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ERS-1

GEN206

– a keen eye on the earth

A watchful eye

A number of **'firsts'** will be achieved by ERS-1:

- the first Active Microwave Instrument **(AMI)** capable of operating as a wind scatterometer or a Synthetic Aperture Radar **(SAR)**;
- a high-resolution Radar Altimeter **(RA)** system including correction for the water column in the atmosphere;
- an Along-Track Scanning Radiometer **(ATSR)** providing the most accurate sea surface temperature data obtained to date;
- a Precise Range & Range Rate Equipment **(PRARE)** designed to determine accurately the satellite's orbit and to calibrate the radar altimeter;
- a Laser Retro-Reflector **(LRR)** permitting range measurements using laser ranging stations on the ground.

A remote-sensing satellite to monitor ocean, ice and land resources

Seas and **oceans** cover some 360 million km^2, equivalent to three quarters of the Earth's surface. Through heat exchange and circulation processes, they are the main driving force of global weather and climate. The enormous economic resources concealed in their depths are being increasingly exploited in ways not envisaged a generation ago. The European continental shelf, for example, has proved only in the last decade to be one of the World's largest sources of oil and gas.

Permanent **ice sheets** cover some 17 million km^2 of the land surface and form a 'cryosphere' the climatological impact of which we are only just beginning to understand. In addition to the ice sheets on land, ice covers some 30 million km^2, or 7%, of the World's seas and oceans. The **ice fields** affect global and local weather and marine productivity, and have important economic impacts on transportation, fishing, and off-shore oil and gas exploitation.

The European Space Agency's **Remote-Sensing Satellite (ERS)** programme currently under development will provide systematic coverage of ocean areas on a highly repetitive basis, allowing global monitoring for meteorological and environmental applications. Much of the data will be collected from remote areas such as the southern oceans and Antarctica, from where little comparable information has been obtained so far.

The first satellite – **ERS-1** – with its unique set of all-weather microwave instruments, will begin in early 1990 to monitor ocean and ice processes for both scientific research and applications purposes. It has an expected lifetime of two years. A second flight unit – **ERS-2** – is presently being considered for a possible launch in 1993. Equipped with an identical payload, ERS-2 will serve the same objectives for an additional period of two to three years, but with a stronger emphasis on operational applications.

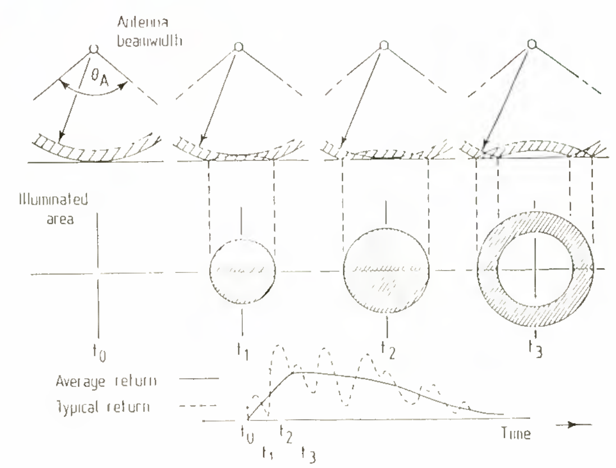
The Payload

The Radar Altimeter

ERS-1 will carry a radar altimeter capable of measuring the distance from the satellite to the surface to an accuracy of tens of centimetres. Its main purpose is to provide accurate measurements of wave height and of the general height of the sea, land and ice surface.

Radar Altimeter Specifications

– wave height range	1–20 m
– accuracy	±0.5 m or ±10%
– altitude measurement	±10 cm (1 σ, 1 s)
– backscatter coefficient measurement	±1 dB (1σ)
– footprint location	nadir
– footprint size	1.6–2.0 km, depending on sea state
– frequency	13.8 GHz (Ku-band)
– bandwidth, ocean mode	330 MHz
– bandwidth, ice mode	82.5 MHz



Radar altimeter operation principle.

The ATSR-M

The Along-Track Scanning Radiometer and Microwave Sounder (ATSR-M) is a passive instrument consisting of an advanced three-channel infrared radiometer and a two-channel nadir viewing microwave sounder.
Unlike the other ERS-1 instruments, the ATSR-M is an experimental package resulting from an ESA Announcement of Opportunity for a scientific add-on package.
The infrared radiometer is being designed and constructed by a UK and Australian consortium, consisting of the Rutherford Appleton Laboratory, Oxford University, Mullard Space Science Laboratory, the UK Meteorological Office and CSIRO in Australia. A consortium of French and Danish laboratories, led by the Centre de Recherche en Physique de l'Environment (CRPE), is responsible for the microwave sounder.

ATSR-M Specifications

IR Radiometer

– swath width	500 km
– spectral channels	3.7, 11 and 12 μm
– spatial resolution	1 km x 1 km
– radiometric resolution	0.1 K
– predicted accuracy	0.5 K over a 50 x 50 km square with 80% cloud cover

Microwave Sounder

– channels	23.8 & 36.5 GHz
– instantaneous field of view	22 km
– predicted accuracy	2 cm

The PRARE

The Precise Range & Range Rate Equipment (PRARE) is a highly accurate instrument which will be used for orbit determination at decimeter level of accuracy as well as for various geodetic applications. The development is financed by the German Ministry of Research & Technology (BMFT) and performed under the responsibility of the Institute of Navigation, Stuttgart University, associated with the Geodetic Research Institute in Munich.
In this two-way microwave ranging system, the on-board equipment performs the measurements in X-band with some additional functions in S-band for ionospheric error correcting purposes. The ground stations are dedicated X-band regenerative transponders. They are small, mobile units of modest cost. Both units, the ground equipment and the spaceborne one, are in many parts identical. One major difference is the S-band unit, which is a transmitter in the spacecraft and a receiver in the ground equipment. The S-band down-link is just needed for the determination of the ionospheric effects.

PRARE Specifications

– up-link	7225.296 MHz 10 Mbit/s PSK (10 MHz bandwidth)
– ground transponder	60 cm parabolic dish, 2 W transmit power
– down-link	8489 MHz 10 Mbit/s PSK (10 MHz bandwidth), 1 W transmit power
– S-band down-link	2248 MHz 1 Mbit/s PSK (1 MHz bandwidth), 1 W transmit power
– satellite antennae	Cross dipoles at X and S bands
– predicted ranging accuracy	5–10 cm

Some typical ERS-1 Products

SAR
– Fast-delivery image*
– Basic single-look image
– Precision image
– Geocoded image

AMI wave mode
– Fast-delivery image spectrum*

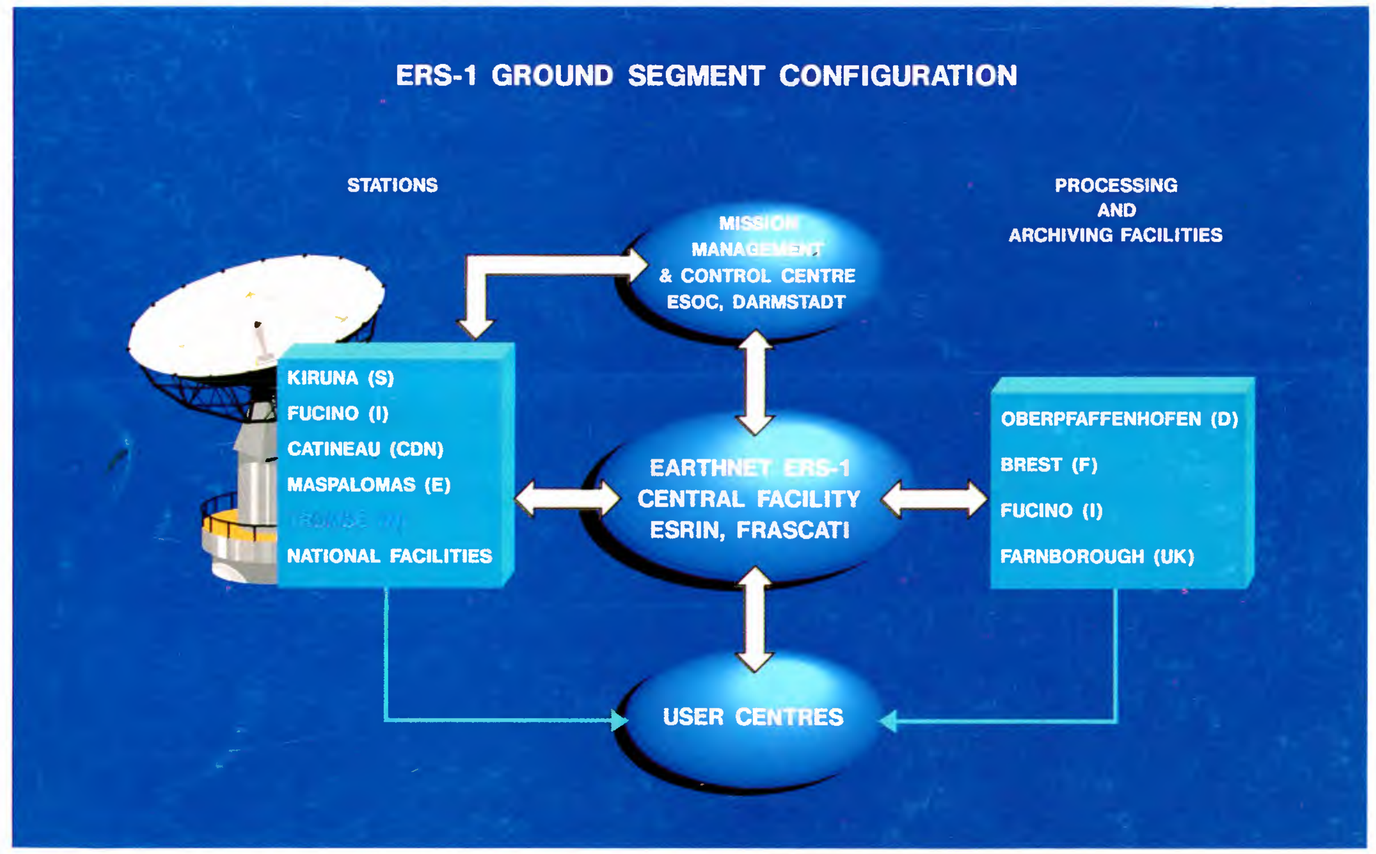
AMI wind mode
– Fast-delivery product*
– Wind field (large/local scale)

Orbit
– PRARE & laser tracking data
– Precise orbit
– ERS-1 tailored gravity model

Radar Altimeter
– Fast-delivery product*
– Ocean product
– Ice product
– Land product
– Sea-surface height
– Sea-surface topography
– Oceanic geoid

ATSR
– Calibrated radiances
– Corrected I-R image
– Sea-surface temperature image
– Cloud-top temperature image
– Microwave brightness temperatures
– MW wat.-vapour & liqu. wat. content

*Fast-Delivery Products



Participating States in ERS-1 Programme

Austria, Belgium, Canada, Denmark, France, Germany, Italy, Netherlands, Norway, Spain, Sweden, Switzerland, United Kingdom

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Front Cover: Photo courtesy © Walter Bonatti, from 'La Mia Patagonia', Massimo Baldini Editore.

The Payload

The Active Microwave Instrument (AMI) – a multipurpose instrumentation with two basic operating modes –

Imaging Mode

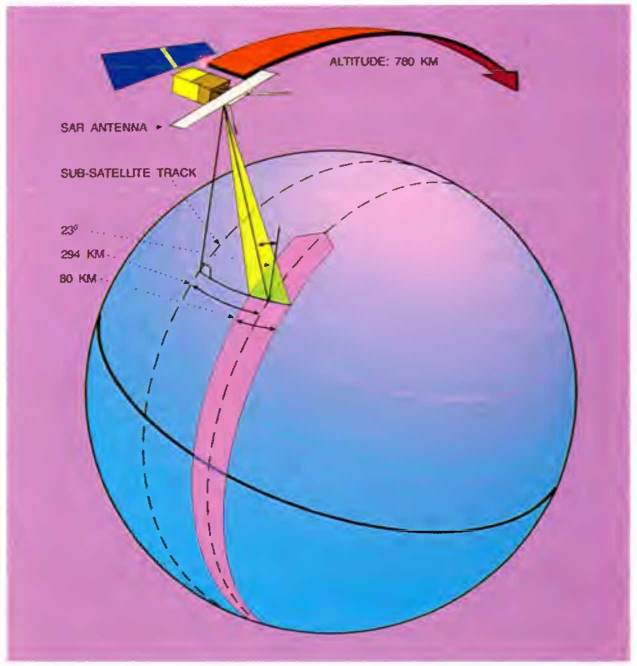
The Synthetic Aperture Radar (SAR)

The SAR on ERS-1 operated in the imaging mode will obtain strips of high-resolution imagery 100 km in width to one side of the satellite. A radar beam illuminates the ground in this strip and an image of the ground is built up from the return signals, which are modified by the scattering properties of the individual targets.

SAR is a version of side-looking radar in which high-resolution in the along-track direction is obtained by processing the overlapping return signals received from a wide beam generated from a short antenna. This simulates the high resolution that would be produced by illumination of each individual target element by a very long antenna. A long antenna is thus 'synthesised' by processing.

Equivalent across-track or range resolution is obtained from the length of the transmitted pulse. The use of pulse compression techniques on board the satellite allows a reduction in the peak power requirements for the system.

The mid-swath depression or incidence angle of the system in normal operation will be 23°. However, for some experimental applications the roll tilt capability of the satellite will be used to vary this up to 35°.



SAR 'image mode' geometry.

Synthetic Aperture Radar Performance

– spatial resolution	30 m x 30 m
– radiometric resolution	2.5 dB at sigma 0 = –18 dB
– swath location	parallel to nadir track and within the wind scatterometer swath
– swath width	99 km
incident angle	23° at mid-swath
frequency	5.3 GHz (C Band)
polarisation	VV
data rate	< 103 Mbps

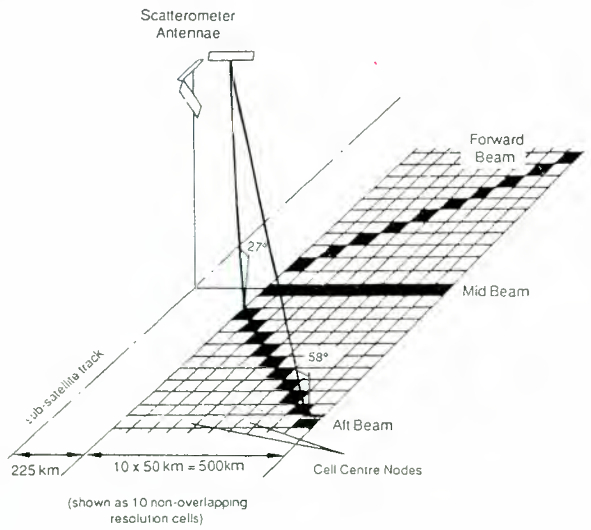
Seasat SAR image of Calabria, Italy (15 September 1978). Processed by DFVLR for ESA/Earthnet.

Wind and Wave Modes

The Wind Scatterometer

The purpose of this instrument is to obtain information on wind speed and direction at the sea surface. These wind vector data can then be incorporated into models, global statistics and climatological data sets.

The scatterometer will measure the power and time delay of a signal transmitted by the satellite and returned from the ocean surface. The power and time delay information is affected by the surface wind conditions. Several readings are required to characterise the wind at a particular point because the returned signal also depends on the angle between the wind direction and the transmitted pulse.
On ERS-1, three antennas will be used to obtain information about the wind at the ocean surface. Each antenna will point in a different direction. Hence for a particular point on the ocean surface three sets of information obtained from three different angles will be used to calculate the surface wind vectors.



SAR 'wind mode' geometry.

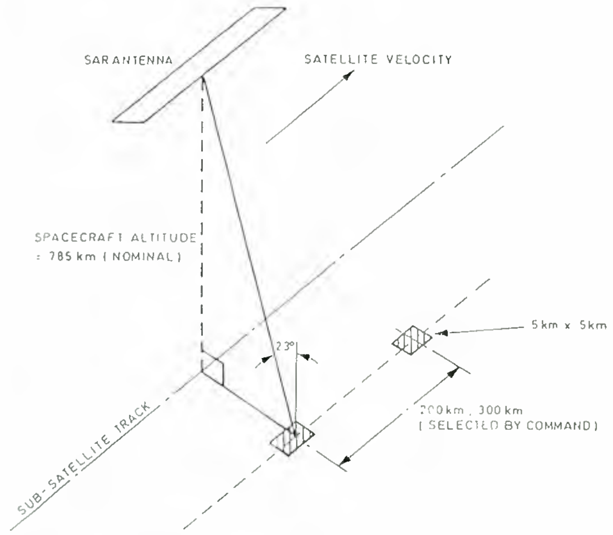
Wind Scatterometer Specifications

– wind direction	0–360°
accuracy	±20°
– wind speed	4 m/s–24 m/s
accuracy	2 m/s or 10%
– spatial resolution	50 km
grid spacing	25 km
swath location	225–725 to side of orbital track
swath width	500 km
incident angle range	27–58°
frequency	5.3 GHz (C-band)
polarisation	VV and HH (2 antenna beams)

The Wave Scatterometer

The Synthetic Aperture Radar can be operated in 'wave mode'. The primary purpose is to measure directional wave spectra – wave energy as a function of the directions and lengths of waves at the ocean surface – from the backscattered radiation from sample areas.

For this function the SAR will be imaging regularly spaced sample areas within the 99 km imagery swath. The images are transformed into wave spectra providing information about wave length and wave direction.



SAR 'wave mode' geometry.

Wave Scatterometer Specifications

– wave direction	0–180° (180° ambiguity)
– wave length	100–1000 m
– accuracy	direction ±20°; length ±25%
– spatial sampling	6 km x 6 km every 200–300 km – programmable anywhere within the SAR image swath
incident angle	23°
frequency	5.3 GHz (C-band)
polarisation	HH