12th July 2001 ran into trouble. This was due to the failure of the upper stage of the launcher to generate its full power. As a result, the two communications satellites - Artemis and B-SAT - that were mounted on the launcher failed to reach their intended geostationary orbits. (Eventually Artemis did do so using the power from its own thrusters.) As a result of this event, the launch of Envisat was postponed further to allow a full investigation into the causes of the launcher's malfunction. Thus Envisat has been in storage at the Space Centre in French Guyana since mid-summer 2001.

Final Stages

Since then, suitable modifications have been made to the engine of Ariane-5's upper stage and exhaustive tests have taken place to validate the changes. Now Ariane-5 has been declared fit for flight once again. So Envisat has been removed from storage, refurbished and checked out before being fitted to the launcher. Obviously, with so much time, effort and money having been spent on the development, construction and testing of Envisat and its many instruments, the hopes and expectations of ESA and the many scientists who are participating both in its actual operations and in the subsequent experiments that will use the data collected by the satellite, are very high. However, given the overall poor record in recent years regarding the launches of Earth observation satellites, their high hopes will also be tinged with a certain amount of anxiety. This is also reflected in the views of the insurance industry, which, according to press reports, has limited its cover against the failure of the satellite to $200 million - a small fraction of its actual cost of $2.3 billion. Besides readers having a vested interest in being able to gain access to the large amounts of valuable image data that will be generated by Envisat, as European taxpayers, we can only hope and pray for a successful launch!

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