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MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

ERS-1: Its Payload and Potential [and Discussion]

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ERS-1: its payload and potential

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European Remote Sensing Satellite Number 1 (ERS-1) is a truly international project promoted by the European Space Agency (E.S.A.) and involving 10 countries. The decisions about what should be the aims of the satellite have been reached as the result of lengthy discussions between E.S.A. and potential customers, and of course have also had to take into account the budgetary limitations imposed by the participating countries. The major objectives of ERS-1 are set out in the paper together with a very brief outline of the capabilities of the instruments required to meet these objectives. The paper concludes by suggesting areas in which there is a need for technological advance, which combined with concentrated marketing activity will ensure a commercial future for the remote sensing capability that will be demonstrated by ERS-1.

1. The aims of ERS-1

The purpose of the ERS-1 spacecraft and its supporting ground infrastructure is to make measurements from which specific products can be made available at sufficient speed to be useful. These products have been carefully established through consultation between expert groups of customers and the E.S.A. They form the requirement for the system and in its turn the ERS-1 payload. The products are now listed.

(i) A map of the surface wind over the complete globe at a spatial interval of 25 km. This product is very perishable and the results must be available to users within hours.

(ii) A global picture of the wave structure sampled at 100 km intervals.

(iii) An image of a large area of ocean or land. This is required to a spatial resolution of 30 m but is only produced when the spacecraft is in view of a suitable ground station.

(iv) Information on sea and ice surface structure by obtaining wave height and the sea surface profile to an accuracy of 10 cm. This operates over the whole globe, and provides a sub-product in the form of valuable data on the ocean currents.

(v) Sea surface temperatures to a high accuracy, available even when there is significant cloud cover.

To summarize, the major products are: global coverage of surface winds; global coverage of sea wave spectra; limited coverage of ocean and land surface imaging; global sea and ice surface structure; global sea surface temperature.

2. Constraints

To collect the necessary data to produce the products, we require full Earth coverage on a regular basis. This can only be achieved by choosing a near polar orbit, and since it is important for many studies to take samples at a constant angle of the sun, or in simpler terms at the same time of day, the orbit is slightly tilted to achieve this object. The orbit slowly precesses so that over a period of three days it is possible with some of the sensors to view the whole Earth. Fifteen and one third orbits are made each day and the spacecraft will fly at a mean altitude of 770 km.

Additionally, it has been decided that the payload must be mated to the platform used by the French satellite 'Systeme Probatoire Observation Terrestriale' (Spot). It is from these decisions that the payload mass, power and data rates and storage statistics can be deduced; they are given in table 1. These would perhaps be meaningless if the comment were not added that the satisfaction of the agreed products within these constraints proves to be an exceptionally demanding requirement.

Table 1. Payload statistics

payload mass	900 kg
payload power consumption	1800 W
X-band data rate in image mode	102 Mbit s^{-1}
X-band data rate in non-image mode	15 Mbit s^{-1}
internal data storage capability	6.5 Gbit

3. The instruments

The ERS-1 payload has been fitted with measuring instruments (see Haskell 1983) to collect the data necessary to supply the products described in §1.

Active microwave instrument

This is a most complex radar operating at 5.36 GHz in a number of modes to measure the sea surface radar reflectivity, to provide in turn:

the wind force and direction over a 500 km swath;

the wave structure (sea state) every 100 km of track;

a radar image over an 80 km swath and 2000 km length for each orbit.

The last measurement is achieved by using Synthetic Aperture Radar (SAR) techniques and is limited by spacecraft power and data storage capacity so that images can only be made for periods of a few minutes and when in direct contact with a ground station.

Radar altimeter

This instrument measures the delay time of a radar pulse from the spacecraft to the sea surface and back. It also examines in detail the shape of the return pulse, which will have been distorted by the depth of the wave structure. Before details of the sea profile can be calculated, it is necessary to add the geoid shape and the spacecraft orbit into the computation. Accurate details of the orbit are obtained by the Precision Range and Rate Experiment (PRARE) and by using the laser reflector in conjunction with ground laser radars.

In practice the radar altimeter can measure the range from spacecraft to the sea with an absolute accuracy of 2 m and a relative accuracy of 10 cm. It can also measure the wave height over a range of 1 to 20 m to an accuracy of 5 cm. It takes measurements at 7 km spacing and in conjunction with the ground terminals can make its product available in 3 h. This instrument also has a capability of measuring wind speed.

Along Track Scanning Radiometer (ATSR)

This instrument operates in the infrared region of the spectrum and measures the magnitude of incoming radiation from the sea surface. Over a 500 km swath it measures the surface temperature of the sea to an accuracy of 0.5 K and the water vapour content of the atmosphere can subsequently be computed to an accuracy of 3%.

Microwave sounder

This measures incoming radiation, in two bands at 24 and 36 GHz, from the sea surface. The radiation measured by both this instrument and the ATSR is modulated by the small-scale atmospheric properties in their respective spectral bands and this information is used to correct the radar altimeter pulse flight time to that relative to a vacuum condition, to calculate the actual distance between the spacecraft and the sea.

4. Data transmission

The instruments listed in §3 generate a great deal of data that has to be transmitted to the ground for subsequent processing into a useful product. This is achieved with the integrated data handling subsystem, a block diagram of which is shown in figure 1.

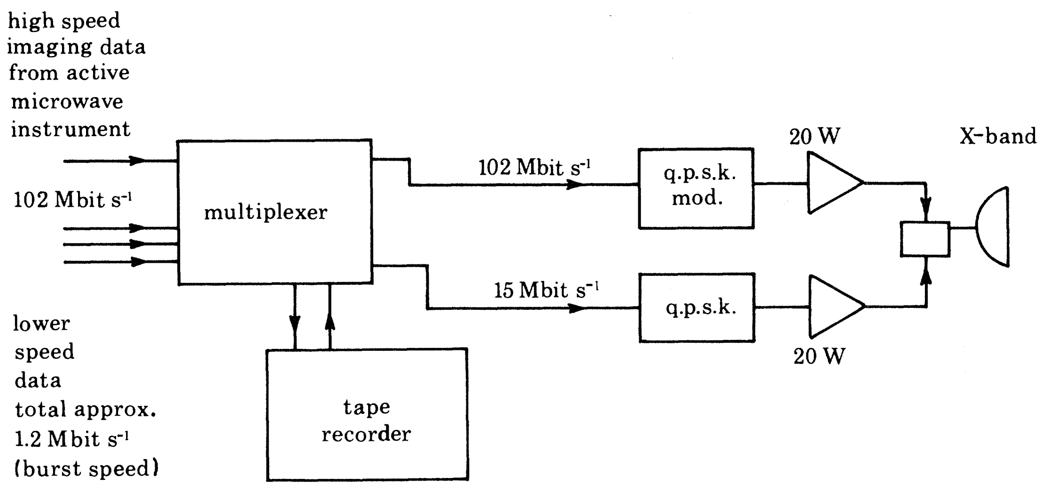

Figure 1. Integrated data-handling subsystem.

It can be readily seen that the very high-speed data generated by the imaging radar at 102 Mbit must be passed directly through the subsystem and transmitted to the ground. The lower speed data can be stored on the tape recorder until the next opportunity of contacting a ground station when the data can be released at 15 Mbit s^{-1} and transmitted to the ground.

Figure 2 shows the relation of the ERS-1 payload to the Spot platform and the configuration of the antennas associated with the measuring instruments described. The ground coverage of the sensors shown in figure 2 is illustrated in figure 3.

5. The potential of ERS-1

It is appropriate to consider the potential of ERS-1 in the light of the title of this symposium. It must be readily apparent that ERS-1 itself will, as soon as it is commissioned, add greatly to the useful data available for weather forecasting, ice reporting, mapping, oceanography and climatology. The results provided by imaging radar are spectacular and can be used to plot the passage of ships as well as oil slicks, and the movements of shallow sand banks. The imaging radar in ERS-1 which is essentially an ocean-observing satellite, could, with small modifications, be used for the purposes of land observation. For this, the potential products could be:

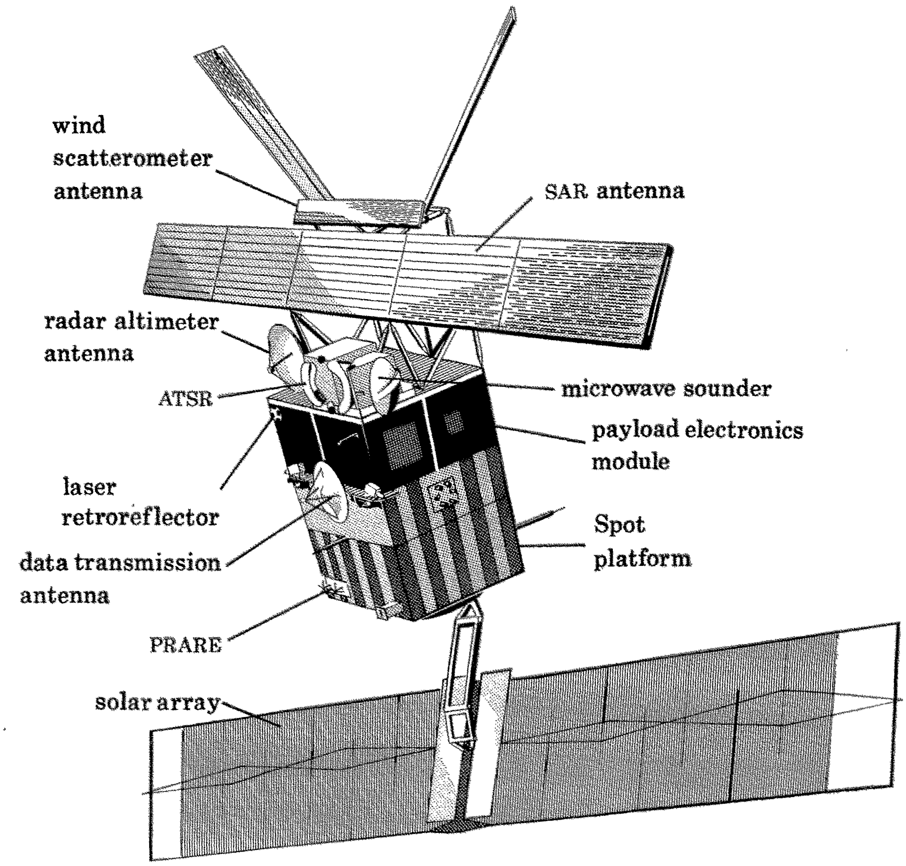

FIGURE 2. ERS-1.

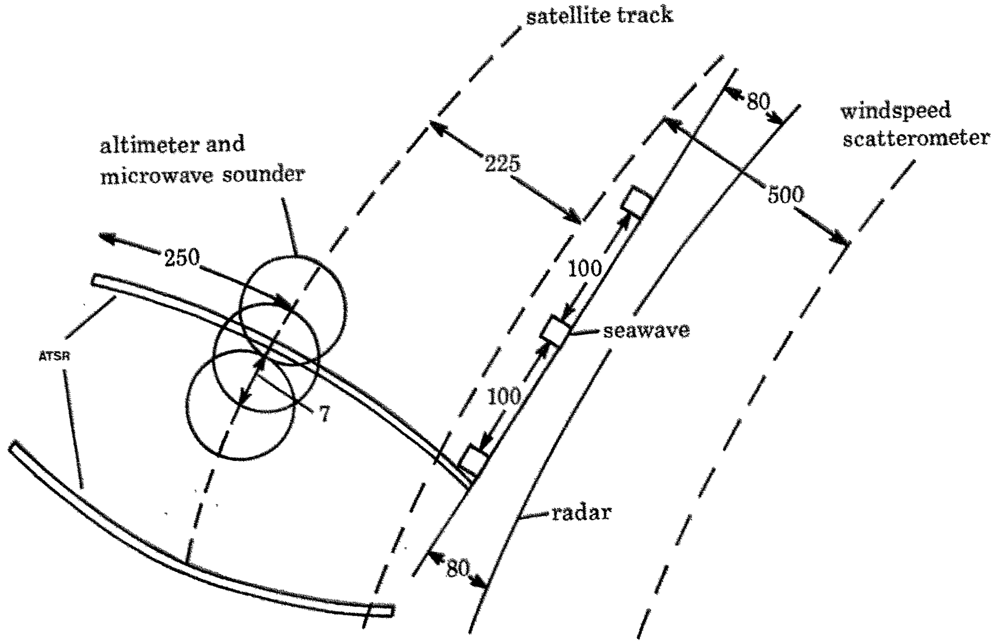

FIGURE 3. ERS-1 coverage. All distances are in kilometres.

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the forecasting of crop development; geological surveys in search of oils and minerals; cartography; the tracking of pests such as locusts; and the control of forest diseases such as the recent elm disease. This list is not meant to be exhaustive, but generally indicates the value of the information and the types of customer that should be interested.

6. The industrialization of ERS-1

If ERS-1 is to be successfully industrialized, it means that its products or other similar required products must be produced so economically that it will be possible to find customers ready to pay a price that will prove profitable to the satellite manufacturer. It is necessary then to examine ERS-1 to establish its weak points from an economic viewpoint and thus to establish the technology targets for the 1990s that will enable successors to ERS-1 to be industrialized.

Swath width

The swath width of the imaging radar is crucial. It is very conceivable that in the years to come, in the interests of maritime law and order, it will be considered desirable to maintain an operational plot of all ships at sea. It can be simply calculated that with a swath width of 100 km and a requirement to image the entire ocean surface four times daily, a system of 120 satellites would be required. This is clearly ridiculous, but if the swath width could be increased to say 600 km, the system would be reduced to 20 satellites and possibly become manageable. If a satellite with a two-sided radar was used the number of satellites could be reduced to 10. A major objective must then be to increase the area covered by the imaging radar of each satellite.

Power limitations on the radar

In ERS-1 the imaging radar is limited to a maximum of ten minutes operation in every orbit of approximately one hundred minutes; this is due to a lack of adequate energy. It should be an objective to ensure that the radar can be operated for at least half of each orbit, although it is probably reasonable to accept that it will not be possible to achieve radar operation when the satellite is in eclipse.

Data transmission

The imaging radar of ERS-1 can only be operated when the satellite is in direct view of a ground station. Ground stations are costly and their number must be kept to a minimum. An objective must be to increase vastly the data storage capability of the satellite, or alternatively to arrange for the processing of the data on board, so that only useful products need to be stored before transmission to the ground. Another solution that should be investigated, and may well be more practical, is to employ a geostationary data relay satellite.

Ground processing

At present the U.K. National Remote Sensing Centre at R.A.E. Farnborough requires more than a day to process a sea area of 25 km × 25 km. It is good to know that new computers have recently been approved, which will greatly reduce that time. However, it is essential that, if remote sensing is to become commercial, the processing of the data, either on board the spacecraft or on the ground, will need to be achieved in real time or at a speed of this order.

Instrument coordination

It would appear a very important technological challenge to coordinate the product of a number of instruments to achieve a simple rapid and reliable conclusion. One could envisage that to achieve a successful prosecution of a ship illegally pumping bilges and causing pollution would require the combined product of an imaging radar, an optical ocean colour monitor and possibly an additional instrument to examine the infrared signature of the ship and hence narrow down its identification. As such matters will be legal in nature the accurate correlation of the products of all the imaging instruments will have to be proved beyond doubt.

Marketing

While the necessary technological steps are being taken to make the ERS-1 concepts economically viable, there must be a major corresponding effort to educate potential customers in the facilities that will be available towards the end of the decade.

7. Conclusion

The timescale for ERS-1 is: beginning of 1984 to end of 1987 for design and manufacture; launch at the end of this period; exploitation from the time of launching to the end of 1990. It appears essential now to start an ERS-1 industrialization preparatory programme, aimed at tackling the problems of swath width, power limitation, data processing and storage and instrument coordination, previously mentioned. At the same time it is the duty of all of us who have been privileged to learn early about the potential of remote sensing to spread the gospel by all means, such as lectures and articles so that the exploitation phase of ERS-1 from 1988 to 1990 will prove to be the culmination of a successful marketing campaign that will lead to the commercial exploitation of improved ERS-1 facilities in the early 1990s or possibly sooner.

Since this paper is a review it contains much material from unpublished papers produced by my colleagues working for the companies and organizations engaged in the European Remote Sensing Programmes. I am indebted to them for this material.

Reference

Haskell, A. 1983 The ERS-1 Programme of the European Space Agency. *ESA Jl* **7**, 1–13.

Discussion

D. G. Stephenson (*Commercial Space Technologies Ltd, Hanwell, London, U.K.*). Will the radar altimeter on ERS-1 be able to detect the ground level swellings that occur over sub-surface magma accumulations and which can be the precursors of volcanic eruptions? A current example being the resort of Mammoth Lake, California. If so, has the possibility of selling these data to local planning and disaster coordinating agencies been examined?

Sir Peter Anson. The radar altimeter on ERS-1 has been designed to work only over the sea. It will not therefore be able to detect the ground level swellings, which can be the precursors of volcanic eruptions.

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