OBSERVING PLANET EARTH

How well do we use the satellite power available?
Technology or customer led?
Is there adequate international collaboration?

POST note 49
February 1994

POSTnotes are intended to give Members an overview of issues arising from science and technology. Members can obtain further details from the PARLIAMENTARY OFFICE OF SCIENCE AND TECHNOLOGY (extension 2840).

Satellites are playing an increasingly important role in monitoring global environmental change as well as in the more familiar weather forecasting. International coordination of Earth observation (EO) satellites for environmental purposes is vital to ensure maximum use of the information generated and avoid duplication of effort.

This briefing note considers the UK and international activities in this field.

THE USES OF SATELLITES

Weather forecasting makes use of satellite data, whereby measurements of winds, cloud cover, temperature and humidity are turned into forecasts in a few hours. Key sources of meteorological data are the European (Meteosat), US (GOES) and Japanese (GMS) geostationary satellites, and US NOAA polar orbiters.

Satellite data are also essential for validating the **climate models** needed to predict the rate of global warming from greenhouse gases (POST Briefing Note 16), and understand the likely climatic effects. Data come from satellites collecting information on atmospheric chemistry, land use patterns, winds, snow and ice, clouds, variations in solar radiation, etc. Satellites are a key to monitoring the growth of the hole in the Antarctic ozone layer since its discovery in 1987 by the British Antarctic Survey, and the depletion that is also occurring over the Arctic.

The effects of major **disasters**, both natural and man-made, can be measured by satellite. Pictures of oil spills or river flooding help direct emergency services. Satellite images form the best method of observing volcanic eruptions; the ash from the 1991 eruption of Mt. Pinatubo was tracked by satellite, quantifying the risk to air traffic, and the longer term effects on the climate.

Currently, a major commercial use of satellite data is in **land observation** - mapping man-made and natural formations, water resources such as snow, ice or lakes, soil characteristics and the type of vegetation cover (crops, forests, grassland etc.). These surveys have many uses, two of which are illustrated in **Box 1**.

BOX 1 LAND COVER IN GREAT BRITAIN & THE AMAZON

In November 1993, the Department of the Environment released a modem 'Domesday Book' survey, based on the first comprehensive satellite mapping of Britain. This map (produced by the Institute of Terrestrial Ecology from American Landsat data) has a resolution of 30m allowing waterways, urban areas, motorways, embankments and tree belts to be identified, as well as fields or areas of different vegetation.

Twenty five different types of ground cover were identified, and computer image processing used to 'recognise' and plot these on a map. The computer map was then supplemented by ground surveys within each cover type to give a detailed description of the cover across the whole of Britain.

The survey has highlighted the decline since 1978 of wildlife habitats such as ponds (10% lost) and hedgerows (20% lost). It has shown the dwindling of plant variety (14% decline in number of species), and the shrinking of woodlands (tree cover is 8% nationally - 2% lower than previous estimates). The map will be used as a reference point for future surveys to keep closer track of key changes in UK land use.

Land cover sensing has also been used in looking at the amount of deforestation in the Amazon. The Brazilian Institute of Space Research used Landsat data to find that in the worst affected state (Rondonia), 1,676 square kilometres (14% of the state area) is now deforested, compared to 1,441 km^2 n 1989.

SATELLITE PROVIDERS

Since the space race started between the USA and the USSR, the number of countries with access to space has grown steadily. While the ability to launch satellites is still restricted to a few countries (USA, Russia, Europe, Japan, China and India), these all offer a launch facility to other countries wishing to place their own satellite in orbit. As the number of countries operating Earth observation satellites increased, the G-7 summit suggested a forum for the providers and users of satellites to exchange information and in 1984, the **Committee on Earth Observation Satellites (CEOS)** was formed. CEOS aims to improve coordination of satellite programmes, to avoid duplication of effort, and to ensure that important measurements continue to be made.

CEOS brings together the agencies of seventeen countries supplying and/or operating Earth observation satellites. Six other agencies have 'observer' status (**Table 1**), and major international research programmes and agencies (e.g. World Meteorological Organisation) are also represented. Since 1984, CEOS has more than doubled its membership.

In 1992, CEOS published a review of EO Satellites, which will be updated regularly. This report, whose summary was presented to the UNCED Conference in Rio de Janeiro, provided an overview of all current and planned Earth observation satellites relevant to envi-

BOX 2 EARTH OBSERVATION SATELLITES

Orbit	Current	Planned	Measurements Available
Geostationary	8	12	Atmospheric dynamics / water and energy cycles; Oceans
Polar / Near Polar	16	38	Atmospheric dynamics / water and energy cycles; Oceans; Land; Ice and snow;
Other	5	6	Crustal Motion/Gravity Field; Atmospheric Chemistry

(N.B. Numbers do not include CIS satellites.)

Geostationary satellites work from a seemingly stationary orbit ~36,000 kms above the equator. They provide frequent information about a particular location, but the resolution is often low, some measurements are not possible, and high latitudes (over 60°) may not be seen. These satellites require a single ground station to transmit and receive data.

Polar orbiting satellites typically circle 300 - 1000 kms above the Earth, and move over or near to the poles. They can cover the whole globe, often with higher spatial resolution. These satellites often require a large number of ground stations, although some have on-board data recording facilities.

The instruments carried by the satellites fall into two categories. **Passive** instruments detect natural radiation emitted or reflected by the Earth, but may be obscured by cloud or haze (over most of Europe, only one image in ten is cloud-free). **Active** instruments avoid this problem by beaming radiation to the ground and analysing the reflection.

ronmental change. There are 29 satellites currently in orbit, with another 56 planned (**Box 2**), and these will provide continuity in all the data currently required. To build and launch an EO satellite costs from £200-600M depending on complexity, **plus** the cost of the ground segment (receiving stations, data processing, analysis and personnel costs). Collaboration between satellite providers is thus essential to ensure the most is made of the money invested. For this reason, many of the current and planned satellites are collaborations between countries or between individual space agencies.

The UK is party to two international treaties, one operated by Eumetsat and the second by the European Space Agency (ESA), both of which draw their membership and funding from Europe, Scandinavia and Canada. Eumetsat is concerned with operational meteorological satellites; ESA is responsible for experimental Earth observation satellites within the European space program. Ad hoc arrangements between agencies are through joint funding (e.g. ASI (Italy) and NASA (USA) for the Lageos II satellite), or by one agency launching an instrument on another agency's satellite (e.g. in 1991, due to the expected loss of NASA's key ozone-measuring satellite NIMBUS-7, a NASA-owned instrument was put into orbit aboard a Russian satellite). Part of CEOS' role is to encourage collaborations to ensure continuity of such vital measurements.

Table 1 COUNTRIES COMPRISING CEOS

Members:	
1984	Brazil, Canada (CSA), India, Europe (ESA),Japan, France, USA (NASA and NOAA)
1986	Italy, UK, Germany
1989	Australia, Europe (Eumetsat)
1991	Sweden
1992	Russia (RSA and ROSKOMGIDROMET)
1993	China (CAST)
Observers:	
Belgium, Europe (CEC), Canada(CCRS), New Zealand, China (NRSCC), Norway	

The UN General Assembly passed a resolution in 1986 that Earth observation should be for the benefit of all countries, and that any data concerning a particular country should be available to that country on a non-discriminatory basis at reasonable cost. CEOS is considering how to implement these principles, and at the most recent meeting (Japan, November 1993), addressed the problem of how to allow access to data by scientists studying global environmental change.

UNITED KINGDOM INVOLVEMENT

UK interests in earth observation are pursued through three broad routes, shown in **Table 2**.

The largest activity takes place via **ESA**, to which the UK contributed £106M[1] in 1992/3. £45M is the compulsory contribution; in addition, Member States can opt in or out of other ESA programmes on space transportation, space stations and platforms, Earth observation and the environment, and telecommunications. £40M of the UK contribution is allocated to Earth observation.

Since the 1987/88 report of the House of Lords Select Committee on Science and Technology, UK policy has been to start funding new projects only of economic or scientific benefit to the UK. Thus, Earth observation has been supported and other projects (space stations and manned transportation) left to other Member States. The UK is the fourth largest contributor to ESA (after France, Germany and Italy), as in **Figure 1**.

ESA operates the principle of *juste retour*, but because all States must contribute to the costs of central facilities, only ~70% of the UK contribution (124 MECU in 1992) is received back in industrial contracts. Most of the central facilities of ESA are in France, Italy, Germany and Holland[2], although the UK does host one of the four ESA Processing and Archiving Facilities (UK-PAF). This is incorporated within the UK Earth Observation Data Centre which is being commercialised by National Remote Sensing Centre (NRSC) Ltd.

1. The UK contribution to ESA is coordinated by the British National Space Centre (BNSC), and earth observation funds come from the budgets of DTI, SERC, DoE and NERC.

2. France (Guyana) hosts the launching site and Headquarters (Paris), Italy (Frascati) the data processing centre, Germany (Darmstadt) the Space Operations Centre, and Holland (Noordwijk) the Space Research and Technology Centre.

Table 2	UNITED KINGDOM FUNDING FOR EARTH OBSERVATION (1992-1993)		
Category	**Department Responsible**	**Amount**	**Purpose/Programme**
ESA	DTI	£40M	ERS-1 (£14M) POEM/Envisat (£13M) Polar Platform (£10M) Other (£3M)
Eumetsat	Met. Office	£11M	e.g. weather forecasting
UK	DTI	£17M	e.g. resource mapping
Research	SERC	£8M	e.g. develop instruments
	Met. Office	£5M	e.g. develop instruments
	MoD	£3M	e.g. space surveillance
	NERC	£1M	e.g. ocean monitoring

Future plans for UK contributions to the ESA Earth observation programme include the funding (by DoE and NERC with Australia)) of the Advanced Along Track Scanning Radiometer. This instrument will fly on the Envisat-1 satellite in 1999 and measure sea-surface temperature. AEA Technology is also considering the feasibility of a launching station at Dounreay for small EO satellites.

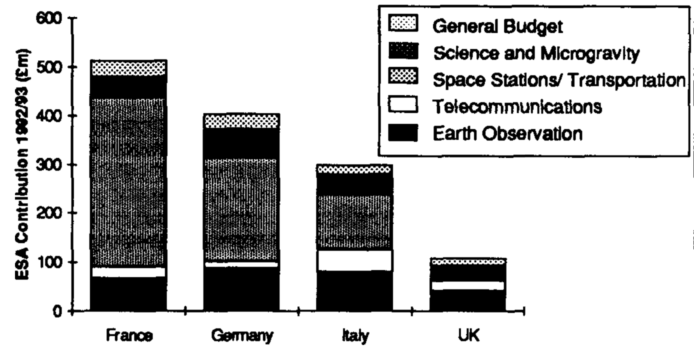
The UK plays an active role in **Eumetsat**, where the contribution of £11M is paid directly by the Meteorological Office. In addition, there are a number of research programmes in Earth observation which are designed to meet the **UK's own needs**. Within the research community, most programmes had evolved within the Science and Engineering Research Council (SERC), but the 1993 White Paper on Science and Technology reassigned responsibility for these to the Natural Environment Research Council (NERC) from 1 April 1994. NERC already uses satellite data within its mainstream science divisions as appropriate. As part of the transfer of responsibility, NERC will establish a new Atmospheric and Earth observation Sciences Directorate, and a Programme Director for Earth observation will be appointed. This will enable NERC to take responsibility for the areas transferred, while ensuring that the transferred funding (between £8.7m and £10.5m per annum) remains focused on the same projects.

ISSUES

International Collaboration

Decisions on which satellites to launch and when are still essentially national or international agency decisions and subject to the inevitable uncertainites of agency budget cycles. Yet the cost, the increasingly international usage of information and the importance to many international programmes of measurement continuity, mean that the international community has an increasingly strong interest in effective coordination. Many are concerned that there is inadequate dialogue between the producers of satellite data and the users, particularly since the missions were generally launched for scientific purposes and environmental and commercial applications developed later.

Figure 1 NATIONAL CONTRIBUTIONS TO ESA (1992/3)



In early 1992, the Prime Minister wrote to other G-7 leaders asking whether the most was being made of existing data, whether full use would be made of future missions, and proposing an initiative to strengthen the CEOS mechanisms. As a result of this, CEOS members have identified three areas for action:

- Increase involvement of large international user programmes (e.g. World Climate Research Programme) in defining their specific requirements.
- Prepare an 'environmental dossier' to raise awareness of environmental user needs. Germany agreed to lead on this (the 'Bonn follow-up') but has not yet completed this task.
- Encourage the use of data by less developed countries. The United Nations Environment Programme has responsibility here, but has made little progress.

More effective use of the information already available would be assisted by easier data access. Rather than setting up a global centralised collection/dissemination facility, the trend is to develop a world-wide distributed data network, based on connections between existing national or regional networks. Data processing could then be routinely performed at one site, and users could gain access via the network to catalogues of data and the data itself.

CEOS members are currently discussing standards for data transmission and storage. Japan and the USA are well advanced with their national networks (in the new US EOS satellites, 60% of the costs are proposed to be allocated to the ground segment of mission operation, data handling, processing and distribution). In Europe however, attempts to catalogue all the information available and promote access to it are at an earlier stage. ESA and Eumetsat catalogue and archive existing data, with distribution becoming increasingly commercial. The EU's Joint Research Centre at Ispra has proposed a Centre for Earth Observation which would help integrate data from different sources and make the data easier to access. The UK and others prefer to see this 'centre' evolve as a series of national facilities linked together, rather than as a single central facility. EU support through the 4th Framework Programme may fund catalogues and data archiving, or data transmission facilities along the same lines as the US 'information superhighways'. Within the UK, the Global Environmental Network for Information Exchange (GENIE) project has been funded by the ESRC to help integrate the UK's data facilities.

Concerning the future status of CEOS, the Minister for Space suggested in 1992 that CEOS together with other international bodies might ultimately evolve into a World Space Agency, with its own funding. However, in view of the many different nations involved and of the independence enjoyed by some of the agencies, many see it as unrealistic to attempt to transform CEOS into an executive body, arguing that it should remain an informal coordinating body. There is however, some support for raising its status by requiring more frequent, formal reports to the G-7 and G-24 summits.

Developing Future Uses

Given the amount of data already available from satellites, there is considerable scope for developing new uses and commercial activities, in addition to the applications described in Box 1.

One promising area is in monitoring the type and amount of agricultural crops grown, where satellite instruments can sense the different wavelengths of light reflected by various crops. An important application is emerging in **detecting fraud under the Common Agricultural Policy**, where satellite surveillance can check whether the claimed crops and acreage are being grown. France has pioneered satellite monitoring of farms and a recent survey identified 2 billion francs worth of false or unsubstantiated claims, out of a total payment of 5 billion francs! Other countries are also using this tool, following a review by the European Parliament in 1990 which showed the scope of satellites in support of EC policies. The EC is funding projects with national governments to demonstrate the use of satellites to monitor oilseed crops and set-aside land (the UK, through NRSC is actively involved in this programme). However operational use for fraud detection is the responsibility of national governments and the EU is not planning any fraud investigations itself.

Within the UK, MAFF has carried out some research on the use of satellite data to identify doubtful claims, which can then be investigated further - checking on the ground is necessary not only to minimise error in data interpretation, but because there is no legal precedent for the use of satellite data. This project cost ~£1M (part-funded by the EC) and finished in October 1993, and further work will take place in 1994. It is not known how many dubious claims were identified, and MAFF is currently assessing the effectiveness and future role of satellite monitoring. Options include using satellites as a routine management tool to direct resources more effectively, or as an occasional means of checking the effectiveness of more traditional means of enforcement.

In view of the scale of CAP fraud, many see satellites as offering a cost-effective means of tackling this problem throughout the Community.

Another new use is in ensuring compliance with international treaties. **Verification of arms-reduction treaties** already poses challenges for military satellites, and the Western European Union is funding studies on the use of satellites dedicated for this purpose, improved on current civil capabilities. In the longer term, international treaties on global environmental change (e.g. the Convention on the Protection of the Ozone Layer, and the Global Climate Convention) may generate a future need to monitor compliance with possible greenhouse gas emissions limits or forest conservation agreements.

Military Earth observation satellites have much higher resolutions than current civil satellites, and the end of the Cold War has opened up a debate on how far military capabilities may be applied in the civil sector. Some Russian military data are becoming available, and there is currently debate within the USA whether some military EO data might be released. At the same time however, three companies (Lockheed, Eyeglass and WorldView) are planning to launch additional high resolution civil satellites, to develop a commercial market for remote sensing information.

An area of particular promise is in high resolution Geographical Information Systems (essentially computer-based maps) for urban planning and other purposes. Western systems cannot match the resolution of aerial surveys, but Russian 2m resolution pictures are becoming available at competitive rates (~£11,000 for an area of 40x40km, and comparable in quality to aerial surveys costing ~£20,000). Other uses are in crop assessment and prediction, identification of mineral sites, urban planning and forestry. Many see considerable potential for such applications, and believe that the limited use to date is due to user awareness being very low. Partly to address this aspect, BNSC initiated in 1992 a major programme to demonstrate possible uses of Earth observation data. This programme has chosen five projects to support initially, including sugar beet prediction and management; off-shore oil exploration; and environmental monitoring of protected landscapes.

Many see EO as needing to move further from being technology to customer led, and other countries as needing to follow the UK lead in separating out the role of Government as customer from that of provider. In particular, it needs to be established whether space-based EO provides value for money when unsubsidised by central funding. Then, satellites and ground support need to be designed around user requirements. Until more progress is made in this area, concerns will remain that the large international investment in the 'hardware' of satellites has not been fully exploited.